Institution: University of Aberdeen

Unit of Assessment: 7 (Earth Systems and Environmental Sciences)

Title of case study: Decision support tools to reduce global greenhouse gas emissions (GHGs)

Period when the underpinning research was undertaken: 2014–2019

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Pete Smith	Prof. in Soils and Global Change	2001–date
Jo Smith	Prof. in Soil Organic Matter	2001–date
Jon Hillier	Reader in Biological Sciences	2006–2018
Euan Phimister	Chair in Economics	1997–date
Paul Hallett	Prof. of Biological Sciences	2013–date
Astley Hastings	Reader in Biological Sciences	2008–date

Period when the claimed impact occurred: 2014-2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact (indicative maximum 100 words)

Climate change, caused by greenhouse gas (GHG) emissions, is one of humanity's greatest environmental challenges. Research led by the University of Aberdeen has developed a range of decision support tools for industry, land managers and policy makers utilizing the best scientific understanding to enable real-world reduction in GHG emissions. The "Cool Farm Tool" has been adopted by an alliance of 82 of the world's largest agri-food businesses and has been used for over 47,000 assessments in 118 countries. It has delivered demonstrable and very significant reductions in GHG emissions from their food production chains. The Windfarm Carbon Calculator has been adopted by the Scottish Government for all windfarm-planning applications of over 50 MW and is used by industry, non-governmental organisations (NGOs) and government to assess potential impacts.

2. Underpinning research (indicative maximum 500 words)

Greenhouse gases are created by a number of activities, especially food production and power generation, and are the main driver of climate change.

The United Nations has estimated that by 2050 the world will need to produce 70% more food to support a global population of 9,000,000,000; up to a third of all GHGs come from the global food system. The migration of power generation to sustainable technologies, such as wind turbines, is reducing the level of GHGs produced. However, the construction of windfarms, especially if they are built on carbon rich peatlands, can lead to the release of GHGs. Minimizing such emissions delivers the maximum positive environmental benefits. Models and tools developed by the University of Aberdeen have provided powerful methods to estimate greenhouse gas emissions, which have enabled mitigation actions across a number of industries.

The research presented in this case study was led by University of Aberdeen researchers Pete Smith (Professor of Soils & Global Change 2001–present) and Jo Smith (Professor in Soil Organic Matter and Nutrient Modelling 2001–present). Other key researchers were Jon Hillier (Reader in Biological Sciences 2006–2018), Euan Phimister (Chair in Economics 1997–present) and Paul Hallett (Professor of Biological Sciences 2008–present). The team collaborated with colleagues at the Consultative Group on International Agricultural Research (CGIAR) research centres (Claire Stirling, Tek Sapkota, Wolde Bori, Bedru Balana) and London School of Hygiene and Tropical Medicine (Alan Dangour and colleagues). Other partners were Forest Research (Mike Perks), the

James Hutton Institute (Jagadeesh Yeluripati and colleagues), The Sustainable Food Lab (Daniella Malin) and industry, Cool Farm Alliance (Rich Heathcote) and Yara, a leading agrochemical company (Frank Brentrup).

The tools presented in this case study were included in the REF2014 (Windfarm Carbon Calculator and Cool Farm Tool). Since that time the tools have been substantially developed further and been deployed more widely, as such, additional impacts have been achieved.

The tools are based on theoretical models of biogeochemical processes and greenhouse gas emissions, described in over 300 journal publications by the team since the REF2014 [1]. After the models were evaluated with independent data and demonstrated to be robust, the team worked with industry partners (such as the Scottish Environmental Protection Agency (SEPA) for windfarms and the Cool Farm Alliance for the Cool Farm Tool) to translate the complex models into tools that could accept readily obtainable, real-world inputs from users in industry.

Research into greenhouse gas emissions from agriculture [3] led to the development of the Cool Farm Tool (2008) in association with Unilever. It used simplified relationships between agricultural management practices (e.g. fertilization, tillage, irrigation, etc.) and emissions of carbon dioxide, methane and nitrous oxide. Since 2013 the Cool Farm Tool has been refined to extend its applicability to perennial crops (e.g. apples, figs and olives) [4]. A water module [5] has now been added that estimates the water footprint of a crop in addition to its greenhouse gas emissions.

The Windfarm Calculator estimates the carbon payback time for a windfarm – the time required for net carbon losses associated with building the windfarm to be balanced by carbon savings through clean energy. Using information such as the depth of peat on which the windfarm would be built and the extent of drainage around the infrastructure, the Calculator (2008) enables planners to avoid developments on sensitive sites, while permitting developments on those where a windfarm does not result in degradation of sensitive soils.

A major evolution of the Windfarm Calculator was the introduction of further modelling (2018) to understand the impact of repowering on carbon emissions; repowering is the process of replacing old wind turbines with new technology. Whilst wind farms exist to generate electricity with minimal carbon (C) footprint, an assessment of repowering has to take into account key processes that affect this such as embedded C (as CO_2 emissions) used in the construction of the repowered wind farm, and any disturbance to the environment that can reduce its capacity to sequester Carbon, including the effectiveness of restoration at the end-of-life [2]. This project, managed by 'Construction Scotland Innovation Centre' and led by the Universities of Glasgow and Aberdeen, fostered collaboration between the SEPA, Engineering company, ARUP Group and Scottish and Southern Energy plc (SSE) and ensured the tool would be appropriate to influence the development of the next generation of windfarms.

3. References to the research (indicative maximum of six references)

References (citations via Scopus)

[1] **Smith, J.U**., Yeluripati, J., **Smith, P**. and Nayak, D.R. 2020. Potential yield challenges to scale-up of Zero Budget Natural Farming. *Nature Sustainability* **3,** 247–252, doi: https://doi.org/10.1038/s41893-019-0469-x, 1 citation.

[2] Waldron, S., **Smith, J**., Taylor, K., McGinnes, C., Roberts, N. and McCallum, D., 2018. Repowering onshore wind farms: A technical and environmental exploration of foundation reuse. *Carbon Landscape and Drainage Knowledge Exchange Network-Led Report; Construction Scotland Innovation Centre: Glasgow, UK*, doi: 10.17605/OSF.IO/SCZDE, 1 citation.

[3] **Smith, P**., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C. and Scholes, B., 2008. Greenhouse gas mitigation in agriculture. *Philosophical transactions of the Royal Society B: Biological Sciences*, *363*(1492), pp.789-813, doi: 10.1098/rstb.2007.2184, 2371 citations.

[4] Ledo, A., **Hastings, A**., Heathcote, R., **Smith, P. and Hillier. J**. 2018. Perennial-GHG: a new generic allometric model to estimate biomass accumulation and greenhouse gas emissions in perennial food and bioenergy crops. *Environmental Modelling and Software* 102, 292–305. doi: https://doi.org/10.1016/j.envsoft.2017.12.005, 7 citations.

[5] Kayatz, B., Harris, F., **Hillier, J**., Adhya, T., Dalin, C., Nayak, D., Green, R.F., **Smith, P**. and Dangour, A.D., 2019. "More crop per drop": Exploring India's cereal water use since 2005. *Science of the total environment*, *673*, pp.207-217. doi: https://doi.org/10.1016/j.scitotenv.2019.03.304, 12 citations.

Grants

Research projects initiated since 2014 totalling greater than GBP8,500,000, funded by UKRI (NERC, BBSRC, EPSRC), EU, Wellcome Trust, Industry (Shell, Unilever), KR Foundation, Scottish Government, Defra and UKERC, have contributed to the science underpinning these Decision Support Tools.

4. Details of the impact (indicative maximum 750 words)

The impact of Aberdeen research has benefited multinational food companies and farmers in developed and developing countries. It has influenced Scottish Government policy and has directly enabled measurable reductions in greenhouse gas emissions, informing best practice for future wind turbine installations.

The impact can be summarized under three headings:
1.Improvement in the environmental performance of agri-food companies
2.Influencing agricultural practice in low- to middle-income countries
3.Reduction in GHG emissions associated with windfarms

Improvement in the environmental performance of agri-food companies

The Cool Farm Tool (https://coolfarmtool.org/) [S1i] was developed in partnership with Unilever, which provided validation data from field trials. By 2013 the company had partnered with 17 industry competitors and created the Cool Farm Alliance in order to enable interested agri-food companies to use the tool to plan their GHG reduction strategies. Project data is confidential to each individual company, but all members can see anonymized aggregate data. Since REF2014, Cool Farm Alliance membership has further grown to 82 companies. There are 10,500 registered users and the tool has been used in 118 different countries to make 47,000 assessments. The success and utility of the tool meant that in 2014 ownership was transferred from UoA to the Cool Farm Alliance, which now administers it and implements updates from the research team [S1ii].

Members of the Alliance include Unilever, PepsiCo, McDonald's, M&S, McCain, Mars, Kellogg's, Heineken, Branston, Danone, Tesco, Heinz and Costco [S2i]. The companies use the tool to calculate the impact of their operations on the environment and its trade-off with their productivity. The tool revolutionized the sector's capacity for empirically based behaviour change, practice and decision-making and has enabled substantial GHG reductions in food supply chains. These have had a significant, quantified impact on their GHG emissions, for example:

- Unilever showed a reduction of 25% in GHG emissions from its tomato farms. The farms represent 80% of global production of field-grown tomatoes and the top five producing countries (US, China, Italy, Spain, Turkey). They now plan to extend this type of analysis to other crops such as onions, garlic, carrots and strawberries [S2ii].
- Danone showed an average reduction in emissions of 12% within one year of starting to use the tool in 13 countries and has introduced a "carbon-adjusted" recurring earnings per share (EPS) evolution that takes into account an estimated financial cost for the absolute GHG emissions on its entire value chain [S2ii].
- Between 2010 and 2015 ADAS and PepsiCo have been working alongside Walkers Crisps to embed the tool in a project to reduce carbon emissions and water use and have achieved

an average reduction of 50% in five years across their UK potato farms [S2ii]. These and many similar examples can be found in [S3i].

The Agricultural Sustainability Manager (Europe) at PepsiCo appreciated that the power of the Cool Farm Tool is that it gives the end user the capacity to properly understand the consequences of individual strategies, saying, *"I like the Cool Farm Tool because it's not a black box. With other tools you… just pay for the study and are delivered the results. This is a better way of engaging."* [S3i].

The development of the water module (2019) of the Cool Farm Tool has enabled Solidaridad (an international development agency), who have worked with 7,361 farmers in Mexico, Columbia and Peru, to achieve yield improvements of 21% alongside a reduction in emissions of nearly 28,000 tonne of CO_2 eq [S3ii].

Influencing agricultural practice in low- to middle-income countries

The Tool was used in over 118 countries between 2013 and 2020. WWF-India (World Wide Fund for Nature – India) produced a report in collaboration with Marks & Spencer and used the Tool to assess the GHG emissions generated by cotton cultivation in Warangal, India, on a pilot scale [S4i]. GHG emissions from farms using traditional cultivation methods were compared with those using better management practices (BMPs). Traditional cultivation was shown to use almost double the amount of fertiliser compared to BMPs. It exceeded the levels recommended by the National Mission for Sustainable Agriculture, India, and produced almost twice the amount of GHG emissions without improving yield. WWF-India now works with farmers in the Warangal district to promote BMPs in cotton production in order to mitigate environmental impact, as reported by Marks & Spencer [S4i, ii].

Reduction in GHG emissions associated with windfarms

The Carbon Calculator for Windfarms on Scottish Peatlands (Windfarm Calculator) (2008 onwards) [2] was originally developed for the Scottish Government. SEPA assumed ownership of the Calculator in 2013 [S5i] and now handle all queries and updates to the tool (2017) and the University of Aberdeen team continue to provide technical updates [S5ii].

Scottish Government policy was changed in 2017 and published in August 2018, when SEPA made use of the tool compulsory for all planning applications under section 36 – Energy infrastructure: Energy consents - gov.scot (https://www.gov.scot/publications/energy-consents-application-procedure-and-publicity-requirements/) for companies attempting to gain energy consents for new onshore windfarms of greater than 50 MW [S6]. As per this policy, developers are now required to calculate potential carbon losses and savings from wind farms on Scottish peatlands. By developing an online Carbon Calculator available at https://informatics.sepa.org.uk/CarbonCalculator/index.jsp, the University of Aberdeen has facilitated this process and informing best practice for future windfarm developments. In 2016, the tool was adapted into a web-based version (which includes the enhancements around forestry, made available by the Scottish Government, the associated factsheet states "*The improved ease of use [of the carbon calculator] will reduce the burden on developers as a consequence of the increased user-friendliness and the more sophisticated entry checking and guidance. The expectation is that this will reduce the number of resubmissions. The improved quality of submissions will reduce the validation work required. It will allow developers to submit carbon assessments and conduct initial carbon assessment screening tests on their proposed developments online in a self-service manner. It will allow an aggregated picture to be made of assessments (initial applications and re-applications) across Scotland*" [S7].

There have been 10 sites (totalling 1247 MW of the 2039 MW (61%) constructed or applied for since 2016 [S8], each of which had to be justified using the tool. This means the Windfarm Calculator has helped retain the huge stock of carbon held in Scottish soils by avoiding the construction of new windfarms on deep peats and forcing a shift in the siting of windfarms to soils lower in carbon. By thus preserving intact peatlands, this provides a two-way reduction in net GHG emissions.

Developments to the Windfarm Calculator, were facilitated through a joint consultancy project with Forest Research (part of DEFRA), and Glasgow University [2] (2018) and highlighted the potential for "repowering" end-of-life windfarms (by replacing old turbines with new technology) [2, see p27]. The results were used to update technical guidance released by the Scottish Government [S10] and were included in a policy statement produced by the Scottish Government in 2017 on repowering [S9].

After it was published, SSE and Scottish Power assessed the options presented by the report and concluded that the re-engineering cost per turbine foundation would be between two and three times higher than a new foundation for the target turbine type. This translates into a multi-million pound cost-avoidance opportunity for a typical >50 MW windfarm and represents an opportunity to resite windfarms on mineral soils and avoid further degradation of peatlands [2]. In May 2020, Scottish Power acquired a 165 MW major new onshore wind project, including the repowering of Scotland's very first commercial windfarm, Hagshaw Hill. It is expected that the overall project could create 600 peak jobs and 280 long-term jobs. Stated in the press release, '*Hagshaw Hill Repowering Ltd has Section 36 planning consent for up to 14 turbines with max tip height of 200m, a 20 MW battery storage facility and a grid connection already secured*.' [S11]

5. Sources to corroborate the impact (indicative maximum of 10 references)

[S1 (group)] (i) Link to Cool Farm tool; (ii) letter from General Manager, Cool Farm Alliance, outlines the vital role of the tool for that organization and its members.

[S2 (group)] (i) List of Alliance members; (ii) specific examples of members using the tool include Unilever, Danone and PepsiCo

[S3 (group)] (i) Companies using the tool: article from 'The Guardian' on the Cool Farm Tool – a better way of engaging with farmers May 2014; (ii) use of tool by Solidaridad (https://coolfarmtool.org/2016/10/smart-farmers-opt-for-the-power-of-data-with-the-cool-farm-tool/)

[S4 (group)] (i) M&S WWF-India Cotton Carbon Emission report, 2013 (https://bit.ly/381d8yT); linked WWF case study (2014), (ii) corroborates M&S investment in Cool Farm Tool (https://bit.ly/3q8J22z)

[S5 (group)] (i) Land Use Planning System SEPA Guidance Note 4: Planning guidance on on-shore windfarm developments. Section 4.11 quotes the Carbon Calculator as the official SEPA tool (https://bit.ly/3cTPO7x); (ii) SEPA presentation slides (2014), 'Renewable development on peatlands: practical considerations in assessing balance of carbon losses and savings' provides a timeline of SEPA validation of the tool and updates

[S6] Scottish Government website. Section 36: Energy Infrastructure: Energy Consents (https://www.gov.scot/policies/energy-infrastructure/energy-consents/)

[S7] Scottish Government site with factsheet for the Carbon Calculator for windfarms on Scottish peatlands – used for windfarm planning applications by industry and for granting consent by Scottish Government and Local Authorities, (https://www.gov.scot/publications/carbon-calculator-for-wind-farms-on-scottish-peatlands-factsheet/)

[S8] Renewables Schemes on the Forestry and Land Scotland National Forests and Land. Shows the 10 over 50 MW sites that were required to use the windfarm tool by regulations in Scotland (https://bit.ly/3tG5O48)

[S9] Key Scottish Government statement on repowering windfarms (https://www.gov.scot/publications/onshore-wind-policy-statement/pages/3/, p. 23-24)

[S10] Calculating potential carbon losses and savings from wind farms on Scottish peatlands Technical Note – Version 2.10.0. Link: https://bit.ly/304txOr

[S11] Scottish Power press release, May 2020 outlines acquisition of 165 MW onshore wind project including repowering of Hagshaw Hill and cites Section 36, Energy Infrastructure: Energy Consents