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Visual evaluation of soil structure: farmers' evaluation and further applications

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Dedication

To all beings in planet earth.

We are fools thinking we can substitute nature by technology;
technology is a tool, not an end.

Kristy Misty.

Acknowledgments

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From the deep of my heart,

Cristina Gil Ruiz

Abstract

Soil resources are being compromised under the pressure of large scale conversion of natural ecosystems into agricultural land. Modern societies are facing increasing erosion due to disturbing the ecological balance in the soil. However, little attention has been paid to soil resources by the society and policy-makers. Besides, soil scientists have not been able to show the importance of soil resources to the rest of the society in the last century. Nevertheless, a new trend of raising soil awareness and education in societies has been developing on the last decade. In that perspective, new tools for education and awareness raising about soils have been created for raising awareness among society. This research focusses on farmers' soil education and awareness and the impact Visual Evaluation of Soil Structure (VESS) method has on farmers in a Spanish and two Norwegian counties. The aim of this study is to explore the relation that farmers have with their soils in terms of knowledge and respect to their soil, to observe the opinion of farmers about VESS, to study what farmers learn when practicing VESS, and to analyse if VESS inspires farmers to take more care of their soils. In deep-interviews, questionnaires, focus group and in field observations were administrated in this exploratory research. Results suggest some differences between organic and conventional farmers in terms of soil knowledge and awareness. Besides, VESS practice has positive effects in terms of soil education and knowledge.

Keywords: *Akershus, Álava, Buskerud, Europe, La Llanada, Levende Matjord, neoliberalism, Norway, socio-economic dynamics, raise, soil awareness, soil education, soil threats, Spain, visual evaluation of soil structure*

Table of contents

List of tables

List of figures

Acronyms

ENSA	European Network on Soil Awareness
ENSB	European Soil Bureau Network
VESS	Visual Evaluation of Soil Structure

1. Introduction

Soil, together with light, air and water, are the base for life on the earth (Carson, 2012; IAASTD, 2009). Different organisms interact with these elements creating diverse ecosystems, and the quality of those elements is crucial for the maintenance of the ecological ballance of those ecosystems (Botkin and Keller, 2003).

Contemporary societies are facing the effects of disturbing the ecological ballance by pollution of the air, soil and water (Merchant, 2005). For instance, soil degradation by intensive farming has both on-site and off-site effects (Mullan, 2013). On-site effects refer to the diminution of soils' water and nutrient-holding capacity (Fullen, 2003), reduction of soils' depth to support roots and biota (Nannipieri et al., 2003) and decrease of organic matter in soils (Langdale et al., 1992). All these perturbations impact on both food security and environmental sustainability (Lal, 1991, Branca et al., 2013). Off-site effects are related to soil erosion, creating human disasters and economic losses by the "muddy flooding" of homes, villages and infrastructures (Boardman, 2010), and environmental distresses such as eutrophication or the increase of nutrients on water bodies that leads to a proliferation of algae and fish reduction (Morgan, 2005).

The European Parliament and the Council of the European Union identified in 2006 seven functions of soils: (i) production of food and biomass; (ii) storage, filtering and transformation of compounds; (iii) habitat for living creatures and gene pool; (iv) physical and cultural environment; (v) source of raw materials; (vi) carbon pool, and (vii) archive of geological and archaeological heritage (Communities, 2006). Despite the soil's central role for environment and society, the market ideology of societies threatens soils by giving priority to economic growth rather than soil preservation (PRACSIS, 2014).

Many of these threats have been accelerated through human activity by large-scale conversion of natural ecosystems into agricultural land (Mullan, 2013). The European Commission has identified the following key threats to soils: biodiversity decline, compaction, contamination, erosion, landslides, organic matter decline, salinization and sealing (Jones et al., 2012). Policy makers can develop policies protecting soils (Potter, 2006), but there is much tension between economic interests

and soil preservation, hence politicians neglect soil preservation when they promote policies of urbanization (Vives and Rullan, 2014) or intensive farming (Huber-Sannwald et al., 2012).

The scientific community has recognized the anthropogenic effect on the soil resources, and soil degradation is a central matter for humankind (Chisci, 1994, Stoate et al., 2001). Scientists also stress that societies must consider soil as a non-renewable resource due its slow formation process. Soil building capacity is one to two centimetres per 100 years under permanent grassland in temperate countries (Jones et al., 2012). This slow formation contrasts with fast soil losses. The European Environmental Agency expected in 2000 that the erosion risk would increase with 80% in European agricultural areas by 2050 (Kirby et al., 2004). Previous studies have shown that land loses 75 billion metric tons of soil worldwide by wind and water effects, mainly in agricultural fields (Myers, 1994). Soil erosion threatens the environment, farming sustainability, general economy, and food security (Pimentel et al., 1995). However, soil erosion still not a matter of concern for the general public (PRACSIS, 2014).

Despite soils' vital functions, they remain hidden below the surface (Bridges and Catizzone, 1996) and far away from people's concern (PRACSIS, 2014). Bouma et al. (2012) claim that soils are only visible on roadcuttings or in pits. This situation requires change because increased public understanding and awareness of the value of soil is mandatory for acting against soil deterioration (Fullen, 2003).

Soils invisibility extends to policy makers. Bridges and Catizzone (1996) stress that it was unbelievable for soil scientists that soil did not receive specific mention at the United Nations Conference in Rio de Janeiro in 1992. Air and water resources are more popular on policy agendas. Some authors express that most of the soils are private property and that hinders to regulate soil resources (PRACSIS, 2014).

In Europe, environmental policies started regulating single pollutants in the 1970s, and extended progressively to water and air resources. In 2006, there was an attempt towards soil legislation. The European Commission adopted a Soil Thematic Strategy and a Soil Framework Directive (Broll, 2010), but in May 2014, the European Union withdrew the proposal (PRACSIS, 2014). Nevertheless, many international organizations and interest groups are promoting soil preservation.

In 2008, The Eurosoil Conference in Vienna had a symposium called "Education in Soil Science and Raising Public Awareness". The participants discussed ways to successfully present soils to the public, and the necessity to have a common approach in Europe to enhance awareness about soil. They supported also the creation of the European Network on Soil Awareness (ENSA) (Broll, 2010). These networks are of vital importance because soil problems will not be solved by soil scientists, but the whole society (Bridges and Catizzone, 1996). ENSA cooperates with the Working Group: "Soil Awareness and Education" of the European Soil Bureau Network and many other interest groups making tools for the development of awareness and education about soil (Fig. 1).

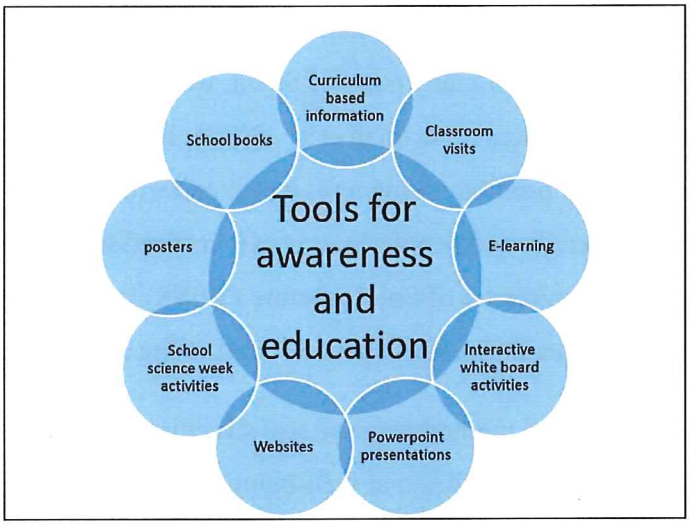

Figure 1. Tools for awareness and education (ESBN, 2009)

These initiatives have three target groups: (1) the education sector, (2) politicians, policy advisors and associated agencies, and (3) public stakeholders such as gardeners, land based industries, land planners, and archaeologists (Jones et al., 2012).

In spite of the positive aspects these tools have, they may hold two intrinsic contradictions: the lack of emphasis on farmers as targeted group, and the lack of in-field education programs. In Europe, agriculture occupies a large portion of land (Jones et al., 2012) hence farmers should be a target group in itself, because they are the principal actors interacting with soils. Besides, experiential learning in farm field school programs has demonstrated to have positive results in knowledge transfer and promotion of ecologically sustainable farming practices (Khatam et al., 2014, Settle et al., 2014, Ortiz et al., 2004)

Therefore, tools that raise soil awareness among farmers in the fields are fundamental for facing the challenges of threatened soils. Many soil scientists are eager to work in this direction with farmers even though some authors concern about the space that soil science will have in the larger arena (Bouma, 2009, Hartemink and McBratney, 2008, Bridges and Catizzone, 1996). In addition, soil scientists have been called to become active actors in the creation of soil awareness among farmers and society (Bouma et al., 2012, Hartemink and McBratney, 2008, Bridges and Catizzone, 1996). Their contribution is crucial for transmitting to farmers the importance of sustainable management of soils and the long term challenges of soil degradation.

In the last decade many in-field working on this direction projects have been promoted. Agroecology is becoming central in many parts of Spain, where farmers, citizens and scientists meet for creating sustainable food systems (Guzman et al., 2013). In Norway, the *Levende Matjord* initiative aims to learn how to promote living soils based on farm resources with the work of Norwegian farmers, soil scientist and people from public institutions REF. Bruce Ball et al. (2012) have developed the Visual Evaluation of Soil Structure (VESS), an easy and not-expensive tool that teaches farmers how to evaluate theirs soils' structure following a scientific method.

In my study I focus on the VESS method because soil structure plays a vital, yet often disregarded, role in sustainable food production and social well-being. A proper soil structure and high aggregate stability influence positively on soil fertility, agronomic productivity and porosity, as well as reduce soil erosion risk (Bronick and Lal, 2005). Thus, it is fundamental that farmers learn how to evaluate their soil structure. At the same time, it is vital that farmers realize how they are affecting the soils with their practices.

This research aims to study if VESS as well as bringing knowledge about soil structure, can be used as a tool for soil education and awareness raising among farmers. The specific objectives are to (i) explore the relation that farmers have with their soils in terms of knowledge and respect to their soil, (ii) observe the opinion of farmers about VESS, (iii) study what farmers learn when practicing VESS, and (iv) analyse if VESS inspires farmers to take more care of their soils.

2. Study sites and research methods

The study was carried out both in Spain and Norway, and I used the same methods for recruiting farmers in both locations. Farmers' participation was obtained from farmers' advisors, personal contacts and the "snowballing" method (Mack et al., 2005). This process and the study site characteristics are described below.

2.1 Study site

Spanish study site and farmers' recruitment

Farmers in Spain were recruited in the southern areas of the Basque Country, in La Llanada County, (Coordinates 42° 50′ 0″ N, 2° 45′ 0″ W). La Llanada is a traditional agricultural area in the Basque Country due to its flat landscape. The landscape has been shaped by the modern agriculture and the homogeneity of monocultures predominates in La Llanada. The climate is Mediterranean temperate, and based on the Word Reference Base for Soil Resource (WRB), its soil is predominantly *Eutric Cambisol (Europakommisjonen Det Fælles, 2005)*. Cereals, potatoes and sugar beet are the most common crops, and there are few animal farms.

Jacinto, a farmers' advisor working in a private farmers' cooperative, facilitated me contact with the first farmers. Jacinto gave me several potentially interested farmers' phone numbers, and he sent emails about the VESS method as well. In the email, a presentation letter from me was attached. I also used my personal contacts in the region whilst applying the snowballing method. Sixteen farmers participated in the study in Spain. Data was collected from April to August 2014.

Norwegian study site and farmers' recruitment

Farmers in Norway were recruited in the counties of Akershus (coordinates 59° 39′ 37″ N, 10° 47′ 1″ E) and Buskerud (coordinates 60° 33′ 30″ N, 9° 6′ 4″ E), both in South-East Norway, where cereals predominate. The climate is continental, and their soils classification are *Gleyic Albeluvisols* and *Haplic Podzols* respectively (Europakommisjonen Det Fælles, 2005).

Berit Svensen, my external thesis supervisor, provided me farmers' contacts and also introduced me to two farmers' advisor called Kari and Pål. Kari made an announcement of my research in a weekly farmers' magazine. Pål provided me the phone number of other farmers. "Snowballing" sampling was also used from personal contacts. Eleven farmers participated in the study in Norway. Data was collected from June to August 2014.

2.2 Research methods

The VESS method consists of extracting a slice of soil and breaking it up manually along the natural boundaries between aggregates (Ball et al., 2013). The soil is then compared to a visual key , paying special attention to the shape, colour, roots, pores and soil aggregates. Several pictures illustrate the different soil structural qualities on the VESS chart. A score ranging from 1 (good) to 5 (poor) is then given, according to how the soil sample compares with the visual key. The 1 to 5 scale is both scientifically and politically accepted (Ball et al., 2007). The core idea of this research is to study if VESS can be used as a tool for soil education and awareness raising among farmers, apart from bringing knowledge about soil structure.

The fieldwork progressed in three steps: (i) pre-VESS data collection, (ii) VESS presentation, chart distribution and VESS practice, and (iii) post-VESS data collection. This was important because I wanted to compare farmers' knowledge and awareness about soil before and after practicing VESS. The three steps sequence was explained in the first contact with each farmer, and although I made clear that I had full availability for them and I was ready to adapt to any timetable and place, many farmers didn't participate because they found the process too time-demanding. I gave the farmers and farmers' advisors pseudonyms to maintain confidentiality.

Step 1: or pre-VESS step. The main aim of this step was to obtain general data about farmers' in-field practices, soil awareness and soil structure knowledge. Data collection methods were semi-structured interviews and open ended questionnaires. The principal reason for using different ways of data collection was that it was very difficult to find farmers willing to spend so much time doing the interviews, so after realizing the challenge of engage farmers in the project, I created open-ended questionnaire that they could fill up in any moment.

Step 2: In the second step farmers practiced VESS. I wanted to check how much learning came from the VESS chart and how much from interaction among people and/or the facilitator. Therefore, I set four different scenarios were set with this purpose:

1st Scenario: In this scenario VESS practice was done in group, and the chart was explained by me as facilitator to a group of farmers. In one case Jacinto, the farmers' advisor, also attended to the practice.

2nd Scenario: In this scenario VESS was practiced by an individual farmers and the method was explained by me as facilitator.

3rd Scenario: In this case VESS was practiced by a group of farmers without the presence of a facilitator.

4th Scenario: In this scenario VESS was practiced by an individual farmer without the presence of a facilitator.

I gathered information through informal interviews and field notes in the first and second scenario, while in the third and fourth scenario I used open ended questionnaires.

Step 3: or post-VESS step. I collected data about positive and negative aspects of the VESS method, practicalities of VESS, new knowledge acquired by the farmers and other feelings and ideas coming after the practice. Semi-structured interviews and open-ended questionnaires were used. Additionally, a focus group was created in Spain on the completion of fieldwork in order to explore new insights and two informal interviews were conducted to farmers' advisors both in Norway and Spain.

All the data collected on the field was recorded and transcribed for later analyse it following the "grounded theory" methodology. Bernard (2011) describes grounded theory as an analytic process that helps to gain a deep understanding of the phenomena under study. This method allows me to analyse the data from multiple perspectives. Because this research intends to be exploratory; it was primordial to be in contact with the data in a very wide perspective.

Note on the methodology

I paid special attention to identify cultural influenced answers during the data analysis due to data collection in two different countries. Despite Spain and Norway are different in terms of culture and socio-political structures, I did not find differences in farmers´ answers based on nationality during my field work. Therefore, all data was analysed together. The only dissimilarities I found were that

Norwegian fields are equipped with drainage systems in some cases, while in the Basque Country drainage pipes do not exist in the farms. Another difference was the size of the farms. Farmers from Álava participating in this research had larger farms than the ones in Norway.

This study has limitations of validity and size. The validity of the sample is achieved by a representation of different people (LeCompte and Schensul, 1999, Schensul et al., 1999, Stebbins, 2001). Regarding the size, an optimal sample in exploratory research (Stebbins, 2001) should had covered at least 30 participants in each scenario in order to assure theoretical saturation. In this research, the size of the sample is not big enough to assure its validity.

In order to make an appealing questionnaire, I reduced the number of questions comparing with my interview guide. Thus, open ended questionnaires may be more limited collecting information, what may cause bias on certain results. This is reminded when necessary with a footnote in the results and discussion.

One potential source of errors in the data collection was the language issue in Norway. Both the Basque interviewer and the Norwegian interviewed were talking in English, presenting some language restrictions. However, in order to ameliorate these limitations, the Norwegian farmer always had the possibility of explaining things in their native languages (in such cases, transcripts translated to English would later be made using Google Translator and the help of Norwegian speakers).

3. Results and discussion

3.1 Farmers and their soil

It was interesting to analyse what was the relationship that farmers had with their soil in terms of knowledge and awareness for later study what was the impact that VESS had on farmers. Although this study was not meant to compare organic and conventional farmers, some different patterns appeared during the data analysis that I consider relevant to mention.

Results suggest that both organic and conventional farmers assess soil quality by looking at soil physical and biological properties. Organic farmers assess soil quality using soil functions as indicators, while organic farmers use chemical soil properties, yield productivity and plant development for assessing soil quality (Table 1).

Table 1. Indicators used by organic and conventional farmers to assess soil quality

	Organic farmers /planning to convert to organic	Conventional farmers
Soil quality indicators	Compaction Soil friability Soil fauna Microorganisms Soil porosity Organic matter Good soil aeration Root penetration Moisture retention capacity	Compaction Soil fauna Soil colour Plants development Nutrient content Yield productivity Right pH

When farmers[1] were asked in the pre-VESS interview about what they see when they observe the soil, organic farmers talk about different concerns or passions, such as succession, soil exploitation, or joy. As explained by Ñaki: "*My favourite thing when I go to the field is to take the soil and smell it, I love smell the soil, I like the soil*". (Ñaki, conventional-organic farmer, Spain). Pablo who is 57 years old said "*I have two daughters and one son and any of them wants to continue* [in the farm], *I am 57 and when I met this people* [organic farmers]" (Pablo, conventional to organic, Spain) Only one from five farmers mentioned soil fauna.

[1] It should be noticed here that this concrete information only comes from the 13 in deep interviews and not from the total of the sample. Thus, these results are not representative for the total of the sample.

On the other hand, conventional farmers' most frequent answer was that depending on the time of the year, they observe either the plants or the soil humidity (six out from nine). This was expressed by Jørgen: "*At this part of the year, I'm not looking to the soil; I'm looking to the plants, if there are funguses or animals. In the spring before I start the work in the soil, I usually take a shovel and stick it on the ground. If I can make a ball, it is too early to start working with*" (Jørgen, conventional farmer, Norway). Three of them recognized that they do not look so much to the soil, as Koldo expressed: "*If it is covered* [the soil] *I observe the crop, if it is healthy, because I do not look so much to the soil. I imagine that the crop is a good representation of how is the soil*" (Koldo, conventional farmer, Spain).

Checking the humidity of soils is necessary for knowing if they can drive the tractors on the field. McMichael and Rogaly (2005) assessed that the utilization of tractors and other technology shapes the focus that farmers have on soils; farmers' soil assessment is thus technologically oriented. In those situations, the utilization of VESS may be positive to broaden farmers' interests about soils.

Despite the farmers' different observations, all of them showed a deep respect and personal connection to their soils. The farmers considered the soil their most valuable resource, and they were proud to work with it and take care of it. Jørgen expressed "*If someone is going to rent my land, then maybe they are not going to be interested to maintain it on the same way I did (...) I'm proud of been a farmer in* Norway" (Jørgen, conventional farmer, Norway). However, in some cases there is a narrow understanding about soil care. All the conventional farmers followed the advice from farmers' advisors where chemical fertilization is a basic part of the practices of soil care for industrial crop production. Gunnar put in this way: "*Some people, not farmers, they say you take all, you are using the soil too much, growing too much, taking out, (...) you are planting and not putting nutrients back. We are putting them back with fertilizer. Of course you need to respect the soil, but it is mechanic, chemic and physical. It is science. Of course if you are putting too much chemicals in the soil then it is difficult, but we have used fertilizers for 100 years in these areas (...) In modern agriculture, feeding all the Worlds' people, we cannot do it without fertilizers, then it will be half of the crop*" (Gunnar, conventional farmer, Norway).

Although conventional farmers have traditional (or indigenous) knowledge, they do not put it into practice. For instance, José recognized that their fields lacked organic matter: "*For improving the*

soil structure I should add more organic matter, because today everything is chemical" (José, conventional farmer, Spain.).

Furthermore, conventional farmers are not warned about the repercussions chemical fertilizer have, for example, on microorganisms, because in many cases farmers' advisors act just like a channel connecting agribusiness products and farmers[2] (Mathieu, 2004). As Jørgen said: "*When I wonder about something, I can ask Kari* [farmers' advisor]. *We pay a fee to be a member, it's a science ring, they do a lot of tests, how to grow in a better way,* (...) *I get advice, and also I need a plan for the fertilizers*" (Jørgen, conventional farmers, Norway).

Thus, conventional farmers may not have all the information as to a complete picture of what their practices' repercussions are in terms of soil ecology, soil quality, and long term crop production. González de Molina (2010) states that scientific and technological knowledge has overcome farmers' traditional knowledge in Europe over time.

At the same time, it may reflect the individualization of farmers in modern agriculture (Giner and Sevilla-Guzman, 1980), and the loss and disregard for indigenous and traditional knowledge among farmers. Some farmers addressed the individualization of farmers like this: "*We don't talk to each other, everybody is struggling in their own farm. Even my father was much more in contact with other farmers in social activities, I don't know why. This is a reality; they are talking about lonely farmers*" (Gunnar, conventional farmer, Norway).

In those cases, the presence of the farmers' advisor is crucial because together with the agribusiness, they have replaced the collective network and knowledge that supported former farming systems. For example, farmers acknowledged the fact that using chemicals damages the environment, but they said that to stop using them is either too difficult in practice or too risky in economic terms. Gunnal said: "M*aybe I'm not correct, the history will tell us, because I'm an old school famer: ploughing, fertilizer... because it is an easy way, but I think it is the only one. It always depends on money. We cannot use so much time, we need to be fast, right and good; we are in a part of the world with economy*" (Gunnal, conventional farmer, Norway).

[2] I visited in La Llanada one farmers' cooperative. It was very shocking for me to see inside one big warehouse boxes of Bayer or Syngenta full of warning labels, and one line of seven to ten men waiting their turn to speak with the farmers' advisor for buy poison. I got the impression that I was in one pharmacy for treating something that is healthy!

The pressure of market-oriented agriculture is apparent in farmers' feelings and ideas, and also visible in their fears and the risk they take. Market-oriented agriculture is shaping the relationship that farmers have with their soils as well as the knowledge they have about it.

Research in all the continents has shown that farmers have very much knowledge about their soils, and can recognize characteristics of soil quality. However, although indigenous knowledge has great importance in peasant agroecosystems (Sillitoe, 1998), it has little relevance in modern farming systems where farmers have adopted scientific approaches to agriculture (Morgan and Murdoch, 2000). In particular, farmers from western countries have increased the use of advanced technologies in their farming systems driven by agribusiness (Ward, 1995, Tsouvalis et al., 2000). Thus, farmers have assimilated this scientific-agribusiness information into their own knowledge for decades.

It may be reasonable to include that apart from the classic recognition of scientific and indigenous knowledge (Ingram, 2008), there is a third type of knowledge which could be labelled "agribusiness knowledge". This agribusiness knowledge is one that many farmers have integrated after strong marketing and it is intimately related to scientific research and technology development. However, its neutrality could be questioned since it is produced under the umbrella of private economic interests. Bourdieu (1996) argued that although scientific method is objective in itself, scientific method's rules do not regulate all phases of research such as the choice of conceptual frames of reference, or the selection of problems to investigate

Advisors with a close link to agro-industry transfer agribusiness knowledge instead of a more holistic knowledge where aspects such as disadvantages of using chemical fertilization for the soil structure would be explained as well. In this scenario, farmers often have limited understanding of the long term consequences of their farming practices. Results suggest that farmers' knowledge is a mixture between their tacit knowledge, scientific knowledge and agribusiness knowledge, and the type of farming practices may determine the knowledge that they have about soils.

3.2 Farmers' opinions about VESS

The opinions that farmers had about VESS are shown in Table 2. Most farmers evaluated the method positively, while some farmers found VESS difficult, unreliable, or incomplete.

Table 2 Farmers VESS method evaluation

Evaluation	Rate of responses
Positive (interesting, easy, clear,)	16/23
Difficult	5/23
Unreliable	4/23
Incomplete	3/23

VESS was considered an accessible tool, interesting and one that gave clear information. Most farmers found it very comprehensive and easy for evaluating soils. Their comments were positive, as Ángel said: "*Very easy to learn, no means are needed; you can do it by yourself*" (Ángel, organic farmer, Spain), or Gunnar in Norway: "*It is very interesting because it is put in a system*" (Gunnar, conventional farmer, Norway).

On the other hand, seven farmers found VESS either difficult to understand, hard to make the soil's structure evaluation, or challenging to follow through. Results suggest that when VESS is practiced alone, farmers without previous experience in VESS tests are more able to find VESS difficult. This was previously observed by Guimaraes et al. (2011). Other possible cause for difficulties may be that VESS was practiced individually. Smith et al. (2012) suggested in their study that peer discussions improve the learning process of farmers. Indeed, when farmers were asked about suggestions for VESS improvement, those who found it difficult suggested that it would be better to practice with more farmers. Olav said: "*I think it is better if we do it with more farmers because then we can compare and see how the different managements affect soils*" (Olav, conventional farmer, Spain). Anniken commented: "*Not everybody has formal education in agriculture; meetings and demonstrations are becoming increasingly important*" (Anniken, conventional famer, Norway). Amaia wrote on her questionnaire: "*I found it quite confusing, it was difficult to evaluate with these keys, and if I would have done it with somebody knowledgeable it would have been easier*" (Amaia, organic farmer, Spain).

Nevertheless, two farmers who had worked in groups found VESS difficult to understand. As noticed during the field work, a plausible explanation may be that the facilitator[3] (me) did not give enough time to read the chart or did not have enough expertise about VESS and soil science. Another reason could be that each person has a particular way of learning as explained by Kolb (1984). One of the farmers explained that in his case: "*It was too fast; I felt some confusion with the pictures and so on*" (José, conventional farmer, Spain)

Four of the farmers doubted about the reliability of VESS. Ritxar, who participated in a group with me as facilitator, said: "*I'm not sure if with this technique you can make a conclusion, if your soil is good, or bad, or regular*" (Ritxar, organic farmer, Spain) while José, also in a group said: "*There was not a clear difference* [among soils], *each person gave a score, for me random*" (José, conventional farmers, Spain). A comment of Haral who did it on his own goes: "*My soils have great* [physical] *differences already, so I do not feel any wiser about how healthy my soils are.*" (Haral, conventional farmer, Norway).

Giarola et al. (2009) discuss their concerns about the possible subjectivity of inexperienced operators in the visual soil structure quality assessment (VSSQA), the former VESS method. However, Guimarães et al. (2011) improved the method making it more objective. The inexperience of operators or the lack of expertise of the facilitator may be possible explanations for farmers' doubts about reliability of VESS.

Three conventional farmers expressed that they were missing information in the chart. They were missing guidance to improve their soil structure once they recognized that it was necessary to improve it. Johan, a conventional farmer thinking about changing to organic, commented in his questionnaire: "*Maybe it could also be some short tips about what you can do if the soil structure is no good*" (Johan, conventional-organic farmer, ØI, Norway). José from Spain said: "*I'm missing the second part, go deeper, what is the next step?*" (José, conventional farmer, Spain), and Olav expressed: "*Yes, I get the score, but now what? What to do?*" (Olav, conventional farmer, Norway).

It is positive that VESS opens the gate for farmers' desire to improve soil structure. In fact, on the pre-VESS interview José and Olav did not have a special interest in soil structure. However, there is

[3] It was very challenging for me to be researcher and facilitator at the same time. Besides, I didn't practice VESS enough times to be fully confident with the tool. There was a great difference between the first time a facilitated a VESS practice and the last one.

not an easy or quick solution for improving soil structure. Intensive farming promotes soil compaction, organic matter loss, and soil mineralization, which creates poor soil structure (Lundekvam *et al.*, 2003, De Santisteban *et al.*, 2006, Skoien *et al.*, 2012, Garcia-Ruiz, 2010, Nachtergaele and Licona-Manzur, 2008).

Jacinto, the Spanish farmers' advisor, stressed in the focus group that most conventional farmers are used to buying solutions from agribusiness. These solutions are expensive and do not go to the root of the problem. For instance, expensive new big wheels have a better design than the old ones and they are not supposed to damage the soil structure as much, but they still cause soil compaction. Gunnar explained the problem that way: "W*e are using a lot of money on good wheels for not putting so much pressure into the fields, because the tractors are heavier and heavier*" (Gunnar, conventional farmer, Norway).

Vanloqueren and Baret (2009) said that scientists often assume that farming systems only need small adaptations, like the example of tractor wheels, to become environmentally sustainable, but larger issues like monoculture are rarely discussed. This idea is transferred to farmers and they end up thinking that making small adaptations will solve large problems. Again, the link between narrow scientific research, agribusiness and knowledge transfer appears to be shaping farmers ideas and thoughts. VESS could be a good platform to challenge these ideas with the help of independent scientists and farmers with different farming practices who could bring and exchange holistic knowledge with the farmers.

Finally, many farmers found challenging to extract the block because the soil was too dry or too rocky. As Karl suggested: "*I suggest to include a sentence* [in the VESS chart] *about what to if the soil is very rocky (...), vertical incisions with the spade didn't let me deep enough*" (Karl, organic farmer, Norway).

3.3 VESS as a learning tool

VESS is a tool designed for the visual evaluation of the soil structure. It aims to allow focus on anthropic soil features such as soil compaction rather than inherent pedological ones, and to foster the exchange of soil knowledge (Ball et al., 2013).

In the pre-VESS interview and questionnaire, farmers gave different definitions of soil structure. There were some farmers more knowledgeable than others in terms of soil structure (Table 3). Even more, some farmers had previous experienced with spade tests. At the same time, three farmers[4] did not have a special interest on soil structure.

Twelve farmers were more knowledgeable about soil structure after practicing VESS, showing an increased interest for it. José said: "*I have realized that the soil structure is very important for production*" (José, conventional farmer, Spain). Andoni added: "*I liked to see the structure and to learn about the reasons affecting it*" (Andoni, conventional farmer, Spain). In some cases they clarified the meaning of soil structure as Koldo expressed: "*In my case, I have never seen before the structure. I observe the texture and the weather conditions. To look at the structure is now on my do-list*", and in other cases they learned how to evaluate the soil structure in their fields. Anniken wrote on her questionnaire: "*I learned that hard soil has edgy aggregates, and can be grey-blue, and smell sulphur*" (Anniken, conventional farmer, Norway).

Results suggest that when closely observing the soil, farmers got a new view on other soil characteristics, since VESS gave the opportunity to dig into the soil and observe it from a different perspective. Twelve farmers were surprized by the soil ecology. Juan mentioned in the questionnaire: "*It was very nice to see the soil structure and its porosity (...) I was surprised observing some worms making the chrysalis for hibernating*" (Juan, conventional-organic farmer, Spain). Karl also discovered new aspects: "*The size of the alfalfa roots impressed me*" (Karl, organic farmer, Norway). Pablo realized that: "*The most important thing is to get off* [the tractor] *and digging into the soil. That we have never done, we stop on the surface. What is bellow? We saw a type of life that you do not usually stop to think about it or to see in our daily life*" (Pablo, conventional-organic farmer).

Three farmers appreciated to observe theory in practice. Root nodules, or the impact that tractor tracks have on root penetration, are concepts that most farmers know in theory, but have not seen in reality: "*It's my first time I see nodules, we know them from theory and now I see them!*" (Patxi, conventional-organic, Spain). Karl knew about the problem and added that: "*I got confirmation that the soil is damaged in the tractor tracks*" (Karl, organic farmer, Norway).

[4] It should be noticed here that this concrete information only comes from the 13 in deep interviews and not from the total of the sample. Thus, these results are not representative for the total of the sample.

In that sense, VESS could be used as a bridge connecting scientific knowledge and practice, where farmers, scientists and other stakeholders can exchange their different knowledge and expertise. That would be a change from the typical knowledge transfer process, where agricultural research creates the knowledge, agricultural extension services transmit, and farmers adopt (Mitton et al., 2007, Mathieu, 2004). There is often critique of how scientific knowledge stays in academic environments without reaching the general society (Bruno et al., 2004), or the fact that local knowledge is frequently disregarded (Supakata and Fayard, 2004).

Data collected during the VESS group practice showed that VESS is actually a suitable platform where tacit or local, scientific and agribusiness knowledge meet, transfer, and evolve. Below there is an extract from the focus group made in Spain after practicing VESS:

> Javi says: "*I saw the tillage layer* [practicing VESS]. *If we had used the disc harrow it would be better. Soil was compacted, what happens is that you must be a master on crop rotations to get things right*" (Javi, organic farmer, Spain).
>
> Patxi replies: "*You must try*" (Patxi, conventional-organic farmer, Spain).
>
> Luis adds: "*Many things influence*" (Luis, conventional farmer, Spain).
>
> *Patxi notices:* "*In our area you prepare it* [the soil] *very well, you seed, it rains and it becomes concrete*".
>
> Ritxar adds: "*The sand runs quickly, it rains, then it becomes compacted and you can't pass even though the tractor weights 20500* [Kg.]. *There are now rollers with spikes and I think they would go very well*" (Ritxar, organic farmer, Spain).

Thanks to VESS (Scientific Knowledge) Javi reflects about the use of different technology (agribusiness knowledge) and recalls the crop rotations (traditional knowledge). Patxi and Luis use their traditional knowledge, and Ritxar add to it agribusiness-technological knowledge).

Results suggest that farmers want to meet together. Eleven farmers mentioned they were eager to meet more farmers and learn from each other. VESS brings the opportunity of both experiencing the soil in a new way and fostering farmers' meetings. Kolb (1984) expresses that the learning process is anchored in experience. That is why it is so important to find tools that are based on concrete experience for creating soil awareness.

Experiential learning and peer discussions are central for acquiring knowledge successfully (Mitton et al., 2007). Studies in Turkey have shown that experiential learning rises children's awareness about soils (Gulay et al., 2011, Gülay Ogelman, 2012), and studies around the world has shown that

peer discussion in Farmers Fields Schools increase farmers' knowledge (Ali and Sharif, 2012, Yang et al., 2008), crop production (Davis et al., 2012), farmers' economy (Mariyono et al., 2013), and favours environmentally sustainable productions (Oladele et al., 2004, Mitei, 2011). Bouma et al. (2012) stressed that soil science is disconnected from real practices in farmers' fields and to develop European Farmers Field Schools is necessary to integrate knowledge and practices. VESS may be an incipient strategy for the development of future Farmers Field Schools in Europe where tacit, scientific and traditional farming knowledge can be exchanged.

3.4 VESS as inspirational tool

Farmers explored soils in a new way when practicing VESS and many of them were inspired by it. For instance, five farmers showed a willingness to repeat VESS for various reasons. Karl said: "*I will probably do it to investigate the cause of low or high yields for example*" (Karl, organic farmer, Norway). Bjørn wrote: "*This is something I should do more often; it connects me with the soil*" (Bjørn, biodinamic farmer, Norway), and he added: "*To dig in the soil inspires me to get a very good fertile soil*". Seven farmers as Anniken expressed their inspiration to learn new things: "*I need to learn to figure out what I must to do; what do I have in the soil that are favorable... and get some teachings*" (Anniken, conventional farmer, Norway), or Ibai: "*I need to learn more, to learn how work the soil and not to accommodate using herbicides*" (Ibai, conventional farmer, Spain). Finally, nine farmers acknowledged the importance of digging into the soil: "*The most important thing is to get down the tractor and dig into the soil, this we have never done before, we stop into the superficial*" (Patxi, conventional-organic farmer, Spain); while others recognized that they could confront the problem of soils with poor structure. Koldo mentioned: "*Doing these kinds of tests is how you realize what is going on, otherwise you do not realize it*" (Koldo, conventional farmer, Spain).

It can be argued that every time a person focuses on something specific she or he becomes more aware of its properties and characteristics. Psychology studies point to the correlation between self-focus and self-awareness (Gibbons et al., 1985). The greater self-focus the greater self-awareness. This idea suggests that it is not VESS in itself what inspires farmers, but the action of been focused on soils during the practice. VESS could be considered then as one channel for creating awareness about soils due to its focus on soils.

Another question is to what extent these inspirations will materialize in a context where there are many influencing factors affecting farmers' decisions. Three large issues to deal with are: (i) the personal level, (ii) farmers' challenge of stepping out from mainstream farming and (iii) looking beyond the so- called "technological paradigm".

First, at the personal level, Prochaska et al. (1994) explains that humans change behaviour going through a cycle of six stages until they achieve to maintain the new behaviour. The stages are precontemplation, contemplation, determination, action, relapse and maintenance(Prochaska et al., 1994). Farmers that are willing to change their farming practices may be in one or other stage, so the materialization of the inspirations can take long or short time depending on the personal stage where the farmer is.

Secondly, farmers' challenge of stepping out from mainstream farming situates outside the farm. European conventional farming systems are embodied in the neoliberal paradigm (Ríos-Núñez, 2013, McKinney, 2013, Sumberg et al., 2013). There, supranational organizations such as the EU or the WTO have great influence on farming activities (Busch and Bain, 2004), limiting the options that farmers have. Furthermore, social, economic and political dynamics favour intensive farming (Martinez and Davis, 2002; Marion, 1998).

The third challenge that farmers meet is the "technological paradigm". As the interviews reveal, some farmers love machinery: "*I like working with machines, I like making pipes, fixing.*" (Gunnar, conventional farmer, Norway).

In many cases, socioeconomic and political dynamics push farmers to use and invest in machinery. Some farmers mentioned that technology was not something they were interested in: "*I feel like a real farmer being in touch with what actually produces the crop. I am so sick and tired hearing about N,P,K and what kind of fertilizer to use, and driving the tractor*" (Bjørn, biodinamic farmer, Norway).

Some farmers are reluctant to use sophisticated technology. Cowan and Gunby (1996) argues that the choice of technology is also set at the macro level. The economics of technology theory shows that when one technology is getting more returns than others, this technology expands more. Farmers that do not have a especial interest in machinery or high tech technology may also be lead to the purchase of these goods because of the technological paradigm trap (Dosi, 1982). All these driving forces create a complex scenario where putting in practice the willingness to improving the

soil structure may not be an easy task for the farmers since they would need the use of marginal technologies.

For instance, if a farmer wants to start working with a donkey-drawn carriage instead of a heavy tractor that compacts the soil, she or he will meet the risks of driving it on roads made for car circulation. The farmer probably would face some problems if there are subsidiary local ordinances that forbid keeping donkeys in the village as well. This supposition may sound simple, but it addresses the reality of the technological paradigm.

Recapitulating, farmers may get inspiration about improving their soil, but there are larger issues playing against the realization of these inspirations. Some issues are linked with social and economic forces, and a collective change is necessary then, while others rely on the farmer at personal level. Learning directly from colleagues who had sustainable agroecosystems may serve as a reference for farmers that want to change their practices, and VESS may serve as platform in which farmers with different farming practices gather together sharing their knowledge and experience.

4. Conclusions, implications and future research

Although I have taken much care doing the methodology, design and data analysis, it must be understood that this small sample should not be extrapolated to create information or assumptions about the wider population. Nevertheless, it may be used as a guide for further research and development.

The data suggests that organic and conventional farmers use different indicators for assessing soil quality. Both use soil physical and biological properties as indicators. Nevertheless, organic farmers use soil functions as well, while conventional farmers indicates soil chemical properties and yield production as soil quality indicators. Both groups have a deep respect and want to take care of their soil. Though, conventional farmers' soil care is guided by partial agribusiness knowledge more than impartial scientific knowledge. Farmers' advisors suggest industrial products for taking care of soil nutrients, and the farmers don't realize that these chemical nutrients benefit the plant damaging the soil. That may be a reason why conventional farmers speak about chemical properties for assessing soil quality while organic farmers speak about soil functions.

VESS was practiced in different situations for testing it under diverse conditions. Although some farmers met some difficulties practicing VESS, most farmers had a positive VESS evaluation. The key for a positive practice seems to be the experience. Results suggest that experienced facilitator and operator may decrease the feeling that some farmers had about VESS unreliability and incompleteness. Finally, appropriate weather conditions and soil moisture are also important

Farmers learned about soil structure, expanded their ideas about soil, and saw theory in practice practicing VESS. Data illustrates that to follow VESS chart instructions favours farmers to be in contact with the soil in a way that their knowledge about soil broadens. Results indicate that VESS is an appropriate platform for knowledge exchange in all the situations. However, the larger the number of people is the greater exchange of knowledge occurs. The presence of a knowledgeable person increases in soil even more the knowledge exchange.

Results suggest that when farmers have a positive evaluation of VESS they get inspired about taking care of their soil. Therefore, the presence of somebody with previous experience is crucial when a farmer practices VESS for the first time. Another explanation for why VESS inspires may be that

VESS provides the frame for farmers to focus on aspects of soils that do not usually consider. This suggests that methods like VESS can be used as a tool for creating soil awareness and promote soil education. With some changes, VESS could be adapted for its use with other actors such as children. VESS may be used as a tool for awareness creation by the numerous institutions working on soils.

For minimizing the negative impacts that some farming systems have on soils, it is vital that farmers expand the knowledge they have about soils. However, farmers are not the only responsible of their farming practices. Policies, economy, or consumption behaviour are social dynamics that have an impact on the farming systems. Not a single solution can stop soil threats; it is a matter of the whole society. However, tools like VESS can be very important to raise awareness about soils through education. More research is needed to assess if tools like VESS can be used for empowering farmers and other actors.

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Appentix

Appentix I: Presentation letter attached to the email (Spain).

Hola, Buenos Días!

Mi nombre es Cris, soy una estudiante de agroecología y ahora mismo estoy realizando mi trabajo de final de estudios. Lo que quiero estudiar es una técnica que sirve para observar la estructura del suelo en los campos de cultivo. Esta técnica ha sido elaborada por un grupo de agricultores y agrónomos.

Lo que han hecho es describir los pasos para hacer un análisis visual de la estructura del suelo (VESS) y escribirlos en un papel. El análisis en sí trata de coger una pala plana, sacar un rectángulo no muy grande de tierra (de un lugar que al grupo de agricultores le interese ver y analizar visualmente), y empezar a seguir los pasos que se describen en el papel (por ejemplo, comparar la tierra con diferentes fotos y evaluarla). Es un método que parece ser súper práctico e interesante, además no se necesita nada más que una pala y media hora. Quizás lo conozcáis ya.

Lo que yo quiero hacer para mi trabajo es ver si este método es para los agricultores tan práctico e interesante como parece, y además quiero saber qué es lo que se aprende practicándolo. A mí me encantó cuando lo descubrí, y me enseñó varias cosas sobre la tierra (en un futuro quiero ser agricultora también, por eso me interesa tanto), pero claro, mi conocimiento es muy limitado porque justo he trabajado un poco en la huerta y quizás por eso me impresionó tanto.

Es por ello que es muy importante para mí probarlo con agricultores, y ver su opinión. Para ello estoy buscando voluntarios que les apetezca participar. Necesito hacer un grupo de 3 o 4 agricultores y agricultoras, e ir a un lugar que les interese analizar (por ejemplo una zona de la pieza donde el cultivo se da muy bien y otra donde al cultivo le cuesta salir). Allí pondríamos en práctica este método y yo además de aprender con vosotros, observaré vuestra conversación y os haré algunas preguntas sobre qué os parece el método. Yo recogeré todo lo que habléis (con una grabadora mejor, así no tengo que estar preocupada tomando notas) y luego esto será el material para realizar mi trabajo. Si luego queréis leer lo que he escrito os lo mando, claro!

Además de la conversación grupal también tendremos una conversación individual antes y después de hacer el análisis. Así que necesito veros 3 veces, una vez antes de hacer el análisis, otra todos juntos, y al final otro encuentro a solas. Para las conversaciones individuales me gustaría invitaros a una cerveza o algo, o si preferís voy al borde o la casa. Lo que quiero decir es que me adapto a vuestro ritmo y preferencias. Para la conversación grupal nos juntamos todos en aquel lugar que os interesa analizar.

Estoy planeando hacer todo esto del 7 al 23 de Abril, y bueno, pues esto es todo! Muchas gracias y espero que os despierte tanta curiosidad esto como a mí. Escribidme si estáis interesad@s un email a crisgilruiz@gmail.com, os estoy esperando!! En él me podéis preguntar lo que queráis.

Un saludo y hasta pronto!

Appentix II: Presentation letter attached to the email (Norway)

Hei!

Jeg heter Cristina Gil Ruiz; jeg er student ved NMBU i Ås, og jeg kommer fra Baskerland, Spania. Jeg gjør min masteroppgave nå om en metode som kalles Visuell Evaluering av Jordstruktur (VEJS).

For å gjennomføre oppgaven trenger jeg å møte bønder fra Akershus som er villige til å svare på noen spørsmål og ønsker å se nærmere på jordstruktur. Mitt opplegg er som følger:

1. dag: Et kort personlig intervju og spørreskjema. Her snakker vi om dyrking og jord generelt. Etter møtet jeg gir bonden et VEJS diagram, og jeg spør om han/hun ønsker å gjennomføre VEJS praksis på hans/hennes felt.

2. dag: En gruppe bønder og jeg skal samles på en gård som er villig til å gjøre gjennomføre VEJS på hans eller hennes felt. Vi tar spadeprøve i fire ulike felt og lærer hvordan man skal vurdere jordstrukturen.

3. dag: Et avsluttende kort personlig intervju og spørreskjema hvor vi snakker om VEJS, jordbruk og jord.

Jeg vet du har det veldig travelt nå, men vi kan prøve å møtes på tre regnværsdager :) Jeg håper du er interessert i å delta, tusen takk!

Med vennlig hilsen,

Cristina Gil Ruiz

99884328

crru@nmbu.no

Appentix III: Pre-VESS interview questions for the "VESS&" group

INTERVIEW QUESTIONS

1. What is a healthy soil for you? How do you recognize a healthy soil?

2. What do you think the functions of the soil are?

3. What do you know about soil structure?

4. What is a degraded soil? Do you know something about it? How do you recognize a degraded soil? How do you know if it is degraded or not?

5. What is an eroded soil?

6. Do you have an special interest about soil structure?

7. What do you see when you observe the soil? What impression do you have? What do you feel inside?

8. How is your field's soil?

9. What is for you to be respectful with the soil? Are you respectful with the soil? Why?

10. Do you think the agriculture practices affect soil structure? How?

11. Would you like to improve your soil structure?

12. Do you like to be in contact with the soil? Do you like to touch the soil?

13. What are your concerns as farmer?

14. How would you define your work?

15. What do you think about the impact of agriculture on the environment?

16. What do you like most about working on the fields?

Appentix IV: Pre-VESS presentation letter and questionnaire.

PRE-VESS

Hei!

You are about to start the Visual Evaluation of Soil Structure (VESS). The VESS method has the vocation to be a tool that gives information on soil structure without the need of any advisor or specialist, in other words, it seeks to empower the farmer.

In order to improve this method it is necessary to deeply analyse its strengths and weaknesses, as well as its potential. This is why I am doing this research, and asking for your collaboration. So thank you very much for participating!

Bellow you have some questions to answer and an introduction to the VESS. The privacy of the respondents will be kept by the researcher. Regarding the questions, the more you extend in the

answers the better. There are no right or wrong answers, just tell what you know from your own experience and knowledge. Feel free to answer in Norwegian if you want!

Takk for samarbeidet!

Pre-EVES questions:

Name:

1. What do you cultivate? Please describe your agricultural practices (ploughing?, use of organic fertilizers?, use of pesticides?, ...)
2. What is a healthy soil? How do you recognize a healthy soil?
3. What is soil structure for you? Does your soil structure need to be improved? Why?
4. What is soil degradation *–jordforringelse-*? Do you think there is soil degradation in your farm or in the area where you live? How do you recognize a degraded soil?

Introduction to VESS:

Print the *VESS pdf* in colour (DIN A3 if possible). If you cannot print the paper, bring your laptop/smartphone to the field or the soil samples where you have your PC.

For taking the samples, you need a spade and some kind of white surface where you can leave the samples. This can be a tray, a plank of wood, or a fabric/plastic on the floor. It is important to be gently with the block, especially when moving it from the spade to the surface where you are going to analyse it.

I recommend taking two samples for the first time doing VESS[1]: the first one in a place of the field where the crops are growing good and the other in a where the crops are not growing so good.

Now you can start following the steps on the VESS chart.

Enjoy it!

[1] The VESS chart says to take up to 10 samples. However, I consider that 2 samples are a good starting point, but feel free to take as many samples as you want!

Appentix V: Post VESS questionnaire.

Hello again!

You've done the Visual Evaluation of Soil Structure (VESS).Please answer the following questions giving as much detail as you can. Use Norwegian language if you prefer.

Takk for samarbeidet!

Name:

1. Did you do the VESS alone or with other people? (If you have done it with more people, please tell who was there: other farmers, farmer advisor, others).

2. Make a description of what you saw when doing VESS.

3. What did you like most doing VESS?

4. What did you like less? Have you had any difficulties?

5. Is there anything that has surprised to you? Have you seen something on the soil that you did not expect?

6. What have you learned doing VESS?

7. Do you have any suggestions for improving the VESS?

Appentix VI: Post-VESS focus group and interview questions:

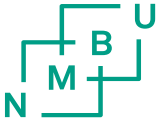
1. What did you like most doing VESS?

2. What did you like less? Have you had any difficulties?

3. Is there anything that has surprised to you? Have you seen something on the soil that you did not expect?

7. What have you learned doing VESS?

8. Do you have any suggestions for improving the VESS?



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