Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture (CIRCASA)

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Analysis of current capacity building and training needs surrounding SOC research and implementation

CONTRIBUTION TO DELIVERABLE D1.3

The science base of a strategic research agenda

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Acronyms

AFOLU	Agriculture Forestry and other Land Use
C	Carbon
CBP	Carbon Benefits Project
CIRCASA	Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture
EU	European Union
FACCE-JPI	Joint Programming Initiative on Agriculture, Food Security and Climate Change
FAO	Food and Agriculture Organisation
GHG	Green House Gas
GSOC	Global Soil Organic Carbon
GSP	Global Soil Partnership
ICS	International Science Council
IFAD	International Fund for Agricultural Development
ISRIC	World Soil Information
ITPS	Intergovernmental Technical Panel on Soils
JRC	Joint Research Centre
MOOC	Massive Open Online Course
MRV	Monitoring Reporting and Verification
NGO	Non-Governmental Organisation
OCP	Online Collaborative Platform
SDG	Sustainable Development Goal
SALM	Sustainable Agricultural Land Management
SLM	Sustainable Land Management
SOC	Soil Organic Carbon
UN	United Nations
UNCCD	UN Convention to Combat Desertification
VCS	Voluntary Carbon Standard
WB	World Bank
WOCAT	World Overview of Conservation Approaches and Technologies

Citation

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Authors

Lead authors:
Eleanor Milne[1] and Steven Banwart[2]

Contributing authors:
Andy Bray[2], Ana Frelih-Larsen[3], Irina Herb[3], Paul Luu[4]

1 Independent consultant (contracted by the University of Leeds),

2 Global Food and Environment Institute, University of Leeds,

3 Ecologic Institut gemeinnützige GmbH,

4 "4 per 1000" Initiative - Executive Secretariat

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1. Introduction

Teaching and training on soil organic carbon (SOC) is key if we are to take advantage of the many benefits of maintaining and enhancing SOC. Not least, a good background and understanding of SOC is needed by the academic, agricultural and land management communities if land management is to be used effectively for climate change mitigation. This report is a scoping study, providing a first look at the resources and provision for the teaching and training of SOC mainly in academia but also in selected international programs and initiatives. It is not a definitive study, but instead provides an insight into SOC teaching and training, identifying commonalities and trends which may be worthy of future investigation. The report draws on three sources of information; two previous CIRCASA reports, an analysis of international programs and initiatives and a survey of academic stakeholders.

2. Synthesis of teaching and training related information from previous CIRCASA tasks

The CIRCASA project has produced two key documents; 'Stakeholder perceptions on the role of SOC management for climate change and SDG's'(CIRCASA 2020) and 'The science base of a strategic research agenda' (Bray et al. 2019). Both reports made findings regarding teaching and training related to soil organic carbon. In this section we highlight the main findings on teaching and training from the two documents which then feed into Section 5 of this report: 'Synthesis and recommendations for teaching, training and capacity building'.

2.1 'Stakeholder perceptions on the role of SOC management for climate change and SDG's'

The stakeholder perceptions activity (CIRCASA 2020) carried out a stakeholder dialogue on challenges, opportunities and knowledge needs related to SOC. Stakeholders included farmers, agricultural managers, agricultural advisory organisations, researchers and others. Information was collected through;

"11 workshops worldwide (235 participants), exchanges with a stakeholder advisory board, a global survey (1369 usable answers) and a survey with Danish farmers (1807 usable responses, representative of Danish farming structure)."

Information was then analysed and presented in terms of knowledge needs identified from responses of farmers and other stakeholders. For all stakeholders, the report identified four key areas where there appeared to be knowledge gaps:

1. Information on farm-level management practices and their effects on SOC
2. The economic costs and benefits of SOC friendly practices
3. Policy mechanisms and the enabling environment for SOC
4. Monitoring, reporting and verification for SOC

It can therefore be assumed that for farmers, agricultural managers, agricultural advisory organisations and researchers there is a lack of access to training and capacity building in these four areas.

Recommendation 2.1a Efforts should be made to extend and set up training and capacity building for farmers, agricultural managers, agricultural advisory organisations, researchers and the agricultural community in general on the four topics above.

For farmers in particular, the report found a need for context specific recommendations on practices that can increase SOC e.g. information on crops, cropping systems and practices which are likely to increase or maintain

SOC in the specific soil/climate and other conditions faced by farmers. They also reported a need for user-friendly tools to help estimate and manage impacts. The need for capacity building and training on these would therefore follow. The report also found farmers wanted to be able to ascertain the economic consequences of implementing SOC friendly practices in both the long and short term and how to manage these consequences.

Recommendation 2.1b More teaching/training and exchange of experience is need for farmers on SOC friendly practices which are specific to the conditions farmers are working in (climate, soil type, crop type etc.)

Recommendation 2.1c Farmers need user-friendly tools to help estimate the impacts of practices on SOC and more teaching/training on how to use these tools.

Recommendation 2.1d Farmers need training on how to account for and recognise the economic consequences of implementing SOC friendly practices.

For other stakeholders (non-farmers), the report found policy makers wanted to know where efforts to increase SOC should be targeted, echoing the message from farmers that a greater understanding of how different farming practices impact SOC under varying conditions is needed. In addition, non-farmer stakeholders also highlighted the economic aspects of increasing SOC. Specifically they wanted a greater understanding of how SOC could be valued and how to interact with C markets. This group also highlighted the need for improved reliability and standardisation of cost effective Monitoring Reporting and Verification (MRV) methods.

Recommendation 2.1e Teaching and training (and access to information) should be made available to policy makers and funding agencies to help them decide where to target funds to support activities that increase SOC. These should include training on biophysical and economic considerations including decision support tools.

The report also considered stakeholder feedback from the point of view of knowledge sharing. They found stakeholders wanted more opportunity for peer to peer learning, suggesting teaching and training opportunities should include opportunity for SOC knowledge exchange between stakeholders.

Recommendation 2.1f SOC teaching and training should include interactive opportunities for learners to exchange knowledge with each other, ensuring a bottom up approach where possible.

2.2 'The science base of a strategic research agenda'

The second report 'The science base of a strategic research agenda' aimed to:

"identify knowledge gaps, trans-disciplinary frontiers, novel technologies and knowledge synthesis needs to draft the science base of a strategic research agenda on agricultural SOC sequestration by showing priorities for research alignment and for enhanced international research cooperation"

As the focus of the Science Base report was on future research needs, a number of inferences on future teaching and training needs could be made from the report. Information in the Science Base report was compiled through a literature review and opinions on this review were then evaluated through a survey which was answered by 211 researchers and scientists. The main aim of the survey was to see how the scientific community rated its understanding of a range of topics relating to SOC. The topics were organised into three research themes:

(1) understanding soil processes
(2) managing and monitoring soil
(3) adoption of best sustainable land management practices

Across the three themes, several areas needing more research were identified, and it can therefore be assumed more teaching and training will be needed to support these. Areas were:

- SOC, inputs, decomposition and preservation
- SOC saturation
- SOC at depth
- Understanding erosion and SOC

Recommendation 2.2a More teaching is needed at postgraduate level on SOC inputs, decomposition and preservation, saturation, erosion and SOC at depth, to provide a good foundation for these subjects in all agro-pedo-climatic conditions.

The report found a consensus that more research was needed on monitoring, reporting and verification (MRV) in general. This fits with findings from the 'stakeholder perceptions' report (Section 2.2.). The authors acknowledged that social scientists were underrepresented in the group that answered the survey. Despite this, economic and socio-cultural barriers to adopting land management practices were ranked amongst the top three most important factors when trying to estimate SOC sequestration potential, with particular emphasis put on understanding and harnessing local knowledge.

Recommendation 2.2b Teaching and training on Monitoring Reporting and Verification for SOC should be informed by research and vice versa.

Recommendation 2.2c Teaching and training is needed on recognising and overcoming economic and socio-cultural barriers to adopting SOC friendly land management practices that make use of local knowledge and information.

Another finding of this report was a need for governments and policy makers to recognise the importance of SOC and that;

"soil is an issue that can, and should, be addressed internationally and by regional bodies such as the EU."

The report goes on to recommend that legal and political soil protection measures are pursued both nationally and internationally. In terms of teaching and training, this infers a need for teaching on science communication surrounding SOC and on how SOC currently features in existing legal and political agreements.

Recommendation 2.2d Increase teaching and training in science communication, specifically on how to convey key messages to policy makers, farmers and other stakeholders about the importance of SOC.

Recommendation 2.2e There is a need for teaching and training on how SOC currently features/is covered in existing national and international legal and political agreements. This could be targeted at international development courses.

3. SOC teaching and training in international programs and initiatives

In this section, an overview is presented of SOC teaching and training resources which are available through

international programs and initiatives. The purpose of this section is to provide a list of resources that may be useful for those wanting to undergo or give teaching and training on SOC. Information was compiled from the authors' own networks and an online search.

3.1 United Nations Environment Program (UN Environment)

UN Environment have an online learning platform which includes a 'Massive Open Online Courses' section.

https://www.unenvironment.org/explore-topics/education-environment/what-we-do/massive-open-online-courses

Some of the courses in this include some teaching on SOC e.g.
'Disasters and ecosystems: Resilience in a changing climate'
'Food and our future: Sustainable food systems in SE Asia'

Others may also include SOC. UN Environment also have resource for teaching and training on greenhouse gas accounting from the 'Agriculture Forestry and Other Land Use – AFOLU' sector which includes SOC through the Carbon Benefits Project www.carbonbenefitsproject.org. Online training videos and power points are available from the 'Resources' page of the website.

3.2 The Food and Agriculture Organisation (FAO)

The FAO has been at the forefront of research and training on soil organic carbon. Much of this has come through its role in the Global Soils Partnership (GSP). In 2017 GSP organised a symposium on SOC (GSOC). This was followed by a large training programme on SOC stock mapping (http://www.fao.org/global-soil-partnership/pillars-action/4-information-and-data-new/global-soil-organic-carbon-gsoc-map/en/). The training events were a huge undertaking and resulted in the first global soil organic carbon map (0-30 cm) ever produced through a consultative and participatory process involving multiple countries. Although this training has now finished, it has significantly increased the capacity of many countries to use the tools and methods needed to develop SOC maps. It has also resulted in a range of online resources which can be used for teaching and training such as the GSOC map application (http://54.229.242.119/GSOCmap/) and U tube videos such as 'SOC – the treasure beneath our feet' 'https://www.youtube.com/watch?v=Ymy0IO7nizw'.

FAO also provides teaching and training on various aspects of SOC available through its E-Learning Centre (https://elearning.fao.org/). SOC is covered in its Climate Change, Adaptation and Mitigation courses namely

- Sustainable land management and land restoration
- Climate smart soil and land management
- Estimating greenhouse gas (GHG) emissions and C sequestration in AFOLU with Ex-Act

3.3 ISRIC – World Soil Information

ISRIC, the international soil reference and information centre, is a regular member of the ISC World Data System. In addition to the work on SOC mapping with the GSP and FAO, space-time modelling of SOC changes for the Nature Conservancy, and various SOC stock mapping projects with partners at national level, ISRIC runs an annual Spring School where participants can sign up for 5 days of teaching on digital soil mapping, classification and assessment of soils, which includes teaching and training on SOC. ISRIC also has a Virtual Classroom (www.isric.org/utilise/capacity-building/virtual-classroom) which includes educational videos on Global Environmental Challenges, including Soils and Climate Change and Sustainable Soil Management which both cover SOC. The latter also contributes to the 'Massive Open Online Course' (MOOC) as mentioned in the UN Environment section above. ISRIC have also run a course on 'The benefits of soil carbon' which included training on the Carbon Benefits Project GHG accounting tools.

3.4 The World Bank

The World Bank have an Open Learning Campus which includes several courses with some coverage of SOC. The most relevant are in the 'Climate Change Online Learning' area - https://olc.worldbank.org/content/climate-change-online-learning.

Courses include:

'Sustainable Agricultural Land Management Projects: Soil Carbon Monitoring (Self-paced)'. This course takes users through the Voluntary Carbon Standards (VCS) carbon accounting methodology for Sustainable Agriculture Land Management (SALM). SALM helps smallholder farmers in developing countries to access carbon markets and includes protocols for measuring, monitoring and reporting on SOC.

'GHG Accounting 101' includes some information about GHG accounting in the agriculture sector (which alludes to SOC).

'Estimating GHG Emissions and Carbon Sequestration in Agriculture, Forestry and Other Land Use with EX-ACT (Self-paced)' which in similarity with the FAO course includes soils as a carbon sink and source.

3.5 International Fund for Agricultural Development (IFAD)

IFAD's e-learning platform has a course on 'Smallholder agriculture, environment and climate change' which covers aspects of soil management and SOC.

3.6 United Nations Convention to Combat Desertification (UNCCD)

SOC is of central importance to the UNCCD who have for a long time recognised the benefits of using SOC as an indicator of land degradation status. The UNCCD Knowledge Hub has a wide range of materials, mainly documents, some of which are available to the general public. These include the recent report on 'Realising the Carbon Benefits of Sustainable Land Management Practices Guidelines for estimation of soil organic carbon in the context of land degradation neutrality planning and monitoring' available from https://www.unccd.int/publications/realising-carbon-benefits-sustainable-land-management-practices-guidelines-estimation. Other documents with relevance to SOC include 'Best practices in SLM' (Sustainable Land Management). The UNCCD also supports and endorses the World Overview of Conservation Approaches and Technologies (WOCAT) an international database of geographically specific sustainable land management practices which in turn is linked to the Carbon Benefits Project GHG accounting tools. WOCAT run a number of teaching and training events mainly in response to requests.

3.7 European Commission Joint Research Centre

The European Commission's Joint Research Centre is the commissions science and knowledge service. It provides links to training courses in the EU and around the world. It also hosts a web application to view the European Soil Database which could be used for SOC teaching and training (https://esdac.jrc.ec.europa.eu/content/european-soil-database-v20-vector-and-attribute-data).
It hosts a variety of symposia and events which cover aspects of SOC teaching and training.

3.8 FACCE-JPI

The EU's Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI)

'brings together 24 countries committed to building an integrated European Research Area addressing the interconnected challenges of sustainable agriculture, food security and impacts of climate change'.

FACCE-JPI provides training to young scientists which includes training on soils and climate change. Details are available through their 'Knowledge hub' https://www.faccejpi.net/en/FACCEJPI/FACCE-JPI/Actions/Core-Theme-1/Knowledge-Hub-MACSUR-SciPol.htm.

3.9 The "4 per 1000" Initiative

The "4 per 1000" Initiative is an international initiative launched by France which aims to:

'demonstrate that agriculture, and, in particular agricultural soils, can play a crucial role where food security and climate change are concerned'

The resources page of their website has a number of videos and documents on SOC that could be used for teaching purposes. They also have links to other resources outside of the initiative and to interesting articles.

Recommendation 3.1 CIRCASA include a specific 'Teaching and Training Resources' area to its 'Online Collaborative Platform', maybe in the 'Knowledge Sharing' part which could include links to the resources listed above and others.

4. Consultation of stakeholders - Survey on capacity building and training needs surrounding soil organic carbon (SOC)

In order to learn about capacity building and training needs surrounding soil organic carbon (SOC) in the research community, relevant stakeholders in universities and research institutes were consulted. This was done via an online survey designed and made available through Cognito Forms. A full version of the survey is given in Appendix A and the survey (now closed) can also be accessed via the link below:

https://www.cognitoforms.com/Independent33/CurrentCapacityBuildingAndTrainingNeedsSurroundingSoilOrganicCarbonNOWCLOSED

4.1. Survey content

The survey consisted of 20 questions organised into 3 sections:

Section 1. General information
This section was aimed at determining the region in which the respondent was based, the region in which they worked (in case this differed from where they were based) and the respondent's area of expertise. It also asked the type of institution they are based in. Respondents were given the option to provide the name of their institution, but an assurance was given that this would not be used in the analysis. This was in order to track the number of institutions represented, while at the same time maintaining the respondent's anonymity.

Section 2. Current SOC teaching
Section 2. asked about current teaching which included SOC at undergraduate and postgraduate level or in short courses in the respondent's institute. The section included questions on the types of courses in which the teaching occurred, the topics covered and whether teaching included laboratory work, field work or modelling.

Section 3. Your opinion of future teaching/training needs for SOC

This final section asked the respondents opinion on how well SOC teaching is covered in different types of undergraduate, postgraduate and short training courses. The last question was an open question on the respondent's thoughts or opinions on SOC teaching and training needs for the future.

4.2. Target group

The target group for this survey was people working in universities or other research institutes which teach subjects which may include SOC. The link was distributed to the following:

- All CIRCASA members
- Academics from the mailing list from CIRCASA Task 1.2 'Reviewing scientific and technical evidence'
- Institutions running relevant courses identified via www.postgrad.com
- Academics from the authors' own networks

The link was posted on the CIRCASA website and social media platforms, and the social media platforms of the authors. In addition, the 'Snowball' approach to distribution was taken whereby those completing the survey were asked to forward the link to others who may also be involved in SOC teaching and training.

The group targeted was not intended to be a definitive list of all those carrying out teaching and training on SOC worldwide, but rather a sample which could serve as a basis for further in-depth regional or national studies in the future.

4.3. Results and Discussion from Section 1. General information

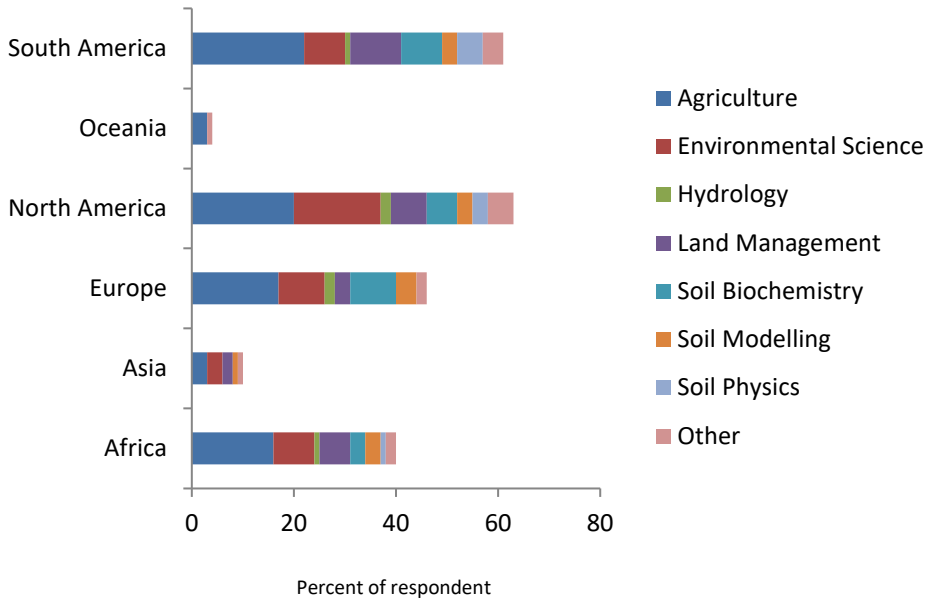
Institutions

A total of 108 people responded to the survey from a minimum of 50 different institutions (53 respondents didn't give their institution, the other 55 who did, came from 50 different institutions). Of the respondents, the majority (66%) were from universities, the next largest group (21%) were from government research institutes, 5% were from non-government research institutes and 7% gave 'other' as their affiliation (giving retired professor, consultant, NGO and international research institute as their affiliation). The main target group was intended to be universities and research institutes, so it was positive that these accounted for 92% of respondents collectively.

Area of Expertise

The survey asked people to identify their area of expertise. Seven possibilities were listed with an open box for 'other' areas not in the list. Respondents were able to choose more than one area of expertise. Of the total respondents, Agriculture was identified as an area of expertise by 35% of respondents, Environmental Science by 20%, Land Management by 12% and Soil Biochemistry by 11%. Soil Physics and Soil Modelling both had 6% and Hydrology 3%. Eight percent of people checked 'other' as their area of expertise, when asked to specify, most responses were a combination/derivation of the categories listed, with the exception of two respondents who listed remote sensing, geospatial science and spatial statistics. A breakdown of expertise by the region in which respondents are based is given in Figure 1. More respondents in North America listed Environmental Science as an area of expertise than in other regions and more respondents in South America listed Land management as an area of expertise.

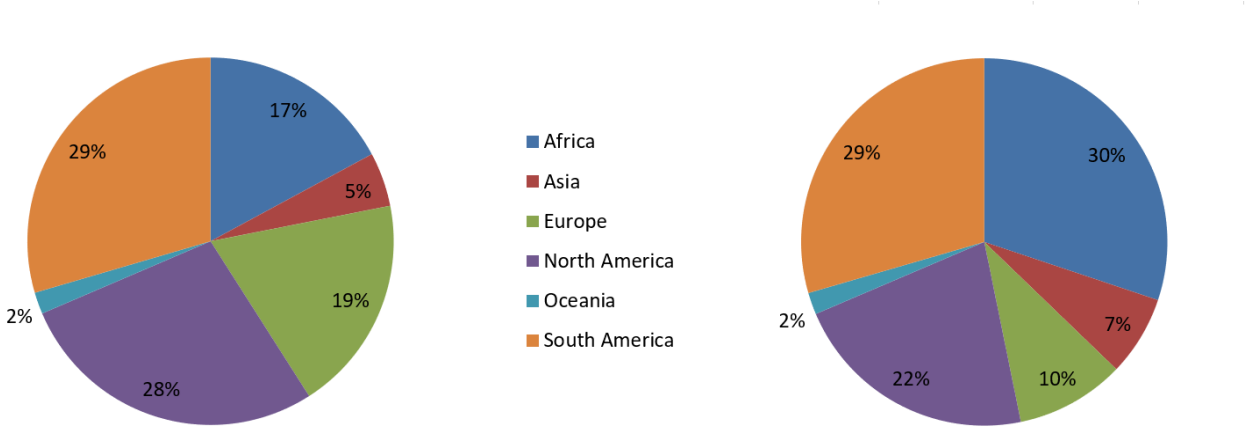
Figure 1. Percentage of respondents from each region reporting expertise in different areas



Geographic Coverage

Respondents were asked where they were based and in which region they are working. Coverage was good but Asia and Oceania were underrepresented. Twenty nine percent of respondents were based South America, 28% in North America, 19% in Europe and 17% in Africa with just 5% in Asia and 2% in Oceania (Figure 2. A). When asked where respondents where working, 30% of respondents reported work based in Africa meaning 15% of those based in Europe and North America combined were actually working on African projects (Figure 2. B).

Figure 2. Area in which respondents are A) based and B) working



4.4. Results and Discussion from Section 2. Current SOC teaching

In Section 2., questions were asked about undergraduate and postgraduate teaching and teaching in short courses that cover SOC.

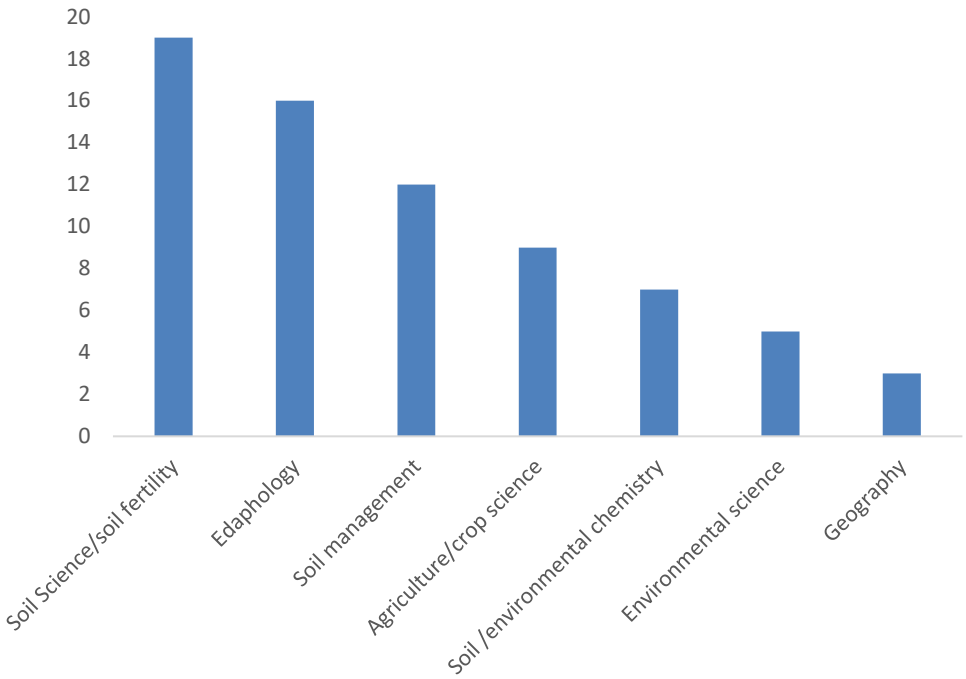
Undergraduate Teaching

Questions 5 -8 asked about undergraduate or undergraduate level teaching on SOC in the respondent's institutes. A total of 69 people from 108 (64%) said yes to the question '5. Does undergraduate or undergraduate level teaching on soil organic carbon occur in your institution?'. Questions 6 - 8 then related to this answer. If respondents answered 'No' to question 5 they were asked to skip Qs 6-8 and go to Q9. Therefore, only the responses from the 69 people who answered 'Yes' to questions 5 were considered in the analysis of undergraduate teaching.

Question 6 asked which undergraduate courses included SOC teaching, respondents were able to list multiple courses. Courses on Soil Science/Soil Fertility was the top response, being listed 19 times, this was followed by Edaphology (16), Soil management (12), Agriculture/crop science (9), Soil chemistry/environmental chemistry (7), Environmental science (5) and Geography (3) (Figure 3.). It was surprising that only 5 Environmental Science courses were listed.

Recommendation 4.1 SOC should be given more coverage in relevant undergraduate courses in general and in particular in Environmental Science courses.

Figure 3. Most prevalent undergraduate courses carrying out teaching on soil organic carbon according to survey respondents



In question 7, respondents were asked to list topics covered during the SOC undergraduate teaching carried out by their institute. They were given five possibilities:

- SOC formation and dynamics,
- Measuring and monitoring SOC
- SOC and soil flora and fauna
- SOC and climate change mitigation

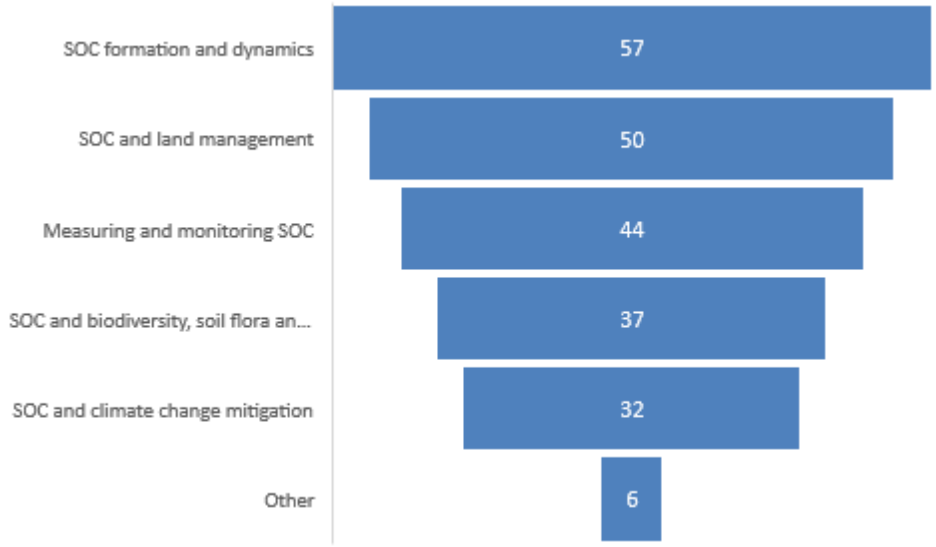
- SOC and land management
- Other (please specify)

of which they were able to choose multiple options. Those that listed 'Other' were asked to provide details. There was fairly even representation for all of the options given (Figure 4.). 'SOC formation and dynamics' was listed the most (57 of the 69 respondents). This was closely followed by 'SOC and land management' listed 50 times and measuring and monitoring SOC listed 44 times. 'SOC biodiversity soil flora and fauna' and 'SOC and climate change mitigation' were also well represented being listed 37 and 32 times respectively. Only 6 respondents listed 'Other' indicating that the suggested topics captured the spectrum of topics reasonably well. Those 6 respondents listed the topics below:

- SOC relationship with soil quality and plant yield,
- SOC in agriculture sustainability
- Soil Science in general, mainly soil properties, soil classification and Agricultural Chemistry
- Sustainable land management
- Carbon sequestration

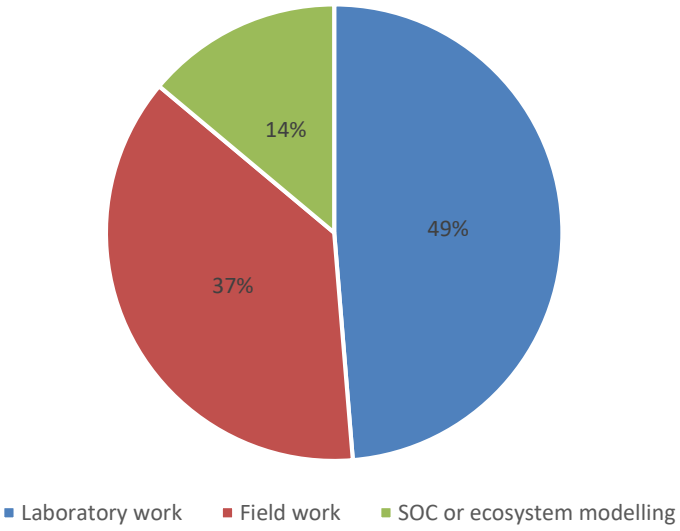
The responses indicate that where SOC teaching does take place at the undergraduate level, it seems to be fairly broad covering most aspects of SOC science. This includes teaching on SOC and climate change mitigation which is a welcome finding.

Figure 4. Topics covered during the SOC undergraduate teaching carried out in respondents' institutes



The final question about undergraduate teaching on SOC asked if the teaching the respondents listed included laboratory work, field work or modelling (SOC or ecosystem). Just under half indicated that laboratory work was included, 37% that field work was included and just 14% that SOC modelling work was included (Figure 5.). This suggests that laboratory work is covered well, field work could feature more widely and that an increase in undergrad teaching of SOC/ecosystem modelling is needed. Greater teaching of SOC modelling at undergraduate level would presumably encourage more research/teaching at the postgraduate level which will be vital for the next generation of scientists considering the role of SOC in climate change mitigation.

Figure 5. Teaching methods included in SOC undergraduate teaching in the respondents' institutes



Postgraduate Teaching

Questions 9 – 12 related to postgraduate teaching and followed the same format as those for undergraduate teaching. Sixty-nine people also said that postgraduate teaching which included SOC occurred in their institute, however this was a different 69 people from those who said undergraduate teaching including SOC occurred. The range of courses listed was wider for postgraduate compared with undergraduate teaching as expected (Figure 6.). Courses on 'agriculture and land management' were listed the most, followed by 'environmental science' and 'soil microbiology/ecology'. The next most likely to include SOC were 'soil chemistry', 'soil science' and 'soil fertility'. Five respondents listed courses specifically on SOC. Other course topics were listed four times or less, with SOC modelling only being listed once.

Figure 6. Most prevalent postgraduate courses carrying out teaching on soil organic carbon according to survey respondents

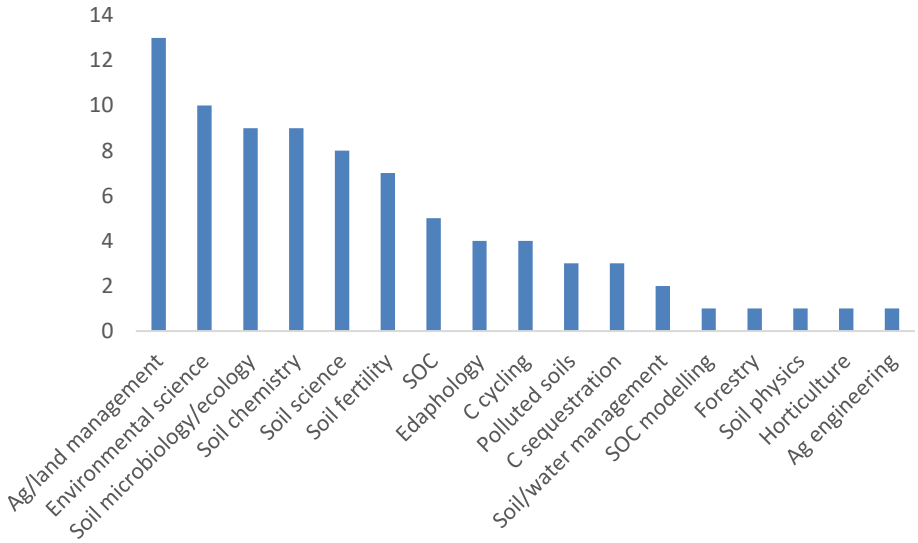
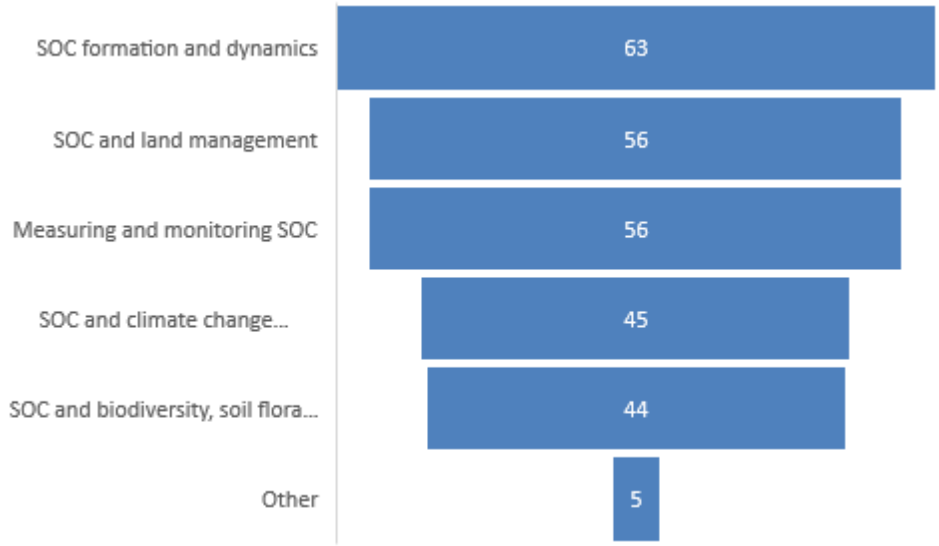


Figure 7. Topics covered during the SOC postgraduate teaching carried out in respondents' institutes



As in the previous section, respondents were asked to list topics covered during the SOC postgraduate teaching carried out by their institute. Again, they were asked to choose from five topics or 'Other' (Figure 7). Topics listed followed the same pattern as undergraduate teaching (Figure 4.), with an even representation across all the topics. SOC formation and dynamics was the most listed topic again and this time SOC biodiversity, flora and fauna was the least listed (just 1 behind SOC and climate change mitigation with 44 and 45 listings respectively). For the 5 who specified 'Other' the flowing topics were given:

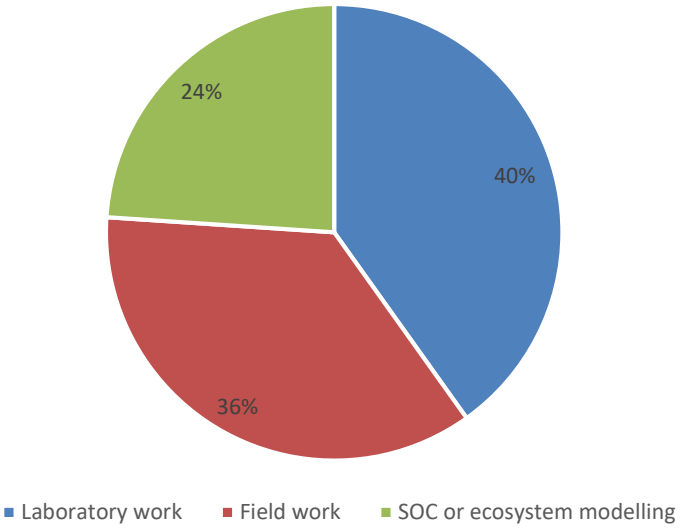
- The relevance of soil organic matter in crop fields
- SOC modelling (2 respondents)
- Carbon capture capacity
- SOC soil quality and plant yield
- C cycles, environmental pollution
- Sustainable land management
- SOC spatial prediction and mapping

The listing of 'spatial prediction and mapping' is interesting and may have been listed more if more academics with expertise in geography had been included in the sample group.

Recommendation 4.2 This survey (or a similar one) should be distributed to groups with a wider range of expertise.

The final question about postgraduate teaching on SOC asked if the teaching the respondents listed included laboratory work, field work or modelling (SOC or ecosystem). Forty percent indicated that laboratory work was included (9% less than for undergraduate teaching), 36% that field work was included (similar to undergraduate teaching at 37%) and 24% that SOC or modelling work was included a 10% increase on the amount reported for undergraduate teaching (Figure 8.). This is to be expected as SOC modelling requires a prior understanding of SOC dynamics, so is likely to get more coverage in postgraduate teaching.

Figure 8. Teaching methods included in SOC postgraduate teaching in the respondents' institutes



Short Courses

The final two questions of this section asked about short courses that include teaching on SOC. The aim was to discover if institutes are running any short courses including SOC teaching and if so what types of courses these are. Twenty fine respondents from 108 (23%) said 'Yes' they were running short courses. The types of courses varied widely as did their apparent target audiences from summer schools for students, courses for professionals seeking training on specific techniques to courses for NGOs and farmers organisations. They included two courses on SOC modelling, four courses about SOC in farming, two on soil spectroscopy and seven courses about land/ecosystem health and using SOC as an indicator. There was also one ecology course and one course specifically about SOC and C sequestration. The availability and target audience of short courses is worthy of further investigation in light of the findings from the Stakeholder Survey (Section 2.1.). Farmers, policy makers and other stakeholders may be unaware of courses that are open to them through academic institutions.

Recommendation 4.3 A comprehensive study should be carried out on the availability, provision and awareness of short courses on SOC.

4.5. Results from Section 3. Your opinion of future teaching/training needs for SOC

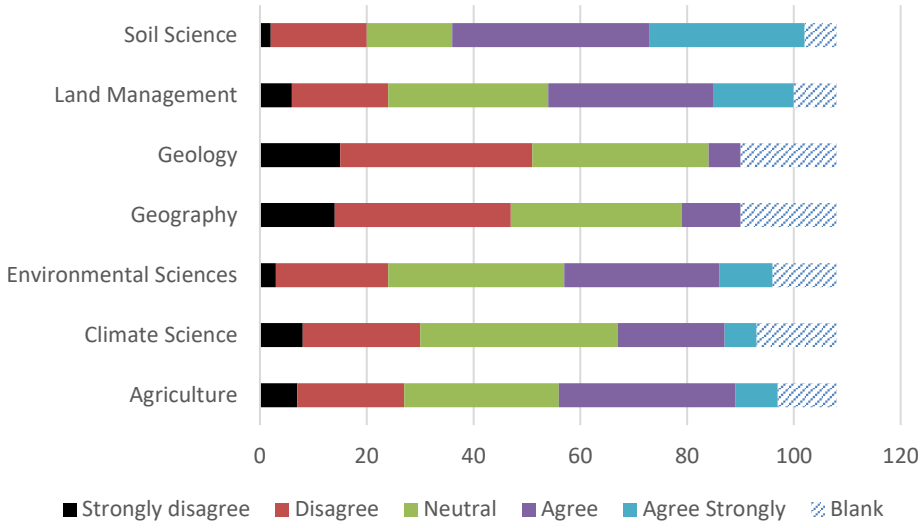
This section of the survey aimed to find out people's opinions on what the future of SOC teaching and training should include.

Question 15 asked if they agreed or disagreed (ranging from 'Strongly Agree' to 'Strongly Disagree') with the following statement – SOC is covered adequately in undergraduate:

- soil science courses
- agricultural courses
- land management courses
- environmental science courses
- geology courses
- geography courses
- climate science courses

Soil Science had the most positive response with 29 respondents 'strongly agreeing' and 37 'agreeing' that SOC is being taught adequately in Soil Science, and only 2 'strongly disagreeing' and 18 'disagreeing'. The subjects where respondents felt SOC wasn't being adequately covered were Geology and Geography. Geography, Geology and Climate Science had the greatest number of neutral responses, suggesting that respondents may not have been from the community that teach these subjects (Figure 9).

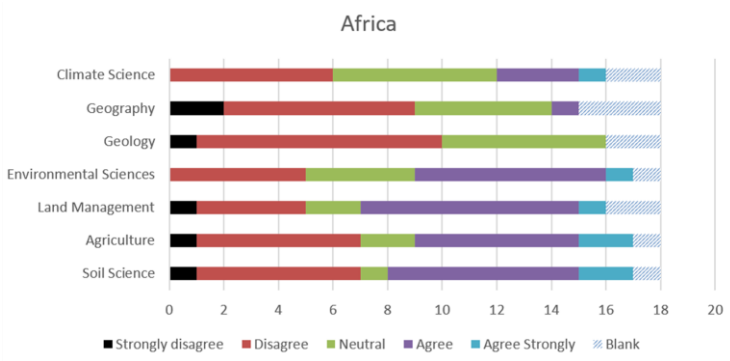
Figure 9. Survey responses to Q 15 'SOC is covered adequately in undergraduate courses on:

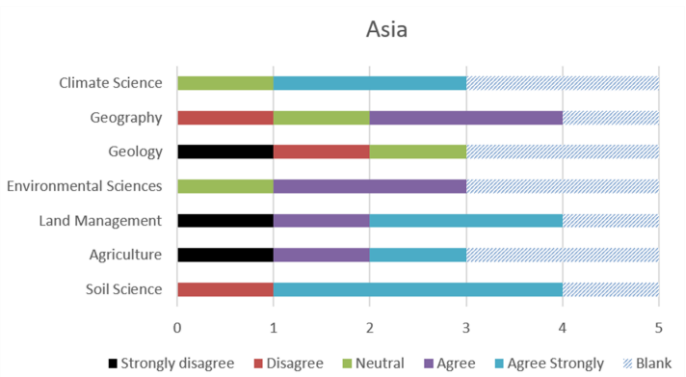


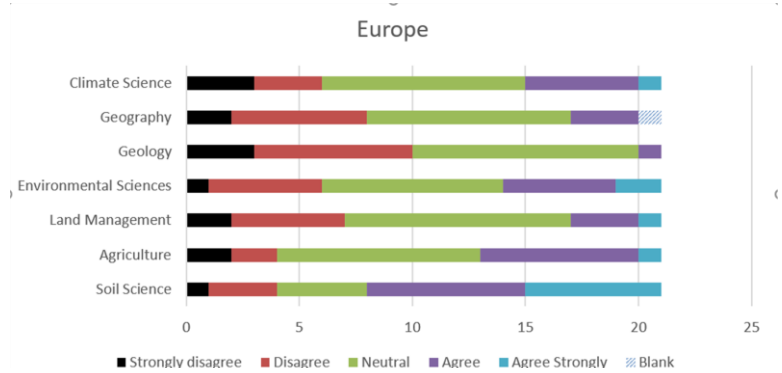
Responses were also broken down by the continent in which the respondents were based (Figures 10). It must be kept in mind that the number of respondents from each continent varied with under representation from Asia and Oceania. Overall dissatisfaction with SOC teaching appeared to be greater in the responses from Africa. Africa also had more dissatisfaction with teaching of SOC in Agriculture and Soil Science courses compared with responses from other continents. Responses from Oceania and Asia were too small to allow any regional inferences to be drawn from the results. Dissatisfaction with teaching of SOC in Geography and Geology University courses were reflected in all continents (apart from Oceania where the sample size was too small). Europe had a very good response rate with the fewest 'Blank' responses but did have the largest number of 'Neutral' responses. Europe and Africa had less satisfaction with SOC teaching in 'Land Management' courses than North America and South America.

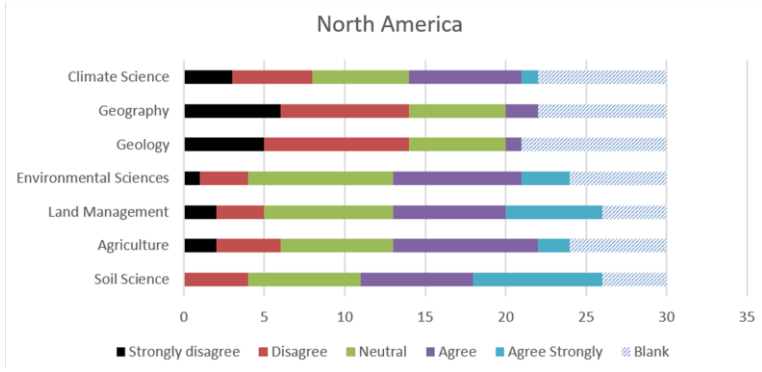
Recommendation 4.4 According to the survey results, ways should be explored of increasing SOC teaching in undergraduate geography and geology courses worldwide, in soil science and agriculture courses in Africa and in land management courses in Europe and Africa.

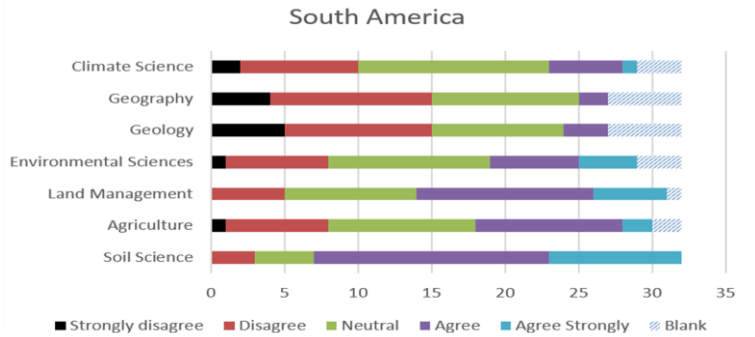
Figure 10. Survey responses to Q 15 'SOC is covered adequately in undergraduate courses on…' by continent

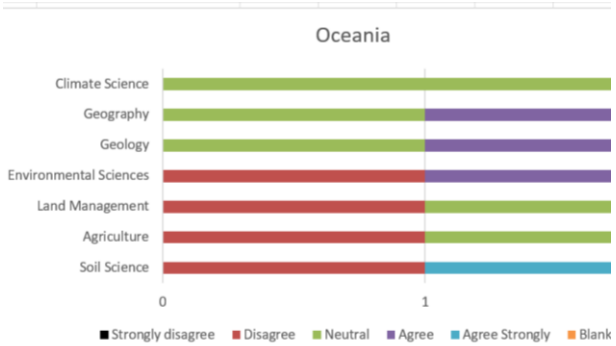











Oceania
Climate Science
Geography
Geology
Environmental Sciences
Land Management
Agriculture
Soil Science
0
1
Strongly disagree
Disagree
Neutral
Agree
Agree Strongly
Blank

Question 16 asked the same question but in reference to postgraduate courses. Results followed a very similar pattern, with Soil Science again having the most positive response with 34 strongly agreeing and 36 agreeing, and with 3 strongly disagreeing and 10 disagreeing (Figure 11.). Again, Geology and Geography were the subjects where respondents felt SOC wasn't being adequately covered. The number of responses left blank were slightly less for this question on postgraduate teaching compared to the question on undergraduate teaching.

Figure 11. Survey responses to Q 16 'SOC is covered adequately in postgraduate courses on:

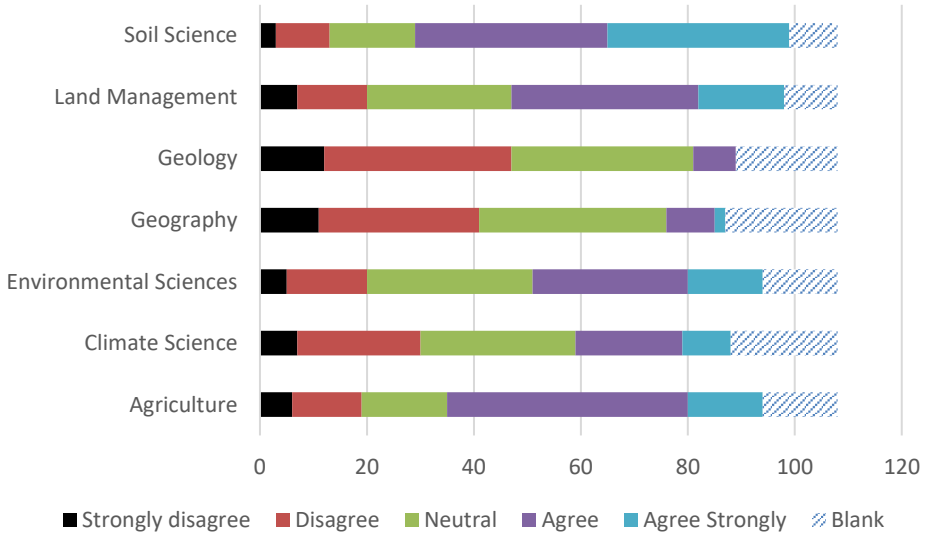
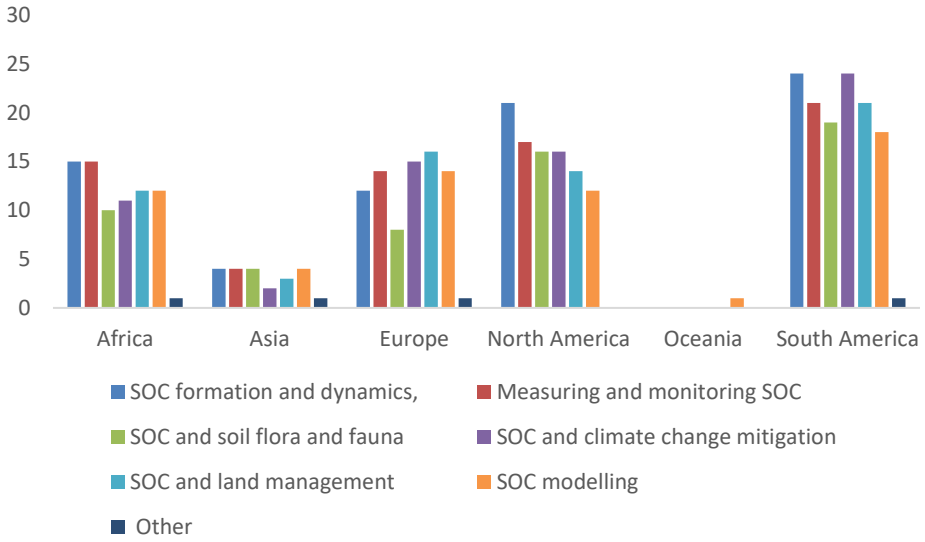


Figure 12. SOC topics about which respondents would like to see more teaching on (both undergrad and postgrad)



The next question (Q 17) asked about which topics respondents would like to see more SOC teaching on in undergraduate and postgraduate courses (Figure 12.). Interestingly, results agreed with findings from Question 15, with respondents in Europe wanting to see more SOC teaching in land management courses (both under and post-graduate), reinforcing Recommendation 4.4. Respondents from Europe chose SOC and climate change

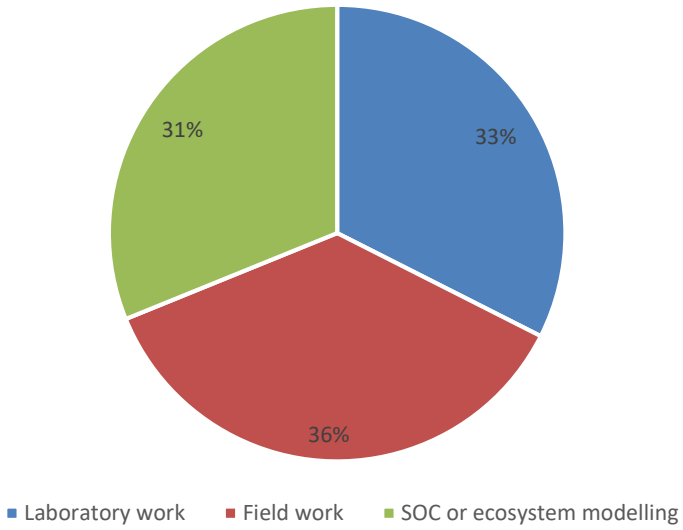
mitigation as the next topic they would like to see more teaching on closely followed by SOC and climate change mitigation and SOC modelling. Respondents in North America, South America and Africa chose SOC formation and dynamics as the topic they would most like to see more teaching on, with Africa listing this joint top with 'Measuring and monitoring SOC'. Measuring and monitoring SOC was listed as the second most important topic in North America.

Recommendation 4.5 In Europe teaching and training on SOC and land management, SOC and climate change mitigation and the role of modelling within this should be increased at both undergraduate and post graduate level.

Recommendation 4.6 In all regions teaching and training on SOC formation and dynamics should be increased.

Question 18. Asked respondents if undergraduate and post graduate teaching should include more laboratory work, field work or SOC/ecosystem modelling. Respondents listed all three choices an almost equal number of times (Figure 13) with Field Work being listed slightly more often. This suggests that overall respondents were happy with the balance between these 3 ways of teaching.

Figure 13. Do you think undergraduate/postgraduate teaching on SOC should include more:



Of the 108 people who answered the survey only 10 thought that there are enough short courses covering different aspects of SOC, the remaining 98 answered 'No' they didn't think there were enough short courses.

Recommendation 4.7 There should be more short courses on SOC in response to a clear demand. Type of course and audience needs to be investigated (see Recommendation 4.3).

Recommendation 4.8 There should be a drive to publicise existing online short courses and resources to all stakeholders especially those in Africa.

Recommendation 4.9 Teaching of SOC should be linked to real world situations in farms and villages to raise awareness and foster collaboration.

The final questions of the survey was open ended, asking people to give any other thoughts on SOC teaching

and training needs. In responses from Africa, a common theme was lack of laboratory equipment hindering work on SOC. A request was also made for more online short courses. It could be that there needs to be a drive to publicise existing online short courses to relevant stakeholders in Africa. A suggestion made by respondents in Asia and Europe was to link SOC teaching in universities with specific farmers and villagers so there was an investment in a specific farm or village by the students and awareness raising for the farmers. Respondents from Europe and North America noted the importance of SOC in relation to fundamental teaching in agriculture and soil science as well as being crucial for climate change mitigation. A couple of respondents from North America also noted the need for training on using specialist equipment associated with SOC research. The responses from South America called for more teaching on a variety of topics including:

- SOC in different climate regions
- SOC and environmental pollutants
- The economics of losing SOC
- SOC modelling

There was also a request for improved SOC data sets at the global level.

Recommendation 4.10 ways of improving laboratory resources for the teaching of SOC should be explored in Africa.

Recommendation 4.11 In North America the need for teaching and training on using specialist equipment used in SOC research should be explored.

Recommendation 4.12 In South America teaching and training on the economic consequences of losing SOC should be increased.

It is worth noting that the survey did not target agricultural schools and colleges. Another survey specifically targeting these institutions would be useful to learn more about SOC teaching being carried out in this sector.

5. Synthesis and Recommendations

5.1. Synthesis

This study provided a first look at teaching and training of SOC, mainly in academia, but also in governmental and non-governmental research institutes. It drew on information from previous CIRCASA activities and an analysis of international programs that included some SOC teaching or training. In addition, information was gathered from a survey answered by 108 respondents, mainly academics from around the world. From the analysis of the previous two CIRCASA studies it can be seen there is a clear desire for more teaching and training on SOC amongst many different stakeholder groups including farmers, land managers, academics and policy makers. Amongst farmers, there was a desire for more teaching centred around their local conditions (e.g. climate and soil type). This agrees with conclusions made by Ingram et al. (2016) who called for 'credibility, salience and legitimacy' in communications about soil carbon to farmers.

The analysis of SOC teaching in international programs revealed that a variety of free online teaching and training resources are available. However, results from all three CIRCASA surveys suggest that these need to be better publicised. This underpins recommendation 3.1, suggesting that CIRCASA (in its role as a global network for soil carbon sequestration) should help to publicise existing resources through its Online Collaborative Platform (OCP). A similar finding came out of the survey which found a demand for more short courses on SOC.

The survey of academic stakeholders suggested the academic community wanted to see more SOC teaching at undergraduate level, particularly in some of the more general courses such as Environmental Science. Respondents from Africa expressed a desire for more SOC teaching in more traditional subjects such as Soil Science and Land Management. This came along side some respondents from Africa saying there was a need for better equipped laboratories for SOC teaching and research. In Europe, respondents wanted more teaching and training on SOC and land management, SOC and climate change mitigation and the role of modelling within this. In all regions, respondents wanted to see more teaching and training on the fundamental principles of SOC science e.g. SOC formation and dynamics.

Both the analysis of previous CIRCASA reports (Section 2.) and the open-ended question in the survey of academics and researchers (Section 4.), identified a need for more teaching and training on the economics associated with SOC management. The CIRCASA Stakeholder Survey (CIRCASA 2020) had already found economics to be an important issue for farmers and land managers, specifically in terms of how changing land management to improve SOC can be beneficial to farmers and over what time scale. If SOC is to be maintained or enhanced, it must be economically feasible for famers and land managers in both the short and the long term. At the moment, it appears that teaching and training on the economics of SOC management could be lacking, at least in the life sciences community. The survey carried out for this report did not adequately capture the opinions of economists and social scientists who may be working in areas dealing with SOC. A further analysis should therefore be carried out to capture feedback and opinions from the socio-economic community who teach in areas with relevance to SOC, and to explore ways of bringing the life sciences and socio-economic teaching communities together. In addition, the SOC training needs of those working in policy should be analysed, and training devised which communicates the benefits of SOC in a clear effective way.

5.2. Summary of Recommendations

2.1a Efforts should be made to set up training and capacity building for farmers agricultural managers, agricultural advisory organisations, researchers and the agricultural community in general on:

1. Information on farm-level management practices and their effects on SOC
2. The economic costs and benefits of SOC friendly practices
3. Policy mechanisms and the enabling environment for SOC
4. Monitoring, reporting and verification for SOC

2.1b More teaching/training is need for farmers on SOC friendly practices which are specific to the conditions farmers are working in (climate, soil type, crop type etc.)

2.1c Farmers need user-friendly tools to help estimate the impacts of practices on SOC and more teaching/training on how to use these tools.

2.1d Farmers need training on how to account for and recognise the economic consequences of implementing SOC friendly practices.

2.1e Teaching and training should be made available to policy makers and funding agencies to help them decide where to target funds to support activities that increase SOC. These should include training on biophysical and economic considerations.

2.1f SOC teaching and training should include interactive opportunities for learners to exchange knowledge with each other.

2.2a More teaching is needed at postgraduate level on SOC inputs, decomposition and preservation, saturation, erosion and SOC at depth, to provide a good foundation for these subjects.

2.2b Teaching and training on Monitoring Reporting and Verification for SOC should be informed by research and visa versa.

2.2c Teaching and training on recognising and overcoming economic and socio-cultural barriers to adopting SOC friendly land management practices is needed which make use of local knowledge and information.

2.2d Increase teaching and training in science communication, specifically on how to convey key messages to policy makers about the importance of SOC.

2.2e There is a need for teaching and training on how SOC currently features/is covered in existing national and international legal and political agreements. This could be targeted at international development courses.

3.1 CIRCASA include a specific 'Teaching and Training Resources' area to its 'Online Collaborative Platform', maybe in the 'Knowledge Sharing' part which could include links to the resources listed above and others.

4.1 SOC should be given more coverage in relevant undergraduate courses in general and, in particular in Environmental Science courses.

4.2 This survey (or a similar one) should be distributed to group with a wider range of expertise.

4.3 A comprehensive study should be carried out on the availability, provision and awareness of short courses on SOC.

4.4 Ways should be explored of increasing SOC teaching in undergraduate geography and geology courses worldwide, in soil science and agriculture courses in Africa and in land management courses in Europe and Africa.

4.5 In Europe teaching and training on SOC and land management, SOC and climate change mitigation and the role of modelling within this should be increased at both undergraduate and post graduate level.

4.6 In all regions teaching and training on SOC formation and dynamics should be increased.

4.7 There should be more short courses on SOC in response to a clear demand. Type of course and audience needs to be investigated (see Recommendation 4.3).

4.8 There should be a drive to publicise existing online short courses and resources to all stakeholders especially those in Africa.

4.9 Teaching of SOC should be linked to real world situations in farms and villages to raise awareness and foster collaboration.

4.10 Ways of improving laboratory resources for the teaching of SOC should be explored in Africa.

4.11 In North America the need for teaching and training on using specialist equipment used in SOC research should be explored.

4.12 In South America teaching and training on the economic consequences of losing SOC should be increased.

6. References

Andrew W. Bray, John H. Kim, Marion Schrumpf, Caroline Peacock, Steven Banwart and contributing authors Louis Schipper, Denis Angers, Ngonidzashe Chirinda, Yuri Lopes Zinn, Alain Albrecht, Peter Kuikman, Pascal Jouquet, Julien Demenois, Mark Farrell, Sébastien Fontaine, Jean-Francois Soussana, Matthias Kuhnert, Eleanor Milne, Sebastien Fontaine, Arezoo Taghizadeh-Toosi, Carlos Eduardo Pellegrino Cerri, Marc Corbeels, Remi Cardinael, Viridiana Alcántara Cervantes, Jørgen E. Olesen, Niels Batjes, Gerard Heuvelink, Stoécio Malta Ferreira Maia, Saskia Keesstra, Lieven Claessens, Beata Emoke Madari, Louis Verchot, Wan Nie, Thierry Brunelle, Dominic Moran, Stefan Frank, Ralph Bodle, Ana Frelih-Larsen, Andrew Dougill, Luca Montanarella, Lindsay Stringer, Claire Chenu, Roland Hiederer, Pete Smith, Cristina Arias-Navarro 2019. *Deliverable D1.3 The science base of a strategic research agenda*. A report from the activities of work package 1, task 1.2. Contains (a) the results of a questionnaire of researchers on perceptions of agricultural soil carbon knowledge and importance, and (b) 12 testable hypotheses for future research into soil organic carbon sequestration in agriculture. European Union's Horizon 2020 research and innovation programme grant agreement N° 774378- Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture.

CIRCASA 2020. Deliverable D2.3: "*Synthesis report on knowledge demands and needs of stakeholders".* [Frelih-Larsen, A.; Ittner, S.; Herb, I , Tarpey, J.;.Olesen, E.J.; Graversgaard, M.; Claessens, L.; Emoke Madari, B.; Razafimbelo, T.; Kontoboytseva, A.; Nciizah, A.; Swanepoel, C.; Katto, C.; Verchot, L.; Baldock, J.; Grundy, M.; Hongmin, D.; Li, Y.; McNeill, S.; Arias-Navarro, C.; Soussana, J., -F.]. European Union's Horizon 2020 research and innovation programme grant agreement N° 774378- Coordination of International Research Cooperation on soil CArbon Sequestration in Agriculture https://doi.org/10.15454/Q0XVVD

Ingram, J. et al. 2016 . Communicating soil carbon science to farmers: Incorporating credibility, salience and legitimacy. Journal of Rural Studies, 48, 115 – 128.

7. Appendix A: Survey

Current capacity building and training needs surrounding Soil Organic Carbon (Open until Feb 9th 2020)

As part of the EU's CIRCASA (Coordination of International Research Cooperation on Soil Carbon Sequestration in Agriculture) project, we are seeking to learn about capacity building and training needs surrounding soil organic carbon (SOC). As part of this process we are consulting relevant stakeholders in universities and research institutes. We would highly appreciate it if you could find time to complete the questionnaire below. The questionnaire considers current teaching and training activities that include SOC, and stakeholder opinions on teaching and training needs surrounding SOC. The final product will be a report which will help inform a future research strategy for SOC.

Section 1. General Information

Name of Institution (This will not be used in the analysis, it is only so we can see how many institions the survey covers)

1. Do you work in:

A university

Other (please specify)

2. What is your area of expertise?

- [x] Agriculture
- [ ] Environmental Science
- [ ] Hydrology
- [ ] Soil biochemistry
- [ ] Soil modelling
- [ ] Soil physics
- [ ] Land management
- [ ] Other

Other (please specify)

3. In which region are you based?

Africa

4. Which region does your work primarily cover? (Select multiple if necessary)

- [x] Africa
- [ ] Asia
- [ ] Europe
- [ ] North America (including Caribbean)
- [ ] South America
- [ ] Oceana

Section 2. Current SOC Teaching

5. Does undergraduate or undergraduate level teaching on soil organic carbon occur in your institution? (if Y go to Q6) (if N go to Q9)

○ Yes ◉ No

6. As far as you know, in your institution which undergraduate course/s include teaching on SOC? (please answer using your own knowledge/experience, a comprehensive list isn't expected!)

7. Which topics are covered in the undergraduate SOC teaching:

☑ SOC formation and dynamics

☐ Measuring and monitoring SOC

☐ SOC and biodiversity, soil flora and fauna

☐ SOC and climate change mitigation

☐ SOC and land management

☐ Other

Other (please specify)

8. Does the undergraduate teaching include:

☑ Laboratory work

☐ Field work

☐ SOC or ecosystem modelling

9. Does postgraduate or advanced level teaching on soil organic carbon occur in your institution? (if Y go to Q10) (N go to Q13)

○ Yes ◉ No

10. Under which postgraduate course/programme does teaching on SOC occur? (please answer using your own knowledge/experience, a comprehensive list isn't expected!)

11. Which topics are covered in the postgraduate level SOC teaching:

- [x] SOC formation and dynamics
- [ ] Measuring and monitoring SOC
- [ ] SOC and biodiversity, soil flora and fauna
- [ ] SOC and climate change mitigation
- [ ] SOC and land management
- [ ] Other

Other (please specify)

12. Does the postgraduate teaching include:

- [x] Laboratory work
- [ ] Field work
- [ ] SOC or ecosystem modelling

13. Does your institution run short courses which include teaching on SOC? (if Y go to Q14)(if N go to Q15)

- ○ Yes
- ◉ No

14. Please list the names of any short courses that include SOC teaching

Section 3. Your opinion of future teaching/training needs for SOC

15. Please indicate if you agree or disagree with the following statement -In general, SOC is covered adequately in the following undergraduate courses:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Soil Science	○	○	○	○	○
Agriculture	○	○	○	○	○
Land Management	○	○	○	○	○
Environmental Science	○	○	○	○	○
Geology	○	○	○	○	○
Geography	○	○	○	○	○
Climate Science	○	○	○	○	○

16. Please indicate if you agree or disagree with the following statement -In general, SOC is covered adequately in the following postgraduate courses:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Soil Science	○	○	○	○	○
Agriculture	○	○	○	○	○
Land Management	○	○	○	○	○
Environmental Science	○	○	○	○	○
Geology	○	○	○	○	○
Geography	○	○	○	○	○
Climate Science	○	○	○	○	○

17. Which of the following topics would you like to see more teaching on in undergraduate and/or postgraduate courses (check any relevant ones):

- ☑ SOC formation and dynamics
- ☐ Measuring and monitoring SOC
- ☐ SOC and biodiversity, soil flora and fauna
- ☐ SOC and climate change mitigation
- ☐ SOC and land management
- ☐ SOC modelling
- ☐ Other

Other (please specify)

18. Do you think undergraduate/postgraduate teaching on SOC should include more:

- ☑ Laboratory work
- ☐ Field work
- ☐ SOC or ecosystem modelling

19. Do you feel there are enough short courses covering SOC?

○ Yes ◉ No

Please give a brief reason

20. Please use the space below to provide any other thoughts or opinions on SOC teaching and training needs for the future.

THANK-YOU!

8. Appendix B: Links to online SOC teaching and training resources

United Nations Environment Program (UN Environment)
MOOC https://www.unenvironment.org/explore-topics/education-environment/what-we-do/massive-open-online-courses
Tools www.carbonbenefitsproject.org

The Food and Agriculture Organisation (FAO)
http://54.229.242.119/GSOCmap/
'SOC – the treasure beneath our feet' https://www.youtube.com/watch?v=Ymy0IO7nizw
E-Learning Centre https://elearning.fao.org/

ISRIC – World Soil Information
www.isric.org/utilise/capacity-building/virtual-classroom

The World Bank
https://olc.worldbank.org/content/climate-change-online-learning.

International Fund for Agricultural Development (IFAD)
https://www.ifad.org/en/web/knowledge/publication/asset/39631833?inheritRedirect=true

United Nations Convention to Combat Desertification (UNCCD)
https://www.unccd.int/publications/realising-carbon-benefits-sustainable-land-management-practices-guidelines-estimation.

European Commission Joint Research Centre
The European Soil Database (which could be used for SOC teaching and training) https://esdac.jrc.ec.europa.eu/content/european-soil-database-v20-vector-and-attribute-data

FACCE-JPI
Training on soils and climate change. https://www.faccejpi.net/en/FACCEJPI/FACCE-JPI/Actions/Core-Theme-1/Knowledge-Hub-MACSUR-SciPol.htm.

Four per 1000
The resources page of their website has a number of videos and documents on SOC that could be used for teaching purposes. https://www.4p1000.org/

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