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SOIL CARBON SEQUESTRATION OF ORGANICC CROP AND LIVESTOCK SYSTEMS AND POTENTIAL FOR ACCREDITATION BY CARBON MARKETS

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During a two-day RTOACC workshop hosted by the Research Institute of Organic Agriculture (FiBL), participants discussed the potential for organic agriculture in carbon markets and the need to develop strategies for the role of organic agriculture in climate policy. To move in this direction requires quantifying and raising recognition of the mitigation potential of organic agriculture. Thus the participants also looked at available data and began a process of identifying data gaps. In doing so, they presented the related ongoing work of their organizations and drew conclusions for the further orientation and actions of the RTOACC. The following synthesizes the discussions, reports and outcomes of the workshop.

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EXISTING GAPS IN AVAILABLE DATA REQUIRED TO QUANTIFY THE MITIGATION POTENTIAL OF ORGANIC AGRICULTURE

Efforts to assess the mitigation potential of organic agriculture still face huge challenges and data gaps. In order to meet these challenges, it is first critical to set base values and then to combine model, experimental and real farm data to reduce the work load required for establishing factorial field experiments. This requires determining how sophisticated the data collection should be and the “type” of organic agriculture that will be included.

RTOACC has identified the areas where data is most needed as:

- input-related emissions, such as from compost or fertilizer preparations,
- process-related emissions and emissions from various management types, such as legume rotations, reduced tillage, N2O dynamics of compost application and soil carbon,
- emissions and soil carbon sequestration of entire production systems,
- emissions of specific crops within complex spatially diverse crop rotation systems.

In order to find ways to fill these data gaps, efforts are underway to set parameters and identify steps for ensuring consistency of data. For example, this could include standardizing key parameters such as: emissions factors for CH_4, N_2O, CO_2, soil carbon stocks and thickness of soil horizons, making use of existing long-term trial, establishing a database, defining standards for data quality and building up a body of knowledge.

Those committed to filling these data gaps face a trade-off between detailed and reliable data that require correspondingly expensive measurement approaches on the one hand, and fast, widely applicable and inexpensive measurement approaches that have correspondingly less detail and reliability on the other. Adequately identifying and supporting mitigation in organic agriculture requires finding a balance between scientific approaches based on detailed empirical data, and those based on broader visionary and conceptual approaches. This means determining which indicators and weights will assess the performance of a certain system against different indicators with respect to mitigation and co-benefits. For example, aggregation into a one-dimensional indicator can be avoided by using multi-dimensional spider diagrams to compare systems and inform decisions. However, it remains important to avoid focusing solely on organic agriculture as a mitigation instrument. It is also necessary to promote its other equally important benefits such as animal welfare, biodiversity, soil fertility and ethics.

RTOACC is committed to contributing to closing these data gaps and providing the scientific basis for decisions on balancing sustainability indicators. Many RTOACC members have specific research underway that is producing relevant data on the mitigation potential of organic farming, such as a meta-study on soil carbon conducted at FiBL (presented further in the text), and two assessments of soil carbon sequestration: one under Mediterranean site conditions conducted by the Spanish Society for Organic Farming (SEAE) and one under tropical site conditions conducted by Educative Cooperation for the Development of Costa Rica (CEDECO).

Organic agriculture can offer sustainable carbon credits. Although the financial rewards of the credits will likely be moderate, they could support financing the transition from a conventional to an organic system or the adoption of certain climate-friendly practices in both plant and animal production. In addition to their mitigation impact, credits related to organic farming practices offer a variety of valuable co-benefits, such as their indirect contribution to food security, yield stability, sustainability and adaptation to climate change, as can be seen specifically in plant and animal production.

- In plant production, the potential for generating carbon credits is mainly seen in compost use, biomass waste and manure storage and handling, fertilizer avoidance, biogas production, agroforestry and in avoided biomass burning. Due to the huge areas under agricultural production, soil carbon sequestration has a considerable global mitigation potential, although the potential per hectare is usually rather low and thus not ideal for the existing carbon crediting mechanisms.
- In animal production, the main potential for generating carbon credits is seen in improving lifetime performance by reducing GHG emissions per unit of output. The reduction of concentrate feed has a huge mitigation potential due to the land-use impact of concentrate feed production. However, capturing this in the existing carbon crediting mechanisms will be difficult, mainly due to the global system boundaries often involved. The potential co-benefits of these credits are manifold such as increased energy efficiency, improved livelihoods, improved biodiversity and soil organic matter, and longer term soil fertility, system stability and resilience.

Credit-based approaches to organic agriculture face specific challenges due to the rather low level of financial flows involved and the need for optimal institutional organization to manage payments from carbon finance. Assessing the carbon price necessary to make mitigation projects in organic agriculture attractive and relevant to farmers requires detailed data on farm economics. Furthermore, due to the low mitigation potential per hectare, several hundred to several thousand farms need to be grouped in order to be worthwhile. In such a context, the organic certification system may offer opportunities to simplify monitoring.

Application of certain techniques has potential to make organic agriculture more efficient; however it will require coordinating a complex set of measurement methods and indicators for a complex set of different farm types. At the workshop it was suggested the establishment of an organic agriculture-climate change board as a straightforward

solution. Properly designed, it could plan and coordinate efficient management and application of all this knowledge, through a pragmatic learning-by-doing exercise.

At the same time, due attention must be given to the incentive and fairness aspects of carbon payments. At this point, only farms changing their management from conventional to organic can apply for these payments. This means that farmers who already converted to organic management, and thus already run their farms sustainably, do not receive anything.

Looking at the long term, carbon finance institutions need to recognize that carbon credits and carbon trade do not provide the best solutions for supporting organic agriculture. RTOACC suggests an approach based on voluntary agreements, using local markets that can build on trust, as opposed to global approaches based on high monitoring requirements. The design of more appropriate policy instruments is another option. These options would have better chances of adoption if, for example, they were based on the idea of combining taxes with subsidies or offered grandfathered emissions payment schemes.

Organic agriculture has the potential to play an important role on the more aggregate level of the newly emerging general approaches in climate policy, such as Nationally Appropriate Mitigation Actions (NAMAs) or National Adaptation Programmes of Action (NAPAs). It also has to be emphasized that the performance of organic agriculture would be advantageous in even broader approaches to climate policy, based on the internalization of external costs, such as through national or global carbon taxes.

POTENTIAL OF SOIL CARBON SEQUESTRATION OF ORGANIC CROP AND LIVESTOCK SYSTEMS

This section looks at a meta study on the carbon sequestration potential of organic agriculture – its aims, methodology and results.

Introduction

In 2010, FiBL conducted a literature review on soil organic carbon (SOC) contents, stocks and sequestration rates in organically managed soils, using 45 suitable scientific papers and 280 different data sets, and undertook a quantitative evaluation of the obtained results using meta-analysis.

Meta-analysis, a statistical procedure that combines data from multiple studies, allows a quantitative proof of a hypothesis and offers a significant advantage over a narrative review that does not allow a quantitative proof of a given phenomenon. Although used mostly in medicine, for example to combine results of clinical studies, meta-analyses can be applied to other disciplines as well, and outcomes can be used to discuss and identify effective applications – which met the requirements of the FiBL study. In contrast to conventional statistical procedures, a meta-analysis takes the sample sizes and significance levels of single data sets into account when calculating the main effect size. This makes it an ideal tool for assessing an entire knowledge area, determining a reliable, average main effect size, and identifying research gaps.

The study had two major goals:

- quantify SOC contents, stocks and sequestration rates in soils under organic and non-organic management,
- analyse factors influencing soil carbon levels.

The factors analysed included climate, soil texture, land use (arable, grassland, horticulture), management (organic or non-organic), crop rotation (with or without grass-clover leys), fertilizer type (with or without organic manure) and fertilization level (below or above 1.4 livestock units per hectare).

Material and methods

Only studies based on pair-wise comparisons (under similar site conditions) for organic and non-organic farming practices were considered. In one case, a fertilizer experiment was included (manure vs. mineral), but all other studies were based on farming system comparisons, where the organic practice was exclusively defined as "organic" by the authors.

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This study followed five steps:

- literature search,
- literature review and evaluation,
- integration into data matrix and parameterization of those studies determined to be positive, meaning they contained a pair-wise comparison of organic vs. non-organic,
- descriptive and explorative statistics with SPSS data mining software,
- meta-analysis with Comprehensive Meta-Analysis (CMA) software.

Online information resources were searched for published studies, using the search terms (abstract/title/keywords): "carbon AND soil AND conventional". The resources searched included: CAB Abstracts, Google Scholar, ISI Web of Knowledge and Conference Proceedings, BIOSIS Previews, Scopus, SCIRUS, AGRICOLA, Scielo, GeoRef database, ScienceDirect and Organic Eprints.

Because of poor data sources from developing countries, recognized experts in organic agriculture, carbon, soil sciences or other relevant fields of research were contacted to contribute further ideas on resource identification and invited to share relevant publications or data. Furthermore a "Call for soil carbon data" was placed as a poster at the Tropentag International Conference on Research for Development in Agriculture and Forestry, Food and Natural Resource Management in Zürich in September 2010 and the literature search remained open until this manuscript was submitted in spring of 2011.

Any publication assessed as positive for the approach was integrated into the data matrix and parameterized accordingly. Descriptive and explorative statistics were computed with SPSS software and meta-analysis with CMA software. The meta-analysis tool allows for a quantitative evaluation of published data taking observation points (= sample numbers) and variation of the target variable (i.e. Soil Organic Carbon (SOC) in this context) into account.

Results

Descriptive statistics. In the initial stage, 45 publications were integrated into the data matrix: 37 peerreviewed papers from scientific journals, and eight peer-reviewed conference proceedings, book chapters or dissertations. All 45 publications are based on pairwise system comparisons, from 44 field research projects consisting of 21 long-term plot experiments, five field trials and 18 farm comparisons. They encompass 280 data sets (lowest data aggregation level: general statistics) based on 2 477 samples (metaanalysis).

Explorative statistics. The average duration of management of all included studies was 16.7 years, with the oldest found in Europe, as shown in Figure 1. No relevant Africa or South America studies were found, so those continents are not represented in the study, as shown in Figure 2. The sampling depths of the different SOC studies varied between 8 and 60 cm, as shown in Figure 3. However, most of the samplings were performed down to 20 cm, with an average recorded soil depth of 22.5 cm. In this first analysis, the total sample number (N) was 2 477. A simple comparison of the data sets (N=280) by analysis of variance (ANOVA) revealed that organically managed soils contained higher SOC contents (concentrations as expressed in mass percents) than conventional soils (Figure 4). The same was true for the SOC stocks (i.e. absolute masses; N=118), even though fewer studies contained data of bulk densities which are necessary to calculate SOC stocks (Figure 5). In soils under organic management, the SOC stocks averaged 37.4 tonnes C ha^{-1}, in comparison to 26.7 tonnes C ha^{-1} under non-organic management.

Meta-analysis of soil organic carbon contents and stocks. The meta-analysis of SOC contents and stocks revealed the same result as had been determined by ANOVA and explorative statistics. Meta-analysis revealed that soils under organic

management showed significantly higher SOC content than those managed non-organically (N=2 477) and that soils under organic management showed significantly higher SOC stocks than those managed non-organically. These results, however, are preliminary and further attempts will be made to get more data for a reliable meta-analysis of SOC stocks as there are far fewer eligible studies on SOC stocks (N=12) than on SOC contents (N=2 477) and also fewer observation points.

Factors influencing the evaluation of soil organic carbon contents. Grassland soils showed higher SOC concentrations in comparison with arable land or horticulture. As studies from Oceania were based mostly on grassland data, they also provided the highest values of SOC contents. A somewhat clear tendency was demonstrated with the multiple analysis of variance that ranked factors influencing SOC contents. The analysis found that climate had the strongest impact on soil organic carbon contents followed by land use (arable, grassland, horticulture) and the management system (organic or non-organic). It should be noted that only studies from Oceania (i.e. New Zealand) provided data on organically and non-organically managed grassland.

Methodological difficulties of the meta-study – The baseline problem

Efforts to determine soil carbon sequestration in organically managed soils face manifold data gaps and methodological difficulties. Apart from differences in management practices that are not unique to organic farming, many of the studies reviewed suffered from shortcomings that reduced their scientific value. One of the most significant limitations was with the baseline. Without baseline data at the inception of a trial or a temporal sequence of measurements, it is impossible to determine whether or not a current measured difference in SOC between two treatments has resulted in a net sequestration of atmospheric CO_2.

In a comparison of the influence of two management practices (A and B) on SOC stocks, the five scenarios depicted in Figure 6 would all lead to the measurement of a greater stock of SOC under practice A. However, a net sequestration of atmospheric CO_2 would only occur in three of the five scenarios (i.e. Scenarios 1, 2 and 3, Figure 6). In Scenario 1, both management practices would lead to a net sequestration, while in Scenario 5, both practices would lead to a net loss of carbon back to the atmosphere. Yet, with a snapshot-in-time approach, both Scenarios 1 and 5 would be interpreted as having resulted in the same relative gain in SOC.

A second consideration involved in defining the influence of applied management practices on SOC stocks was whether SOC has stabilized at a new steady state value indicative of the original management practice or is still changing and progressing towards a new equilibrium value. This consideration is often the underlying reason for the various scenarios in Figure 6.

Figure 1
Monitoring length of different management practices (organic and conventional) considered in the farming system comparison (N=2477)

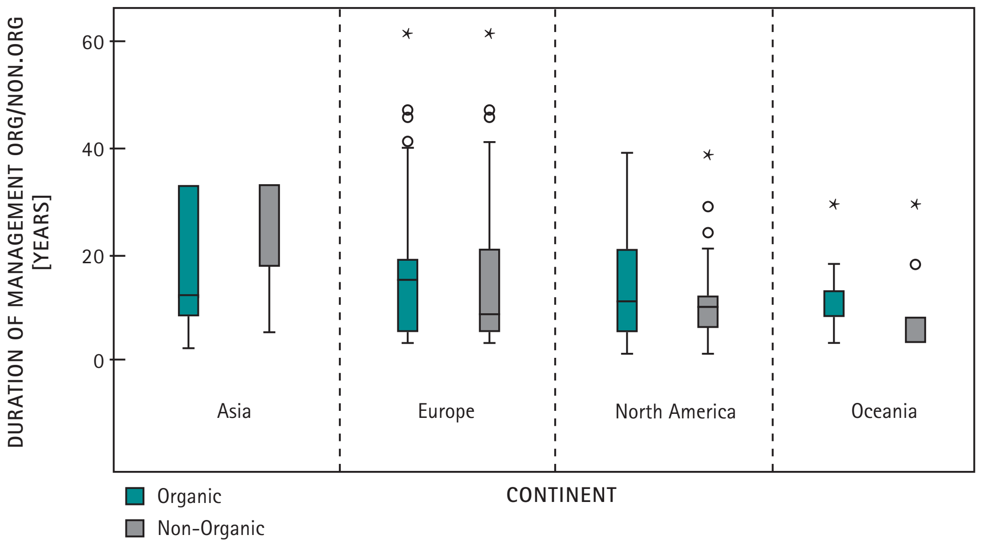

Figure 2
Geographical distribution of the sample of soil carbon studies used in the pair-wise comparisons of organic and non-organic management

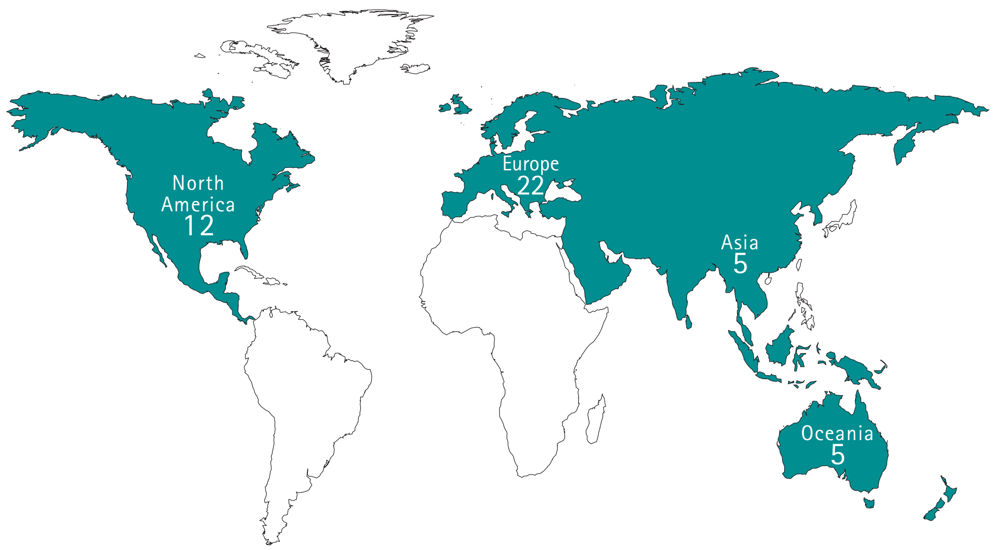

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Figure 3
Variation in sampling soil depth of different analyzed soil carbon studies (N=2477)

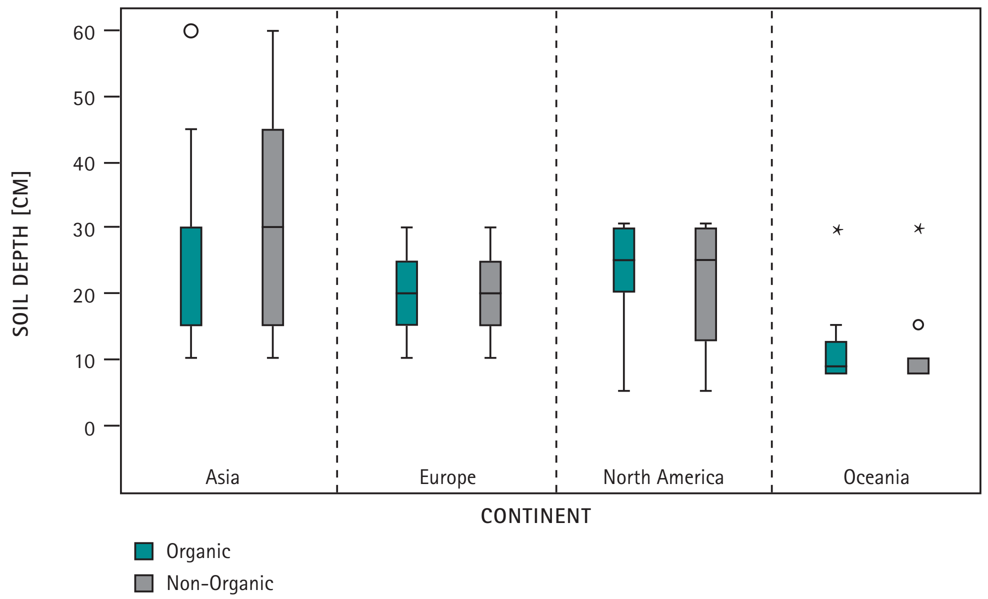


Figure 4
Soil organic carbon (SOC) contents (expressed in %) are significantly higher in organically managed soils

mean	N	Std. Deviation
1.630145	280	1.0946869

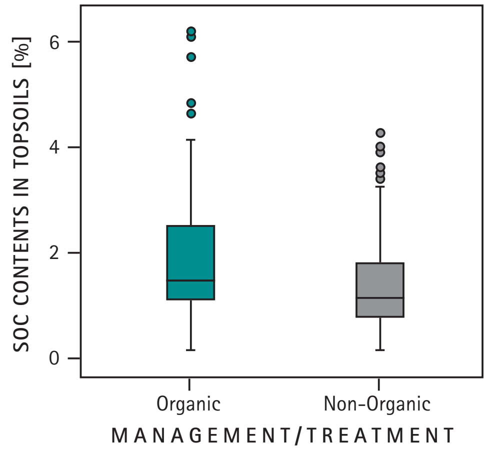


Figure 5
Soil organic carbon (SOC) stocks (expressed in tonne of carbon ha^{-1}) are significantly higher in organically managed soils

mean	N	Std. Deviation
30.081845	118	26.4863352

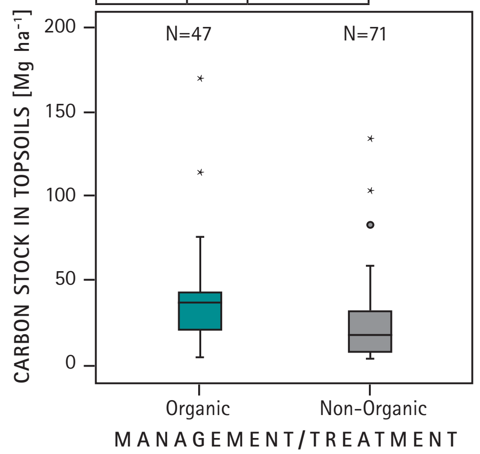
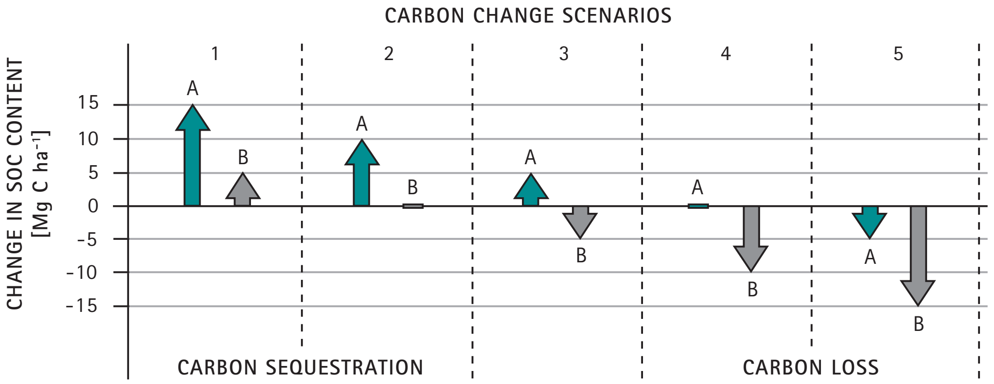


Figure 6

Five different scenarios of carbon change induced by two management treatments (A—blue arrows and B—grey arrows) after a set amount of time.

The arrows indicate the direction of carbon change and their size reflects the magnitude of carbon change. All five scenarios give the same relative difference in SOC between treatment A and treatment B (10 Mg C ha^{-1})

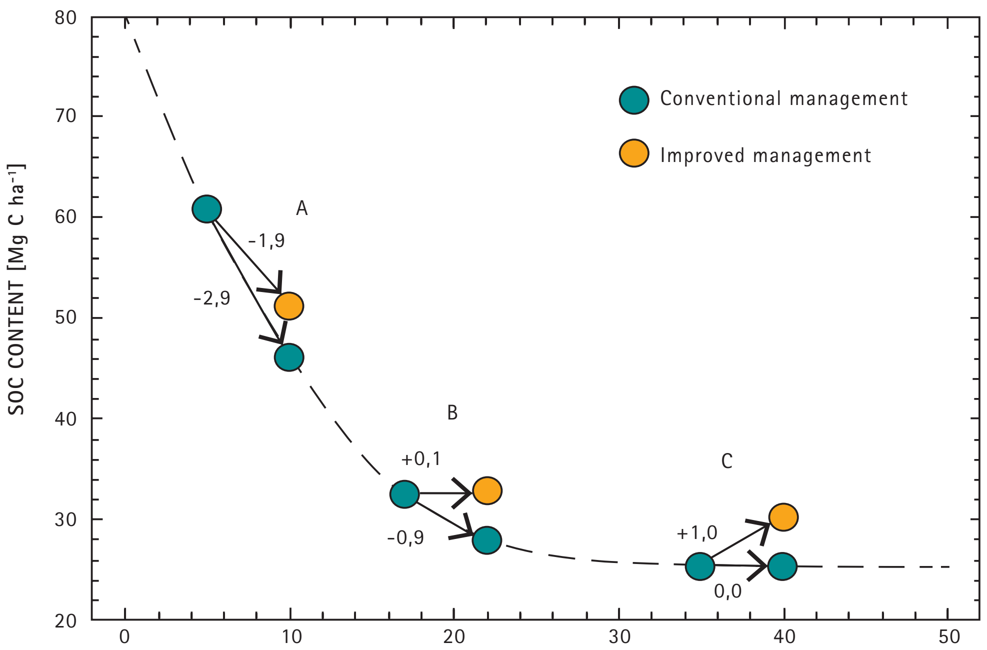


Source: Sanderman & Baldock, 2010

Figure 7

Hypothetical field trial simulation comparing conventional and improved management practices initiated at three different times (A, B and C) after converting a natural ecosystem to agricultural production in year zero

All three points show the same relative gain of 5 Mg C ha^{-1} in the improved management practice over a five year period; however, the actual rate of change is completely different



Source: Sanderman & Baldock, 2010

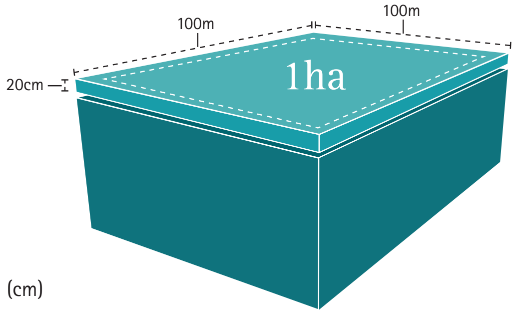
Evidence suggests that imposing agriculture on previously undisturbed soil will result in a 20–50 percent loss of SOC (Lal, 2004), with the rate of loss being greatest initially and then diminishing over time (dashed line in Figure 7) with a new equilibrium not reached for 20–100 years. In addition, different SOC sequestration outcomes will be obtained if two management practices (conventional and best practice in terms of SOC accumulation) are initiated at different times after clearing (points A, B and C in Figure 7).

The relative difference in SOC content measured between the two management treatments at all three times is similar (5 tonnes of Carbon ha−1 over a five-year period). However, the benefit is completely different in terms of sequestration of atmospheric CO2 relative to the conditions present at the start of the three experiments. Without SOC measurements taken at the start of each of the experiments (A, B and C), the different carbon sequestration scenarios depicted in Figure 7 would not be evident and the best management system may be inappropriately considered to have sequestered atmospheric carbon.

Missing bulk densities and shallow sampling. The majority of publications, identified above in the Preliminary Results section, reported SOC concentrations rather than stocks. The great majority of these studies were originally designed to define the influence of agricultural management practices on plant dry matter production, grain yields and other agronomic properties and, as a result, many long-term trials reported neither SOC stocks nor soil bulk density. If the latter were reported, SOC stocks could be calculated as shown in Figure 8. SOC concentration is a key indicator for soil fertility but assessing the sequestration potential requires the amount of CO_2 or C stored in a given soil, which is the absolute mass, i.e. SOC stock = t C ha^{-1}.

Another problem is the shallow soil sampling. The median of the sampled soil depths of the farm system comparisons is 22.5 cm. While this soil depth covers more or less the entire cultivation horizon of agricultural soils, a substantial part of SOC will not be considered at this depth (P. Smith, personal communication). Fliessbach *et al.* (1999) found that in farming systems of the DOK trial in Switzerland, which contain two years of deep-rooting grass-clover leys, 64 percent of the total SOC stocks are deposited between 20–80 cm soil depths. In many parts of the world, organic farming systems are relying on the soil fertility build-up of deep-rooting grass-legume mixtures and on the incorporation of plant residues by deep-digging earthworms, making it quite likely that the currently available data sets underestimate the SOC stocks in organically managed soils. This is particularly significant considering that in deeper soil horizons, SOC seems to be more stabilized. Radiocarbon analyses of microbial short-chain Phospholipid Fatty Acids (PLFA) from different soil depths showed that the PLFAs in surface soils were derived largely from fresh plant residues whereas the radiocarbon values of PLFAs at 30–45 cm soil depth suggest the contribution of more stabilized soil organic matter (Rethemeyer *et al.*, 2005).

Figure 8
Scheme and equation used to calculate soil organic carbon (SOC) stock



carbon stock (t/ha) =
soil organic carbon (g/kg) • bulk density (g/cm³) • depth (cm)
SOC (g/kg) • BD (g/cm³) • depth (cm)

Source: Häni, 2010

Poor data availability for major cropping systems and continents. In addition to the fact that no peer-reviewed study containing farming system comparison and reporting SOC values exists for the African continent or for Central and South America, the Asian continent is largely under-represented with only five studies (see Figure 2). Grassland, as a land use, is only covered by two studies from New Zealand, which does not reflect the reality at all. Grassland is the dominating agricultural land use in many parts of Africa and Central Asia (e.g. Mongolia), and pastoralism – as a traditional and sustainable land use system built on grassland farming – is not represented at all. Also major food commodities such as rice and many tubers are not reflected in the system comparisons found in the literature search.

Summary and conclusions

The core work of the comprehensive literature review integrated more than 40 scientific publications into a meaningful data matrix. Quantitative evaluation of this comprehensive data set revealed strong scientific evidence for higher SOC contents in soils under organic farming, which is also in accordance with the findings of Leifeld and Fuhrer (2010). Their evaluation of 32 peer-reviewed papers and 68 data sets revealed that after conversion, SOC contents in organic systems increased annually by 2.2 percent on average, whereas in conventional systems, SOC did not change significantly. There is a lack of SOC data for developing countries, with no farm system comparison data from Africa and Latin America, and only limited data on SOC stocks which is crucial for determining carbon storage in soil. While this means that C sequestration rates for organic farming practices cannot be assessed reliably at the moment, further attempts will be made to access more reliable data on soil carbon stocks.

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Next steps

The data matrix for the meta-analysis on SOC in organic and non-organic farming systems will be further refined in a manner that allows the variables of soil texture (i.e. clay content), crop rotation, fertilizer type and fertilization level to be used for further statistical evaluation and for a scientifically sound assessment of the factors influencing SOC in agricultural soils at a global scale. Also, authors of included publications will be asked for data on soil bulk density. Meanwhile, the FiBL worldwide network is contacting more people, including those from developing countries, seeking further relevant data that will enable a sound meta-analysis on SOC stocks and a sound calculation of C sequestration rates. Further, FiBL will continue to conduct a literature search relevant to the SOC study.

The research topic “C sequestration in organically managed soils” is far from full exploration. Even with a scientific paper produced on the above-mentioned meta-analysis findings, some important land-use types, such as grasslands and agroforestry in Africa, have not yet been investigated on SOC in a pairwise system comparison. It is unrealistic to expect representative SOC data for major cropping systems from Africa, Asia and South America within a short time-frame. This means that further research will be needed to fill these data and knowledge gaps. In this regard, the RTOACC can serve as a platform to exchange ideas and promote the bilateral or multilateral research on C sequestration as influenced by organic farming systems. However in future SOC investigations, the above described data gaps and methodological uncertainties should be taken into account.

POTENTIAL FOR ACCREDITATION OF AN ORGANIC FARMING SYSTEM METHODOLOGY FOR THE CARBON MARKET

This section looks at existing and foreseen methodologies that will help quantify and simplify the understanding of organic agriculture's potential role in the carbon market.

The methodology development undertaken by FiBL aimed to capture the mitigation potential of organic agriculture projects in developing countries for the carbon market. Of course, organic agriculture provides a range of benefits other than its mitigation potential. Its potential to provide carbon offsets as well as many additional sustainability benefits would translate into higher financial rewards for the farmers.

Carbon market context

There are only a few projects that deal with land use, land use change, forestry and agriculture in the Clean Development Mechanism (CDM) (Figure 9). The forestry sector has a much higher share of the Voluntary Carbon Market (VCM) than agricultural activities (Figure 10). Further developments will see an increase in forestry offsets, e.g. under the UN Reducing Emissions from Deforestation and Forest Degradation (REDD+) project. However, agriculture will increasingly gain importance, as reflected in the recent submission of methodologies and protocols aimed at capturing the mitigation potential of agriculture, mainly soil carbon and nitrous oxide via optimized fertilizer management, such as the World Bank Voluntary Carbon Standard (VCS) methodology for Sustainable Agricultural Land Management (SALM) or the International Fertilizer Association "4R: right source, rate, time, place" approach applied in the new nitrous oxide emission reductions strategies from Canada and the USA (GoA2010; International Fertilizer Industry Association, 2009; VCS, 2010).

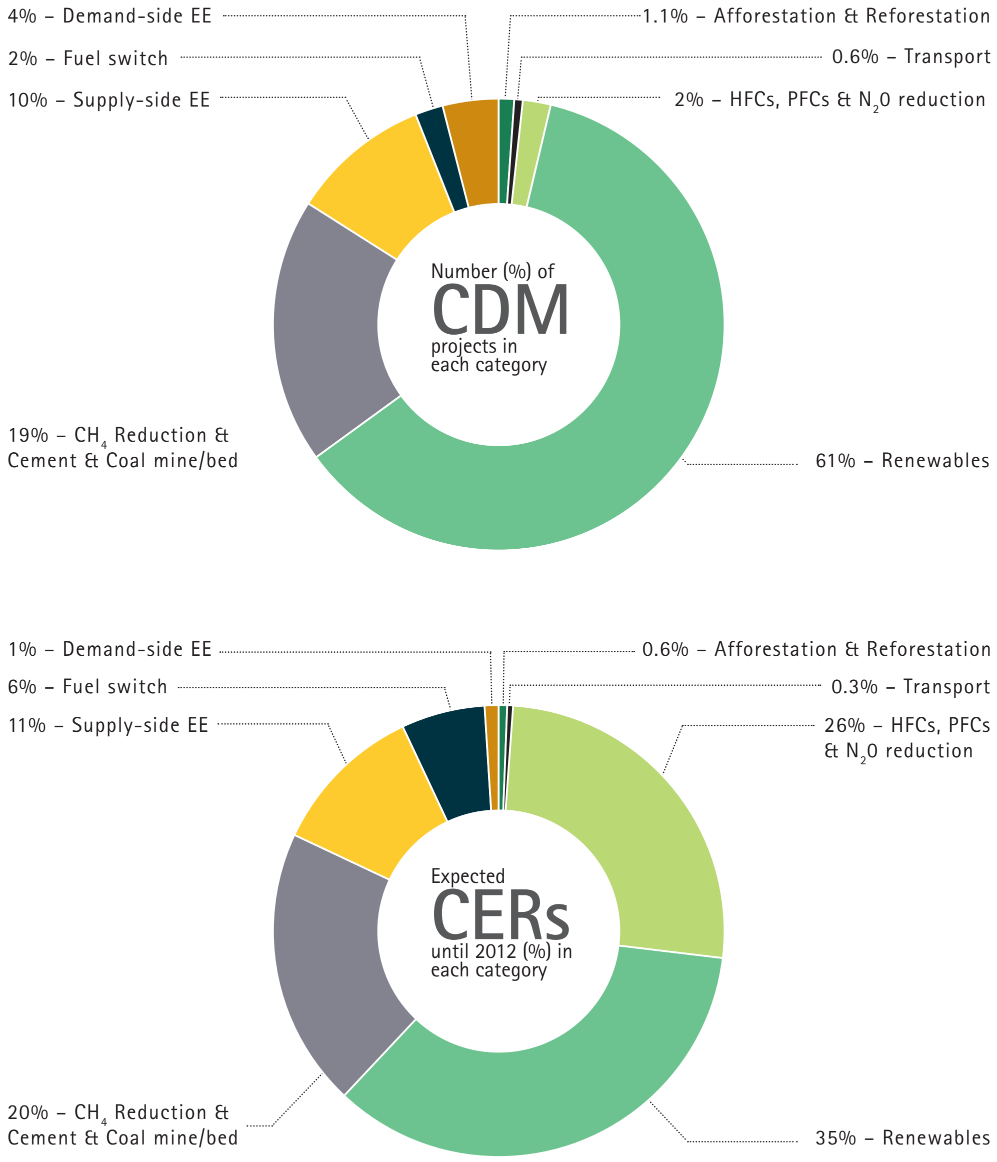
Compared to 2008, 2009 saw several striking shifts in transaction volumes by project type. Hydro projects experienced the most significant market share losses, dropping from 32 percent to 7 percent (16.4 to 3.2 $MtCO_2eq$); wind, from 15 percent to 8 percent of the market (7.7 to 3.4 $MtCO_2eq$); and energy efficiency, from 4 percent to 1.4 percent (2.1 to 0.6 $MtCO_2eq$). The reasons for agriculture's - and to a less extent forestry's - low share of the Voluntary Carbon Market (VCM) are manifold. However, all are related to the complex biological systems involved, which are not standardized or as easily quantifiable as industrial processes. Thus, Monitoring Reporting and Verification (MRV) is highly demanding for agricultural and forestry systems, as the relevant data is highly variable and default values are not reliably capturing a single project at hand. Project, which are unviable under the CDM are somewhat more viable under VCM where requirements can be considerably lower.

Figure 9

Certified Emissions Reduction (CERs) expected until 2012 from a number of different projects carried out in different sectors under the Clean Development Mechanism (CDM)

(a) Number and distribution in different sectors of existing projects (N = 5600) as recorded in the CDM project pipeline, November 2010.

(b) Contribution of projects belonging to different sectors to the total certified GHG emission reduction in 2012 (Total CERs in 2012 = 2 800 Mt CO_2eq / 210 Mt CO_2eq traded in 2009).



Source: UNEP-RISOE 2010, CDM pipeline as of November 1, 2010, http://cdmpipeline.org/

Figure 10a

Percentage of market share achieved by different project types for Carbon Emission Reductions (CERs) in the Voluntary Carbon Market (VCM), 2009

Compared to 2008 several striking shifts in transaction volumes by project type were recorded in 2009 with a prevalence of projects related to methane, followed by forestry and other land-based related projects (24%) while significant market share losses were recorded for project related to water (7%) and wind (8%).

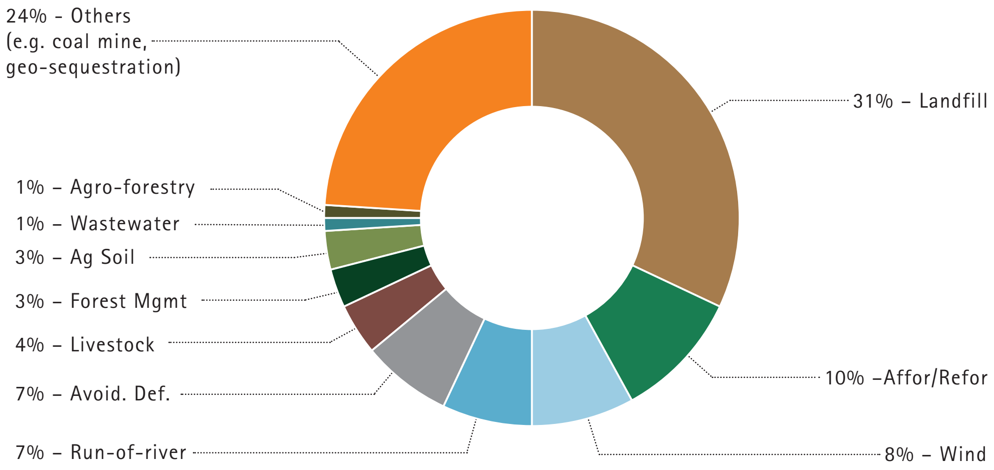


Figure 10b

Percentage of market share achieved by different land-based project types in the Voluntary Carbon Market (VCM), 2008 vs. 2009

The Carbon Emission Reductions (CERs) achieved by forestry and other land-based related projects passed from a market share of 11% (5.7 $MtCO_2eq$) in 2008 to a 24% (10.4 $MtCO_2eq$) in 2009.

LAND-BASED CREDITS SOLD OTC, 2008 VS. 2009				
	Volumes of land-based credits ($ktCO_2eq$)		Market share of land-based credits relative to the total	
Project Type	2008	2009	2008	2009
Afforestation/reforestation	4 091	4 253	8%	10%
Avoided deforestation (REDD)	730	2 846	1%	7%
Forest management	431	1 349	1%	3%
Agricultural soil	267	1 250	0.5%	3%
Agro-forestry	-	625	-	1%
Other land-based projects	130	109	0.3%	0.3%
TOTAL	5 650[28]	10 432	11%	24%

Source: Ecosystem Marketplace and Bloomberg New Energy Finance
For a list of forestry projects visit Ecosystem Marketplace's Forst Carbon Portal, www.forestcarbonportal.com

Source: Hamilton *et al.*, 2010

A second barrier for land-based projects is the impermanence of generated credits, as they are mostly based on reversible land use change or management practices. In addition, due to the specific dynamics of the systems involved (soil, biomass growth, biomass waste, decay, etc.), issuance time can be considerably delayed in relation to project start.

Finally, profitability of such projects tends to be low, as they generate low numbers of credits per hectare. Thus huge areas need to be covered, which again adds to the MRV problems. Forestry or agroforestry projects that have a higher density of credit generation per hectare are somewhat exceptions to this. Similarly, biogas projects and composting are more profitable, as their reliance on industrial processes in centralized plants reduces MRV costs. The MRV problems encountered in land-based projects were most recently illustrated, for example, by the rejection of the improved rice-cropping methodology NM0046 submitted to the CDM, which is largely due to a lack of knowledge on the underlying processes and their quantification or MRV[4].

Material and methods

The methodology development was based on an expert assessment of the current status of agriculture- related methodologies in the CDM and for the VCM. FiBL expertise on organic agriculture was combined with South Pole Carbon Ltd (SPC) expertise on carbon markets and the institutions of carbon finance, and with expert inputs from other RTOACC members. The assessment included the mitigation potential of organic agriculture and its wider sustainability performance when applied in smallholder contexts of developing countries (including the results from the RTOACC workshop previously described) as well as the specific aspects of existing methodologies such as composting, optimized fertilizer use, N_2O protocols (in North America), rice production and agroforestry. This latter assessment was based on the original documents, expert comments from the stakeholder consultations on each methodology found on the Web, input from South Pole Carbon Ltd (SPC), and personal information from experts who participated in the RTOACC Workshop, and other institutions. A particular focus was given on the reliability and viability of quantification, such as the MRV of the mitigation potential claimed on project level.

4 However, an improved rice methodology is now accepted.

Results

A methodology for converting farming practices from conventional to organic management has no chance of being approved, as it is not specific enough. Thus, the approach focused on key practices in organic agriculture which can be captured in such a way as to make quantification of their mitigation potential compatible with the requirements from project-based offset mechanisms. For this, the aim was to develop a CDM methodology, as this is the most demanding and most respected standard. Knowing how a certain practice will have to be treated under the CDM, it can easily be simplified to meet lower standards, such as for the VCM.

Organic practices and characteristics of principal potential for carbon credit generation include:

- replacement of chemical fertilizers,
- production and application of compost,
- application of legumes in crop rotations,
- avoidance of burning agricultural waste and residues,
- increase of soil organic matter (e.g. soil carbon sequestration).

However, the latter practice, soil carbon sequestration, is not as effective from the carbon offset perspective as originally assumed, particularly when compared with mitigation practices involving methane emissions, such as optimized manure management, or methane recovery and biogas use from manure (see Figure 11). Hence the decision was made not to develop soil carbon sequestration to a carbon offset methodology, at least initially.

Further practices of importance to carbon capture include: agroforestry, restoration and less intensive use of peatlands, replacement of peat with compost in planting substrates, optimized rice production and certain processing steps such as those in wine and cheese making.

The decision was made to start with the "low-hanging fruit", regarding both the complexity of MRV and profitability regarding the number of credits per hectare. With the goal of capturing core practices of organic agriculture and the existence of methodologies for certain of the practices mentioned above (e.g. methane capture and biogas production, agroforestry), it was decided to revise the existing CDM compost production methodology (abbreviated as AMS.III-F) by adding biomass burning to the baseline, and mulching and optimal manure management to the project activity. In the same line, the AMS.III-R methodology was revised, which can be understood as a version of AMS.III-F specifically adapted to the context of smallholders though, for example, simplified MRV requirements. In order to capture the mitigation potential of organic agriculture regarding fertilizer application and soil carbon sequestration, a new methodology was developed, based on the existing CDM methodology AMS.III-A, which generates carbon credits by reducing chemical fertilizer use through inoculating legumes in the crop rotations.

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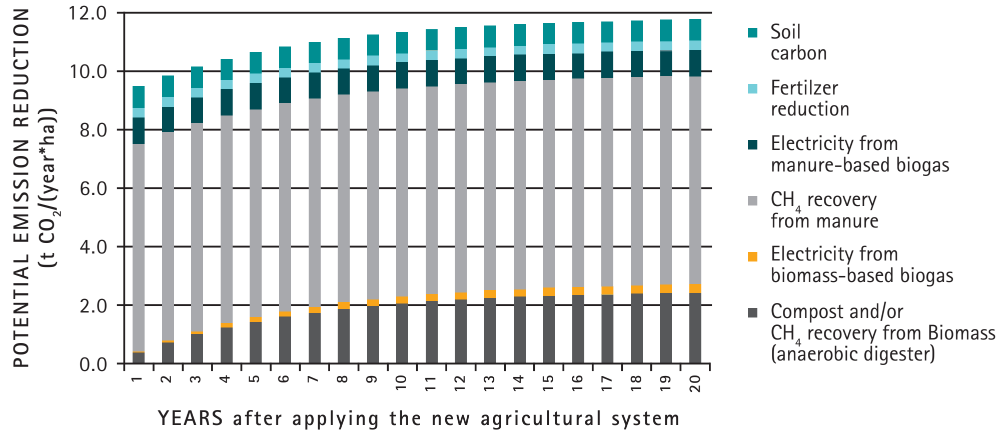
Figure 11

Rough and preliminary estimates of the potential of emission reductions achieved with mitigation practices applicable within organic agriculture



Source: based on calculations from South Pole Carbon Asset Management Ltd.

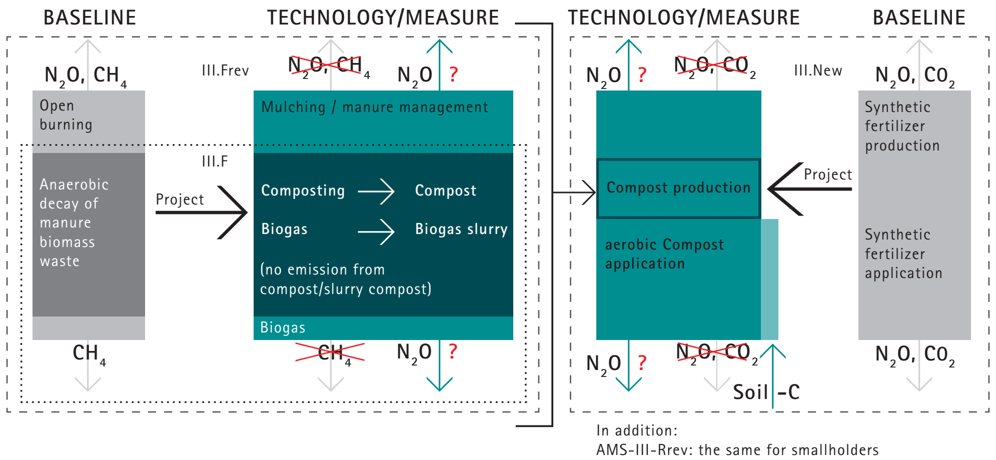
Existing methodologies were further assessed with regard to soil-carbon sequestration, reduced and optimized chemical fertilizer use under various standards of the VCM (SALM, former CCX soil-C protocol, and Canadian and US N_2O protocols GoA 2010, VCS 2010), optimized rice cropping (NM0046 was rejected, mainly due to MRV problems) and agroforestry under the CDM.

Summary and conclusions

The tangible results of this work include two methodology revisions and a newly developed methodology for the CDM, which are now ready for implementation in existing projects. They capture organic waste, fertilizer management and soil dynamics (nitrous oxide/soil carbon) on farms in a consistent way, which is adequate for the particularities of organic farms and which can be captured in the institutional framework of carbon offset methodologies (Figure 12).

Adding biomass burning to the baseline in these methodologies is the most important revision. Biomass burning is a widely used and very unsustainable practice that has many adverse effects other than GHG emissions. It affects local air quality and leads to considerable nutrient losses. Making avoidance of this applicable for the carbon market is an important step and generates sustainable carbon credits. Avoidance of biomass burning can be applied in a smallholder context, but it also makes sense on large scale, such as sugar cane plantations where pre-harvest burning is often the common practice. Furthermore, the avoidance of synthetic fertilizers and increased use

Figure 12
The interplay of the revisions of existing CDM methodology AMS.III-F and the new methodology based on AMS.III-A



of compost or mulching also improve resource and nutrient management. The revision of AMS.III-R also makes these opportunities available specifically to smallholders.

This work on carbon offset methodologies provided insights into the specific challenges that organic agriculture (and agriculture in general) faces when combined with the established institutions of carbon markets and offset mechanisms. Particular challenges are related to scientifically credible MRV (e.g. based on on-site measurements) *vs.* the practical applicability of MRV in a concrete project without incurring prohibitive costs (e.g. making heavy use of global default values). Other challenges relate to the comparability of outputs in the baseline and under the project activity. If crop rotations change, for example, the same-level-of-services assumption, which is important to avoid leakage of emissions, is difficult to assess and ensure. It remains open as to whether such assessments should be based on some monetarization or on other aggregation approaches, such as via energy contents. One solution to this problem currently adopted in certain CDM methodologies is prescribing crop rotations for the whole project lifetime and restricting phosphorus (P) and potassium (K) inputs under the project activity to the same levels as before. These conditions are clearly unviable, which likely is the reason no projects are using the AMS.III-A methodology, which has these applicability conditions. Finally, profitability, and in relation to that, additionality of projects in agriculture remains a topic, as the amounts of credits generated will remain relatively low. Assuring additionality will be less a problem when based on institutional rather than financial barriers.

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Insights also were gained on ways to further develop carbon market institutions in order to account adequately for the specific characteristics of agriculture. For example, one approach called for refraining from undertaking project-based reduction in agriculture and instead capturing its mitigation potential in national strategies, based on a large number of projects where the default values for mitigation potential apply on average.

Next steps

FiBL will apply the two revised methodologies to existing projects in order to gain insights on their strengths and weaknesses in realistic settings. Subsequently, the methodologies will be further adapted and refined, in particular to include a monitoring section. Also, FiBL will prepare a Project Design Document necessary to submit the methodology revisions to the UN Framework Convention on Climate Change (UNFCCC).

However, for the time being, the new methodology on fertilizer application and soil carbon sequestration will not be applied, due to large scientific uncertainties. MRV requirements will either become prohibitively expensive or will remain scientifically weak, thus not leading to reliable mitigation accounting. It is however suggested to undertake revisions for the existing and submitted methodologies and protocols that contain fertilizer application and soil-carbon in order to make them applicable for organic agriculture as well, if possible. This will work for the World Bank VCS methodology SALM, but likely not for the Canadian N_2O protocol. Future data availability on soil carbon will also be monitored intensively. Given that the uncertainties and challenges of MRV can be reduced considerably, the new methodology on fertilizer application and soil carbon sequestration will be adapted and submitted to the UNFCCC.

As previously discussed, capturing the mitigation potential in agriculture on an aggregate level, such as in the context of NAMAs, seems more appropriate than capturing it via the established offset mechanisms. Project-based offsets in agriculture have a fundamental problem, due to the high variability of the biogeochemical processes involved and the correspondingly high uncertainty of emissions or mitigation in specific, concrete cases. Carbon offsets make sense in a context of standardized and reliably quantifiable processes, such as for emissions from industrial processes or energy generation. Beyond recognizing that the mitigation potential of single projects in agriculture cannot be quantified correctly, it is questionable how reliable it is to offset standardized and quantified emissions in industrial countries with emission reductions from highly uncertain agriculture mitigation in developing countries. On the other hand, on aggregate for the average of thousands of projects, the mitigation potential can be quantified, if reliable default values are available.