



# **ORGANIC AGRICULTURE AND CARBON SEQUESTRATION**

**Possibilities and constrains for the consideration of  
organic agriculture within carbon accounting systems**

**by**

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## Acronyms

AFOLU	Agriculture, Forestry and Land Use
CCBA	Climate, Community and Biodiversity Alliance
CCX	Chicago Carbon Exchange
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
EFDB	Emission Factor Data Base
EFMA	European Fertilizers Manufactures Association
EU	European Union
ETS	Emission Trading Scheme
GHG	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standardization Organisation
JI	Joint Implementation
LULUCF	Land Use, Land Use Change and Forestry
MAFF	Ministry of Agriculture, Fisheries and Food of the United Kingdom
NRCS	Natural Resources Conservation Standard
PAS	Publicly Available Specification
RES	Renewable Energy Sources
RTFO	Renewable Transport Fuel Obligation
tCER	temporary Certified Emission Reduction
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
USD	United States Dollar
VCS	Voluntary Carbon Standard

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# 1 Introduction

This document discusses the opportunities and constraints of carbon accounting for organic agriculture management in developed and developing countries.

Organic agriculture offers a unique combination of environmentally-sound practices with low external inputs while contributing to food availability (Zundel et al., 2007). In developed countries, there is a steadily growing market for organic products, driven by the rising consumer awareness for health and environment (Willer et al., 2009), which offers farmers a chance to produce for premium price markets and hence, an opportunity to increase their farm profitability and livelihoods.

Recent studies have highlighted the substantial contribution of organic agriculture to climate change mitigation and adaptation (Niggli et al., 2009; Scialabba and Muller-Lindenlauf, 2010, in print). The potential of organic agriculture to mitigate climate change is mostly claimed on the basis of assumptions concerning the soil carbon sequestration potential of organic management.

Terrestrial carbon sequestration is proposed by scientists as an effective mitigation option because it combines mitigation with positive effects on environmental conservation and soil fertility (Smith, 2007). The UN carbon credit system (CDM, UN-REDD) includes terrestrial carbon sequestration in terms of forests and degraded lands. Agricultural carbon mitigation is not yet included but is expected to be included in further UNFCCC protocols. Voluntary carbon markets partly include agricultural soil management practices, but up to now none of them includes organic agriculture (see Tables A and B in Annex: Place of agriculture in carbon trading instruments).

The aim of this document is to describe the potential of organic agriculture to sequester carbon and to meet the requirements of carbon accounting systems, including factors such as carbon permanence, leakage and additionality. Furthermore, the document discusses the suitability of measurement and verification methodologies to agriculture systems, including an analysis of existing carbon accounting instruments in terms of their usability for organic agricultural management practices.

## 2 Definition of organic agriculture

According to the Codex Alimentarius Commission, “*organic agriculture is a holistic production management system that avoids use of synthetic fertilizers, pesticides and genetically modified organisms, minimizes pollution of air, soil and water, and optimizes the health and productivity of interdependent communities of plants, animals and people.*” To meet these objectives, organic agriculture farmers need to implement a series of practices that optimize nutrient and energy flows and minimize risk, such as: crop rotations and enhanced crop diversity; different combinations of livestock and plants; symbiotic Nitrogen fixation with legumes; application of organic manure; and biological pest control. All these strategies seek to make the best use of local resources. Hence, organic systems are inherently adapted to site-specific endowments and limitations. Essential practices of organic agriculture used to supply nutrients without mineral fertilizers are known to have positive effects on soil carbon, in particular manure application or legume cultivations.

In 2007, certified organic lands were of 32 million hectares, involving 1.2 million farmers (Willer et al., 2009). In addition, in developing countries, a huge number of uncertified farms apply organic agriculture practices (e.g. polycultures) for their own subsistence purposes.

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These farmers are normally in marginalized rural communities having neither access to agricultural input commodities like mineral fertilizers or pesticides nor market access to supply certified organic products.

### 3 Sequestration potential of organic agriculture

A literature review of studies comparing carbon sequestration in soil under organic and conventional management identified 11 relevant papers (see Table 1). All these studies showed a higher soil carbon content in organic plots, as compared to conventional management practices. In one comparative field trial, the baseline carbon content of the organic plots was higher, and so was the total carbon decrease over time (Stalenga et al., 2008). But, this study was not randomized, and the organic matter balance of 20 organic farms surveyed in the same study was positive and higher than in conventional managed farms. All studies featuring statistical analysis showed a *significant* advantage of at least enhanced organic practices compared to the conventional standard. In one study, the higher carbon sequestration was only significant for organic farming combined with no tillage, but not for a deep tillage organic system (Tizio et al., 2008). In one other study, only the biodynamic system with high livestock density showed a significant advantage (Fliessbach et al., 2007). One study showed slightly higher sequestration for an optimized conventional system including some “organic” strategies such as cover crops, crop rotation and mulches without abstaining from mineral fertilizers use (Wells et al., 2000); however, the difference of the optimized “conventional” system to the “organic” system including the same conservation practices was not significant. In USA, a comparative field trial showed a lower sequestration in the organic system as compared to the no tillage system (Grandy et al., 2007), but a statistical analysis is not given. The sampling depth of this trial was only 5 cm. Two randomized long-term trials comparing organic and conventional farming practices for over 20 years showed remarkable higher carbon contents in the organic plots. In Switzerland, a long-term trial for a biodynamic system showed a stable carbon content, while a carbon loss of 15% in 21 years was measured for the compared conventional systems (Fliessbach, 2007). A field trial in USA measured about one tonne per hectare and year higher sequestration in the organic systems as compared to the conventional system (Hepperly et al., 2006). Similar results were found in another USA field trial carried out over 8 years (Teasdale et al., 2007).

Niggli et al. (2009) estimated the global average sequestration potential of organic croplands to be 0.9-2.4 Gt CO<sub>2</sub> per year, which is equivalent to an average sequestration potential of about 200 to 400 kg C per hectare and year for all croplands. This estimate fits well with the data found in the literature review given in Table 1. It is to be mentioned that in developing countries, there is a huge knowledge gap on this topic.

Critiques mention that organic agriculture hinders no-tillage, which is considered to be another strategy with high soil carbon sequestration potential. No-tillage is difficult to implement in organic agricultural systems because of the accompanied insurgence of weeds that cannot be treated with herbicides such as done in conventional systems. Three of the comparative field trials included a no-tillage plot. One of these studies found significantly higher concentrations of combustible C in the organic system as compared to the no-till conventional system (Teasdale et al., 2007). Another study found a tendency but not a significant higher carbon content in the organic system (Wells et al. 2000). The only study showing an advantage of the no-tillage system (Grandy et al., 2007) does not include replications and can't be analysed statistically. One other study comparing organic farming with reduced tillage found a higher sequestration rate for the organic system, but this study as well is a side comparison excluding replications (Küstermann et al., 2008). A literature review of no-tillage systems, carried-out in

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2007, came to the conclusion that studies involving deeper sampling generally show no advantage for conservation tillage or even a disadvantage as compared to conventionally tilled soils (Baker, 2007). The comparative studies analysing the effect of carbon sequestration in organic farming do also not so far include deep sampling. But organic crop rotations include cultivation of deep rooting legumes which increase the carbon content in deeper soil layers by rhizo-depositon and dead root biomass.

In addition to the soil carbon pool, organic agriculture encourages agro forestry as well as the integration of landscape elements, leading to a further carbon sequestration in plant biomass. (e.g. IFOAM Norms 2002; East African Organic Standard 2007; Pacific Organic Standard 2009). Also, biomass burning, a major contributor to emissions, is restricted in organic agriculture.

High carbon sequestration potential is also reported in grassland soils (Smith et al., 2007). As pastures are the favoured feeding strategy for organic cattle, organic livestock production is an option for profitable maintenance of grasslands. Combined with a limited livestock density to prevent overgrazing, organic grassland farming could be a way to optimize carbon sequestration in grasslands (Rice, 2001; Liebig, 2005). The global carbon sequestration potential by improved pasture management practices was calculate to 0.22 t C per ha per year (Watson et al., 2000).

Besides the described technical potential, the economic potential has to be analysed. To do so, a detailed analysis of carbon sequestration rate, yield effects, farm management costs, measurement and verification costs and carbon credit prices has to be carried out. To give a first coarse estimate, returns of about 15 USD per hectare and year can be expected<sup>1</sup>. Costs of implementation, extension services, certification and verification have to be subtracted. E.g. the costs of analysing one soil sample are 9-23 USD in the EU (Stolbovoy et al., 2007).

## **4 Other positive impacts of organic agriculture**

Organic agriculture has various positive environmental effects, chiefly enhancing biodiversity (Hole et al., 2005; McNeely, 2001) and reducing the energy use for agricultural production (Ziesemer, 2007). Emissions from mineral fertilizers production, which contribute alone to 1% of global anthropogenic greenhouse gas emissions, are totally omitted (FAOSTAT; EFMA; Williams, 2006). Furthermore, organic agricultural practices show ways of efficient nutrient management, which is going to become even more important in times of limited resources. While agricultural productivity increased substantially during the last decades by using higher amounts of mineral fertilizers, the global efficiency of Nitrogen use decreased from 80 to 30% (Erismann et al., 2008). Organic agricultural practices can contribute to a more efficient use of nitrogen by planting legumes and catch crops and integrated livestock production. Integration of landscape elements and higher soil organic matter contents increase the water capturing capacity of the agricultural system and lower the risk of soil erosion. Hence, the risk of yield losses by extreme weather events is lowered (Lotter, 2003). Abstention from all chemical pesticides avoids the risk of health damage by chemicals for farmers and consumers. Water quality is increased both by lower nitrate leaching and abstention from agro-chemicals (Stolze et al., 2000).

The organic agricultural community developed a broad range of practices for enhancing productivity without relying on external agricultural inputs. These strategies can be used to

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<sup>1</sup> Based on a price of 3-4 USD per t of CO<sub>2</sub> for a five years temporary credit and a sequestration rate of 1 t carbon per hectare and year (=3.66 t CO<sub>2</sub>-equivalents).

increase the agricultural productivity and the livelihoods of rural communities who have no access to inputs, which still is the majority of the rural poor. As already mentioned in the introduction, organic agriculture can promote food availability and increase the income of small scale farmers (Zundel et al., 2007; FAO, 2009). A growing demand for organically produced food in industrialized countries can offer access to premium prices and hence higher income (Willer et al., 2009).

**Table 1: Literature review carbon sequestration in organic farming**

Reference	Components compared	Carbon stocks at end of trial (g C per kg soil)	Carbon stock change (kg C per ha and year)	Depth of sampling	Years of trial	
Stalenga et al., 2008	Organic System	15	-599	not indicated	12	
Poland	Conventional System	14.4	-50			
Comparative field trial	Integrated System	13.8	-300			
Küstermann et al., 2008	organic	-	180	not indicated	10	
Germany	conventional reduced till with C input (manure, residues)	-	-120			
Wells et al., 2000	organic	18.5	bc	-	10 cm	3.5
Australia	conventional multiple tillage	14.9	ab	-		
Randomized comparative field trial	conventional reduced tillage	11.8	a	-		
	conventional no tillage	14.3	ab	-		
	conventional evolving (cover crops, rotations, mulches)	20.7	c	-		
Tizio et al., 2008	organic deep tillage	11	a	-	not indicated	5
Italy	organic minimum tillage	12.7	b	-		
Randomized comparative field trial	conventional deep tillage	11.5	a	-		
	conventional minimum tillage	11.8	a	-		
Lagomarsino et al., 2009	organic (mean for three crops)	12.7	a	-	20	5
Italy	conventional (mean for three crops)	11.8	b	-		
Randomized comparative field trial						
Ciavatta et al., 2008	organic orchard 0-15 cm row	14.9	a	-	0-15 cm and 30-50 cm	18
Italy	conventional orchard 0-15 cm row	8.1	b	-		
Side comparison	organic orchard 30-50 cm row	8	b	-		
	conventional orchard 30-50 cm row	6.8	b	-		
	organic orchard 0-15 cm interrow	10.6	a	-		
	conventional orchard 0-15 cm interrow	7.8	b	-		
	organic orchard 30-50 cm interrow	6.1	b	-		
	conventional orchard 30-50 cm interrow	6.2	b	-		

Reference	Components compared	Carbon stocks at end of trial (g C per kg soil)	Carbon stock change (kg C per ha and year)	Depth of sampling	Years of trial
Grandy et al., 2007	conventional	9.1	0	5 cm	12
USA	low input with legume cover	10.9	89		
Comparative field trial	organic with legume cover	11.3	123		
	no tillage	13	220		
	permanent alfalfa	14.2	284		
	permanent poplar	13.5	191		
	successional ecosystem recently abandoned	16.6	316		
	historically tilled 50 years ago	18.5	91		
	never tilled 50 years old	34.9	0		
	never tilled forest	31.1	0		
	Fiessbach et al., 2007	no fertilization	11.83 b	-	20 cm
Switzerland	conventional without manure	13.00 b	-		
Randomized Comparative field trial	biodynamic 0.7 LU per ha	13.40 ab	-		
	organic 0.7 LU per ha	12.25 b	-		
	conventional 0.7 LU per ha	11.89 b	-		
	biodynamic 1.4 LU per ha	14.91 a	-		
	organic 1.4 LU per ha	13.30 ab	-		
	conventional 1.4 LU per ha	13.34 ab	-		
Pimentel et al., 2005	organic animal based	25 a	1218 a	not indicated	22
USA	organic legume based	24 a	857 a		
Randomized Comparative field trial	conventional	20 b	217 b		
Kessel et al., 2006	corn organic	12.6 b	-	not indicated	4
USA	corn integrated	9.58 a	-		
Comparative field trial (3 replications)	corn conventional	10.06 a	-		
	tomato organic	12.94 c	-		
	tomato integrated	10.74 b	-		
	tomato conventional	9.09 a	-		
	Teasdale et al., 2007	organic 0-7.5 cm	19.2 a	-	30 cm
USA	living mulch 0-7.5 cm	14.4 c	-		
Randomized Comparative field trial	cover crop 0-7.5 cm	17.3 b	-		
	no-tillage 0-7.5 cm	15.5 c	-		
	organic 7.5-15 cm	15.9 a	-		
	living mulch 7.5-15 cm	11.1 c	-		
	cover crop 7.5-15 cm	12.4 b	-		
	no-tillage 7.5-15 cm	11.1 c	-		
	organic 15-30cm	10.3 a	-		
	living mulch 15-30cm	7.4 b	-		
	cover crop 15-30cm	7.8 b	-		
	no-tillage 15-30cm	7.1 b	-		

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## **5 Issues related to the consideration of organic agriculture as a soil carbon sequestration strategy**

### **5.1 Permanence**

#### **5.1.1 Definition**

One of the main concerns related to the use of terrestrial carbon sinks as a greenhouse gas mitigation option is permanence, that is the time carbon will remain stored after been fixed in vegetation. Losses of terrestrial carbon are caused by disturbances, such as fire, wind-throw, drought or pests, and through human activities like deforestation and changes in agricultural practices leading to land degradation.

For example for no-tillage, it has been shown that the carbon stored by no tillage is released by a single ploughing, presumably because of its labile soil quality (Stockfisch 1999).

The following problems concerning non permanence have to be considered:

- carbon release after the commitment period by a change of management practices;
- carbon release or reduced carbon fixation during the commitment period, due to unexpected events (e.g. fires, yield losses) or illegal management practices.

The problem of non-permanence is not specific to organic agriculture. The reversibility of carbon storage is characteristic for all terrestrial carbon stocks. So, strategies to handle permanence of other terrestrial carbon can be suitable for organic agriculture.

#### **5.1.2 Carbon release after the commitment period**

Carbon release after the commitment period can be handled by temporary certified emission reduction credits (tCERs) (UNFCCC, 2003c). tCERs expire on a defined date (end of commitment period, end of an arbitrary period, or other) and can be renewed where monitoring, verification and certification for the project demonstrates that the carbon sequestration on which the original tCERs were issued remains intact.

The values of tCER for carbon market depend on the type of contract, either bilateral or unilateral. Bilateral projects are contracts between an investor, e.g. a company which wants to become carbon neutral, and a seller, e.g. a farmers' community. In bilateral projects, the investor might be interested in a long commitment period, thus purchasing an entire "stream" of tCERs for several consecutive commitment periods. Uncertainties during the contract period might be covered by buyers, sellers or insurances depending on the contract conditions (Dutschke & Schlamadinger, 2003). The lower the risk of project failure and the longer the project live span, the higher is the value of the contract for the buyer. Unilateral tCERs are emission reductions offered on the market. They generally only apply to a 5 year window of a project (i.e. duration of commitment period in regulatory carbon market). There is no uncertainty for the investor. This is more suitable for companies foreseeing reduction potentials in the next commitment period, or for nations or companies who want to build-up a compliance reserve. For nations or companies expecting high reduction obligations in the next commitment period, these tCERs are less valuable (Dutschke & Schlamadinger, 2003).

From a farmer perspective, only carbon sequestration which is most likely to be renewed for a stream of commitment periods offers long-term income opportunities. Short-term income

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opportunities (e.g. for one commitment period of five years) can be useful to finance the transition period to a more sustainable farming system.

Considering that organic farmers inherently commit to such management for accessing certification and price premium beyond carbon credit advantages, organic agriculture has a lower risk of non-commitment as compared to conventional management. Although permanence could be assumed to be high in organic agriculture, additionality has to be evaluated (see below).

### **5.1.3 Carbon release during the commitment period (project failure)**

Carbon release during the project lifespan by unexpected external shocks (e.g. droughts, fires) or by failures in sequestration predictions are a high risk for the credit seller. The risk of failures in sequestration predictions should be lowered to the highest possible extent by investments in research and modelling (see measurement and verification section). Uncertainties have to be carefully analysed. The remaining risk, together with the risk of external shocks, has to be compensated. UNFCCC suggests the following compensation strategies (UNFCCC, 2003a):

- Insurance: an insurance provider would be required to replace the Certified Emission Reductions (CERs) associated with a loss of carbon with an equivalent quantity of CERs.
- Credit reserves: specific amounts of CERs that are not retired and are held in order to compensate any possible losses.
- Buffers: specific amounts of carbon stored by the project which are held aside for compensating any possible loss of carbon.

The amount of credit reserves, buffers or insurance costs highly depend on the assumed risk of project failures. Manageable and appropriate calculation methods for organic agriculture have to be developed. Guarantee systems of existing carbon standards (such as VCS, see below) can be used as guidelines.

Compared to forests, where most of the biomass is stored above ground, in organic agricultural systems the dominant carbon stock is soil organic matter. Soil organic matter is less exposed to external shocks like fires, and is less likely to be destroyed by human interaction (e.g. illegal harvest).

Some scientific studies showed a higher stability of soil organic matter in organic systems, as compared to no-tillage (Stockfisch et al. 1999). Hence, organic systems can be assumed to be more resistant to management failures. But a proper implementation of organic principles is needed to avoid nutrient depletion.

### **5.1.4 In brief**

Carbon sequestration by organic agriculture faces the risk of non permanence, as all strategies for terrestrial carbon sequestration. There are already risk management strategies available in the UNFCCC system that can be adapted to agricultural sequestration projects. Also, guidance can be taken from voluntary carbon standards such as Voluntary Carbon Standard (VCS) or Chicago Climate Exchange (CCX). The risk of carbon release by external shocks, whether during or after the commitment period, is not higher for organic projects, as compared to forest or no-tillage projects. The risk of non-compliance, and hence of carbon release, is lower in organic agriculture due to other positive effects of that system, such as availability of premium prices or increases in productivity.

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## 5.2 Leakage

### 5.2.1 Definition

Leakage in CDM projects is defined as the *”net change of anthropogenic emissions by sources of greenhouse gases which occurs outside the project boundary, and which is measurable and attributable to the CDM project activity”* (3/CMP.1, Annex, paragraph 51).

Examples for leakage are (Metz et al., 2007):

- direct leakage: when activities formerly carried out in the project area are shifted to an other piece of land.
- indirect leakage: for example, when timber companies invest less in new forest in anticipation of future timber production from carbon forests.

### 5.2.2 Risk of leakage by lower yields

Agricultural projects can result in significant leakage when yields are affected. Reduced yields are likely to be compensated elsewhere, thus leading to higher carbon emissions in fields outside the project boundaries (Murray, 2007). Where organic systems can achieve yields comparable or even higher than conventional production systems, the risk of leakage is low. A review undertaken in 2007 showed that average yield losses under organic management for developed countries from zero to 20%, while in the case of developing countries, hardly any yield reduction is associated but the opposite (Badgley et al., 2007). In particular, in arid tropical areas with degraded soils, higher yields in organic systems are common (Pretty, 2002).

In cases of lower yields, a detailed analysis of emission leakage needs to be carried-out. Where cropping systems productivity is good, natural ecosystems are saved, in particular forests, resulting in higher overall sequestration rates from both cropped soils and forested areas. A comparison of the sequestration rates in organic and conventional agricultural systems with simple default values for carbon sequestration in forests showed an advantage of the organic system in USA, where high sequestration rates have been reported, and a disadvantage for European systems, where the agricultural sequestration rate was much lower and so were the yields of the organic system (see 2).

**Table 2: Comparison of the sequestration potential of a "organic" and a "conventional+forest" system based on the measured sequestration rates of 4 comparative field trials in Europe and the USA**

Reference	Sequestration rate in kg C per ha and year <sup>1)</sup>		Relative productivity of organic system		Potential carbon sequestration by afforestation [in kg per ha and year <sup>2)</sup> ]	Total sequestration (kg C per ha and year)		
	Organic	Conventional	Relative yields	Additional area demand [ha]		Conventional + forest	Advantage/disadvantage of organic system	
Switzerland <sup>3)</sup>	min	-123	-207	84%	1.2	1700	98	-221
	max	42	-207	83%	1.2	1700	117	-75
Germany <sup>4)</sup>		180	-120	57%	1.8	1700	663	-483
USA Maryland <sup>5)</sup>	min	810	0	83%	1.2	3300	561	249
	max	1738	0	83%	1.2	3300	561	1177
USA Pennsylvania <sup>6)</sup>	min	857	217	92%	1.1	3300	464	393
	max	1218	217	97%	1.0	3300	309	909

<sup>1)</sup> Niggli et al., 2009, p.10. Adapted.  
<sup>2)</sup> Sequestration rates taken from Brown, S. (ed.) 1996. Management of forest for mitigation of greenhouse gas emissions. In: Watson, R. R. et al. (eds.): Impacts adaptation and mitigation of climate change: scientific-technical analyses. Cambridge University Press.  
<sup>3)</sup> Fließbach et al., 2007 ; Mäder et al., 2002  
<sup>4)</sup> Rühling et al., 2005 ; Küstermann et al., 2008  
<sup>5)</sup> Teasdale et al., 2007  
<sup>6)</sup> Hepperly et al., 2006; Pimentel et al., 2005

### 5.2.3 Risk of leakage by higher emissions from other greenhouse gas sources

Besides the direct leakage of terrestrial carbon, the impact of organic management on other greenhouse gas sources, such as CH<sub>4</sub> and N<sub>2</sub>O emissions, must be taken into account.

As Nitrogen is far more limited in organic systems, there is a strong incentive to avoid losses and enhance soil fertility (Stolze et al., 2000). Catch and cover crops as well as intercropping, which are all common practices in organic farming, extract plant available Nitrogen unused by the preceding crop and keep it to the system. Therefore, they reduce the level of reactive Nitrogen in the topsoil, which is the main driving factor for N<sub>2</sub>O emissions (Ruser et al., 2001; Smith et al., 1998). A comparative study showed lower overall emissions of the organic system as compared to the conventional system, even though very high emissions occurred after incorporation of legumes (Flessa et al., 2002). Thus there seems to be a trend towards lower N<sub>2</sub>O emissions in organic agricultural systems. A risk of leakage is therefore not given.

Methane emissions from enteric fermentation can be higher in organic systems with cattle. The quantity of methane emitted per product unit depends on the animal diet and the cow breed's performance. High milk yields per cow reduce emissions per product unit. High energy feedstuff (e.g. grains, soy) can additionally reduce emissions because methane emissions mainly derive from the digestion of fibre from roughage. In developed countries, organic management usually achieves lower milk yields per cow than conventional production. However in developing countries, where two thirds of the enteric methane emissions occur, organic systems achieve higher milk yields, as more careful management improves the relatively low performance of traditional systems (Badgley, 2007). Furthermore, the roughage fed in organic systems mostly derives from grasslands, which by that can be productively used

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and conserved for nature conservation and carbon sequestration. Feeding cattle with grains instead of roughage to lower methane emissions can become a risk for food security and should be considered critically. To sum up, for organic agriculture projects including cattle, methane emissions must be carefully assessed but also counter-balanced with positive carbon effects derived from grassland conservation.

The energy use in organic systems is lower than in conventional systems, mostly because of the abstention from energy intensive mineral fertilizers (Ziesemer, 2007; William, 2006; MAFF, 2000). So there is no leakage in emissions from energy use.

#### **5.2.4 In brief**

Emission leakage can derive from lower yields leading to extension of agricultural area at the expense of natural ecosystems with high carbon stocks, from higher emissions of N<sub>2</sub>O and CH<sub>4</sub> or a higher energy demand per product unit. In general, the risk of emission leakage in organic agricultural management projects is low. In degraded areas and in developing countries, similar or even higher yields compared to conventional production are likely. In cases of lower yields leakage has to be analysed. Emissions of N<sub>2</sub>O are likely to be lower under organic management. Where cattle production is included, methane emissions must be counter-balanced with positive carbon effects.

### **5.3 Additionality**

#### **5.3.1 Definition**

*"A project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM project activity" ( 3/CMP.1, Annex, paragraph 43).*

If a carbon credit is granted for activities that would occur anyway, then it is not effectively negating the emission that is allowed by procuring the offset credit. So, as for permanence and leakage, additionality is a condition for projects which is convenient to offset carbon emissions. Additionality is given if the net sink enhancement resulting from a project activity goes beyond legal requirements and commercial practices (UNFCCC, 2003b).

#### **5.3.2 Additionality of organic agriculture projects**

As organic agriculture goes beyond legal practices in all countries, the focus of the analysis has to be made on commercial practices.

An UNFCCC REDD project is considered to be additional if the proposed project activity is economically less attractive than at least one other land use scenario without the revenue from the sale of CERs (UNFCCC, 2007a).

It can be argued that an organic agriculture projects might not be additional, if it is expected to be implemented without the additional financing by carbon credits because of its other economical vantages (e.g. price premium). In a number of cases, organic agriculture projects may be the economically most attractive land use option in the long run, without being put in to practice because the necessary investment in the initial phase of the project cannot be afforded. Examples for initial investments are investments in the adaptation of farm structure (e.g. planting of trees), investments in knowledge and in some cases lower yields during the conversion phase while premium prices cannot be accessed. Carbon credits could facilitate

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such projects and hence combine real greenhouse gas mitigation with additional positive effects on environmental integrity, livelihoods and food security.

In a second or following commitment period, it has to be checked if additionality for an established organic project is still given. If a continued organic management became the most economic farming practices on the project side, further crediting would not be justified according to the principle of additionality.

### **5.3.3 In brief**

Additionality of organic agricultural management projects is given only if the project would not be realised without the carbon credits. It is assumed that additionality is likely in many cases for the conversion period, when high investments are needed. Additionality has to be re-checked after conversion period.

## **6 Measurement and verification of carbon sequestration in organic agriculture**

To be credible in carbon markets, carbon sequestration has to be verifiable. Verification is achieved by measurements and approved calculation methods. The availability of approved measurement and verification methods depends on the type of carbon stock (i.e. above ground, below ground) and land use system.

Organic agricultural projects sequester carbon both in above ground (e.g. trees, hedges, permanent crops) and in below-ground (soil organic carbon) stocks. For grassland and annual crops, the primary carbon stock is below ground. Most of these ecosystems have large annual carbon uptake rates, but much of the gain is exported in the form of agricultural products and their associated waste materials; this gain is rapidly released to the atmosphere. In agroforestry and perennial crops, additional remarkable amounts of carbon are stored above ground in wooden plant biomass (Watson et al., 2000).

### **6.1 Field sampling**

Field measurements can be the most accurate measurements (Havemann, 2009). The accuracy depends on the spatial heterogeneity of the carbon stock, the number of samples taken and the sampling plan.

Above ground carbon in plants biomass can be measured destructively by sample harvesting or non-destructively by allometric methods.

Soil carbon can be measured by soil sampling or spectroscopic methods. The accuracy of soil samples depends on the depth of the soil samples taken. Sampling depth must capture all management-induced changes. In organically managed soils, carbon sequestration occurs in deeper soil layers, most likely through the cultivation of deep rooting legumes. Hence a deep sampling beyond the usual 30 cm is recommended.

Different methodologies are available for measuring the soil organic carbon content (Table 3). For accurate sampling, mathematical methods to determine the number of samples and a sampling plan are needed. A method for calculating the number of sample plots for afforestation and reforestation projects within the CDM program is given by UNFCCC executive board (UNFCCC, 2009a), based on standard statistical methods. A more detailed description including agricultural soils developed for the European Union is given by Stolbovoy et al., 2005. This document also describes how to calculate the soil carbon stocks

based on sampling and how to determine uncertainties. The described methodologies can be adapted to agriculture and organic farming. Due to the higher diversity of organic systems, it is likely that a higher number of samples will be needed to achieve the same accuracy.

Field measurements are not only a basis for sequestration verification in the specific project but can and must be used to enhance quality of remote sensing measurements and the definition of default values. To achieve reliable default values, field samples from organically managed soils could be collected in a database and made available to the public for further analysis and for project planning.

**Table 3: Destructive and non destructive methods for measuring soil organic carbon content (Havemann, 2009, adapted)**

Method	Description
<b>Destructive Methods</b>	<p><b>Loss on Ignition:</b> Measurement of sample weight change after oven - drying. This can over estimate soil organic matter as, depending on the ignition temperature and sample size, the inorganic components of the sample may also change in weight during the heating process so they should also be measured.</p> <p><b>CO<sub>2</sub> Combustion Analysis:</b> Measurement of CO<sub>2</sub> emitted from oxidation of organic carbon. Instrument error associated with dry combustion auto analyzers are &lt;0.1%, overall lab measurement error using proper protocols is 1-2%. This method measures total carbon, not organic carbon. Inorganic carbon should be removed from soil before analysis or measured separately for correction of organic carbon.</p> <p><b>Walkley Black acid digestion:</b> Uses chromic acid to measure oxidizable organic carbon in the soil. Inaccurate for soils with high contents of very stable carbon (e.g. Black Carbon).</p> <p><b>New methods:</b> Analytical pyrolysis</p>
<b>Non destructive methods</b>	<p><b>Spectroscopy:</b> Mid and near infrared reflectance spectroscopy (MIR and NIR) to be utilized for measuring soil organic carbon (hand held or in the lab) in conjunction with dry combustion analyses. Is much less costly than traditional methods, and greatly increases speed of analysis. These techniques are beginning to become commercially viable and can be integrated into farm equipment.</p> <p><b>Inelastic Neutron Scattering (INS):</b> This is not yet commercially viable.</p>

## 6.2 Remote sensing

Remote sensing includes aircraft or space-based measurements using optical, radar or laser (lidar)<sup>2</sup> sensors. A description of different available sensor resolutions and sensor types is given by Havemann (2009).

Remote sensing has been used to record land use and land cover change for several decades and is particularly well-suited to capture large-scale events like deforestation. The quality of the data gained by remote sensing highly depends on the quality of pixel classification. Adequate ground verification is needed to minimize classification errors. The carbon content of the specific land cover classes has to be determined by field sampling. But remote sensing

<sup>2</sup> Light detection and ranging (Lidar) is a method to determine distance and surface structures comparable to radar systems (radar-radiowave detection and ranging). Instead of radiowaves, scattered light is used. The range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal.

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technology is a very useful tool for adequate up-scaling of sample data and for observation of land use changes.

Radar and lidar sensors are more powerful tools compared to optical remote sensing. They can be used to measure 3D structures including vegetation canopy structure and surface structure including soil moisture (Havemann, 2009).

Some land cover and land use classes may be spectrally inseparable. Remote sensing imagery using the free or cheap coarse and medium resolution imagery like “Landsat” in some cases cannot resolve the small field sizes in small scale farms. High resolution imagery can partly solve this problem, but the overall accuracy of crop classification is still low (e.g. 70% for Mali; by Doraiswamy et al., 2007).

In addition, slight differences like farming practices are difficult to identify by remote sensing. A field trial in Japan showed that tillage practices and fertilizer regimes can be discriminated by remote sensing using multispectral airborne images (Hache et al., 2005). But, in a spatially large, management diverse study area, tilled class accuracy with remote sensing using Landsat lead to unacceptable results (Brickley et al., 2006). The quality of the discrimination of farming practices depend highly on the time when the pictures are taken and a calibration to the local conditions is needed (Hache et al., 2005, Brickley et al., 2006).

Direct estimation of soil organic matter using remote sensing relies on the relationship between the quantity of soil organic matter and soil colour (Havemann, 2009). This method requires visible bare ground. The quality of results depends on litter, soil moisture, texture, chemical composition, parent material and current soil condition (e.g. tillage status). The uncertainty of the gained data is high. Considering the fact that some authors found high differences in soil carbon content in deeper soil layers (Baker, 2007), remote sensing might not be a useful tool direct measurement of soil carbon.

For organic agriculture systems, the estimation of soil carbon by remote sensing classification of fields may be further hindered by the diverse cropping systems recommended for organic agriculture and the use of rare crops for which few data exist for remote sensing calibration.

### **6.3 Models and default values**

All extrapolation of measurement data requires some kind of modelling. So measurement and verification methods can't stand on their own without any model assumptions, even if high quality remote sensing and measurement data is available.

Pre-estimates of sequestration rates used for project planning cannot rely on side measurements and must use models and default values to predict future development of carbon stocks. A high quality of the pre-estimates is essential for the economic reliability of a project. Various soil carbon models have been developed (Table 4). The most suitable one for climate-related questions seems to be the Yasso07 model. But, land management practices are not yet implemented into the model. Another tool for estimating terrestrial carbon stocks and stock changes is the EX-ACT tool, developed by FAO as guidance for project design and decision-making and currently available in a BETA version. The model is predominantly based on IPCC guidelines 2006 (Eggleston et al., 2006).

The existing models do not include specific default values for organic farming systems. As an estimate, conventional default values can be used as far as they represent organic farming strategies (e.g. manure application, agroforestry). In general, the models can be used for organic systems as far as agriculture is included and the parameter values, e.g. for yield, crop residues and organic fertilization, can be adapted. Reliable input data for organic agriculture has to be provided by organic research institutions.

As the variance between organic farming systems around the world is high, a definition of organic systems and farming practices that need to be considered in organic agriculture carbon modelling has to be defined. Emission factors for organic farming practices should be defined and collected in a database. The database with the highest level of approval is the IPCC Emission Factor Database (EFDB). Data that still lack approval could be published for review in a database owned and run by a scientific institution.

Finally, models must be approved by certification bodies before been used for carbon credit projects.

**Table 4: Soil carbon models**

Name	Description
<b>Century</b>	General model of plant-soil nutrient cycling which can be used to simulate carbon and nutrient dynamics for different types of ecosystems including grasslands and agricultural lands
<b>DNDC</b>	DNDC (i.e., DeNitrification-DeComposition), simulation model of carbon and nitrogen biogeochemistry in agro-ecosystems.
<b>Biome-BGC</b>	Estimates fluxes and storage of energy, water, carbon, and nitrogen for the vegetation and soil components of terrestrial ecosystems.
<b>Rothamsted Carbon Model</b>	Medium to long-term soil organic matter turnover model
<b>Yasso07</b>	Widely applicable soil carbon model with output characterized by uncertainty estimates. It was developed in particular focussing on climate and land use issues as well as greenhouse gas inventory systems.
<b>EX-ACT</b>	Ex-ante appraisal carbon-balance tool

## 6.4 Prospects for organic agriculture

Measurement and modelling of carbon sequestration for the agriculture sector are not yet well developed, but there are some promising approaches. A systematic review of terrestrial carbon measurement methodologies currently carried-out by a group of scientists coordinated by FAO may give further evidence on the reliability of different measurement methodologies.

For organic agriculture, the inherent diverse and side specific structure may hinder simple measurement and modelling strategies. Effort must be made to develop measurement and modelling approaches suitable for holistic organic farming systems, as well as to define default values proper to organic crop production. Where organic systems include practices accounted for in conventional measurement and modelling approaches, the respective default values can be used.

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## **7 Possible interfaces with existing carbon accounting standards**

Currently, most of the existing carbon accounting instruments do not yet consider agricultural carbon sequestration (see Table B in Annex). Exceptions are the IPCC AFOLU guidelines 2006, the Chicago Climate Exchange (CCX), and the Voluntary Carbon Standards (VCS). In the following section, a short introduction to these tools is given. The aim is to evaluate the extent to which these standards handle the issues described above and to see if these instruments could be used for the implementation of an offset protocol for organic agriculture.

### **7.1 IPCC guidelines AFOLU 2006**

The IPCC guidelines propose default values (for tier 1 approach) for soil carbon stock changes by considering:

- tillage system: full tillage, reduced tillage and no tillage;
- input level: low, medium, high without manure, high with manure;
- land use type: set aside, perennial crop, paddy rice and long-term cultivated;
- moisture regime: wet/dry; and
- temperature regime: temperate/boreal, tropical and tropical mountains.

The carbon stock change factors rely to a 20 years timeframe and carbon changes to a depth of 30 cm (IPCC, 2006). Errors vary from +/-4% (no tillage, temperate zones) to +/- 50%, such as for paddy rice or tropical mountainous areas (IPCC 2006).

For key categories, default values should be replaced by national or regional data to the largest possible extent (use of tier 2 or tier 3 approaches). Key categories can be identified using a pre-determined cumulative emissions threshold. Key categories are those that, when summed together in descending order of magnitude, add up to 95 percent of the total national anthropogenic greenhouse gas emissions (Eggelston, 2006b).

As far as detailed methodologies (tier 2 or tier 3) are used on national level, the used data and methods are possibly useful for sequestration estimates on regional or project level for carbon credit estimates. Sequestration projects could try to get access to the data used for national emission inventories.

As neither organic farming and such nor many of the organic farming practices are integrated within the IPCC guidelines, IPCC is of little use for estimating the sequestration potential of organic agriculture projects as a whole. Nevertheless, default values for practices used in organic agriculture ( e.g. manure application) can be used.

### **7.2 Voluntary Carbon Standard (VCS)**

The Voluntary Carbon Standards is one of the very few carbon standards already including agricultural land management (see Table B in Annex). A broad range of eligible activities for cropland and grassland management practices is listed (e.g. no-till, elimination of bare fallows, use of cover crops, creation of field buffers, introduction of agroforestry).

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Leakage is assumed to be zero for projects smaller than 10 000 hectare. Concomitant increases in N<sub>2</sub>O, CH<sub>4</sub> and fossil-derived CO<sub>2</sub> have to be accounted. For monitoring the greenhouse gas benefits of agricultural projects, randomized samples allowing a statistical significant determination of changes at a 95% confidence level are required. For a general estimation of the methodology, quality assurance and uncertainty analysis, the standard refers to IPCC 2006 guidelines.

VCS requires a risk assessment for project failure and carbon losses for all projects. Depending on the project risk, carbon credits are deposited in a credit buffer and released only after verification. Validation and verification is carried-out by an independent certifier. For validation and verification, designated entities approved under CDM or JI are eligible. California Climate Action Registry Certification bodies are eligible for verification but not for validation.

### **7.3 Chicago Carbon Exchange**

This standard includes a protocol for continuous conservation tillage and conversion to grassland and sustainably-managed rangelands. No-tillage is defined as tillage practices in accordance with NRCS Handbook of Conservation Practices.

A continuous 5 year forward commitment to the practices specified in the protocol is required.

It is assumed that *“within a Continuous Conservation Tillage and Conversion to Grassland Soil Carbon Sequestration Offset Project, GHG sources above the baseline of normal cropland activities are extremely rare and that in most instances, emissions are below the baseline scenario”*. Hence, potentially higher N<sub>2</sub>O emissions are not discussed within the protocol.

*“CCX does not expect continuous conservation tillage or grassland conversion projects to result in new or changed activities that increase GHG emissions outside of the Project Boundary and, therefore, no project specific leakage assessment is required”*. Effects of no-tillage on yields as a possible source of leakage are not discussed.

The standard attributes fix carbon exchange offsets of 0.2-0.6 metric tons C per acre, depending on the country. Verification includes the check of implementation of conservation tillage practices. But verification by field sampling or remote sensing is not specified.

Each CCX continuous conservation tillage project has to place 20% of the offsets into a reserve pool. These offsets are released to the project owners upon satisfaction of the long-term commitment.

### **7.4 Implication for organic agriculture**

Existing carbon offset protocols can be used as examples for the development of organic agriculture protocols for project implementation proceedings, risk management and verification strategies. But up to now, the existing offset protocols are partly very simplified, and there is no harmonisation between the different voluntary standards e.g. concerning verification requirements.

It must be considered that organic systems are more diverse than the few practices so far included in voluntary carbon standards. Also, organic practices differ remarkably, as adaptive management is a central concern. Hence an offset protocol for organic farming should be more a general guideline on how to estimate and verify carbon stocks. The VCS guidelines can be used as an example. Fixed sequestration rates as in the CCX protocol for no-tillage seem to be less appropriate. As the currently available approved guidelines do not include adequate default

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values and verification strategies for organic farming practices, there is a high need to develop such values if an offset protocol for organic farming shall be implemented. It has to be taken in mind that organic certification itself is not sufficient for carbon accounting as it allows a wide range of different farming practices.

## **8 Organic agriculture and specific carbon offset protocols**

The carbon sequestration potential of organic agriculture relies on specific practices that are common for organic management but that could also be considered in disaggregated offset protocols. These practices include:

- extended crop rotations;
- cultivation of nitrogen fixing plants;
- reduced erosion by avoiding bare fallow;
- reduced erosion by integrating landscape elements;
- set-aside land (e.g. field margins);
- use of manure (from livestock production or green manure) instead of mineral fertilizers;
- implementation of agroforestry;
- reduced use of synthetic fertilizers.

All these practices are recommended as mitigation strategies by the IPCC (Smith, 2007) except for reduced use of synthetic fertilizers, which is mentioned by the Terrestrial Carbon Group Project (2009) for its positive effects on soil micro-organisms. They could be implemented each in a single offset protocol.

But an additional aggregated offset protocol for organic agriculture has some inherent advantage compared with disaggregated protocols for specific practices.

First, certification of organic production and carbon crediting could be combined in the same certification system. This way certification costs could be lowered and efficiency could be increased. Existing cooperation and knowledge of organic farmers' organisations and certifiers could be integrated.

Second, organic farming as a holistic approach usually combines several of the above-mentioned practices. It is assumed that a combination of different measurements is more efficient than implementing only one specific practice. Having only disaggregated protocols available could increase certification costs and by that hinder access to carbon credits.

Third, organic agriculture could support the implementation of these techniques, which face a number of technical and financial challenges (Smith et al., 2008). Within the organic sector, a broad knowledge on how to implement these practices is developed and could help to overcome the technical challenges and facilitate adapted implementation. Premium price organic markets could help to overcome financial challenges.

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## 9 Conclusions and recommendations

### 9.1. Conclusions

The following preconditions have to be met for an integration of a farming management strategy into carbon markets (Perez, 2007):

- Capacity of the agricultural practices to enhance C storage;
- Capacity of farmers to adapt and maintain these practices;
- Ability to monitor C stocks;
- Institutional capacity to aggregate C credits;
- Access of farmers to incentive payments.

The section below summarizes how these preconditions could be met by organic agriculture.

**Capacity of organic practices to enhance C storage.** There is scientific evidence that organic agriculture can sequester more carbon than conventional agricultural practices or inhibit the carbon release. All available studies showed higher carbon stocks in organic systems as compared to conventionally farmed sides. To avoid leakage, organic agricultural systems should achieve yields comparable to conventional systems, which are likely for areas where currently low-input agriculture is practiced or where soil quality is degraded, which are at the same time areas where sequestration projects could be realised with high technical sequestration potential and low project costs.

**Capacity of farmers to adapt and maintain these practices.** Farmers' capacity building needs investment that could be facilitated by carbon accounting projects. Organic agricultural practices are less input-dependent than conventional practices and hence, are suitable to marginalized populations.

**Ability to monitor C stocks.** This is the biggest constrain for carbon accreditation of agricultural projects in general and organic agriculture projects in particular. First, below ground soil organic carbon, which is the main carbon stock in agricultural systems, is very difficult or almost impossible to measure by remote sensing. Second, the diverse structure of organic agricultural systems render modelling and measurement more complex. Third, organic systems tend to cultivate diverse and rare species and breeds, for which few data is available on carbon content, yields and sequestration potential. The quantity of sequestered carbon differed widely between the comparative studies reviewed in this document. Research is needed to foster both measurement methods and data bases for default values. Especially for developing countries, the data gap is still huge.

**Institutional capacity to aggregate C credits.** Up to now, agricultural practices are not part of the UN carbon offset program. Further developments in carbon trading have to be awaited (or promoted). Participation in voluntary carbon markets is possible as soon as standards are defined. Cooperation with certification bodies could be helpful to achieve this aim.

**Access of farmers to incentive payments.** A comprehensive study on costs and benefits of carbon crediting for organic farming is needed to check conditions making carbon crediting for organic projects suitable.

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Organic agriculture is a promising approach for sustainable terrestrial carbon sequestration. Combined with its positive effects for sustainable development, organic agriculture is a strategy particularly suitable for degraded areas and communities with limited access to external agricultural input. Creating access to carbon markets for these communities could be a way to combine climate change mitigation with food security and rural development in a synergistic and efficient manner.

Compared with disaggregated offset protocols (e.g. for conservation tillage), the inherent potential of organic agriculture lays in its holistic approach combining different practices known to increase soil and biomass carbon and its potential to facilitate implementation by supporting enhanced livelihoods. Combining organic certification and carbon certification within the same certification body could furthermore reduce certification costs.

## 9.2. Recommendations

For an integration of organic agricultural management into carbon accounting systems and hence taking advantage of its additional positive effects on sustainability, a considerable effort in research and development of an offset protocol is needed. Stakeholders in organic agriculture, as well as institutions working on carbon management and quantification in agricultural lands in general, should be involved in a coordinated development process.

In particular, effort should be put into the following topics:

**Modelling of costs and gains.** If the costs of measurement, verification, certification and transactions exceed the gains by carbon credits, carbon trading is not a suitable option for farmers. Costs and gains should be modelled focussing on small-scale farmers in developing countries.

**Database for default values and models for carbon sequestration in organic agriculture.** For project planning, accurate data on expected sequestration rates is needed. A systematic review of the peer-reviewed literature, grey literature and databases including unpublished data from organic researchers should be carried out to define: (a) the different types of agricultural farming systems; (b) suitable methods to estimate the carbon sequestration rates in the specific systems and for different carbon stocks; and (c) implementation of a comprehensive database for agricultural carbon sequestration rates. For bullets b) and c), strong cooperation between developers of disaggregated offset protocols and organic farming experts should be facilitated to achieve a maximum outcome.

**Definition of measurement and verification strategies suitable for organic agriculture.** Guidelines for sampling plans, measurement methods and models for estimating total sequestered carbon based on these measurements are needed. This effort should be preferably carried when the results of the systematic review on terrestrial carbon measurement, coordinated by FAO, will come to an end in the fourth quarter of 2010.

**Pilot projects.** Pilot projects for voluntary carbon crediting in organic agriculture projects could be supported or implemented by the institutions who will be involved in gathering further information. Pilot projects could be helpful to gather practical experience in project planning, technical implementation, carbon sequestration measurement and social and ecological impacts. Groups of farmers could be integrated in a participatory approach for the development of standards. An example for a pilot project is e.g. the Western Kenya Smallholder Agriculture Carbon Finance Project, financed by the World Bank Carbon Finance Unit (World Bank, 2008). The advantage of pilot projects could be to collect data on different aspects of carbon accounting system (e.g. technical and social aspects) at the same time and place and under field conditions, allowing a holistic evaluation.

## Annex: Place of agriculture in carbon trading instruments

**Table A: Emission trading schemes in Kyoto Annex I countries and their relation to agriculture**

Country	Description of scheme
<b>European Union</b>	Mandatory scheme covering CO <sub>2</sub> emissions from major installations in selected sectors, including energy, ferrous metals, mineral industry and pulp and paper. Agriculture and Forestry are not integrated.
<b>New Zealand</b>	Mandatory cap and trade scheme. Agriculture will be covered on a voluntary base in 2011 and on a mandatory base in 2012, with full obligations in 2015.
<b>Norway</b>	Cap and trade scheme for CO <sub>2</sub> emissions from large direct emitters in selected (mainly industry) sectors for 2005 to 2007. Fully linked to the EU ETS from 2008.
<b>Switzerland</b>	Voluntary scheme in conjunction with an exemption from proposed mandatory CO <sub>2</sub> taxes covers CO <sub>2</sub> emissions from large companies or groups of companies that opt in to the scheme. Agriculture and Forestry is not included.
<b>United States</b>	Voluntary cap and trade system: Includes offset protocols for carbon sequestration by conservation tillage, conversion to grassland (minimum commitment period: 5 years). Permanence is guaranteed by holding exchange offsets as escrow in a soil carbon reserve pool.
<b>Canada</b>	Provincial voluntary carbon market in Alberta including agricultural offset protocols, e.g. for no-tillage.
<b>Australia</b>	Carbon trading scheme in process of parliament approval. Agriculture has been excluded from emission trading scheme while allowing farmers to generate carbon credits. Processors of agricultural commodities are included.
<b>Japan</b>	Trial carbon-trading market, not including agriculture
<b>Russian Federation</b>	Sells carbon offsets under joint implementation. Mitigation focus on industries and less on agriculture and forestry

**Table B: Carbon sequestration in agriculture and forestry in different carbon accounting standards**

Standard	Carbon sequestration in	
	Forestry	Agriculture
<b>Emission reduction and sequestration standards</b>		
<b>CDM</b> ( <a href="http://cdm.unfccc.int/">http://cdm.unfccc.int/</a> )	reduced emission from deforestation and degradation projects. 10 registered projects worldwide	not included (127 projects are registered as agricultural projects, but they only comprise improved animal waste management, methane capturing and bioenergy projects)
<b>Social Carbon</b> ( <a href="http://www.socialcarbon.com">http://www.socialcarbon.com</a> )	standards not available to public, private profit enterprise/trademark	
<b>Carbonfix</b> ( <a href="http://www.carbonfix.info">http://www.carbonfix.info</a> )	C in soils not included in calculation of baseline, fixation and leakage	not included
<b>CCBA</b> ( <a href="http://www.climate-standards.org">http://www.climate-standards.org</a> )	included. use of IPCC AFOLU 2006 standards	<b>included.</b> use of IPCC AFOLU 2006 standards
<b>CDM Gold Standards</b> ( <a href="http://www.cdmgoldstandard.org/">http://www.cdmgoldstandard.org/</a> )	(standards for CDM projects)	not included because not included in CDM
<b>VCS</b> ( <a href="http://www.v-c-s.org">http://www.v-c-s.org</a> )	includes afforestation, reforestation and revegetation as well as sustainable forest management	<b>includes</b> improved cropland and grassland management projects
<b>Plan Vivo</b> ( <a href="http://www.planvivo.org/">http://www.planvivo.org/</a> )	included	not included
<b>Chicago Climate Exchange</b> ( <a href="http://www.chicagoclimatex.com/">http://www.chicagoclimatex.com/</a> )	includes afforestation, reforestation and revegetation as well as sustainable forest management	<b>includes</b> standards for sustainable rangeland management and conservation tillage
<b>California Climate Action Reserve</b> ( <a href="http://www.climateregistry.org/">http://www.climateregistry.org/</a> )	special protocol for forestry industry included. accounting for soil carbon is optional.	no special protocol included. accounting for soil carbon optional according to the general guidelines
<b>Corporate Emission accounting standards</b>		
<b>GHG protocol corporate standard</b> ( <a href="http://www.ghgprotocol.org/standards/corporate-standard">http://www.ghgprotocol.org/standards/corporate-standard</a> )	assessment of carbon sequestration as far as affected by the company	
<b>Global Reporting Initiative</b> ( <a href="http://www.globalreporting.org">http://www.globalreporting.org</a> )	carbon sequestration not directly named but partly integrated by referring to IPCC standards	
<b>Product based climate assurance standards</b>		
<b>GHG reporting in the RTFO Renewable Transport Fuels Obligation</b> ( <a href="http://www.renewablefuelsagency.org/about/therftfo.cfm">http://www.renewablefuelsagency.org/about/therftfo.cfm</a> )	standard for suppliers of fossil fuels. protection of above and below ground biomass stocks and soil degradation are included	
<b>PAS 2050</b> ( <a href="http://www.carbontrust.co.uk/carbon/briefing/pre-measurement.htm">http://www.carbontrust.co.uk/carbon/briefing/pre-measurement.htm</a> )	land use change included, forest management excluded. country default values for LUC.	land use change included (uses IPCC Guidelines). management (e.g. tillage) excluded. Country default values for LUC.
<b>Biofuel sustainability criteria in the RES directive</b> ( <a href="http://www.managenergy.net/prodcuts/R80.htm">http://www.managenergy.net/prodcuts/R80.htm</a> )	Biofuels only	
<b>ISO 14067 - Carbon footprint of products and</b> <b>ISO 14044:2006 - Environmental management - Life cycle assessment - Requirements and guidelines</b> ( <a href="http://www.iso.org/iso/catalogue">http://www.iso.org/iso/catalogue</a> )	general guideline on LCA definitions, execution phases and constitutive elements	

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## References

- Badgley, C., Moghtader, J., Quintero, E., Zakem, E., Chappell, M.J., Avilés-Vázquez, K., Samulon, A. and Perfecto, I. 2007. Organic agriculture and the global food supply. *Renewable Agriculture and Food Systems* 22: 86-108.
- Baker, J.M., Ochsner, T.E., Venterea, R.T. and Griffis, T.J. 2007. Tillage and soil carbon sequestration – What do we really know?. *Agriculture, Ecosystems and Environment* 118, 1-5.
- Bodnár, F. 2008. Carbon Baseline Sumbawanga, Tanzania. May 2008.  
<HTTP://WWW.GROLINK.SE/EPOPA/PUBLICATIONS/SUMBAWANGACARBONSUMMARYMAY%2008.PDF>
- Brown, S., D. Shoch, T. Pearson, and M. Delaney. 2004. Methods for Measuring and Monitoring Forestry Carbon Projects in California. Winrock International, for the California Energy Commission, PIER Energy-Related Environmental Research. 500-04-072F.  
[HTTP://WWW.FS.FED.US/PSW/PROGRAMS/CUFR/PRODUCTS/12/PSW\\_CUFR699\\_BROWN\\_MEASURING\\_C.PDF](HTTP://WWW.FS.FED.US/PSW/PROGRAMS/CUFR/PRODUCTS/12/PSW_CUFR699_BROWN_MEASURING_C.PDF)
- Chan, K.Y. 2001. Soil particulate organic carbon under different land use management. *Soil Use and Management* 17, 217-221.
- Ciavatta, C., Gioacchini, P., Montecchio, D. 2008. Can organic farming contribute to carbon sequestration? A survey in a pear orchard in Emilia Romagna Region, Italy. *Cultivating the future based on science. Volume 2: Livestock, socio-economy and cross disciplinary research in organic agriculture. Proceedings of the Second Scientific Conference of the International Society of Organic Agriculture Research (ISO FAR), held at the 16th IFOAM Organic World Conference in Cooperation with the International Federation of Organic Agriculture Movements (IFOAM) and the Consorzio ModenaBio in Modena, Italy, 18-20 June.*
- Codex Alimentarius Commission. Guidelines for the Production, Processing, Labelling and Marketing of Organically Produced Foods. Available at:  
[HTTP://WWW.CODEXALIMENTARIUS.NET/DOWNLOAD/STANDARDS/360/CXG\\_032E.PDF](HTTP://WWW.CODEXALIMENTARIUS.NET/DOWNLOAD/STANDARDS/360/CXG_032E.PDF).
- Dutschke, M. and Schlamadinger, B. 2003. Practical Issues Concerning Temporary Carbon Credits in the CDM. Discussion Paper. Hamburg Institute of International Economics.  
<HTTP://AGECONSEARCH.UMN.EDU/BITSTREAM/26241/1/DF030227.PDF>
- East African Community 2007. East African organic products standard.
- Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds.) 2006. IPCC Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and other land use.  
<HTTP://WWW.IPCC-NGGIP.IGES.OR.JP/PUBLIC/2006GL/VOL4.HTML>
- EFDB – User Manual for WEB Application (Version 2.0). Appendix A: Criteria to be used in the evaluation by the EFDB Editorial Board. download 4. December 2009.  
[http://www.ipcc-nggip.iges.or.jp/EFDB/documents/EFDB\\_User\\_Manual\\_A-D.pdf](http://www.ipcc-nggip.iges.or.jp/EFDB/documents/EFDB_User_Manual_A-D.pdf)
- Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds.) 2006b. IPCC Guidelines for National Greenhouse Gas Inventories. Volume 1: General guidance and reporting. <http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol1.html>
- El-Hage-Scialabba, N. 2007. Organic agriculture and food security. International Conference on Organic Agriculture and Food Security, 3-5. May 2007, FAO, Italy.  
<ftp://ftp.fao.org/docrep/fao/meeting/012/ah952e.pdf>
- EFMA (European Fertilizer Manufacturers Association). Understanding Nitrogen and its use in agriculture. Brussels.
- Erismann, J.W., Sutton, M.A., Galloway, J., Klimont, Y. and Winiwarter, W. 2008. How a century of ammonia synthesis changed the world. *Nature Geoscience* 1, 636-639.

- 
- FAO 2009. Increasing incomes and food security of small farmers in West and Central Africa through exports of organic and fair-trade tropical products. Mango, Pineapple, Cocoa. Trade and Markets Division of the Food and Agriculture Organisation of the United Nations. GCP/RAF/404/GER. Rome.  
<FTP://FTP.FAO.ORG/DOCREP/FAO/FIELD/009/AK800E/AK800E00.PDF>  
<FTP://FTP.FAO.ORG/DOCREP/FAO/FIELD/009/AK798E/AK798E00.PDF>  
<ftp://ftp.fao.org/docrep/fao/field/009/ak799e/ak799e00.pdf>
  - FAOSTAT. <HTTP://FAOSTAT.FAO.ORG/DEFAULT.ASPX>.
  - Flessa, H., Ruser, R., Doersch, R., Kamp, T., Jimenez, M.A., Munch, J.C. and Beese, F. 2002. Integrated evaluation of greenhouse gas emissions from two farming systems in southern Germany: Special consideration of soil N<sub>2</sub>O emissions. *Agriculture, Ecosystems and environment* 91: 175-189.
  - Fliessbach, A., Oberholzer, H.-R., Gunst, L. and Mäder, P. 2007. Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. *Agriculture, Ecosystems & Environment* 118,273-284.
  - Grandy, A.S. and Robertson, G.P. 2007. Land-use intensity effects on soil organic carbon accumulation rates and mechanisms. *Ecosystems* 10: 59-71.
  - Havemann, T. 2009. Measuring and Monitoring Terrestrial Carbon. The State of the Science and Implications for Policy Makers. Prepared for The Terrestrial Carbon Group.  
[HTTP://WWW.TERRESTRIALCARBON.ORG/SITE/DEFAULTSITE/FILESYSTEM/DOCUMENTS/MEASURING%20MONITORING%20TERRESTRIAL%20CARBON%20090901\\_2.PDF](HTTP://WWW.TERRESTRIALCARBON.ORG/SITE/DEFAULTSITE/FILESYSTEM/DOCUMENTS/MEASURING%20MONITORING%20TERRESTRIAL%20CARBON%20090901_2.PDF)
  - Hepperly, P., Douds, Jr., and Seidel, R. 2006. The Rodale farming system trial 1981-2005: long term analysis of organic and conventional maize and soybean cropping systems. In: Long-term field experiments in organic farming. Raupp, J., Pekrun, C., Oltmanns, M. and Köpke, U. (eds.). pp 15-32. International Society of Organic Agricultural Research (ISO FAR), Bonn.
  - Hole, D.G., Perkins, A.J., Wilson, J.D., Alexander, I.H., Grice, P.V., Evans, A.D. 2005. Does organic farming benefit biodiversity? *Biological Conservation* 122: 113-130.
  - International Federation of Organic Agricultural Movements (IFOAM) 2002. Basic Standards for Organic Production and Processing approved by the IFOAM General Assembly, Victoria, Canada, August 2002.
  - Kessel, Ch. van, Six, J. and Chung, H. 2006. Sequestering C in stable soil organic matter fractions: How important is fertilizer-N in sequestering Carbon? Kearney Foundation of Soil Science: Soil Carbon and Californias Ecosystem.
  - Küstermann, B., Kainz, M., and Hülsbergen, K.-J. 2008. Modeling carbon cycles and estimation of greenhouse gas emissions from organic and conventional farming systems. *Renewable Agriculture and Food Systems* 23: 38-52.
  - Lal, R. 2004. Soil carbon sequestration impacts on global climate change and food security. *Science* 304: 1623-1627.
  - Liebig, M.A., Morgan, J.A., Reeder, J.D., Ellert, B.H., Gollany, H.T. and Schuman, G.E. 2005. Greenhouse gas contributions and mitigation potential of agricultural practices in northwestern USA and western Canada. *Soil & Tillage Research* 83: 25-52.
  - Lotter, D., Seidel, R. and Liebhardt, W. 2003. The Performance of Organic and Conventional Cropping Systems in an Extreme Climate Year. *American Journal of Alternative Agriculture* 18: 146-154.
  - Mäder, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P. and Niggli, U. (2002): Soil Fertility and Biodiversity in Organic Farming. *Science* 296, 1694-1697.
  - McNeely, J.A., & Scherr, S.J. 2001. Common Ground, Common Future. How Eco-agriculture can help feed the world and save wild biodiversity. IUCN and Future Harvest, May 2001.
  - Ministry of Agriculture, Fisheries and Food of the United Kingdom (MAFF) 2000. Energy use in organic farming systems. MAFF project code OF01082.

- 
- Metz, B., Davidson, O.R., Bosch, P.R., Dave, R. and Meyer, L.A. (eds) 2007. Contribution of Working Group III: Mitigation. Fourth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.  
[HTTP://WWW.IPCC.CH/PUBLICATIONS\\_AND\\_DATA/PUBLICATIONS\\_IPCC\\_FOURTH\\_ASSESSMENT\\_REPORT\\_WG3\\_REPORT\\_MITIGATION\\_OF\\_CLIMATE\\_CHANGE.HTM](http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm)
  - Murray, B.C., Sohngen, B. and Ross, M.T. Economic consequences of consideration of permanence, leakage and additionality for soil carbon sequestration projects. *Climatic Change* (2007) 80:127–143.  
[HTTP://WWW.SPRINGERLINK.COM/CONTENT/Lj77757232590311/FULLTEXT.PDF](http://www.springerlink.com/content/Lj77757232590311/fulltext.pdf)
  - Nemes, N. 2009. Comparative analysis of organic and non-organic farming systems. A critical assessment of farm profitability. FAO, Rome.  
[FTP://FTP.FAO.ORG/DOCREP/FAO/011/AK355E/AK355E00.PDF](ftp://ftp.fao.org/docrep/fao/011/ak355e/ak355e00.pdf)
  - Niggli, U., Fliessbach, A., Hepperly, P. and Scialabba, N. 2009. Low Greenhouse Gas Agriculture: Mitigation and Adaptation Potential of Sustainable Farming Systems. FAO, April 2009, Rev. 2 – 2009.  
[FTP://FTP.FAO.ORG/DOCREP/FAO/010/AI781E/AI781E00.PDF](ftp://ftp.fao.org/docrep/fao/010/AI781E/AI781E00.pdf)
  - Perez, C., Roncoli, C., Neely, C., Steiner, J.L. 2007. Can carbon sequestration markets benefit low-income producers in semi arid Africa? Potentials and challenges. *Agricultural Systems* 94: 2-12.
  - Pimentel, D., Hepperly, P., Hanson, J., Douds, D. and Seidel, R. 2005. Environmental, energetic and economic comparison of organic and conventional farming systems. *Bioscience* 55, 573-582.
  - Pretty, J. 2002. Lessons from certified and non certified organic projects in developing countries. In N. El-Hage Scialabba, C. Hattam (eds.). *Organic agriculture, environment and food security*. FAO, Rome. p. 139-162.
  - Rice, C.W. and Owensby, C.E. 2001. Effects of fire and grazing on soil carbon in rangelands. In R. Follet, M.M. Kimble and R. Lal (eds.). *The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect*. Lewis Publishers, Boca Raton, Florida. pp. 323-342.
  - Rühling, I., Ruser, R., Kölbl, A., Priesack, E., Gutser, R. 2005. Kohlenstoff und Stickstoff in Agrarökosystemen. In: *Landwirtschaft und Umwelt – ein Spannungsfeld*. Osinski, E., Meyer-Aurich, A., Huber, B., Rühling, I., Gerl, G., Schröder, P (eds.). pp 99-154. Ökom Verlag, München.
  - Ruser, R., Flessa, H., Schilling, R., Beese, F., and Munch, J.C. 2001. Effects of crop-specific field management and N fertilization and N<sub>2</sub>O emissions from a fine-loamy soil. *Nutrient Cycling in Agroecosystems* 59: 177-191.
  - Schwarze, R., Niles, J.O. and Olander, J. 2003. Understanding and Managing Leakage in Forest-Based Greenhouse Gas Mitigation Projects. The Nature Conservancy and The Royal Society.  
[HTTP://PDF.DEC.ORG/PDF\\_DOCS/PNACY489.PDF](http://pdf.dec.org/pdf_docs/PNACY489.pdf)
  - Scialabba, N. and Müller-Lindenlauf, M. 2010. Organic Agriculture and Climate Change. Renewable Agriculture and Food Systems. Requested Review. In print.
  - Secretariat of the Pacific Community 2008. Pacific organic standard. Prepared by the Regional Organic Task Force.
  - Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B., O. Sirotenko, M. Howden, T. McAllister, G. Pan, V. Romanenkov, U. Schneider, S. Towprayoon, M. Wattenbach and J. Smith. 2008. Greenhouse gas mitigation in agriculture. *Philosophical Transactions of The Royal Society*, 363: 789-813.
  - Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B. and Sirotenko, O. 2007: Agriculture. In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
  - Smith, K.A., McTaggart, I.P., Dobbie, K.E. and Conen, F. 1998. Emissions of N<sub>2</sub>O from Scottish agricultural soils, as a function of fertilizer N. *Nutrient Cycling in Agroecosystems* 52: 123-130.

- 
- Stalenga, J., Kawalec, A. 2008. Emissions of greenhouse gases and soil organic matter balance in different farming systems. *International Agrophysics* 22, 287-290.
  - Stockfisch, N., Forstreuter, T., and Ehlers, W. 1999. Ploughing effects on soil organic matter after twenty years of conservation tillage in Lower Saxony, Germany. *Soil and Tillage Research* 52: 91-101.
  - Stolbovoy, V., Montanarella, L., Filippi, N., Selvaradjou, S., Panagos, P. and Gallego, J. 2005. Soil Sampling Protocol to Certify the Changes of Organic Carbon Stock in Mineral Soils of European Union. EUR 21576 EN, 12 pp. Office for Official Publications of the European Communities, Luxembourg.
  - Stolze, M., Piorr, A., Haring, A. and Dabbert, S. 2000. The Environmental Impacts of Organic Farming in Europe. In: *Organic Farming in Europe: Economics and Policy*. Vol. 6. University of Hohenheim, Stuttgart.
  - Terrestrial Carbon Group Project 2009. A Roadmap for Terrestrial Carbon: Research Needs for Implementation of Carbon Management in Agriculture, Forestry and Other Land Uses. Rapid Assessment – Revised Draft. September 2009. Published by UN-REDD, The World Bank, CGIAR and The Heinz Center.
  - Teasdale, J. R., Coffman, C. B. and Mangum, R. W., 2007. Potential long-term benefits of no-tillage and organic cropping systems for grain production and soil improvement. *Agronomy Journal* 99 (5): 1297-1305.
  - Tizio, A., di Lagomarsino, A., Moscatelli, M.C., Marinari, S. and Mancinelli, S.G.R. 2008. The effects of system management on soil carbon dynamics. *Lucrari Stiintifice – Universitatea de Stiinte Agronomice si Medicina Veterinara Bucuresti. Seria B, Horticulture*. Volume 51, 645-650.
  - UNFCCC 2003a. Methodological issues. Land use, land use change and forestry: definitions and modalities for including afforestation and reforestation activities under article 12. of the Kyoto protocol in the first commitment period. Options paper on modalities for addressing non-permanence. FCCC/SBSTA/2003/5.  
[HTTP://WWW.CCSR.U-TOKYO.AC.JP/UNFCCC3/PDFS/UNFCCC.INT/RESOURCE/DOCS/2003/SBSTA/05.PDF](http://www.ccsr.u-tokyo.ac.jp/unfccc3/pdfs/unfccc.int/resource/docs/2003/sbsta/05.pdf)
  - UNFCCC 2003b. Methodological issues. Land use, land use change and forestry: definitions and modalities for including afforestation and reforestation activities under article 12. of the Kyoto protocol in the first commitment period. Options paper on modalities for addressing baselines, additionality and leakage. FCCC/SBSTA/2003/6.  
[HTTP://WWW.CCSR.U-TOKYO.AC.JP/UNFCCC3/PDFS/UNFCCC.INT/RESOURCE/DOCS/2003/SBSTA/06.PDF](http://www.ccsr.u-tokyo.ac.jp/unfccc3/pdfs/unfccc.int/resource/docs/2003/sbsta/06.pdf)
  - UNFCCC 2003c. Modalities and procedures for afforestation and reforestation project activities under the clean development mechanism in the first commitment period of the Kyoto Protocol. Decision Conference of the Parties 9, Milano, Italy.  
[http://unfccc.int/cop9/latest/sbsta\\_127.pdf](http://unfccc.int/cop9/latest/sbsta_127.pdf)
  - UNFCCC 2007a. A/R Methodological Tool “Tool for the Demonstration and Assessment of Additionality in A/R CDM Project Activities” (Version 02)”. EB 35 Report Annex 17.  
[HTTP://CDM.UNFCCC.INT/METHODOLOGIES/ARMETHODOLOGIES/TOOLS/AR-AM-TOOL-01-V2.PDF](http://cdm.unfccc.int/methodologies/armethodologies/tools/ar-am-tool-01-v2.pdf)
  - UNFCCC 2009a. A/R Methodological Tool “Calculation of the number of sample plots for measurements within A/R CDM project activities”. EB 46 Report Annex 19.  
[HTTP://CDM.UNFCCC.INT/METHODOLOGIES/ARMETHODOLOGIES/TOOLS/AR-AM-TOOL-03-V2.PDF](http://cdm.unfccc.int/methodologies/armethodologies/tools/ar-am-tool-03-v2.pdf)
  - Watson, R.T., Noble, I.R., Bolin, B., Ravindranath, N.H., Verardo, D.J. Dokken, D.J. (Eds.) 2000. IPCC Special Report on Land Use, Land Use Change and Forestry. Cambridge University Press, UK.  
[HTTP://WWW.IPCC.CH/IPCCREPORTS/SRES/LAND\\_USE/](http://www.ipcc.ch/ipccreports/sres/land_use/)
  - Wells, T., Chan, K.Y. and Cornish, P.E. 2000. Impact of different conventional and alternative farming systems on soil quality. *Agriculture, Ecosystems and Environment* 80: 47-60.
  - Willer, H. and Kilcher, L. (eds.) 2009. *The World of Organic Agriculture. Statistics and Emerging Trends 2009*. IFOAM, Bonn; FiBL, Frick; ITC, Geneva.
  - Williams, A.G., Audsley, E. and Sandars, D.L. (2006) Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra. Available on and [www.defra.gov.uk](http://www.defra.gov.uk).
  - World Bank 2008. Western Kenya Smallholder Agriculture Carbon Finance project. Adaption of Sustainable Land Management practices on small-holder farms in Kenya to increase staple food production and generate carbon revenues. World Bank Carbon Finance Business. Submitted May 2008.

- 
- Zieseimer, J. 2007. Energy use in organic food systems. Natural Resources Management and Environment Department Food and Agriculture Organization of the United Nations, Rome, 2007.
  - ˘ <http://www.fao.org/docs/eims/upload/233069/energy-use-oa.pdf>
  - Zundel, Ch., Kilcher, L. 2007. Organic agriculture and food availability. International Conference on Organic Agriculture and Food Security, 3.-5. May 2007, FAO, Italy.
- <FTP://FTP.FAO.ORG/PAIA/ORGANICAG/OFS/OFS-2007-1.PDF>