

Scotland's Rural College

Communicating soil carbon science to farmers: incorporating credibility, salience and legitimacy

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1 **Communicating soil carbon science to farmers: incorporating credibility, salience and**
2 **legitimacy**

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41
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45
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47 particular the case study partners and stakeholders.

51 **Abstract**

52

53 A key narrative within climate change science is that conserving and improving soil carbon through
54 agricultural practices can contribute to agricultural productivity and is a promising option for
55 mitigating carbon loss through sequestration. This paper examines the potential disconnect between
56 science and practice in the context of communicating information about soil carbon management. It
57 focuses on the information producing process and on stakeholder (adviser, farmer representative,
58 policy maker etc) assessment of the attributes credibility, salience and legitimacy. In doing this it
59 draws on results from consultations with stakeholders in the SmartSOIL project which aimed to
60 provide decision support guidelines about practices that optimise carbon mitigation and crop
61 productivity. An iterative methodology, used to engage stakeholders in developing, testing and
62 validating a range of decision support guidelines in six case study regions across Europe, is described.
63 This process enhanced legitimacy and revealed the importance, and the different dimensions, of
64 stakeholder views on credibility and salience. The results also highlight the complexities and
65 contested nature of managing soil carbon. Some insights are gained into how to achieve more
66 effective communication about soil carbon management, including the need to provide
67 opportunities in projects and research programmes for dialogue to engender better understanding
68 between science and practice.

69

70 **Keywords:** soil carbon, soil organic carbon, farmers, advisers, agricultural practices, mitigation,
71 credibility, salience, legitimacy,

72

73

74

75 **1. Introduction**

76

77 Debates in rural contexts about the authoritative status and legitimacy accorded to scientific
78 knowledge have been played out in contested arenas of conservation agriculture, diffuse pollution,
79 GMOs, animal disease, pollinators and agri-environmental management (Blackstock et al., 2010, Fish
80 et al., 2003, Maye et al., 2014, Maderson and Wynne-Jones, 2016, Sumberg and Thompson, 2012).
81 More widely, recognition of science's institutionalised power and its denial of the legitimacy of other
82 knowledges has led to a more democratic model of science and society (Wynne, 1996, Whatmore,
83 2009). At the same time a growing appreciation of the complexity of social-ecological systems has
84 prompted calls for a more appropriate science that "will be based on the assumptions of
85 unpredictability, incomplete control, and a plurality of legitimate perspectives" (Funtowicz and
86 Ravetz, 1995 p1). A redefined position of scientific knowledge is also proposed for contributing to
87 the negotiation processes in the context of competing claims on natural resources (Giller et al.,
88 2008). This paper is situated against this theoretical backdrop. It examines the challenges of
89 communicating information about the complex and uncertain science behind soil carbon
90 management and draws on the notions of credibility, salience and legitimacy elaborated in the
91 Science and Technology literature (Cash et al., 2002).

92

93 Conserving and improving soil carbon through agricultural land management provides an important
94 opportunity to address the major global challenges of rapid climate change, degradation of soil and
95 water quality and urgent and growing demand for food (Banwart et al., 2014). Soil organic carbon
96 (SOC) supports essential soil functions, prominent among these is the considerable potential for land
97 management strategies for mitigating carbon loss (Desjardins et al., 2005). A number of
98 'climate-smart' arable land management practices, such as cover crops, crop residues and reduced
99 tillage, have shown potential for carbon sequestration by protecting, maintaining and increasing SOC

100 stocks (Lal, 2003, Smith, 2004, Smith, 2012, Paustian et al., 2016). Many of these practices are also
101 considered to improve soil productivity and profitability of farming systems (Lal, 2006). Thus soil can
102 be managed positively to enhance the multiple benefits that SOC provides (Kahiluoto et al., 2014).
103 As stated by OECD (2015 p.1) “soil organic matter, essentially made of carbon, is not only one of the
104 determining factors of agricultural productivity, and a powerful support to crop resilience and
105 adaptation to climate change, but also a promising option to sequester atmospheric CO₂ captured
106 by photosynthesis”.

107
108 These are the key narratives associated with soil carbon, they underpin international scientific and
109 political interests in carbon sequestration, articulated for example in IPCC reports (Smith, 2012,
110 Smith et al., 2007b), are central to initiatives such as FAO’s Climate Smart Agriculture and France’s “4
111 per 1000” proposal endorsed by the COP 21 Steering Committee in 2015 (OECD, 2015), and are the
112 basis of voluntary and market based measures (Rocheouste et al., 2015, Dumbrell et al., 2016). This
113 framing can be characterised as techno-scientific, based as it is on the underlying assumption that
114 problems are of a technical nature and can be solved with agronomic interventions supported by
115 scientific evidence (Feola et al., 2015). Understanding and removing barriers and increasing the
116 acceptance of soil management using voluntary, compliance and economic measures is seen as a
117 core strategy (Paustian et al., 2016). Accordingly it is assumed that the potential for agricultural
118 practices to sequester carbon and achieve the multiple benefits described can be realised if land
119 managers are persuaded to change practice, and that information plays a central role in this process.

120
121 Whilst this behavioural model which assumes an ‘information deficit’ is widely critiqued (Fleming
122 and Vanclay, 2011, Moser, 2010), the nature and the processes involved in communicating
123 information across the science-practice interface remain of interest. As scholars have argued the
124 quality of the linkage between knowledge and action strongly influences the acceptance of new
125 practices (Vogel et al., 2007). This has been demonstrated extensively in agricultural research
126 projects which endeavour to bridge the so-called divide between scientific or technical solutions and
127 implementation in the field (Carberry et al., 2002, McCown, 2001, Millar and Curtis, 1999). The
128 process of knowledge development influences the substance of the knowledge developed
129 (Jacobson, 2007, McNie, 2007, Pielke Jr, 2007) as such the need to pay attention to internal and
130 external scientific processes and the quality of evidence produced has been highlighted (Van der
131 Sluijs et al., 2008). The requirement for greater sensitivity to farmers’ understandings of scientific
132 knowledge when exploring management responses particularly for complex and contested issues
133 has also been identified (Holloway, 1999).

134
135 The nature of the linkage is pertinent to the context of climate mitigation and adaptation which is
136 difficult to communicate beyond the scientific community, due to its inherent uncertainty and
137 complexity (Hammill and Tanner, 2011, Moser, 2010, Shackley and Wynne, 1996). This is significant
138 given that managing carbon sequestration is a new and technically complex topic, and according to
139 Dilling and Failey (2013) lacks sufficient supportive information for land managers.

140
141 Communicating effectively about soil carbon management presents some particular challenges.
142 Many of the claims and promotional messages are centred on the scientific characterisation of the
143 potential of practices to enhance carbon sequestration (Dilling and Failey, 2013). This can be
144 problematic since soil carbon dynamics are associated with scientific uncertainty and debate
145 concerning not only the effectiveness of practices in enhancing soil carbon but also in the role of soil
146 carbon in mitigation (Powlson et al., 2011, Mackey et al., 2013, Stockmann et al., 2013, Sommer and
147 Bossio, 2014, Söderström et al., 2014, Bradford et al., 2016). Furthermore, the interest in soil carbon
148 is perceived to be driven by a political climate change agenda and not always relevant to farmer

149 interests, priorities or aligned to their beliefs (Arbuckle et al., 2014, Wilke and Morton, 2015,
150 Sumberg et al., 2013).

151
152 All these issues create problems with respect to scientific information being perceived as credible,
153 relevant and considerate of everyday lives and priorities of the farming community. They also
154 highlight that, in order to support land managers' information needs concerning soil carbon
155 management, researchers must become more attuned to the process of producing information as
156 well as the ultimate decision context in which information might be used (Dilling and Failey, 2013).

157
158 With this in mind this paper seeks to examine the potential disconnect between science and practice
159 in the context of communicating information about soil carbon management. Specifically, it focuses
160 on the information producing process and on stakeholder assessment of the attributes *credibility*,
161 *salience and legitimacy*, drawing on results from consultations with representatives from the
162 farming community in the SmartSOIL project. This interdisciplinary project aimed to provide
163 scientifically grounded decision support to a range of beneficiaries about practices that optimise
164 carbon mitigation and crop productivity.

165 166 **2. Conceptualisation –credibility, salience and legitimacy**

167 168 **2.1 Farmer behaviour and communication**

169 Farmers are the group on which the tasks of climate change adaptation and mitigation in agriculture
170 will mainly fall (Berry et al., 2006). As the main agents undertaking these tasks their behaviour
171 influences how and with what success scientifically derived programmes and measures are realised
172 on the ground (Feola et al., 2015). Many studies taking a techno-scientific view have focused on
173 technological, informational, educational, political and attitudinal barriers to implementing
174 adaptation and mitigation practices on the farm (Smith et al., 2007a, Feliciano et al., 2014, Arbuckle
175 et al., 2014, Cook and Ma, 2014, Burbi et al., 2013, Dumbrell et al., 2016). This follows a long
176 tradition of behavioural studies in rural contexts in which factors explaining non-adoption of
177 agronomic practices, innovations and agri-environmental schemes (AES) are evaluated (Feder and
178 Umali, 1993, Knowler and Bradshaw, 2007, Siebert et al., 2006, Prokopy et al., 2008). In response to
179 criticisms that such approaches do not accommodate farmers' diverse rationalities, there has been a
180 shift towards understanding and influencing behaviour in wider terms of socio-cultural influences,
181 identity and social embeddedness and social principles (Feola et al., 2015, Burton, 2004, Vanclay,
182 2004). Accordingly Fleming and Vanclay (2011 p16) call for social understanding of climate change
183 asserting that "there is no such thing as a barrier to change, only legitimate reasons not to change".
184 Likewise Moran et al. (2013) argue that mitigation win-win messages constructed to persuade
185 farmers to change practices oversimplify and neglect socio-cultural aspects of farmer behaviour. In
186 line with this, prominence is increasingly given both in rural and climate mitigation and adaptation
187 contexts to identifying these legitimate reasons by putting more effort into understanding the
188 complexity of farmer decision contexts, as well as to making the process of knowledge production
189 and exchange more effective (McNie, 2007, Hegger et al., 2012, Raymond et al., 2010).

190 191 **2.2 The science-practice boundaries**

192 In the agricultural setting, the tensions at the interface between science and practice have been the
193 focus of much scholastic work, with attention given to science-farmer relations, specifically the
194 nature of the knowledge they hold, the processes involved in the production and exchange of this
195 knowledge, and the conflict and alignment over the validity and relevance of knowledge constructed
196 in different contexts (Eshuis and Stuiver, 2005). Scientist and farmer communities are characterised
197 by different: epistemologies, ways of framing problems, perspectives informed by values, interests,

198 context, lifeworlds, and experiences (Tsouvalis et al., 2000, Ramisch, 2014, Raedeke and Rikoon,
199 1997, Turnbull, 1993). Specifically in relation to soil management, differing aims, methods and
200 context of work have been identified in the two communities (Ingram et al., 2010). The notion of
201 boundaries has been used to conceptualise the interface between these communities or domains
202 and to reveal their epistemic divides (Wenger, 1999, Long, 2001, Carlile, 2004, O'Kane et al., 2008).

203

204 The Science and Technology literature explores how such boundaries at the science-policy interface
205 between communities of experts and decision makers can be understood and managed (Jasanoff,
206 1987). According to Cash et al. (2003 p.8086), there is a “prevalence of different norms and
207 expectations in the two communities [experts and decision makers] regarding such crucial concepts
208 as what constitutes reliable evidence, convincing argument, procedural fairness, and appropriate
209 characterization of uncertainty”. Based on evaluations of scientific advice and environmental
210 assessments, they assert that scientific information is likely to be more effective in influencing the
211 social responses if it is perceived by relevant stakeholders to be, not only credible, but also salient
212 and legitimate. They suggest that actors on different sides of the science-policy boundary perceive
213 and value the attributes of credibility, salience and legitimacy differently and this makes boundary
214 crossing difficult.

215

216 This body of work is pertinent to understanding the quality of linkage between scientific and farming
217 communities with respect to managing soil carbon. Particularly as scientists are being called upon to
218 translate scientific knowledge into practical tools for land managers on, for example, soil function
219 (Doran, 2002), and as farmers and land managers are increasingly targeted by scientists to
220 collaborate in research and to develop these tools (Oliver et al., 2012, de Bruyn and Abbey, 2003).

221

222 **2.3 Credibility**

223 Credible information is perceived by the users to be accurate, valid, and of high quality. It relates to
224 the nature of the knowledge and methods of its production and perceived validity (Cash et al.,
225 2003). In scientific arenas it refers to the scientific plausibility of the technical evidence and
226 arguments. Status has always been accorded to scientific knowledge, by virtue of its rigour, systemic
227 approach and rationality. However credibility can be interpreted differently in different domains and
228 as such is disputed across boundaries, where there can be conflict, imposition, negotiation, strategic
229 adjustment and compromise over resources and knowledge, particularly concerning what is valid
230 and true knowledge, and what is not. Furthermore, when science enters the social arena of the land
231 manager, knowledge can become contested and negotiated (Long, 2001, Giller et al., 2008).

232

233 Credibility has long been known to influence how farmers receive and use information, for example,
234 in studies of acceptance of scientific decision support tools (Carberry et al., 2002), and in providing
235 agronomic and agri-environmental advice (Sutherland et al., 2013, Mills et al., 2016, Ingram, 2008).
236 In such cases farmers’ experiences of the efficacy of particular scientifically derived advice and
237 prescriptions do not accord with their own knowledge and observations (Riley, 2008). This can be
238 compounded by conflicting information (Vanclay and Lawrence, 1994). Credibility, in the sense of
239 believability, is evaluated simultaneously through multiple dimensions, including trustworthiness
240 and expertise; although trust often refers to the source of information (people and social
241 institutions) others argue that it is a perceived quality, it does not reside in people, objects or a piece
242 of information (Tseng and Fogg, 1999)

243

244 In communicating the impacts and benefits of climate change adaptation and mitigation to farmers,
245 credibility is influenced by limited scientific evidence and uncertainty (Hammill and Tanner, 2011,
246 Harvey et al., 2014). Here according to Moser (2010 p35) uncertainty can stem from the lack of data,

247 lack of adequate theoretical understanding of environmental system interactions and “the
248 unavoidable inadequacy of representing nature’s complexity in models”. Specifically for soil carbon
249 there are indications that scientifically validated information about sequestration is important to
250 public land managers in USA who look for ‘reliable’, ‘unbiased’, and ‘the best available science’ to
251 help them make decisions about changing practice (Dilling and Failey, 2013). However, the
252 complexity and the contested nature of the soil carbon science suggest that this scientific authority
253 might not be fully available to support recommendations on effective practices for storing SOC.
254

255 Uncertainties exist because the carbon sequestration benefits of different practices depend on
256 multiple variables: soil texture, soil taxonomy, climate, management and many other local factors.
257 Furthermore, as SOC responds slowly to changes in agricultural management, most SOC changes
258 require many years to be detectable by present analytical methods, and can only be reliably
259 measured in long-term experiments (Smith, 2012, Smith et al., 2005, Desjardins et al., 2005). Also
260 the relationship between specific practices, soil carbon and yield has not yet been fully established
261 because SOC derived effects are confounded with those of soil management (Schjønning et al.,
262 2009), and other non-carbon related benefits, such as enhanced soil moisture. The scientific
263 ambiguity about the effect of reduced tillage (Baker et al., 2007), no-till (Powlson et al., 2014) and
264 conservation agriculture (Andersson and D’Souza, 2014) on SOC and yield, demonstrates that the
265 impacts, the synergies, co-benefits (and trade-offs) of certain practices are still to be clarified
266 (Henriksen and Hussey, 2011). Although similar difficulties have been experienced with extrapolating
267 science to predict responses for agricultural systems in other contexts such as water quality and
268 environmental conservation, reducing SOC science to credible messages for land managers is
269 particularly challenging, not least because of the lack of immediacy in measurable impacts.
270

271 **2.4 Salience**

272 The importance of compatibility or ‘goodness of fit’ of innovations or measures in making them
273 more acceptable to farmers is well established (Pannell et al., 2006, Wilson and Hart, 2001). Salience
274 is a related concept but in the science-policy interface context refers specifically to how relevant
275 information is to the needs of the decision maker. Actors can be expected to have different
276 knowledge interests, so their criteria for what constitutes relevant knowledge differs (Hegger et al.,
277 2012, Cash et al., 2002). Information that is timely and informs decision makers about problems that
278 are on their agendas has high salience. This has long been recognised in different models and
279 approaches to agricultural extension (Black, 2000, Rogers, 2010). In relation to soil carbon, the
280 credibility challenges referred to above are played out in a wider setting of complex decision making
281 for SOC management, where there are a range of barriers and opportunities, transaction costs and
282 economic trade-offs to consider which can constrain the potential to enhance carbon sequestration
283 (Dumbrell et al., 2016). These conflicting priorities have implications for producing information from
284 science that is salient to users. Dumbrell et al. (2016) recognised this in their analysis of adoption of
285 carbon farming in Australia where they identified the importance of communicating the co-benefits
286 and the synergies of carbon farming practices with existing farming practices. In other contexts such as
287 diffuse pollution researchers and policy makers have created win-win narratives to persuade land
288 managers of the economic co-benefits of changing practices (McGonigle et al., 2012).
289

290 **2.5 Legitimacy**

291 Legitimacy refers to the extent to which knowledge production has been respectful of the divergent
292 values and beliefs of stakeholders, unbiased in its conduct and fair in its treatment of opposing views
293 and interests (Hegger et al., 2012, Cash et al., 2002). The need for processes to accommodate
294 stakeholders’ views, knowledge and priorities is recognised in agricultural research, as it is in
295 community management settings where the democratic ideal of stakeholder participation is well
296 established (Leeuwis and van den Ban, 2004). This is in part due to disengagement from scientific
297 explanations of issues and problems because of the imposition of prescriptive and reductive models

298 which do not meet peoples everyday experiences (Wynne, 1996). This resistance together with a
299 general challenge to scientific superiority has favoured approaches based on the principles of
300 consultation, empowerment and ownership of the problem (Lee and Roth, 2006). These emphasise
301 inclusiveness, in which individuals have a legitimate right to influence processes that have a direct
302 bearing on them. A range of concepts and research techniques are employed to help scientists elicit
303 and respect land manager views and knowledge. These include different degrees of participation
304 and stakeholder engagement, and enable some co-production of knowledge (Millar and Curtis, 1999,
305 Carr and Wilkinson, 2005, Pohl et al., 2010, de Bruyn and Abbey, 2003). In the context of climate
306 change, the importance of iterativity and of creating a dialogue between those producing and those
307 using information, often through a brokerage organisation, have also been recognised, particularly
308 given the complexity of the subject matter (Dilling and Lemos, 2011).

309
310 Being legitimate also means that the information is perceived to be free from political persuasion or
311 bias. Specifically Sumberg et al. (2013) point out scientific interest in soil carbon management for
312 mitigation cannot be considered neutral, and for this reason this new narrative is subject to
313 contestation. In this respect, there is concern that where political interests drive certain agendas,
314 they do not always reflect the interests of the land managers. This is apparent in the range of land
315 manager beliefs and attitudes about the evidence and perceived relevance of predicted climate
316 change impacts (Arbuckle et al., 2014, Prokopy et al., 2015, Fleming and Vanclay, 2011).

317
318 The significance of credibility, salience and legitimacy to producing and communicating information
319 about soil carbon management from science to practice is clear. This paper aims therefore to situate
320 analysis of a consultative process in the SmartSOIL project within this framework, specifically
321 exploring the farming community stakeholder perceptions of these three attributes. Overall it aims
322 to use these insights to inform more effective communication about soil carbon management from
323 science to practice.

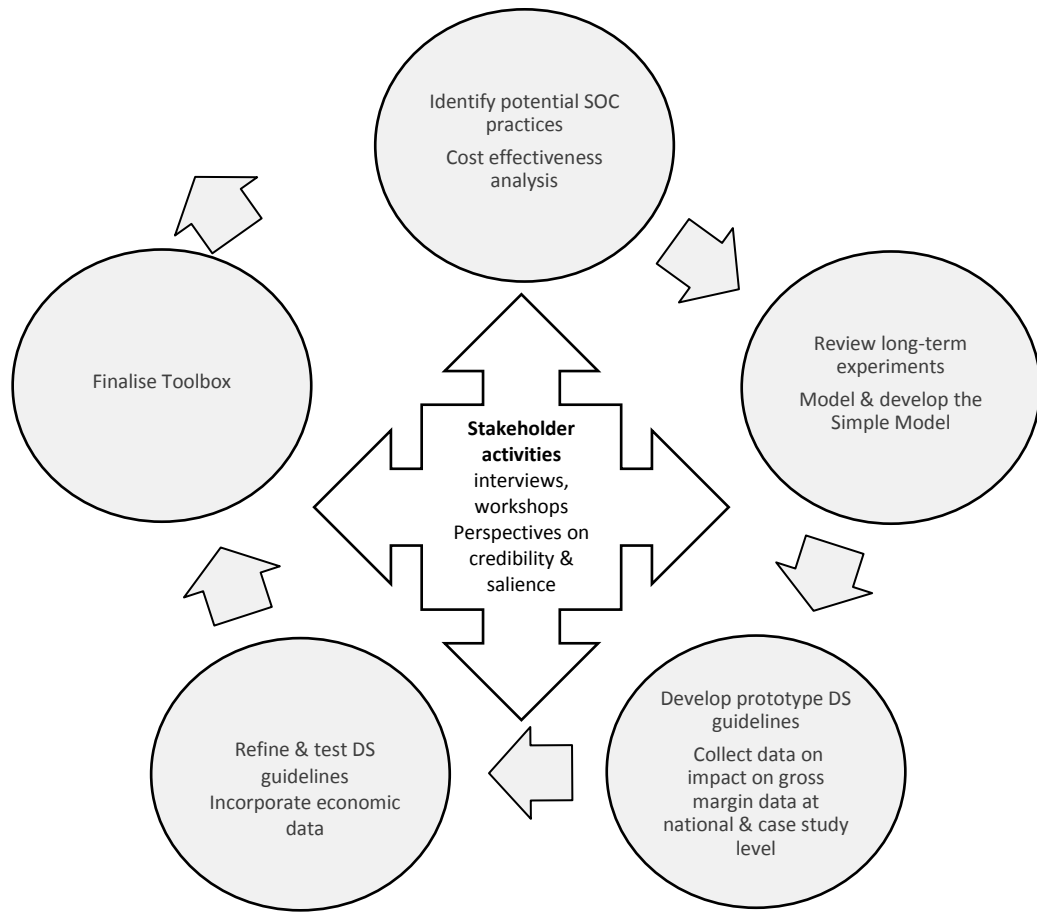
324 325 **3. Context and methodology**

326
327 The project sought to provide scientifically grounded recommendations and information to the
328 farming community about soil carbon management. It developed an interdisciplinary approach,
329 combining scientific insights and understanding of the farming socio-economic context, and had
330 two overall aims:

- 331 • To identify agronomic practices (called here SOC practices) in arable and mixed farming
332 systems that result in an optimised balance between crop productivity and soil carbon
333 sequestration.
- 334 • To develop and deliver decision support guidelines for different European soils and
335 categories of beneficiaries (farmers, farm advisory services, and policy makers).

336
337
338

339 Figure 1. The project's iterative methodology
340



341 Five sets of SOC practices (sharing similar principles) were identified as having the potential to
342 increase soil carbon stocks and optimise productivity: cover (and catch) crops, crop rotations,
343 residue management, conservation agriculture, and manure management. These were selected by
344 drawing on an extensive review of research, project experimentation and project partner expertise
345 (Wösten and Kuikman, 2014). The project used meta-analyses of data from European LTEs with a
346 view to modelling and predicting the impact of these different practices on SOC and yield. This
347 modelling was the basis of a 'Simple Model' (which aimed to predict the effects of crop management
348 on developments in soil carbon and resulting effects on crop yield potential and response to
349 nitrogen fertilization) which was used to develop a computer based decision support tool (DST)
350 (Naumann et al., 2015). Cost effectiveness analysis was also conducted for these practices in
351 different contexts (Sánchez et al., 2016, McVittie, 2014).

352
353 Understanding the perspectives and the information needs of the farming community, as well as
354 barriers and incentives to implementing the SOC practices, was an integral part of this four year
355 project, as was developing, testing and validating a range of decision support guidelines. This was
356 achieved through stakeholder engagement in six case study regions in: Denmark, Hungary, Italy,
357 Poland, Scotland and Spain using a series of interviews and participatory workshops throughout the
358 project. This paper focuses on the findings from these activities.

359
360 Thus, although not explicitly recognised at its inception, the project was conceived on the basis that:
361 authoritative scientific analysis could provide *credible* information on practices that store SOC; that
362 an emphasis on optimisation of crop productivity as well as carbon mitigation (with cost
363 effectiveness a key consideration) can provide *salient* information to the farming community; and
364 that a process of iterative stakeholder consultation throughout the project enhances the *legitimacy*
365 of the information produced.

366
367 Case study regions (Table 1) were selected to represent different bio-geographical (farming systems,
368 soil type, SOC content, risk of soil carbon loss) and socio-economic contexts across Europe.
369 Stakeholders in each case study included: agricultural advisers (from public extension and
370 commercial services), farmer representative bodies (from agricultural chambers etc) and some
371 leading farmers, research practitioners and policy makers (different levels of officials and decision
372 makers with an interest in soil or climate). These categories are loosely defined as in practice they
373 are blurred with some actors playing new hybrid intermediary roles. Project case study partners,
374 themselves linked to agronomy and advisory institutions, used their professional networks and
375 existing relationships to identify and purposely select a range of stakeholders from the categories
376 listed above. These stakeholders did not have any particular expertise or prior exposure to soil
377 carbon initiatives but were selected on the basis that they could comprehend and express a view
378 about the subject. None of the case study regions had schemes or measures in place specifically
379 targeting soil carbon management.

380
381 In a preliminary consultation, 68 stakeholder interviews (face to face and telephone), were carried
382 out by case study project partners (approximately 10 per case study). These were preceded by seven
383 pilot interviews in UK. In total 39 advisers, 24 policy maker/decision makers and 5 others (research
384 practitioners and decision makers) were interviewed. In this early research phase interviewees were
385 asked about the farming community's level of awareness and implementation of SOC practices in
386 the case study region and about barriers to and incentives for their implementation. Their views on
387 what information is used and/or needed to assist them in implementing the five SOC practices were
388 specifically sought. The interview schedules were developed referring to the literature and expert
389 knowledge about information needs, barriers and incentives for soil and mitigation, management
390 practices (as referred to in Section 2).

391

392 The results of this consultation were fed back into the project’s scientific processes of modelling,
 393 cost effectiveness analysis, and into the scoping and development of formats for decision support
 394 guidelines. Following this, two sequential stakeholder participatory workshops were held in each
 395 case study, with the same interviewees as well as additional stakeholders, including farmer
 396 representatives attending (with 5-20 stakeholders in each workshop). Each interaction allowed
 397 stakeholders to evaluate and feedback on the project outputs in a cycle of analysis, evaluation,
 398 feedback and refinement. This iterative process is shown in Figure 1. Stakeholders consulted are
 399 listed in Table 1.

400
 401
 402

Table1. Case study stakeholders engaged in interviews and workshops throughout the project

Case study regions and typical farming systems		Adviser	Farmer represent.	Policy maker	Research practitioner	Adviser-policy maker
Zealand Denmark Cereal and livestock	interview	4		3		
	WS1	7		1		
	WS2	3	2			
Central Region Hungary Large scale Cereals, small dairy, mixed and horticulture	interview	5		2	3	
	WS1	17		3		
	WS2	5	4	5		
Tuscany Italy Large scale wheat, olives, vines	interview	3		5		1
	WS1	2	3	2	3	
	WS2	2	4		2	
Mazowieckie Poland Small/medium scale cereal, orchards	interview	13		4		1
	WS1	14	3	4		
	WS2	8	3			
Eastern Scotland Large-scale cereal and potato/ arable, mixed farming	interview	7		5		
	WS1	5				
	WS2	N/A	N/A	N/A	N/A	N/A
Spain Andalucia Large scale olives Aragon Rainfed and irrigated crops	interview	6		5		
	WS1	4	5	1		1
	WS2	3	20			
UK pilot	interview	4		2	1	

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 408

Standardised interview and workshop methods were used in all case studies, the latter included presentations followed by participatory exercises, and a ranking exercise in Workshop 1 to ascertain participants’ views about preferred information formats (from a list that included: DST, real life

409 examples, GIS maps, videos, podcasts, factsheets, interactive social media). Data was collected by
410 project partners in each case study using a common format and method. Interview and workshop
411 data was collected as audio recordings and written notes. Interview data were transcribed and
412 translated into English; workshop data were used to prepare a workshop report which was then
413 translated into English. Analysis of all interview transcripts and workshop reports was then
414 undertaken by the case study coordinator by identifying and manually coding common (repeated)
415 themes across the case studies according to recognised methods (Ryan and Bernard, 2003).
416 Credibility and salience, and legitimacy emerged as strong recurrent themes out of the data. The
417 expression of these themes differed subtly in the case studies but it was possible to draw these
418 together under common constructs. The interview questions and subsequent workshop topics were
419 framed by some *a priori* understanding of the issue (as described above) however the three broad
420 themes were not anticipated before analysing the data.

421
422 Results from both the interviews and the workshops are presented below, structured around these
423 the three themes with an emphasis on advisers' views. The analysis also draws, in part, on the
424 project scientists' interpretations of the process gathered in meetings. Attention is directed in this
425 paper to how the stakeholder views informed the scientific project process and helped to shape the
426 decision support guidelines for farmers and advisers. The project processes and stakeholder input in
427 developing a DST, the economic and cost effectiveness outputs, and policy recommendations are
428 reported elsewhere (www.smartsoil.eu).

429

430 **4. Results**

431

432 In general terms awareness and use of SOC practices was reported as low in the case study regions.
433 This is backed up by analysis of data from the EU-27 regions which shows limited implementation of
434 SOC management practices (Sánchez et al., 2016). Not surprisingly, stakeholder awareness,
435 understanding and implementing of SOC practices differed between case study regions due to
436 different biophysical, farming, socio-economic contexts and institutional contexts, as reported
437 elsewhere (Ingram et al., 2014b, Ingram et al., 2014a). In Denmark and Scotland there is a growing
438 interest in the farming and policy maker community in soil health and the role of soil organic matter,
439 and in some cases soil carbon, particularly amongst organic farms, innovative farms and large
440 agri-businesses. In other countries, notably Poland, awareness and implementation remains low
441 reflecting limited political interest. There is also variation in the extent of farmer awareness both
442 between and within countries reflecting farmer age, educational background and farm type; while
443 for advisers, their knowledge and awareness is related to the quality and institutional culture of the
444 country's advisory service.

445

446 Although a number of views and issues were raised in discussions, reference to credibility and
447 relevance of information about SOC practices which could provide an optimised balance between
448 crop productivity and soil carbon sequestration were repeatedly made and these are reported here.
449 Given the diversity of case studies and the number of respondents, it is not possible to fully
450 elaborate on their range of views nor their different background characteristics and contexts. In
451 these results shared and common views are drawn out and presented, although it is not the
452 intention to suggest that the stakeholder categories in each case study represent homogenous
453 groups of actors. The information needs, synthesised and framed round the three attributes, are
454 shown in Figure 2.

455

456 **4.1 Credibility**

457 One of the main concerns expressed by interviewees was the perceived scientific uncertainty about
458 the benefits of SOC practices. A common view, particularly amongst advisers, was that there is little
459 scientific consensus about what are the best practices for enhancing soil carbon and yield under

460 certain conditions. In Spain one adviser commented *“The scientific community is not yet in*
461 *agreement and it will be difficult to achieve. Lacking concrete analysis all over Spain, let alone Europe*
462 *and globally”*.

463
464 As one adviser in Denmark noted *‘the cause and effect relationship between soil carbon and yield*
465 *seem to be lacking or very theoretical’*. There is a perception that scientists themselves do not yet
466 fully understand soil carbon dynamics and it is only when there is agreement amongst scientists that
467 management recommendations will have real credibility. A research practitioner from UK (pilot
468 interview) expressed this view saying *“One of the problems is that there is so much uncertainty about*
469 *carbon at the simplest level. It would be helpful to have consensus in the scientific community first of*
470 *all”*.

471
472 Respondents referred to debates about the efficacy of different practices for sequestering carbon
473 and for enhancing crop productivity and the fact that a systematic assessment is missing. As a result
474 advisers are left uncertain about what recommendations to make, as this one from Spain explains
475 *“Even ‘experts’ [like him] don’t know which practice to recommend to farmers when they ask “how*
476 *can I conserve the quality of soil and mitigate climate change?”*. *The practices are too complicated”*.
477 Other respondents agree that there is a lack of clarity on what constitutes best practice. Advisers
478 emphasise the need for certainty when they make recommendations, as one Danish adviser said
479 *“What ‘we believe’ is not enough for the farmers”*, and an Italian adviser supported this saying *“At*
480 *the advising level it is crucial to have proof, and evidence of the effects of a practice”*.

481
482 Dealing with the issue of heterogeneity at a regional and at a farm scale is also a concern for
483 researchers and advisers who point out that translating recommendations to the farm level is
484 complicated by variable local conditions. According to a Spanish respondent:

485
486 *There already exist mitigation measures but there is no concrete process for their*
487 *implementation depending on the specific requirements of each farm. We have to be aware*
488 *of different areas and different practices. What might apply to one farm will not be*
489 *appropriate for another.*

490
491 Most respondents stressed the importance of evidence when providing information about practices,
492 however, there were differing views about what constitutes evidence. While the advisers look more
493 for scientific validation (cause and effect relationships) and seek the authority of the scientific
494 knowledge producing process, farmers are described as largely uninterested in scientific
495 explanation, preferring to look to their own experiences and those of other farmers for proof. This is
496 illustrated by this Spanish farmer representative’s comment, *“Although many farmers do not*
497 *understand the scientific knowledge, they clearly see the results of the practices in the field”*. This
498 view is widely supported, in Hungary for example an adviser remarked that *“Real life experience is*
499 *more powerful than other information channels”* while in Poland farmers apparently distrust
500 theoretical information but are more open to solutions that have already been tested by other
501 farmers. Others suggest that this experiential knowledge prevents the acceptance of scientific
502 knowledge. According to one Danish interviewee, and supported by a respondent in Italy,
503 *“Regardless of the scientific validity, farmers act on their gut feelings, not rationally, and are not*
504 *always open to other inputs”*.

505
506 In line with these views, an exercise conducted in the Workshop 1 to identify the most effective way
507 of communicating the benefits of SOC practices to farmers, ranked real life examples as the highest
508 in all but one of the case studies, and factsheets as second highest, (videos and DSTs tended to be
509 ranked next depending on the case study, social media was the least preferred in all workshops). The
510 preference for factsheets reflects the view articulated by this Scottish respondent that, *“hard copy*

511 *technical notes are still the most useful as they are tangible and familiar to farmers and can be*
512 *discussed with an adviser in the field".* Others agreed that technical notes which provide proof of the
513 benefits are important, as a Polish farmer representative remarked:

514
515 *Farmers are not expecting any theoretical data presenting the reasons why the selected*
516 *actions should be launched; they want specific information on what steps should be taken to*
517 *implement a given measure and what effects (especially short-term) they will have.*
518

519 Respondents from other case studies concurred saying that the most useful materials for farmers
520 give concrete guidelines on farming practices. They suggested that manuals and factsheets provide
521 evidence by showing a positive impact, as one respondent in Spain said "*Farmers need*
522 *documentation that a certain change or practice will either increase output or reap other benefits in*
523 *terms of savings".* Respondents also tended to agree that it is essential to simplify the information
524 and use the 'right' language in order to communicate a complex message to local situations.

525
526 One Polish adviser however, argued for a different approach, saying that uncertainty expressed by
527 advisers and farmers about carbon reflects their poor understanding of its significance for climate
528 change mitigation. He suggested that, "*priority should be given to the development of materials*
529 *presenting relations between agriculture and climate protection and the resulting need for higher*
530 *carbon sequestration".* In his view this explanation would provide good foundations on which to
531 build a credible message about mitigation practices. In accordance with this, a policy maker in Spain
532 suggested that building an understanding of scientific principles is fundamental to communicating
533 scientifically complex recommendations:

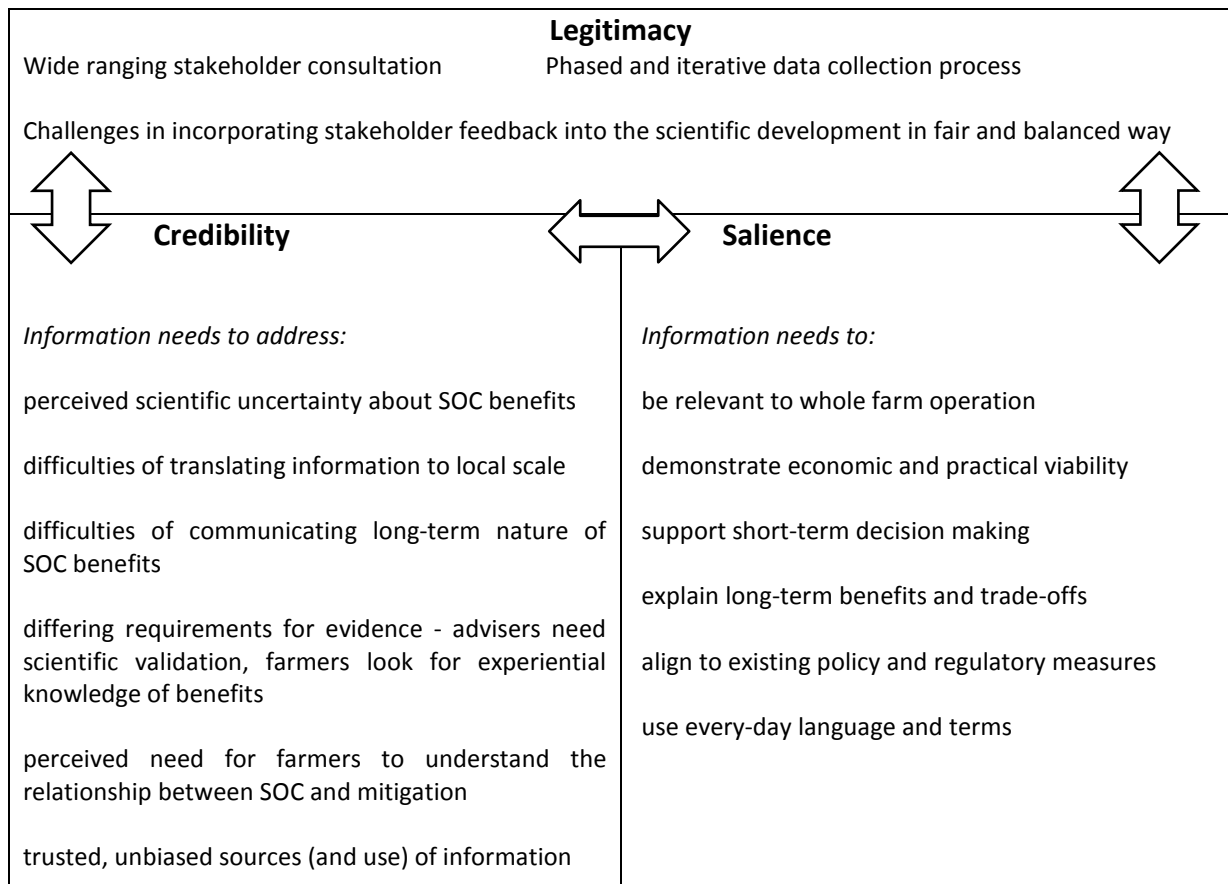
534
535 *To farmers, we have to go back to explain the carbon cycle, they understand completely as*
536 *they have seen the results and worked in the field for years, but they are lacking technical*
537 *knowledge. If they are aware of the carbon cycle, they would be less inclined to employ bad*
538 *practices. Only once they have a good scientific knowledge base, then we can start to include*
539 *mitigation methods. Farmers don't know technically why they do what they do.*
540

541 These comments show the different and sometimes contradictory perspectives on the need for, and
542 the constituents of, credible information about soil carbon for land managers. These differing views
543 cannot be explained by any particular adviser or farmer characteristic, although the advisers who
544 were sufficiently well informed or science-literate to question the science were all from the four
545 western European case studies. Additional comments also revealed that some elements
546 (observation at practical demonstrations, tangible information, simple language) are equally
547 pertinent to both credibility and salience.

548
549 With respect to the trustworthiness or believability of the information, some interviewees perceived
550 policy makers' knowledge and action to be based on something political rather than scientific
551 information. One stakeholder in Italy for example, expressed concern that policy makers might
552 misinterpret and use project outputs as evidence to support burdensome policy measures. The
553 potential manipulation of scientific evidence thus is a further dimension of credibility.

554
555

556 Figure 2. Dimensions of credibility, salience and legitimacy in relation to information on soil carbon
 557 management
 558



559
 560 **4.2 Salience**
 561 Information about SOC practices was questioned by many respondents according to its relevance to
 562 day-to-day farm activities and priorities, the time and spatial scale of operations and impacts,
 563 economic viability and regulatory measures. Some interviewees felt that scientists, and the policy
 564 makers they inform, are removed from 'the real world'. In Spain, for example, one adviser remarked:
 565

566 *Farmers know their practices well. You have to break down barriers between research and*
 567 *day-to-day practice of farmers. Even if the scientific community come to a consensus on best*
 568 *practice, it is likely that the practices defined will be so far removed from current practice*
 569 *that they [farmers] won't implement it. If the messages we want to communicate do not*
 570 *convey economically viable ideas, then they will be worthless.*

571
 572 This shows that relevance of information to the farm operations and business is an overriding
 573 concern for farmers. Farmer judgment (and hence the judgements of the advisers who support
 574 them) of scientific information takes place in a wider context of decision making where economic
 575 viability is central. As put by one Italian adviser "All management practices should be evaluated by
 576 the criteria: What does the farmer gain? Not by what does the soil gain?" Interestingly this remark
 577 suggests that soil benefits are not always equated with business benefits.
 578

579 Currently in the case study regions, there is no demonstrable commercial or policy incentive for
 580 farmers to consider the SOC practices. Consequently managing soil specifically for soil carbon is seen
 581 as insignificant, as one Polish adviser explains "Climate protection is not a priority for Poland

582 *Farmers have far more pressing issues – how to maintain a profitable production, rather than actions*
583 *to protect environment or climate”, a sentiment reiterated in other case studies. Demonstrating*
584 *economic viability of practices therefore becomes paramount, as this farmer representative from*
585 *Spain remarked:*

586
587 *Farmers take decisions primarily for financial reasons and if they are to implement mitigation*
588 *measures they must be seen as economically advantageous and will be more effective if seen*
589 *in terms on possible savings or losses of incomes.*

590
591 One of the difficulties of communicating economic advantages is the long-term nature of SOC
592 benefits to soil and potentially to yield and farm business, as shown in this comment by a Polish
593 policy maker:

594
595 *Due to a low level of environmental awareness, farmers will not accept voluntary measures*
596 *or activities that require immediate expenses, but bring benefits in the long-term. This is*
597 *reflected in advisory services, as advisers are unwilling to promote such practices.*

598
599 This sentiment was echoed in all case studies where respondents stressed that any guidance or tool
600 conveying long-term SOC gains for which economic benefits are difficult to demonstrate will be
601 “hard to sell”. Initial financial penalties (machinery, seeds etc) incurred when starting some SOC
602 practices make the long-term argument less appealing. For this reason a Spanish adviser said “*Even if*
603 *you put lots of effort in to convincing them that a certain practice will be good in the long-term, I*
604 *think this will be fairly ineffective”*. Clearly planning for long-term gains in productivity are not always
605 compatible with the short-term decision making environment of farmers and advisers who look for
606 current information (inputs costs, market, varieties and disease resistance, weather, policy measures
607 and regulation) to plan the next season or the next rotation. As one farmer representative from
608 Hungary noted, farmers will be more interested in information to help them to decide “*whether you*
609 *remove the straw this year or not”* than in a long-term perspective.

610
611 Aligning information about SOC practices with existing policy measures was also identified as
612 important. However, most current measures (some cross compliance GAECs) only indirectly relate to
613 soil carbon. Farmers in Hungary and Poland are described as being overly concerned with support to
614 allow them to comply with regulations, as one adviser in Poland explained “*Farmers do not expect*
615 *advisers to provide them with technological information. They want support on how to fulfil the EU*
616 *requirements”*.

617
618 Nor is soil carbon part of the farmers’ or advisers’ vocabulary or every-day language, since it is still a
619 relatively new issue for farmers. Although they are familiar with soil organic matter which is
620 universally recognised as relevant to soil quality and crop productivity, the benefits of soil carbon
621 and the functions it provides are not that well recognised or considered relevant. Indeed, some
622 advisers pointed out that some farmers’ interest in the soil itself is still limited, illustrated in this
623 Scottish adviser’s comment “*we’re finding people that aren’t carrying out a soil analysis, far less than*
624 *knowing what their carbon content is”*.

625
626 Advisers tended to agree that information should not just focus on individual practices, as in reality
627 farmers apply these in combination, for example, residue management, cover crops and rotations
628 are often integrated. Similarly they commented that information on a single aspect, such as soil
629 carbon, is not helpful since in soil management, physical, biological and chemical considerations
630 overlap. Consequently, as one farmer representative in Italy remarked “*information which is too*
631 *specific [i.e. soil carbon] and communicated as an isolated issue is doomed to failure”*.

632

633 **4.3 Legitimacy**

634 **4.3.1 Stakeholder engagement**

635 The intention was to consult a range of stakeholders who could represent both their own and
636 farmers' divergent values, beliefs, and information environments. Consulting advisers and
637 representatives of farmers, rather than talking to farmers themselves, clearly has some limitations.
638 However, this was considered the best approach given the time and resource constraints of the
639 project and the fact that these stakeholders (and advisers in particular) are often highly attuned to
640 farmers' priorities. The results support this choice of stakeholder, as they reveal good insights into
641 the farming community and experience of a wide range of farmer types, existing management
642 practices and contexts. The results also show that, although the process uncovered a range of values,
643 concerns associated with different actors, there was enough commonality at one level to suggest
644 that the process had been sufficiently thorough and fair with respect to the breadth of perspectives.

645
646 Furthermore a phased and iterative process involving repeated face to face dialogue in interviews
647 and participatory workshops with some of the same stakeholders presented opportunities for
648 continuity, relationship building and project engagement. However, not all stakeholders readily
649 engaged with such processes and case study partners experienced some difficulties both in
650 recruiting and maintaining continuity due to other pressures on their time as well as a general
651 disinterest in the topic. In these situations the case study partners were adaptable and arranged for
652 alternative consultation methods, or alternative stakeholders, where possible.

653

654 **4.3.2 Incorporating feedback**

655 Whilst obstacles with stakeholder engagement could be addressed to some extent, incorporating
656 stakeholder feedback into the scientific development of the project in a fair and balanced way
657 proved more problematic. With respect to credibility the stakeholder views about uncertainty and
658 their demand for clarity, different forms of evidence and proof presented some challenges for the
659 project and for developing project decision support guidelines.

660

661 A comprehensive scientific review of long-term experiments in the project did not reveal with any
662 certainty the expected relationship between SOC and yield for the selected SOC practices which
663 would have provided the clarity that some stakeholders sought. This led some project scientists to
664 question established thinking and to reframe the ambitions of the project to some extent. One
665 summed up his frustration saying "*we want to believe that there is a clear causal relationship
666 between soil carbon increases and yields but the review does not show this*". Furthermore, although
667 the project scientists agreed that the central principles of managing soil carbon to benefit soil
668 functions could be identified, they wrestled with transferring these principles into definitive decision
669 support guidance applicable to the different spatial and temporal scales that farmers operate at. The
670 problems in communicating the uncertainties involved, outside their usual boundaries of scientific
671 protocols, were summed up in a frequent expression used by scientists, "*it depends*". This caution
672 demonstrates their reluctance to provide recommendations unless it can be done "*with confidence*".

673

674 The scientists, guided by the project objectives and their own interests, also, not surprisingly have a
675 different view to the stakeholders of what constitutes relevant information. Although keen to
676 produce useful information for farmers, they regard the issue through the lens of soil carbon and all
677 the functions it supplies. Being asked to address stakeholder feedback, challenged them to consider
678 the different interpretations of salience.

679

680 Notwithstanding this dissonance, the project modelling and other activities did build on and enhance
681 the body of existing knowledge by developing new scientific principles, a Simple Model as a basis for
682 the DST (Olesen, 2014), and cost effectiveness assessments of practices and impact of practices on

683 gross margins at case study region and farm level (Sánchez et al., 2016). These all provided the
684 scientific underpinning for the decision support guidelines (see Figure.1).

685

686 Taking into account varied stakeholder views about what constitutes credible and salient
687 information and their associated preferences for different information formats, it was clear that a
688 one-size-fits-all approach to decision support was not appropriate. As such a Toolbox of different
689 materials was developed comprising Real Life Case leaflets for each case study (with accompanying
690 videos), FactSheets on each of the selected SOC practices, a DST, policy options, maps and scientific
691 outputs (www.smartsoil.eu). Figure 3 shows how stakeholder feedback shaped the Real Life Case
692 and FactSheets design and content, the development of the other tools is reported elsewhere
693 (Naumann et al., 2015). Real Life Cases and FactSheets catered for the different forms of evidence
694 identified as important, the former were developed for those (mainly farmers) who favour
695 experiential evidence and the latter for those (advisers and some farmers) who prefer evidence
696 explained in terms of validated causal relationships and scientific principles. Economic data was a
697 key element in each of these decision support guides with costs and benefits of practices and impact
698 on gross margins presented so that synergies and trade-offs could be judged. Both Real Life Cases
699 and FactSheets use language and terminology familiar to farmers and present the key messages
700 within the context of managing the whole farm system. These decision support guides were scoped
701 following the interviews, drafted after Workshop 1, reviewed and evaluated in Workshop 2 and then
702 adapted and finalised accordingly. Feedback on the draft guides, although mostly positive, was
703 sometimes contradictory, demonstrating the difficulty in carrying out a truly legitimate process
704 when diverse views are expressed.

705

706 **5. Discussion**

707

708 With reference to Science and Technology systems Cash et al. (2003) argue that traditionally
709 scientists have overestimated the importance of credibility focusing on how to create authoritative,
710 believable, and trusted information, and in doing so under-valued salience and legitimacy. In this
711 project, although establishing scientific credibility was central to the aims, the objectives and
712 methodology also took account of stakeholders' interpretations of credibility and salience, and of
713 legitimacy. The results illustrate the need to pay attention to stakeholder assessment of these
714 attributes, but also highlight some challenges in doing so.

715

716 Overall, the extensive stakeholder consultation showed that the notion of the science-farm divide is
717 too simplistic, as recognised elsewhere (e.g. Vogel et al., 2007). The picture is more nuanced than the
718 polarised term suggests with a number of actors, sectors, dimensions, domains and levels of activity
719 involved each with different interpretations of the nature and extent of credibility and salience
720 required when producing information. These are played out differently in the project and in each
721 case study according to the role of the stakeholder and the regional and local contexts. This reflects
722 the complex knowledge systems that science and practice actors operate within and has implications
723 for information provision.

724

725 **5.1 Credibility**

726 The results presented here show that credibility is multi-dimensional with stakeholders referring to
727 different criteria to assess what, for them, is valid and believable. Scientific plausibility has long been
728 the currency of scientists but this research reveals the significance advisers place on this. This was
729 articulated in terms of perceived scientific uncertainty and inadequacy of the technical evidence and
730 arguments, which they felt undermined the validity of any claims and therefore potentially their
731 advice to farmers. Uncertainty is a fluid concept and has a number of dimensions, one of which is
732 confidence, a term frequently used by stakeholders and scientists. This corresponds to Sigel et al.'s
733 (2010) notion of uncertainty (when a person lacks the confidence about their knowledge relating to

734 a specific question) which they place on a spectrum between certainty (where they have confidence)
735 and a lack of knowledge. Uncertainty is known to challenge the authority of climate science. The way
736 in which scientists communicate uncertainty, and the boundary devices they use, affects the
737 perceived authority of the science (Shackley and Wynne, 1996). In this respect Van der Sluijs et al.
738 (2008) contend that the quality of evidence for complex and contested issues is a function of the
739 scientific processes behind it. They argue that framing of the problem, the narrative for the solution,
740 the review and interpretation of results, the distribution of roles in knowledge production and
741 assessment, and the function of the results in determining the policy are important for the
742 knowledge becoming either 'contested' or 'robust'. Reference by advisers to the "scientific
743 community" as the source of uncertainty reveals a further facet of credibility. This is significant since
744 high credibility sources are known to be particularly important when messages are complex and
745 there is little available experience (O'keefe, 2015). According to respondents, farmers place less
746 emphasis on scientific explanations, however, it is possible that farmers rely on and trust their
747 advisers to validate the science for them, this is known to be the case when the messages or topics
748 are complex (Ingram, 2008, Feder et al., 2004); and where farmers require 'definite' advice, as
749 opposed to what they perceive as 'vague or contradictory' information from scientific sources
750 (Holloway, 1999).

751
752 This distinction between farmer and adviser interpretations of credibility is clearly very broad and
753 does not capture the heterogeneity of their knowledge orientations. Previous work, for example, has
754 shown that farmers utilise quite different criteria to determine the reliability and applicability of new
755 information (Raedeke and Rikoon, 1997), as do advisers (Ingram, 2008); while for achieving carbon
756 sequestration, different sorts of land managers have been shown to place differing emphases on the
757 robustness of scientific evidence (Dilling and Failey, 2013). However, in this project this broad
758 distinction has been a useful heuristic in steering the development of the decision support guidelines
759 to ensure that differing information-use tendencies are catered for.

760
761 These results raise the wider question of how to promote management where evidence is perceived
762 as weak. Cash et al. (2002 p.4) point out "Credibility is hard to establish in arenas in which
763 considerable uncertainty and scientific disagreement exists, either about facts or causal
764 relationships". Achieving multiple benefits from managing soil carbon has become part of a new
765 persuasive narrative however it is clear that there is still scientific debate, particularly when it comes
766 to providing convincing evidence about the benefits of practices at the farm level. This is aligned to
767 discussions around 'contested agronomy' where political framings steer the promotion of practices,
768 such as conservation agriculture, despite weak evidence (Sumberg and Thompson, 2012, Whitfield
769 et al., 2015). Furthermore some commentators suggest that uncertainty can lead to or justify
770 inaction. Fleming and Vanclay (2011) for example observed what they called a discourse of
771 questioning in which farmers emphasised aspects of uncertainty or incomplete knowledge in
772 relation to the complexity of climate change. These farmers avoided further attempts to find
773 information and waited until an answer could be legitimated by more scientific endeavour.

774 775 **5.2 Saliency**

776 Fundamental differences in the characterisation of soil carbon management in relation to focus,
777 language, approach and spatial and temporal scales were revealed, showing how the farming
778 community and project scientists employ different criteria about what constitutes salient
779 information. Stakeholders identified the need for information to be aligned towards farmer priorities
780 and convey "*economically viable ideas*" rather than framing it around carbon or climate change
781 mitigation which is currently largely irrelevant to farmers. Furthermore, while project scientists put
782 carbon at the centre of their research, farmers are described as taking a whole farm view and not
783 singling out isolated aspects. As previous researchers have shown, scientists dealing with soil are
784 often concerned with one small element of the farmers' world, they disaggregate the different

785 components and in doing this cannot provide information relevant to the operation of wider farming
786 system (Liebig and Doran, 1999, Ingram et al., 2010). In dealing with this the decision support
787 guidelines present information on the benefits as well as the synergies, co-benefits and trade-offs of
788 carbon management and ensure this is relevant to the whole farm context (Figure 3).

789
790 Salience can be increased when the scales and reliability of the information are aligned with the
791 scale and nature of the decision (Cash et al., 2003). However, matching information and decision
792 making with respect to time and scale is problematic when managing soil carbon. Soil carbon
793 responds slowly to changes in agricultural management, in ecosystem terms it is what is called a
794 'slow' variable whereas crop production (which is shaped by soil carbon) is a 'fast variable' (Walker
795 et al., 2012). Communicating this relationship and such a distinction in immediacy is difficult. The
796 challenge of providing information that explains and makes the long-term benefits of accumulating
797 carbon relevant to short-term operators is clear; farmers and advisers look for evidence of
798 immediate benefits, whilst science demonstrates SOC change and subsequent soil function and yield
799 benefits in decadal terms using long-term experiments and models. This tension is demonstrated in
800 studies of land managers' attitudes to soil health and productivity (Bennett and Cattle, 2013) and in
801 many other contexts where short-term motivations (and information needs) override long-term
802 strategies and benefits, for example, on-farm conservation (Siebert et al., 2006) and climate change
803 adaptation (Bradshaw et al., 2004). However, research also shows that farmers are used to longer
804 term strategic decision making (crop selection, equipment investments, or land purchases) (Stone
805 and Meinke, 2006) and are motivated by security and long-term farm viability (Siebert et al., 2006).
806 In this respect the potential for applications of seasonal weather/climate information to tactical and
807 strategic decisions has been recognised (Prokopy et al., 2015). Arguably therefore, information on
808 the long-term benefits of improved soil function, and the sustained crop productivity this brings, can
809 be useful to farmers/advisers. As such the decision support guidelines produced by the project
810 describe both short and long-term impacts, both in quantitative (yields, costs etc) and qualitative
811 (increased resilience, confidence and learning) terms.

812
813 Matching information with the scale of the decision is equally difficult, as it involves translating
814 scientific information (often from uniform experimental plots) to the finer spatial scale of the farm.
815 Such alignment is complicated by the inherently variable nature of soils and the environmental
816 factors, including climatic conditions and management regime, which affect SOC stocks. This is a
817 common experience since science tends to utilise reductive models in which it assumes that people
818 have common interests and contexts which are definable by science. The project struggled with
819 developing simple information which has wide applicability and yet meets land managers' needs for
820 guidance on incorporating carbon into decision-making at the local level. This is a recurrent problem
821 in formulating soil management guidelines (Bennett and Cattle, 2013). Real Life Cases developed in
822 the project overcome this problem to an extent, in that they are illustrative of certain local
823 conditions, they are however inevitably limited in the number of situations they can represent;
824 meanwhile the FactSheets have wider relevance but rely on users to translate overarching principles
825 to local situations.

826 827 **5.3 Legitimacy**

828 A key part of achieving legitimacy was the project's iterative methodology. Iterativity has been
829 shown to be an important element of both science-policy (Sarkki et al., 2015, White et al., 2010) and
830 science-practice interfaces, especially when uncertainty is high and values are contested (Carberry et
831 al., 2002, Oliver et al., 2012). The research reported here demonstrates that a short-term project
832 setting can provide an interactive space where repeated dialogue enables the scientists to
833 understand the decision contexts of the information users. Participation alone does not guarantee
834 legitimacy, differences in the nature and level of participation, and in particular whose views are
835 sought and taken into account, affected the process, as observed in other contexts (Neef and

836 Neubert, 2011). As well as managing participation, managing feedback and expectations was also
837 important in this project. There were challenges of incorporating wide ranging and sometimes
838 contradictory stakeholder views in a fair way, and in this case the question arises, not only “Is the
839 process fair? But, if so, “Fair to whom?” Adaptability and responsiveness were key in dealing with
840 these issues and developing decision support guidelines suited to different user needs, and that met
841 both scientist and stakeholder criteria for acceptability. Furthermore, as commentators note,
842 however consultative an approach may be, ultimately choices are made about which problems and
843 potential solutions will be considered and which ones will not and this is clearly the case in a
844 research project which has a defined remit and outputs agreed with the funders and steered by
845 political agendas (Leeuwis et al., 2004, Cash et al., 2003, Giller et al., 2008).
846

847 In summary although credibility has been portrayed as solely a scientific interest and salience and
848 legitimacy as 'societal' interests (Cash et al. 2003), this research has revealed that stakeholder and
849 project partners have criteria related to all three attributes as found by other scholars (Hegger et al.,
850 2012, Roux et al., 2006, White et al., 2010). It has also shown that criteria differ between and within
851 stakeholder groups. The challenges this presents for providing decision support guidelines about soil
852 carbon management are evident and akin to those identified in wider elements of communicating
853 climate change. As Moser (2010) observes individual information needs are multi-dimensional, it is
854 too simplistic to assume individuals merely lack information or understanding.
855

856 ***5.4 Dynamic interplay between the three attributes***

857 The results also reveal an interplay between stakeholders' views on credibility and salience and
858 between these and the legitimacy provided by the project methodology. This is in-line with other
859 research which has shown that the three attributes are, not only tightly coupled, but often in
860 dynamic tension (Cash et al., 2002, Hegger et al., 2012).
861

862 Increasing legitimacy through extensive consultation across a range of European stakeholders
863 potentially had some negative effects on the salience of the information produced by the project.
864 Stakeholders' different interests and priorities led in some part to diluting and re-framing the issues
865 in a way that made some information irrelevant to some stakeholders; as what is considered
866 important or valued in one case study was not relevant in another. Although it was possible to refine
867 and orientate the salience of Real Life Cases towards particular interests at the case study level, this
868 was more challenging for EU wide FactSheets, where accommodating all the feedback risked them
869 becoming too generic. When it comes to reconciling stakeholder views and providing relevant
870 information, inevitably a balance must be struck according to the scale of delivery.
871

872 Efforts to increase legitimacy can also decrease credibility. Given the space to articulate their views,
873 some respondents exposed, and arguably emphasised, the scientific uncertainties about the
874 potential benefits of the SOC practices, possibly because of personal beliefs, as found elsewhere
875 with climate change communication (Moser, 2010). Participatory processes to allow legitimacy
876 provide opportunities for stakeholders to express doubts about the way research is produced,
877 validated and communicated and this can represent some fundamental difficulties for scientists
878 (Sumberg and Thompson, 2012, Vogel et al., 2007). There are also issues of raising expectations
879 amongst stakeholders through consultative processes, and of the difficulties in achieving a balance
880 between credibility and salience where scientific uncertainties compete, and have to be reconciled,
881 with the certainty of everyday farming challenges and priorities. Vogel et al. (2007) also point out
882 that stakeholders often have high expectations as to how soon decision-specific information
883 becomes available, meanwhile scientists may want to err on the side of caution referring their work
884 to the peer review process. Legitimacy can also decrease credibility if the science is seen as being
885 'tainted' by stakeholders with a particular interest who might bias the process (Cash et al., 2002). In
886 relation to this some stakeholders expressed unease about policy makers input and their potential

887 misinterpretation of the information. This is seen to be a concern in rural settings where policy
888 makers are described as using the discourses of certainty and technical expertise as legitimate
889 arbiters of technical measures and environmental standards (Pretty, 1995, Whatmore, 2009).
890

891 **6. Conclusion**

892
893 This paper sought to examine the potential disconnect between science and practice in the context
894 of a project concerned with creating and communicating information about soil carbon
895 management. The results suggest that, although there are potential boundaries between the
896 scientific ambitions of the project and the potential end-user requirements, there are opportunities
897 to overcome these. Enabling multiple perspectives to be considered, incorporated and
898 accommodated through a legitimate process, revealed the importance, and the different
899 dimensions, of stakeholder views on credibility and salience. The impetus on land managers to
900 sequester carbon is likely to intensify. In order to support their future information requirements
901 projects and programmes will need to consider such processes that can reveal, and act on, these
902 attributes. This is particularly important given the complexities and contested nature of managing
903 soil carbon. Stakeholders not only reveal their different criteria and priorities with respect to
904 credibility and salience, they also question the narratives developing around soil carbon, highlighting
905 perceived weaknesses in the scientific evidence. This demonstrates the importance of providing
906 opportunities for dialogue to engender greater understanding between science and practice, and in
907 particular to reconcile the tension between credibility, salience, and legitimacy.
908

909 Beyond enhancing our understanding in the context of managing soil carbon, these results offer
910 some wider insights for research in rural settings more generally. Although the notions of credibility,
911 salience, and legitimacy have been recognised as important in a number of research contexts, the
912 interplay between them has hitherto received little attention. Such relationships are important given
913 that researchers are tasked with understanding an increasing number of scientifically delimited
914 controversies in environmental and resource management which are being negotiated at the
915 individual, community and societal level. This study shows that for complex problems there is a need
916 for a more nuanced understanding not only of the processes of stakeholder engagement in research,
917 but also the production, communication and framing of scientific evidence.
918

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DECISION SUPPORT GUIDELINES

CREDIBILITY FEEDBACK

Farmers prefer experiential evidence & solutions already tested by other farmers,
Farmers defer to experiential knowledge *regardless of scientific validity*

“At the advising level it is crucial to have a proof, & evidence of the effects of a practice”

“Farmers need documentation that a certain change or practice will either increase output or reap other benefits in terms of savings”

“To farmers, we have to go back to explain the carbon cycle”

Real Life Case leaflets & videos

Individual farmer stories focus on specific combinations of SOC practices setting out the benefits & drawbacks in the whole farm context

Impacts on yield, costs & gross margin figures provided

Long-term resilience in productivity emphasised & short-term financial penalties explained

Captures the motivations & intangible benefits (learning experiences & confidence building) which are hard to quantify in monetary or yield terms

FactSheets for 5 key SOC practices

Sets out the principles of how each practice (& combinations) benefit the soil & its functions

Data to show potential yield gains & cost savings

Impact on gross margin, impact on SOC & N input (from model) with graphs & charts

Synergies, co-benefits & trade-offs explained

Boxes with scientific explanation (principles) about SOC, cause & effect and links to mitigation

Uses terms like SOM & soil quality, not soil carbon

SALIENCE FEEDBACK

“If the messages we want to communicate do not convey economically viable ideas, then they will be worthless”

Farmers operate at the whole farm level, *“Information which is too specific [i.e. soil carbon] & communicated as an isolated issue is doomed to fail”*

Short-term penalties, long-term benefits & drawbacks should be provided

Variability at farm level needs to be addressed

Simple language & familiar terms needed

Figure 3. Development of decision support guidelines according to stakeholder perspectives on credibility and salience

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