



UNIVERSITY OF
GLOUCESTERSHIRE

This is a peer-reviewed, post-print (final draft post-refereeing) version of the following published document, This is the peer reviewed version of the following article: Mills, Jane , Reed, Matt , Skaalsveen, Kamilla and Ingram, Julie (2019) The use of Twitter for sustainable soil management knowledge exchange. *Soil Use and Management*, 35 (1). pp. 195-203., which has been published in final form at <https://onlinelibrary.wiley.com/doi/abs/10.1111/sum.12485?af=R> and is licensed under All Rights Reserved license:

Mills, Jane ORCID: 0000-0003-3835-3058, Reed, Matt ORCID: 0000-0003-1105-9625, Skaalsveen, Kamilla and Ingram, Julie ORCID: 0000-0003-0712-4789 (2019) The use of Twitter for sustainable soil management knowledge exchange. *Soil Use and Management*, 35 (1). pp. 195-203. doi:10.1111/sum.12485

Official URL: <https://onlinelibrary.wiley.com/doi/abs/10.1111/sum.12485?af=R>

DOI: <http://dx.doi.org/10.1111/sum.12485>

EPrint URI: <https://eprints.glos.ac.uk/id/eprint/6502>

Disclaimer

The University of Gloucestershire has obtained warranties from all depositors as to their title in the material deposited and as to their right to deposit such material.

The University of Gloucestershire makes no representation or warranties of commercial utility, title, or fitness for a particular purpose or any other warranty, express or implied in respect of any material deposited.

The University of Gloucestershire makes no representation that the use of the materials will not infringe any patent, copyright, trademark or other property or proprietary rights.

The University of Gloucestershire accepts no liability for any infringement of intellectual property rights in any material deposited but will remove such material from public view pending investigation in the event of an allegation of any such infringement.

PLEASE SCROLL DOWN FOR TEXT.

MS. JANE MILLS (Orcid ID : 0000-0003-3835-3058)

DR JULIE INGRAM (Orcid ID : 0000-0003-0712-4789)

Article type : Special Issue Paper

The use of Twitter for knowledge exchange on sustainable soil management

Jane MILLS*, Matt REED, Kamilla SKAALSVEEN and Julie INGRAM

Countryside & Community Research Institute, University of Gloucestershire, UK

***Corresponding Author:** Jane Mills; jmills@glos.ac.uk

Running title: Twitter for sustainable soil management learning

Summary

Encouraging the uptake of sustainable soil management practices often requires on-farm experiential learning and adaptation over a sustained period, rather than the traditional knowledge transfer processes of identifying a problem and implementing a solution. Farmer-to-farmer learning networks are emerging with farmers experimenting and sharing knowledge about these practices amongst themselves. One potential communication

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/sum.12485

This article is protected by copyright. All rights reserved.

channel for such interaction and knowledge sharing is social media and Twitter in particular. A content analysis of a Twitter account for an EU research project, SoilCare, and in-depth qualitative interviews with five farmers using Twitter were used to illustrate the extent and type of farmer-to-farmer knowledge sharing in relation to sustainable soil management practices. Evidence of farmer learning and knowledge sharing on Twitter with respect to these practices was identified. Twitter can capture the immediacy of the field operations and visual impacts in the field. Furthermore, the brief messages channeled through Twitter appeal to time-constrained farmers. The ability for interaction around a particular hashtags in Twitter is developing virtual networks of practice in relation to sustainable soil management and within these networks farmer champions are emerging that are respected by other farmers. Twitter works best for those actively seeking information, rather than passive recipients of new knowledge. Therefore, its use with other forms of face-to-face interaction as part of a blended learning approach is recommended. Twitter also offers a potential space for other actors, such as researchers and advisers, to interact and share knowledge with farmers.

Keywords: sustainable soil management, social media, Twitter, farmer learning, knowledge exchange

Introduction

It is widely recognised that some farming practices within European crop production are reducing soil quality which in turn is affecting productivity (Jones *et al.*, 2012). Currently production levels are maintained by increased use of agricultural inputs and technology that may reduce profitability due to their costs, while also negatively affecting the environment (Rockström *et al.*, 2009). Sustainable soil management (SSM) practices are required that

both improve the quality of the soil and increase productivity. In a European context, such practices might include, crop rotations, cover crops residue management, reduced tillage operations, fertiliser and manure management to restore soil carbon. It is the aim of SoilCare (Soil Care for profitable and sustainable crop production in Europe) (www.soilcare-project.eu), an interdisciplinary research project funded by EU Horizon 2020, to identify and test soil management practices appropriate to particular pedo-climatic and socio-economic conditions that have the potential to optimise soil quality and crop productivity across Europe.

Whilst the potential of these SSM practices to improve soil quality and productivity is recognised amongst the scientific community, their uptake by farmers across Europe has been slow (Lahmar, 2010). There are certain characteristics of SSM practices that we consider below that mean their uptake might not follow traditional innovation adoption processes. Instead, there is an interesting emergence of farmer-to-farmer learning networks with farmers experimenting and sharing knowledge about these practices amongst themselves.

One potential communication media for sharing knowledge and interactive communication process is social media and in particular Twitter (twitter.com), one of the most widely used social media tools. Evidence is emerging of the use of Twitter accounts for communication and learning in other sectors, such as engineering (Palmer, 2016) and the medical and health care sectors (Grajales III *et al.*, 2014), but to date there is limited information on the use of Twitter for learning and knowledge sharing within the agricultural community.

The aim of this paper, therefore, is to use the SoilCare Twitter account, which currently has over 1,200 followers, to explore the extent and type of farmer-to-farmer knowledge sharing in relation to SSM practices. This outcome will be achieved by profiling those who are

following the SoilCare Twitter account, analysing tweets related to particular SSM hashtags and interviewing a select number of farmers following the SoilCare Twitter account to illustrate their social media usage.

Literature Review

Social media and farmer-to-farmer learning

Traditionally, within agricultural extension models, the dissemination of new knowledge was conceptualised as a linear process from a central point to the land manager (Röling, 1992). These traditional extension models assume that innovations (and knowledge) originate in science and are transferred to land managers who adopt them. This ‘knowledge transfer’ approach to advice focuses on knowledge production, communicative intervention and knowledge consumption (measured as behavioural change). More recently, bottom-up ‘human development’ approaches have emerged which are based on the principles of participation, empowerment and ownership of the problem (Röling & Jiggins, 1994). The implication is that, given the right conditions, information, mutual interaction and opportunity, land managers will develop their own appropriate solutions to their problems.

The process is one of experiential learning, rather than passive knowledge utilisation.

Extension or advice based on the linear model is seen as appropriate for the promotion of discrete technologies or seasonal operations, such as sub-soiling. Sustainable soil management, however, is not only about individual technologies but about different ways of thinking about the management of complex and locally-variable systems, sometimes requiring systemic changes. Moreover, the benefits of SSM practices are not immediately apparent and are often only realised in the medium- to long-term. It can take several years for improved soil quality to impact on crop yields and the improvements in soil are not always immediately observable. As a result, help with on-farm experimentation and

This article is protected by copyright. All rights reserved.

adaptation are required over a sustained period, rather than the traditional knowledge transfer processes of identifying a problem and implementing a solution (Darnhofer *et al.*, 2010). A more adaptive approach is required, one of “act, monitor, learn, adapt” (Burton *et al.*, 2007). This process of experiential learning can be enhanced through social interaction and knowledge sharing with others in the same situations.

One potential opportunity to facilitate increased social interaction and learning within the agricultural industry is the use of social media, which globally is increasing rapidly. There were 2.46 billion social media users around the globe in 2017 and this is expected to rise to 3.02 billion by 2021 (Statista, 2018). However, current emphasis is placed on instrumental uses of social media for disseminating information and transferring messages, compared to a more dialogical form of communication which engages users in reflective and problem-solving discussion (Chowdhury & Odame, 2013).

From the literature, it would appear that social media can have a number of functions within the agricultural industry, namely marketing and consumer engagement; lobbying and campaigning; networking and knowledge-sharing and crisis communication (see Table 1).

Increases in the use of social media amongst the agricultural community has been particularly noted in the literature in USA, Canada, Australia and UK (Chowdhury & Odame, 2013; Stanley, 2013). Although to date, social media has largely been used successfully in the agricultural industry for marketing and lobbying, there is greater potential for its use as an interactive, learning and knowledge-sharing global platform (Stanley, 2013).

Some notable examples of knowledge-sharing platforms are starting to emerge, for example, the #Agchat discussion forums, which are weekly moderated Twitter discussions that were initially founded in the United States and now operate in UK (#Agrichat), Australia (#AgChatOZ) and New Zealand (#AgChatNZ). Also, various farmer communities of practice are starting to develop, such as #clubhectare in UK, which started with a group of farmers discussing arable farming related issues on Twitter, who then decided to meet up socially. The group now has 342 members and is growing globally (Stanley, 2013).

Whilst there is evidence of increased use of social media amongst the farming community, there appears to be a reluctance to use it as an outreach platform amongst farm advisers (Newbury *et al.*, 2014; Suchiradipta & Saravanan, 2016). Reasons for this relate to concerns about lack of skills and competency and perceptions about the time required to engage in social media and loss of control over messages posted, related to a sense of responsibility for the messages (Newbury *et al.*, 2014; Suchiradipta & Saravanan, 2016).

Twitter usage in agricultural industry

Different social media platforms (e.g. blogs, Facebook, LinkedIn, Twitter, YouTube) have different functions. This paper focuses on one particular form of social media, Twitter, which has been promoted as a tool for collective learning processes and the co-creation of knowledge (Chowdhury & Odhame, 2014). Twitter is a micro-blogging platform in which users can currently publish messages of up to 140 character and towards the end of 2017 it had 330 million monthly active users globally. The use of Twitter has proliferated with the increase of smartphones. An on-line survey of UK and French farmers in 2014, found that 89 % of respondents owned a smartphone, 84 % used it for farm management, and 72 % used it on a daily basis (Dehnen-Schmutz *et al.*, 2016).

Individual users of Twitter adopt a 'handle' which is distinguished by an @ sign. Users can mention other users by using their handle or take part in wider debates by using an indexing term denoted by the use of a hashtag or #. It is also possible to follow the tweets of particular users. This allows people to organise their interests or activity in Twitter by communities of interest or social networks. The system also allows users to connect to other forms of internet-based media and this is a very common use of Twitter to link to longer or more detailed information. Users can post links to webpages, photographs, videos or audio files, as well as use the Twitter space for their own compositions. With the exception of tweets from protected accounts, all tweets are publically available. Re-tweeting and replying to the tweeted posts indicate expressions of intentional communication. A higher level of retweeting is seen as an indicator of a more active engagement and interaction in the Twitter environment, rather than simple one-way communication (Simply Measured, 2014).

It is this more active engagement and interactive use of Twitter that is the focus of this paper. We wish to explore whether there is potential for Twitter to drive the uptake of SSM by engaging others as well as facilitating discussion among various actors (e.g. farmers, researchers, knowledge brokers, policy makers, entrepreneurs). Does Twitter have the potential for creating a learning environment where there is a knowledge-sharing from experiences of implementing SSM practices?

Method

This paper was based on twin streams of data. Firstly, data were derived from an online analysis of the SoilCare Twitter account. The account was first established in 2016 to support the dissemination activity of the SoilCare project, with almost daily activity targeted at all users interested in soil research. The account gained 1226 followers over 21 months between 11th March 2016 and the 22nd December 2017. Secondly, to provide illustrative

This article is protected by copyright. All rights reserved.

examples of Twitter usage, qualitative interviews were conducted with five farmers who are active Twitter users.

Using Twitonomy and the Ncapture facility of the qualitative analytic software, Nvivo 11, we collected the entire Twitter feed of @SoilCare_eu which allowed us to consider not only who follows the account but their interactions and some of the content of their responses. We initially undertook a profiling of each user in order to ascertain the interests of those following the SoilCare Twitter account. Using Twitonomy we were able to collect the Twitter profile descriptions of each of the 1226 Followers and then manually place them into one of 8 pre-determined user categories based on their profile description. We then focused on analysing the Twitter activity of those describing themselves as farmers. Among these farmers, the number of tweets ranged from 10,397 to 5, suggesting some very active farmers and some less so. We were able to collect data about these farmers' Twitter accounts and in this way were able to follow the networks of interaction and influence around particular hashtags and accounts, looking for incidences of sustained discussion, from the starting point of @SoilCare_eu.

To understand more fully farmers' use of Twitter for supporting SSM we undertook in-depth, qualitative interviews with five farmers who are active in using Twitter to discuss SSM. A semi-structured questionnaire was designed with 24 questions derived from an analysis of the key issues in the literature and structured around two key themes: the reasons for using Twitter and details about the practical use of Twitter. A farmer following the SoilCare Twitter account, who actively discussed SSM issues, was contacted initially via the Direct Message facility on Twitter and a telephone interview arranged. A chain referral sample (snowballing) approach was used to identify further interviewees, by asking farmers for others with whom they interacted about SSM on Twitter. This approach proved an effective

way of gaining access to a population in an efficient way. The interviews lasted between 30 minutes and 1 hour. The interviews were transcribed and a content analysis undertaken to identify key statements that illustrated the farmers' use of Twitter. The data were first coded into broad categories using *a priori* deductive codes, such as 'reasons for use of Twitter' and 'practical use of Twitter'. The second stage of the analysis took an inductive approach to further coding, capturing common themes. All the farmers were from the UK and covered a range of ages, farm type and farm size (Table 2).

These interviews aimed to illustrate Twitter usage for sustainable soil management by farmers actively using Twitter. As only five interviews were conducted, their use is limited to indicative purposes only. Further interviews are recommended for future research that fully explains the underlying processes in farmers' Twitter usage.

As Twitter is in the public domain, some have argued that academic analysis is unproblematic. However, as authors, we contend that few who post on Twitter realise the insights that can be gained from sustained scrutiny and that obtaining informed consent from all participants is impractical (Reed & Keech, 2017). Therefore, in reporting the results we have made anonymous the comments of participants.

Results

Our initial analysis of the 1206 followers of @SoilCare_eu showed that the majority of followers were from the scientific community (24%), and 6% were PhD students (see Table 3). This result is unsurprising given that SoilCare is a scientific research project. Interestingly, 10% of the followers identified themselves as farmers, growers or farm

managers. In comparison, there were fewer followers from the farm advisory services (7%) and there was a particularly small number of followers from the policy community (1%).

Figure 1 shows the majority of the followers in the farmers/growers/farm managers category came from the United Kingdom (64%), with others from USA, Canada, Australia, other European countries, Africa and one from South America.

If we consider the numbers of friends, followers and tweets posted, the farmers stood out as being particularly active on average, posting over a third as many Tweets as other categories. The mean number of tweets by farmers was 3972, the average number of followers was 1451 and the average number of people they were following was 1216 (total sample average: tweets-2547; followers-538; and followed-1073). Therefore, farmers were more active in posting onto Twitter, were more likely to be followed, but only a little more likely to be following others, which made them active and potential influencers. Whilst the paper is focused on the farmer participants in the Twitter feed, it is clear that this was a heterogeneous group, using Twitter for different reasons and pursuing different strategies (Table 3).

Within this group of farmers was a subset who were both particularly active, but also influential. Farmer SF was the most active and had posted over 100,000 tweets. He was followed by over 13,000 people and in turn followed over 10,000 (a followers:following (FF) ratio of 1.26). This suggests an approach to Twitter of high volume postings, and reciprocal following. Farmer Alpha had a distinctive profile. He had posted over 24,000 tweets, had 9500 followers, but he was only following 1795 people, a FF ratio of 5.26, which indicated that other people were listening to him. The tweets of farmers such as Farmer Alpha and

Farmer SF included several hashtags, suggesting that they were coordinating their discussions through indexing terms that they know and control.

In the period November 2017 to February 2018, we collected tweets from the @SoilCare_eu Twitter feed using indexing terms for two SSM practices, 300 were using #covercrops and 394 using #notill. A single tweet can contain several indexing terms so in this way people can participate in several con-current discussions, also this can cross languages with for example Spanish language tweets including an English indexing term. This means that these threads of conversation can cross languages, nations, time zones and bio-physical conditions, gaining participants who contribute a range of media and perspectives.

Figure 2 illustrates a simplified extract of part of a conversation initiated by Farmer Alpha using the #covercrops hashtag, and a photograph of a field that he had ‘crimped’¹ but this had been only partially successful. A discussion emerged over 2 days about the practice, which led to a sharing of practical knowledge and consideration of alternative approaches. In the end the exchange drew in 18 farmers and one CEO of an NGO, of which 15 were based in UK, but three from other countries (USA, Canada and Germany). This seemingly quotidian discussion included photographs, emoticons, videos of machinery in operation and technical details as well as jokes and references to the wider context of the farming sector. Even in this simplified form, the social, technological and symbolic sophistication of the exchanges is evident. Also, it was a highly efficient way of gathering information; within a short exchange, questions about the operation and supply of the equipment were dealt with and

¹ Crimping – use of bladed roller designed to roll, cut and bruise cover crops before drilling.

included an opportunity to see one machine in operation, as well as finding a source of such equipment. As a published discussion it remains visible and available to others searching through the index terms #covercrops.

Whilst this extract provides a useful example of how Twitter can be used for farmer-to-farmer learning, the interviews provided more details to illustrate how Twitter is being used by farmers for knowledge sharing and learning.

Reasons for use of Twitter

All the interviewed farmers were self-taught in the use of Twitter. Two interviewees said that they opened an account after becoming a Nuffield Scholar², as Twitter was promoted there.

An important influence on the use of Twitter was the need to seek information about innovative farming practices, such as Conservation Agriculture, when “looking over the neighbour’s fence” for advice was no longer sufficient. Twitter provided the opportunity to interact with farmers all over the UK, as well as Europe and the wider world.

“...you don't just go to your neighbour farmer, because it is not happening there, but on Twitter you can get hold of people from all around the country, and indeed Europe and America, and Australia with the same practices” (Farmer AB).

The speed of response and convenience of Twitter was also an important factor in its usage:

² A UK scholarship that funds up to 20 individuals a year to research topics of interest in either farming, food, horticulture or rural industries. Scholars can travel anywhere in the world to further their knowledge and understanding of their chosen study topic.

“...I guess it is convenient for me as I have always got my phone on me, and there are odd times when I am being in a tractor or in a vehicle stopped or just walking somewhere and you can really quickly access it” (Farmer W).

Farmer M said he thought Twitter was well suited for farmers as they are not in any direct competition and more likely to collaborate with each other as *“...there is no commercial edge to be had”*.

The impacts on the business were in the realms of providing inspiration and an extra stream of information as well as making the job more interesting. Interaction on Twitter could broaden the farmer’s outlook and generate more questions about their practices:

“...it has given me, as a manager, more of a wider interest in different things instead of just carrying on with what I have always done or what is done locally, from looking over the hedge, now you are looking on a national scale”(Farmer M).

The use of Twitter for networking was important to the farmers, either actively or by happenstance *“...I don’t actively use it for networking, it just happens” (Farmer M)*. The network was mainly other farmers, and often those with the same farming practices, although Farmer AH said that he followed farmers doing different things from himself to prevent being in a ‘bubble’. Researchers working with related subjects often were part of the network, and agronomic information was welcomed as an important contribution to the farmers’ knowledge. They all had a common view that their Twitter networks were purely business related, while other social interaction would be more likely to happen on *Facebook*

or *WhatsApp*. They explained that they would follow someone if they found them interesting at the time and unfollow them as soon as they lost the interest.

Twitter was also seen as a good starting point for getting more information or to discuss new ideas. It is a useful platform to figure out other farmers' past experiences with a certain type of practice: "...you get bullet points through Twitter - it is a gateway" (Farmer M). The farmers said they were interacting and sharing knowledge on Twitter, as well as asking questions. They were mainly influenced by groups of farmers or individuals that they respected, while they were of the impression that they mainly influenced those farmers doing similar things as themselves. However, Farmer AH, Farmer AB, Farmer D and Farmer M acknowledged their potential role as brokers of information (although farmer M said that he does not try to be a disseminator, but that he is sharing and wants opinions back). Farmer AH and Farmer M were taking this role on to get reactions and opinions back from all around the world, while Farmer AB and Farmer D seemed to be more driven by the idea of contributing to sharing knowledge, as people had shared with them in the past.

"...as people have shared information with me in the past, I feel like I should return the favour" (Farmer D).

Practical use of Twitter

The farmers did not use a lot of hashtags, those mentioned were; #notill, #rootsnotiron, #harvest17, #crosslot, #soilhealth, #ironnotroots, #Ilovetofarming and #Farmersfit. Pictures, were largely used and seen as an important form of communication:

“...obviously it is very easy for me to say that I have got a lovely oilseed rape bean companion crop or whatever, but if I actually put a picture of it up there it has much more impact...” (Farmer AB)

Most of the farmers seemed to have good experiences with asking questions on Twitter and thought their network had a lot of knowledge that could benefit them. Four of the farmers used Twitter actively for learning, whereas one farmer said that he only used it to get in contact with people, but may utilize their network for learning in the future. Although Twitter was seen as a good tool for learning, non-virtual interaction was still valued as the better way, especially if you are standing in the field talking about the relevant practice. The farmers predicted more innovative farming as a result of Twitter usage. The reason for this is that it provides inspiration to try new methods from observing practices of others on Twitter.

The farmers had different expectations to the future of learning amongst farmers through the use of Twitter. As they did not think any other social media was better for the purpose of knowledge exchange or more user-friendly, they mostly expected that the Twitter usage would increase with new and younger farmers.

The extent of Twitter usage was described as a bit of an explosion during the last few years. Farmer AB related how at a meeting he attended a few years ago, where the participants were asked how they preferred to receive information, he was the only one in the room raising his hand when asked about Twitter. He expected that the situation would be quite different today.

Discussion

Clearly, our findings indicate that Twitter does have the potential for farmer learning and knowledge sharing with respect to SSM. In fact, Twitter appears to be particularly suited to SSM as it can capture the immediacy of the field operations and visual impacts in the field. Furthermore, the brief messages channeled through Twitter appeal to time-constrained farmers.

It would also appear that the ability for interaction around particular hashtags in Twitter has the potential to develop virtual networks of practice in relation to SSM. These are mainly networks of peers, which is significant in the context of studies of how farmers learn and whom they most trust (Sutherland et al., 2013). Within these networks farmer champions can emerge, that are respected by other farmers. It was felt that observation of practices used by other farmers on Twitter who were respected and trusted as sources of information was likely to provide the inspiration for others to try new practices. Within our analysis, there was evidence of some highly interactive and influential farmers, with a larger number of followers. Currently, it appears that younger and more innovative farmers are interacting on Twitter, but as discussions are publicly available, the information is accessible to all. Also with respect to sharing learning, Twitter allows the process of individual experiential learning and adaptation to be enhanced through social interaction and knowledge sharing with others in the same situations (Darnhofer et al., 2010). Our findings suggest that Twitter can provide a dialogical form of communication, which engages users in practical problem-solving discussion, contrary to Chowdhury & Odame's (2013) findings that amongst Canadian agri-food and rural stakeholders, Twitter usage was for simple message exchange.

One distinct constraint of Twitter for the agriculture community relates to geographical inequalities resulting from poor technology infrastructure in some rural areas of Europe (Bos & Owen; Morris & James). However, with increasing density of smartphone availability and rural bandwidth, Twitter is a technology that will become increasingly accessible to most people without the need for specific training.

Despite these technological constraints, the interviewees reported that Twitter has many advantages, it is available to all and has lower social barriers to participation compared to other forms of social media, it also allows for much wider networking and access to a variety of resources, ranging from photographs through to peer-reviewed research. As reported in the interviews, other platforms such as *Facebook* and *WhatsApp* are used alongside Twitter, but for other purposes, both benefiting from and being disadvantaged by having higher social barriers (Thakur *et al.*, 2017).

Certainly, we can see, even in this relatively small sample of data, indications of the development of virtual communities of practice. The combination of the smartphone, 4G mobile services and Twitter satisfies some of the preconditions for such communities, as identified by Hansen and colleagues, of collaborative tools that enable sharing and co-creation (Hansen *et al.*, 2014). However, in the interviews, the importance of face-to-face interaction was also very clear. Meeting in the field is particularly important for soil which has sensory elements that farmers like to engage with via touch, smell *etc.* that can only be achieved on the ground. This points to the importance of 'blended learning' approaches which combine the on-line with the off-line knowledge exchanges (Cullen *et al.*, 2016).

The complex and sophisticated capabilities of Twitter discussions open opportunities to transcend social and geographical barriers. Our interviews and the number of farmers following @SoilCare_eu indicate that farmers are prepared to access the results of scientific research they find on Twitter. However, the interactions were largely farmer-to-farmer with little evidence in the farmer interviews or Figure 2 of scientists and advisers interacting directly with farmers through Twitter. This suggests that there is the potential for such actors to become more involved in engaging directly with farmers through social media platforms. The range of people following @SoilCare_eu would indicate that there is an opportunity for greater exchange amongst different actors through more active Twitter strategies, particularly if social media is used as an iterative, rather than a passive one-way process (Kaushik *et al.*, 2018; Phillips *et al.*, 2018). Significantly, although we searched in English, hashtag discussions appeared in other languages, indicating new opportunities for exchange and discussion across countries and continents.

Conclusion

Our content analysis of the @SoilCare_eu Twitter account and the analysis of the farmer interviews have clearly identified an existing use of Twitter to share knowledge between farmers about practices related to SSM. We identified examples of knowledge-sharing, using photos, videos and links to scientific publications and reports. The immediacy and convenience of this platform is considered advantageous. Also, farmers are willing to share information in relation to SSM in this space as the topic is not considered commercially competitive. At the moment, Twitter usage by farmers appears concentrated in particular countries, but as the technology becomes increasingly more accessible the Twitter community will grow with opportunities to share knowledge across countries and continents.

Twitter is seen as a useful source of additional information and particularly important for generating new ideas. However, farmer preference is still to share knowledge and learn from others in a face-to-face environment. Consequently, we conclude that there is potential for a more deliberate use of Twitter for combined virtual and non-virtual blended learning approaches in relation to SSM.

Finally, much of the knowledge-sharing activity in relation to SSM on Twitter is taking place between farmers. There is an opportunity for scientists and advisers to engage with the discussions and conversations on SSM and use this space to interact and engage with farmers on the topic.

Acknowledgements

This work was part of SoilCare (Soil care for profitable and sustainable crop production in Europe). Grant Agreement 677407 funded by the European Union's Horizon 2020 research and innovation programme. www.Soilcare-project.eu. 2016-2021. We thank the farmers who kindly agreed to be interviewed for this research.

References

- Bertaux, D. 1981. *Biography and Society: The Life History Approach in the Social Sciences*, Sage Publications, London.
- Bos, E. & Owen, L. 2016. Virtual reconnection: The online spaces of alternative food networks in England. *Journal of rural studies*, **45**, 1-14.
- Burton, R., Dwyer, J., Blackstock, K., Ingram, J., Brown, K., Mills, J., Schwarz, G., Mathews, K. & Slee, B. 2007. Influencing positive environmental behaviour among farmers and landowners-a literature review. *Report to DEFRA. Socio-Economic Research Group, The Macaulay Land Use Research Institute*.
- Chowdhury, A. & Odame, H. H. 2013. Social media for enhancing innovation in agri-food and rural development: current dynamics in Ontario, Canada. *Journal of rural and community development*, **8**.
- Cullen, B., Amos, D. & Padel, S. 2016. Organic Knowledge Network Arable OK-Net Arable-D2. 1 Description of farmer innovation groups. In.
- Darnhofer, I., Bellon, S., Dedieu, B. & Milestad, R. 2010. Adaptiveness to enhance the sustainability of farming systems. A review. *Agronomy for Sustainable Development*, **30**, 545-555.
- Dehnen-Schmutz, K., Foster, G. L., Owen, L. & Persello, S. 2016. Exploring the role of smartphone technology for citizen science in agriculture. *Agronomy for Sustainable Development*, **36**, 25.
- Grajales III, F. J., Sheps, S., Ho, K., Novak-Lauscher, H. & Eysenbach, G. 2014. Social media: a review and tutorial of applications in medicine and health care. *Journal of medical Internet research*, **16**.
- Hansen, J. P., Jespersen, L. M., Jensen, A. L., Holst, K., Mathiesen, C., Brunori, G., Halberg, N. & Rasmussen, I. A. 2014. ICT and social media as drivers of multi-actor innovation in agriculture. *CIGR Proceedings*, **1**.
- Jones, A., Panagos, P., Barcelo, S., Bouraoui, F., Bosco, C., Dewitte, O., Gardi, C., Erhard, M., Hervás, J., Hiederer, R. & Jeffery, S. 2012. The state of soil in Europe (SOER). JRC reference reports. Report 25186.
- Kaushik, P., Chowdhury, A., Hambly Odame, H. & van Paassen, A. 2018. Social Media for Enhancing Stakeholders' Innovation Networks in Ontario, Canada. *Journal of Agricultural & Food Information*, **1-23**.
- Lahmar, R. 2010. Adoption of conservation agriculture in Europe: lessons of the KASSA project. *Land use policy*, **27**, 4-10.
- Materia, V. C., Giarè, F. & Klerkx, L. 2015. Increasing Knowledge Flows between the Agricultural Research and Advisory System in Italy: Combining Virtual and Non-virtual Interaction in Communities of Practice. *The Journal of Agricultural Education and Extension*, **21**, 203-218.
- Morris, W. & James, P. 2017. Social media, an entrepreneurial opportunity for agriculture-based enterprises. *Journal of Small Business and Enterprise Development*, **24**, 1028-1045.
- Newbury, E., Humphreys, L. & Fuess, L. 2014. Over the Hurdles: Barriers to Social Media Use in Extension Offices. *Journal of Extension*, **52**, n5.
- Palmer, S. 2016. The representation of engineering education as a social media topic on Twitter. In: *PAEE/ALE 2016: Proceedings of the 8th International Symposium on Project Approaches in Engineering Education and 14th Active Learning in Engineering Education Combined Conference and Workshop*. Project Approaches in Engineering Education Association, pp. 37-44.
- Phillips, T., Klerkx, L. & McEntee, M. 2018. An Investigation of Social Media's Roles in Knowledge Exchange by Farmers. In: *13th European IFSA Symposium, 1-5 July 2018*. Chania (Greece).
- Reed, M. & Keech, D. 2017. Making the city smart from the grassroots up: The sustainable food networks of Bristol. *City, Culture and Society*, **in press**.

- Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E., Lenton, T., Scheffer, M., Folke, C. & Schellnhuber, H. J. 2009. Planetary boundaries: exploring the safe operating space for humanity. *Ecology and society*, **14**.
- Röling, N. 1992. The emergence of knowledge systems thinking: a changing perception of relationships among innovation, knowledge process and configuration. *Knowledge and policy*, *5*, 42-64.
- Röling, N. & Jiggins, J. 1994. Policy paradigm for sustainable farming. *European Journal of Agricultural Education and Extension*, **1**, 23-43.
- Simply Measured 2014. The Complete Guide to Twitter Analytics. In: *How to analyze the metrics that matter*.
- Stanley, S. 2013. Harnessing social media in agriculture. *A Report for the New Zealand Nuffield Farming Scholarship Trust NZ Nuffield Scholar*.
- Statista 2018. Number of social media users worldwide from 2010 to 2021. <https://www.statista.com/statistics/278414/number-of-worldwide-social-network-users/>.
- Suchiradipita, B. & Saravanan, R. 2016. Social media: Shaping the future of agricultural extension and advisory services. *GFRAS interest group on ICT4RAS discussion paper, GFRAS: Lindau, Switzerland*, *9*.
- Sutherland, L.-A., Mills, J., Ingram, J., Burton, R. J., Dwyer, J. & Blackstock, K. 2013. Considering the source: Commercialisation and trust in agri-environmental information and advisory services in England. *Journal of Environmental Management*, **118**, 96-105.
- Thakur, D., Chander, M. & Sinha, S. 2017. Whatsapp for farmers: Enhancing the scope and coverage of traditional agricultural extension. *International Journal of Science, Environment*, **6**, 2190-2201.

TABLES

TABLE 1 Social media functions in the agricultural industry

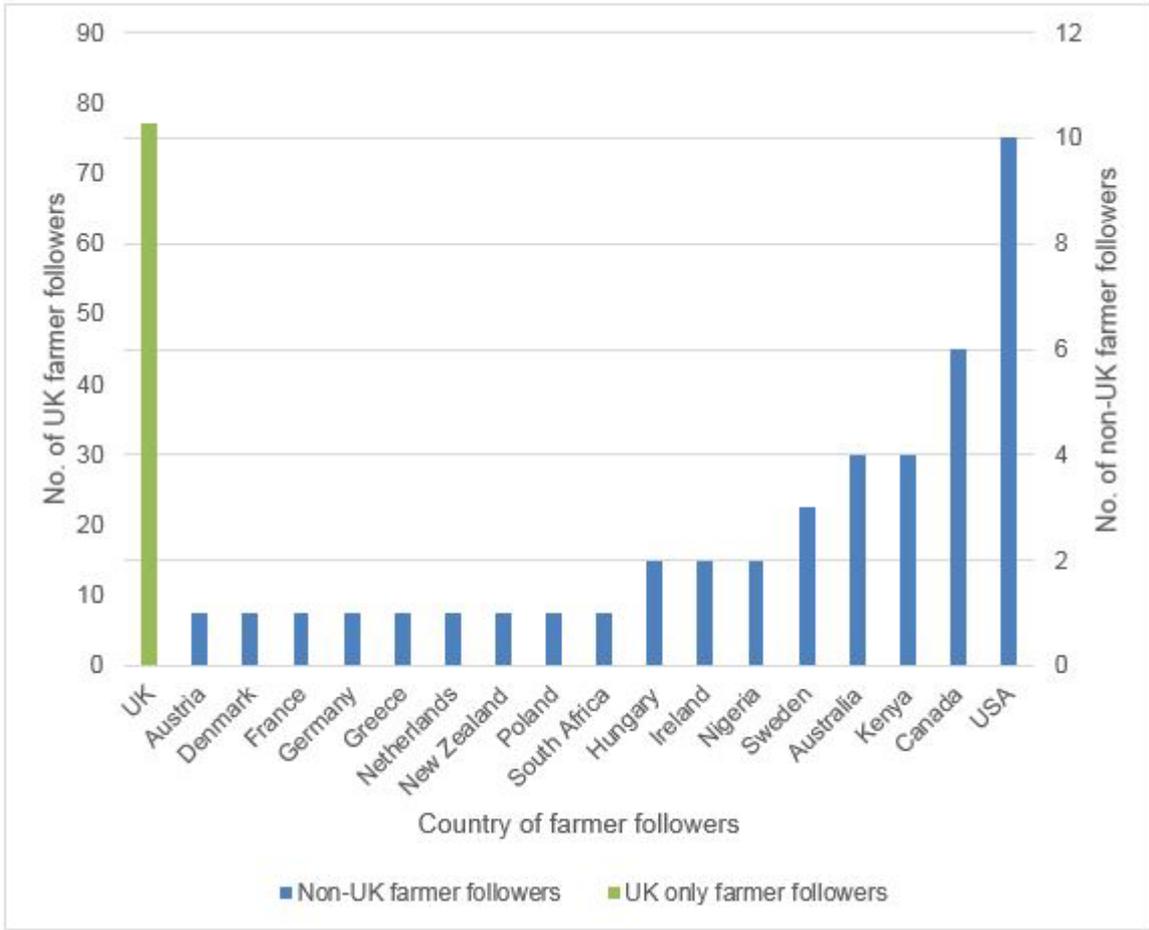
Social media functions	Examples of usage	References
Marketing and consumer engagement	<ul style="list-style-type: none">• Increase product/brand awareness• Enabling farms to connect with customers• Building trust with customers• Increasing traceability	(Chowdhury & Odame, 2013; Stanley, 2013; Bos & Owen, 2016; Morris & James, 2017; Kaushik et al., 2018)
Lobbying and campaigning	<ul style="list-style-type: none">• bringing together a collective voice to campaign for change• UK #sosdairy campaign in which Twitter was used to raise awareness of the problems of the dairy industry	(Stanley, 2013)
Networking and knowledge-sharing (farmer-to-farmer)	<ul style="list-style-type: none">• interaction with other farmers, nationally and globally.• Joint learning and knowledge co-creation• #AgChat discussion forums	(Stanley, 2013; Materia <i>et al.</i> , 2015; Phillips et al., 2018)
Crisis communication	<ul style="list-style-type: none">• a channel for communicating problems or issues within the agricultural industry.	(Stanley, 2013)

TABLE 2 Details of farmers interviewed

Farmer	Age	Farm type	Farm size
AH	38	Arable	330
AB	47	Mixed	450
D	35	Arable	900
M	48	Arable	800
W	51	Mixed	1250

TABLE 3 User categorization and frequencies of followers of @SoilCare_eu.

Category	No.	% of total
Scientist/Researcher	286	24
PhD Student	69	6
Science project/programme	52	4
Commercial business/product/service	181	15
Farmer adviser/agronomist/trainer	89	7
NGO/campaigner/forum/commentator/media	126	10
Farmer/grower/farm manager/contractor	123	10
Policy-maker	9	1
Uncategorised	271	22
Total	1206	99



Crimping #covercrops 3 weeks on. Dying where the tractor wheels went but not everywhere



Replying to [redacted] 24 Nov 2017
Does the crimper need to exert the same weight per sq inch as the tractor tyres?
1 1

[redacted] 24 Nov 2017
Certainly needs to be greater weight or more impact somehow
2 1

[redacted] 24 Nov 2017
Can you ballast the barrel with water?
1 1

[redacted] 24 Nov 2017
Already was ballasted weight at 310kg/m
1 1

[redacted] 24 Nov 2017
We run our Crimper at about 400-500kg/m

Replying to [redacted]
It would be interesting to see if it is more effective if done during or just before frosty weather.
1 1

[redacted] 24 Nov 2017
I have no doubt it would be
1 1

[redacted] 24 Nov 2017
Will have a go with the Cambridge rollers
1 2

[redacted] 25 Nov 2017
Replying to [redacted]
I made a crimper roller vid when I visited Stefano Canali of @CREA_Ricerca in Italy.
They sharpen the crimper bars and fill the whole thing with water

In Line Roller Crimper (ILRC) Italy 2014
Reducing tillage while adopting less invasive ways of controlling weeds and conserving soil and soil biota. This Italian research project on roller crimper d...
youtube.com

[redacted] 25 Nov 2017
Not sure about travelling at 2kph for the 2nd pass, interesting idea though
1 1 3

[redacted] 24 Nov 2017
Replying to [redacted]
Yup.
1 1

[redacted] 24 Nov 2017
Maybe the crimper needs just a bit of positive drive. 2 or 3% faster the ground speed. Similar to the tractor tires...maybe??
1 2

[redacted] 24 Nov 2017
Or a double crimper, first roller crimps, and second just a conventional roller.

Have you seen the Dalbo one Jake?
Unfortunately video only shows maize stubble:
m.facebook.com/story.php?stor...
1 1

[redacted] 25 Nov 2017
Replying to [redacted]
Front and rear mounted crimper or positive drive? What's your estimated cost /ha and fuel use vs spraying #glyphosateisvital
1 1

[redacted] 24 Nov 2017
Replying to [redacted]
If the wheel slip/friction on the plants produces the result then a machine designed to do the same but wider should sort problem IYSWIM
1 1

[redacted] 24 Nov 2017
Replying to [redacted]
Definitely an area which needs more work.
1 1

[redacted] 24 Nov 2017
Replying to [redacted]
:-|
1 1

[redacted] 24 Nov 2017
Replying to [redacted]
Tractor wheels are the best crimpers. However you have to wonder about the compaction underneath, wonder if something like the terracompressor might be a good idea for crimping steketee.com/category/Grond...
1 1

[redacted] 24 Nov 2017
It's in the Double crimpl Not just the tires
1 1

[redacted] 24 Nov 2017
Replying to [redacted]
Cambridge rolls next time?