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Collated Research Outputs for Case Studies

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Dissemination Level

PU	Public	**X**
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Contents

Glossary

AW	Anglian Water
Ca	Calcium
CLA	Country Land and Business Association
CORDIS	Community Research and Development Information Service
CS	Case Studies
CSP	Case Study Partners
DRA	Dynamic Research Agenda
EA	Environment Agency
EIP	European Innovation Partnership
EU	European Union
FF	Farm Frites
K	Potassium
LiDAR	Light Detection and Ranging
Natural England	Natural England
N	Nitrogen
NGO	Non-Government Organisation
NFU	National Farmers Union
P	Phosphorus
TRV	Tobacco Rattle Virus
VALERIE	VALorising European Research for Innovation in agriculturE and forestry
WFD	Water Framework Directive
WFF	Water Friendly Farming Project
WP	Work Package
WVP	Welland Valley Partnership

1 Introduction

1.1 Introduction

This report collates the research outputs generated by this process in the ten VALERIE Case Studies (CS) in six countries (see Table 1.1). The premise of the VALERIE project is that many research projects in agriculture and forestry provide excellent scientific results but that outreach and translation of these results into farming and forestry practices is not always effective. The challenge is therefore seen as boosting innovation by facilitating the uptake of formal and empirical knowledge, and its integration into field practices. The project aims to address this by translating research outcomes with a special interest in innovative and applicable approaches into end-user content and format (for farmers, advisers, supply chain actors etc.). It does this by extracting and summarising knowledge from national, international and EU research projects and studies concerning innovations in agriculture and forestry (with a focus on six selected themes). However, rather than a top down process of translation or transfer of scientific outputs to practitioners, the project has adopted an interactive co-innovation approach working with stakeholders in the CSs. Central to this approach is an iterative methodology in which the project can collect a wide range of innovation issues, learn how potential users articulate questions for research about these issues, and understand how they screen, filter and test extracted research outputs. This approach understands that solutions derived from research need to be utilised and re-built in the field, with the involvement of relevant actors. This stakeholder-driven process has generated research outputs in different formats, and from a number of sources throughout the project. These are the subject of this report.

1.2 Aims

The VALERIE co-innovation process, as detailed in Deliverable 3.341 *Co-innovation plans: report of first round of case study meetings* and described below, has resulted in a number of research outputs in each CS. This report aims to collate research outputs from the co-innovation process in the CSs and to describe the process by which they were created.

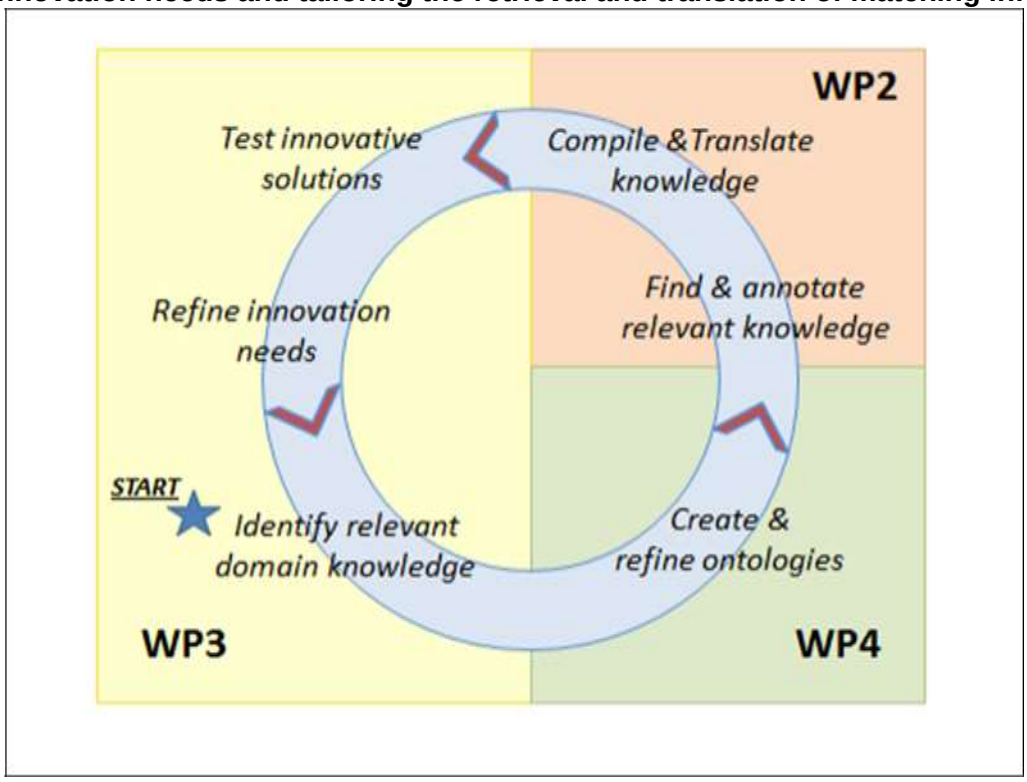
Table 1.1 VALERIE Case Studies

Name of CS	CSP and country	Topic	Stakeholders
Sustainable forest biomass	TAPIO Finland	Sustainable forestry management and smart use of biomass	Researchers, forest owners, forestry organisations, wood ash supply chain
Agroecology: managing plant protection	CETIOM France	Sustainable cereal cultivation	Farmers, technical institutes, agricultural chambers, machinery companies
Innovative arable cropping	ACTA France	Reducing herbicides use in arable crops	Technical institutes, agricultural chambers, farmers, research institutes, storage agencies
Sustainable forest management and ecosystem services	USSE Spain	Improving the economic and environmental performance of forestry in Navarra	Forest owners, municipalities, forest authority and extension service, value chain organisations
Improving milling wheat quality	Cadir Lab Italy	Fertilisation, IPM and fungi control in sustainable milling wheat supply chain	Farmers, wheat-stocking cooperatives, seed companies, pesticide companies, wheat-buying companies
Drip irrigation management in tomatoes and maize	Cadir Lab Italy	Sustainable water and nutrient management	Farmers, cooperative for tomato transformation, public experimental station
Sustainable onion supply chains	DLV Netherlands	Improvement in onion quantity and quality	Farmers, seed companies, packers, exporters, suppliers of fertilizers and pesticides
Sustainable potato supply chains	DLV Poland	Sustainable potato production for the French fry industry	Farmers, processing and exporting industry, suppliers of fertilizers and pesticides, experimental station and research
Catchment scale resource use efficiency	GWCT UK	Sustainable farming at landscape scale	Environment agency, NFU, NGOs, professional nutrient management group, agric. levy boards
Soil management in livestock supply chains	GWCT UK	Sustainable soil management in livestock production	Farmers, advisers, supply chain

1.3 Context and background to the tests in the case studies

This Deliverable concludes the Work Package 3 (WP3) activities in that it brings together all the CS research outputs generated in the project. These outputs represent innovation solutions provided by research (extracted by WP2) and translated into field practices through stakeholder testing and screening. The documented results are codified in trial leaflets which are annotated and added to the ask-Valerie.eu document base, thus competing the VALERIE cycle shown in Figure 1.1. The project relies on a basic structure that links three work packages in an iterative cycle, driven by stakeholders (see Figure 1.1). We shall refer to the three work packages as: 'Extract knowledge' (WP2), 'Case studies on innovation' (WP3), and 'Ontology' (WP4).

Figure 1.1 Schematic presentation of iterative, stakeholder-driven process of identifying innovation needs and tailoring the retrieval and translation of matching information



2 Co-innovation methodology

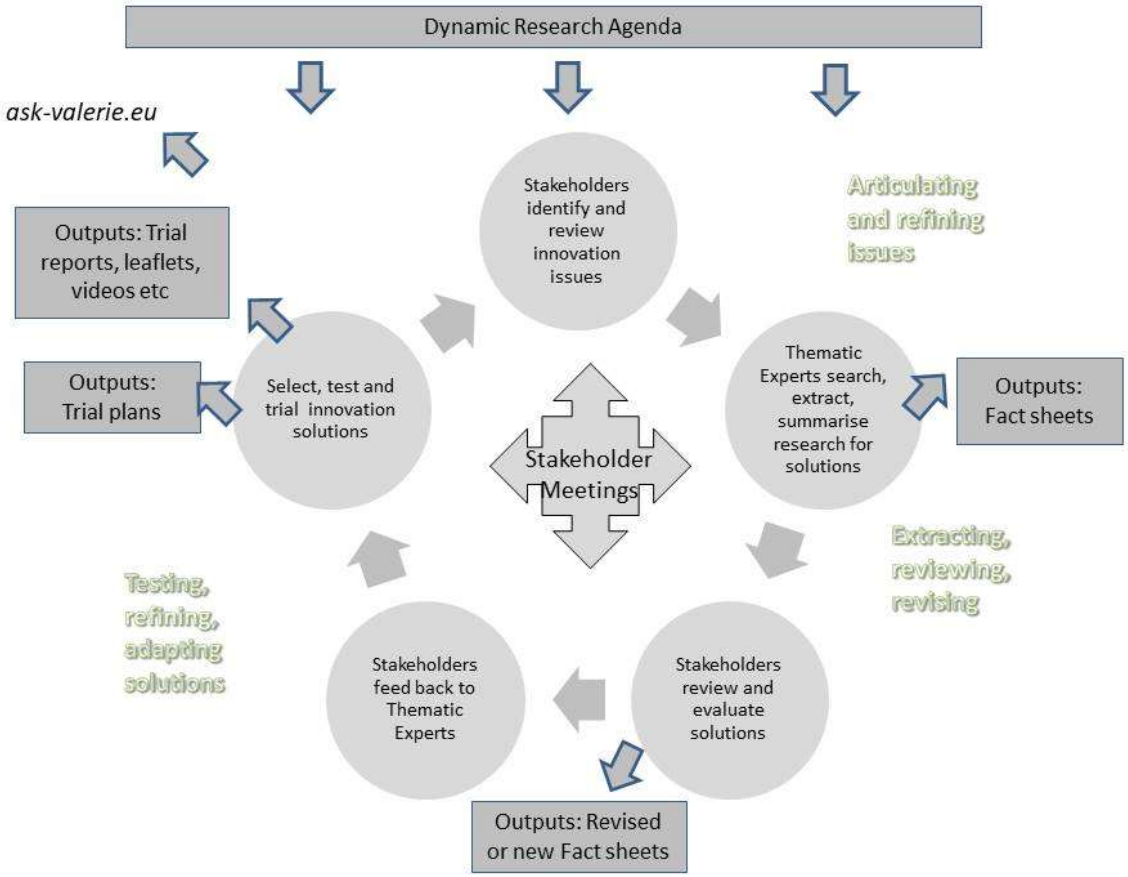
Case studies and their stakeholder communities are at the core of the co-innovation process as described in Deliverable 3.341. Ten CSs were selected to represent different regions and production systems across the themes, and are organised around a particular supply chain, sector, or landscape, and so cover different scales and dimensions and incorporate different stakeholder communities.

The methodology is underpinned by an iterative or cyclical process based on regular participatory meetings with stakeholders in the CS (see Figure 2.1). The cycle starts with stakeholders in each CS identifying innovation issues and articulating these as issues, research needs or questions in participatory meetings. These meetings are facilitated by Case Study Partners (CSPs), project partners who are extension specialists connected to the CS. Thematic Experts, who are project scientists (who also attend the meetings) then search existing scientific literature for innovation solutions to address these issues, and extract, synthesise or summarise the relevant solution-oriented research findings (factsheets). Stakeholders screen, evaluate and refine these solutions for their innovation potential and feedback to the project Thematic Experts, thus completing one cycle. The cycle is repeated and, at each iteration, innovation issues and solutions are reviewed, re-articulated and refined, further information or clarification (by stakeholders and Thematic Experts) is sought and new or modified innovation issues and solutions are generated.

A key tool in the process is the Dynamic Research Agenda (DRA) which CSPs use together with stakeholders to monitor, review, revisit and refine the innovation issues and solutions at each meeting. A minimum of five stakeholder meetings are held in each CS over the project period, however, stakeholder and CSP interactions take place throughout. As the cycles progress the stakeholders identify trials to apply and test the potential of selected innovation solutions in the local context (trial plans and reports). The research team has been working

together with the stakeholders to apply, test and refine screened research outputs in CS, evaluating their innovation potential in the local context, assessing the viability of solutions. These trial results feedback into the iterative process and provide co-created empirical knowledge (trial leaflets) to be integrated into ask-Valerie.eu. The trials are particularly important for the stakeholders as it provides a concrete output of their involvement in the project. This tangible output was considered an important element of the project and of the co-innovation process overall. Selecting and operationalizing the trials themselves ensures that they address issues of significance and relevance to stakeholders.

Figure 2.1 Stakeholder interactive methodology



3 Research outputs

3.1 Introduction

As such research outputs are created as tangible outputs at different stages of the process (see Table 3.1):

- Identifying innovation issues. Monitoring the process, feedback, adaptation with the *Dynamic Research Agenda.*
- Translating research outcomes with innovation potential into formats for use by end-users (farmers, advisers, and enterprises in the supply chain) creates *factsheets.*
- Testing and refining research outputs in CS settings creates *trial plans, reports and leaflets.*

Table 3.1 Research outputs produced in each stage of iteration

Stage of iteration	Research outputs
Identifying innovation issues. Monitoring the process – prioritization, feedback, adaptation etc.	• Dynamic Research Agenda (DRA) diagram
Translating research outcomes with innovation potential into formats for use by end-users (farmers, advisers, and enterprises in the supply chain)	• Factsheets on innovation • Mini factsheets on innovation
Testing and refining research outputs in CS settings	• Trial/demonstration plans and reports • Stakeholder trial/ demonstration leaflet • CSP produced outputs (leaflets, articles, farm walks/open days, videos etc.)

3.2 Dynamic Research Agenda

The DRA were used as a tool in each CS to identify the innovation issues and then monitor, review, revisit and refine with stakeholders the innovation issues and solutions at each meeting and document the co-innovation process. The DRA is modified from the Dynamic Agenda, a reflexive learning-oriented monitoring process (Van Mierlo et al., 2010). DRAs were created in each CS by the CSP following training and guidelines provided and with WP3 input. They document a process of moving from an unstructured, generic problem to a series of specific issues that contribute to a problem. From this series of specific issues, the CSP and the stakeholders are trying to focus down and identify the subject of a trial. The DRA also provides a means of understanding the iteration, dialogue and adaptation following the Thematic Experts' inputs and the stakeholders' feedback. They reveal how Thematic Experts start to understand user requirements (and contexts), interpret research outputs and factsheet design and how stakeholders evaluate, utilise and adapt research. The DRA illustrate how the process is not always linear or straightforward with stakeholders sometimes lacking consensus on the topic or the CSP steering the selection to ensure that the trial is within the scope and timeframe of the project. As such the DRA reveal and document the complex and flexible process of co-innovation.

3.3 Factsheets on innovation

In the preliminary meeting stakeholders identified innovation issues and research needs. In response the project Thematic Experts created bespoke factsheets summarising and

synthesising the relevant research to provide an innovation solution. In extracting research, Thematic Experts apply a systemic and organised search for published scientific knowledge using conventional search engines. They also search national repositories and databases, EU sources (CORDIS, EIP) and international projects. Reports, scientific publications, grey literature, technical notes relevant to the CS issues are retrieved and provided to stakeholders. The most relevant are used to prepare factsheets of specific innovation solutions for the stakeholders, typically a two page synthesis with a common template (innovation issues, innovation challenges, innovation solution, evidence of benefits, and drawbacks). A list of the factsheets prepared for the CSs is presented in Annex 1.

Stakeholders evaluated these following a structured process common to all CS and fed back on both the content and the format, asking for more details, clarification or a different focus, as described in Deliverable 3.341. These factsheets provided the basis for the dialogue that continued in the subsequent meetings. Whilst some were unused, others stimulated further more focused interest in a topic and led to the selection of trials to test out the research. These factsheets also provide useful synthesises of research which have been added to ask-Valerie.eu.

In addition to these bespoke CS factsheets, a number of mini-factsheets were also created by project Thematic Experts identifying innovations related to the 6 project themes, as described in Deliverable 2.261 *Mid-term version catalog potential innovations for the methodology*. A mini-factsheet is a short document containing an overview of the innovation, links to practical and scientific documents describing the innovation, links to projects where the innovation was studied or developed, the issues that the innovation wants to address, and the related concepts (terms taken from VALERIE's ontology to facilitate search with ask-Valerie.eu). Mini-factsheets include both scientific papers and practically-oriented documents (e.g. factsheets, guidelines). A list of the mini-factsheets prepared for the CSs is presented in Annex 2.

3.4 Stakeholder trial/demonstration leaflets

Each CS, after 2-3 stakeholder meetings, identified a topic for a trial based on evidence provided by factsheets and internal negotiation. The aim of the trials was to test and screen research outputs in the local context and at farm level. In most cases the trials were conducted on stakeholders' fields. These ranged in scope, format and length from formal scientific trials to less formal demonstration plots and one-off field trips. Some developed existing research ideas while others pioneered new research. For many the innovation was as much about the overall approach of involving stakeholders as it was about in producing rigorous scientific outputs. The trial plans were provided by CSPs for each CS followed guidelines provided by the WP3 team and according to allocated budgets. Subsequent report sheet protocols were completed by CSPs when the trial results were available.

Based on the trial sheet reports each CSP compiled a trial/demonstration leaflet. These are 2-4 page illustrated leaflets in pdf format which will be used to disseminate main trial findings. They follow the same template and intend to describe the stakeholder involvement in the trial process as well as the main research findings. Where appropriate they are accompanied by annexes containing more detailed results. Stakeholders were keen to share their findings with others working on similar issues. They also favour short precise factsheet or technical note format. Their preferences helped to steer the design of the leaflets.

3.5 Case Study Partner produced outputs

In a number of the CSs additional material about the trials and CS activities in general were prepared such as leaflets created by stakeholders, articles, and videos. Activities including farm walks, open days and technical expert presentations were also part of the CS portfolio of research outputs.

4 Sustainable forest biomass, Finland

4.1 Context

Wood ash is a waste product from biomass power stations. There is a need to understand the potential value of wood ash as a forest fertilizer, and so contribute to the circular economy in Finland. Wood ash fertilizer is already used effectively on peat forest soils in Finland but little is known about the impacts of using it on mineral forest soils. The possibility of using wood ash for road construction is also of interest to the stakeholders.

TAPIO working with the VALERIE project has brought together forest owners and managers, ash producers, ash operators, researchers, developers, and policy-makers to identify innovations in forestry practice in Finland. It was particularly important to get the decision makers to understand the value of wood ash.

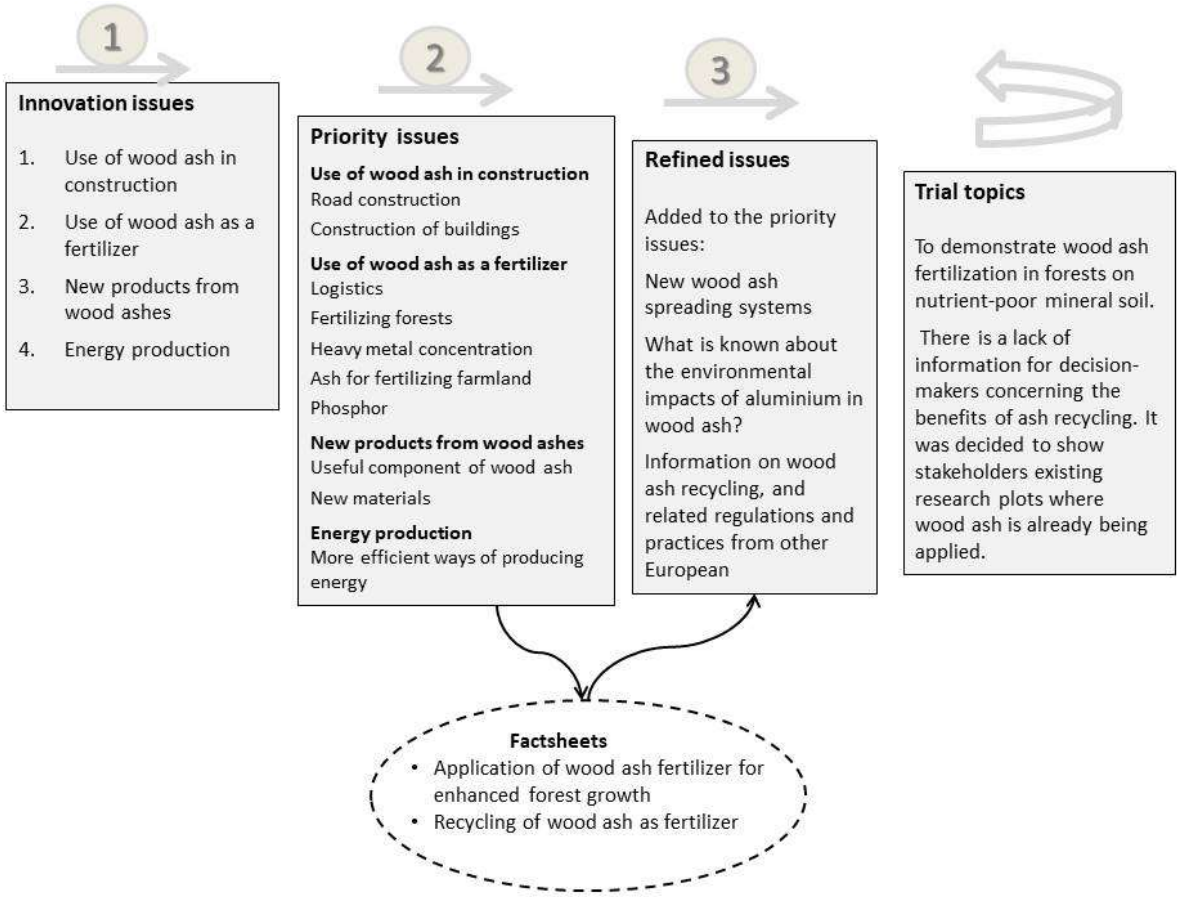
4.2 Dynamic Research Agenda

The first meeting included a wide range of stakeholders with an interest in the use of forest biomass for energy production and wood ash recycling. In the participatory workshop during the drafting of the DRA a range of issues were identified relating to regulations for ash recycling, heavy metal concentration in ash, low profitability of ash recycling and small size of the forest plots. After the initial discussion 4 main innovation issues were identified for further consideration:

1. Use of wood ash in construction.
2. Use of wood ash as a fertilizer.
3. New products from wood ashes.
4. Energy production.

As the DRA in Figure 4.1 shows the stakeholders then identified 10 priority issues. In the second meeting the priority issues were revisited and stakeholders identified additional research questions. Stakeholders also reported that a major issue preventing the recycling of wood ash is the lack of information about the positive impact of wood ash among key decision makers (e.g. cities, municipalities and regional organisations). The stakeholders and CSP decided that the trial could be used to help address this. The main area of interest is the use of wood ash as a fertilizer for forest mineral soils, wood ash is already used for forest peat soils. As forestry trials take a long time to establish and provide results, the trial took the form of a demonstration field trip showing stakeholders existing research plots where wood ash is already being applied. This provides an opportunity to demonstrate existing trials and to collect information about the benefits, the barriers and the feasibility of using wood ash as a fertilizer.

Figure 4.1 Sustainable Forest Biomass Case Study Dynamic Research Agenda



Two factsheets were produced after the first meeting by the Thematic Experts:

- Application of wood ash fertilizer for enhanced forest growth.
- Recycling of wood ash as fertilizer.

In the second meeting the stakeholders reported that they were mainly satisfied with the subject matter of the factsheets but they should be translated from English to have a greater impact across the target audience, many of whom did not speak English. The review of the DRA identified two additional topics which the stakeholders thought would benefit from factsheets.

4.3 Factsheets on innovation

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Application of wood ash fertilizer for enhanced forest growth

Picture source: http://energiaklass.wordpress.com/2012/05/24/on-the-15-17-may-an-ash-recycling-benchmarking-was-held-in-vaxjo/

What is it?

Approximately 600,000 tonnes of wood and peat ash is generated in Finland annually as by-product of energy production. Of this, wood ash represents about 150 000 tonnes per year (25 %). In Sweden, 800 000 tonnes of ash are produced annually. Of this, 300 000 tonnes consist of pure wood ash that is capable of being recycled[4]. Ash effectively reduces soil acidity and pure wood ash contains all the nutrients that trees need for their growth, except nitrogen (N)[1]. Ash fertilization can be used to restore the nutrient imbalance in intensively managed forest and increase forest production.

1

Problem to be solved

Less than half of the total amount of pure wood ash produced in Sweden and Finland is currently re-used as fertilizer[4] and large amounts of wood ash are still disposed of in landfills. There are opportunities to reduce the amount of wood ash disposed in landfills and re-use this useful material to a greater extent, for instance as a forest fertilizer.

How does it work

Before application, the wood ash has to be stabilised to avoid problems with dust, and to avoid direct damage to soil or vegetation. Therefore, only granulated or self-hardened ash is permitted for use as forest fertilizer. Granulation is the most effective ash stabilisation method currently in use. The fertilizer product can be enhanced during the granulation process by mixing together different types of ash or by adding nutrients. Boron, and occasionally phosphorus or potassium, are added into ash products that are intended for forest fertilization[2]. After granulation the ash is spread to the forest by tractor or helicopter.

Wood ash fertilizer by Ecolan.

Advantages and disadvantages of the practice

+ Positive impact on tree growth, especially on drained peatland forests

Ash fertilization causes long-lasting improvements in a stand's nutrient condition. These effects last at least 30 years[3] and sometimes up to 50 years, which is considerably longer compared to chemical fertilizers[4]. Most likely this long lasting effect can be attributed to an optimized pH of the soil which stimulates microbial activity (including nitrifying bacteria)[3]. Ash has good fertilization effects on nitrogen-rich drained peatlands, where tree growth is limited by poor availability of potassium and phosphorus. These sites are typically *Vaccinium vitis-idaea* and *Vaccinium myrtillus* type forests with a thick layer of relatively decomposed peat[1,2]. Ash fertilization increases tree growth depending on the amount of nitrogen in peat[5]. On nitrogen-rich sites the increase in tree growth is approximately 2-6 m^3/ha/y and on nitrogen-poor sites 1–3 m^3/ha/y during one rotation. In Finland, depending on the nutrient contents, approximately 3-5 tonnes/ha of ash needs to be spread in peatland forests in order to meet the recommended nutrient quantities for fertilization (P 40–50 kg/ha and K 80–100 kg/ha)[6]. Due to the fast dissolution of potassium and possible leaching, some sites may need

two rounds of fertilization per rotation[1,2]. In Sweden, the maximum amount allowed is 3 tonnes/ha per 10 year period, or 6 t/ha during the whole rotation period.

+ Speed up re-vegetation in cut-away peatlands

Ash fertilization is suitable for cut away peatlands[2] that will be afforested for energy wood production or re-vegetated for environmental reasons. Tree growth on cut-away peatlands is mostly limited by a lack of phosphorus and potassium and occasionally also by lack of boron. Ash fertilization is a good alternative for commercial P-K fertilizers. The recommended dosage is: P 50 kg/ha, K 80–150 kg/ha and B 1.5 kg/ha[7]. This equals to about 3-5 tonnes ash/ha[6].

+ Possibilities to enhance tree growth on poor mineral soils

On mineral soils, tree growth is limited by a lack of nitrogen, and therefore ash fertilization usually does not increase tree growth. However, in mineral soils ash fertilization can be used to prevent growth disorders caused e.g. by nutrient imbalances or lack of boron[2]. In addition, ash fertilizers can be supplemented with nitrogen. Experiments have demonstrated increased tree growth on poor mineral soils after applying ash fertilizer with added nitrogen[3,4,8,9]. Nitrogen fertilization gave a positive effect on tree growth which lasted for about 5-7 years. When nitrogen fertilization was applied in combination with wood ash, this positive effect on tree growth lasted for longer periods, in some cases up to 30 years[3,8,9].

+ Impact on soil

Ash fertilization reduces soil acidity and causes a long-lasting increase in the total nutrient stores of the surface soil[4]. Ash can be used to replace nutrient losses caused by wood biomass harvesting and to prevent soil acidification. Ash fertilising can be supplemented with added calcium or lime[4]. In Sweden, ash fertilization has been applied mainly as a measure to counteract acidification[4]. Moreover, ash fertilization increases soil microbial activity which in turn speeds up the decomposition of organic matter and the release of nitrogen to plants which is beneficial for plant growth[3,8].

- Heavy metal concentrations

Some power plants and some areas in Finland generate wood ash that exceeds the maximum concentrations allowed for heavy metals. For example, the cadmium concentration of ash may not exceed 25 mg/kg and the arsenic concentration cannot exceed 40 mg/kg[12]. Small amounts of contaminated fuel fractions can already cause high concentrations of heavy metals in the ash. Therefore, it is recommendable that power plants ensure that wood and peat fuels do not use any polluted fuels sources such as lead-contaminated demolition wood[4].

Costs

Ground spreading by tractor is more common and more cost-efficient compared to aerial spreading by helicopter (see also factsheet 'Recycling of wood ash as fertilizer'). In Finnish conditions, the costs for aerial spreading were about 241 €/ha and for ground spreading about 167 €/ha[10].

Other resources required

In Finland, recommendations for ash recycling are provided by Forestry Development Centre TAPIO[11]. The utilisation of ash as fertilizer is regulated by the Fertilizer Product Act (539/2006) and related decrees (Ministry of Agriculture and Forestry Decree 24/11)[12]. The Finnish Food Safety Authority Evira is in charge of the supervision of fertilizer products. Ash samples need to be analysed by a qualified laboratory before the ash can be used as a forest fertilizer. In general, samples should be taken from lots of 250 - 500 tonnes of ash, or at least once per firing season[4]. For Sweden, recommendations for ash recycling are given by the Swedish Forest Agency[13].

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Swedish Forest Agency, Head office: Vallgatan 8, Jönköping, Postal address: S-551 83 Jönköping, Sweden, www.skogsstyrelsen.se

Source of the research

The Granulation of Ash in North Ostrobothnia project [In Finnish: Tuhkan rakeistus Pohjois-Pohjanmaalla] European Regional Development Fund (ERDF)(2007-2013) of the European Union

EU Life project ReCash [Regular Recycling of Wood Ash to Prevent Waste Production] http://www.skogsstyrelsen.se/en/AUTHORITY/Projects/Avslutade-projekt/Internationella-projekt/RecAsh/

National research, e.g. by the Finnish Forest Research Institute (METLA) http://www.metla.fi/

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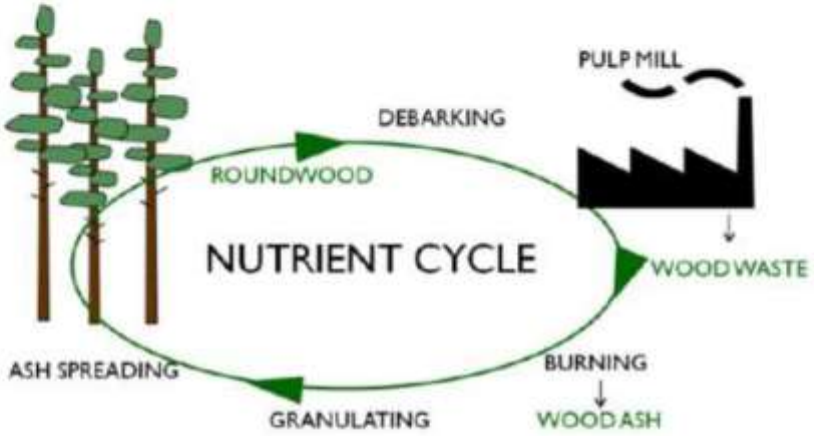
Valerie

Recycling of wood ash as fertilizer



Picture source: www.promobio.eu

What is it?

Ash from energy wood can be pelletized and returned to the forest to maintain the nutrient balance and reduce acidity of forest soils.

Ash contains all the nutrients that trees need for their growth, except nitrogen, and returning these helps to maintain or increase forest production. Ash also contains heavy metals and is classified as waste. In Sweden and Finland there is wide experience with legislative and technical aspects of recycling of wood ash as fertilizer. This knowledge is transferable to other contexts.

Problem to be solved

Energy production from forest biomass generates large volumes of ash that may end up in landfill. Recycling of the ash reduces landfilling, and is required to maintain fertility and reduce acidification of forest soils. For energy production, annually about 300 000 tons of pure wood ash is produced in Sweden and 150 000 tons in Finland. In addition, power and heating plants produce peat ash in larger volumes, and it is sometimes mixed with wood ash. The pulp and paper industry also produce substantial amounts of ash. Pure wood ash has most opportunities for recycling because of a more suitable nutrient ratio compared to peat ash.

1

How does it work

Ash is granulated or pelletized and returned to forest area. The granulated ash can be spread through ground application or by helicopter, and if needed combined with lime and/or nitrogen fertilizer. Dosage depends on soil fertility and in Sweden maximum values are given for forest fertilization to prevent negative impacts: 3 t/ha of ash dry matter per 10 year period, or 6 t/ha during the total rotation period. The fertilizer effect lasts for decades as the ash granules slowly dissolve.

Advantages and disadvantages of the innovation

Ash recycling maintains the nutrient balance of forest soils and reduces soil acidification, thereby maintaining forest productivity on the long term. Heavy metal concentrations in ash can exceed the maximum allowable limits, depending on the concentration in the harvested biomass. Use of waste wood or mixing ash from fossil fuel may also increase heavy metal content. In addition, mixing with peat ash may lower the nutrient concentration (Ca, P and K), making the ash less suitable as fertilizer.

Costs

Ground-based spreading is cheaper than spreading by helicopter (Table). A study in Finland on fertilization of peat-land forest with wood ash showed a positive internal rate of return of investment of 3-12 percent.

Table. Comparison of costs (€/ha) of forest fertilization with granulated wood ash and chemical fertilizer in Finnish conditions (data from 2006; source: Väätäinen et al., 2011).

	Granulated ash		*Chemical fertilizer*
	Helicopter	*Forwarder*	*Helicopter*
Price of fertilizer	*80*	*80*	*156*
Transportation costs	*28*	*28*	*9*
Spreading costs	*118*	*44*	*23*
Supervision costs	*15*	*15*	*15*
Total costs	*241*	*167*	*203*

Large ground spreaders can drive on skid roads while smaller tractors, usually farm tractors of various types, can be driven into the stand without using skid roads. If ash is applied to wet ground, in association with precipitation or at the wrong time of year, the spreading vehicle may cause machine tracks and root damage. On peat soils it is recommended to carry out ash spreading in winter when the ground is frozen and protected by a thick snow cover.

Helicopter spreading is more flexible than ground spreading as it avoids problems concerning the bearing capacity of the soil. Spreading by helicopter can also be a viable option in dense stands where there are no roads, on steep slopes or in other inaccessible terrain where ground spreading is difficult. However, the cost of helicopter spreading is higher compared to ground spreading.

Legal aspects and guidelines

Policy, legislation, certification, and recommendations and guidelines differ between European countries, and an overview is given by Stupak et al. (2007). Utilisation of wood for energy is often not encouraged in forest legislation, and sometimes even restricted for environmental reasons. For Sweden, updated recommendations for ash recycling are given by the Swedish Forest Agency (2008), referring to Swedish legal regulations. For Finland, recommendations for ash recycling are provided by the Forestry Development Centre TAPIO (2014) and is regulated by the Fertiliser Product Act (539/2006) and related decrees (Ministry of Agriculture and Forestry Decree 24/11).

Contacts (manufacturer, service provider, developer)

FA Forest Ltd, P.O.Box 2000, 70601 Kuopio; visiting address: Viestikatu 3, 70600 Kuopio, Finland (www.ecolan.fi/)

Swedish Forest Agency, Skogsstyrelsen, SE- 551 83 Jönköping, Sweden, +46 36 35 93 00 www.skogsstyrelsen.se/en/

Source of the research

Projects: RecAsh, PromoBio (EU but not FP5-7) and Wood-en-man

References

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3

4.4 Stakeholder trial/demonstration leaflets

Valerie

This project is funded as a collaborative project under the 7th European Framework Programme,Grant Agreement No.: FP7-KBBE-2013-7-613825-VALERIE Duration: January 2014 – December 2017

Valorising European Research for Innovation in Agriculture and Forestry

VALERIE Stakeholder Trials:

Demonstrating the use of wood ash as a forest fertilizer on mineral forest soils in the Joensuu area, Finland

The problem

Wood ash is a waste product from biomass power stations in Finland. There is a need to understand the potential value of wood ash as a forest fertilizer, and so contribute to the goals of a circular economy in Finland. The volume of ash is increasing all the time and recycling it is expensive. There is a lack of information about wood ash use for the growing number of people involved in small energy and heat plants. Use of wood ash fertilizer presents a potentially economically viable solution to address problems with nutrient poor forest soils and associated declines in tree growth. Wood ash fertilizer is already used effectively on peat forest soils in Finland but little is known about the impacts of using it on mineral forest soils.

The proposed solution

The target of this 'trial' is to demonstrate wood ash fertilization in forests on nutrient-poor mineral soil. Under current forest management, the stands are harvested by logging and the nutrients are removed from the site. Using the wood ash offers a chance to return nutrients to the soil as has already been demonstrated in peat soils. Other recycling options such as road construction were also discussed and demonstrated but are not reported here.

Stakeholders

TAPIO working with the Valerie project has brought together forest owners and managers, ash producers (e.g. community energy cooperatives), ash processors and operators, researchers, developers, energy providers and policy-makers to identify innovations in forestry practice in Finland. These stakeholders identified the potential for wood ash to be used as a fertilizer on mineral forest soil. In the Joensuu area the share of bioenergy in energy production is very high and there are plenty of organisations who are interested in wood ash recycling. Ecolan (an ash processor) has a long practical experience of wood ash analyses, forest fertilizers and other wood ash products making them one of the key stakeholders.

Aims and Method

As forestry trials take a long time to establish and provide results it was decided to show stakeholders existing research plots where wood ash is already being applied. This provided an opportunity to demonstrate existing trials and to collect information about the benefits, the barriers and the feasibility of using wood ash as a fertilizer.

Demonstration field trips were held with TAPIO organisers and some 20 stakeholders from a range of organisations in the Joensuu area to look at:

- Demonstration of the use of wood ash plus nitrogen fertilization on mineral soil at a pilot study site run by Ecolan
- A 40 year old wood ash fertilized peatland forest and a control stand without wood ash

During the field trip, stakeholders were also asked to complete a questionnaire about the barriers to wood ash use. In addition to the site visits there were expert presentations about the chemistry of wood ash and its effect on mineral soils, the influence of the wood ash on forest berries and mushrooms and forest biodiversity.

Results

Granulated wood ash fertilization samples with and without nitrogen

Demonstration of wood ash fertilization with nitrogen on the mineral soil.

Ecolan presented a new fertilizer where wood ash has been combined with nitrogen (urea from Yara) and granulated to make its spreading easier. In this established demonstration (with different treatments of wood ash), wood ash with nitrogen was used to fertilize the mineral soil forest. In total the fertilizer treatment consisted of 2700kg/ha wood ash with 300kg/ha nitrogen. Newly developed machinery was demonstrated for wood ash spreading in the mineral soil forest. Results from this formal trial were not yet available. The stakeholders were enthusiastic about the new product and saw the machinery, which was new to them, spread the ash easily. They also learned that the rainfall dissolved the wood ash quickly making it available for uptake by trees.

Wood ash spreading equipment mounted on a forwarder

Demonstration of a 40 year old wood ash fertilized peatland forest

The stakeholders visited an old wood ash fertilizer experiment on a drained peatland where they observed the positive influence of wood ash on peatland forest. The fertilization, which took place 40 years ago, increased growth of Scots pine trees and the financial performance of forest management has increased significantly compared to a control plot. The stakeholders were particularly interested in the obvious difference between fertilized and unfertilized stands and this stimulated discussion about the importance of old experimental stands.

The development of annual volume growth of Scots pine 1985–2010.

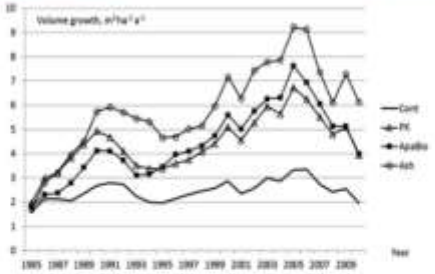
PK = PK for peatlands 600kg ha^{-1},

Apa =Apatite 385kg ha^{-1};

Bio = Biotite 1700kg ha^{-1};

Ash = Wood ash 4500kg ha^{-1}, dust-like wood ash from a heating plant in Oulu city

(Moilanen et al., 2015)



The area fertilized by ash

The control area

The ash fertilization has compensated for the lack of phosphorus and potassium and increased the volume growth six times compared to the control.

Photos: Jorma Issakainen

Overall stakeholder involvement and feedback

The demonstrations improved the stakeholders' awareness of using wood ash fertilization in forest mineral soils. They valued the opportunity to see demonstrations in the field, this helped to stimulate discussion and identify the stakeholders' expectations and opinions about wood ash fertilizer. In summary:

- Stakeholders strongly support ash fertilization because it offers a use for the waste product of the combustion process. It is a natural fertilizer and helps to restore the nutrient balance of forest soil after felling. For them the positive impact on soil fertility is that it lasts considerably longer than that of artificial fertilizers.
- The most significant obstacle to ash utilization seems to be the lack of knowledge about the beneficial effects (on soil nutrient content and tree growth) of wood ash fertilizer. The higher total cost of ash fertilization compared to artificial fertilization and the lack of operators offering ash fertilization were also mentioned as limitations.
- The main risks and challenges of ash fertilization (compared to the use of artificial fertilizers) according to the stakeholders are:
    - the product and its composition (e.g. N-content) are unknown,
    - the ash quality is important, any contamination with other wastes will negatively affect the quality of ash
    - demand and supply (ash production and granulation) do not necessarily coincide in the same area
    - the spreading of dry ash is especially difficult, and
    - there is a lot of regulation related to ash fertilization

When asked what should be done to remove the barriers, stakeholders agreed that improved information and practical education (work guidance, workshops etc.) showing the positive growth effects, and making the price competitive, are needed. In particular, they felt that policy makers and forest owners need to understand the value of wood ash, and regard it as a useful by-product rather than a waste product.

Key findings

- Stakeholders identified wood ash fertilizer use on mineral soils as a key innovation opportunity.
- Existing demonstration sites and trials provide evidence and practical insights of spreading of wood ash and its impact on yield.
- The barriers of using ash (include limited information, unknown quality, practical and institutional limitations) should be addressed through dissemination of information and awareness raising.

Further reading

Moilanen M., Hytönen J., Hökkä H., Ahtikoski A. (2015). Fertilization increased growth of Scots pine and financial performance of forest management in a drained peatland in Finland. Silva Fennica vol. 49: 3

Acknowledgements

TAPIO (https://tapio.fi/) and EFI (http://www.efi.int/portal/) are partners in VALERIE.

We wish to acknowledge the following persons and companies:
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Wood ash

Stakeholder visit to a forest renewal site

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5 Agroecology: managing plant protection, France

5.1 Context

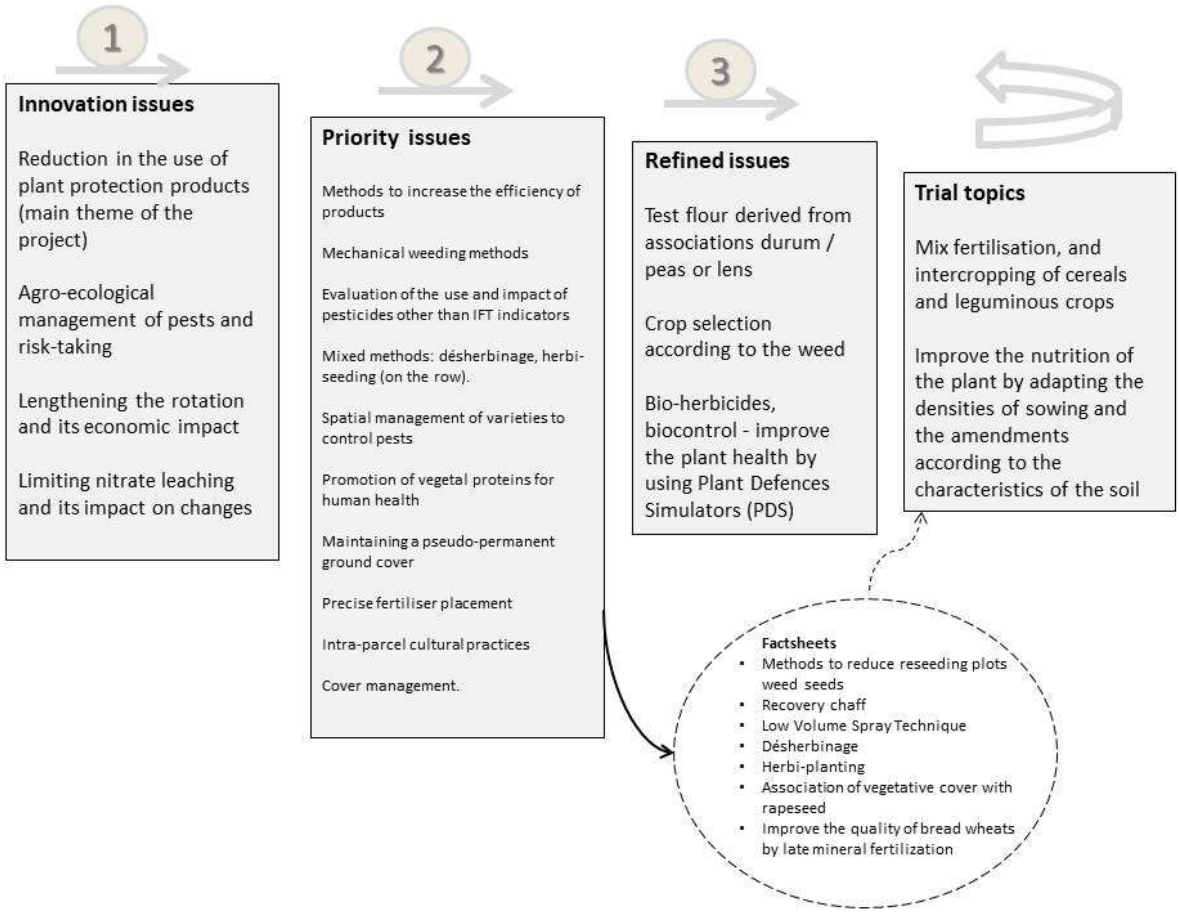
This CS is concerned with agro-ecological farm management. It draws on an existing project run by the Qualisol cooperative. This cooperative has set up a project funded under the agro-ecological plan for France called CASDAR "*collective mobilization project for the agroecology*". This builds on a previous initiative with 31 interested farmers. Covering the area of a watershed, the project brings together relevant technical partners: two other cooperatives, technical institutes, an agricultural college, a water association and research teams. The project focuses on the thematic priorities for Arable Farming Systems in a water stake territory:

- Reduction in the use of plant protection products (main theme of the project).
- Agro-ecological management of pests and risk-taking.
- Lengthening the rotation and its economic consequences.
- Limiting nitrate leaching and its impact on changes in agricultural techniques.

5.2 Dynamic Research Agenda

The DRA (Figure 5.1) shows that 4 broad themes of research need were identified by the stakeholders in the initial meeting: Reduction of the use of herbicides and the optimization of fertilization in arable crops; Agro-ecological management of pests and risk taking; Lengthening the rotation; Limiting nitrate leaching. The 4 themes were explored in more detail by the stakeholders, which in turn generated 10 priority issues. The stakeholders then went on to identify further research needs: Test flour derived from associations durum / peas or lens; Crop selection according to the weed, and Bio-herbicides, biocontrol - improve the plant health by using Plant Defences Simulators (PDS). The topic Bio-herbicide control was primarily selected for trial: "Bio-herbicides and regulation of plant cover" and stakeholders requested further information to support this trial. However it became evident that this was not possible due to restrictions in using the bio-herbicides. Following a reappraisal between the CSP and the stakeholders, the trial topics as listed in the DRA were selected and implemented.

Figure 5.1 Agroecology Case Study Dynamic Research Agenda



The Thematic Experts prepared 7 factsheets. The factsheets were reviewed and evaluated by the stakeholders and two of them were considered to identify important innovations which should be explored further. Overall the stakeholders found the contents of the factsheets to be too general or covering techniques already mastered by farmers.

5.3 Factsheets on innovation

Valerie

Combine row crop sowing and herbicide band-spraying

Contact: Yolaine Hily (INRA, UMR AGIR, yolaine.hily@toulouse.inra.fr)

What is it?

Row crop sowing and pre-emergence herbicide band-spraying performed at the same time. Soil active herbicide is only sprayed on the row; consequently the herbicide quantity is reduced.

Problem to be solved

According to a European directive, pesticide use has to be reduced. This technique can ensure both an effective weed control and a significant reduction of pesticide applied (40 to 60%).

How does it work?

Sowing of row crops (maize, oilseed rape, sunflower, soybean, sugar beet...) is combined with band-spraying of pre-emergence soil active herbicide. This spraying is localized on the crop row (intra-row). Inter-rows hoeing can be performed afterward to control weeds between rows.

Optimal conditions:

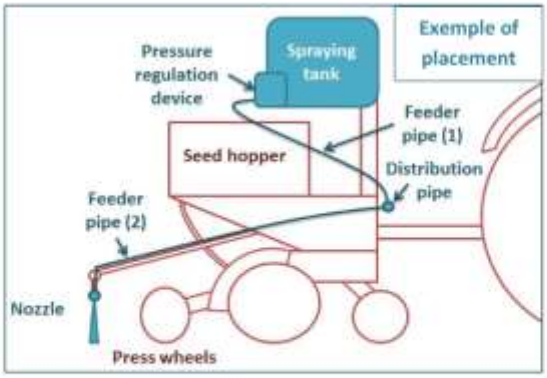
This technique is adapted to almost all soil types, except stony soils. Soil active herbicides are also more efficient on moist soils, and on soils with low organic matter.

Material:

- Spraying tank (200 to 1500 L)
- Electric pump
- Pressure regulation: manual or electronic
- Uniform coverage flat fan nozzles (spraying has to be homogeneous since there is no overlapping)
- Filters, pipes, anti-drip systems (one for each nozzle)

Principle of operation:

The spraying tank is placed on the front (better weight repartition) or behind the tractor (over the sowing machine) and supplies a nozzle per row. The spraying tank is linked, through the pump, to a distribution pipe which includes one exit per nozzle/seeding unit. The regulation device ensures the continuous treatment delivery and the right dose/ha. Herbicide



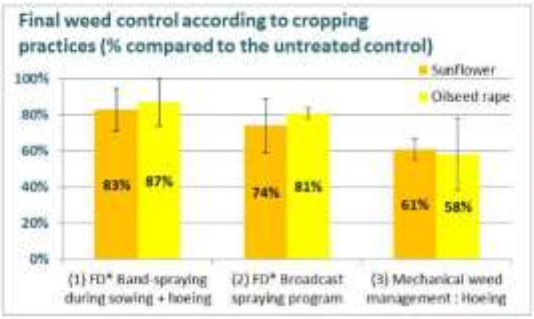
Valerie

treatment is applied directly after the press wheels of the seeding unit; the sprayed area is restricted to a band (10 to 20 cm on the both sides of the row → 20 to 40cm, *picture* below).

Inter-rows have to be maintained weed-free by hoeing; weed control can then be completed by localized herbicide spraying as well (*fact sheet available*). If needed, conventional spraying operations can be further performed.

Performances:

If the conditions are favorable (moist soil but no long rainy periods, no soil compaction), this technique associated with inter-row hoeing can be more efficient than conventional herbicide spraying (*chart below*).



*FD : Full Dose

Source CETIOM

According to field trials, combined band-spraying and sowing ensure an effective weeds management on the row if the weed pressure is low or medium. In case of extreme weather conditions favorable for weeds (rainy spring), this technique has to be associated with other weed control methods.

Remark: if a field is not perfectly square and if corners can't be maintained by hoeing, these latter have to be sprayed conventionally to reduce weed pressure.

Advantages and limits of the technique

+	-
• 40 to 60% herbicide use reduction → Economic and environmental benefits • Improved treatment efficiency since the soil has been freshly tilled • Almost no drift (nozzles are close to the soil) • No weed competition on the row up to one month • Time-saving technique	• Weight repartition on the tractor due to the additional spraying tank • The efficiency of the technique is variable according to the weather conditions • Higher concentration required from the driver to manage seeding and spraying at the same time

Costs

Cost of the equipment between 1000 and 6000€ (French data, without VAT) according to:

- the volume of the spraying tank;
- nozzles;
- options for the pressure regulation (electronic / manual).

Chaff recovery

What is chaff?

Chaff is composed of finely chopped straw, protective casings of the seeds of cereal crop, and parts of weeds (straw, seeds, flowers...). Generally, chaff is dispersed during harvest and buried into the soil during tillage. The seeds of weeds into the chaff are able to germinate, so it is necessary to use herbicides on the next crop.
The chaff quantity let into the field is the equivalent of the half the straw harvested:

	Wheat	Barley	Winter rape
Chaff	2.3 t/ha	1.5 t/ha	0.8 t/ha
Straw	4.2 t/ha	4 t/ha	2.3 t/ha
Seed	80 q/ha	70 q/ha	40 q/ha

Source: ETS Thierart

Problem to be solved

Chaff recovery allows to reduce the use of herbicides by exporting weed seeds out of the field, this is also a new product to valorise.

Principle: 2 methods

There are 2 methods to recover chaff:

- The method of recovery on the swath:

This method is easier regarding the logistic. Chaff gets out at the back of combine harvester by a turbine. This turbine projects chaff on the swath by a PVC pipe. So chaff is compacted with straw. This straw used as bedding in livestock farming contains viable seeds of weeds. So manure resulting of this bedding contains these seeds as well. Before using manure, it is necessary to compost it to destroy the seeds.

- The method of full recovery:

This method requires more workforce and equipment. A recovery system is installed at the combine harvester. The system is either (i) a trailer coupled at the combine harvester and the chaff is projected inside by a blower, or (ii) a compartment installed at the back of the combine harvester to stock chaff, the compartment is regularly emptied at the end of the field. Chaff is taken by a container or a baler. With this method, chaff can be used in more diverse ways.

Advantages

- Recovery of weed seeds and small or broken seeds of the harvested crop possible valorisation.
- Reduction of weed infestation with an impact on the soil seed bank and a significant effect after 2-3 years.
- Saving on herbicides.
- Limitation of the fungal diseases propagation like Fusarium head blight which develops on the protective casings of the seeds.
- No tillage and direct seeding facilitated.
- A solution to control herbicide resistant weeds in recovering the seeds of these weeds.

- It is applied at different crops: cereals, winter rape, peas, sunflower and corn.

For the method of recovery on the swath:

- Bale of straw density is higher. The weight of the bale is increased by 15%.

For the method of full recovery:

- Chaff is harvested alone. But can be valorised

Disadvantages

- The impact on the weeds is variable. It concerns only weeds which are mature at the harvest.
- Loss of organic matter in case of chaff recovery and no applications of organic fertilisers.
- The chaff yield is variable and depends on the conditions (time of the day, moisture) and on the type of combine harvester. The chaff yield is highest in the morning.
- Higher oil consumption of the combine harvester.
- Important financial investment for the equipment. This investment is different for both methods.

For the method of recovery on the swath:

- Risk of jam if chaff has a high moisture content and is in high volume.
- Obligation to reduce the speed of the combine harvester to keep the harvest clean.
- The system is difficult to dismount.
- The use of a swather is banned to keep the advantages of the method.
- Wind speeds can have a negative effect in making chaff fall next to the swath.

For the method of full recovery:

- Extra harvest time of 1 h/ha (emptying time and place).
- Difficulty to take chaff (pressing, loading, transport...).
- 20% of the combine harvesters can't be equipped.

Costs

The price is around 8 500€ for the method of recovery on the swath and around 28 000€ for the method of full recovery. But the price depends of the combine harvester to equip.

Uses of the chaff

- Food for farmed animals:

Interesting for chicken because chaff is rich in silica and trace elements and composed by small seeds. Rich in fibres and facilitating the ruminant digestion, chaff is also interesting for cattle. In addition, it is palatable food supplement.

- Bedding for farmed animals:

Chaff has over 4% of dust and a better absorption capacity than straw. In addition it has also a rapid warm-up due to the low moisture content.

- Methanization:

The chaff methanogenic power is two and a half times higher than corn silage methanogenic power and ten times higher than manure methanogenic power. Weed seeds are destroyed during the digestion.

- Alternative fuel:

Transformed into compact briquettes or granules, chaff is a good alternative fuel with a calorific value of 15 000 kJ/h. So 1 ha of chaff is the equivalent of 520 L of oil or 3 cubic meters of wood.

- Agro-materials:

Chaff can be entered in the composition of insulation or building materials.

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Low Volume spraying (LVS)

Contact: Yolaine Hily (INRA, UMR AGIR, yolaine.hily@toulouse.inra.fr)

What is it?

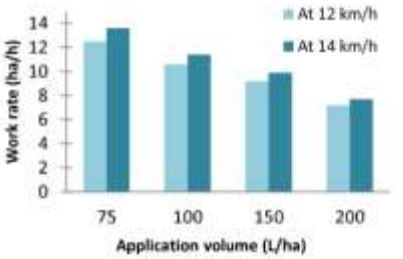
Low volume spraying consists in reducing the amount of water used to dilute the active ingredients in crop protection spraying treatments. Spraying volume is considered as low up to 80L/ha. This technique can be used for every crop (cereals, beets, oilseed rape, maize, vegetables...) and with most of the sprayers but must be adapted to pesticide formulation and target characteristics. This technic is more and more used but requires control of the main spraying parameters.

Spraying volume can be reduced to 30L/ha (Ultra Low Volume) but up to 50L/ha specialized sprayers have to be used.

Problem to be solved

Spraying volume reduction is not systematically associated with a chemical dose reduction, even if farmers associate these techniques often. The main objective of this technique is more to optimise spraying operations. Indeed, work rates for a given field spraying system are influenced by:

i) filling cycle,
ii) sprayer forward speed,
iii) above all, application volume (chart below).



Source : Computer modelling-TAG Silsoe Spray applications

How does it work

The most important issue in low volume spraying is to guarantee a good spraying quality, i.e. target coverage (percentage of treated surface area that has a chemical deposit, related to the amount of impacts on the target) and uniformity of the deposit. These parameters depend on amount and size of droplets and spraying pattern, but they are not influenced (within a certain range) by the amount of water used for spraying.

Lower carrier volume requires spraying medium-sized droplets (250-350µm), to reach optimal impact amount. But the smaller the droplets, the higher the risk of spray drift. Technical adaptations have to be implemented to ensure the spraying quality:

- Choose spraying parameters : driving speed, pressure and flow
- Spray with optimal environmental conditions is necessary when using low volume spraying:

Temperature	15 to 20°C during the day
Air moisture	75-80% (dew is really helpful in LVS)
Wind speed	Less than 5-10km/h
Soil moisture (for soil active products)	Moist soil is needed to secure the efficiency

Optimal spraying conditions are early in the morning or late in the evening.

- Adapt nozzles (find a compromise between number and size of droplets) and filtration systems (regularly maintained : the thinner the nozzle, the more risks of obstruction)
- Use eventually spraying adjuvants (oils/salts/wetting agents…): they must be adapted to the product applied and spraying conditions

Effects on the products:

Notice that the efficacy of plant protection products can be influenced by different parameters:

Impact of different factors on products performances		Soil active products	Foliar contact products	Foliar systemic products	Both foliar and soil active
Mixture properties	Lower carrier volume	0	--	++	0 to --
	Adjuvants	-	0	++	- to ++
Weather conditions	Temperature	0	0	+	0
	T variations	--	-	0	0
	Humidity	0	++	++	0 to ++
	Dew	0	- to +	+	++

Source : Arvalis (France)

Generally speaking, low volume spraying can benefit to systemic pesticides but can alter the protection efficacy of some contact products.

Chemical dose reduction may be possible but only for some products and in association with the best spraying conditions and preventive management (agronomy, regular monitoring).
Low volume spraying requires high technical skills to adapt the volume/products/parameters to crop/target/weather conditions. It takes several years to master the technique and technical advice is highly recommended to implement it on a farm.

➔ **Always consider your local conditions and consult a qualified agronomist if necessary**

Advantages and disadvantages of the innovation

+	-
- Time-saving (filling cycle and transport) - Cost reduction: Less water and fuel - Easily implemented on regular sprayers - Homogeneous / best spraying conditions (when properly operated) - Possible chemical doses reduction - Possible protection efficiency enhancement (less interaction with water components, higher concentration)	- Highly technical, technical advice required - Reducing drift nozzles could be necessary but few of them are adapted to carrier volume reduction (not under 80L/ha) - Requires optimal spraying conditions → reduced useful time "windows" - Risks of leave damages if too high concentration of pesticides

Costs

Low investment required for this technique (easily implemented with most of the regular sprayers). Nozzles and filters maintenance is key factor for the efficiency of the technique (around 300-400€; *French data*).

Other resources required

Weather measuring devices (measuring application conditions): thermometer, anemometer, hygrometer

Methods to avoid weed reseeding

Problem to be solved

Weeds present into a field are able to set seeds and so they are the main source of recharging the soil seed bank of the next years. The weed seeds are also brought into the field by the agricultural equipment, crop and cover crop seed, organic fertilizers, wind, animal, etc. Some methods limiting weed seeds inputs exist and can reduce the use of herbicides.

Methods to limit inputs of exogenous weed seeds

Weed seed inputs in the field can be limited by applying prevention methods:

- Using certified seeds:

The certified seeds have a specific purity guaranteed (percentage of impurities). In France, the State Service for control and seed certification establishes specific purity standard between 95% and 99% according to the crop species. Seed sorting is under control by professionals, so the weed seed rate is very low.

- Cleaning of the farm equipment:

Soil tilling equipment can be a dissemination vector of perennials between fields. Harvesting equipment is also a dissemination vector for many weeds. So to avoid transfers, it is necessary to clean the soil tilling and harvesting equipment. It is preferable to harvest first the cleanest fields and to finish by harvesting the most contaminated fields. Cleaning the combine harvester between two fields is also recommended. The combine harvester must be placed on a lane, in front of uncultivated area to be cleaned. If there is wind, the back of the combine harvester must be protected from wind to avoid the weed seed dissemination.

- Composting of the manure:

The application of manure can be a source of contamination by the seeds present inside fodders eaten by animals and straw used as bedding. A technique to destroy an important part of seeds present in the manure is to compost it. It is necessary to reach high temperatures for a few days. For example, a temperature of about 50°C during 3 days of composting fully devitalizes seeds of *Amaranthus retroflexus* and *Echinochloa crus-galli*. Generally, the time to compost manure in order to destroy all seeds is longer than 1 month. The outside temperature of the manure pile is lower than the inside temperature. So it is necessary to turn the pile regularly.

- Maintenance of the field borders:

The field borders are sources of contamination by weed seeds. Wind and water can transport weed seeds from field border which contaminate the field itself. These areas may show positive environmental functions as they can be refuges for beneficial insects or act as buffer zones to protect water courses from plant protection product and/or nutrient transfer due to runoff. So the fully destruction is not advised, but it is possible to mow these borders before weeds set seeds. To limit the seed transport by wind, it is advised to plant hedges on the field borders. Ditches and irrigation canals must be maintained too.

Methods to limit the self-supply of the field on weed seeds

Some methods avoid the weed seed production or the weed seed fall on the soil:

- Weed topping:

Principle: Generally, there is a difference in size between weeds and crop (weeds are higher than crop). The weed topping exploits this difference. The machine cut the flower of weeds before seeds are produced. The machine is placed in front of the tractor on the loader or at the place of counterweights. The cutting height is nearest and just over the crop. Weed topping can be used as a complement to other weed control methods.

Crop: This method can be used for all types of crop.

Efficacy: The efficacy depends on the height difference between crop and weed and the weed stem rigidity. If weeds are very flexible, they will be laid down and not cut by the machine. They keep growing after.

Advantages:

- Good efficiency against *Rumex crispus* and *Cirsium arvense*.
- Quick operating speed which is variable between 1 and 3 ha by hour.

Disadvantages:

- The machine is delicate and sensitive to jams and wind.
- Low efficiency against some weeds, for example wild oat (*Avena fatua*).

Costs: between 3 000€ and 11 800€ for a weed topping machine

- Chaff recovery:

Principle: Chaff recovery allows to recover weed seeds contained in chaff and to export them out of the field. There are 2 methods to recover chaff. The first method is to recover chaff on the straw swath. The second method is to install a compartment at the back of the combine harvester or to couple a trailer at the combine harvester where the chaff, with weed seeds, is projected inside.

Crop: This method can be used on cereals, winter rape, peas, sunflower, and corn crops.

Efficacy: The reduction of weed seeds in the soil seed soil is significant after 2 or 3 years.

Advantages:

- No tillage and direct seeding facilitated.
- A solution to control herbicide resistant weeds in recovering the seeds of these weeds.
- Chaff has various applications.

Disadvantages:

- The impact on the weeds is variable. It concerns only weeds which are mature at the harvest.
- Loss of organic matter if chaff is recovered and there are no applications of organic fertilisers.
- Higher oil consumption of the combine harvester.

Costs: The price is around 8 500€ for the method of recovery on the swath and around 28 000€ for the method of full recovery. But the price depends of the combine harvester.

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Valerie

Improving "Superior Bread" and "Improver Wheat" quality through late mineral fertilization

What is it?

It is a strategy of late-season N mineral fertilization based on granular and/or foliar application to increase protein content and improve protein quality of bread wheat..

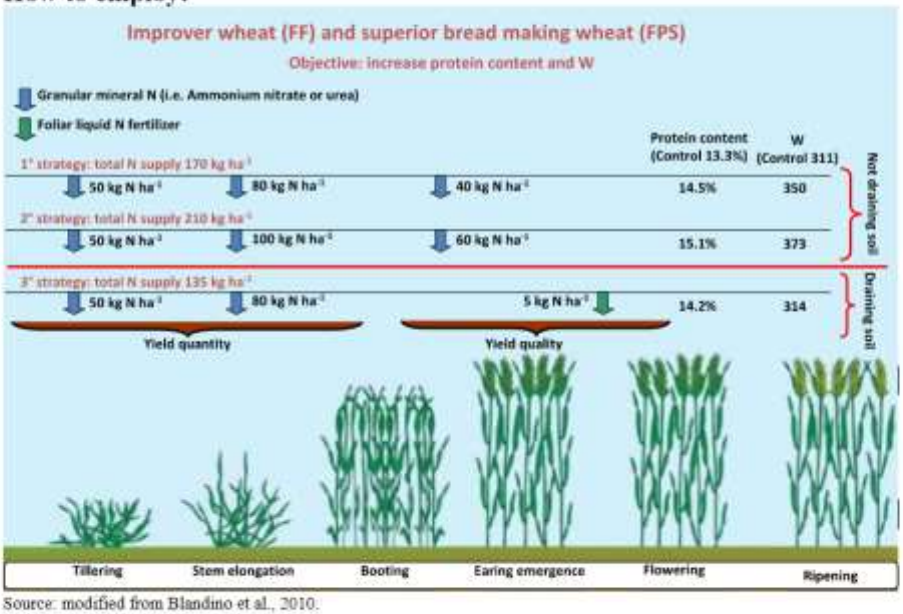
The following wheat quality categories (Foca et al., 2007) are considered:

1) improver wheat (FF): protein content (% dry matter) >13.5 and dough strength (W) >300;
2) superior bread making wheat (FPS): protein content >11.5 and W >250.

Problem to be solved.

To foster late N uptake in wheat between booting and milk development stages.

How to employ:



Source: modified from Blandino et al., 2010.

Positive side effects

1) Stability of yield and quality in FF and FPS wheat quality categories;
2) Reduction of potential N leaching in sandy soil when foliar replaces granular fertilizers;
3) Foliar spraying let late N application in climatic zones with insufficient spring rainfall.
4) Foliar spraying can be coupled with pesticide application reducing application costs.

Disadvantages

1) Foliar sprays strategy can damage canopy during heading and flowering stage in high daily temperature conditions (> 26 C°) especially if N supplied is more than 10-15 kg/ha. It is suggested to supply this type of liquid fertilizers only in cool climatic conditions.
2) N uptake consequent to Urea or Ammonium Nitrate granular fertilization can be very low in climatic zones with insufficient spring rainfall. Foliar spraying is suggested.
3) N use efficiency of late N application can be quite low. Catch crop after wheat harvest can be required to recover mineral N in soil.

Costs

Strategy	Application	Cost increase
1	Centrifugal spreader	+37%
2	Centrifugal spreader	+58%
3	Application with sprayer bar:	
	Only foliar fertilizer	+41%
	Togheter with anti- fungal	+18%

The different strategies imply a cost increase. Values reported in the table refers to the percentage of increase with respect to an usual fertilization management based on two distributions of granular fertilizers and a total supply of 130 kg N ha^{-1} (RDP threshold).

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Combination of rape and temporary plant cover

What is it?

This technique consists in sowing at the same time rape and frost-susceptible associated cover crops. Associated cover plant is a temporary plant cover which is sown in combination with a cash crop to improve the agronomic performance, technical and economic results of the main crop. The cover crop must have these characteristics:

- It must have a good cover power to compete with weeds.
- It must be frost-sensitive to be destroyed during the winter without herbicide.
- It must supply nitrogen to rape in improving rape root growth and/or mineralizing in the spring.

This technique is not advised when the weed infestation risk is high because is not efficient.

Combination of rape and a mixed plant cover (common vetch, purple vetch, Egyptian clover) ©CETIOM

Problem to be solved

Rape is a crop which requires high nutrient, herbicide and insecticide inputs. So the CETIOM (French agricultural institute of oleaginous crop), developed this technique to reduce inputs in the Northern part of France. The combination of rape and plant cover reduces fertilizer, herbicide and insecticide application rates and improves the soil quality.

How does it work?

Key stages of rape and plant cover combination (Source modified from A. Davoine – 2013)

Principle

In autumn the plant cover grows quickly, so it exerts competition against weeds. During winter, it freezes and dies. In February it decomposes and releases nitrogen for the neighbouring rape. Furthermore, the plant cover will disturb the life cycle of autumn insect pests (cabbage fly - *Delia radicum*, cabbage stem flea beetle - *Psylliodes chrysocephala* and rape winter stem weevil - *Ceutorhynchus napi*) because it hides rape at the beginning.

Rape has to be sown early; both implantations of rape and companion plant can be combined (one operation) or require two different and successive operations. If the rape seeding is after the plant cover seeding, there is an important risk of competition between them. If the plant cover is sown too late, there is no competition with weeds. The simultaneous seeding of rape and plant cover can be done in one if the sowing machine has two hoppers, one for rape and the other for plant cover, or if rape and plant cover are mixed in a single

hopper. In this case, several types of seed size are necessary. At least 3 seed sizes for the cover crop can avoid stratification in the sowing machine. It is possible to do the seeding in two operations in the same day, the plant cover can be sown by cereal or broadcast sowing machines, and the rape by precision sowing machine.

Choice of associated plant cover

The plant cover must not be very sensitive to herbicides compatible with rape because some herbicides can be applied before the rape emergence. Mixing different plant species for the cover can secure the combination, vary seed sizes and multiply effects of different species.

Table with characteristics of some species for plant cover

Species	Seed rate	Effect	Frost-sensitivity	Sensitivity to rape-specific herbicides
Lentil - *Lens culinaris*	12-25 kg/ha	Nitrogen, soil cover and structure	-7°C according to the stage	High
Faba bean - *Vicia faba*	50-70 kg/ha	Soil structure, nitrogen	-10°C	Low
Common or purple vetch - *Vicia sativa*	8-15 kg/ha	Soil cover, nitrogen	-10°C	Medium
Chickling vetch - *Lathyrus sativus*	30-40 kg/ha	Nitrogen, soil cover and structure	-5 at -7°C according to the stage	Medium
Fenugreek - *Trigonella foenum-graecum*	20-30 kg/ha	Nitrogen, soil cover and structure	-5 at -7°C according to the stage	Medium
Egyptian clover - *Trifolium alexandrinum* L.	10-20 kg/ha	Nitrogen	-10°C according to the year	Medium

Effects of associated plant cover

There is not enough experimentation to show a significant effect of the associated plant cover on autumn insect pests. Experiments show that the associated plant cover reduces the competition between weeds and rape but it does not limit the amount of weeds (weed/m²). So its effect consists only in weed biomass reduction. A broadleaf herbicide treatment may be necessary but at a lower dose. Furthermore, the associated plant cover can make available from 20 to 60 kg N/ha to the rape.

Advantages

- The yield is higher or equal compared to the yield of a single rape crop in 75% of cases. In rare cases, the yield is reduced by 200 kg/ha.
- Competition with weed in autumn. This competition has a significant effect on *Geranium* but no effect on *Galium*.
- The plant cover mineralization makes nitrogen available to the rape.
- The rape root growth is better due to the root system of the plant cover.
- Global improvement of the soil quality.
- Reduction of nutrient inputs (about 39%), energy inputs (11%) and greenhouse gases emissions (6%).

Disadvantages

- In case of mild winter, the plant cover is not destroyed. So an additional herbicide treatment or/and mechanical weeding are required. Sometimes, the field can't be harvested because the cover crop surpasses the rape.
- Requires more labour and a long time before the farmer masters this technique (highly technical method)

Costs

Some companies sell seed mixtures dedicated to companion planting. The prices vary from 20 to 50 €/ha. But regarding the input reduction, it is possible to reach an overall cost reduction of 50 €/ha.

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5.4 Stakeholder trial/demonstration leaflets

Valerie

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Valorising European Research for Innovation in Agriculture and Forestry

VALERIE Stakeholder Trials:

Demonstration of combined cropping of wheat and lentils

The problem

In France, as in much of Europe, many farmer cooperatives are dependent on the import of protein crops for livestock feed. Demand for protein crops is high in organic and conventional sectors and some farmers are growing lentils and high protein wheat to meet their protein deficit, although problems associated with establishment of lentils and lodging of both crops remains a challenge in both sectors in the Midi-Pyrénées region.

The proposed solution

Developing lentil production and supply in organic and conventional sectors can partially meet farmer demand and offer diversification opportunities. In particular, growing wheat in combination with lentils provides an opportunity to maximize lentil production and increase protein content in the wheat. However applied field experiments and demonstrations are still needed to determine the most effective establishment methods to achieve the best outcome for both crops. This research has been enabled and facilitated by the Qualisol cooperative, which has acquired an optical sorter to help harvest the combined crops. The development of this technology has allowed the cooperative to justify testing wheat and lentil intercropping at a large scale.

Stakeholders

The main stakeholder groups are the farmers and supply chain actors of the Qualisol cooperative. One of the aims of the cooperative and its members is to diversify the crops in conventional and organic agriculture and to develop markets to secure agricultural income within the territory. The Toulouse agroecology platform (located at Auzeville agricultural college) supports the Qualisol Technical Service in testing the technical feasibility of intercropping. The different ideas tested in the field have originated from Qualisol farmer groups, including the EEIG (Economic and Environmental Interest Group), Post-Maet Gimone project partners and farmers in organic farming systems.

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Aims and Method

The main aim of the trial was to assess the effect of wheat and lentil intercropping on wheat protein and lentil performance, specifically examining different establishment methods and seed rates. These trials can be considered more as demonstrations as they are primarily intended to support discussions between Qualisol technicians and farmers. Indeed the co-development process involving farmer groups and students preparing a diploma on Agronomy Crop Production was one of the main innovations reported here. All the stakeholders were involved in field trial implementation.

The trial aims to evaluate how different sowing and establishment methods for intercropped wheat and lentils affect lentil performance (yield and quality) and wheat protein content.

Three treatments were tested:

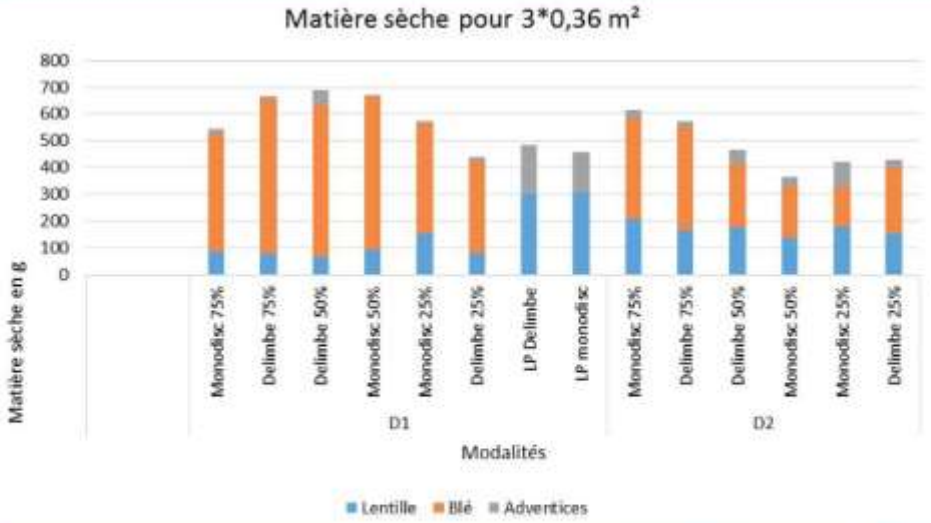
- Testing different lentil seeding methods (oversown into established wheat or undersown with the wheat)
- Testing a winter improved soft wheat variety and a spring wheat variety
- Testing 3 sowing densities of both wheat varieties

Sowing with a single seed drill (wheat and lentil mixed in the seed drill box)

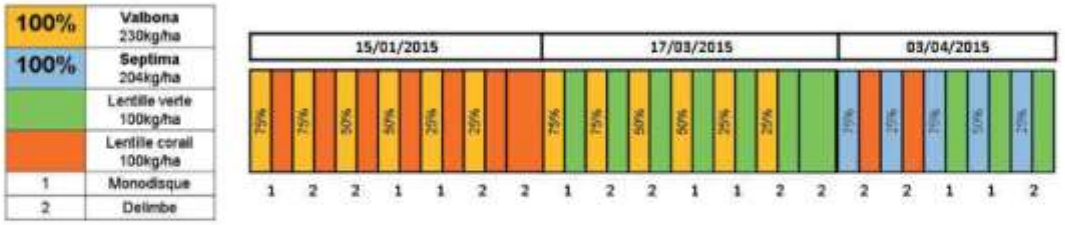
Sowing with a weeder harrow & delimbe type seed drill after sowing wheat with a single disc seeder

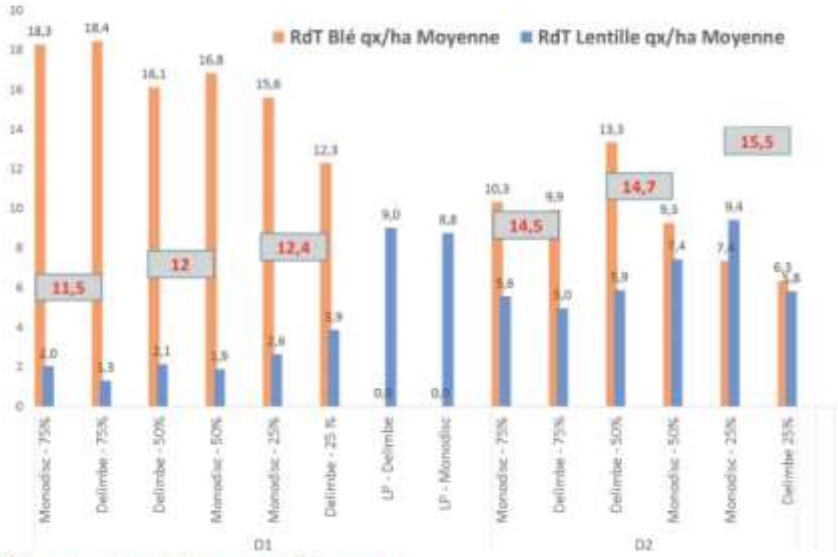
The wheat varieties were matched separately with specific crop establishment methods: lentils were oversown into the winter wheat variety, and undersowing of lentils was carried out with spring wheat. Both varieties of wheat were sown at three seeding rates: 75%, 50% and 25% of the recommended dose in monovarietal plantings. For the wheat sown on January 15, the lentils were oversown into the established wheat on March 17. Prior to the lentil sowing, a rotary hoe was used to facilitate soil to lentil seed contact.

Results



Result A: Dry organic matter (lentils, wheat, weeds)





Result B: Average yield in wheat and lentils for each modality (n=3).

Protein content refers to an average sample of each modality

Different modes of crop establishment

Undersown lentils after wheat establishment. The aim was to optimise wheat emergence by drilling in the optimum period for germination (i.e. in mid-January) and to sow lentils in the wheat (mid-March). However, oversowing the lentils created too much competition for the lentils and resulted in reduced lentil yield. Wheat outcompetes lentils for light, water and nutrients in this type of sowing. The poor rooting of the lentils sown in wheat did not allow good establishment resulting in losses at the seedling emergence stage. During periods of soil moisture deficit, the wheat, which was well rooted, outcompeted the lentil crop for water. There were no differences in yield between sowing with a single-disc or weeder harrow.

Lentils undersown with wheat (simultaneous drilling). This method involves sowing wheat and lentil crops simultaneously at the optimum time for lentil establishment, thereby reducing the workload for the farmer. Sowing with a single-disc provides better quality seedlings (securing the emergence of the wheat and the lentils) compared to sowing with a weeder harrow; and better lentil rooting, development and yield. It also improves the lentil stem height. This treatment resulted in higher wheat protein content, most probably due to the N fixed by the lentils. There were also indications that this intercropping establishment method reduced pest pressure.

Sowing density. Lentils are sensitive to competition from any other plant species, thus oversowing into a growing crop resulted in significant yield penalties for the lentil crop (> 50% loss compared to the monocropped control: "single lentils"). Simultaneous sowing secured lentil yields, provided that the wheat seed rate was less than 50% of the recommended rate to limit the competition from the wheat crop.

Next steps

The results from the field trial show that it is also necessary to adjust the seed rate according to the soil type. The high sensitivity of the lentils to water stress should be taken into account both in the choice of field plots and the seed rates recommended by technicians. Intercropping helped to reduce pest pressure. Nevertheless when pest pressure was high, it still had a significant (negative) impact on yield. In an attempt to better control disease pressure on wheat, some new formulations designed to stimulate the natural crop defence mechanisms will be introduced in the next intercropping experiments. The intercropping trials will be extended, with research into using companion plants such as wild flax (Camelina sativa) to provide support to the cash crops and reduce lodging.

The proposed trials are aligned with Qualisol's aim to diversify farming systems by integrating different techniques such as cover cropping and intercropping, and supporting new innovations to develop appropriate crop management on each farm.
This project aimed to have an impact across the whole area covered by the Qualisol cooperative and was validated through an EIP-Operational Group in September 2016 (a project for Total Quality Agriculture).

Overall stakeholder involvement and feedback

The involvement of farmers, students, field technicians and the development service throughout the trial ensured engagement and interest from all stakeholder groups and a good level of understanding. This led to an increase in the area growing intercropped wheat and lentils in organic and conventional agriculture. More than 300 ha of intercropped wheat and lentils have now been established within the Qualisol territory. In conventional agriculture, more than 700 ha of lentils were introduced. The results in terms of lentil and wheat yields were very encouraging, demonstrating real economic benefits to the farmer. However some technical difficulties in sorting grains post-harvest do remain.

Farmers visited the demonstrations during the AgroEcology platform open days at the agricultural college. The trials were presented by Agronomy and Crop Productions Diploma students to more than 150 farmers in the Midi-Pyrénées region; there was also a specific visit with technicians and development services (5 leader farmers and 3 Qualisol technicians). Feedback on the trials from Qualisol farmers was conducted in February 2017 for the launch of the new campaign.

Key findings

- Oversowing lentils into an established wheat crop created too much competition for the lentil crop and resulted in significant yield losses.
- Simultaneous undersowing of lentils with spring wheat provided more positive results and sowing with a single-disc resulted in better emergence.
- Simultaneous sowing secured good lentil yields, provided the wheat density was less than 50% of the recommended seed rate.
- Strong farmer and student involvement throughout the development of the trial ensured engagement and interest.
- More than 300 ha of intercropped wheat and lentils have now been established within the Qualisol territory.

Acknowledgements

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6 Innovative arable cropping, France

6.1 Context

The arable farmers in the Berry region from central France (departments of Indre and Cher) grow mainly rapeseed, wheat and winter barley. Their farms are between 100 and 500 hectares and contain a variety of soil types but mainly superficial calcareous clay. Despite progress in crop genetics, the average yields on these farms have not increased for over 20 years.

Since 2005, some of the farmers have met in a group with their advisor to find solutions to the problem of maintaining the economic viability and sustainability of their farming systems. For these farmers who are keen to move towards more efficient systems, in economic terms and productivity, improving soil quality is the primary objective.

Short rotations have been identified as a weakness in the system, being responsible for recurrent weed problems. To tackle them, farmers have gradually shifted towards simplified tillage in terms of number of operations and working depth. However, this simplified tillage is not always beneficial to the structural qualities of the soil. In the last ten years there has been some crop diversification to extend the intensive, high input production systems based on a short rotation of rapeseed, wheat and winter barley. Farmers have introduced a variety of crops: sunflower, corn, durum wheat, and legumes mixed in the crop or between crops.

The group of farmers, coordinated by the advisor, aim to develop new techniques and investigate alternative approaches that reduce the impact of farming on the environment and improve soil properties. These aims include:

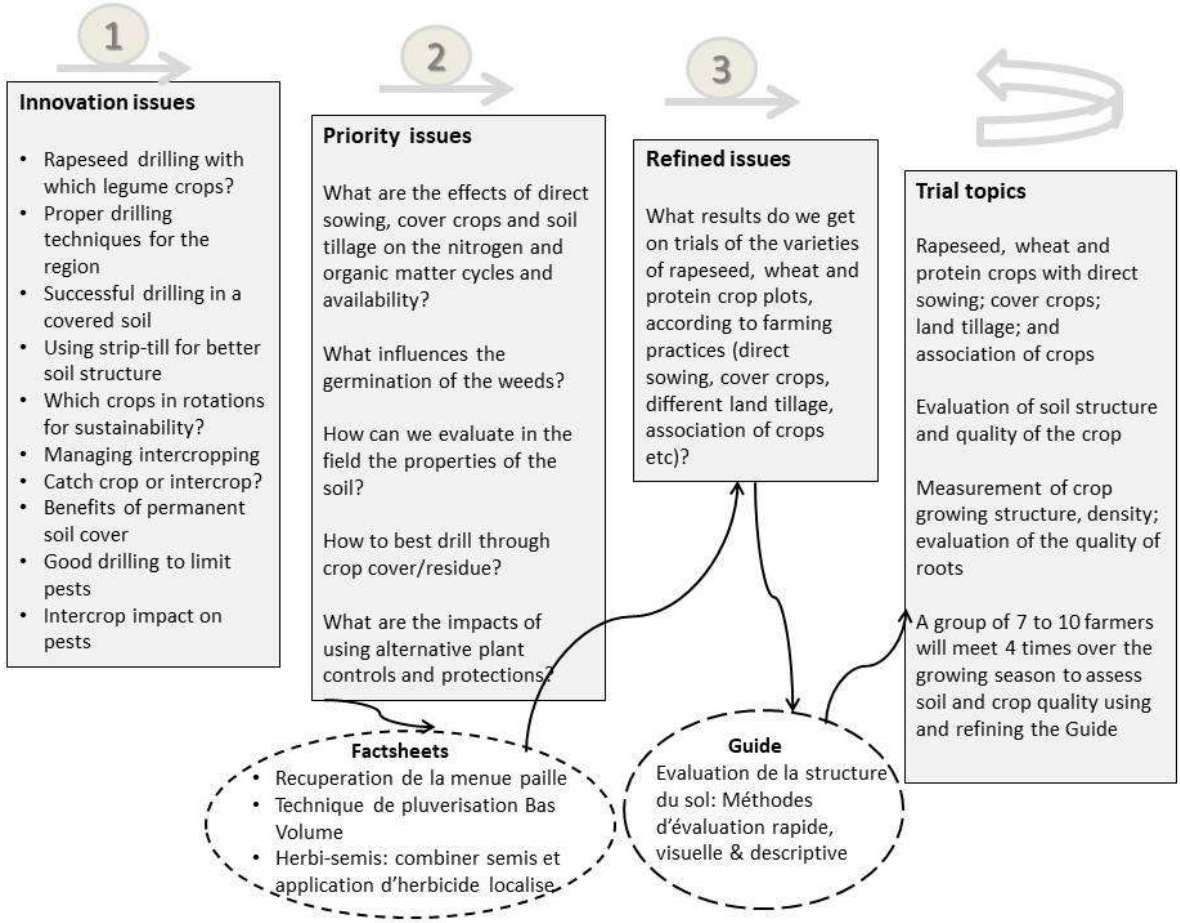
- Improving the quality of oilseed rape drilling and autumn growth in order to better withstand autumn weed and disease threats, and limit spring nitrogen input.
- Direct seeding in permanent cover: e.g. oilseed rape sown together with cover crops, then direct seeding of wheat under cover of clover or alfalfa.

Group discussions, regular meetings and on farm testing have been undertaken since 2005. The group expanded in 2013 with the introduction of a new project called "*SYPPRE*". For this project, a dozen farmers meet 3 to 4 times a year to discuss and learn about innovative cropping systems.

6.2 Dynamic Research Agenda

In this CS, stakeholders selected issues already known to them, but were able to progressively construct a set of new specific questions. In the first meeting the CSP considered it was not necessary to ask the group to identify their wider goals and visions as they have been active together since 2005 and these are well known. Stakeholders formulated innovation issues collectively. The process involved gradual construction of research questions from keywords and issues shared by farmers and produced a refined list of five questions. The DRA (Figure 6.1) shows how the five issues are progressed with reviews in each meeting, and used to select and formulate the trial protocols. Of the five questions there was a particular interest in the effects of agricultural practices such as direct sowing, cover crops and soil tillage on soil and yield and in how to evaluate in the field the properties of the soil (its structure, texture and health); this formed the basis of the trial as described in the DRA.

Figure 6.1 Innovative Arable Case Study Dynamic Research Agenda



Preliminary factsheets were prepared by Thematic Experts synthesising scientific papers, and providing potential innovation solutions to CS issues. These are two page illustrated formats with scientific information presented as graphs, and costs of techniques detailed. Farmers' comments primarily concerned the credibility of content. Due to local CS arrangements the factsheets were prepared before the first meeting so although they provided evidence from research material, they did not directly address stakeholders questions.

6.3 Factsheets on innovation

Combine inter-row hoeing and intra-row herbicide treatment on the same tool

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Principle

The technique consists in combining inter-row mechanical weeding (hoeing) and intra-row spraying of post-emergence herbicides in a unique operation. Hoeing and herbicide spraying overlap on 5 cm.
This method provides an effective weed control and reduces the use of herbicides by over 60%.
This weed control technique is used for maize and it can be used for several row-crops like beet, sunflower or oilseed rape.

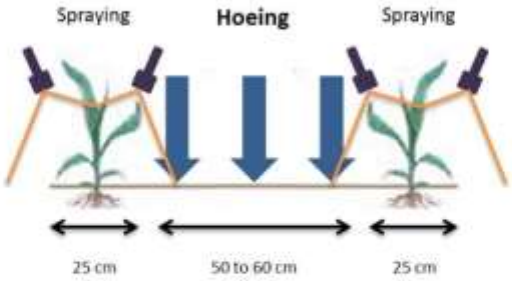

Illustration of the principle for maize

Example for maize

For maize two operations are needed:

- The first intervention should be performed when crop is at the 3-5-leaf stage with hoeing and herbicide treatment combined. To have a good efficiency, it is necessary to do this intervention before the 2-leaf stage of weeds. The recommended operating speed is 6-8 km/h.
- The second intervention should be performed when crop is at the 8-10-leaf stage and consists in hoeing only. The recommended operating speed is 10 km/h.

Problem to be solved

According to Directive 2009/128/EC, farmers will have to reduce their use of pesticides. Techniques have to be developed to reach this first objective without reducing crop economic performances.

How does it work?

Material

Spray equipment for localised treatment can be added on hoeing machine. The spray equipment is composed by (i) two nozzles for each crop row linked to (ii) a control system. Generally, this equipment is located at the back of the tractor. The distance between rows must be the same for the sowing machine and the hoeing machine. To operate more precisely, it is possible to use an auto-guidance system (GPS).

Environmental conditions of use

The optimal conditions for hoeing (hottest hours of the day and dry conditions) are the opposite of the best/optimal conditions for herbicide treatment (moderate temperature and high hygrometry). So, to have efficient weed control it is necessary to find a compromise between these conditions. Rain events immediately after the intervention may reduce overall efficacy by reducing herbicide absorption in weeds in intra-row and by reducing desiccation of partially uprooted weeds in inter-row.

Efficacy

For this technique, the intra-row efficacy is higher than the inter-row efficacy. When the environmental conditions are good, the efficacy of this technique is approximately similar to chemical weed control and the intra-row efficacy is better because the herbicide is provide closer to weeds.
For maize, the hoeing in second intervention is not always necessary.

Advantages

- 60 to 70% reduction of herbicides.
- Efficient weed control in the row.
- Destruction of the dicotyledonous weeds which are difficult to control by herbicides in the intra-row.
- Destruction of environmental habitat for some crop pests like slug.
- Reduction of herbicide resistance selection due to the lower use of herbicides.
- Advantages of hoeing :
    - Destruction of the slaking crust, so support the infiltration of water and limit the runoff,
    - Improve drought resistance,
    - Better soil heating,
    - Better soil oxygenation, so a better organic matter mineralization.
- No yield loss despite 5 to 10% uprooted maize plants.

Disadvantages

- Difficulty in finding good conditions for both hoeing and spraying.
- Low operating speed.
- Difficulty with weeds which emerge in stages. These weeds can emerge again in the row after the intervention.
- Risks of nozzles obstruction due to the soil proximity. Earth particles splashed up. So it is necessary to monitor the nozzles carefully.
- Important financial investment.

Costs

The costs are variable. It depends on the number of rows on the hoeing machine and the type of spray equipment.

	Investment
Lowest price: simple 4-rows hoeing machine + spray equipment	5 300€
Highest : 12-rows machine + spray equipment + GPS guidance	27 000€

(Average costs in France in 2012)

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Chaff recovery

What is chaff?

Chaff is composed of finely chopped straw, protective casings of the seeds of cereal crop, and parts of weeds (straw, seeds, flowers…). Generally, chaff is dispersed during harvest and buried into the soil during tillage. The seeds of weeds into the chaff are able to germinate, so it is necessary to use herbicides on the next crop.
The chaff quantity let into the field is the equivalent of the half the straw harvested:

	Wheat	Barley	Winter rape
Chaff	2.3 t/ha	1.5 t/ha	0.8 t/ha
Straw	4.2 t/ha	4 t/ha	2.3 t/ha
Seed	80 q/ha	70 q/ha	40 q/ha

Source: ETS Thierart

Problem to be solved

Chaff recovery allows to reduce the use of herbicides by exporting weed seeds out of the field, this is also a new product to valorise.

Principle: 2 methods

There are 2 methods to recover chaff:

- The method of recovery on the swath:

This method is easier regarding the logistic. Chaff gets out at the back of combine harvester by a turbine. This turbine projects chaff on the swath by a PVC pipe. So chaff is compacted with straw. This straw used as bedding in livestock farming contains viable seeds of weeds. So manure resulting of this bedding contains these seeds as well. Before using manure, it is necessary to compost it to destroy the seeds.

- The method of full recovery:

This method requires more workforce and equipment. A recovery system is installed at the combine harvester. The system is either (i) a trailer coupled at the combine harvester and the chaff is projected inside by a blower, or (ii) a compartment installed at the back of the combine harvester to stock chaff, the compartment is regularly emptied at the end of the field. Chaff is taken by a container or a baler. With this method, chaff can be used in more diverse ways.

Advantages

- Recovery of weed seeds and small or broken seeds of the harvested crop possible valorisation.
- Reduction of weed infestation with an impact on the soil seed bank and a significant effect after 2-3 years.
- Saving on herbicides.
- Limitation of the fungal diseases propagation like Fusarium head blight which develops on the protective casings of the seeds.
- No tillage and direct seeding facilitated.
- A solution to control herbicide resistant weeds in recovering the seeds of these weeds.

- It is applied at different crops: cereals, winter rape, peas, sunflower and corn.

For the method of recovery on the swath:

- Bale of straw density is higher. The weight of the bale is increased by 15%.

For the method of full recovery:

- Chaff is harvested alone. But can be valorised

Disadvantages

- The impact on the weeds is variable. It concerns only weeds which are mature at the harvest.
- Loss of organic matter in case of chaff recovery and no applications of organic fertilisers.
- The chaff yield is variable and depends on the conditions (time of the day, moisture) and on the type of combine harvester. The chaff yield is highest in the morning.
- Higher oil consumption of the combine harvester.
- Important financial investment for the equipment. This investment is different for both methods.

For the method of recovery on the swath:

- Risk of jam if chaff has a high moisture content and is in high volume.
- Obligation to reduce the speed of the combine harvester to keep the harvest clean.
- The system is difficult to dismount.
- The use of a swather is banned to keep the advantages of the method.
- Wind speeds can have a negative effect in making chaff fall next to the swath.

For the method of full recovery:

- Extra harvest time of 1 h/ha (emptying time and place).
- Difficulty to take chaff (pressing, loading, transport...).
- 20% of the combine harvesters can't be equipped.

Costs

The price is around 8 500€ for the method of recovery on the swath and around 28 000€ for the method of full recovery. But the price depends of the combine harvester to equip.

Uses of the chaff

- Food for farmed animals:

Interesting for chicken because chaff is rich in silica and trace elements and composed by small seeds. Rich in fibres and facilitating the ruminant digestion, chaff is also interesting for cattle. In addition, it is palatable food supplement.

- Bedding for farmed animals:

Chaff has over 4% of dust and a better absorption capacity than straw. In addition it has also a rapid warm-up due to the low moisture content.

- Methanization:

The chaff methanogenic power is two and a half times higher than corn silage methanogenic power and ten times higher than manure methanogenic power. Weed seeds are destroyed during the digestion.

- Alternative fuel:

Transformed into compact briquettes or granules, chaff is a good alternative fuel with a calorific value of 15 000 kJ/h. So 1 ha of chaff is the equivalent of 520 L of oil or 3 cubic meters of wood.

- Agro-materials:

Chaff can be entered in the composition of insulation or building materials.

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Low Volume spraying (LVS)

Contact: Yolaine Hily (INRA, UMR AGIR, yolaine.hily@toulouse.inra.fr)

What is it?

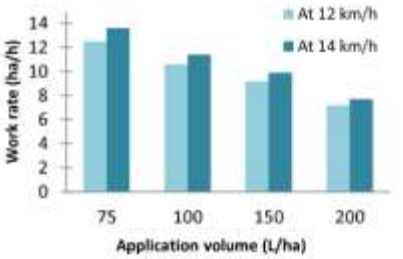
Low volume spraying consists in reducing the amount of water used to dilute the active ingredients in crop protection spraying treatments. Spraying volume is considered as low up to 80L/ha. This technique can be used for every crop (cereals, beets, oilseed rape, maize, vegetables...) and with most of the sprayers but must be adapted to pesticide formulation and target characteristics. This technic is more and more used but requires control of the main spraying parameters.

Spraying volume can be reduced to 30L/ha (Ultra Low Volume) but up to 50L/ha specialized sprayers have to be used.

Problem to be solved

Spraying volume reduction is not systematically associated with a chemical dose reduction, even if farmers associate these techniques often. The main objective of this technique is more to optimise spraying operations. Indeed, work rates for a given field spraying system are influenced by:

i) filling cycle,
ii) sprayer forward speed,
iii) above all, application volume (chart below).



Source : Computer modelling-TAG Silsoe Spray applications

How does it work

The most important issue in low volume spraying is to guarantee a good spraying quality, i.e. target coverage (percentage of treated surface area that has a chemical deposit, related to the amount of impacts on the target) and uniformity of the deposit. These parameters depend on amount and size of droplets and spraying pattern, but they are not influenced (within a certain range) by the amount of water used for spraying.

Lower carrier volume requires spraying medium-sized droplets (250-350µm), to reach optimal impact amount. But the smaller the droplets, the higher the risk of spray drift. Technical adaptations have to be implemented to ensure the spraying quality:

- Choose spraying parameters : driving speed, pressure and flow
- Spray with optimal environmental conditions is necessary when using low volume spraying:

Temperature	15 to 20°C during the day
Air moisture	75-80% (dew is really helpful in LVS)
Wind speed	Less than 5-10km/h
Soil moisture (for soil active products)	Moist soil is needed to secure the efficiency

Optimal spraying conditions are early in the morning or late in the evening.

- Adapt nozzles (find a compromise between number and size of droplets) and filtration systems (regularly maintained : the thinner the nozzle, the more risks of obstruction)
- Use eventually spraying adjuvants (oils/salts/wetting agents…): they must be adapted to the product applied and spraying conditions

Effects on the products:

Notice that the efficacy of plant protection products can be influenced by different parameters:

Impact of different factors on products performances		Soil active products	Foliar contact products	Foliar systemic products	Both foliar and soil active
Mixture properties	Lower carrier volume	0	--	++	0 to --
	Adjuvants	-	0	++	- to ++
Weather conditions	Temperature	0	0	+	0
	T variations	--	-	0	0
	Humidity	0	++	++	0 to ++
	Dew	0	- to +	+	++

Source : Arvalis (France)

Generally speaking, low volume spraying can benefit to systemic pesticides but can alter the protection efficacy of some contact products.

Chemical dose reduction may be possible but only for some products and in association with the best spraying conditions and preventive management (agronomy, regular monitoring).
Low volume spraying requires high technical skills to adapt the volume/products/parameters to crop/target/weather conditions. It takes several years to master the technique and technical advice is highly recommended to implement it on a farm.

➔ **Always consider your local conditions and consult a qualified agronomist if necessary**

Advantages and disadvantages of the innovation

+	-
- Time-saving (filling cycle and transport) - Cost reduction: Less water and fuel - Easily implemented on regular sprayers - Homogeneous / best spraying conditions (when properly operated) - Possible chemical doses reduction - Possible protection efficiency enhancement (less interaction with water components, higher concentration)	- Highly technical, technical advice required - Reducing drift nozzles could be necessary but few of them are adapted to carrier volume reduction (not under 80L/ha) - Requires optimal spraying conditions → reduced useful time "windows" - Risks of leave damages if too high concentration of pesticides

Costs

Low investment required for this technique (easily implemented with most of the regular sprayers). Nozzles and filters maintenance is key factor for the efficiency of the technique (around 300-400€; *French data*).

Other resources required

Weather measuring devices (measuring application conditions): thermometer, anemometer, hygrometer

Combination of rape and temporary plant cover

What is it?

This technique consists in sowing at the same time rape and frost-susceptible associated cover crops. Associated cover plant is a temporary plant cover which is sown in combination with a cash crop to improve the agronomic performance, technical and economic results of the main crop. The cover crop must have these characteristics:

- It must have a good cover power to compete with weeds.
- It must be frost-sensitive to be destroyed during the winter without herbicide.
- It must supply nitrogen to rape in improving rape root growth and/or mineralizing in the spring.

This technique is not advised when the weed infestation risk is high because is not efficient.

Combination of rape and a mixed plant cover (common vetch, purple vetch, Egyptian clover) ©CETIOM

Problem to be solved

Rape is a crop which requires high nutrient, herbicide and insecticide inputs. So the CETIOM (French agricultural institute of oleaginous crop), developed this technique to reduce inputs in the Northern part of France. The combination of rape and plant cover reduces fertilizer, herbicide and insecticide application rates and improves the soil quality.

How does it work?

Key stages of rape and plant cover combination (Source modified from A. Davoine – 2013)

Principle

In autumn the plant cover grows quickly, so it exerts competition against weeds. During winter, it freezes and dies. In February it decomposes and releases nitrogen for the neighbouring rape. Furthermore, the plant cover will disturb the life cycle of autumn insect pests (cabbage fly - *Delia radicum*, cabbage stem flea beetle - *Psylliodes chrysocephala* and rape winter stem weevil - *Ceutorhynchus napi*) because it hides rape at the beginning.

Rape has to be sown early; both implantations of rape and companion plant can be combined (one operation) or require two different and successive operations. If the rape seeding is after the plant cover seeding, there is an important risk of competition between them. If the plant cover is sown too late, there is no competition with weeds. The simultaneous seeding of rape and plant cover can be done in one if the sowing machine has two hoppers, one for rape and the other for plant cover, or if rape and plant cover are mixed in a single

hopper. In this case, several types of seed size are necessary. At least 3 seed sizes for the cover crop can avoid stratification in the sowing machine. It is possible to do the seeding in two operations in the same day, the plant cover can be sown by cereal or broadcast sowing machines, and the rape by precision sowing machine.

Choice of associated plant cover

The plant cover must not be very sensitive to herbicides compatible with rape because some herbicides can be applied before the rape emergence. Mixing different plant species for the cover can secure the combination, vary seed sizes and multiply effects of different species.

Table with characteristics of some species for plant cover

Species	Seed rate	Effect	Frost-sensitivity	Sensitivity to rape-specific herbicides
Lentil - *Lens culinaris*	12-25 kg/ha	Nitrogen, soil cover and structure	-7°C according to the stage	High
Faba bean - *Vicia faba*	50-70 kg/ha	Soil structure, nitrogen	-10°C	Low
Common or purple vetch - *Vicia sativa*	8-15 kg/ha	Soil cover, nitrogen	-10°C	Medium
Chickling vetch - *Lathyrus sativus*	30-40 kg/ha	Nitrogen, soil cover and structure	-5 at -7°C according to the stage	Medium
Fenugreek - *Trigonella foenum-graecum*	20-30 kg/ha	Nitrogen, soil cover and structure	-5 at -7°C according to the stage	Medium
Egyptian clover - *Trifolium alexandrinum* L.	10-20 kg/ha	Nitrogen	-10°C according to the year	Medium

Effects of associated plant cover

There is not enough experimentation to show a significant effect of the associated plant cover on autumn insect pests. Experiments show that the associated plant cover reduces the competition between weeds and rape but it does not limit the amount of weeds (weed/m²). So its effect consists only in weed biomass reduction. A broadleaf herbicide treatment may be necessary but at a lower dose. Furthermore, the associated plant cover can make available from 20 to 60 kg N/ha to the rape.

Advantages

- The yield is higher or equal compared to the yield of a single rape crop in 75% of cases. In rare cases, the yield is reduced by 200 kg/ha.
- Competition with weed in autumn. This competition has a significant effect on *Geranium* but no effect on *Galium*.
- The plant cover mineralization makes nitrogen available to the rape.
- The rape root growth is better due to the root system of the plant cover.
- Global improvement of the soil quality.
- Reduction of nutrient inputs (about 39%), energy inputs (11%) and greenhouse gases emissions (6%).

Disadvantages

- In case of mild winter, the plant cover is not destroyed. So an additional herbicide treatment or/and mechanical weeding are required. Sometimes, the field can't be harvested because the cover crop surpasses the rape.
- Requires more labour and a long time before the farmer masters this technique (highly technical method)

Costs

Some companies sell seed mixtures dedicated to companion planting. The prices vary from 20 to 50 €/ha. But regarding the input reduction, it is possible to reach an overall cost reduction of 50 €/ha.

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Combine row crop sowing and herbicide band-spraying

Contact: Yolaine Hily (INRA, UMR AGIR, yolaine.hily@toulouse.inra.fr)

What is it?

Row crop sowing and pre-emergence herbicide band-spraying performed at the same time. Soil active herbicide is only sprayed on the row; consequently the herbicide quantity is reduced.

Problem to be solved

According to a European directive, pesticide use has to be reduced. This technique can ensure both an effective weed control and a significant reduction of pesticide applied (40 to 60%).

How does it work?

Sowing of row crops (maize, oilseed rape, sunflower, soybean, sugar beet…) is combined with band-spraying of pre-emergence soil active herbicide. This spraying is localized on the crop row (intra-row). Inter-rows hoeing can be performed afterward to control weeds between rows.

Optimal conditions:

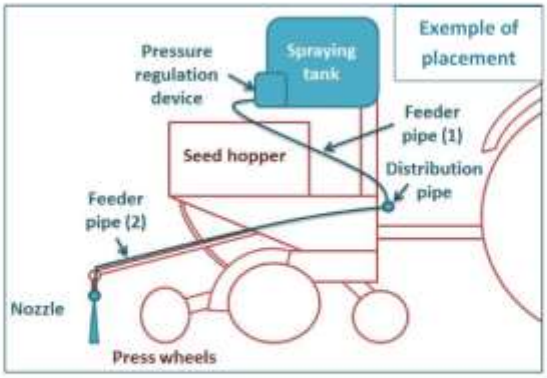
This technique is adapted to almost all soil types, except stony soils. Soil active herbicides are also more efficient on moist soils, and on soils with low organic matter.

Material:

- Spraying tank (200 to 1500 L)
- Electric pump
- Pressure regulation: manual or electronic
- Uniform coverage flat fan nozzles (spraying has to be homogeneous since there is no overlapping)
- Filters, pipes, anti-drip systems (one for each nozzle)

Principle of operation:

The spraying tank is placed on the front (better weight repartition) or behind the tractor (over the sowing machine) and supplies a nozzle per row. The spraying tank is linked, through the pump, to a distribution pipe which includes one exit per nozzle/seeding unit. The regulation device ensures the continuous treatment delivery and the right dose/ha. Herbicide

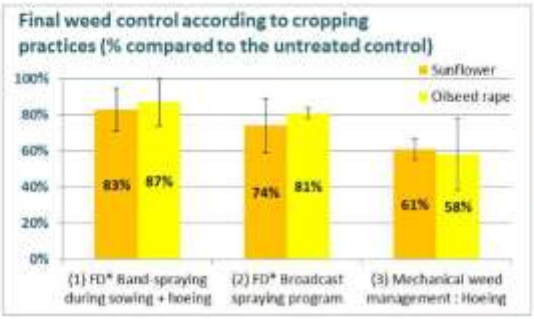


treatment is applied directly after the press wheels of the seeding unit; the sprayed area is restricted to a band (10 to 20 cm on the both sides of the row → 20 to 40cm, *picture* below).

Inter-rows have to be maintained weed-free by hoeing; weed control can then be completed by localized herbicide spraying as well (*fact sheet available*). If needed, conventional spraying operations can be further performed.

Performances:

If the conditions are favorable (moist soil but no long rainy periods, no soil compaction), this technique associated with inter-row hoeing can be more efficient than conventional herbicide spraying (*chart below*).



*FD : Full Dose

Source CETIOM

According to field trials, combined band-spraying and sowing ensure an effective weeds management on the row if the weed pressure is low or medium. In case of extreme weather conditions favorable for weeds (rainy spring), this technique has to be associated with other weed control methods.

Remark: if a field is not perfectly square and if corners can't be maintained by hoeing, these latter have to be sprayed conventionally to reduce weed pressure.

Advantages and limits of the technique

+	-
• 40 to 60% herbicide use reduction → Economic and environmental benefits • Improved treatment efficiency since the soil has been freshly tilled • Almost no drift (nozzles are close to the soil) • No weed competition on the row up to one month • Time-saving technique	• Weight repartition on the tractor due to the additional spraying tank • The efficiency of the technique is variable according to the weather conditions • Higher concentration required from the driver to manage seeding and spraying at the same time

Costs

Cost of the equipment between 1000 and 6000€ (French data, without VAT) according to:

- the volume of the spraying tank;
- nozzles;
- options for the pressure regulation (electronic / manual).

6.4 Stakeholder trial/demonstration leaflets

Valerie

This project is funded as a collaborative project under the 7th European Framework Programme,Grant Agreement No.: FP7-KBBE-2013-7-613825-VALERIE
Duration: January 2014 – December 2017

Valorising European Research for Innovation in Agriculture and Forestry

VALERIE Stakeholder Trials:

Sustainable innovative practices in the central region of France: a focus on soil structure assessment in the field

The problem

Arable farming in Berry, in the central region of France (departments of Indre and Cher), is characterised by oilseed rape, wheat and barley grown in rotation. Over the last 20 years yields have been decreasing or stagnating. An agronomic diagnosis (2005-2012) based on 500 agricultural plots linked the problem to short rotation, weeds and pests (especially insects). The quality of the seed planting phase, germination, rooting and weed infestation, as well as crop growth in the autumn, were identified as the main factors limiting potential crop yield. To tackle the short rotations identified as responsible for recurrent weed and insects problems, farmers have gradually shifted towards simplified tillage in terms of number of operations and working depth. However, this simplified tillage is not always beneficial to the structural qualities of the soil.

The proposed solution

Sustainable innovative practices, which involve adjusting tillage practices (no- or reduced- tillage) and sowing dates, lengthening crop rotations, and growing cover crops and new crop associations (oilseed rape in legumes cover, winter pea and barley/wheat), were identified by farmers as having the potential to address these problems. Specifically farmers requested better decision support to help them select the most appropriate practices for managing the soil (e.g. no-till, cover crops, crop association, sowing dates, etc.) under particular climatic and environmental conditions, and as part of this a field method to assess soil structure was proposed.

Stakeholders

A group of 15 arable farmers and 5 public and private advisors have been working together with group discussions, regular meetings and on-farm testing since 2015 and are supported by an agronomist from Terres Inovia. The farms, which vary in size from 100 to 500 hectares, are located in the departments of Indre and Cher, where the soils are typically calcareous clay (stony) soils. These farmers regard soil quality as the key factor in achieving more productive and efficient systems. This group is accustomed to interacting with research projects.

www.valerie.eu @Valerie_project 1

Aims and Method

The trials aim to;

- Examine how management of soil tillage (deep tillage, no-tillage, reduced-tillage, etc.), cover crops and crop associations affect soil quality characteristics
- Examine how soil quality influences crop growth processes and yields for different soil and crop management
- Collect data to create a decision support tool to guide farmers in selecting innovative cropping practices. This tool includes simple field soil structure assessment.

Field experiments

On-farm trials were conducted in a network of 10 farms over two years (2015 & 2016). Conventional and innovative practices are compared in the same plot with data collected on 19 oilseed rape plots, 16 wheat plots and 7 protein crop plots (pea, faba bean).

The tested innovative practices were:

- ***Seeding methods:*** No-till versus strip-till. Conventional seed drill or seed drill equipped with tine coulter and alternations of seeding methods. The performance of a prototype no-till seed drill was also tested.
- ***Lengthening of the rotation:*** Introduction of protein plants
- ***Cover crops in intercropping:*** As frequently as possible
- ***Associations of crops:*** Service plants (oilseed rape/ legumes), association of two cash crops (wheat/grain legumes).

Data Collected

Main visual analysis of soils:

- The colour: using organic matter content and the presence of hydromorphic features
- The type of clods: indicates level of compaction
- The porosity: biological (earthworms, roots), structural (peds) and textural indications
- The presence of organic matter

Main observations on crops are:

- At the beginning of winter: stand structure, roots and aerial growth, nitrogen content, Nitrogen Nutrition Index
- At flowering stage: sanitary state, growth, nitrogen content, Nitrogen Nutrition Index
- At G4 stage of oilseed rape: health state, growth, nitrogen content
- At harvest: crop yield

A group of 7-10 farmers met at four key periods over the crop growing season to assess soil and crop quality and to help select the most effective practices. The group was coordinated by the Terres Inovia agronomist and a technical assistant (who carried out soil sampling, photography, inventory of samples, database management etc.). Farmers were invited to join in the sampling and in-field soil structure evaluation (on some 25-30 field plots). At each occasion, discussion amongst farmers helped to improve and adapt a quick, visual, demonstrative soil quality assessment method on successions of oilseed rape in cover plants and wheat in association with grain legumes.

Field evaluation farmers, advisers and soil scientists

Field trial on soil structure characteristics	Field tests with the 15 farmers of the Berry group. 5 regional advisers and a soil scientist tested a tool based on quick visual assessment of structure and porosity using a spade test.
Measurements of plant structure, density and growth	Measurements were made during autumn in 2015 & 2016
Evaluation of the quality of roots (length, biomass)	The tap root lengths were measured at the beginning of winter (2015-16) with comparisons between different soil tillage
Evaluation of soil structure and quality of the crop	The state of the soil structure and its porosity were evaluated during the autumn 2015. Measurements of plant growth were conducted during the flowering and G4 stage of oilseed rape.

Results

Results are summarised from the on-farm trials carried out over two years (2015-2016) on 25-30 field plots over 10 farms. Full results are available in the Annexes.

At the beginning of winter, there was no difference in tap root length of oilseed rape between conventional or innovative plots.

During the autumn, there was a high % of healthy plants (in relation to flea beetles or rape winter stem weevils) in innovative* oilseed rape compared to conventional. A strong correlation was observed between the % of healthy plants and crop biomass at this stage.

During spring, innovative oilseed rape presented better biomass growth and nitrogen dilution curves showed that nitrogen concentrations in soils were not limiting. For all plots, yields were also higher for innovative compared to conventional oilseed rape, 34 vs. 27 quintaux**/ha

After innovative oilseed rape, wheat crops, associated with or without legumes presented similar yields limited by water excess and low solar radiation. Yields were lower with N fertilization (34 vs. 47 quintaux/ha) but unfertilized crops did not show diseases and presented higher grain quality compared to fertilized plots.

Oilseed rape with companion plants (limiting the impact of autumn insects) and of oilseed rape alone

The field trials were used to develop and test a decision support tool based on four steps:

1. Field information (weeds, pests, risks etc.)
2. In-field assessments (soil structure, crop residue etc.)
3. Decision making (use of innovative practice?)
4. Evaluation

A simple guide for field assessment of soil structure was developed to support this process (Annex 2 & 3).

Farmers and advisers assessment of the on-field method to assess soil quality

Picture: Terres Inovia

**Oilseed rape in association with legume cover with or without N fertilization in no-tillage or simplified tillage.*

***quintaux = 100kg*

Overall stakeholder involvement and feedback

The farmer group, together with their agronomist, have been central to the identification of the trial topic, the on-farm trial design, and data collection and tool development. Holding farmer meetings on the plots, at each of the four key growth periods, to sample and discuss results provided stakeholder input throughout.

In addition annual group meetings were held, together with a wider and larger groups of farmers and advisers in the region, to view different plot comparisons and discuss the results of the growing season (of oilseed rape and wheat/ protein crops).

Although the stakeholders found the results interesting and co-developed the field soil assessment method, they agreed that further trials and testing with farmers is needed to fully address the issues raised. Even for these innovative farmers observation of soil structure is unfamiliar, so further training is needed to support them in soil assessment. They found the contribution of the soil scientist was very beneficial to help them better understand their soils, but they reported that the focus on the long term assessment of soil and its intervention did not address their need for short term diagnostics for crop management. They proposed some revisions to the tool, amongst them use of non-scientific terms to describe soil peds.

Key findings

Oilseed rape in a no-till or reduced-tillage situation in association with cover plants:

- Decreases weed and insect pressure. Good oilseed rape biomass at the beginning of winter can be linked to a decrease in weeds and insect pressure.
- Increases yields of oilseed rape and of the following wheat.
- The decision support tool could help the farmers and advisers choose the best practices in these new cropping systems.

Further reading

Annex 1. Trial details - material, method and main results

Annex 2. Field trial on soil structure characterisation

Annex 3. Evaluation of Soil Structure (French)

Annex 4. A video demonstrating the decision support tool (in French with English subtitles)

https://youtu.be/u4fE-4x6Ypw.

Annex 5. Detailed results (French)

Acknowledgements

Gilles Sauzet, Anne-Sophie Perrin, Thierry Moulins, Véronique Quartier, Thibaut Pruvot, Joël Moulin (Chambre d'Agriculture de l'Indre), Anne-Marie Tremblay, Etienne Pilorgé

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6.5 Case Study Partner produced outputs

The CSP produced 5 Annexes to accompany the stakeholder trial leaflet:

- Annex 1. Trial details - material, method and main results
- Annex 2. Field trial on soil structure characterisation
- Annex 3. Evaluation of Soil Structure (French)
- Annex 4. A video demonstrating the decision support tool (in French with English subtitles) https://youtu.be/u4fE-4x6Ypw.
- Annex 5. Detailed results (French)

The Annexes can be found on the VALERIE website at: http://www.valerie.eu/

7 Sustainable forest management and ecosystem services, Navarra and Basque Country, Spain

7.1 Context

In many parts of the Pyrenees sustainable forest management had declined in recent decades. Forest ownership is often characterized by small and fragmented plots which are a barrier to economically viable forest management practices and the maintenance and enhancement of biodiversity and ecosystem services. There is an opportunity for forest owners to achieve sustainable management through joint forest management planning. However, a major barrier in the planning process is a lack of empirical data on the physical characteristics of the forest which can be used to inform management. Light Detection and Ranging (LiDAR) technology has the potential to provide much of the required information.

The VALERIE project has brought together a wide range of stakeholders, including individual forest landowners, the local authority, technical staff and forest engineers from the Navarra Forestry Society (Foresna), technical staff from the Mediterranean regional office of the European Forest Institute (Efimed) and the Government of Navarre's technicians and officers responsible for the Roncal area. Meetings have been carried out with forest owners to identify their problems and to show them the proposed innovation. There are also regular meetings with the Government of Navarre´s technicians and officers.

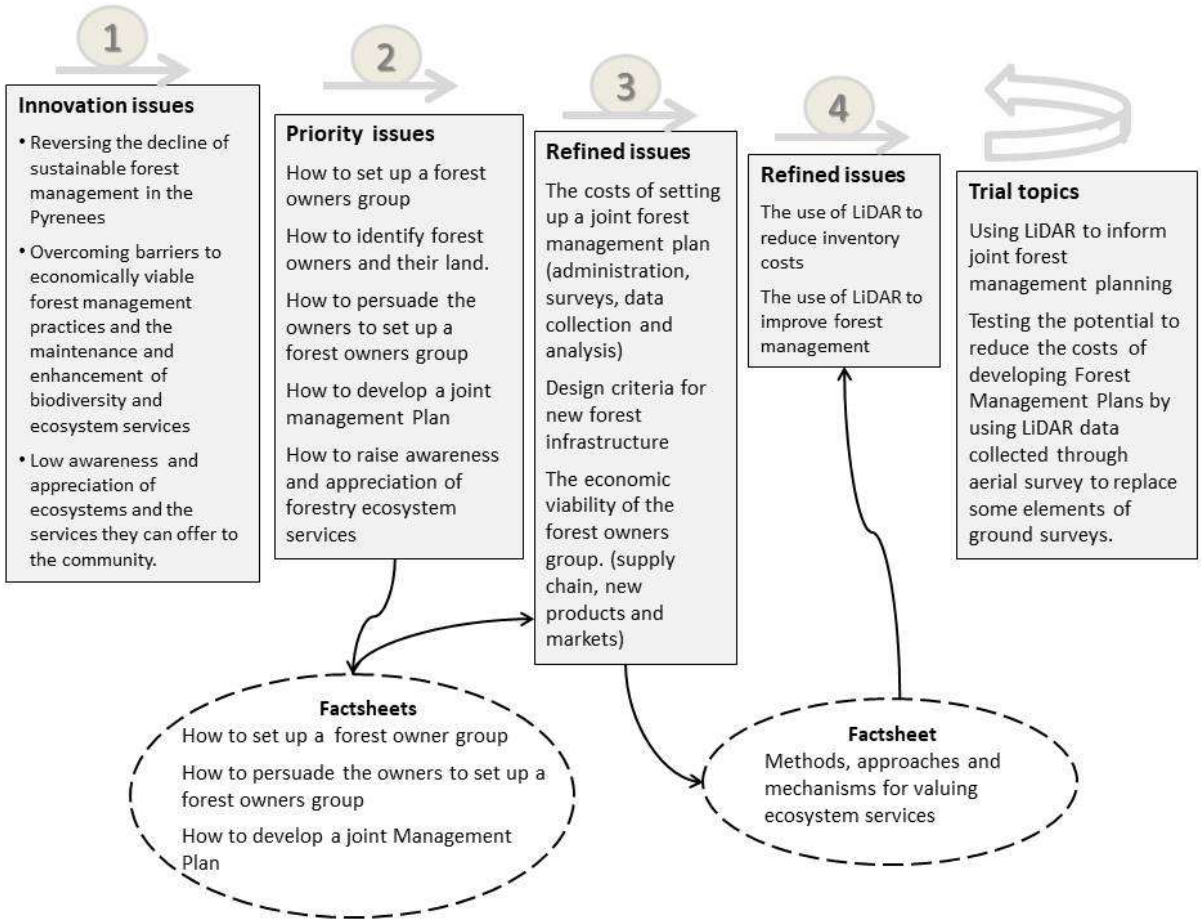
7.2 Dynamic Research Agenda

This CS is notable for its focus on social innovations in relation to sustainable forest management. In the first meeting the CSP and stakeholder identified three broad themes where innovative solutions were required:

- Reversing the decline of sustainable forest management in the Pyrenees
- Overcoming barriers to economically viable forest management practices and the maintenance and enhancement of biodiversity and ecosystem services
- Low awareness and appreciation of ecosystems and the services they can offer to the community.

The DRA (Figure 7.1) shows that stakeholders then identified 5 priority issues for further investigation through the production of factsheets. The CSP and stakeholders were interested in a particular set of issues surrounding the creation of a forest owners' group and a joint forest management plan as a means of promoting and achieving sustainable forest management in the Roncal valley. As the project developed the CSP and stakeholders worked together to create the forest owners' group and joint forest management plan. In subsequent meetings the CSP and stakeholders discussed and addressed any issues that arose. One area of interest was the use of LiDAR technology to inform forest management and at the same time reduce the cost of producing a joint management plan. This interest in LiDAR became the topic of the trial.

Figure 7.1 Sustainable Forest Management and Ecosystem Services Case Study Dynamic Research Agenda



The Thematic Experts produced 3 factsheets after the first meeting and an additional one later in the project. The CSP reported that the factsheets produced after the first meeting were very useful in providing ideas for the creation of the forest owners' group and the joint forest management plan. In this CS there was a very close working relationship throughout the project between the Thematic Experts for forestry, the CSP and the stakeholders. When the CSP and stakeholders expressed an interest in the use of LiDAR technology for forest management the Thematic Experts were able to produce mini-factsheets on the use of LiDAR to reduce inventory costs and to improve forest management.

7.3 Factsheets on innovation

Valerie

How to set up a forest owner group?

What is it?

The forest group can be defined, according to current forest legislation, as an association of natural, legal or private persons who voluntarily or mandatory (if determined by the government) bring together the forest properties over which they hold any right, in order to make a joint management thereof.

The forestry land group can be:

Case 1: The lands are grouped to be managed and/or exploited and each landowner, who is a member of the group, keeps the property over their forestry land.

Case 2: Specific ownership disappears and the member is then holder of an abstract portion instead of a specific forest land.

The fact that the forestry lands are adjacent or neighboring is an advantage but not a requirement. The nature of the forest land group is determined by comprehensive planning and management.

1

Problems to be solved

Forests of the Pyrenees from both Spanish and French sides are neglected because:

- The properties are very atomized, there are many small plots. An average of 2 ha per plot represents the average area of management today.
- There are owners who do not know where their plots or their plot limits are. There is a lack of forest culture and unawareness of silviculture and technical management plans.
- It is sometimes difficult to find the forest owner as they are living outside the territory.
- The land registry is out of date and in most cases does not match the boundaries that are recognized in the Public Registry of Property. In some cases it is difficult to define the property (e.g.: dual ownership lands or undefined boundaries).
- Ageing in much of the landowner population and the new generation who will be taking over is unaware of the forest knowledge and management.
- Actions in the forest become more expensive due to the different orography features of the land and such exploitation has no profitability for the owner or the industry.
- Difficulty for the creation and maintenance of joint infrastructures.
- The territories are away from the companies and transport makes the product value more expensive.
- The quality of products is low and the level of extraction is less than natural growth.
- Lack of awareness of territorial initiatives on the critical roles of forests.
- As a result of the above, the Pyrenees, which used to be a very active aerea, now lack forest management, which is detrimental to the forest from three points of view:

1st Environmental:

- Aging, deterioration and imbalance of the masses.
- Increased risk of fires.
- There is a greater presence of disease in the forest.
- The risk that some trees are blown over by wind or snow increases.
- Delay in the forests by the lack of silvicultural treatments that can even lead to endangering forest persistence.
- The non-intervention causes decreased tree growth and increased quality of the surface covered with weeds, hampering further work and increasing the risk of fire.

2nd Economic:

- At the moment there is a source of untapped resources that are wasted in the forest, wood, hunting, mycology and other products.
- Many local industries have to go get their raw material further afield with all that implies, such as a higher cost and increased pollution.

3rd Psychological and Human:

- Rural areas are abandoned and the remaining population is aged.
- The generational change does not occur because there are no alternatives.
- There is a major loss of culture and knowledge of the region. Many traditions disappear and with them, the cultural past of a place.

Image: Atomization of the property

OBJECTIVES

The aim is to achieve a reunification of forest owners, through cooperation in the submission of services and timber market. The idea is to train larger management units which will generate a greater benefit when an increase in the economy of scale is given (joint timber sales, work organization, purchase of materials, etc).

It is intended by this concentration of territory:

- To promote rational management of forests.
- To define a management project of the masses that propose innovative silvicultural solutions adapted to different situations of the chosen massif.

- To enhance production through diversification: sales to paper mills, board manufacturers, energy sector (biomass), hunting, mycology.
- To get the PEFC label for sustainable forest management.
- Not only to improve and regenerate the health of forests of the Pyrenees, but also to improve resources.
- To establish partnerships between companies and government agencies for research and development.

How does it work

1) Search for potentially producing areas that are neglected and unmanaged because the owners have small, fragmented and diverse plots.
2) Looking to introduce the idea of grouping it is necessary to convene a briefing to see if the actors of the involved territory are interested. Afterwards, several meetings must be held to inform and ask for the administrative documentation and to see the dimension of the group in terms of area and owners. The legal form of incorporation, by-laws and membership of the organization must be explained.
3) In terms of the territory it must be taken into account:

- Relief: areas with rugged relief, over 60% slope in general, will be excluded.
- Density of tracks: search for areas with an adequate network of tracks, to start work in the short, medium term, and from there, to be able to plan new ones.
- Stands: interesting areas of Scots pine (Pinus sylvestris) and Silver fir (Abies alba).
- Avoid areas with figures of comprehensive protection: because of the difficulty with exploitation and achievement of short-term goals it would entail.

Advantages and disadvantages of the innovation

- The group makes forest owners stronger:
  - Greater negotiation power with industries.
  - Improvement of forest product prices, since more products are put in the market and the costs are lowered.

- Greater recognition by Administrative Entities and Government that recognize them as valid interlocutors.
- Communication is faster and smoother and safety is generated among individuals when being part of a collective.

- Drawbacks:
  - It is a slow process and motivation and energy must be kept high.
  - Sometimes internal or external tensions and suspicions are risen.
  - They have a high cost for previous work performed.

Costs

There will be costs in the first year, when a preliminary meeting must be held to see if there is interest. Other costs will be generated during the search for interesting areas, their development and the meetings held until getting the administrative documentation, together with all the technical material.

Staff: Forest Engineer: €30,000 per year.

Technical support staff: €10,000 per year.

Travel expenses: depending on the area and the number of journeys to be made

Office supplies, printing, maps, cartography: €6,000

LEGAL ASPECTS

1. Forest legislation of the country where it operates must be considered.
2. Possible environmental laws, and from local and national administration must be considered.
3. Laws relating to data protection must be considered.
4. Consider social figures given by the Civil and Commercial Law or the cooperative legislation of each country in order to build these organizations.

Contacts (manufacturer, service provider, developer)

FORESNA, EFIMED

Source of the research

Innovation was conducted and further developed with funds from Foresna-Zurgaia and collaboration with the Government of Navarra in the case of the Forest Owner Group from Roncal.

5

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How to persuade the owners to set up a forest owner group?

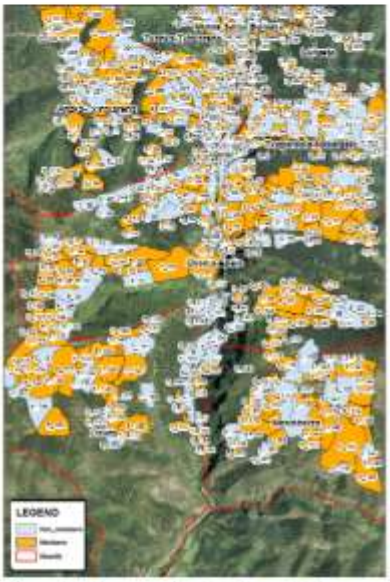

Image. Initial situation of the distribution of the plots

What is it?

As detailed in Factsheet 1, the forest owner group can be defined, according to current forest legislation, as an association of natural, legal or private persons who voluntarily or mandatory (if determined by the government) bring together the forest properties over which they hold any right, in order to make a joint management thereof.

Thus, the first problem that arises is how to initiate the creation of this group, given the multitude of actors involved.

Problem to be solved

When looking to come up with the creation of a forest owner group, we come against some problems: whether the owner trusts the person proposing the idea of union and the distrust that joining others generates. Some owners see the forest owner group as an opportunity as they think they could benefit from its collective mode of operation, whereas others raise the possibility of being harmed by neighbours they don't like.

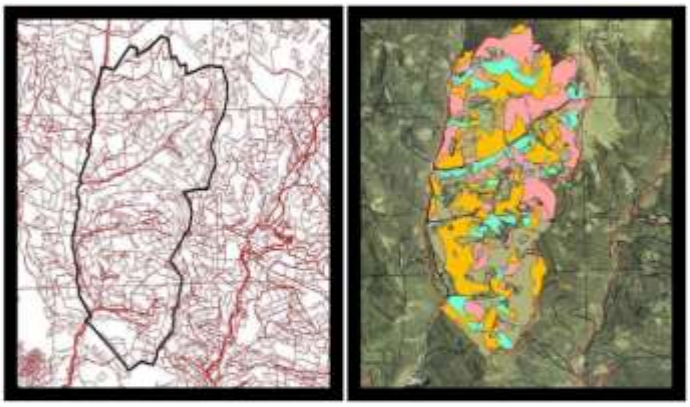

Image: Initial situation of the forest view, and final image of how it is going to be managed and treated

How does it work?

Basic tools:

- Presentations made to owners dealing with: legal issues, operation of the group, plots problems in the area and possible technical solutions, strengths, weaknesses, opportunities and threats.
- Consideration of potential costs and benefits.
- Discussions in assembly, the meeting to provide a platform for discussion.
- Individual survey on expectations about forest ownership and the group. It can be conducted at some point in any setting meeting, and its results can be explained in the next meeting.

Conducting the survey involves: designing, monitoring while it is being filled and analyzing results. The basic criteria for design would be: concision (short sentences, few questions=max 1 page), objective question wording (avoid leading questions), key questions (addressing key points). The information extracted is valuable for both the orientation of the activities, and for the subsequent management plan.

Both the presentations and the questions made afterwards are to convey transparency and professionalism. They must be short enough for people to stay focused (eg max. 45 min in total to give information, the rest of the time for the debate). The presentations will be made in easy-to-understand language: little technical and near the local lingo. If there are complicated issues which require charts or diagrams, they should be given in a pamphlet to be read quietly at home. Different issues should be dealt with in different meetings. Doubts that arise should be noted down for future meetings.

2

Speaking protocol: at meetings where there is a government institution, the Mayor of the place will preside and will speak as they are the highest institution in the place, except that they want to give this honour to other person, out of courtesy. The technician in charge will take over the meeting in all other matters.

Advantages and disadvantages of the innovation

- A survey involves preparation and analysis time, but the information extracted can confirm whether the owners' concerns match the technicians', or if there is a need to work in either direction to improve communication on certain issues or to include other criteria that has not been covered yet.
- It has been shown that owners consider four axes/dimensions when managing: economic expectation over the property, a sense of moral duty, the model of how the forest should be, and the attitude towards natural hazards (Dominguez & Shannon, 2011).
- Knowing the motivations of owners help deal with individual preference elements in contrast with elements of cooperation among owners (Kittredge, 2005). The benefits of coordinated action may not be visible for many of the actors, therefore they need to be explained (Rickenbach et al., 2006). Also, the costs in terms of loss of decision making power (delegation of management, delegation of tactical decisions) have to be explained.
- Presentations on current issues of great value for the owners show that the technician does not act with their own agenda but adapts to the owners' interests.
- It has been shown that technical solutions suggested by technicians are widely considered by the owners in their decision making. Technicians are an important agent of influence on the opinion forming of the owner when considering different management alternatives (Primmer & Karppinen, 2010;. Gossum Van etal., 2005) (including participation in certain grants, programs, accepting certain forestry interventions).

In addition, it has been shown that in cases of high uncertainty (eg. fluctuating wood prices, climate change) and complexity (eg. interrelations between technological improvements and geopolitics of oil prices, etc.), owners rely on people and organizations that convey confidence, and take the mental models they provide. (Schlüter & Koch, 2009)

- Having the political establishment gives a character of seriousness / solemnity to the meeting. Not respecting the more or less formal protocols of the area can lead to estrangement.

3

- Owners' criteria: it is often "I want it to be without any cost for me, and if possible, to make a profit from it" The efficient management of the group is required.
- Encourage interaction among different members of the group involves creating new relationships among strangers (weak ties) and strengthens the relationships among acquaintances from the specific forest field (strong ties). There is evidence that members often talk about their property problems with an average of three members of the group and with technicians (strong ties), and consider the rest (weak ties) reliable (M. Rickenbach, 2009) . This facilitates joint decision making.

Costs

Transactional costs connected with setting meetings, in order to present the institution and the idea.

Time devoted to designing and analyzing the survey.

They will depend on how structured the forestry sector has been so far, as well as on the knowledge of the property.

Legal aspects

- Check budget lines allocated to this kind of initiatives by local, regional or national governments, and sustainable forest management.
- Assess and be aware of the fiscal improvements or possible deductions that may exist for forest owners.
- Study which of the different models under the law of each country is the most appropriate for each situation of the territory.

Contacts (manufacturer, service provider, developer)

FORESNA, EFIMED

Source of the research

Innovation was conducted and further developed with funds from Foresna-Zurgaia and collaboration with the Government of Navarra in the case of the Forest Owner Group from Roncal.

4

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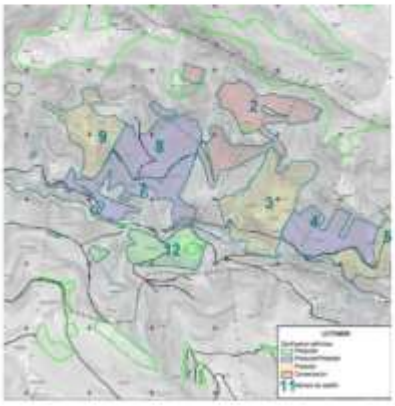
5

Valerie

How to develop a joint Management Plan?



What is it?

Forest planning should be carried out by Technical Management Plans grouping properties and forests of various individuals, and not be managed from an individual but global view. So, there is a need of Technical Management Plans that bring together various owners, and the methodology for their implementation must be established.

Innovation would be part of the global planning of forests, considering its services to society.

Problem to be solved

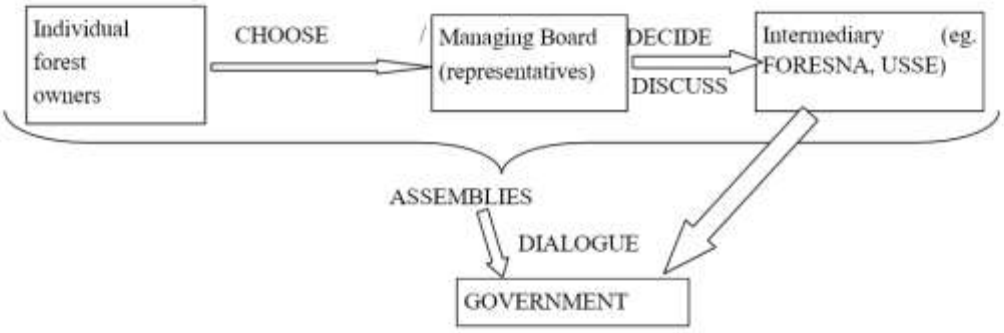
Grouping the owners must be considered and achieved, and conduct a planning document that meets all their demands, and the demands of society. Within the Technical Management Plan the following issues must be resolved primarily:

- Identifying infrastructure to create.
- Inventory of actual stocks and accurate characterization of habitats.
- Planning of forestry interventions: type, location, intensity and timing.
- A minimum of 10 years is recommended, consistent with the specifications that may be established in the legislation of each zone is recommended.

How does it work?

These steps must be taken for proper operation:

1) Grouping the owners and their lands (previous Factsheets)
2) Meeting and interviewing the owners to find out about their interests
3) Office working to establish fieldwork
4) Visit and field inventory
5) Meetings to define the objectives with the owners or the Board (management body)
6) Establishment of a ten-year planning
7) Approval of the Technical Management Plan by all the actors, first by the owners, and subsequently by the Government.



Advantages and disadvantages of the innovation

The development of a joint Technical Management Plan shows the following advantages and disadvantages:

Advantages:

- Inventory may be interesting for some owners to know the contents of their property and its value / potential.
- Transparency of interventions and benefit sharing.

- Advantages and disadvantages of the different approaches to participation, in terms of perception of legitimacy, fair treatment and transparency. Eg.: Focus groups for management plans in community forests in Galicia (Marey-Pérez, Calvo-González, & Dominguez-Torres, 2014)
- How to explain the benefits of joint action (Paige Fischer & Charnley, 2012)
- Comprehensive management of the forest and joint benefit.
- Planning according to global needs and, in turn, introducing requirements of society and taking into account the services offered by the forest.
- Greater ease in handling by the authorities.

Disadvantages:

- Internalization of adjacency externalities: when an intervention for the sake of the group affects negatively an owner, compensation mechanisms must be searched in order to have a sense of fair treatment.
- Areas where no action is established may lead to additional costs so they should not be introduced.
- Greater efforts in the implementation.

Costs

Individual Planning	Joint planning	Profit
50 - 80 €/ha	10 - 30 €/ha	According to productivity and field location. **Variable**

Contacts (manufacturer, service provider, developer)

FORESNA, EFIMED

Source of the research

Innovation was conducted and further developed with funds from Foresna-Zurgaia and collaboration with the Government of Navarra in the case of the Forest Owner Group from Roncal.

References

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Methods, approaches and mechanisms for valuing ecosystem services

What is this factsheet about?

This factsheet provides an overview of different methods, approaches and mechanisms for valuing ecosystem services.

Problems to be solved

A major problem is that most services that are public goods are under pressure because there is no financial value in the marketplace. This factsheet gives i) an overview of methods for evaluating the value of different types of ecosystem services, ii) guidelines for effective organizing of funding mechanisms for ecosystem services and iii) practical examples of valuing of and payment for ecosystem services.

Introduction

Ecosystem services are the diverse benefits we derive from the natural environment. They are ecological characteristics, functions and processes that directly or indirectly contribute to human wellbeing (Costanza et al. 2017). Examples are the supply of food, water and timber (provisioning services), the regulation of air quality, climate and flood risk (regulating services) and opportunities for recreation, tourism and education (cultural services) (AECOM, 2015). Most provisioning services refer to private goods. Most regulating services are public goods and most cultural services consist of a mix of private and public goods. Public goods are non-excludable and multiple users can benefit from using them (Constanza et al. 2017). Supportive services like soil formation, nutrient cycling and provisioning of habitat contribute indirectly to human well-being by maintaining the processes and functions necessary for provisioning, regulating and cultural services (Constanza et al. 2017). The majority of ecosystem services have been degraded in previous decades while food production has increased (MEA, 2005). While some ecosystem services like food and timber have a financial value in the marketplace, others that are also vital to our wellbeing are not. Ecosystem managers (farmers, loggers or protected area managers) often receive fewer benefits from land uses preferred by the community than they would receive from alternative land uses that produce negative externalities.

Payment of Ecosystem Services

Payment by the service users can help to make conservation the more attractive option for ecosystem managers. Payment of Ecosystem Services (PES) has gained a lot of attention. PES seeks to internalize what would otherwise be an externality (Pagiola and Platais, 2007). Payment for ecosystem services was defined as a voluntary transaction between service users and service providers that are conditional on agreed rules of natural resource management for generating offsite services (Wunder 2005; 2015). In practice many PES like schemes were realised that did not meet the exact definition of PES (Prokaflieva, 2016). Therefore broader definitions emerged like: the transfer of resources between social actors, which aims to create incentives to align individual and/or collective land use decisions with the social interest in the management of natural resources (Marudian et al. 2010)

The thinking of valuing ecosystem services has been shaped mainly by economics. Economic value is often defined in strict economic terms as "aggregate willingness-to-pay for the stream of services or to accept compensation for their loss" (Constanza et al. 2017). Within the group of economic techniques , contingent valuation is the most frequently applied method, followed by market price approaches and the

travel cost method. Other methods are hedonic pricing, benefits transfer and choice experiment and deliberative economic valuation (Pröbst-Haider, 2015).

Figure 1 gives an overview of the economic oriented approaches to value ecosystem services (Pröbst-Haider, 2015).

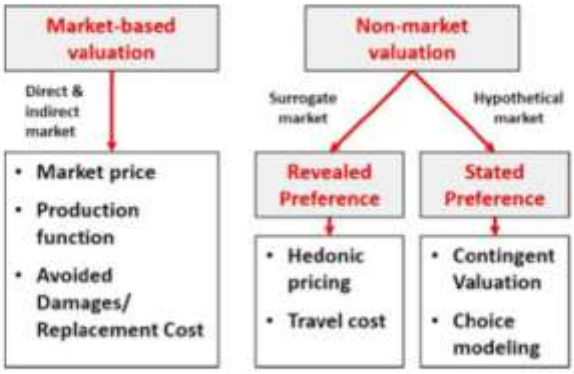

Figure 1. overview of the economic oriented approaches to value ecosystem services

Table 1 gives an overview of the recommended method to valuate different types of cultural ecosystem services including a short explanation of the different methods.

Table 1. Overview of recommended methods to valuate cultural ecosystem services (after Farber et al. (2006), Pagiola, von Ritter, and Bishop (2004) and Bell et al. (2009)).

	Proposed methods for evaluation				
Ecosystem service	**Contingent valuation**	**Choice experiment**	**Travel cost**	**Hedonic pricing**	**Amenability for economic valuation**
	Service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives, e.g. willingness to pay	Service demand may be elicited based on the ranking, rating or selecting of alternative choice-sets which have different combination attributes	Service demand may require travel, the costs of which can reflect the implied value of the service (e.g. recreation areas for distant visitors who are willing to pay for the journey)	Service demand may be reflected in the process people will pay for associated goods, such as housing prices near attractive green spaces	
Recreation	x	x	x	x	High
Aesthetics	x	x	x	x	High
Education	–	–	–	–	Low
Spiritual	x	x		–	Low

Issues to take in consideration are (Engel et al. 2008)

- payment offered to ecosystem managers must exceed the additional benefits they would receive from the alternative land use and must be less than the value of the benefit to ecosystem users;
- for payments to be conditional it must be possible to verify the existence of the service and to establish a baseline against which additional units provided can be measured;
- ideally payments must be based on ES provided (output based); in many cases this is not possible and payments are directed to adoption of particular land uses. (input based payment programmes

In practice there are user financed programs where the service buyers are the actual service users - like water quality, watershed protection, financed by a municipality, electricity consortium, urban water users (by a fee) and government financed programs where service buyers are a third party (typically the government) like conservation of forest area financed by a central government or state agency and user financed programs

Examples of user financed program are i) Vittel (Nestlé waters) that initiated a watershed program with payment to all 27 farmers in a watershed to assure good water quality and ii) Northeim project for agrobiodiversity in Germany; payments to farmers for changed land uses. A private foundation pays farmers to reduce agricultural intensification and to adopt practices that favor species richness. (Wunder et al. 2008).

Alternatives for the strict economic oriented approaches

Some researchers stress that pricing is a reductionist approach to our understanding of ecosystem goods and services and they are more worth than a predefined price (Kosoy et al. 2010; Small et al. 2017). Ecosystem services are the direct and indirect contributions to sustainable human wellbeing which is more than only the sum of individual, self-assessed welfare (Constanza et al. 2017). Ecosystems have mixed groups of beneficiaries. Therefore it is crucial that ecosystem goods and services are valued differently by multiple stakeholders and that these values will not be captured by market prices alone (Small et al. 2017).

There is also an intrinsic value of ecosystems. Davidson (2013) distinguished two types of non-use values: warm glow value related to the satisfaction people may derive from altruism towards nature and existence value related to the satisfaction people may derive from the knowledge that nature exists and originating in the human needs for self-transcendence.

Other authors pointed at other values for ecosystem services based on the the sub-goals for sustainability wellbeing: the fairness of distribution of services at the community scale and the sustainability goals for whole systems (Constanza and Folke, 1997; Constanza et al. 2017).

To include these issues, alternative to the strict conventional economic oriented approaches have been developed. Non-economic techniques for valueing have been proposed like consultative methods, questionnaires, in depth interviews, citizen juries. They are participatory methods and valuations where combinations of valuation methods are used involving many stakeholders with different perspectives (Christie et al. 2008; Constanza et al. 2017).

Classification systems

Different frameworks have been developed to link ecosystem services to societal benefits, like the Millennium Ecosystem Assessment (MEA) linking ecosystem services and constituents of wellbeing (Braat and Groot, 2012), The Economics of Ecosystems and Biodiversity Project (TEEB), the Common International Classification of Ecosystem Services (CICES), the Final Ecosystem Goods and Services Classification system (FEGS) and the National Ecosystem Services Classification System (NESCS).

The frameworks of MEA and TEEB are presented below.

Figure 2. Overview of the MEA Framework (Braat and Groot, 2012)

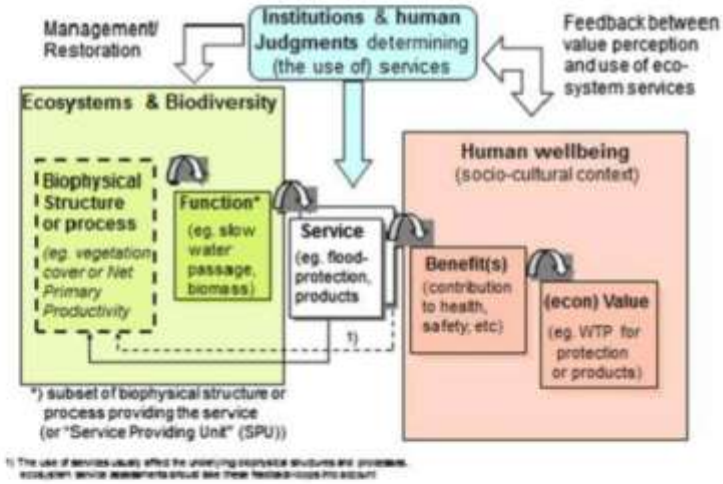

Figure 3. Framework of linking ecosystems to human well-being in the TEEB framework (Braat and Groot, 2012)

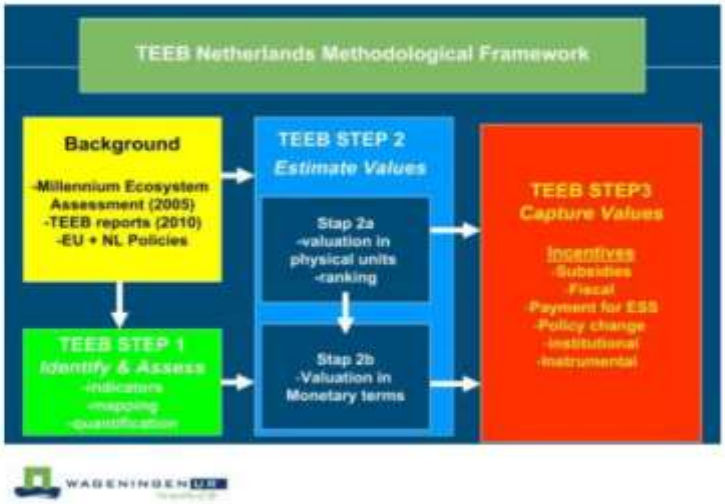

Figure 4. Steps in the TEEB framework procedure (Braat and Groot, 2012)

The largest global effort in establishing a framework for ecosystem services is that of IPBES: the Intergovernmental Platform on Biodiversity and Ecosystem Services. It's aim is to develop assessments matched to policy needs and support capacity building across scales and topics (Diaz et al. 2015). The key elements are nature and the benefits people derive from nature and a good quality of life. It highlights the central role of institutions and governance and decision-making and includes multiple knowledge systems. It uses a pluralistic valuation integrating biophysical, socio-cultural, economic, health, and holistic valuations, integrated into policies based on shared responsibilities (Pascual et al. 2017; Costanza et al. 2017).

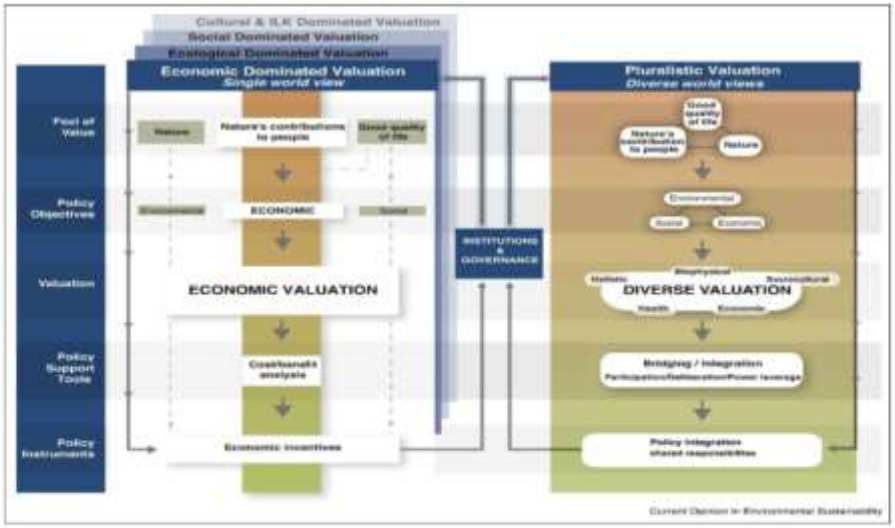

Figure 5. Pluralistic valuation in the IPBES framework (Pascual et al. 2017)

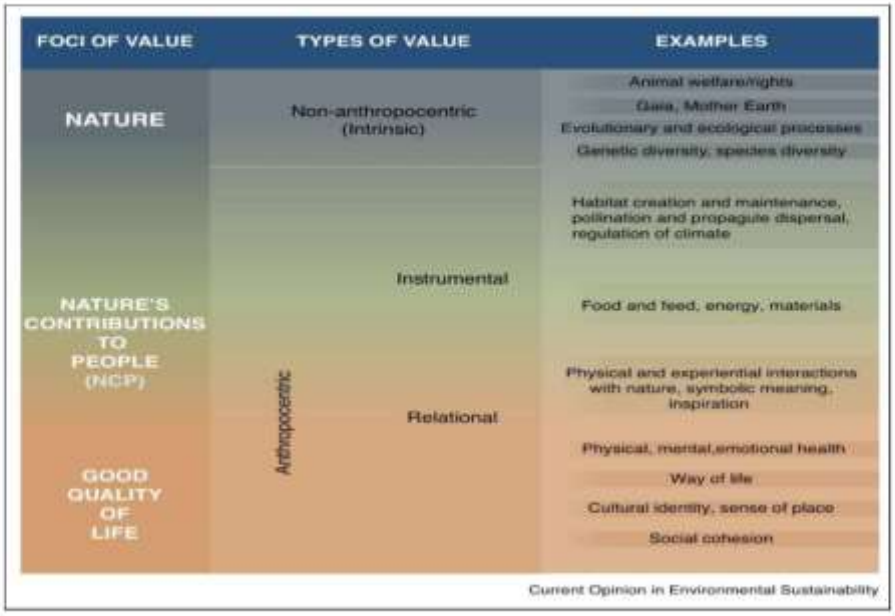

Figure 6. IPBES framework. The divers values related to nature, nature's contribution to people and a good quality of life (Pascual et al., 2017)

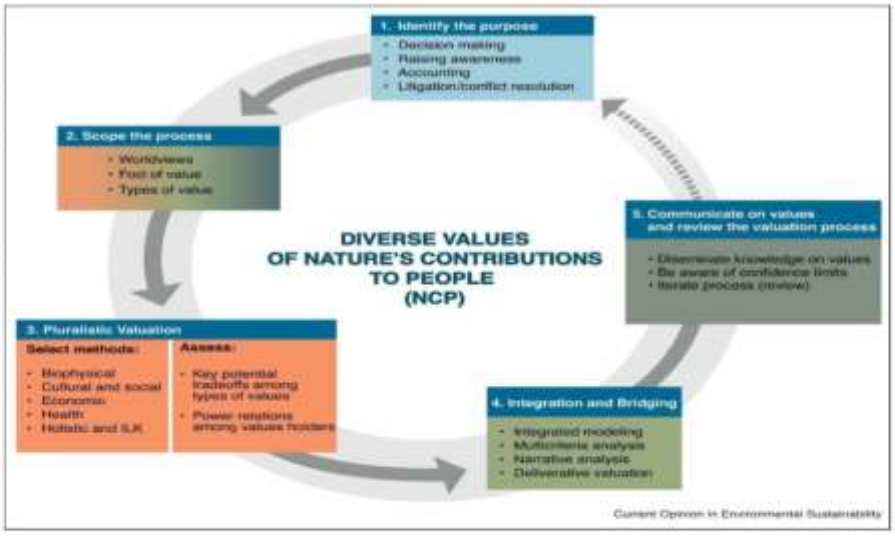

Figure 7. The IPBES approach for assessing values and conducting valuation studies. This five step approach gives structure and transparency to the accountability of the valuation process. It may be used at a community, landscape, bioregional and national level for raising awareness, decision making, or conflict resolution (Pascual et. al. 2017).

Governance systems

Given the public goods nature of many ecosystem services, well-functioning institutions and governance systems are needed that can deal with the perspectives of different stakeholders in the valuation of different types of services. They have to employ an appropriated combination of private, state, and common property right systems (Costanza et al. 2017). Successful funding mechanisms require a thorough design and a well-functioning governance system. Mechanism design issues are issues like what the payments are made for, how the funds are collected and distributed, identifying the recipients of the funds and issues like contract length, payment type, frequency and timing (Prokofieva, 2016).

Generally, three main types of governance structures can be identified: hierarchies, markets and community management (Vatn, 2010). Hierarchy: the power of decision rests with a top level like the government. Market: This is a system of voluntary exchange. The final allocation of resources is determined by the largest willingness to pay. Individuals, firms and governments may be agents in markets. Community management: this is based on cooperation. Individuals formulate both individual and common goals. Community allocation seems to rest to a large extent on a general rule of reciprocity. In reality there are asymmetries in power and access making additional specific rights concerning access and withdrawal necessary.

Several issues have been identified that need consideration for developing well-functioning and fair governance systems for ecosystem services Wunder et al. 2008; Vatn, 2010, Carius, 2012; Constanza et al. 2017)

- It asks efforts to create a market; service and rights, groups of users and providers must be specified. Often an intermediary is needed to define goods and establish group of sellers and buyers and the price. An issue is the transition costs.
- User based systems are generally more efficient than government financed systems. However when the number of agents involved increases, using markets becomes more costly and public bodies can much easier raise the necessary funding through taxes or fees.
- One should be careful that payments do not crowd out normative obligations based on sophisticated cultural process of regulating interconnection. The distinction between payment as an incentive and as a compensation is important.
- For administrative or contracting purposes, PES tend to separate ecosystem services. Yet ecosystems usually provide multiple benefits. The joint consideration of bundling of various functions could generate synergies and co-benefits.
- The effectiveness of PES schemes may be reduced by leakage that occurs when the provision of ecosystem services in one location reduces ecosystem services in other sites. This should be addressed in contracts

This leads to several recommendations for policy makers (Vatn, 2010; Braat and Groot, 2012; Carius, 2012; Constanza et al. 2017)

- We should use integrated measurements, valuations and decisions support, ideally using transdisciplinary teams and strategies in close collaboration with ecosystem stakeholders.
- We need to better understand how payment of ecosystem services can be formulated to strengthen not ruin cooperative will.
- We should examine the potential to contribute to sustainable development of principles such as 'polluter pays', beneficiary pays and full-cost-recovery'; we should develop tools to facilitate principles of no net loss and net positive impact to make them normal business practice; we should focus more energy on involvement of stakeholders in ecosystem services management.

- We should pay sufficient attention to the design phase of PES schemes. Expertise of governmental and non-governmental organizations, research teams or consultants should be used for the central technical and coordinating tasks.

Practical examples of valuing of and payment for ecosystem services

In different reports concrete examples of payments for ecosystem services have been described (Eustafor, 2011; Matzdorf et al. 2014; DEFRA, 2016; Viszlai et al. 2016)). Buyers of services can be water companies, recreational visitors, local tourism business, local authorities, industry, developers, central governments and consumers and local communities (DEFRA, 2016).

In practice three broad types of PES have been identified (AECOM, 2015):

- **Public payment schemes** through which government pays land or resource managers to enhance ecosystem services on behalf of the wider public
- **Private payment schemes**, self organized private deals in which beneficiaries of ecosystem services contract directly with service providers and
- **Public-private payment schemes** that draw on both government and private funds to pay land or other resource managers for the delivery of ecosystem services.

They have been developed at a range of spatial scales: international, national, catchment and local.

Examples of Private-public schemes for provisioning and cultural ecosystem services (Matzdorf et al. 2014; Eustafor, 2011)

Recreational Ecosystem Service. Westcountry Angling Passport UK: Initiated by the Westcountry Rivers Trust and private landowners. Recreational anglers are granted access to private fishing grounds for a fee. Beforehand, the owners invested in the unkeep of the waters and the riparian zones to increase the recreational value for the paying guests. Overall ecological condition of the water bodies is being improved. Tokens which can be purchased and redeemed through the environmental organization serve as a means of payment.

Biodiversity. Blühendes Steinburg, Germany: The Stiftung Naturschutz Schleswig-Holstein and the local farmers' association are testing two innovative mechanisms for PES as part of the pilot project. Farmers are paid output-based for the extensive management of grassland, whereby they must show evidence of indicator species on their fields. The farmers themselves determine the amount of the payment to be received in advance following a tendering process.

Water ecosystem services. Upstream Thinking with Westcountry Rivers Trust, UK: A water company finances various projects in South West England to improve the water quality in key watersheds. Farmers receive payments if they reduce nutrient and pollutant discharge into waters by improving their land management. This in turn reduces the company's water treatment costs.

Multiple ecosystem services. Pumium Project UK: Initiated by the Montgomeryshire Wildlife Trust, the PES aims to provide ecosystem services in combination with social and economic benefits. Farmers are encouraged to change their current land management to provide ecosystem services. In order to avoid double funding with government agri-environmental programs, the farmers are paid to maintain the infrastructure that the Trust has implemented.

Water quality for companies. In France and Poland arrangements are in place where businesses are paying land managers, farmers and foresters to maintain the water quality.

Recreational Ecosystem Services. Finland: A partnership is established with the Scouting organisation for developing permanent outdoor and camping facilities.

Visitor giving schemes. UK. Visitors and businesses can contribute directly to specific projects in the area they visit using mobile digital technologies (apps). (Visit England, 2014)

Payment of Dairy company to farmers for sustainable farming methods. Netherlands. Under the Foqus program of Friesland Campina, farmers are required to perform sustainability measures like outdoor grazing and management of the landscape. Farmers receive a bonus on the milk price by the dairy company. All members of the dairy company pay for this bonus.

Examples of (Voluntary) governmental payments (Matzdorf et al. 2014; Defra, 2013; Eustafor, 2011)

Biodiversity. Naturschutzgerechte Bewirtschaftung von Grünland in der nordrhein-westfälischem Eifel Germany: Since the mid-1980's, farmers in the Eifel region have been paid to maintain and extensively cultivate environmentally valuable land. It has now been in operation for 30 years and is today a governmental program coordinated by the biological stations in cooperation with the district landscape agencies.

Multiple ecosystem services. The English Woodland Grant UK: This Grant scheme was introduced in 2005 with the key aims to sustain and increase the public benefits derived from existing woodlands and investing in new woodlands for public benefit. It consists of grants for the management of woodland in accordance with the UK Forestry Standard covering habitats across England. It is funded by the UK government.

In some cases demand results from regulatory requirements like the case below.

Biodiversity. 100 Äcker für die Vielfalt. Germany: The goal of the project, initiated by scientists, landscape conservationists and a nature protection foundation, is to establish a national network of conservation fields for wild arable plant species. Funds for financing land purchases and for paying farmers tending the land are acquired through a regionally specific mix of payments for compensation measures, agri-environmental programs, and state and foundation resources.

Carbon markets. There are several voluntary projects to sequester forest carbon. Forest carbon trade is gaining more interest and several forest carbon credit projects are initiated.

Forest diversity services. Forest Diversity Program METSO: Finland. This program is a collaboration between the ministries of environment, agriculture and forestry, the Finnish Environmental institute and the forest development centre Tapio. Conservation agreements are either permanent or temporary. Landowners get financial compensation for conserving areas and tax-free for permanent protection. Compensation is based on opportunity costs, which means compensation for lost timber income. There is no direct payment for nature values.

Development of nature and landscape. European and provincial subsidies for conservation and development of nature and landscape: Netherlands. In the Netherlands, regional organizations of farmers have obtained the responsibilities to perform conservation of nature and landscape measures to realise the international obligations of the Netherlands. Farmers interested in providing nature and landscape services are member of one of these regional organizations. The regional organizations are contracted by provinces and financed by a mix of EU and national funding.

Social services integrated in the social, re-integration and healthcare framework

Some of the cultural ecosystem services have been incorporated in the financial frameworks of the social, re-integration and healthcare sector. Some examples are presented below.

Care services provided by farmers

Netherlands. In the Netherlands farmers providing care services are financed by national and local funding regulations for social and health care services. They have access to these social care budgets

when they are accepted by local authorities or health insurance companies as care providers. The can be contracted as individual farmers or as a member of one of the regional organisations of care farms. In order to be contracted they need to meet some quality guidelines (Hassink, 2017).

Flanders. In Flanders a regulation has been developed for supporting farmers that provide care and educational services to drop outs from schools. The funding originates from rural development funds. The Flemish support organization Groene Zorg takes care of the regulation (DiIacovo and O' Connor, 2009).

Social services provided by farmers

Italy. In Italy social farmers and social cooperatives are supported by local and regional authorities. There are specific financial support structures for social farms and social cooperatives (DiIacovo and O' Connor, 2009; Dell'olio et al. 2017). They can also benefit from tax relief. In addition social farmers have a preferred position in the tendering processes of local and regional authorities, like selling of their products to public canteens. In addition funding is available for the re-integration process of vulnerable citizens.

Educational services.

In various countries farmers offer educational services to school classes.

Netherlands. In the Netherlands they are financed by different mechanisms. They can be contracted by local nature, environmental educational organizations to provide these services. In some cases they are paid directly by school organizations (www.boerderijschool.nl) or financed by agricultural companies (like dairy industry) as part of the public relations of the agricultural sector (Hassink et al. 2009).

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7.4 Stakeholder trial/demonstration leaflets

Valerie

This project is funded as a collaborative project under the 7th European Framework Programme,Grant Agreement No.: FP7-KBBE-2013-7-613825-VALERIE Duration: January 2014 – December 2017

Valorising European Research for Innovation in Agriculture and Forestry

VALERIE Stakeholder Trials:

Using LiDAR to inform joint forest management planning with a forest owners group in Roncal, Navarra, Spain

The problem

In many parts of the Pyrenees sustainable forest management had declined in recent decades. Forest ownership is often characterized by small and fragmented plots which are a barrier to economically viable forest management practices and the maintenance and enhancement of biodiversity and ecosystem services. There is an opportunity for forest owners to achieve sustainable management through joint forest management planning. However, a major barrier in the planning process is a lack of empirical data on the physical characteristics of the forest which can be used to inform management. Light Detection and Ranging (LiDAR) is a remote sensing technique that uses laser pulses to survey the surface of the Earth and has the potential to provide much of the required information.

The proposed solution

Gathering empirical data using ground surveys to inform Forest Management Plans can be time consuming and expensive. There is potential to reduce the time and cost of developing Forest Management Plans by using LiDAR data collected through aerial survey to replace some elements of the ground surveys. In this trial, we are implementing the LiDAR technique as an innovation for joint forest management planning. The trial is taking place in Roncal, a valley in the north of Navarra. A meeting in August 2015 identified the forest owners requirements. In April 2016 the LiDAR data was analysed and the first results were used to develop the Forest Management Plan.

Stakeholders

The stakeholders are: individual forest landowners, the local authority, technical staff and forest engineers from the Navarra Forestry Society (Foresna), technical staff from the Mediterranean regional office of the European Forest Institute (Efimed) and the Government of Navarra's technicians and officers responsible for the Roncal area. Meetings have been carried out with forest owners to identify their problems and to show them the proposed innovation. There are also regular meetings with the Government of Navarra's technicians and officers.

Aims and Method

The nature of this trial is scientific demonstration of a new technique in forest planning. The aim is to transform the scientific results obtained from using the LiDAR technique in such a way that they can be included in the Forest Management Plan and be easily understood by stakeholders. The innovative use of LiDAR technology will assist forest owners with the sustainable management of the forest.

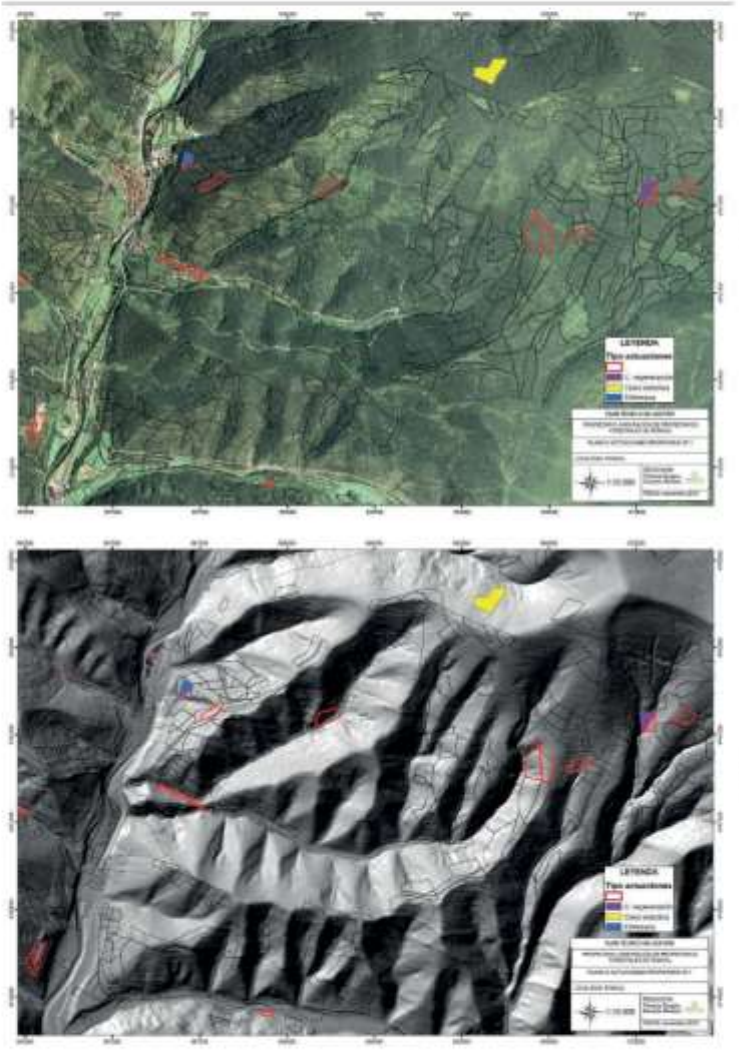
Results

A major advantage of using LiDAR technology for forest planning is that it is cost effective and is able to collect information on forest characteristics without the need for extensive ground surveys.

As part of the trial, information has been expressed in a range of different maps and discussed with stakeholders.

For example:

- (Slopes) Map of field slopes
- (Topography) Map of surface condition
- (Ho) Map of tree height
- (Fcc) Map of forest canopy cover



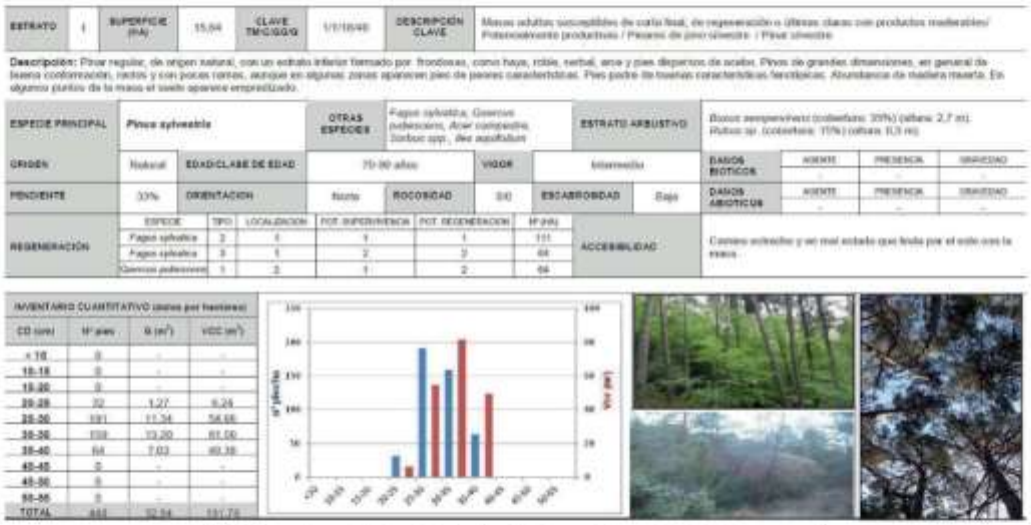
Aerial Photograph

LiDAR image

Part of the Roncal study area showing management options for individually owned forest plots

Working with the different maps we have defined 8 types of woodlands depending on their characteristics. This is very helpful as it provides a first idea of the potential of wood production in the different areas of the forest. Using the LiDAR data we can identify the roads that are in use and their type by measuring their width. We can also find the location of old roads that are no longer in use. This is very important because current maps do not provide this information and forest owners have often forgotten where the old roads are located. Knowing the location of old abandoned roads is helpful when planning new roads to improve access to the forest.Using LiDAR it has been possible to inform the forest owners of the quality of their forest and the location of the old forest roads.

This engagement with forest owners is very important in increasing their motivation towards joint forest management and addressing difficult issues such as the need to plan for new roads into the forest and proposed management practice in different parts of the forest.



LiDAR results contribute to the physical description of individually owned forest plots and are used to inform their future management.

Overall stakeholder involvement and feedback

Use of the LiDAR innovation has helped to facilitate joint forest management planning, which can be seen as a social innovation. Stakeholders motivation is higher now than at the beginning of the process. The LiDAR trial is important in engaging stakeholders and sustaining their interest in joint forest management. Holding meetings with stakeholders to discuss the early results from the LiDAR survey was important in maintaining their interest and motivation. Throughout the LiDAR trial, it has been important to keep all the stakeholders informed of the progress being made and to manage expectations.

Stakeholders appreciate the reduction of costs in general planning and the improved planning of access to the forest using the abandoned roads which has resulted from the LiDAR survey. Feedback from stakeholders indicates that joint forest management and the use of LiDAR technology has the potential to improve sustainable forest management and wood production in the Roncal area.

The stakeholders are very interested in the potential of LiDAR technology to provide more information on the characteristics of the forest cover, such as the volume of the trees and a range of other variables needed for further planning. While it is possible for LiDAR to provide this information, more analysis of the data is required using statistical programs supported by ground surveys to validate the results.

Key findings

- The LiDAR survey collected empirical data on the physical characteristics of the forest which was used to inform joint forest management planning in the Roncal area.
- The main problem encountered in using LiDAR in the trial was the technical knowledge needed to understand the LiDAR data.
- Discussion of the early LiDAR results has helped to engage and promote interactions between the forest owners and raise interest in joint forest management.
- When the LiDAR results are used to inform the Forest Management Plan the innovation is helpful for all stakeholders.
- The stakeholders understand the potential of the innovation. There are high expectations that the Forest Management Plan will be able to deliver improvements in forest management. However, this may lead to problems if these expectations cannot be fulfilled.

Acknowledgements

USSE www.usse-eu.org/en/inicio and EFI www.efi.int/portal/ are partners in VALERIE

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8 Improving milling wheat quality, Italy

8.1 Context

Problems with the quality of the local bread wheat production are increasing for many farmers. This is firstly due to the continuous drop of prices of the global and local market. Secondly, the national authorities have reduced the number of available and permitted pesticides to prevent environmental and health issues. Moreover, atypical weather conditions during the growing season increases the stress on plants while it is developing important tissues and nutrients. Furthermore, the customer and therefore the industry are more interested in alternative ways of farming, especially if they help reduce the use of chemicals.

The VALERIE project has brought together farmers, co-operatives offering storage facilities, millers of various sizes and capacity, seed and pesticides companies (retailers and producers).

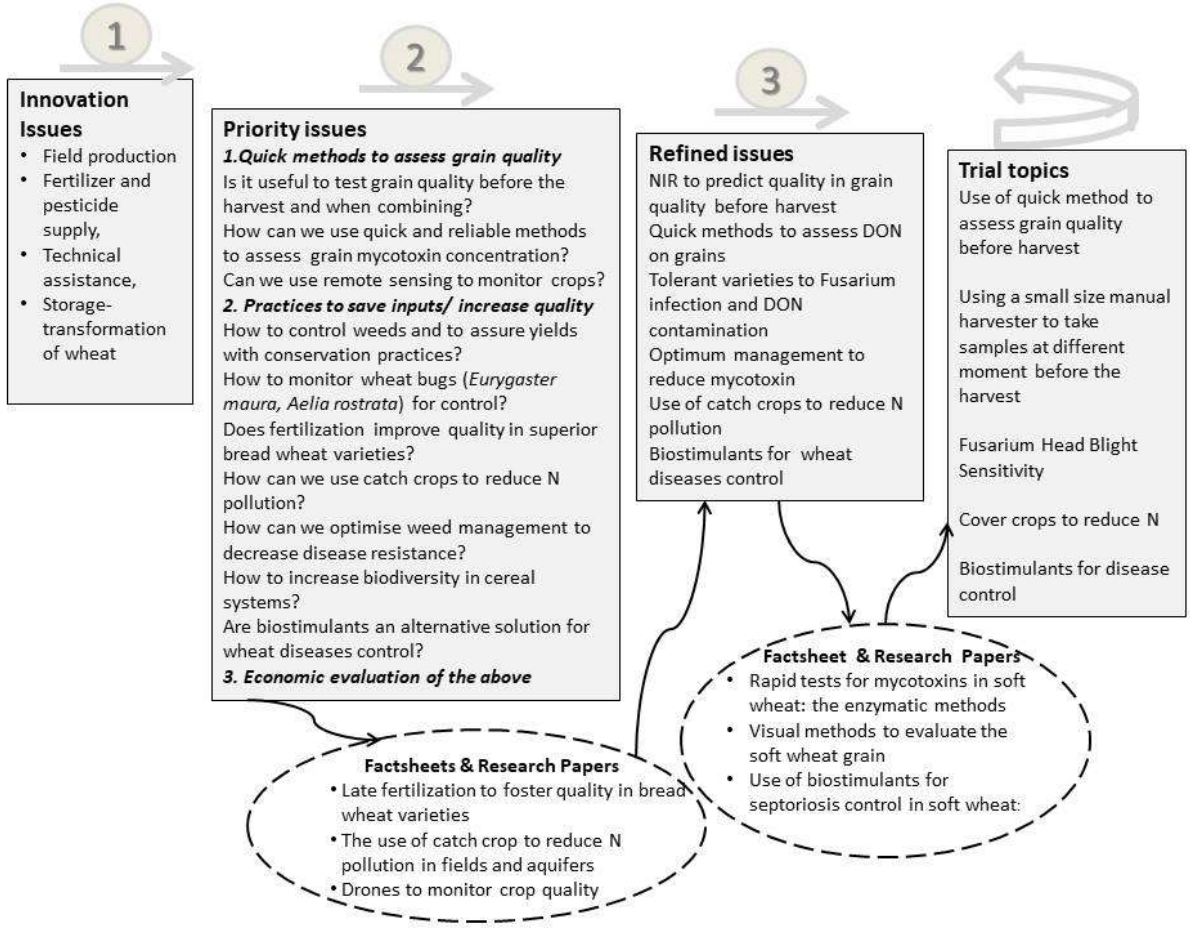
8.2 Dynamic Research Agenda

To reflect the stakeholder community the first meeting explored issues in four areas: Field production; Fertiliser and pesticide supply; Technical assistance; Storage-transformation of wheat. This allowed sufficient scope in goals and visions across the whole supply chain to be expressed but generated a long list (17) of issues many of which could not be answered by scientific knowledge. These issues were narrowed down in a process steered by the CSP and Thematic Experts, to issues and research questions concerning production, since these could be potentially resolved with scientific information. The resultant issues were categorised by the CSP into three different domains:

1. Quick methods for quality assessment of grains.
2. Agricultural practices to save inputs and increase quality.
3. Economical evaluation of the most innovative practices.

The DRA (Figure 8.1) shows how these remain and are reviewed at each meeting, with a particular focus on quick field testing methods to assess grain quality (to measure grain weight and moisture) to help farmers to decide when to harvest, which was selected as the topic for trialling.

Figure 8.1 Wheat Supply Chain Case Study Dynamic Research Agenda



Thematic Experts summarised and synthesised outputs from several scientific papers to prepare three factsheets. When these were presented at Meeting 2 the stakeholders felt that they were not particularly useful or relevant. In the absence of further factsheets from the Thematic Experts, the CSPs themselves prepared factsheets for three selected issues identified as important in Meeting 1 using scientific documents provided by the Thematic Experts but drawing on their own resources and understanding of stakeholders needs.

Together the factsheets from experts and CSPs led to the selection of trials as outlined in the leaflets below.

8.3 Factsheets on innovation

Valerie

Improving "Superior Bread" and "Improver Wheat" quality through late mineral fertilization

What is it?

It is a strategy of late-season N mineral fertilization based on granular and/or foliar application to increase protein content and improve protein quality of bread wheat..

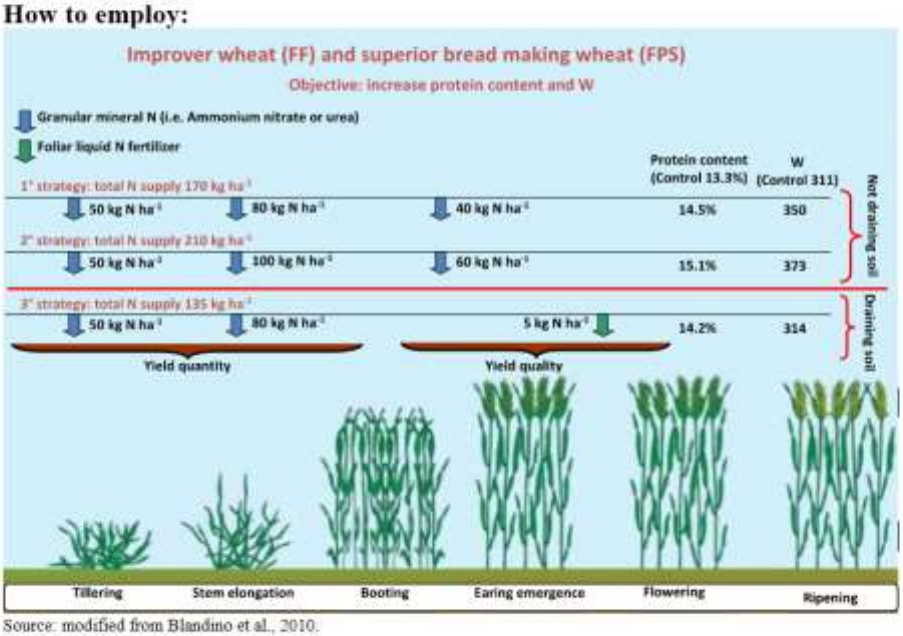
The following wheat quality categories (Foca et al., 2007) are considered:

1) improver wheat (FF): protein content (% dry matter) >13.5 and dough strength (W) >300;
2) superior bread making wheat (FPS): protein content >11.5 and W >250.

Problem to be solved.

To foster late N uptake in wheat between booting and milk development stages.

How to employ:



Source: modified from Blandino et al., 2010.

Positive side effects

1) Stability of yield and quality in FF and FPS wheat quality categories;
2) Reduction of potential N leaching in sandy soil when foliar replaces granular fertilizers;
3) Foliar spraying let late N application in climatic zones with insufficient spring rainfall.
4) Foliar spraying can be coupled with pesticide application reducing application costs.

Disadvantages

1) Foliar sprays strategy can damage canopy during heading and flowering stage in high daily temperature conditions (> 26 C°) especially if N supplied is more than 10-15 kg/ha. It is suggested to supply this type of liquid fertilizers only in cool climatic conditions.
2) N uptake consequent to Urea or Ammonium Nitrate granular fertilization can be very low in climatic zones with insufficient spring rainfall. Foliar spraying is suggested.
3) N use efficiency of late N application can be quite low. Catch crop after wheat harvest can be required to recover mineral N in soil.

Costs

Strategy	Application	Cost increase
1	Centrifugal spreader	+37%
2	Centrifugal spreader	+58%
3	Application with sprayer bar:	
	Only foliar fertilizer	+41%
	Togheter with anti- fungal	+18%

The different strategies imply a cost increase. Values reported in the table refers to the percentage of increase with respect to an usual fertilization management based on two distributions of granular fertilizers and a total supply of 130 kg N ha^{-1} (RDP threshold).

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Catch crops to reduce N leaching

What is it?

Catch crops are subsidiary crops included in crop rotation aiming at taking up available nitrogen (N) remained in the soil after the harvest of the main crop. They are able to decrease nitrate leaching from the cropping system (on average by 53% when a grass catch crop is used in the autumn-spring period). At the end of the growing period they can be left on surface or incorporated into the soil. In this fact sheet we consider also subsidiary crops that are harvested and have the same function of catching N.

Problems to be solved

Nitrate leaching losses can occur in croplands with a bare fallow in crop rotation, especially during the rainy and/or low evapotranspiration period with a high probability of drainage. In continental climates, these periods last from autumn to spring. Summer catch crop can be effective when they anticipate N uptake before the leaching period.

Positive side effects and different environment (they differ among catch crop species)

During growth:

1) They control soil erosion.
2) They limit early season weed seed germination.
3) They improve soil structure due to roots growing and organic matter addition derived from below biomass.

If incorporated in the soil as green manure:

4) They further improve soil structure due to organic matter addition derived from above ground biomass.
5) They make captured available N for the following main crop, thus reducing the need for mineral fertilizers.
6) They increase phosphorus and potassium uptake of the following crop.
7) They increase soil organic matter and soil organic N. This increase is correlated to the frequency of catch crops in crop rotation.
8) They supply N from N fixation if legume species are included(in mixture with grass or in pure stands).

Disadvantages

1) Nitrogen immobilization may occur if the incorporated biomass has a large C/N (>20). If soil mineral N is scarce, N immobilization can decrease the yield of the subsequent crop. One solution to this problem is to sow a cover crop mixture (grass with legume species) to reduce the C/N ratio and increase net N mineralization.

2) Eventual depressive effects may occur due to the release of natural herbicidal molecules into the soil (allelopathy). To avoid this problem, respect a delay between the incorporation of the catch crop and the sowing of the following main crop (especially for Brassica cover crops).

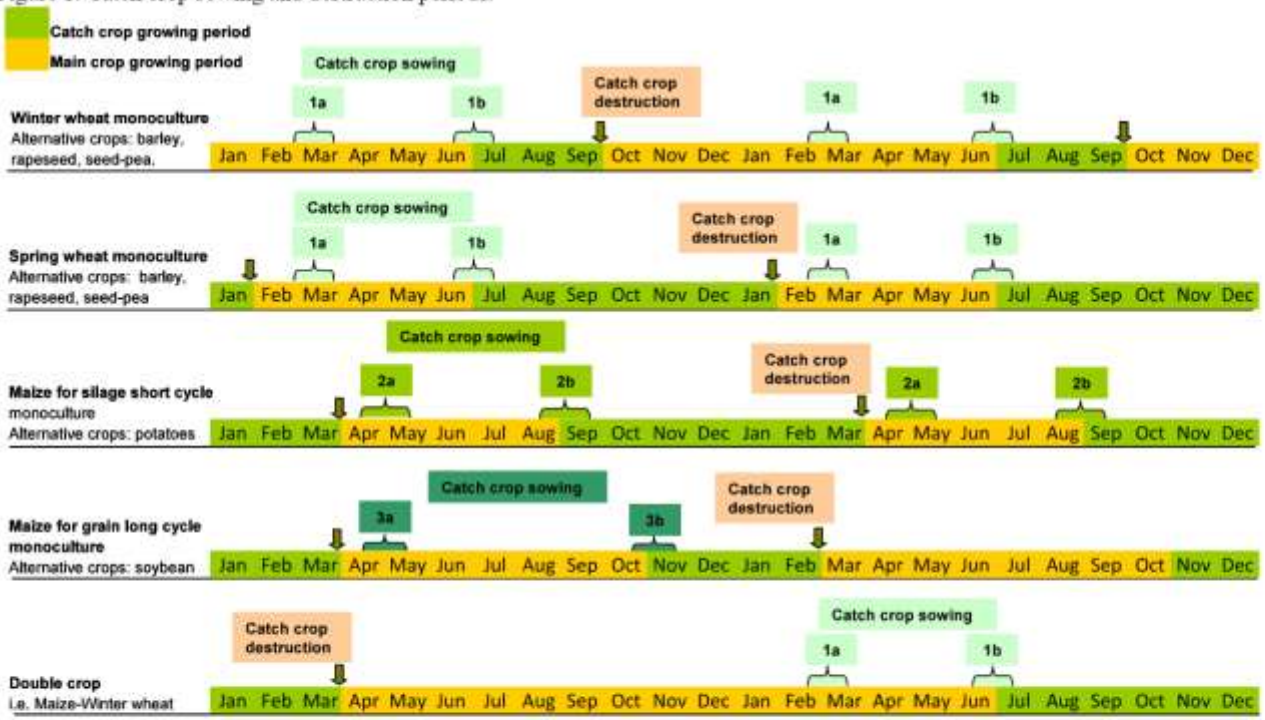
3) Irrigation eventually needed for summer catch crops.

How to manage catch crops

Position in crop rotation

Catch crop growing period depends on the crop rotation. Figure 1 reports five examples of introduction of catch crops in five different crop rotations. Different catch crop sowing periods are represented with different numbers and shade of green color.

Figure 1: Catch crop sowing and destruction periods.



Catch crops species and sowing suggested management.
Table 1 reports the different species that can be sown during the three different periods reported in figure 1.

Table 1: Suggested catch crop species for the different sowing periods.

Sowing period	Previous main crop	Species
1	Winter and spring cereals (i.e. wheat, barley) Winter and spring legumes (i.e. seed-pea) Rapeseed	*Lolium multiflorum* *Panicum miliaceum* *Panicum italicum* *Avena sativa* *Trifolium spp.* *Fagopyrum esculentum* Mixture
2	Summer crop short cycle (i.e. Maize silage, potatoes)	*Lolium perenne* *Lolium multiflorum* *Secale cereale* *Avena sativa* *Triticum aestivum* *Brassica napus* *Sinapis alba* Mixture
3	Summer crop long cycle (i.e. Maize for grain harvest, soybean)	*Lolium multiflorum* *Secale cereale* *Hordeum vulgare* *Avena sativa* *Brassica napus* *Vicia villosa* Mixture

Sowing management must be adapted to catch crop seeds characteristics and farm machines availability.

a) Seeding technique "a" in figure 1 (1a, 2a, 3a):

- Undersowing the catch crop on cereals or on maize in spring (broadcast seeding on the standing crop before harvest);
- Drill seeding into a growing cereal;

b) Seeding technique "b" in figure 1 (1b, 2b, 3b) for cereals:

- Drill seeding on the stubble;
- Broadcast seeding on stubble;
- Broadcast seeding after crop harvest, and seed bed preparation with disk harrowing and rolling;
- Broadcast seeding after crop harvest and seed bed preparation with ploughing and disk harrowing
- Precision seeding after ploughing and disk harrowing;
- Sod seeding into crop residues;

Seeding technique "b" in figure 1 (2b, 3b) for Cruciferous:

- Precision seeding after ploughing and disk harrowing.

In warm and dry environment, irrigation might be needed when catch crops seeded in early summer.

Biomass destruction management

Biomass catch crop destruction can be:

1. removed;
2. killed with herbicides spraying and left on soil surface or incorporated into the soil;
3. killed with flail mulcher and left on soil surface or incorporated into the soil.

Effects of catch crop management on N leaching:

Table 2 summarizes the efficiency of different kinds of catch crop species. It includes different types of soils and climatic conditions.

Table 2: Requirements, effects on N leaching and soil N availability, strengths of different species of catch crops and conditions and practices that discourage adoption. (Source: Justes et al., 2012)

Effects	Grass	Cruciferous	Legumes	Mixture
Requirements	Rather early seeding on soil frost-free or little frozen	Early seeding on soil frost-free according to species and temperature	Very early seeding on soil frost-free	Mixture must be adapted to the N availability
N leaching reduction (%)	30 to 80%	30 to 90%	0 to 40%	20 to 60%
N release for the succeeding main crop (%) (soil available N for main crop/N uptake of catch crop)	-20 to +10%	-10 to +30%	+10 to +50%	+10 to +40%
Strengths	Efficient in high N input cropping systems and in Atlantic climate	Highly efficient or efficient in high N input cropping systems and in Continental climate	Efficient in low N input cropping systems. Lower competition with main crop in undersowing	Intermediate efficiency due to species plasticity according to N availability
Conditions and practices that discourage adoption	Clay soil (late incorporation)	Clay soil if the cover crop is not sensitive to frost (late incorporation)	Intensive cropping systems with large manure or N inputs	Intensive cropping systems with large N inputs

Some experimental results are reported in figure 2. Although they are referred to specific pedo-climatic situations, the described effects can be considered meaningful in wider pedo-climatic environments.

Figure 2: Factors influencing efficiency of N leaching reduction for specific situations.

Best practices	Soil	Alternative management			Percentage of leaching reduction vs no catch crop
		Worse	vs	Better	
Biomass destruction	Sandy, Sandy loam	Lolium perenne, left on surface, minimum tillage or sod seeding	vs	Lolium perenne, incorporated with ploughing	
	Sandy, Sandy loam	Lolium perenne, removed, sod seeding or minimum tillage	vs	Lolium perenne, incorporated with ploughing	
Time of ploughing	Sandy, Sandy loam	Lolium perenne, autumn ploughing	vs	Lolium perenne, spring ploughing	
Growing period	Silty soil	Avena sativa, from end of August to end of November	vs	Secale cereale, from beginning of October to end of April	
Selected species	Sandy, Sandy loam, Silty clay loam or Clay loam	Vicia villosa	vs	Avena sativa	
	Silty clay loam or Clay loam	Vicia villosa	vs	Hordeum vulgare	
	Silty clay loam or Clay loam	Vicia villosa +Triticosecale	vs	Secale cereale / Triticosecale	
	Silty soil	Vicia villosa	vs	Sinapis alba	
	Silty soil	Vicia villosa	vs	Trifolium spp	

Costs for catch crop

Costs for catch crop managements include seed purchase (table 3), sowing and destruction management (table 4).

Table 3: Seeds quantity, costs for kg and for hectare, VAT excluded, for some catch crops seeds in North-West Italy.

Cereals	Seeds kg/ha	Cost €/kg	Cost €/ha
Lolium perenne L. *Lolium multiflorum L.*	35-45	2.40	96.00
Panicum miliaceum L. *Panicum italicum L.*	10/15-40	1.08	28.40
Avena sativa L.	120-150		
Secale cereale L.	150-200	0.75	131.25
Triticum aestivum L.	200-250	0.62	139.50
Hordeum vulgare L	200-250	0.68	153.00
Legumes			
Vicia villosa L.	200	1.20	240.00
Trifolium spp.	5-7	5.00-8.00	45.00
Cruciferous			
Brassica napus L.	10		
Brassica juncea L.	8-10	9.00	81.00
Sinapis alba L.	10		
Mixture			
Mixture (Sinapis alba L.+ Brassica juncea L.)	10	12.00	120.00

Table 4: Costs of some proposed management practices (VAT excluded) in North-West Italy.

Sowing	Operation	Cost €/ha
Broadcast seeding on stubble or on the standing crop before harvest	Broadcast fertilizer spreader	29
Broadcast seeding after crop harvest, and seed bed preparation with disk harrowing and rolling	Total	125
	Disking	77
	Rolling	18
	Broadcast fertilizer spreader	29
Broadcast seeding after crop harvest and seed bed preparation with ploughing and disk harrowing	Total	217
	Ploughing	110
	Disking	77
	Broadcast fertilizer spreader	29
Sod seeding into crop residues or into a growing cereal	Seed drill	100
Precision seeding after ploughing and disk harrowing	Total	235
	Ploughing	110
	Disking	77
	Classic seed drill	47
(Irrigation)*		
	Surface	7
	Sprinkler	35
Destruction of biomass	-	-
Left on soil surface	Herbicides spraying	39
	Flail mulcher	50
Removed	Harvester	160

Note:* €/ha for 30 mm supplied with only one application.

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Link

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http://luirig.altervista.org/flora/taxa/index1.php?scientific-name=panicum+miliaceum

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http://plants.usda.gov/java/coverCrops

Metodi visivi per la valutazione qualitativa della granella di frumento tenero

Introduzione tecnica.

Conoscere le **caratteristiche fisiche** della granella (e delle loro eventuali difettosità) riveste grande importanza nella commercializzazione. La valutazione visiva della granella rappresenta tuttora un valido strumento per definire i possibili **difetti** (come fratture, infezione da micotossine). Riportiamo di seguito alcune immagini di difetti della granella facilmente rilevabili.

Frumento pre-germinato

Impurità di semi in frumento

Insetti (punteruolo del grano)

Istruzioni per l'uso.

I metodi di analisi visiva della granella sono due: "Metodo del peso ettolitrico" (1) e "Metodo della setacciatura progressiva" (2). Il metodo del **peso ettolitrico** permette un riscontro visivo del frumento attraverso lo stato di riempimento della granella: è determinato con **bilancia** del volume di **250 ml** (se i valori sono bassi significa che la granella può aver subito attacchi fungini o fitofagi). In alternativa, adottando la pratica della **setacciatura progressiva** è possibile esaminare un campione di **250 g** sottoposto a **2 setacciature consecutive** (maglie di 3,5 e 1 mm), al fine di un primo riscontro delle **impurità** (inerti ed insetti vivi). Dal setacciato si pesa un campione di circa **50/100g**, sparso poi su un piano per la valutazione dei difetti (**chicchi spezzati, parassitizzati, volpati, avariati, cariati,** ecc…); nel setaccio rimarranno le impurità relative ai chicchi che vanno sottratte dal conto iniziale. Esistono altri metodi, fra cui il metodo inglese **GAFTA** (troppo laborioso) e quello francese previsto nei contratti **INCOGRAIN** dove da 1kg di granella, si effettuano varie setacciature con maglie di diverso calibro solo per rilevare le impurità.

Vantaggi dell'innovazione.

Le caratteristiche merceologiche, a differenza di altre, possono essere riconosciute visivamente e quantificate in modo abbastanza semplice. L'osservazione esterna della granella (chicchi ammuffiti, dimensioni, forma, peso ettolitrico) riveste una tecnica valida per la **valutazione preliminare** del campione e permette di capire se sono necessarie ulteriori analisi (chimiche). E' facilmente applicabile per i **cerealicoltori**, ma anche per i **trasformatori** e tutti gli operatori della filiera, fra cui gli addetti ai **centri di stoccaggio** o ai **magazzini portuali**.

Costo e modelli commerciali disponibili.

Per l'acquisto della **bilancia** (peso ettolitrico) la spesa è di **circa 420 €** circa mentre per l'acquisto dei **setacci in metallo** (di diversa apertura da 1 a 3,5 mm) i prezzi ammontano a circa **220 € cadauno**.

17/12/2015 Quargnento (AL) - 3°incontro progetto Valerie – Caso studio qualità frumento tenero

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- www.agritechstore.it/misuratore_del_peso_specifico_da_14_litro_ps100.html;
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Test rapidi per micotossine in frumento tenero: il metodo enzimatico

Introduzione tecnica.

I metodi di rilevazione tradizionale delle micotossine sono accurati e precisi, ma le lunghe tempistiche delle analisi (anche 10 ore) e i costi sostenuti (fino a 80 € per campione), sono spesso incompatibili con il ritmo della filiera cerealicola. Inoltre per queste analisi è richiesta la presenza di personale qualificato e specializzato, peraltro non sempre disponibile.

Approfondimento.

I nuovi **test rapidi** in sperimentazione permettono di velocizzare la diagnosi di infezione. Fra i vari metodi si annoverano quello della **fluorescenza**, i **metodi immunoenzimatici** e utilizzo di **spettroscopia ad infrarosso**. Questi test permettono di analizzare un ampio spettro di micotossine (fra cui il **DON**, maggiormente presente in frumento tenero).

Istruzioni per l'uso.

Tra i precedenti metodi l'uso di **strisce adesive** è senz'altro uno dei più rapidi ed efficaci. Prevede di sopporre i campioni ad un **analisi qualitativa o quantitativa** mediante estrazione **soluzioni alcoliche** o **acqua distillata**.
Per ogni analisi si consuma un tester di **soluzione tampone** (utilizzabile fino a 12 ore fuori frigo). Il campione viene sottoposto ad una breve **incubazione (45°C)** prima dell'interpretazione dei risultati. Per l'analisi del DON macinare il campione finemente e **pesare circa 10 g** cui si aggiungono **50 ml di acqua**; agitare energicamente la provetta per 1 minuto poi attendere la decantazione del liquido che contiene le micotossine.
Il liquido viene inserito in una altra provetta preparata con soluzione tampone (agitare), previa filtrazione e centrifuga. Immergere una striscia adesiva nel liquido per evidenziare la contaminazione: se sono apparse **linee colorate, dopo 2-3 minuti**, la presenza di micotossine è confermata.

Vantaggi dell'innovazione.

Questi **test** sono complessivamente **economici, pratici** e gestibili da personale non specializzato (ma qualificato); presentano il vantaggio per lo stoccatore di sapere in breve tempo se le partite di granella sono di buona qualità o vanno scartate. I test rapidi consentono di effettuare le analisi anche direttamente nel centro di stoccaggio (senza richiedere tarature o calibrazioni). Esegue un'analisi accurata in pochi minuti (con possibilità eventuale di stampa immediata). Il sistema permette di analizzare fino a **4 campioni simultaneamente**.

Costo e modelli commerciali disponibili.

Il costo medio dei modelli disponibili (es. **Charm ROSA®**) comporta un investimento iniziale di circa **6000 €**, per l'acquisto della strumentazione necessaria (bilance, micropipette, puntali, lettori, centrifuga, carta da filtro, ecc).

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I biostimolanti per il controllo della septoriosi nel frumento tenero: l'esempio della laminarina

Introduzione.

Recentemente sono disponibili alcuni nuovi prodotti a base di estratti vegetali in grado di stimolare la **difese delle piante** al fine di migliorare l'assorbimento dei nutrienti e la resistenza a stress fisiologici o derivanti da funghi patogeni. Questi prodotti sono definiti "**biostimolanti**"; tra i molti prodotti vedremo l'effetto di una sostanza derivante dall'alga bruna (*Laminaria digitata*) chiamata appunto **laminarina**.

Come funziona?

I meccanismi di difesa naturale, posseduti dalle piante, vengono attivati tramite il riconoscimento di molecole segnale note come "**elicitori**", prodotte dal patogeno o dalla pianta stessa. Una volta riconosciuti, la pianta adotta alcune strategie di difesa fra cui il rafforzamento della parete cellulare (barriere di natura fisica) o la produzione di alcune sostanze quali le **fitoalessine** o alcune proteine di difesa (inibizione per via chimica). E' raccomandato contro la septoriosi del frumento tenero (*Septoria tritici*), per la quale ha ottenuto la registrazione in Francia e in Gran Bretagna.

Istruzioni per l'uso.

Il prodotto, autorizzato anche in **agricoltura biologica** (Reg.(UE) 889/2008), può essere utilmente applicato per il controllo della **septoria** del **frumento tenero** ad un dosaggio pari a **0,5 l/ha**. Un eventuale sotto dosaggio comporta una riduzione di efficacia del trattamento, mentre non si assiste ad un aumento di efficacia, utilizzando dosi maggiori. Il prodotto può essere impiegato mediante botte/irroratrice, previa diluizione in acqua. Il periodo ottimale per la sua distribuzione è l'**inizio levata** (indicativamente mese di aprile). Il prodotto, assorbito per via fogliare è traslocato poi nell'intera pianta, per via sistemica. L'eventuale utilizzo ripetuto del prodotto non comporta induzione di resistenze sui funghi patogeni. Può essere applicato unitamente ad altri formulati, in quanto è compatibile con la maggioranza di fungicidi comunemente utilizzati.

Vantaggi dell'innovazione.

Essendo una sostanza di origine naturale, **non è richiesto alcun tempo di carenza** mentre il **tempo di rientro** è pari a **6 ore**. Possiede un **ottimo profilo tossicologico**, non risultando pericoloso né per la salute dell'uomo né per l'ambiente. Per limitare il rischio di inquinamento da deriva, è richiesto di rispettare una **fascia non trattata** dai corpi idrici superficiali **pari a 5 m**. Dall'esperienza francese è emerso come l'impiego di questo prodotto unitamente al trattamento con un fungicida di sintesi (anziché 2) permetta di mantenere sostanzialmente invariate le rese. Dai risultati è emerso come le due tipologie di strategie non comportino una differenza significativa in termini di resa.

Costo e modelli commerciali disponibili.

In commercio la laminarina è presente nel prodotto fitosanitario **Vacciplant®**. Il costo relativo all'acquisto del prodotto si aggira intorno a 50€/litro; prevendo un'applicazione di 0,5 l/ha, l'incidenza del prodotto è pari a circa **25€/ha**.

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8.4 Stakeholder trial/demonstration leaflets

Valerie

This project is funded as a collaborative project under the 7th European Framework Programme,Grant Agreement No.: FP7-KBBE-2013-7-613825-VALERIE Duration: January 2014 – December 2017

Valorising European Research for Innovation in Agriculture and Forestry

VALERIE Stakeholder Trials:

Cover crop experiences of farmers in Alessandria, Italy

The problem

Due to a lack of livestock and organic matter input into fields, local soil fertility is slowly decreasing in many parts of Alessandria county. In order to obtain more consistent yields and quality, most of the farmers apply mineral fertilizers to their land that can only have a limited effect on soil organic matter through increasing productivity. Farmers need cheap solutions to increase soil fertility in the long run and increase the sustainability of the agricultural system. Unlike other countries, farmers are not obliged to use cover crops in Italy, and during winter, many fields are left uncovered and exposed to rainfall, frost and wind. While this helps to break up lumpy, clayey soils, it impoverishes their nutrient content.

The proposed solution

Cover crops or catch crops can be a good solution to this problem for farmers, especially after winter wheat that is followed by any other spring crop, such as maize (corn) or processing tomato. Cover crops have to be sown by the beginning of autumn, when the first rainfalls are available and they have to develop in the period up to the early spring. The earlier they are sown, the more growth. Ploughing or other soil tillage (harrowing) can be performed during spring, when needed.

Stakeholders

The issue of soil fertility was raised by the wheat supply chain farmers during initial discussions in the project. Soil quality is slowly decreasing throughout the county and special product applications (such as amendments or compost) are too expensive. Many of the farmers were unaware of, or did not consider, cover crops as a solution. It was important that through the Valerie project, the farmers could experience the use of cover crop in their fields and on their soils and understand the feasibility of this practice.

Aims and Method

This field demonstration operated at the farm level with the aim of allowing farmers to try this innovation in their fields and to experience the practical management aspects in relation to sowing, managing and burying cover crops. Since it is very difficult to measure the effect of the cover crop in its natural condition, and it is even more complicated when performed directly on the farm, no measurements or analyses were attempted. What counted most was to collect stakeholders' impressions and reactions to this innovation. The trial will be continued into the winter of 2017 in order to allow more farmers to be involved and experience this practice.

Results

Regarding the first experience with cover crops we have observed that:

- The sowing technique can vary farm to farm, depending on availability of either the sowing machine or the fertilizer spreader. Seed mixes can be tricky and can lead to uneven sowing in the field, since smaller seeds can follow first while the larger ones tend to stay in the tank.
- It requires at least a minimum tillage. In fact, it is better to cover the seeds with a minimum amount of soil to help sprouting and protect them from insects and birds. A sod seeding sowing machine can be used. If the fertilizer spreader is used for sowing, it is advisable to disk harrow first.
- Sowing period is the key factor for a successful cover crop. For our area, the period after the harvest should be avoided because of hot temperatures and dry conditions. It is advisable to sow the cover or catch crop at the same time as rapeseed or rye grass, which means by early October at the latest.
- The type of soil can influence the use of cover crop. In fact, lumpy and clayey soils can benefit from a late summer ploughing (rather than cover crops) followed by cold and rainy winters that help loosen soil particles and improve the structure.
- The amount of biomass produced by the cover crop can vary from sowing date and the selected species. Brassicacae and grasses are good organic matter producers, while legumes help fix nitrogen.

In 2016, two species were trialled: *Sinapsis alba* (White Mustard) and *Vicia villosa* (common vatch) in seven farms, as listed in the table.

The trial will continue into the winter of 2017 and the farmers will receive two different seed mixes instead of pure seed species. Mix A comprises mustard, radish and daikon, while mix B contains oats, vetch and brassicae.

The trial will be run in the same way as the previous year.

Farm ID	Location	Vetch - hectares	White Mustard - hectares
A	Bosco Marengo	3	3
B	Pozzolo Formigaro	2	3
C	Pozzolo Formigaro	3	-
D	Alessandria	-	9
E	Quargneto	4	-
F	Predosa	5	10
G	Predosa	3	6
	Total	**20**	**31**

Overall stakeholder involvement and feedback

Stakeholders were asked to try the mixes in their own fields especially after wheat. Some of them were really interested and enthusiastic about the experience, while others were less so. So far, the benefits of this solution will not be visible until the next crop year. We are planning to set up a trial in our experimental field to show in 2019 the effect of the use of cover crops.

Key findings

- Cover crops can represent a good opportunity to increasing soil fertility in the Alessandria agricultural area but the normal practice needs to be adapted to the local situation;
- The choice of the species or the mix can influence the final results;
- It is important to sow the cover crops at the right time. The best period is between September and October, before wheat sowing.

Further reading

VALERIE trial leaflet: Sampling for quality assessment and improvement for a wheat supply chain in Alessandria, Italy

VALERIE trial leaflet: Evaluation for biostimulants in the bread wheat value-chain, Alessandria, Italy.

Acknowledgements

Cadir Lab (http://www.cadirlab.it/) is a partner in VALERIE.
Thank you to Novasem and Semfor for the supply of the seeds and the following farmers hosting the mixes: Franco Maranzana, Antonio Gemma, Silvano Barberis and Retorto S.S.

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Valerie

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Valorising European Research for Innovation in Agriculture and Forestry

VALERIE Stakeholder Trials:

Evaluation of biostimulants in the bread wheat value-chain, Alessandria, Italy

The problem

Recently, problems for farmers with quality during the production of local bread wheat have increased. Firstly, this is due to a continuous decline in prices on the global and local market. Secondly, the national authorities have reduced the number of available and permitted pesticides to control pest and disease. Moreover, atypical weather conditions are increasing stress on plants during the most important crop stages for ensuring yield and quality. This is particularly important for farmers with producer contracts that ensure premium prices, but specify conditions for the grain quality. In addition, the customer, and therefore the industry, is more interested in alternative ways of farming, especially if they help reduce the use of chemicals.

The proposed solution

Some products called "biostimulants", derived from seaweeds and micronutrients, can be a helpful solution to the issue. They are not classified as pesticides as they enhance the natural defence of the plants. In the market, many products with promising results are sold and advertised and it is difficult for farmers to understand if these products are useful or not, as declared. It is also important to understand and show if their use is economically viable.

Stakeholders

The stakeholders comprised a broad group of farmers, supply chain players, cooperatives offering storage, millers, input suppliers, retailers and processors concerned with producing high quality bread wheat. This knowledge gap was not mentioned during intitial discussions in the project with the stakeholders in 2014, since biostimulants were not popular on the market. The trial topic emerged during later discussions in 2015 as a possible innovation for the value-chain. In fact, these products are now required by the official guidelines of the value-chains that are followed by some of the farmers in the area.

Aims and Method

This experimental activity should be considered a farm demonstration aiming to:

- Show the farmer the existence of this type of product
- Support them on the correct use
- Assess the effect of the biostimulants on the crop
- Calculate the cost benefit balance of the use of biostimulants on bread wheat
- Help the farmer to save money from unnecessary expenses

The data collected are as follows:

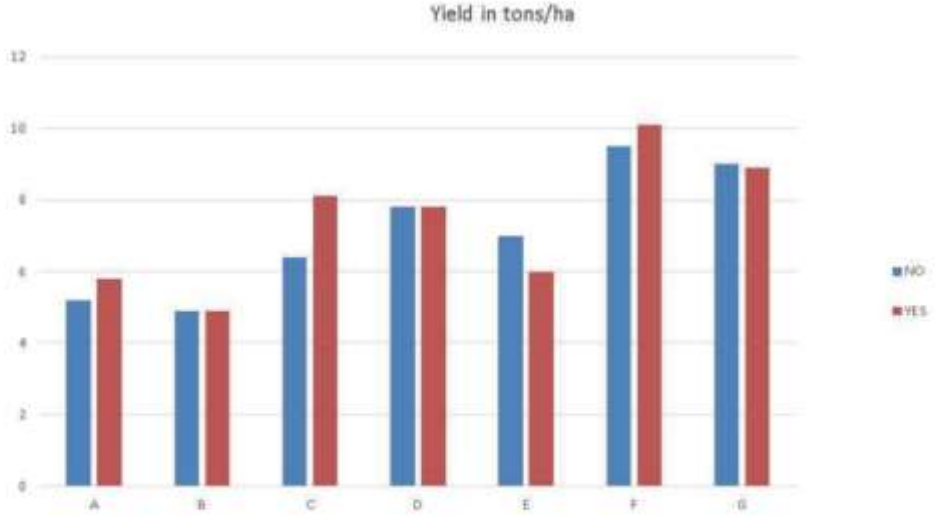
- Yield for each field;
- Main quality parameters that are assesed during grain collection (and therefore, influencing the price of the lot).

In 2016, a biostimulant based on the component "GEA 249" was tested for bread wheat varieties. The product contains low concentrations of Nitrogen, Micronutrients and seaweed extracts. According to the product information, it helps the plant to tolerate stress provoked by environmental conditions and pathogens.

The product was distributed to seven farmers in the Harmony value-chain[1]. Each farmer had to choose two fields with the same wheat variety with similar soil conditions. They used the biostimulant in one field, and the second field was a control test for comparison. The product was applied during flowering/earring crop stage.

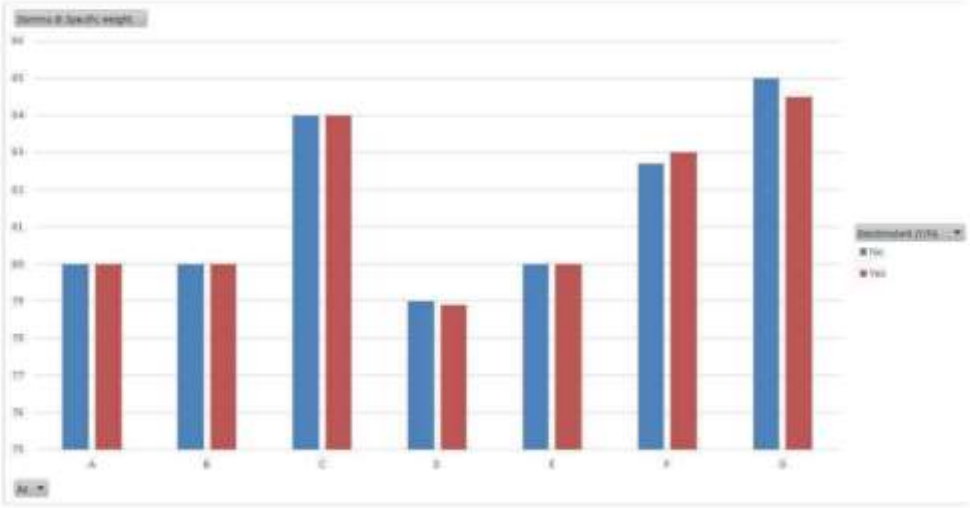
Results

In the figure below, we show the results for yield in tons/ha. Each farm is represented with a letter (A to G).



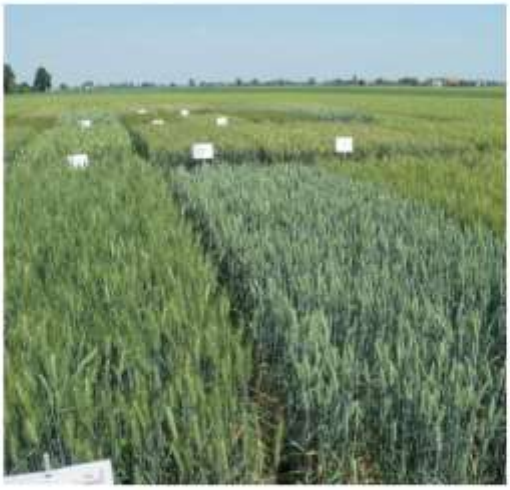
[1]The Sustainable wheat **Harmony** value-chain, trademarked from Mondelez International, that has been developing in Alessandria county since 2014.

Similarly, the figure below shows results for specific weight, expressed in kg/hl.



Overall stakeholder involvement and feedback

The stakeholders were directly involved in the trial as they applied the product on their own fields. They were really eager to test the product by themselves, but ultimately it was very difficult to observe a difference. For this reason, the trial lasted only one season (2016).



Key findings

- Biostimulants can be used for more intensive crop systems, such as fruit and vegetable production or for extensive crops with higher values (strong wheat, processing tomato).
- Within the bread wheat value-chain context, the viability of the crop is very low and it is more important for farmers to concentrate on the quality parameters that help ensure the price (yield and specific weight).

Further reading

VALERIE trial leaflet: Sampling for quality assessment and improvement for a wheat supply chain in Alessandria, Italy.

Acknowledgements

Cadir Lab http://www.cadirlab.it is a partner in VALERIE.

Thank you to the farmers hosting the trials: Retorto S.s., Antonio Gemma, Franco Maranzana, Silvano Barberis, Albertazzi Giuseppina, Albertazzi Giovanni and Parodi Marco.

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Valorising European Research for Innovation in Agriculture and Forestry

VALERIE Stakeholder Trials:

Fusarium Head Blight Sensitivity of bread wheat variety in Alessandria, Italy

The problem

Choosing the best varieties for a value-chain requires a lot of testing and must include the key factors, such as productivity, adaptability and pathogen sensitivity, especially to Fusarium Head Blight (FHB). While the two former parameters are already assessed by local trialling activity sponsored by seed companies, the latter is not assessed by a specific experiment. Unlike other countries, there are no national research organisations performing this activity. At the same time, seed companies launch new wheat varieties every September, with new characteristics that are different from other vegetal materials. Therefore, trials need to be repeated almost every two or three years and references need to be updated very quickly. It is important for farmers to know the FHB sensitivity of the varieties of the Harmony value-chain[1] to know which to select, based on previous crop and climate conditions.

The proposed solution

The solution proposed in the trial consists of a field test in the Cadir Lab experimental fields, in order to compare the FHB sensitivity of the seven varieties allowed in the Harmony value-chain contract. In the trial we used untreated seeds to also identify the sensitivity of other fungal pathogens (leaf blotch and yellow rust). We also focused on the mycotoxin content (Deoxinivalenol) of the grain following the EU standards for food contaminants for human health.

Stakeholders

The stakeholders involved in this trial belong to the whole Harmony supply chain, starting from farmers to the miller. Farmers are interested in this trial since they can obtain some information on pathogen sensitivity of the variety they are growing and with this they can decide whether to avoid one pesticide application (during early spring). Storage cooperatives are interested as they are selling certified seeds, plant protection products and they store and mix the grain lots, which must be mycotoxin free.

[1] The Sustainable wheat Harmony value-chain, trademarked from Mondelez International, that has been developing in Alessandria county since 2014.

Aims and Method

The trial follows a comparative test set up. It comprised 7 bread wheat varieties (Altamira, Solehio, Graindor, Calabro, Moisson, Oregrain and Rubisko) in plots measuring 1.5m of width and 30m of length, replicated 3 times in sequence, one next to the other. Each plot was divided into 4 subplots, 6 metres long, to apply 4 different treatments with the experimental sprayer:

- Untreated or Blank, with no fungicide application
- One yearly treatment fungicide application with Strobilurine molecules (Azoxystrobin)
- One late treatment fungicide with triazole molecules (Tebuconazolo)
- Complete fungicide strategy combing the early and late treatment

Drone picture of the trial

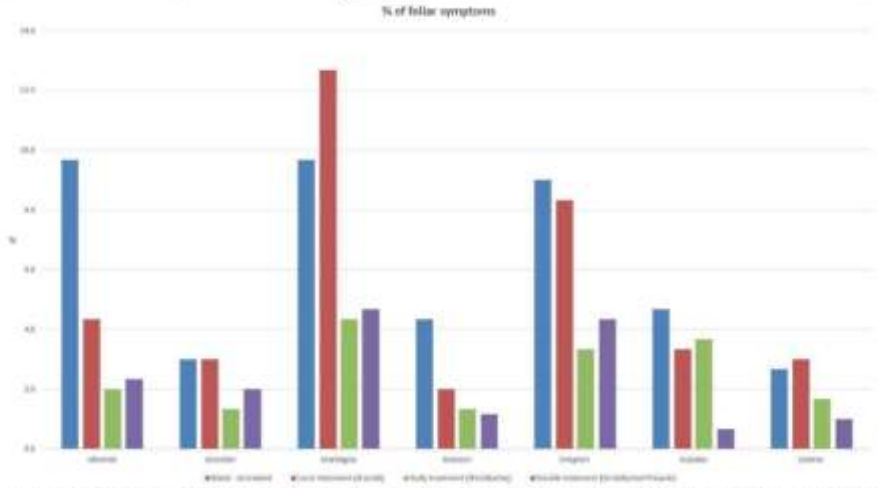
The trial consisted a total of 84 subplots, in which we performed two types of assessments:

- Visual evaluation of pathogen symptoms;
- Test ELISA quantification of Deoxinivalenol content in grains performed by the Laboratory of the University of Turin.

We did not assess the yield and other qualitative parameters of the trial.

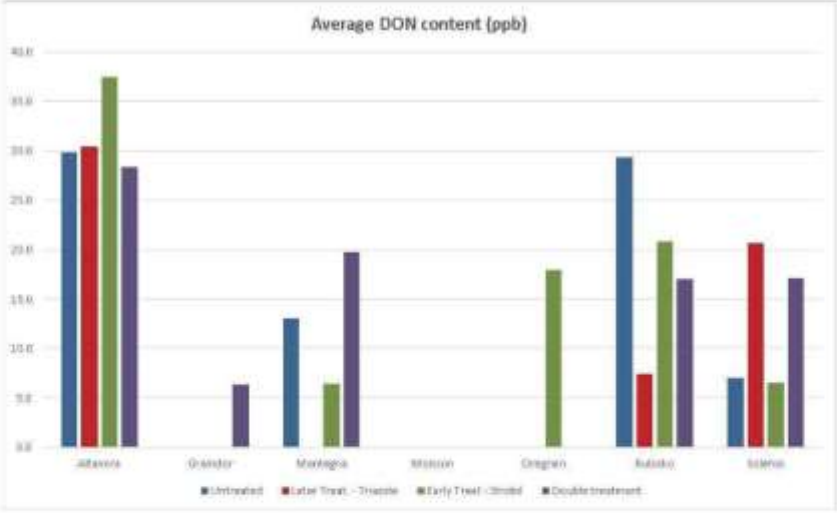
Results

Due to very dry conditions, pathogen symptoms were very rare and we could see only a slight difference between the treatments and varieties as represented in the figure below:



As visible in the figure, values (% foliar symptoms) are very low, compared to an average situation. Nevertheless, the sensitivity of varieties for foliar pathogens is quite clear.

The situation of mycotoxin content is shown in the figure below.



From the assessed data, we can see that the variety Altamira has higher than average DON content values, as well as Rubisko. Nevertheless, assessed values are very low and do not have any influence on the sanitary quality of the grains where the legal threshold of DON in soft wheat is below 1,250 ppb (ug/kg).

In this trial, the average assessed value in the grain is about 21 ppb, which is an excellent result, 50 times lower than the threshold.

Overall stakeholder involvement and feedback

Stakeholders visited the trial during May 2017 and saw the low differences in sensitivity between each variety. In order to communicate the trial set-up and the first results, a poster was prepared and presented during the demo-day. The assessed data are useful for the supply-chain because they help farmers to have a good reference of the FHB of the varieties and give a clear picture of the DON accumulation in the area.

Key findings

The main findings of this trial are:

- Our regional climate is not favourable for FHB linked mycotoxins (such as DON) for the most common varieties of Harmony value-chain;
- The selected varieties for the trial can accumulate very low concentrations of mycotoxins thanks to their low genetic sensitivity to FHB infection;
- A good fungicide stategy helps grow a healthier wheat crop and without mycotoxin infection

Further reading

VALERIE trial leaflet: Sampling for quality assessment and improvement for a wheat supply chain in Alessandria, Italy

VALERIE trial leaflet: Evaluation of biostimulants in the bread wheat value-chain, Alessandria, Italy.

Acknowledgements

Cadir Lab http://www.cadirlab.it is a partner in VALERIE.
Thank you to Limagrain Italia, Novasem, RAGT Italia, Syngenta Italia, Adaglio Sementi, SIS Sementi and Consorzio Agrario del Piemonte Orientale as providers of the untreated seeds and Prof. Massimo Blandino, University of Turin, for the analysis of the samples.

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Valorising European Research for Innovation in Agriculture and Forestry

VALERIE Stakeholder Trials:

Sampling for quality assessment and improvement for a wheat supply chain in Alessandria, Italy.

The problem

Developing local value-chains can offer a good solution for product valorisation and a safer way to manage the wheat trade. Nevertheless, local value chains need to pay close attention to product quality and the homogenous specification of the product, among all farmers. This is the case for the Sustainable wheat **Harmony** value-chain, trademarked from Mondelez International, that has been developing in Alessandria county since 2014. **Local farmers do not usually take part in an organised value-chain and the quality of their production is very variable.** Storage cooperatives collect different grain lots from farmers and must ensure good sorting based on a quality assessment. Knowing the quality before storage can be useful for them.

The proposed solution

Tools and networks to assess the grain quality before the harvest could help to identify in advance what type of grains the farmers will deliver and if they respected the guidelines of the supply chain. We aimed to set-up a pilot experience to test a methodology of sampling grains in the field **before the harvest** to inform both farmers and cooperatives about the batch quality.

Stakeholders

Stakeholders were asked to identify the main issues and knowledge gaps regarding wheat production during the first discussions of the project. This issue emerged as one of the most important for all members of the meeting: farmers, technicians, storage cooperatives and millers. Even if it does not deal with a specific technical issue or a knowledge gap, the trial topic comprises different aspects of logistics and organisation.

Aims and Method

This experimental activity should be considered a pilot experience (or farm demonstration) aiming to:

- Use a manual harvester to collect samples in the field before the harvest and the use of a portable grain tester to measure humidity and specific weight directly in the field.
- Validate the methodology of representative sampling in the field through the definition of the minimum significant numbers of subsamples.
- Validate the reliability of data collected before harvest and in post-harvest for different varieties.
- Analyse the data and understand what parameters can influence the quality of the grains.

Results

After two years of activity, we found that:

- The best time for assessment is a few days before the harvest, if no rainfall has occurred.
- At least 30 subsamples have to be taken to achieve a representative sample.
- The result obtained in pre-harvest is reliable and can be used to confirm the quality of the grain to farmers.

We also learned that:

- It is not possible to use this method in all fields of the supply chain especially if their dimensions are very big.
- Time during the harvest is very short and time between sampling and analysis needs to be as short as possible. It is best if the analysis can be performed in the field.
- In order to save time and improve logistics, this method can be used in some pilot-fields on the farm.
- Once the sample is taken, mycotoxin can be measured, if climate conditions highlight the risk of fungal disease.
- A sampling plan in the field can be defined by the cooperative in order to screen the quality of the grain (technological parameters and presence of mycotoxins). This can comprise pre-harvest and post-harvest sample collecting.

Overall stakeholder involvement and feedback

Stakeholders have been directly involved in the trial which took place in their fields. They were informed about the grain quality in their fields under contracts. In addition, we also sampled grain after the harvest and a large number of samples were analysed by the laboratory of the miller. Thanks to this activity and the requirements of the supply chain we have information about the fertilization, pesticide application, yield and grain quality. We studied the correlation of the field data with the quality of the product and we were able to provide personalised advice to every farmer in the supply chain.

Key findings

The key findings relate to the overall activity of quality assessment over the supply chain.

- Grain quality for bread quality is strongly influenced by crop techniques, such as fertilization and pesticide applications.
- We recommend fertilizing above a given threshold (130kg/ha of Nitrogen) and we set the requirement to treat the crop with fungicide and pesticide during earing stage.
- Grain with insufficient fertilization and treatments must be discarded.

Further reading

VALERIE trial leaflet: Evaluation of biostimulants in the bread wheat value-chain, Alessandria, Italy.

VALERIE trial leaflet: Fusarium Head Blight Sensitivity of bread wheat variety in Alessandria, Italy.

Acknowledgements

Cadir Lab www.cadirlab.it is a partner in VALERIE.
Thank you to all the Harmony supply chain farmers from Alessandria and the technicians of the Consorzio Agrario del Piemonte Orientale.

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9 Drip irrigation management in tomatoes and maize, Italy

9.1 Context

In the territory, the availability of water for agricultural use is not high and not evenly distributed. High productive crops, asmmaize and processing tomato, requires a large amount of water is required, especially during the hottest season, when rainfall is scarce or showery and evapotranspiration is high. In order to combat this, farmers are adopting alternative techniques, such as drip-irrigation with the intent to improve water efficiency, without reducing yield and quality.

A drip irrigation system is commonly associated with greenhouses or horticultural crops, not with field crops. However during the last decades, in many parts of the world with a shortage of water, this system is spreading and it is seen as the most sustainable way to use water efficiently. Nevertheless, it requires special machines, a lot of plastic materials, and time and labour for setting-up. For this reason, innovations and solutions are still required to reduce costs and increase yields and quality.

The stakeholders for the VALERIE project include members from the whole supply chain:

- Farmers – 8 members.
- Irrigation system suppliers - 2 members.
- Processers - 2 members.
- Cooperatives – 3 members.
- Seed and pesticide companies – 2 members.
- Technicians – 3 members.

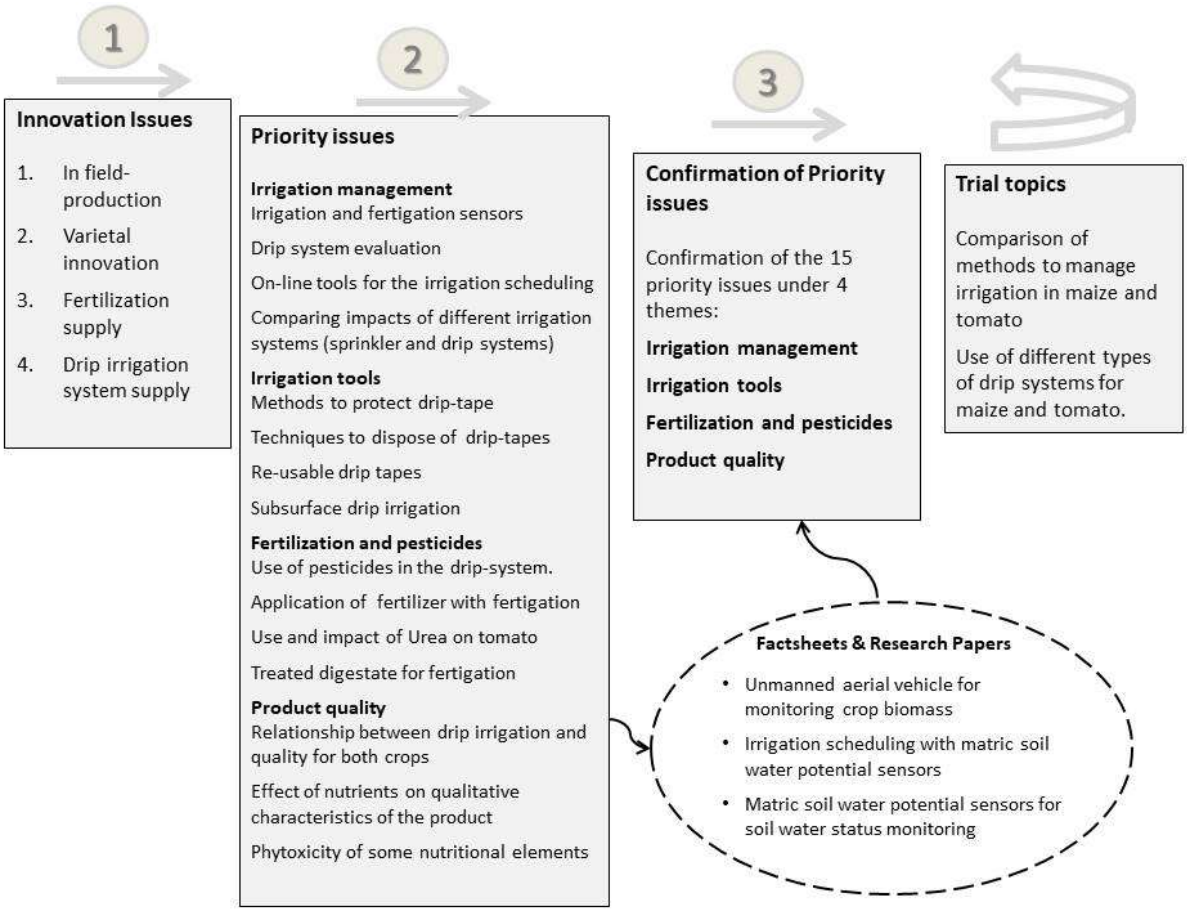
9.2 Dynamic Research Agenda

In this CS the CSP used a group exercise to make the discussion of innovation issues easier and more fruitful for the project. This lasted about 1 hour and all stakeholders were very interested and active. The stakeholder discussion of innovation issues was organised around 4 subjects:

1. In field-production.
2. Varietal innovation.
3. Fertilization supply.
4. Drip irrigation system supply.

Many technical research needs came out during this discussion part but some were related only to one of the crops. The DRA (Figure 9.1) shows that 15 priority issues were identified. At the 2nd Meeting there was limited reflection and refinement of the priority issues due to limited time available. . The CSP listed and read together with the stakeholders all innovation needs and issues that were identified in Meeting 1. At the end of the presentation, the stakeholders only made a few comments so the list was not revised. In summary two issues were identified that the stakeholders thought would benefit from a field trial. However, following further reflection and with some steerage from the CSP, this group decided to trial a decision support tool for irrigation management, this is a "sensor station" which is able to detect simultaneously weather data and soil humidity values which can help farmers modify and improve their irrigation schedule.

Figure 9.1 Drip irrigation Management in Tomatoes and Maize Case Study Dynamic Research Agenda



The Thematic Experts produced 3 factsheets after Meeting 1 and these were evaluated and discussed in relation to the innovation issues in Meeting 2. The factsheets were concerned with: a description of available probes to measure water soil content, the use of probes to manage irrigation in the field and the use of drones to monitor crop situation in a wide area. In general the stakeholders found the factsheets useful in informing them about the innovation issues.

9.3 Factsheets on innovation

Valerie

"Unmanned aerial vehicle for monitoring crop biomass"

Martina Corti, University of Milano

What is it?

Unmanned aerial vehicles (UAVs) can fly periodically over the field mounting digital cameras in order to acquire spectral information describing the status of the crop. This information can be related for example to the fraction of canopy cover, the above ground biomass, the crop N content. UAVs can be used in arable crops, tree crops and forestry. There are no limitations due to soil type, but there are limitations due to atmospheric conditions and legal requirements.

Problem to be solved

Farmers may want to estimate the amount of above ground biomass in their fields to evaluate the spatial variability of crop growth, in order to detect soil problems (e.g., impeded drainage, water logging). Other reasons might be to check if drip irrigation systems are distributing water homogeneously over the field (i.e. if they are not damaged) or if there are areas characterized by low nutrient availability.

How does it work

Physical principle. Optical sensors record the light reflected by the crop. Each material (including vegetation) has its own reflectance curve that shows the fraction of the incident energy that is reflected at different wavelengths. In crop reflectance measurements, typically two or three wavebands are chosen. This allows the calculation of vegetation indices, which are then related to the above ground biomass and to other variables indicating crop status.

A camera records light intensity but the interest here is in reflectance, i.e. the fraction of incident light reflected by the crop. Reflectances can be retrieved by (1) measuring incident light intensity along with reflected light or (2) placing calibration panels with known reflectances in the field and include them in the images.

UAV. There are two types of UAVs: fixed wing and rotary wing. The first are lightweight and are ideal for mapping large areas because generally have long endurance but they need a landing strip. The second ones can fly in every direction and they are ideal for detailed land

mapping because of their high manoeuvrability. The UAV can fly automatically following a planned course using its GPS sensor, but the flight must be always supervised by the operator.

Depending on the flying height, the focal length of the lens, and the movements of the UAV, the images taken will have different viewing angles and will overlap to a greater or lesser extent. The images need to be rectified and stitched together to build an ortho-image of the entire field.

Camera. The cheapest solution is to use a commercial digital camera, and modify it to acquire near-infrared instead of red (or blue) intensity; this can be achieved by removing the filter blocking the near infrared radiation, and adding a specific filter; therefore the camera will obtain reflection in the blue (or red), green and near-infrared wavebands, which are used to calculate vegetation indices. Professional cameras for vegetation monitoring are available commercially at substantially higher cost.

Advantages and disadvantages of the innovation

The UAV type (its dimensions but also its electronic parts and motor efficiency), the weight transported, the area to be covered and UAV's battery life affect each other. Battery life can range from below 30 minutes to more than one hour, and decreases with payload weight. Therefore, the path of flights must be planned and the UAV must be carefully chosen depending on the weight. The UAVs normally used in agriculture have a maximum weight of 2.5 kg.

Once the images of the vegetation are collected, image processing is needed. This implies: building an ortho-image of the field; retrieving reflectance and correcting it to take into account of local conditions; calculating one or more vegetation indices; estimating the biomass within the field (provided that calibration curves exist between the vegetation index and the above ground biomass). As a final result, a map is obtained representing the spatial variability of above ground biomass. These operations are complex, not fully automated and therefore represent a time-consuming activity to be carried out by a specialist.

Costs (VAT excluded)

Costs for UAVs can vary between 2,500 and 33,000 €.

Costs for digital cameras can vary between 250 and 37,000 €. The low range is for common digital cameras modified for agricultural uses. The high range is for professional cameras for vegetation monitoring.

Costs of services: the market is relatively young, therefore we provide one example of cost for UAV flight and image processing to support irrigation scheduling; this cost can vary between 80 and 150 € per ha and per date; price can be negotiable depending on the area to be covered.

Other resources required

Depending on the country, specific normative requirements have to be met in order to fly a UAV. In Italy, the person operating the UAV must possess a flight licence. Moreover, the UAV must be certified. Finally, an authorization shall be obtained before each flight or group of flights. UAVs can be used at the maximum flying height of 70 m within an area of 200 m radius, or at a maximum height of 150 m within an area of 300 m radius. Simplified procedures are possible if the UAV weigh less than 2 kg.

All the requisites (UAV, modified camera, license and post-processing) require that the whole work is carried out by a specialised company.

Contacts

Products:

- Digital Cameras:
  - http://publiclab.org/wiki/infragram-convertible-cameras: list of common digital cameras that can be modified and used for agricultural management
  - Tetracam: http://www.tetracam.com/Products-orig.htm
- UAV:
  - SKYROBOTIC, Terni (Italy). http://www.skyrobotic.com/2014/?project=sr-sf6-sioux
- UAV with digital cameras for agricultural application:
  - DELAIR-TECH, Toulouse (France). http://www.delair-tech.com/en/our-products/crop-map

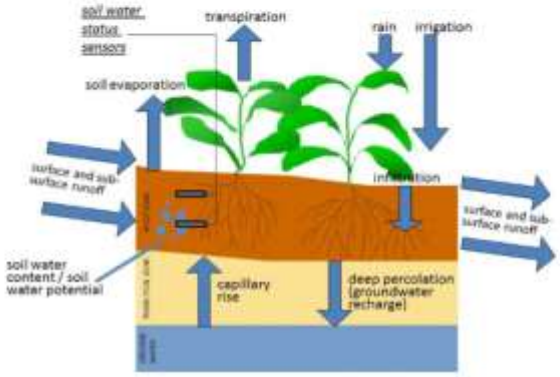
Service providers:

- UAV flight and image processing:
  - CGEO, Monza Brianza (Italy). http://www.cgeo.it/it/services.html
  - URSULA Agriculture Ltd, Aberystwyth and Salisbury (UK). http://www.ursula-agriculture.com/how-we-work/technology/

Valerie

"Irrigation scheduling with matric soil water potential sensors"

Arianna Facchi, University of Milano



What is it?

Water status sensors (measuring volumetric soil water content or matric soil water potential) installed at various depth in the soil root zone can play an important role in improving the irrigation management. This document focuses on how to use soil water potential sensors for this purpose. Particular sensor types are illustrated in the separate fact-sheet entitled "Matric soil water potential sensors for soil water status monitoring".

Problem to be solved

Monitoring of the soil water status in the root zone is fundamental for farmers, as it helps them to improve the production, conserve water, reduce environmental impacts and save money. Knowledge of the soil water status provides a valuable support to irrigation scheduling, because it allows to determine when and how much to irrigate. Well-managed irrigation meets the crop water needs, avoiding over- or under-irrigation. Over-irrigation wastes energy and water (and therefore increases irrigation cost), but also enhances the leaching of fertilizers below the root zone, erosion, and transport of soil and chemical compounds into the drainage ditches. Under-irrigation leads to a reduction in crop yields due to temporary drought stress.

How does it work

Matric soil water potential (SWP). The matric soil water potential, SWP (kPa, centibars, cm), is a basic soil water status property fundamental to plant water availability. It expresses how strongly water is held to the solid matrix of the soil by electrostatic and capillary forces. If

soil is saturated, SWP is zero and water is freely available. As soil water content decreases, SWP becomes increasingly negative because the mentioned forces bind water to the solid matrix, and energy must be spent to extract it. The same SWP value may correspond to a range of different soil water contents (SWC) when different soil types are considered, but always refers to the same energy status or availability of the water.

Soil water potential thresholds. Typical thresholds (or characteristic values) of SWP are field capacity (SWP_{FC}), wilting point (SWP_{WP}), and the beginning of crop water stress (SWP_C). The corresponding water contents (SWC_{FC}, SWC_{WP}, SWC_C) are strongly soil-dependent, but SWP values at these thresholds are more stable. At field capacity SWP is around -10/-20 kPa (the first for coarser soils, the second for fine-textured soils, while intermediate values apply for loamy soils), while at the wilting point SWP is at about -1000/-2000 kPa depending only on the type of crop (an average value of -1500 kPa is commonly used for most crops). The SWP_C threshold (SWP value below which the crop water stress starts), is crucial for irrigation scheduling. It depends on the specific crop and, to a lower extent, to the site-specific climate conditions, soil type and irrigation method. The following Table summarizes SWP_C for some of the main crops in Europe, grouped in three classes with respect to their sensitivity to soil water stress. The maximum rooting depth for the different crops is reported in brackets.

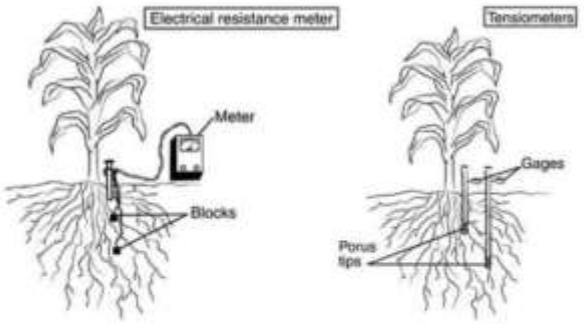
Sensitivity	SWP_C*	Crop and Maximum Root Depth** (in brackets)
High	-20 / -35 kPa	Broccoli (0.4-0.6 m); Celery (0.3-0.5 m); Lettuce (0.3-0.5 m); Onion (0.3-0.6 m); Potato (0.4-0.6 m); Cabbage (0.5-0.8 m); Strawberry (0-2-0.3 m)
Medium	-35 / -45 kPa	Beans (0.5-0.9 m); Carrot (0.5-1.0 m); Maize (1.0-1.7 m); Cucumber (0.7-1.2 m); Eggplant (0.7-1.2 m); Tomato (0.7-1.5 m); Sweet melon (0.8-1.5 m); Apples, Cherries, Pears (1.0-2.0 m); Apricots, Peaches, Stone Fruit (1.0-2.0 m); Citrus (1.0-1.5 m)
Low	> -45 kPa	Beets (0.6-1.0 m); Sweet potato (1.0-1.5 m); Alfalfa (1.0-2.0 m); Ryegrass (0.6-1.0 m)

* SWP_C values higher (i.e. closer to 0 kPa) than those reported in the Table are recommended for critical crop periods (i.e.; silking for maize or fruit expansion for tomatoes). On the contrary, lower SWP_C values (i.e. more negative) may be used for climatic conditions inducing a low crop evapotranspiration (i.e. cool, humid climates) or for fine-textured soils.

** The larger root depth values are for soils having no layering or other characteristics that can restrict rooting depth and for rainfed crops. For irrigation scheduling, if no site-specific information is available, the lower values may be used.

Compiled after different Authors

Irrigation scheduling. A simplified approach is normally adopted to support irrigation scheduling decisions. A first SWP sensor is installed at one-third of the rooting depth. A second sensor may be additionally positioned between two-thirds of the root depth and its end. The first sensor is used to decide "when" to irrigate, by indicating when SWP starts to fall below SWP_C. In drip irrigation systems, SWP_C thresholds may not be reached because small water volumes must be applied frequently in time to achieve high irrigation efficiency. Here, irrigation usually starts at -25/-30 kPa, which is still above the SWP_C of many crops. The deeper sensor may be used to stop the irrigation event, dealing with "how much" water shall be delivered. In particular, when SWP of the deeper sensor exceeds SWP_{FC}, irrigation should be stopped to reduce percolation water losses below the root zone.



Sensor positioning in the field. Sensors must be installed at representative sites in the field, taking into account soil type, crop stand, water table depth, slope, wind and sunshine conditions. Crop at the selected point must have a medium to high development and evapotranspiration, compared to the average in the field. In the case of drip irrigation, sensors must be located somewhere between the plant and the water source (not too close and not too far from the dripper). If more than one soil profile can be instrumented per field, sites should be selected to represent homogeneous areas from the irrigation management point of view. SWP sensors may be read manually by the farmer with a certain frequency (e.g., once per day), or may be connected to a data-logger for continuous reading.

Advantages and disadvantages of the innovation

Since plant water uptake responds to the matric soil water potential, rather than soil water content, it makes sense to use SWP in determining when to irrigate. Despite of this, it is not easy to find in the literature comprehensive information on SWP thresholds to be used for irrigation. Thresholds reported in the Table are good standards, but values may vary in site-specific conditions as a consequence of many factors, such as the SWP sensor installation depth, its position with respect to the crop geometry and irrigation devices, climatic conditions and soil type of the site. Further research is then needed to better describe their behavior with respect to these factors.

Another critical aspect that must be taken into account is the slow response of many sensors nowadays available on the market to a quick variation in SWP as a consequence of a fast wetting event. This may sometimes constitute a difficulty in using SWP readings to stop irrigation.

Finally, it is important to keep in mind that the operating range for hydraulic tensiometers (the oldest and cheapest instruments for SWP monitoring) is between 0 and -85 kPa, which is quite limiting in the case of very fine-textured soil or when deficit irrigation is performed. Other instruments are available on the market that should be used when lower SWP are expected.

Other resources required

Need for basic knowledge of soil hydrology. Need for familiarity with user interfaces of electronic devices in the case of data-logger programming.

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National Projects

MIPA-FLOPRO - Italy

MIPA-ECOIDRIFLOR - Italy

MIPA IRRIFLORVIVA - Italy

AGL2001-2068, Spanish Ministry of Science and Technology and FEDER - Spain

2020 Wheat® project at Rothamsted Research - UK

Valerie

"Matric soil water potential sensors for soil water status monitoring"

Arianna Facchi, University of Milano

What is it?

Sensors can be installed in the soil root zone to monitor the soil water status, measuring one of the two following variables: volumetric soil water content (water volume stored in the pore system of a volume of soil, in cm^3cm^{-3}) or matric soil water potential (expressing how strongly water is held to the solid matrix of the soil by electrostatic and capillary forces, in kPa or centibars or cm). Sensors can provide instantaneous measurements (depending on the instrument, through direct readings or through the connection with a hand-held readout unit) or continuous data (if connected to a data-logger). This document focuses only on sensors measuring soil water potential (SWP).

Problem to be solved

At the farm level, irrigation is generally scheduled based on the grower's experience. Soil water status information can be very useful to achieve a more precise irrigation scheduling. For information on how to use root zone soil water potential sensors for this purpose, see the fact-sheet: "Irrigation scheduling with matric soil water potential sensors".

How does it work

This section illustrates soil water potential sensors most widely adopted for practical uses.

Hydraulic tensiometers. Hydraulic tensiometers are constituted by a microporous ceramic cup connected to a dial vacuum gauge through a plastic shaft filled with distilled and degassed water. When the ceramic cup is buried into the soil at the desired depth, micropores allow the hydraulic connection between water in the soil and that present within the cup, thus the water in the tensiometer reaches equilibrium with the surrounding soil. When water is pulled out through the ceramic tip by drying soil, a tension is originated in the tube; when soil is re-watered, the decrease in water potential gradient causes a reverse water movement. As the soil

goes through drying and wetting cycles as a result of evapotranspiration and watering (by irrigation or rainfall), tension readings can be taken. Instantaneous reading of the soil water potential can be taken using the dial vacuum gauge, while for continuous reading a pressure transducer must be installed on the tensiometer, transforming the tension inside the instrument into an electrical signal (in millivolt) that can be recorded by a data-logger. A calibration equation is then needed to obtain the matric soil water potential from the recorded data. The picture on the left shows two hydraulic tensiometers with vacuum gauges, with and without pressure transducer.

Electrical resistance sensors. Electrical resistance sensors, among which the granular matrix Watermark 200SS sensor (Irrometer Company, USA) is the most well-known, consist of a porous material in which stainless steel electrodes are embedded. When placed in the soil, the water in the porous material tends to reach an equilibrium with the soil water. The electrodes measure the electrical resistance (in ohm) of the porous material, which can be converted into the matric soil water potential by means of a calibration equation. Watermark 200SS sensor is shown in the central picture.

Gypsum block are the oldest and simplest electrical resistance sensors. Since they are less resistant and long-lived than other advanced sensors, they are not addresses in this document.

Dielectrical sensors. They utilize the dielectric sensing technology currently adopted in soil moisture sensors (see the fact-sheet "Volumetric soil water content sensors for soil water status monitoring" for more details), to which ceramic blocks are added. A dielectric sensor is used to measure the water content of the porous ceramic body, which is in equilibrium with the matric potential of the surrounding soil. The probe sensor output in millivolt (proportional to the water content of the ceramic) is converted into soil matric potential by using a calibration equation. The first sensor of this type was the MPS-1 Dielectric Water Potential Sensor (Decagon Devices Inc., USA). Recently, Delta-T Devices (UK) has been developing a second sensor of this type, named DT160 and shown in the picture on the right, which is still in a prototype phase. This sensor is expected to provide a higher accuracy for the same price.

Advantages and disadvantages of the innovation

The following Table summarizes advantages and disadvantages of the selected sensors.

SENSORS	Hydraulic tensiometers	Watermark 200SS	MPS-1 Dielectric WPS
Measuring range	0 to -85 kPa	0 to -240 kPa	-10 to -500 kPa
Reaction time to changes in soil water status	Slow, due to small pores of the ceramic tip	Intermediate, due to larger pores of the porous matrix	Fast (10 min to 1 hour depending on SWP)
Accuracy	High (0.1 – 1.0 kPa)	Low	Intermediate (25% of reading from -10 kPa to -100 kPa)
Need for soil-specific calibration	Direct measure of SWP, no need for calibration	Usually don't needed; if conducted it can improve the accuracy significantly	Usually don't needed; if conducted it can improve the accuracy significantly
Cost of sensor (approximate)	70-150 € (+ press. transduc: 150-300 €)	30-50 €	180-250 €
User maintenance	costly (e.g., water refilling)	none	none
Lifetime	> 5 years	> 5 years	> 5 years
Influence of salinity	None, salts move freely through the ceramic cup	Compensated for commonly found salinity levels	–
Influence of temperature	None, but the formation of air bubbles in the shaft may result in temperature dependent errors in reading	Soil temperature variation can affect slightly sensor performance. To increase the accuracy, temperature can be	Soil temperature is measured by the sensor

		measured with another sensor and used to correct SWP	
Functioning with freezing temperature	Not advisable conditions. If needed, precaution to avoid ice formation must be taken	Not affected	Not affected
Need of hand-held readout units or data-loggers	Not needed. For the connection to a data-logger a pressure transducer is needed	Needed	Needed

No information can be found in the literature when - is reported in the Table.

Only hydraulic tensiometers can be considered "standalone instruments", since soil water potential can be obtained directly with a glance at their gauge. All the remaining sensors need to be connected to hand-held readout units or data-loggers, thus the cost of these devices must be added to the sensors' cost.

Other resources required

Need for basic knowledge of soil hydrology. Need for familiarity with user interfaces of electronic devices in the case of data-logger programming.

Contacts

- Hydraulic tensiometers:
  - SKYE Instruments Ltd., 21 Ddole Enterprise Park Llandrindod Wells, Powys LD1 6DF UK, http://www.skyeinstruments.com/
  - UMS (Umweltanalytische Mess-Systeme), Gmunderstraße 37, D-81379, München, Germany, http://www.ums-muc.de/
- Electrical resistance sensors:
  - Watermark 200SS: IRROMETER Company, Inc., 1425 Palmyrita Ave., Riverside, CA 92507, USA, http://www.irrometer.com
- Dielectrical sensors:
  - DT160: G. Lock, M. Jenkins, T. Peloe, K Burek, Delta-T Devices, 130 Low Road, Burwell, Cambridge, CB25 OEJ, UK, http://www.ums-muc.de/
  - MPS-1: Decagon Devices Inc., 2365 NE Hopkins Court, Pullman, WA 99163, USA, http://www.decagon.com/

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National Projects

MIPA-FLOPRO - Italy

MIPA-ECOIDRIFLOR - Italy

MIPA IRRIFLORVIVA - Italy

AGL2001-2068, Spanish Ministry of Science and Technology and FEDER - Spain

2020 Wheat® project at Rothamsted Research - UK

9.4 Stakeholder trial/demonstration leaflets

Valerie

This project is funded as a collaborative project under the 7th European Framework Programme,Grant Agreement No.: FP7-KBBE-2013-7-613825-VALERIE Duration: January 2014 – December 2017

Valorising European Research for Innovation in Agriculture and Forestry

VALERIE Stakeholder Trials:

Maize and Tomato drip irrigation in Alessandria, Italy.

The problem

In the county of Alessandria, the availability of water for agricultural use is low and unevenly distributed. Highly productive crops, such as maize and processing tomato (and other industrial crops), require a large amount of water which is drawn from limited underground sources (wells). Over the last few decades, farmers have started adopting more sustainable techniques for irrigation, such as sprinklers and drip irrigation system. In this way, they have reduced the amount of water required.

The use of low-volume irrigation systems requires a higher level of technical knowledge in terms of crop needs and irrigation scheduling according to weather data. Decision support tools (DST) (and systems) could help farmers manage water shortage and increase water efficiency use during the summer, ensuring yield and crop quality.

The proposed solution

The chosen DST for this field demonstration comprises a "sensor station" which is able to detect simultaneously **weather data** and **soil humidity values**, covering a wide area thanks to wireless technology. Every **sensor station** is composed of one weather station connected to two wireless units in which two soil humidity probes are connected. The sensor station can transfer all data in real-time by GPRS network to a web platform, accessible from any electronic device with internet access, such as a computer, tablet or smartphone. The front-end of the web platform is intuitive and user-friendly. Netsens (www.netsens.eu) have developed this innovation, in cooperation with some Italian Universities, in previously financed projects.

Stakeholders

The stakeholders comprised a small group of farmers, technicians from cooperatives and processing factories and a few retailers concerned with increasing yield and the viability of irrigated crops in the area. Among the numerous knowledge gaps that were identified during the first project discussions in 2014, irrigation management through sensors emerged as more innovative and suitable for a field demonstration over three years. In addition, this technology has started to develop and spread, and many enterprises have now developed their own systems with different features and specifications.

Although benchmarking of all these systems was not possible for the case study, this particular technology was selected with the stakeholders to determine its feasibility.

Aims and Method

Our trial is structured as a field demonstation. Three sensor stations were rented and together with the probes were set on three different farms and on different fields, and where possible, selected in areas representative of the local agricultural system.

The aim of the field demonstration was to let farmers try and use a DST to manage the irrigation of maize and tomato regardless of the irrigation system, as long as it was sustainable.

Results

During the first year of trialling (2015, one year after the project started) we encountered many technical problems related to the placing of the sensor stations.

Three farms offered to host and to try the technology for the following crops: onion (one field) + maize (two fields) + fresh tomato (one field) + processing tomato (two fields) + white beans (one field).

As this first experiment was conducted on many crops it was possible to collect a lot of technical and practical information. Eventually, we identified that this technology can be difficult to implement with tall crops, such as maize (about 2.5 meters in height) and underground crops (onions). The best data feedback and the most practical ease of use occurred with the processing (or fresh) tomatoes in open fields.

During the second and third years (2016 and 2017) the activity was more effective due to the previous years' experience as we selected three different farms specialising in processing tomato production.

What have we learned from the experience?

- The innovation is very useful but it is not manageable by the farmer: it is very complex to use and results can be influenced by major mistakes such as probe positioning and interference with machinery;
- It is necessary to continue the demonstration because it meets an important need for the crop (processing tomato), especially if a module of predictive models on pathogens (mildew) is added;
- The system soil + weather can be expensive for a farm;
- The system should be set up as a network over a cultivation area at the field scale.

Overall stakeholder involvement and feedback

The stakeholders identified the knowledge gap and were directly involved in the demonstration from the start, as together with them, the technology was set up on their own farms and fields. They received access to the online platform to access the data from their computer and smart phone. Farmers involved were really satisfied with the innovation and it meant they could modify and improve their irrigation schedule. Moreover, they also asked to implement the modelling on mildew for processing tomatoes that Netsens developed at the end of 2017, thanks to our technical contribution.

Key findings

The main findings regarding this field demonstration are more related to the use of the technology and not to the technology itself.

We found out that:

- The introduction of this technology is very complex and it can easily result in failure if not used correctly;
- Even if this innovation is useful for the farmer and has a positive return on his/her activity, it does not mean that the farmer is the direct user of the innovation

Further reading

www.netsens.it

Acknowledgements

Cadir Lab http://www.cadirlab.it is a partner in VALERIE.
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10 Sustainable onion supply chains, Netherlands

10.1 Context

Onions are an important crop for arable farmers in the clay regions of The Netherlands: the South West of The Netherlands and the 'Flevo polders'. The total acreage of onions in The Netherlands is approximately 20,000 ha. Over the last few years the onion growers are facing serious problems concerning the quality of their product. It is a growing concern for the whole chain: approximately 85% of the Dutch produce (900,000 tons on average) is exported. The (international) market is asking for optimal product quality, grown in a sustainable way. The major issues for the onion value chain:

- The damage of soil born fungi and nematodes is growing over the last years.
- Control of air borne fungi. Especially the control of Botrytis spp. Is a problem.
- Optimal fertilizer strategies. There is a relation between varieties, optimal N-rate and quality of the unions.
- Monitoring of product quality. New innovative nondestructive methods to determine the internal quality of onions at the end of the growing season would be of great help.
- Carbon footprint of the onion crop.

The CS stakeholder community convened for the VALERIE project comprises:

- Farmers, onion growers.
- Buyers
- Packers
- Exporters
- DLV Plant
- Frugiventa, branch organisation for onion traders/exporters.

10.2 Dynamic Research Agenda

The Dynamic Research Agenda (Figure 10.1) shows that in the 1st meeting the stakeholders discussed the problems and challenges of the onion supply chain. Innovation issues were identified in 4 areas:

1. Quality aspect of the exported product. Storage and transportation problems.
2. Solutions to the serious problems cause by Botrytis spp. Effectivity of fungicides, timing of sprayings, and choice of fungicides.
3. Prevention of fungus transmission by seeds, which causes early infection in the field.
4. A special question for traders is if and how product waste can be 'validated'.

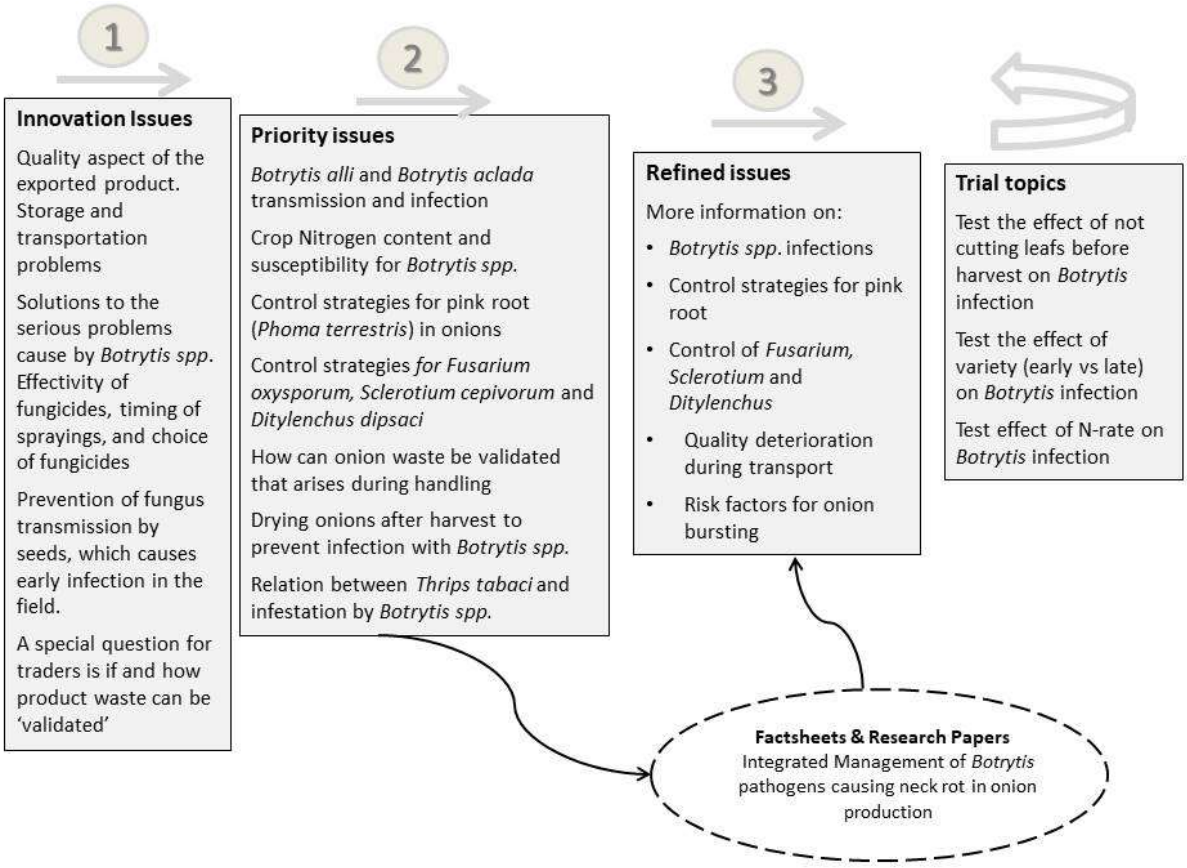
Further discussion of the innovation issues and the need for research resulted in the identification of 7 priority issues by the stakeholders. At the next meeting these priority issues were refined with interest for further information centering around:

- *Botrytis* spp. Infections.
- Control strategies for pink root.
- Control of *Fusarium, Sclerotium* and *Ditylenchus*.

- Quality deterioration during transport
- Risk factors for onion bursting

The stakeholders showed most interest in the problems caused by Botrytis spp. Infections and 3 potential trials were proposed on this topic.

Figure 10.1 Sustainable Onion Supply Chains Case Study Dynamic Research Agenda



The Thematic Experts produced 1 factsheet for this CS on the integrated management of *Botrytis* pathogens causing neck rot in onion production. The stakeholders reviewed the factsheet in Meeting 2 and reported that the information provided was very relevant because it gave a complete overview of the life cycle of the fungus and the risk factors. It provoked discussion and, helped to generate new questions and inform the selection of the trial topics. They particularly valued this input of research from other countries that VALERIE provided and this triggered the trial to see if the same results could be achieved in the Netherlands.

10.3 Factsheets on innovation

Valerie

Integrated Management of Botrytis pathogens causing neck rot in onion production

Contact: Yolaine Hily (INRA - UMR AGIR) - yolaine.hily@toulouse.inra.fr

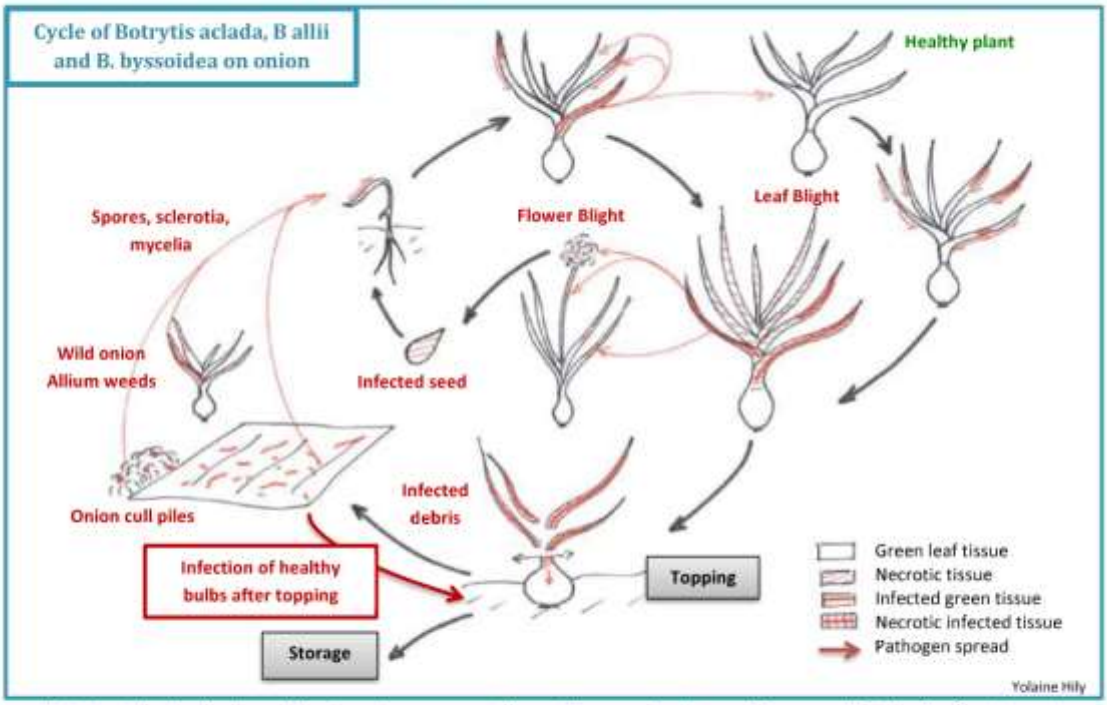
What does it mean?

The three main pathogens causing onion neck rot are B. allii, B. aclada and B. byssoidea (mycelial form). The first two fungi have been also reported causing leaf and umbel blight as well. Performing an integrated management of the pathogens (at each step of the production process) must allow controlling the incidence of the final disease which only appears during storage.

Problem to be solved: Important losses and quality problems in onion production

Botrytis are soiborne pathogens for onion (can also be seedborne). They can grow and produce spores on dry or green onion leaf tissues which are spread by wind to wounded bulbs. The main important point of infection is through soft and green neck tissue of onion bulb, especially after topping. Pathogens spread to the onion neck symptomlessly and neck rot only occurs during storage. Losses during storage due to neck rot can reach 30 to 100%.

Symptoms and cycle of the pathogens



Botrytis allii, B aclada and B. byssoidea are specific pathogens of alliums. More specifically, the fungi survive (sclerotia or mycelium) into the soil on organic matter, infected crop residues and onion cull piles. Spores develop from mycelium or sclerotia during periods of high humidity (a period of 24 hours is necessary for infection to occur). Pathogens develop between 10 and 24°C (optimum). After 30°C the development of the fungus is stopped.

The pathogen enters the plant through wounds, senescent leaf tissue and tips but also closely topped necks or improperly dried necks. Successful infection can cause the death of onion tops within a week. Secondary inoculum

produced can be disseminated to other plants and fields (spores can be spread by wind (300m!) and splashing to healthy plants).
In Europe, internal infections of seeds by Botrytis allii and B. aclada have been reported. It has been even shown that B. allii was able to survive in seeds for more than 3 years, so seed storage does not help to eliminate the fungus.

Symptoms of three related diseases caused by Botrytis (numbers are referring to the above pictures):

- (1) Leaf blight: Spores kill leaves epidermal cells and cause small yellow to white, oval flecks, usually late in the season. Some leaves can be infected but do not show any symptom. Critical period for infection: beginning of bulbing.
- (2) Umbel/flower blight: lesions develop at any point along the scape, girdling the scape and causing the scape to lodge. Spores produced by the fungus (gray concentric rings on the scape) can spread to the flower and infect the seed. Umbel and scape blight reduce seed yield and quality and may result in infected seeds.
- (3) Neck rot: After harvest and during storage, neck and first scales of onion present a brown semi-watery decay without any external symptom. The infected parts dry rapidly. Gray mycelia grow between onion scales.

N.B.: Plants infected by Botrytis spp. are more susceptible to other pathogens, mechanical injury and insect damage.

Factors favoring epidemics

- Infected seeds, infected onion debris, pile of onions culls close to the field
- Long high humidity periods (spore production) and windy and rainy conditions (spore dispersal)
- **During storage:** poor ventilation, high humidity and temperature higher than 5°C can produce storage rot on infected bulbs.

Main control measures

Rotation	• Respect a delay of 2 to 5 years between two onion crops (and allium crops like leeks, garlic, shallot...). Even if it will not eliminate the fungus, it will help maintaining the incidence of the disease low.
Seeds and cultivars	• Seed only high quality disease-free onion seeds and transplants. • Select varieties that mature quickly so neck tissues dry before storage.
Fertilisation and irrigation	• Avoid excess or late nitrogen fertilization (after 5th leaf stage) which sensitize the crop to diseases, delay bulbs maturity and lengthen the requirement of field/storage curing. • Avoid also late irrigation when tops are drying (must help onions to dry down at the end of the season).
Pests	• Control any pest which could cause wounds to bulbs/leaves. • Late application of fungicides could be necessary to slow down the spread of the disease and reduce neck contamination.
Residues management	• Proper sanitation of infected and discarded culls onions. • Incorporate onion debris into the soil after harvest. • Take care of wild onions in and out of the field.
Storage and curing	• Allow onions to cure properly before and after topping. If needed, dry bulbs before storing. Storage conditions: temperature: 0 to 5 °C (monitor storage regularly); humidity: 65 to 70% promote air circulation by leaving space between crates or bulked onions.

Other resources required

Efficient drying and storage system

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10.4 Stakeholder trial/demonstration leaflets

Valerie

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Duration: January 2014 – December 2017

Valorising European Research for Innovation in Agriculture and Forestry

VALERIE Stakeholder Trials:

The use of leaf treatment on the infection rate of neck rot in Onions in The Netherlands

The problem

Over the years 2010-2013 the onion growers were facing serious problems concerning the quality of their product due to "neck rot" caused by *Botrytis* spp. It is a growing concern for the whole supply chain as approximately 85% of the Dutch produce (900,000 tons on average) is exported. Symptoms of neck rot show up sometimes during the storage period or during transport to export locations. Control of *Botrytis* spp. is not so easy, it is unclear when and how infection takes place. It is known that variety, nitrogen (N) rate and harvesting method play a role. Measures to prevent infection of the onion bulb is the innovation issue being examined here.

The proposed solution

From the research literature provided by the VALERIE scientists, we discovered that in some other countries the onion leaves are not chopped before harvesting. In The Netherlands, growers do chop the leaves, creating an infection route for the neck rot fungus. We tested different strategies of leaf treatment: no leaf chopping, "normal", "short" and "long" leaf chopping. The onions are stored and checked for neck rot infection after an incubation period of 2 months. N-rate and varieties also have an influence on neck rot. We did a survey on 15 farm fields, with different varieties and N-rates, and assessed the neck rot infection rate 2 months after harvest.

Stakeholders

The stakeholders are growers, advisers, traders and seed companies and a representative of the branch organisation for the onion value chain. The topic was identified in the first stakeholder meeting of the project. Neck rot is of importance for the whole value chain. The infection becomes visible during the storage period (a problem for the grower) or during transport to export locations (a problem for the traders). There are also differences between varieties, which is why seed companies are interested in finding a solution to the problem as well. A high N-rate increases yield in tonnes per ha, but has a negative influence on product quality, it also increases the risk of neck rot. So far, high quality (neck rot free) onions do not sell at a premium in the market.

Aims and Method

A trial and survey were conducted. The nature of the neck rot **trial** is scientific with different varieties, treatments and replicates. The objective is assess the influence of leaf treatment (see Fig 1) before harvest on the infection rate of neck rot in two different onion varieties; Type 1, a variety with a thick neck; Type 2, a variety with a thin neck. This was conducted at the Onion Innovation Centre Rusthoeve, Colijnsplaat.

In **the survey**, which was less formal, we selected 15 fields in different parts of The Netherlands, collected data from these fields (variety, N-rate, biomass development) and assessed the infection rate with neck rot 2 months after harvest.

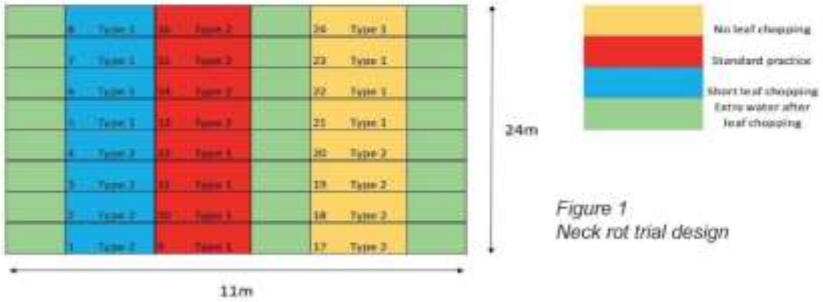

Figure 1
Neck rot trial design

Results

The trial in 2015 was destroyed by a hail storm in early September 2015, 2 weeks before harvest. As such, we could not collect any data. In 2016, the trial was harvested but there was no infection of neck rot observed, most probably due to the extremely warm and dry September month (Table 1). Also in general, the 2016 growing season showed very few problems with neck rot in practice.

Field Trial Sample	Onion Variety	Number of onions with:			
		Neck Rot	Bacteria	Fusarium	Soft Rot
1	Type 1		1		
2	Type 1				
3	Type 1				1
4	Type 1				
5	Type 2				1
6	Type 2				4
7	Type 2				5
8	Type 2				1

Table 1: Results of field trial (2016)

Two years of trials did not provide any useful results, for this reason we decided to repeat the trial in 2017.
Unlike September 2016, September 2017 was very wet in large parts of the country, also on the location of the trial, the Onion Innovation Centre.
The expectation was that due to the very wet September 2017, neck rot would be observed. The results show a significant number of onions with disease or other quality symptoms (170 out of 634), but from these 170 only 4 were caused by neck rot.

Field	Number of Onions	Number of onions with:			
		Neck Rot	Bacteria	Fusarium	Soft Rot
1	77	3	31	22	
2	64		3	5	
3	40		14		1
4	55		11	2	2
5	43		6		2
6	38	1	7		3
7	47		2	10	1
8	56		2	5	2
9	56		2	6	1
10	47		6	3	
11	67		2		1
12	44		10	4	

Table 2: Results of field trial (2017)

Survey - assessment of farm fields in 2017

In addition to the field trial we conducted an assessment of 3 farm fields from 4 different regions, 12 in total. The expectation was that due to the very wet September 2017 neck rot would show up. The samples from these farm fields were assessed in the same manner as the field trial samples. The results below, show a significant number of onions with disease or other quality symptoms, much more than in 2015-2016. In 2017, 97 out of 667 (15.5%) showed quality problems but from these 97, only 1 was caused by neck rot.

Field	Number of Onions	Number of onions with:			
		Neck Rot	Bacteria	Fusarium	Soft Rot
1	56			4	1
2	54				3
3	57				10
4	65	1		23	2
5	57		1		8
6	62			2	
7	55				12
8	53			4	
9	64		3	9	
10	45		3	5	
11	52				4
12	47				2

Table 3: Assessments of farm fields (2017)

Overall stakeholder involvement and feedback

Stakeholders have been involved through the stakeholder meetings and through the national onion innovation event that takes place every August. The VALERIE trial was part of the guided tour over the fields.

With limited results, the stakeholders have been unable to judge if the tested innovation is a solution. From the international research literature, it is known that not chopping leaves before harvest has a positive effect and results in lower neck rot infections, however we do not know how big this influence is under Dutch climate conditions. The results would have to be convincing in order to get stakeholder support for this measure as it would involve a significant "change of practice" throughout the supply chain.

Neck rot problems vary over the years, after a couple of years with few infections, the stakeholders lose interest in the problem. Although stakeholders realise that neck rot is still a serious threat for onion quality, not chopping the leaves in the field makes it necessary to do so at a later stage. This solution would require investment, and so far it is not clear if this is a profitable option.

Key findings

- Neck rot was a big problem in 2010-2014
- 2015, 2016 and 2017 showed few problems with neck rot
- Literature shows that N-rate, variety and harvesting method play a role in risk of neck rot
- There was no difference between the treatments in the 2016 and 2017 trial, as neck rot did not show up, or was minimal, in the trials
- The risk factors for neck rot infections in the field are not very well understood, neck rot infections are hard to predict with the current knowledge, more research is necessary

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Delphy https://delphy.nl.en, formerly DLV, is a partner in VALERIE

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11 Sustainable potato supply chains, Netherlands

11.1 Context

The French fry industry in Poland is quite new. The Farm Frites company involved produce French fries in the North of Poland, partly on their own farm, partly from 60 contract growers in the region. Production of high quality potatoes at a low cost price is crucial for this industry, with a lot of competition from other companies. Brown spots caused by Tobacco Rattle Virus (TRV) and nematodes are a major problem for the growers in the region and the impact is felt across the whole value chain. The factory cannot process potatoes with a higher percentage of brown spots than the norm. Potatoes with a higher percentage are rejected and this represents a big loss for farmers but also a problem for the factory. The interest of the seed potato company is clear, when the problem can't be solved the acreage of the most important variety at this moment, Innovator, will decline. As there are no good alternative varieties for the specific market the whole value chain has a great interest to solve the problem.

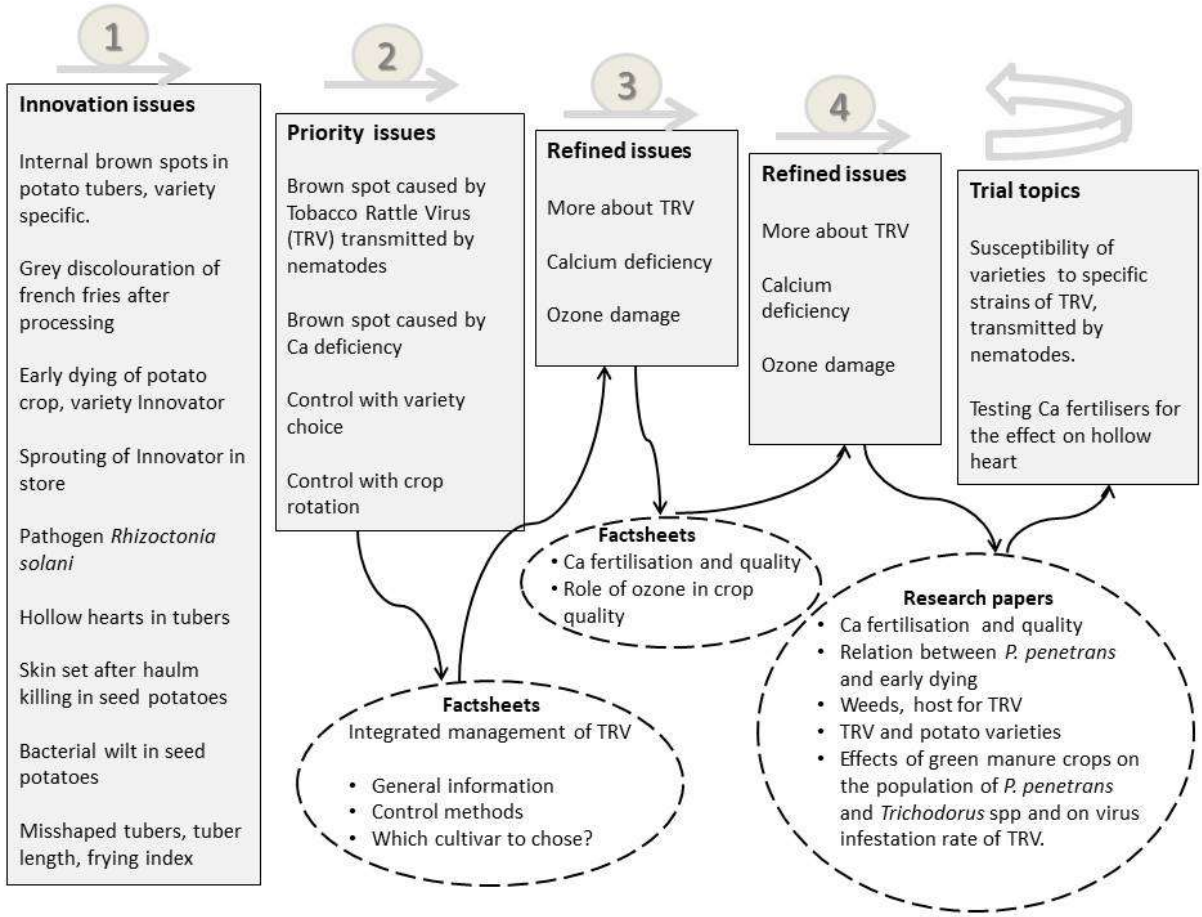
The CS stakeholder community convened for the VALERIE project comprised:

- Farmers, growing potatoes for Farm Frites (FF).
- FF Poland, the farm, growing potatoes for the factory.
- FF, the factory, located in Lembork, 50 km East of Slupsk.
- Agrico Poland, potato seed producer.

11.2 Dynamic Research Agenda

In this CS stakeholders identified familiar issues which are progressively reviewed as the meetings are repeated with drilling down into the available research to address pressing specific quality problems, as shown in the DRA (Figure 11.1). In the first meeting nine broad issues were initially collected, mostly concerning crop quality, then analysed by stakeholders in a group discussion with the main priority identified as controlling internal brown spot in potato tubers. This is a prevalent issue and represents a major quality problem in processing of French fries. The preliminary issues focused on known or suspected factors that cause TRV, calcium (Ca) deficiency; and on potential solutions through control with different varieties and with rotation. The DRA shows that, as meetings progressed and information from research is increasingly made available, the list of stakeholder questions becomes more refined, although the key issues remained. From the stakeholder perspective, they are not clear whether the issues identified can be addressed with scientific knowledge.

Figure 11.1 Potato Supply Chain Case Study Dynamic Research Agenda



The Thematic Experts synthesised current research understanding of brown spot issues from some 10-15 scientific papers and prepared three illustrated factsheets oriented towards solutions. These were supported by other formats- scientific papers and expert presentations. The stakeholders described the factsheets as valuable, in that they collated information, allowed them to review current understanding, and gave a good summary of the available knowledge about all aspects of TRV. However, reviewing the 'state of the art' in research prompted revised specific questions from stakeholders.

In Meeting 2 and the following meetings, as well as commenting on the factsheets and reiterating their interest in learning more about ongoing research on brown spot and TRV, the original innovation issues list was reviewed and updated, and further issues were identified (the effect of Ca-fertilization and the possible role of ozone on crop quality) and trial topics were identified.

11.3 Factsheets on innovation

Valerie

Integrated management of Tobacco Rattle Virus (TRV) in potato production (1): General information

Contact: Yolaine Hily (INRA, UMR AGIR – yolaine.hily@toulouse.inra.fr)

TRV, a preoccupying issue for the potato production

TRV is transmitted in soil by nematode vectors (Trichorids, found in lighter, open-textured soils). It can affect several cash crops, potato in particular. The most characteristic symptoms in potato are brown necrotic spots and arcs named "spraing disease" (corky ringspot (CRS)) into the tuber flesh. The tubers presenting such necrosis are unsellable. Its presence has been reported in many countries, from the USA to Europe.

A broad host range for TRV and the vector nematode

TRV has one of the widest host ranges even if it is especially a virus of weeds. Any TRV host plant can act as a virus source and induce the perpetuation of the virus within fields and local nematode population.

Lot of cash crops could be infected with different degrees of susceptibility: e.g. potato, tobacco, tulip, onion, barley, rye, cabbage, lettuce. Wheat and corn have been also reported (in the USA) as poor hosts for TRV but playing the role of a virus reservoir.

The virus can infect more than 400 crop species (mono and dicotyledonous). The table below presents few common weed species known to be suitable hosts of TRV:

Weed	Common name
a) *Capsella bursa-pastoris*	shepherd's purse
b) *Chenopodium album*	fathen, lambsquarters
c) *Polygonum aviculare*	knotgrass, knotweed
d) *Polygonum convolvulus*	bindweed, wild buckwheat
e) *Senecio vulgaris*	groundsel
f) *Stellaria media*	chickweed
g) *Taraxacum officinale*	dandelion
h) *Viola arvensis*	field pansy, violet

a) b) c) d) e) f) g) h)

Even if the virus remains mainly into the roots, in few cases TRV has been shown to spread systemically and to be transmitted through the seeds of its host plants (up to 10% of infected seeds by *Viola arvensis*). As a result, as soon as the virus has infected a site, it will be present into the seedbank. From that point, cleaning an infected weed population becomes highly problematical (due to the survival of seeds into the soil).

Symptoms in potato

- Into the tuber flesh: typical internal symptoms named corky ringspot (CRS), internal sprouting and necrotic arcs (*picture* included into the diagram below)
- On potato plant: depending on the cultivar, the virus can spread systemically into the plant, resulting in stem mottles and leaf lesions (*picture*).

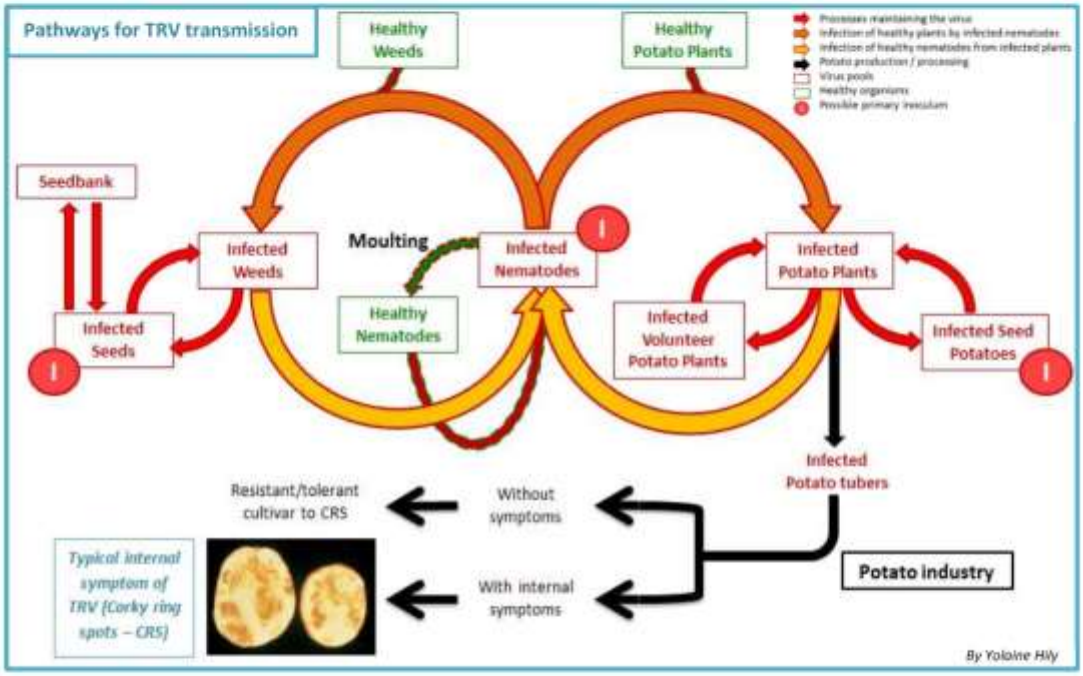
Source: Phil Hamm Oregon State University

The expression of the symptoms is a very complex process and depends on the interaction between i) potato cultivars, ii) TRV strains, iii) vector species and weather conditions. Some potato cultivar will not show any visible symptoms, even if they are infected (asymptomatic carrier).

Cycle of Tobacco Rattle Virus in potato production

TRV is transmitted to healthy plants by infected vector nematodes (which feed on the roots). Notice that the nematode is virus-free at the beginning of its life; he acquires the virus by feeding on an infected plant. During its life, the nematodes become virus-free again every time they molt.

The first infection of a field can be caused by i) infected weed seeds or ii) infected nematodes brought into the field by contaminated machinery or by iii) infected seed-potatoes introduced into a virus-free field. An infected field shows a patchy distribution of the virus.



Other factors impacting the incidence of spraing disease

Even if the interaction between potato cultivar and virus type/nematode specie could explain the expression of spraing in tubers, other factors seem to have a strong impact on it as well. In this way, some weather and soil conditions have an influence on the incidence of spraing (CRS).

High temperature and dry conditions seem to decrease it, while the soil irrigation (and wet weather conditions) seems to increase it, making easier the movement by and transmission of TRV by the vector nematode. Annual records of rainfall and spraing disease in Scotland suggested that spraing is most prevalent when the summer is wettest.

No "ready-to-use" solution

TRV is **almost impossible to eliminate from a site**, as soon as it is establish. It is therefore particularly important not to introduce it to new sites. A holistic and systemic strategy has to be implemented to control it and limit the pressure on the potato crop (more information in the second Fact sheet).

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https://www.southlandorganics.com/article/microorganisms-enrich-your-soil-part-iii

Integrated management of Tobacco Rattle Virus (TRV) in potato production (2): Control methods

Contact: Yolaine Hily (INRA, UMR AGIR – yolaine.hily@toulouse.inra.fr)

Problem to be solved

TRV has a very long survival period in soil in absence of potato crop (present in weeds and seedbank) and is virtually impossible to eliminate as soon as it is established within a site. However, some control methods can contribute to reduce the number of nematode vectors, slow the progression of the virus and even decrease its pressure on potato crop. To be effective, control methods need to target the weed population as the original virus source, but also the vector nematode populations.

Management of the virus: a combination of several control measures is necessary

Weed control:

TRV is mostly a virus of weeds, so a precise weed control is the key stone of an integrated control of the virus and control measures aimed at controlling TRV must target the weeds (original virus source) in order to prevent the virus to be reproduced.

Many weeds can be infected by TRV, so "ready to use solutions" do not exist. Every procedure included into an integrated weed management could help reducing the pressure of the virus:

- Long and diversified rotations, including different botanical families, winter and spring crops, is a first measure to implement.
- False seedbed technique (cultivation) allows reducing the seedbank, eliminating potential virus sources from the field (*illustration below*). This technique is not effective for dormant seeds.
- Mechanical weeding and chemical treatments should be used efficiently to control weeds but also to manage the risks of herbicide resistance. As far as possible, weed seedlings should be destroyed early and at least before they go to seed.

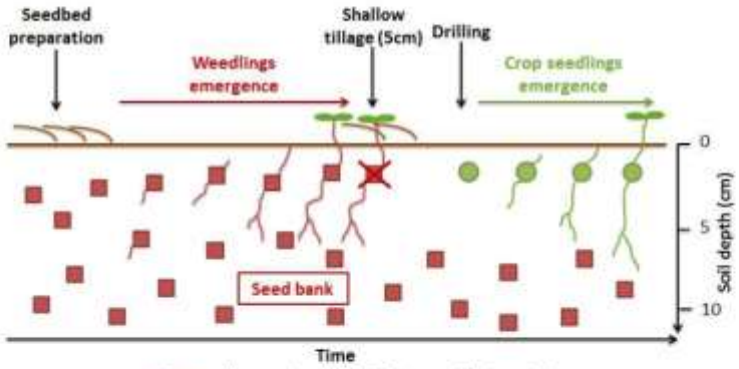


Figure: illustration of the False seedbed technique

All these measures aim at i) reducing the amount of weeds as effective virus sources, ii) preventing the accumulation of latent potential sources (dormant grains).

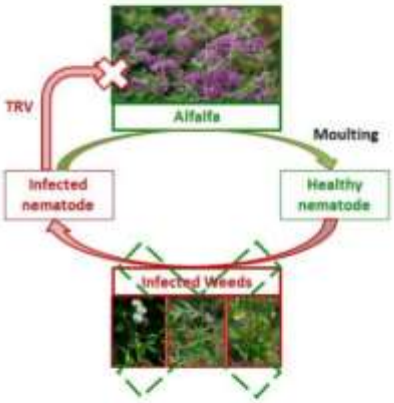
Cultural methods:

As TRV is mostly a virus of weeds, rotation has no significant effect on itself. But some rules should be followed to limit the virus pressure on the potato crop:

- Include cereals into the rotation (they are poor hosts for the virus)
- Respect a quiet long delay between two potato crops.

Biological control:

As it is a suitable host for the nematode but a non-host plant for the virus, Alfalfa has been shown (bioassays in green house) to be able to "clean" an infected nematode population after a few months (2-3 months). But field trials have shown that this plant cannot be effective if weeds are not strictly controlled (*illustration*). This plant can be grown as rotational crop or cover crop.



Fodder radish has been shown to reduce the nematode numbers (release of biochemical acting on the nematodes). But the insufficient reduction in spraing symptoms in the following potato crop suggested that this technique may not be efficient without being combined to other control measures.

Notice that the nematode control ability will differ among cultivars!

Which seed-potatoes to choose?

TRV has been reported to be transmitted to daughter potato tubers. As a result, a first infection could be caused by the introduction of infected seed-potatoes into a virus-free field. Using certified seed-potatoes is highly recommended as the first guarantee for high quality virus-free seed-potatoes. It may also prevent the spread of the virus within an infected field.

Some potato cultivars seem to be resistant to the virus or to the expression of the virus (spraing disease). The first may be an additional control measure to limit the development of the virus. The second may be a short term solution for potato growers: tubers may not show any symptoms and may be saleable. But these cultivars may also act as virus reservoir and maintain the virus in this way. (*More details in the following fact-sheet*).

Chemical control:

Some years ago, soil fumigants were used to control the nematode vector (D-D, methyl-bromide, aldicarb...). Although these chemicals provided satisfying control, they were unsafe for the environment and for the human health. They have been withdrawn in Europe and are no-longer used.

Other control measures:

Machinery maintenance: clean carefully machines to prevent the virus from spreading and first infection of virus-free fields.

Volunteer potatoes control: because of its ability to be transmitted to daughter potato tubers, TRV may be present into volunteer potato plants with can act as sources for virus acquisition by vector nematodes. So, it is highly recommended to take care of the volunteers and to remove cull potato from field edges.

Irrigation: Excessive irrigation should be avoided at tuber initiation as infection is most likely at this stage (nematodes move into soil water).

Fertilization: some studies have shown a reduction of TRV incidence after applying composts.

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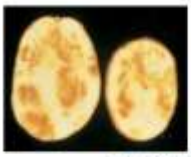

Integrated management of Tobacco Rattle Virus (TRV) in potato production (3): Which cultivar to choose? - Focus on the French fry production

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What is it?

In Integrated Pest Management, using resistant cultivar is one of the common control measures. This is often an easy and cheap way to control pests and diseases. Some potato cultivars have been reported to be resistant to TRV. Such cultivars exhibit rarely symptoms (Corky ringspot – CRS).

Which cultivar to choose?

Virus detection and nematode species determination

Before choosing the potato cultivar, the presence of the virus within a field has to be determined. Assessment by RT-PCR* is the most efficient method but using highly susceptible bait plants might be more convenient. But multiple samples need to be collected and tested to guarantee an efficient detection of TRV, considering the patchy distribution of the vector nematodes.

It has been shown that several TRV strains exist; some nematode species have been specifically associated to one or more specific virus strains. Some studies showed also that each potato cultivar is more sensitive to one/several virus strains. The determination (by RT-PCR) of the nematode specie (thereby the associated TRV strains) present into a field might allow choosing the most suitable potato cultivars to grow if the field is already infected. But for now, only limited data are available on the susceptibility of cultivars to determined virus strains.

Different levels of resistance to Tobacco Rattle Virus (TRV)

The European Cultivated Potato Database contains data on 4169 potato cultivars. Each variety is qualitatively described according to its physiological characteristics (plant, tuber, tubering...), the possible utilisations and its resistance to several diseases (fungal, bacterial, viruses) and pests, for a total of a hundred of items. By an advanced search, you can select the most suitable cultivar according to your objectives and needs in term of resistance but also in terms of technical properties (e.g. Susceptibility to TRV or French fry suitability).

Susceptibility to TRV differs among potato cultivars. Some of them have been reported as resistant to the virus (e.g. Arran Pilot, Bintje, Saturna, Fronika, Record). Such cultivars are the most effective (and easiest) method of 'control' since they exhibit rarely symptoms, allowing farmers to produce marketable tubers at the end of the season.

But these cultivars cannot provide a real control of the virus since i) the soil and vector nematodes remain infected and ii) few of these cultivars are truly resistant but are just tolerant: even if they exhibit few symptoms, potato plants and tubers could be systemically infected (asymptomatic carrier) and play the role of virus source for non-infected vector nematodes from field to field.

*RT-PCR: Reverse Transcription Polymerase Chain Reaction

Using high quality virus-free seed potatoes

Some potato cultivars, as described in the previous section, exhibit rarely symptoms but might be infected. Infected seed-potato may be the first virus-source within a non-infected field. To secure these fields and limit the spread of the virus within infected fields, **it is highly recommended to use high quality tubers, certified virus-free**.

Focus on Innovator, Russet Burbank and Santana, three cultivars strongly required by the French fry industry but susceptible to TRV

Innovator seems to be a high productive cultivar, concealing the qualities of a Dutch and an American genetic. However, the variety owner precises that Innovator is susceptible to TRV.

Russet Burbank is a very old cultivar but have the particularity to produce very long tubers, perfect to make long fries. This is the 'favorite' variety of McDonald. However, this variety is quiet sensitive to pests and diseases, including TRV. Infected by the virus, this cultivar will show the typical internal symptoms.

In a Dutch study, **Santana** was the most susceptible cultivar to TRV and also the most sensitive variety for spraing among 6 potato varieties. This study revealed the high susceptibility of Santana to a determined TRV strain (PRN).
Moreover Santana seems extremely sensitive to spraing, since CRS were present while TRV was not detected into the tuber flesh (and tubers had been exposed to the virus). It means that Santana may exhibit symptoms even for a very low virus concentration.

Besides, Santana presents a high transmission rate for some TRV and it seems to be transmitted through generations of plants (at least three) and on to its tubers. The use of certified seed-potatoes is highly justified for this cultivar.

Regarding available data, Innovator, Russet Burbank and Santana are susceptible to TRV. The probability to show internal symptoms in presence of the virus is very high in these cultivars. So, **growing these varieties into an infected field should be highly discouraged.**

In case of a strong demand from the industry for these cultivars, control measures (described in previous fact sheets) should be implemented, the more measures, the better.

Advantages and disadvantages of the innovation

+	-
• Easy to implement • Enable the production of saleable potatoes from infected fields	• No cultivar matches all criteria (e.g. resistance, productivity, French fry suitability…) • Use of resistant cultivar cannot guarantee to control the virus

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11.4 Stakeholder trial/demonstration leaflets

Valerie

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Duration: January 2014 – December 2017

Valorising European Research for Innovation in Agriculture and Forestry

VALERIE Stakeholder Trials:

Potato brown spot issues in the supply chain in northern Poland: testing the susceptibility of potato varieties to Tobacco Rattle Virus

The problem

Brown spots on potatoes are a major problem for the growers and the impact can be felt across the whole value chain. This is particularly the case for potatoes grown in northern Poland for the French fries supply chain as processors and retailers require blemish-free white flesh and long potatoes. Innovator is one of the varieties that meet these requirements, but this variety is susceptible to Tobacco Rattle Virus (TRV), which causes internal brown spots in the tuber flesh. The vectors for TRV are nematodes, especially *Trichodorus* spp. Infection rates vary but in some years the damage can be >25%. For this reason growers look for alternative varieties, which are not as susceptible to TRV.

Proposed solution

Stakeholders and VALERIE project scientists scanned the scientific literature for solutions to this issue. Previous research in Scotland and the Netherlands found that other varieties were less susceptible to TRV. Based on this, the stakeholders decided to test other varieties for susceptibility to TRV in the northern Poland context so that they could meet their clients' requirements. Stakeholders also wanted to find out more about how to assess and manage infestation levels of their fields

Stakeholders

DLV/Delphy working with the VALERIE project has brought together stakeholders from the French fry industry in northern Poland. The Farm Frites company produce French fries in this region for a number of clients, like McDonalds. They produce potatoes partly on their own farm and partly from 60 contract growers in the region. These, together with potato seed producers (owners of the potato varieties), represent the supply chain stakeholders engaged with the project in identifying and testing solutions to the brown spot/TRV problem.

Potatoes with a high percentage of brown spots are rejected by the factory and this represents a big loss for farmers. The interest of the seed potato company is also clear, as persistent problems with the Innovator variety mean the acreage will decline. As there are no good alternative varieties for this specific market, the whole value chain has a great interest in solving the problem, although the factory and the growers are most interested in the outcomes. The factory provides a list of varieties they accept and the farmers chose from these.

Aims and method

The aim of the trial was to find out the susceptibility of current and potentially new varieties for specific strains of Tobacco Rattle Virus (TRV) transmitted by nematodes (*Trichodorus* spp.).

A field experiment was set up to test susceptibility in five varieties at the Farm Frites farm in Bobrowniki. Nematodes are not usually evenly spread over the field but are present in clusters so the first stage was to identify infected areas by soil sampling and analysis for nematodes. The experiment was then set up on two spots infected with *Trichodorus primitivus*, an important vector for TRV.

Five varieties: Innovator (standard), Zorba, Ludmilla, Ivory Russet, and Russet Burbank were planted.

The design was alternating a row with Innovator and a row with the tested varieties, with five tubers of each variety in each row. There were five replicates.

Data collected

After harvesting, tuber quality was assessed for all varieties. They were monitored for the symptoms of infestation with TRV - brown spots in the tuber flesh. The analysis of the tuber samples took place in the laboratory of Farm Frites.

A demonstration plot was also set up at the same site testing 11 varieties on a heavily infected spot with just one replicate. Assessment was made of the tuber quality of all the tested varieties together with the stakeholders on open field days.

Results

Field experiment results

Variety	% tubers with symptoms	
Innovator	5.4	B*
Ivory Russet	0.0	A
Ludmilla	0.0	A
Russet Burbank	2.2	AB
Zorba	6.0	B
gemiddeld	3.6	
F prob**	0.002	
LSD 5%***	4.7	

Table1. Percentage of tubers with symptoms of TRV, Bobrowniki (Polen) Field Experiment 2015-2016

Notes

*Differences are significant if objects do not have the same letter. In this case Ivory Russet (A) and Ludmilla (A) are significantly better than, Zorba (B) and Innovator (B).
**if F prob. is lower than 0.05 (5%) the variety effect is statistically reliable
***Difference between objects needed to be significant. Ivory Russet and Russet Burbank is 2.2, less than 4.7 and therefore not significant.

Significant differences in percentage of tubers infected with TRV were found between varieties in the field experiment, shown in Table 1.

Ludmilla and Ivory Russet did not show any symptoms on any of the plots, whereas Innovator showed an average 5.4% of tubers infected with TRV. The spread between the plots and samples was substantial, with Innovator showing between 0- 50% tubers infected with TRV, this indicates an uneven spreading of the nematodes within the trial plot.

Demonstration plot results

Variety	% tubers with symptoms	
New 1	2.1	A
New 2	1.1	A
New 3	0.0	A
Fontana	3.3	A
Innovator	32.3	C
Ivory Russet	14.3	ABC
Ludmilla	0.0	A
Markies	1.1	A
Russet Burbank	17.8	ABC
Santana	24.6	BC
Zorba	9.4	AB
gemiddeld	9.6	
F prob.	0.04	
LSD 5%	21.0	

Table 2. Percentage of tubers with symptoms of TRV Bierkowo (Polen) Demonstration Trial 2015-2016.

In the demonstration plot significant differences were also found between the varieties. The high percentage of TRV symptoms in Ivory Russet was an interesting outcome, although these were very light symptoms which are acceptable for the industry. This prompted the question: Is a specific strain of the TRV at stake or something else?

Some new varieties (new 1-3) showed promising low infection rates with TRV. These will be tested further for other agronomic characteristics.

These are useful results although as the stakeholders pointed out, TRV susceptibility is only one of the important characteristics of a variety. Ivory Russet and Ludmilla have a lower yield potential and Ivory Russet yield is particularly affected by dry and warm weather. This complicates the choice of variety for stakeholders.

Notes – see Table 1

Overall stakeholder involvement and feedback

Stakeholders identified the issue for investigation and were involved from the beginning of the field trial which was conducted on the Farm Frites farm. They visited the trial and discussed the results on a regular basis, and visited the demonstration plot after the growing season when the results became clear.

All stakeholders found the results interesting and will consider them in the variety planning for next year. The results help the growers decide which variety and field combinations are possible and less risky. Stakeholders agreed that these trial results can offer a solution for fields with a dense *T. primitivus* population infection, and that part of the Innovator acreage could be replaced by the less susceptible varieties. Also some of the new varieties possibly can replace Innovator in the coming years. However stakeholders were also reminded that other characteristics of the alternative varieties (yield capacity, susceptibility to warm and dry weather and storability) are potential barriers to their widespread use, compared to Innovator, a popular high yielding variety.

The results also prompted discussion about strategies for managing the nematode population and the virus load of the nematodes by taking specific agronomic measures, such as the choice of green manures and cover crops.

Key findings

- Stakeholders identified brown spot caused by TRV infection as a big problem throughout the supply chain
- A trial and a demonstration plot was set up to assess susceptibility of five varieties in comparison to the standard, Innovator
- Ivory Russet and Ludmilla are good alternative varieties to Innovator with less susceptibility to TRV, however other variety characteristics need to be considered as well
- Some new varieties show little susceptibility to TRV in the demonstration trial. These varieties will be tested further, looking at infection and other characteristics
- The nematode control strategy needs more attention on the farms of the contract growers. Most of the growers do not have good information about the infestation levels of their fields
- Choice of cover crop and green manure affects the population of nematodes and the virus load of the nematodes –this is a topic for future research

Further reading

VALERIE Fact Sheet: Integrated management of Tobacco Rattle Virus (TRV) in potato production (1): General information

VALERIE Fact Sheet: Integrated management of Tobacco Rattle Virus (TRV) in potato production (2): Control methods

VALERIE Fact Sheet: Integrated management of Tobacco Rattle Virus (TRV) in potato production (3): Which cultivar to choose? - Focus on the French fry production

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Delphy https://delphy.nl/en, formerly DLV, is a partner in VALERIE

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12 Catchment scale resource use efficiency, UK

12.1 Context

The Welland Valley Partnership (WVP) was formed in 2011 with the aim of bringing together stakeholders from the catchment of the River Welland and its tributaries, in order to forge ideas for, and progress, river enhancement activities, for the benefit of the water as a resource for the community and for the benefit of wildlife. The partnership is chaired by the Welland Rivers Trust, with a wide range of stakeholders, from individuals, local authorities and government agencies such as Environment Agency (EA) and Natural England (NE), farming representatives such as the National Farmers Union (NFU) and Country Land and Business Association (CLA), Non-Government Organisations (NGO's) and the local water company Anglian Water (AW). The Partnership is driven in part by the requirements of the Water Framework Directive (WFD) and is supported financially mainly by the by the EA.

The Game and Wildlife Conservation Trust is a partner in the WVP and contributes towards its objectives through the Water Friendly Farming project. The project tests to what extent to which the WFD targets can be reached by applying practical evidence-based mitigation measures at the landscape scale and involves three headwater catchments, covering nearly 30km^2. The Resource Protection Group acts as a stakeholder steering group for the CS study and comprises:

- 5 local farmers within the WVP.
- GCWT.
- NFU.
- EA.
- NE.
- Agricultural industry advisor.
- Conservation advisor.

This group all met at the VALERIE first meeting; since then local farmers have been meeting and discussing ask-Valerie.eu, field trials and demonstration work.

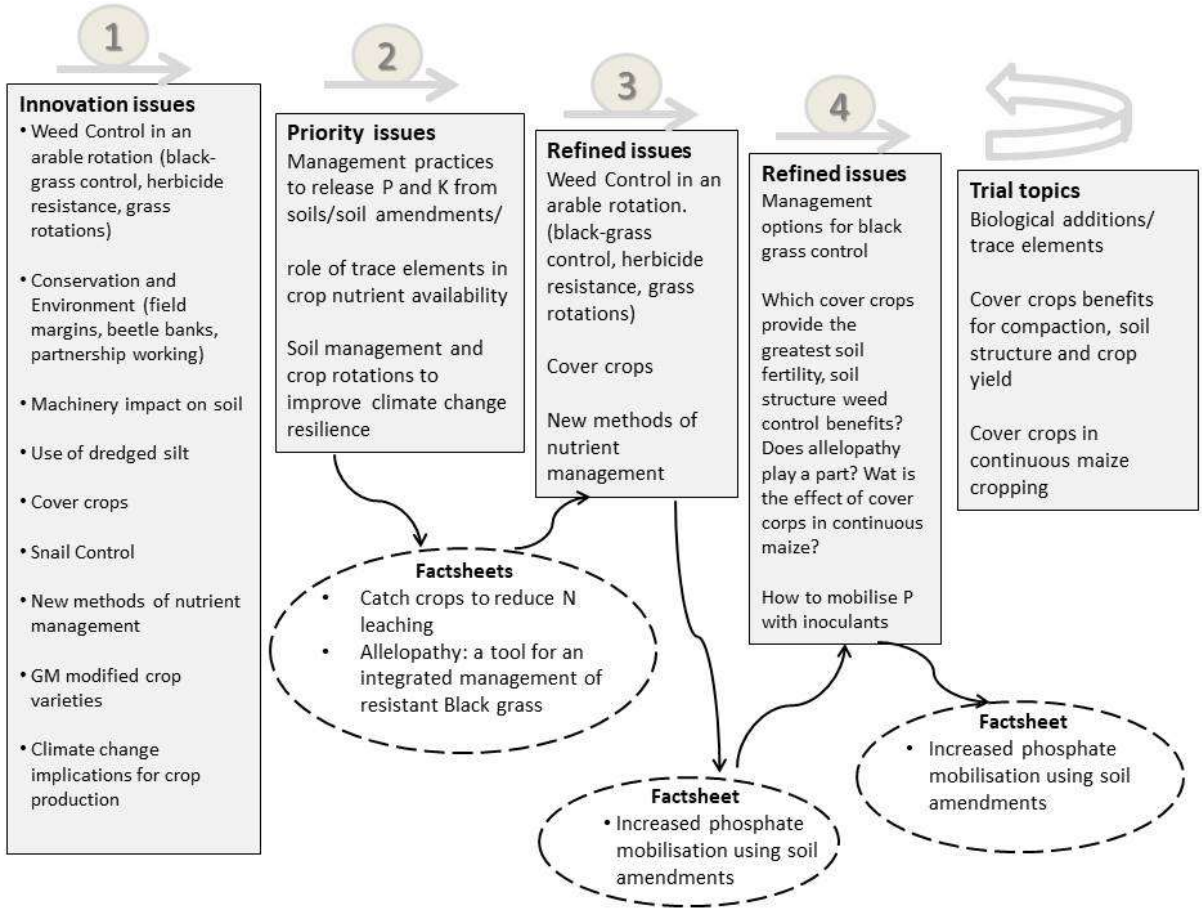
12.2 Dynamic Research Agenda

The DRA (Figure 12.1) shows that in this CS the stakeholders identified a broad range of issues that were of initial interest. Over the course of subsequent meetings these issues were revisited and discussed with a narrowing down and concentration on a smaller number of key issues. In the first meeting nine issues were identified which were prioritised by stakeholders into 3 themes:

1. Management practices to release P and K from soils/soil amendments.
2. Role of trace elements in nutrient availability to crops.
3. Soil management and crop rotations to improve resilience to climate change.

These issues were reviewed and refined at subsequent meetings with the stakeholders and CSP working together to identify 3 topics where scientific knowledge was considered to be lacking and suitable for further exploration through field trails.

Figure 12.1 Catchment Scale Resource Use Efficiency Case Study Dynamic Research Agenda



Thematic Experts summarised and synthesised outputs from several scientific papers to prepare two factsheets. The stakeholders' reviewed and provided feedback on the factsheets at the second meeting. The factsheets were considered to be useful but the feeling among the stakeholders was that the information presented needed to be orientated more towards practical solutions. The refinement of the research issues by the stakeholders led to a request for factsheets on increasing phosphate mobilisation using soil amendments.

Valerie

Catch crops to reduce N leaching

What is it?

Catch crops are subsidiary crops included in crop rotation aiming at taking up available nitrogen (N) remained in the soil after the harvest of the main crop. They are able to decrease nitrate leaching from the cropping system (on average by 53% when a grass catch crop is used in the autumn-spring period). At the end of the growing period they can be left on surface or incorporated into the soil. In this fact sheet we consider also subsidiary crops that are harvested and have the same function of catching N.

Problems to be solved

Nitrate leaching losses can occur in croplands with a bare fallow in crop rotation, especially during the rainy and/or low evapotranspiration period with a high probability of drainage. In continental climates, these periods last from autumn to spring. Summer catch crop can be effective when they anticipate N uptake before the leaching period.

Positive side effects and different environment (they differ among catch crop species)

During growth:
1) They control soil erosion.
2) They limit early season weed seed germination.
3) They improve soil structure due to roots growing and organic matter addition derived from below biomass.

If incorporated in the soil as green manure:
4) They further improve soil structure due to organic matter addition derived from above ground biomass.
5) They make captured available N for the following main crop, thus reducing the need for mineral fertilizers.
6) They increase phosphorus and potassium uptake of the following crop.
7) They increase soil organic matter and soil organic N. This increase is correlated to the frequency of catch crops in crop rotation.
8) They supply N from N fixation if legume species are included(in mixture with grass or in pure stands).

Disadvantages

1) Nitrogen immobilization may occur if the incorporated biomass has a large C/N (>20). If soil mineral N is scarce, N immobilization can decrease the yield of the subsequent crop. One solution to this problem is to sow a cover crop mixture (grass with legume species) to reduce the C/N ratio and increase net N mineralization.

2) Eventual depressive effects may occur due to the release of natural herbicidal molecules into the soil (allelopathy). To avoid this problem, respect a delay between the incorporation of the catch crop and the sowing of the following main crop (especially for Brassica cover crops).

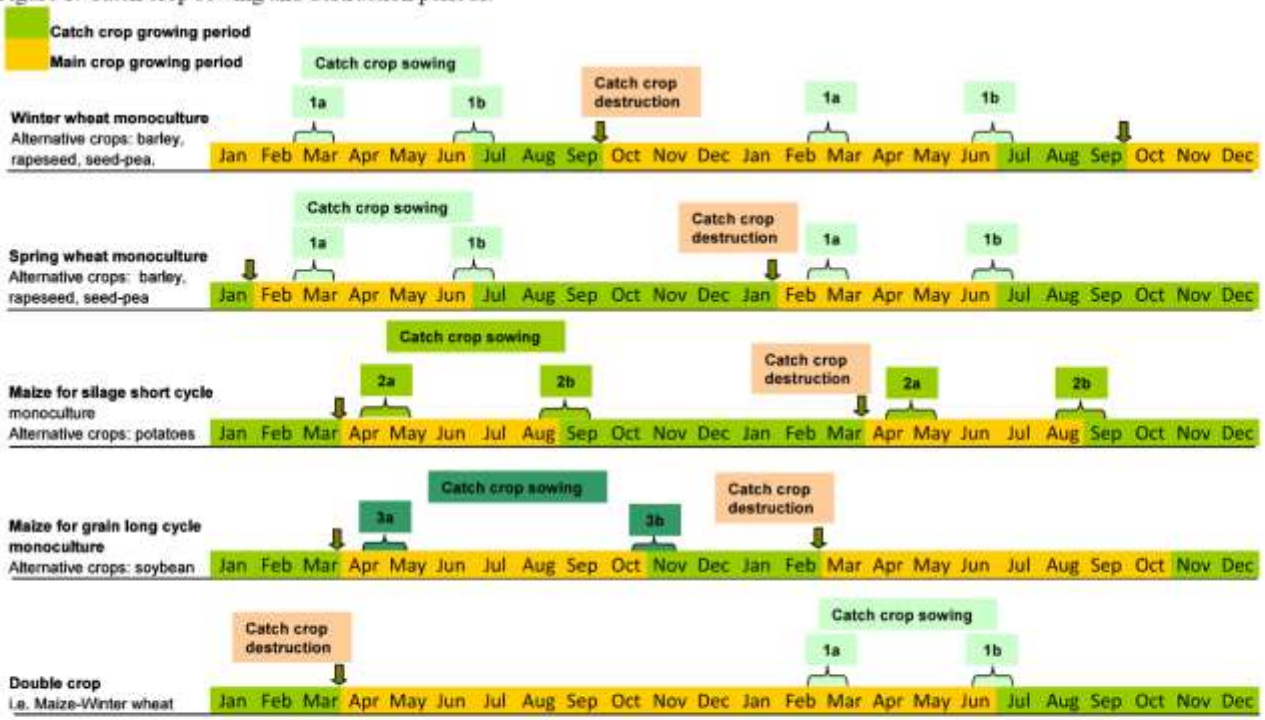
3) Irrigation eventually needed for summer catch crops.

How to manage catch crops

Position in crop rotation

Catch crop growing period depends on the crop rotation. Figure 1 reports five examples of introduction of catch crops in five different crop rotations. Different catch crop sowing periods are represented with different numbers and shade of green color.

Figure 1: Catch crop sowing and destruction periods.



Catch crops species and sowing suggested management.
Table 1 reports the different species that can be sown during the three different periods reported in figure 1.

Table 1: Suggested catch crop species for the different sowing periods.

Sowing period	Previous main crop	Species
1	Winter and spring cereals (i.e. wheat, barley) Winter and spring legumes (i.e. seed-pea) Rapeseed	*Lolium multiflorum* *Panicum miliaceum* *Panicum italicum* *Avena sativa* *Trifolium spp.* *Fagopyrum esculentum* Mixture
2	Summer crop short cycle (i.e. Maize silage, potatoes)	*Lolium perenne* *Lolium multiflorum* *Secale cereale* *Avena sativa* *Triticum aestivum* *Brassica napus* *Sinapis alba* Mixture
3	Summer crop long cycle (i.e. Maize for grain harvest, soybean)	*Lolium multiflorum* *Secale cereale* *Hordeum vulgare* *Avena sativa* *Brassica napus* *Vicia villosa* Mixture

Sowing management must be adapted to catch crop seeds characteristics and farm machines availability.

a) Seeding technique "a" in figure 1 (1a, 2a, 3a):

- Undersowing the catch crop on cereals or on maize in spring (broadcast seeding on the standing crop before harvest);
- Drill seeding into a growing cereal;

b) Seeding technique "b" in figure 1 (1b, 2b, 3b) for cereals:

- Drill seeding on the stubble;
- Broadcast seeding on stubble;
- Broadcast seeding after crop harvest, and seed bed preparation with disk harrowing and rolling;
- Broadcast seeding after crop harvest and seed bed preparation with ploughing and disk harrowing
- Precision seeding after ploughing and disk harrowing;
- Sod seeding into crop residues;

Seeding technique "b" in figure 1 (2b, 3b) for Cruciferous:

- Precision seeding after ploughing and disk harrowing.

In warm and dry environment, irrigation might be needed when catch crops seeded in early summer.

Biomass destruction management

Biomass catch crop destruction can be:

1. removed;
2. killed with herbicides spraying and left on soil surface or incorporated into the soil;
3. killed with flail mulcher and left on soil surface or incorporated into the soil.

Effects of catch crop management on N leaching:

Table 2 summarizes the efficiency of different kinds of catch crop species. It includes different types of soils and climatic conditions.

Table 2: Requirements, effects on N leaching and soil N availability, strengths of different species of catch crops and conditions and practices that discourage adoption. (Source: Justes et al., 2012)

Effects	Grass	Cruciferous	Legumes	Mixture
Requirements	Rather early seeding on soil frost-free or little frozen	Early seeding on soil frost-free according to species and temperature	Very early seeding on soil frost-free	Mixture must be adapted to the N availability
N leaching reduction (%)	30 to 80%	30 to 90%	0 to 40%	20 to 60%
N release for the succeeding main crop (%) (soil available N for main crop/N uptake of catch crop)	-20 to +10%	-10 to +30%	+10 to +50%	+10 to +40%
Strengths	Efficient in high N input cropping systems and in Atlantic climate	Highly efficient or efficient in high N input cropping systems and in Continental climate	Efficient in low N input cropping systems. Lower competition with main crop in undersowing	Intermediate efficiency due to species plasticity according to N availability
Conditions and practices that discourage adoption	Clay soil (late incorporation)	Clay soil if the cover crop is not sensitive to frost (late incorporation)	Intensive cropping systems with large manure or N inputs	Intensive cropping systems with large N inputs

Some experimental results are reported in figure 2. Although they are referred to specific pedo-climatic situations, the described effects can be considered meaningful in wider pedo-climatic environments.

Figure 2: Factors influencing efficiency of N leaching reduction for specific situations.

Best practices	Soil	Alternative management			Percentage of leaching reduction vs no catch crop
		Worse	vs	Better	
Biomass destruction	Sandy, Sandy loam	Lolium perenne, left on surface, minimum tillage or sod seeding	vs	Lolium perenne, incorporated with ploughing	
	Sandy, Sandy loam	Lolium perenne, removed, sod seeding or minimum tillage	vs	Lolium perenne, incorporated with ploughing	
Time of ploughing	Sandy, Sandy loam	Lolium perenne, autumn ploughing	vs	Lolium perenne, spring ploughing	
Growing period	Silty soil	Avena sativa, from end of August to end of November	vs	Secale cereale, from beginning of October to end of April	
Selected species	Sandy, Sandy loam, Silty clay loam or Clay loam	Vicia villosa	vs	Avena sativa	
	Silty clay loam or Clay loam	Vicia villosa	vs	Hordeum vulgare	
	Silty clay loam or Clay loam	Vicia villosa +Triticosecale	vs	Secale cereale / Triticosecale	
	Silty soil	Vicia villosa	vs	Sinapis alba	
	Silty soil	Vicia villosa	vs	Trifolium spp	

Costs for catch crop

Costs for catch crop managements include seed purchase (table 3), sowing and destruction management (table 4).

Table 3: Seeds quantity, costs for kg and for hectare, VAT excluded, for some catch crops seeds in North-West Italy.

Cereals	Seeds kg/ha	Cost €/kg	Cost €/ha
Lolium perenne L. *Lolium multiflorum L.*	35-45	2.40	96.00
Panicum miliaceum L. *Panicum italicum L.*	10/15-40	1.08	28.40
Avena sativa L.	120-150		
Secale cereale L.	150-200	0.75	131.25
Triticum aestivum L.	200-250	0.62	139.50
Hordeum vulgare L.	200-250	0.68	153.00
Legumes			
Vicia villosa L.	200	1.20	240.00
Trifolium spp.	5-7	5.00-8.00	45.00
Cruciferous			
Brassica napus L.	10		
Brassica juncea L.	8-10	9.00	81.00
Sinapis alba L.	10		
Mixture			
Mixture (Sinapis alba L.+ Brassica juncea L.)	10	12.00	120.00

Table 4: Costs of some proposed management practices (VAT excluded) in North-West Italy.

Sowing	Operation	Cost €/ha
Broadcast seeding on stubble or on the standing crop before harvest	Broadcast fertilizer spreader	29
Broadcast seeding after crop harvest, and seed bed preparation with disk harrowing and rolling	Total	125
	Disking	77
	Rolling	18
	Broadcast fertilizer spreader	29
Broadcast seeding after crop harvest and seed bed preparation with ploughing and disk harrowing	Total	217
	Ploughing	110
	Disking	77
	Broadcast fertilizer spreader	29
Sod seeding into crop residues or into a growing cereal	Seed drill	100
Precision seeding after ploughing and disk harrowing	Total	235
	Ploughing	110
	Disking	77
	Classic seed drill	47
(Irrigation)*		
	Surface	7
	Sprinkler	35
Destruction of biomass	-	-
Left on soil surface	Herbicides spraying	39
	Flail mulcher	50
Removed	Harvester	160

Note:* €/ha for 30 mm supplied with only one application.

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http://plants.usda.gov/java/coverCrops

Valerie

Allelopathy: a tool for an Integrated Weed Management. Application to resistant Black grass (*Alopecurus myosuroides* Huds.) in UK

Contact: Yolaine Hily (INRA, UMR AGIR, yolaine.hily@toulouse.inra.fr)

What is it: Use natural molecule release to control weeds and slow development herbicide resistance

Allelopathy has been defined as the effect of one plant on another through the release of a chemical compound (allelochemical) into the environment. These chemicals produced naturally by plants can be located in the whole plant with higher concentrations in some organs (stem, leaves, roots…); they can affect weeds but possibly following crop as well. Many plants have shown allelopathic properties, including cover crops (catch crops) and cash crops; in this way they could be used to compete with and control weeds.

Problem to be solved: Black grass, a weed resistant to many herbicides

The intensive use of herbicides and progressive decrease of the number of active substances available on the market induce a high selection pressure on weeds, pushing numerous species to develop resistance to herbicides. In UK, resistant black grass is the major concern among herbicide-resistant weeds. Important densities of resistant plants have been reported, causing important yield loses. In wheat, an infestation level of 100 plants/m² can cause a yield loss of 1 t/ha or more. Alternative weed management strategies are needed to control these resistant weeds.

How to include cover crops into an Integrated Weed Management

The first level of an integrated weed management is clearly the increase of the rotation length and the number and type of cash crops for diversifying sowing periods. The cover crops could be used only in addition to rotation and soil tillage levers and then could not probably solve alone the control of weeds. The re-design of cropping systems is certainly needed. Notice that the weed suppressive ability of a cover crop specie results on one hand from its ability to compete for light, water and nutrients and the other hand from its allelopathic potential.

Choice of the cover crop species:

No ready-to-use solution exists. Choosing a cover crop among the multitude of species available must be done considering:

- The weather conditions (temperature, periods of freezing, rainfall…).
- The length of the fallow period (which is short before winter crops and long before spring crops).
- The time of emergence of the targeted weed: here **Black grass** develops in autumn and spring; so ideally, the cover crop must be competitive in late summer, survive the winter and have biofumigation effects after incorporation in spring, which is very hypothetic in arable cropping systems. However, it could also provide weed control either in autumn (and winterkill) or in spring (if sown early).
- The following cash crop (some crops could be sensitive to allochemicals).
- Other beneficial/negative effects caused by cover crops (see below).

Allelopathic potential differs also among plant species and cultivars. Before choosing definitely the cover crop, check with local experts for specific adaptation information.

It is possible to mix different cover crop species and benefit from their different properties (e.g. the mixture Rye + hairy vetch + fodder radish could be a good compromise to provide satisfactory weed control (allelopathy, shading and mulch) and to reduce eventual nitrogen immobilisation during mulch decomposition).

Remark: plant species belonging to the Cruciferous family (Turnip rape, white, brown and Indian mustard) are also well known for their high allelopathic potential, especially after their incorporation into the soil, but also with associated species in mixtures.

Examples of possible cover crop species with allelopathic potential:

	Traits	Seeding time	Weed Control period	Other benefits/side effects
Fodder radish (either a cover crop or cash crop) *Raphanus sativus L.*	-Rapid germination and growth in autumn -Winterkills (-4°C) -Quick decomposing residues	Late summer	Autumn and early spring	-Weed control does not last during the following warm cropping period. Therefore, post emergence herbicides are needed in spring. -Fodder radish does not tolerate very wet soils -Alleviation of soil compaction -Enhancement of the seedbed (thin residues layer) -Improvement of N nutrition of the following crop
Winter oilseed rape (cover crop) *Brassica napus L.* *Brassica rapa L.*	-Rapid germination and growth in autumn - Overwintering	Early autumn	Autumn and spring	-Strong competitive ability in autumn -Development correlated to soil nitrogen concentration -Respect a delay before sowing next crop (possible effects of allelochemicals)
Rye (either a cover crop or cash crop) *Secale cereale L.*	-Overwintering -Rapid growth, overcompetes weeds -Biomass production in spring	Early autumn	Autumn and spring	-Physical weed germination control in spring (mulch) -Possible N immobilisation due to the mulch decomposition (less N available for the following crop) -Allelopathic potential declines with development

Incorporation: optimizing the effects of allelochemicals and physical cover

Allochemicals are released from the dead mulch produced by mowing, rolling, chopping or spraying the cover crop. The residues can be left on the soil and provide additional physical control on weed seedlings (help reducing temperature variations and light penetration) but will decompose slower. Effective weed control has been reported during several weeks after mulching of some cover crop species. **Adapt the cover crop management and respect a short delay before sowing the succeeding cash crop in order to avoid depressive effects.**

Other application of allelopathy: competitive crop varieties with high allelopathic potential:

In agriculture, cover crops are known to provide weed control through competition and allelopathy. But some crops possess also allelopathic potentials (e.g. oat and rye). Some studies have shown that this potential differs among cultivars. Thus, choosing a competitive cultivar presenting high allelopathic potential could be another way to use allelopathy as a tool to control black grass within the crop, complementing the action of cover crops in this way.

Advantages and limitations of the use of cover crops

+	-
• Natural method using natural chemical compounds, short-lived and without environmental effect. • Efficient weed control if included into an integrated weed management • Other possible beneficial effects (depending on the cover crop): - alleviation of soil compaction, - reduction of nitrate leaching, - improved crop nutrition, - stimulation of following cash crops, - control of soil erosion and runoff, - enhancement of soil organic matter rate.	• Unpredictable effects. Production and effective release of allelochemicals resulting in weed suppression depend on: - Growth conditions of the catch crop (rainfall, nutrients…) - Growth stage: usually allochemicals concentration is higher in young plant parts - Amount of catch crops organic matter (which has been related to the weed control level) - How the cover crop has been destroyed and incorporated (or not) into the soil - Weather conditions during the decomposition and soil type (impacts persistence of molecules) • Possible depressive effects on the following crops: persistence of allelochemicals into the soil and/or nitrogen immobilisation due to the decomposition of the mulch.

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12.4 Case Study Partner produced outputs

The CSP produced a report of the field trial on Mycorrhizal fungi seed treatment (Rootella) on Maize.

Valerie

Field Trial Report for the Welland Valley Partnership Case Study

Mycorrhizal fungi seed treatment (Rootella) on Maize

Trial Location: Stakeholder Farm in the Welland Valley

Background

This trail was the second attempt by the Case Study Partners to establish a crop using a Mycorrhizal Fungi applied to the seed as Rootella.

Four plots of inoculated wheat, one on each farm, were drilled in September 2015, for comparison with untreated crop in the rest of the selected fields. However, because of the small quantity of inoculant available, these were difficult to drill with conventional farm drills and crop cover was uneven, providing very limited opportunity for data collection. However, the group learnt about the principle of seed inoculation with mycorrhizal fungi, including seed treatment and practicalities of drilling. We plan to obtain feedback further from each of the farmers, and basic crop data, but to concentrate remaining resources on a more rigorous experimental design in a small area of spring-sown maize on one farm.

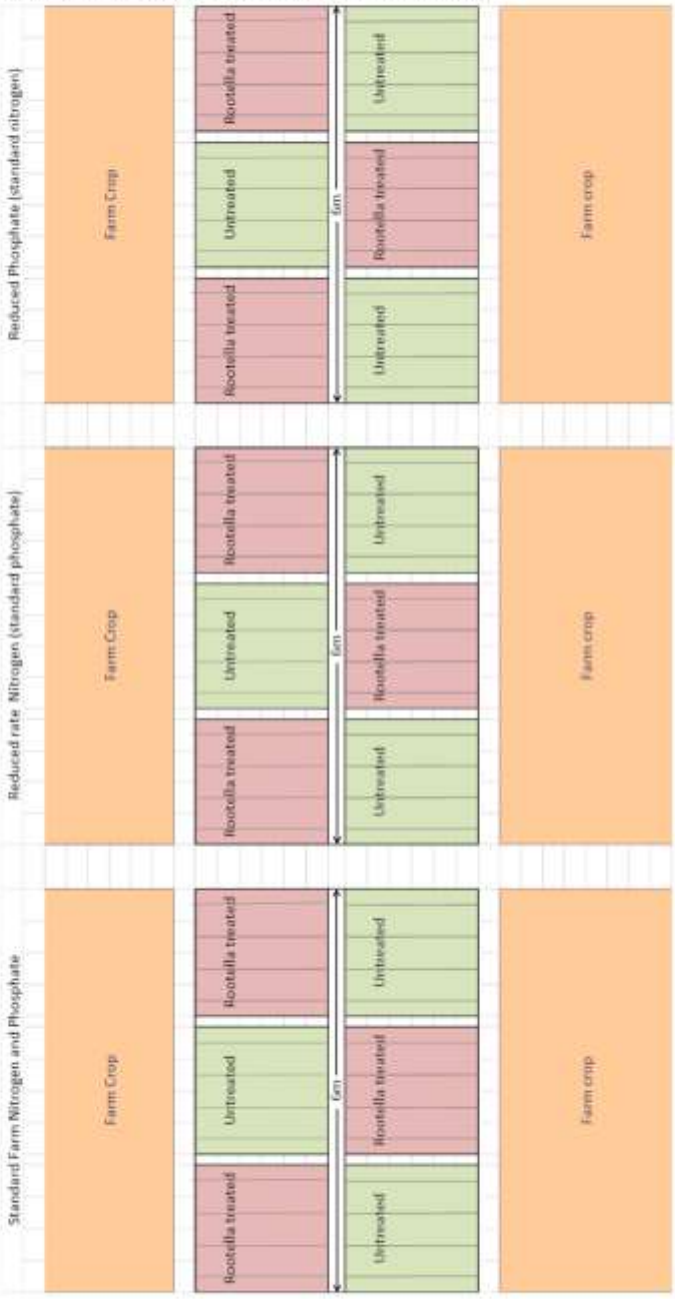
Maize was selected by the farmers as the timing of sowing fits with the schedule for the current project, and because interest in the potential of inoculating this crop is shared by the producer of the inoculant, and by two farm businesses involved in the project.

Protocol:

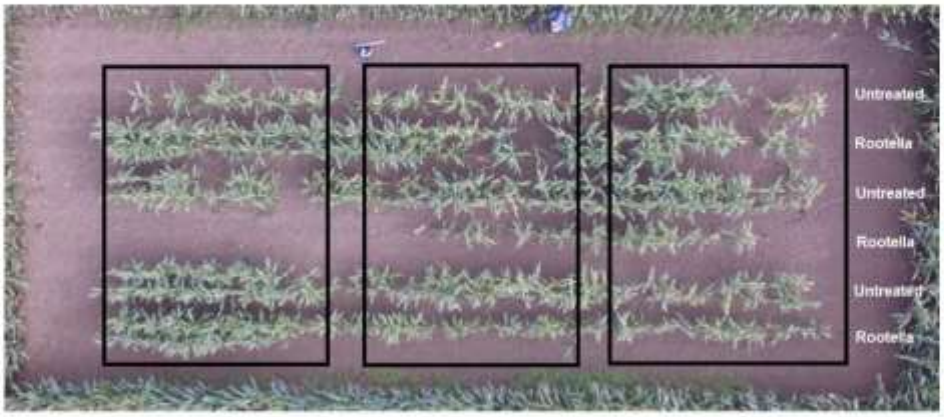
- The trial is investigating whether Phosphate and Nitrogen usage can be reduced through the use of Mycorrhizal Fungi applied to the seed as Rootella.
- Maize was drilled using a hand drill in a 6m wide strip left blank by the farm drill.
- The maize seed had the Rootella seed treatment applied as per Groundwork's instructions.
- The Untreated and Rootella treated seeds were drilled in paired rows
- A guard strip acted as a buffer to keep the treated seed away from the untreated seed- with at least 50cm between treatments.
- There were 3 trial blocks. One with standard farm N and P, one with zero N and standard P, and one with standard N and zero P.
- The plots were harvested by hand and assessed by Velcourt R&D.

Trial:

The plots were laid out as shown in the figure below.



The picture below shows the crop after establishment.



Standard N, Zero P **Zero N, Standard P** **Standard Farm N and P**

- The trial was drilled on the 20th of May and harvested on the 5th of October.
- The number of plants in each treatment was counted.
- 20 plants per treatment were cut at the base and the weight of the plants recorded.
- The number of cobs per plant and total cob weight was recorded.
- There were some problems with crop establishment where the trial drill went through the compacted soil of the tramlines, shown on the drone photo above.

SOIL ANALYSIS REPORT

Laboratory Sample Reference	Field Details			Index			mg/l (Available)		
	No.	Name or O.S. Reference with Cropping Details	Soil pH	P	K	Mg	P	K	Mg
37617/16	1	**MAIZE 0-30** *No cropping details given*	6.8	1	1	4	9.8	93	208
37618/16	2	**MAIZE 30-60** *No cropping details given*	7.2	0	1	4	7.0	109	203

- The soil had an index of 1/0 for Phosphate

There were no visual differences between the Rootella treated plots compared to the untreated plots.

Results:

Treatments				
		Seed treatment	**Seed bed fertiliser**	**Plants per Ha**
1		Untreated	Standard P+N	36190
2		Rootella	Standard P+N	22540
3		Untreated	P only	40635
4		Rootella	P only	34603
5		Untreated	N only	37143
6		Rootella	N only	55746
			F-test Probability	0.182
			5%LSD	n/a
		Factorial Assessment	**Seed treatment**	
			Untreated	37989
			Rootella	37630
			F-test Probability	0.956
			5%LSD	n/a
			Seed Bed Fert	
			Standard N+P	29365
			P only	46444
			N only	37619
			F-test Probability	0.14
			5%LSD	n/a
			rootella.fertiliser	0.146

- A lot of variation between the treatments caused by the establishment.
- No significant differences between the treatments in terms of Rootella or fertiliser.

Treatment		Seed Treatment	Seedbed Fertiliser	Weight per plant /kg	T/Ha (fresh weight)
1		Untreated	Standard P+N	0.65	23.7
2		Rootella	Standard P+N	0.71	16
3		Untreated	P only	0.63	25.4
4		Rootella	P only	0.46	17
5		Untreated	N only	0.67	24
6		Rootella	N only	0.49	27.1
			F-test Probability	0.009	0.651
			5%LSD	0.13	n/a
			% C.V		43
		Factorial Assessment	**Seed treatment**		
			Untreated	0.7	24.3
			Rootella	0.6	20.0
			F-test Probability	0.017	0.367
			5%LSD	0.08	n/a
			Seed Bed Fert		
			Standard N+P	0.7	19.8
			P only	0.6	21.2
			N only	0.5	25.5
			F-test Probability	0.028	0.584
			5%LSD	0.09	n/a

- No significant difference between the treatments in terms of plant weight or fresh weight.

Treatment		Seed treatment	Seedbed Fertiliser	Cobs per plant	Cob weight per plant /kg
1		Untreated	Standard P+N	1.67	0.35
2		Rootella	Standard P+N	1.67	0.35
3		Untreated	P only	1.63	0.35
4		Rootella	P only	1.23	0.25
5		Untreated	N only	1.53	0.37
6		Rootella	N only	1.30	0.25
			F-test Probability	0.004	0.005
			5%LSD	0.22	0.06
			% C.V		
		Factorial Assessment	**Seed treatment**		
			Untreated	1.6	0.4
			Rootella	1.4	0.3
			F-test Probability	0.004	0.002
			5%LSD	0.13	0.04
			Seed Bed Fert		
			Standard N+P	1.7	0.3
			P only	1.4	0.3
			N only	1.4	0.3
			F-test Probability	0.009	0.09
			5%LSD	0.15	0.04
				0.048	0.029

- No significant difference between the treatments in terms of cobs per plant and cob weight.

Conclusion and next steps

This trial was initiated as a result of interest from the Welland farmer group in the possible role of mycorrhizal inoculants to mobilise soil phosphorus, maintaining or increasing crop performance without the application of phosphate fertiliser. The trial found no significant difference in any of the productivity variables measured in a maize crop. However, the interest prompted by this project has contributed to the development of two new research themes at the Allerton Project research and demonstration farm. As part of the H2020 SoilCare project a mycorrhizal inoculant is one of the three treatments being investigated to reduce soil compaction in an autumn-sown wheat crop. A PhD project is investigating the role of different cover crop species in capturing and mobilising phosphorus through microbial enzyme activity, prior to a spring-sown cereal crop. The results will be shared with farmers through the local farmer network, and through the other ongoing knowledge exchange activities of the Allerton Project.

AS the results of the trial were considered inconclusive and there was a desire to undertake further work it was decided not to hold a field trial demonstration day. The stakeholders did however want to continue with a demonstration event. This lead to the establishment of a series of soil demonstration days hosted at the Allerton Project and delivered in partnership with industry stakeholders, soils experts and industry partners. The first of these was held on 27th March 2017, at the request of the Project Valerie Stakeholders one of the key speakers at this event focussed on Mycorrhizal fungi and what can they deliver. This demonstration event is covered in a separate brief report.

Jim Egan – WVP Case Study Lead

On 27th March 2017 the CSP organised a soil management demonstration event for the Welland Valley Partnership and the Allerton Project.

Report of Welland Valley Partnership / Allerton Project Soil Management Demonstration Event 27th March 2017 at the Allerton Project.

1. **Introduction.**
   This demonstration day was delivered in partnership with two key national stakeholders, The National Farmers Union (NFU) and LEAF, Linking the Environment & Farming. The topics for discussions and demonstration were decided by the Allerton Project team following input project partners including The Water Friendly Farming Project, The Welland Valley Partnership (Project Valerie Stakeholders) and our sponsors and event partners.

   All those involved wanted to deliver a practical day based on applied research and good field demonstrations.

2. **The Demonstration Day.**
   The full agenda for the day can be found in Annex 1. Industry sponsors for the day were Kings Crops and Dale Drills. Speakers came from The Allerton Project, LEAF, NIAB TAG and Sheffield University with the NFU providing the chair for the day.

   The key note speaker was Dr Jonathan Leake from the University of Sheffield who gave a talk titled "Mycorrhizal fungi – what can they deliver?"

   There were 43 attendees including farmers, policy makers ad industry leaders.

   The full day was summarised in a blog published on the GWCT Website and included in Annex 2. The event was also covered in the national farming press with an article in the Famers Guardian and in the NFU members magazine. There was local coverage on the BBC Radio Lincolnshire Farming Programme.

   There was also coverage through social media, the Twitter coverage is summarised by following this link, https://storify.com/Gameandwildlife/soils-day-2017-at-the-gwct-allerton-project.

Report of Welland Valley Partnership / Allerton Project Soil Management Demonstration Event 27th March 2017 at the Allerton Project.

Annex 1: The Agenda

Cover Crops: The growing research into their management and impacts.

GWCT / LEAF/ NFU Technical Soils day for farmers and professional advisers

27th March 2017 - The Allerton Project, Loddington, Leicestershire LE7 9XE

Chair for the Day Mike Hambly, NFU National Combinable Crops Board

Many thanks to our sponsors Dale Drills and Kings for supporting the day.

09.45 Arrival & Coffee

10:00 Welcome and introductions – Mike Hambly,

10:15 Soils, The Allerton Project and The SiP Project – Dr Felicity Crotty, The Allerton Project; an update.

The impact of using cover crops - Ron Stobart, NIAB TAG

Break

Cover Crops and direct drilling, a farmer's view- Chris Bayliss, LEAF Demonstration Farmer and Head of Farming at Sir Richard Sutton Settled Estates.

Mycorrhizal fungi – what can they deliver? - Professor Jonathan R Leake, the University of Sheffield

13:00 Lunch

13:30 Farm tour – this will include:

- James Dale, Dale Drills – the challenges of direct drilling
- Discussions on destroying cover crops and establishing the following crop.
- Richard Barnes Kings – seed mixes, options and opportunities
- The Allerton Project field trials - Phil Jarvis and Dr Felicity Crotty, The Allerton Project
- There will be a John Deere drill and Sumo subsoiler on display.

15:30 Closing remarks, tea & coffee, depart.

Report of Welland Valley Partnership / Allerton Project Soil Management Demonstration Event 27th March 2017 at the Allerton Project.

Annex 2: Event Blog

Raising the Sustainable Soil Profile- Soils Day, March 2017- The Allerton Project

Amelia Woolford, Project Development Officer

It's becoming an age-old tale that farmers, as some of the custodians of the countryside, need to take care of their soil, as without it, we can't farm. We know that soils are important for our crops and therefore food security, as well as the wider environmental benefits supported by good soil health. By its very nature, without this essential component, we would not be able to grow food, provide wildlife habitats, prevent flooding or have clean water.

£5.3 billion is spent on agriculture annually and 25% of this goes on soil degradation costs (Defra, 2012). There is no one single strategy to tackle this impact. It is therefore important to consider your objectives and management strategy, from sowing methods and dates, pest protection and establishment along with crop rotation, which advances in agricultural technology will help with.

At the Allerton project in Leicestershire, numerous studies are in action to investigate the impact of cover cropping and cultivation methods on soil resilience. The Project in partnership with the National Farmers Union (NFU) and LEAF hosted a stimulating event, sponsored by Dale Drills and Kings. A range of experts attended to discuss the latest industry research and how farmers can and are leading the way to achieve healthy soils for the benefit of the environment, crop yields and consumers.

The soils day was attended by nearly 50 farmers, NFU members, industry advisers, researchers and policy makers and was chaired by Mike Hambly (NFU, National Combinable Crops Board).

We kick started the day with a research review from Dr. Felicity Crotty (the Allerton Project soil scientist), who highlighted the innovative 3-year SIP project and the benefits that cover cropping can bring. These include, but are not limited to, nutrient retention, ecosystem provisioning, increased organic matter, reduced soil erosion, livestock forage and weed control. We also learnt that earthworm weight can be greater per hectare underground than the livestock above ground which graze it!

Following this, Ron Stobart of NIAB evaluated the impact of cover cropping at a landscape scale, he was quick to point out that; *'Patience and careful management in cover cropping is required! Benefits are not always immediate and there are challenges along*

the way.'

There are many risk factors within these systems which require careful management. Greenbridge pests and diseases, rotational conflict, weeds such as volunteer cover crops in following cash crop and destruction methods must be thought out.

Event feedback; 'Over the winter I have been to several conferences and talks but this event stood out as it was the best in terms of speakers, topics chosen, and practical demonstrations of what could be achieved. Excellent!'

Mike Hambly concluded this session; *'Like with anything, in farming, timeliness is everything'.*

Chris Baylis- LEAF demonstration farmer and head of farming for Sutton Settled Estates gave a farmer's view on the practicalities of cover cropping and direct drilling. In his system, there are 6 key aims; utilise cultural control of weeds, pests and diseases, maintain the soil nutrient balance, spread financial risk, increase biodiversity, maintain soil structure and spread workload to utilise on farm resources. It is worth noting that success isn't always what you see. This can be put into context with green area and rooting depth, although it is important to retain soil cover, we also want the underground benefits of cover cropping, so balancing starter fertilizer is crucial. Chris also commented that drainage must be managed, as there are challenges with cover cropping on heavy land.

Our final speaker, Professor Jonathan Leake discussed the importance of mycorrhizal fungi and what they can deliver. In 2 million hectares of wheat in the UK there is mycorrhizal hyphae that would stretch from the earth to the sun 26,000 times or over 500 times to Pluto! Cover cropping can be used as a nurse crop for mycorrhiza and its presence will encourage phosphorus capture and nutrient use efficiency. It will also contribute to improved soil structure and greater organic matter. However, it must be said that soil structure cannot be attributed to one sole component but a combination of management strategies.

A soils day wouldn't be complete without a farm tour, looking at the Allerton Project's research in action and of course, a look at some shiny kit. In the field discussions on future challenges facing soil management ensued. Conversation centred around soil management practices across the diverse soil types in the UK. Sited on the farmyard were examples of machinery and a quick drilling demo- this included Dale Drills, John Deere, Sumo, and Claydon, some of which are used by the Allerton project to direct drill seeds into the untilled land.

Changes to cultivation techniques can help to build a resilient soil, that can withstand more frequent and exceptional weather events such as flash flooding and drought. This will be vital as we go forward so that we can continue to farm our food efficiently while caring for the environment.

Phil Jarvis, Head of Farming at the Allerton project stated; *'I want to improve my soil health and profitability, but patience is key, there's no right or wrong, it's what fits with the system'.*

Dr Felicity Crotty pointed out the 3 types of earthworms found in UK soils, whilst Dr Alastair Leake compared soils

Event feedback; 'We thought we knew it all 15 years ago, now we know nothing as we open new horizons.'

from farm fields within 200 metres of each other, permanent pasture through to arable.

The day brought some insightful debate. These systems are not easy on heavy land but are important for the diversity across all farming systems. We must not ignore the massive impact the approaches discussed can help increase soil resilience. This can help reduce the £1.5 billion cost to the economy of soil degradation. The real question is how to reward farmers for delivering resilient soils, but establishment methods and success is measured by an individual farm basis, there is no one size fits all solution.

This event at the Allerton Project has shown how food production works in harmony, as well as enhancing the farmed environment. With a UK population of 60 million people, set to rise to 70 million in the next decade, food and farming needed to be at the heart of Government and that the A in Defra should once again stand for agriculture. Although we strive for farming to be profitable it is more than being a businessman, it's about being environmentally aware.

Future questions to consider;

- Are black oats better, in cover crops, than others?
- Were cover crops direct drilled? Soil disturbance stimulates biological activity including weed germination.
- Is there a role for grazing cover crops in arable systems?

13 Soil management in livestock supply chains, UK

13.1 Context

Outdoor pig production systems are increasingly popular in the UK. Outdoor pig enterprises can act as a "*break crop*" in arable rotations and, through their manure, can also provide savings in the use of inorganic fertilizers for the following arable crop. However, outdoor pig production is also often associated with significant environmental issues including soil erosion, nutrient loss and water pollution. The purpose of the CS is to find innovative management practices which will reduce the negative environmental impacts of outdoor pig production as part of arable crop rotations. The CS lead representing farmers is Fawley Farms; this business has 17 outdoor pig producers and has a working relationship with Dalehead BQP, the largest pig producer in the UK.

The key stakeholder organisations are:

- Suffolk Farming Wildlife Advisory Group.
- Kings Seeds.
- Fawley Farms.
- 12 outdoor pig producers/herdsmen.
- Dalehead BQP.

13.2 Dynamic Research Agenda

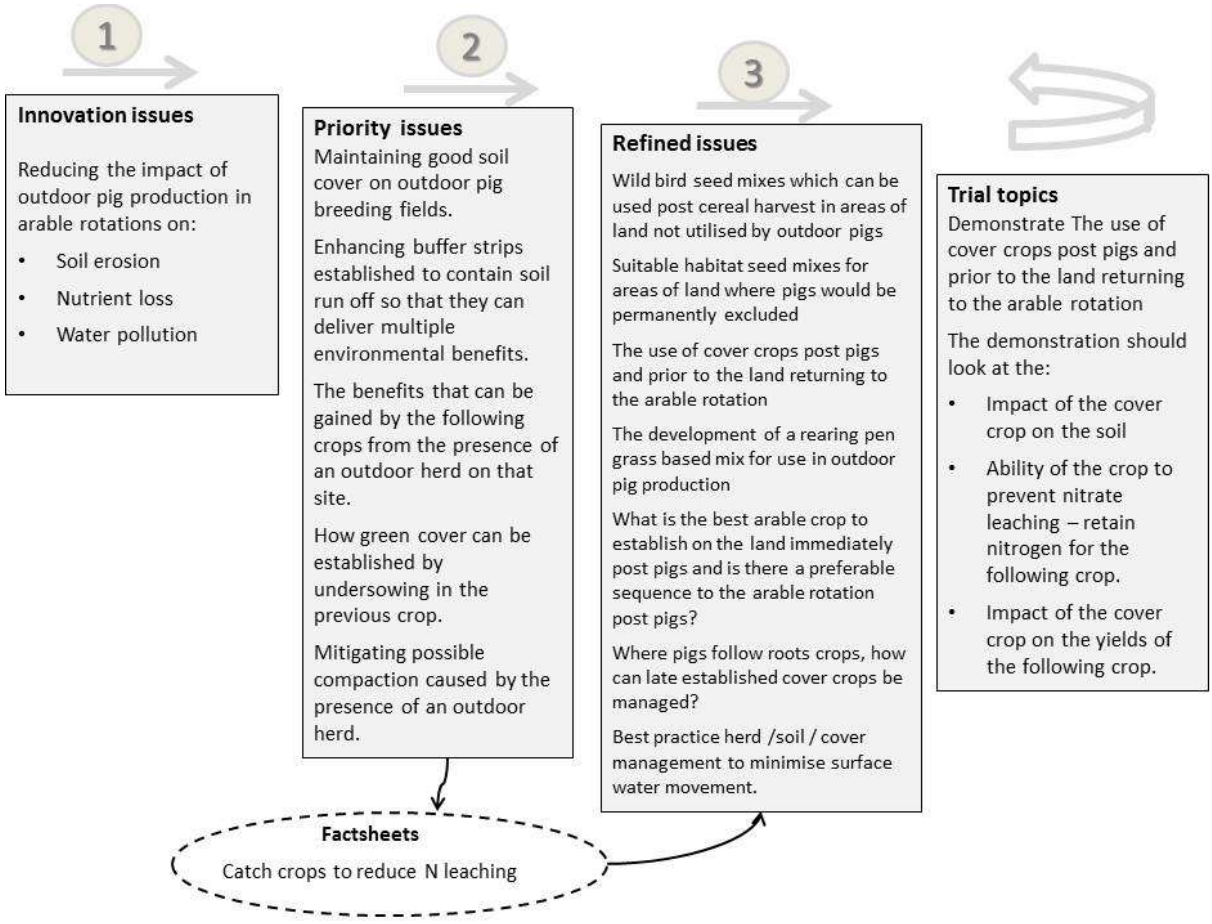
The stakeholders in this CS were particularly interested in reducing the environmental impacts of outdoor pig production within an arable crop rotation. In the first meeting the stakeholders identified three main environmental problems for which they were seeking innovative solutions:

1. Soil erosion.
2. Nutrient loss.
3. Water pollution.

The CSP facilitated a discussion which identified five priority issues that the stakeholders suggested would benefit from further investigation (See DRA in Figure 13.1). At the second meeting the CSP and stakeholders refined the priority issues into a more specific list of research questions, some of which were considered as potential field demonstration topics. After a further CSP facilitated discussion the stakeholders decided their favoured approach would be to identify a site where “The use of cover crops post pigs and prior to the land returning to the arable rotation” could be demonstrated. It was also agreed that the demonstration should look at the:

- Impact of the cover crop on the soil.
- Ability of the crop to prevent nitrate leaching – retain nitrogen for the following crop.
- Impact of the cover crop on the yields of the following crop.

Figure 13.1 Soil Management in Livestock Supply Chains Case Study Dynamic Research Agenda



The Thematic Experts produced a single factsheet for the CS on the use of catch crops to reduce nitrogen leaching. In this CS there was an interesting and dynamic interaction between the CSP and the stakeholders. During the second meeting when the innovation issues were refined the stakeholders expressed an interest in improving outdoor pig production sites from an environmental and wildlife perspective. This interest was not taken forward as a demonstration topic but it was developed across a significant supply chain as a separate project.

13.3 Factsheets on innovation

Valerie

Catch crops to reduce N leaching

What is it?

Catch crops are subsidiary crops included in crop rotation aiming at taking up available nitrogen (N) remained in the soil after the harvest of the main crop. They are able to decrease nitrate leaching from the cropping system (on average by 53% when a grass catch crop is used in the autumn-spring period). At the end of the growing period they can be left on surface or incorporated into the soil. In this fact sheet we consider also subsidiary crops that are harvested and have the same function of catching N.

Problems to be solved

Nitrate leaching losses can occur in croplands with a bare fallow in crop rotation, especially during the rainy and/or low evapotranspiration period with a high probability of drainage. In continental climates, these periods last from autumn to spring. Summer catch crop can be effective when they anticipate N uptake before the leaching period.

Positive side effects and different environment (they differ among catch crop species)

During growth:

1) They control soil erosion.
2) They limit early season weed seed germination.
3) They improve soil structure due to roots growing and organic matter addition derived from below biomass.

If incorporated in the soil as green manure:

4) They further improve soil structure due to organic matter addition derived from above ground biomass.
5) They make captured available N for the following main crop, thus reducing the need for mineral fertilizers.
6) They increase phosphorus and potassium uptake of the following crop.
7) They increase soil organic matter and soil organic N. This increase is correlated to the frequency of catch crops in crop rotation.
8) They supply N from N fixation if legume species are included(in mixture with grass or in pure stands).

Disadvantages

1) Nitrogen immobilization may occur if the incorporated biomass has a large C/N (>20). If soil mineral N is scarce, N immobilization can decrease the yield of the subsequent crop. One solution to this problem is to sow a cover crop mixture (grass with legume species) to reduce the C/N ratio and increase net N mineralization.

2) Eventual depressive effects may occur due to the release of natural herbicidal molecules into the soil (allelopathy). To avoid this problem, respect a delay between the incorporation of the catch crop and the sowing of the following main crop (especially for Brassica cover crops).

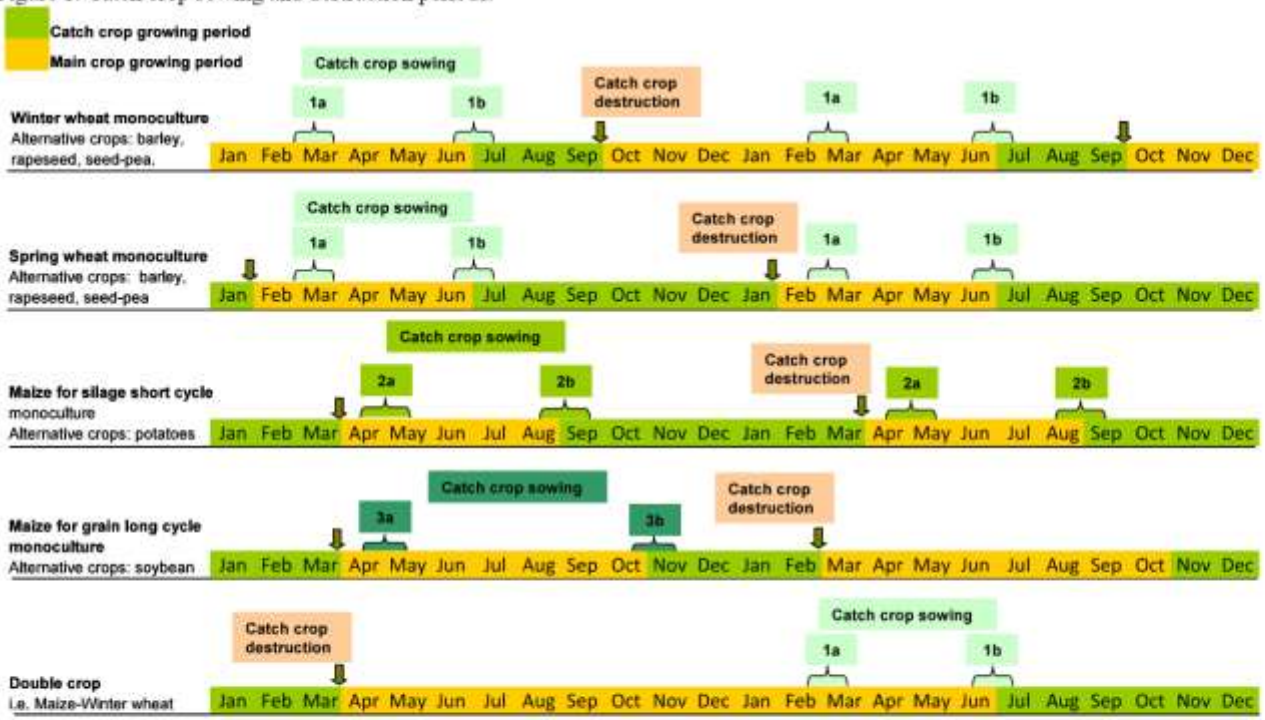
3) Irrigation eventually needed for summer catch crops.

How to manage catch crops

Position in crop rotation

Catch crop growing period depends on the crop rotation. Figure 1 reports five examples of introduction of catch crops in five different crop rotations. Different catch crop sowing periods are represented with different numbers and shade of green color.

Figure 1: Catch crop sowing and destruction periods.



Catch crops species and sowing suggested management.
Table 1 reports the different species that can be sown during the three different periods reported in figure 1.

Table 1: Suggested catch crop species for the different sowing periods.

Sowing period	Previous main crop	Species
1	Winter and spring cereals (i.e. wheat, barley) Winter and spring legumes (i.e. seed-pea) Rapeseed	*Lolium multiflorum* *Panicum miliaceum* *Panicum italicum* *Avena sativa* *Trifolium spp.* *Fagopyrum esculentum* Mixture
2	Summer crop short cycle (i.e. Maize silage, potatoes)	*Lolium perenne* *Lolium multiflorum* *Secale cereale* *Avena sativa* *Triticum aestivum* *Brassica napus* *Sinapis alba* Mixture
3	Summer crop long cycle (i.e. Maize for grain harvest, soybean)	*Lolium multiflorum* *Secale cereale* *Hordeum vulgare* *Avena sativa* *Brassica napus* *Vicia villosa* Mixture

Sowing management must be adapted to catch crop seeds characteristics and farm machines availability.

a) Seeding technique "a" in figure 1 (1a, 2a, 3a):

- Undersowing the catch crop on cereals or on maize in spring (broadcast seeding on the standing crop before harvest);
- Drill seeding into a growing cereal;

b) Seeding technique "b" in figure 1 (1b, 2b, 3b) for cereals:

- Drill seeding on the stubble;
- Broadcast seeding on stubble;
- Broadcast seeding after crop harvest, and seed bed preparation with disk harrowing and rolling;
- Broadcast seeding after crop harvest and seed bed preparation with ploughing and disk harrowing
- Precision seeding after ploughing and disk harrowing;
- Sod seeding into crop residues;

Seeding technique "b" in figure 1 (2b, 3b) for Cruciferous:

- Precision seeding after ploughing and disk harrowing.

In warm and dry environment, irrigation might be needed when catch crops seeded in early summer.

Biomass destruction management

Biomass catch crop destruction can be:

1. removed;
2. killed with herbicides spraying and left on soil surface or incorporated into the soil;
3. killed with flail mulcher and left on soil surface or incorporated into the soil.

Effects of catch crop management on N leaching:

Table 2 summarizes the efficiency of different kinds of catch crop species. It includes different types of soils and climatic conditions.

Table 2: Requirements, effects on N leaching and soil N availability, strengths of different species of catch crops and conditions and practices that discourage adoption. (Source: Justes et al., 2012)

Effects	Grass	Cruciferous	Legumes	Mixture
Requirements	Rather early seeding on soil frost-free or little frozen	Early seeding on soil frost-free according to species and temperature	Very early seeding on soil frost-free	Mixture must be adapted to the N availability
N leaching reduction (%)	30 to 80%	30 to 90%	0 to 40%	20 to 60%
N release for the succeeding main crop (%) (soil available N for main crop/N uptake of catch crop)	-20 to +10%	-10 to +30%	+10 to +50%	+10 to +40%
Strengths	Efficient in high N input cropping systems and in Atlantic climate	Highly efficient or efficient in high N input cropping systems and in Continental climate	Efficient in low N input cropping systems. Lower competition with main crop in undersowing	Intermediate efficiency due to species plasticity according to N availability
Conditions and practices that discourage adoption	Clay soil (late incorporation)	Clay soil if the cover crop is not sensitive to frost (late incorporation)	Intensive cropping systems with large manure or N inputs	Intensive cropping systems with large N inputs

Some experimental results are reported in figure 2. Although they are referred to specific pedo-climatic situations, the described effects can be considered meaningful in wider pedo-climatic environments.

Figure 2: Factors influencing efficiency of N leaching reduction for specific situations.

Best practices	Soil	Alternative management			Percentage of leaching reduction vs no catch crop
		Worse	vs	Better	
Biomass destruction	Sandy, Sandy loam	Lolium perenne, left on surface, minimum tillage or sod seeding	vs	Lolium perenne, incorporated with ploughing	0 20 40 60 80 100
	Sandy, Sandy loam	Lolium perenne, removed, sod seeding or minimum tillage	vs	Lolium perenne, incorporated with ploughing	0 20 40 60 80 100
Time of ploughing	Sandy, Sandy loam	Lolium perenne, autumn ploughing	vs	Lolium perenne, spring ploughing	0 20 40 60 80 100
Growing period	Silty soil	Avena sativa, from end of August to end of November	vs	Secale cereale, from beginning of October to end of April	0 20 40 60 80 100
Selected species	Sandy, Sandy loam, Silty clay loam or Clay loam	Vicia villosa	vs	Avena sativa	0 20 40 60 80 100
	Silty clay loam or Clay loam	Vicia villosa	vs	Hordeum vulgare	0 20 40 60 80 100
	Silty clay loam or Clay loam	Vicia villosa +Triticosecale	vs	Secale cereale / Triticosecale	0 20 40 60 80 100
	Silty soil	Vicia villosa	vs	Sinapis alba	0 20 40 60 80 100
	Silty soil	Vicia villosa	vs	Trifolium spp	0 20 40 60 80 100

Costs for catch crop

Costs for catch crop managements include seed purchase (table 3), sowing and destruction management (table 4).

Table 3: Seeds quantity, costs for kg and for hectare, VAT excluded, for some catch crops seeds in North-West Italy.

Cereals	Seeds kg/ha	Cost €/kg	Cost €/ha
Lolium perenne L. *Lolium multiflorum L.*	35-45	2.40	96.00
Panicum miliaceum L. *Panicum italicum L.*	10/15-40	1.08	28.40
Avena sativa L.	120-150		
Secale cereale L.	150-200	0.75	131.25
Triticum aestivum L.	200-250	0.62	139.50
Hordeum vulgare L.	200-250	0.68	153.00
Legumes			
Vicia villosa L.	200	1.20	240.00
Trifolium spp.	5-7	5.00-8.00	45.00
Cruciferous			
Brassica napus L.	10		
Brassica juncea L.	8-10	9.00	81.00
Sinapis alba L.	10		
Mixture			
Mixture (Sinapis alba L.+ Brassica juncea L.)	10	12.00	120.00

Table 4: Costs of some proposed management practices (VAT excluded) in North-West Italy.

Sowing	Operation	Cost €/ha
Broadcast seeding on stubble or on the standing crop before harvest	Broadcast fertilizer spreader	29
Broadcast seeding after crop harvest, and seed bed preparation with disk harrowing and rolling	Total	125
	Disking	77
	Rolling	18
	Broadcast fertilizer spreader	29
Broadcast seeding after crop harvest and seed bed preparation with ploughing and disk harrowing	Total	217
	Ploughing	110
	Disking	77
	Broadcast fertilizer spreader	29
Sod seeding into crop residues or into a growing cereal	Seed drill	100
Precision seeding after ploughing and disk harrowing	Total	235
	Ploughing	110
	Disking	77
	Classic seed drill	47
(Irrigation)*		
	Surface	7
	Sprinkler	35
Destruction of biomass	-	-
Left on soil surface	Herbicides spraying	39
	Flail mulcher	50
Removed	Harvester	160

Note:* €/ha for 30 mm supplied with only one application.

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http://luirig.altervista.org/flora/taxa/index1.php?scientific-name=panicum+miliaceum

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http://plants.usda.gov/java/coverCrops

13.4 Case Study Partner produced outputs

Technical Note: Cover Crops & Outdoor Pigs produced by South Wat Farming and Wildlife Advisory Group and Essex Water

Cover Crops & Outdoor Pigs

1. Key Points

1. Cover crop uptake of up to 70kgN/ha, potentially reducing nitrate leaching by a similar amount. This nitrogen is worth up to £30/ha
2. SMNs show very high autumn residuals of 200-300kgN/ha after pigs, which have the potential to leach during the winter. Spring SMNs remained high reflecting the dry and mild winter and offering scope for reduced N applications to the following crop
3. Cover crops reduced soil erosion potential and therefore also reduced chance of cross compliance failure

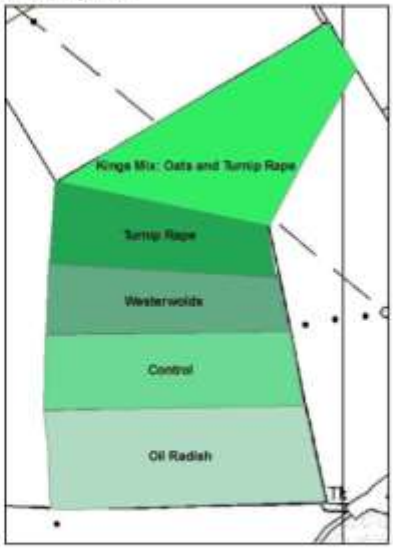
2. Background

Outdoor pig systems and arable farming both work well together, pig manure is rich in nitrogen (N), phosphorus (P) and potassium (K), leaving high residues in the soil, which can be available to the following arable crop. Outdoor pig production is well suited to sites where soil is free draining such as chalk and sand, however these soils are prone to leaching. Where high nutrient residues are left in the soil following outdoor pigs and where crop uptake is limited, these nutrients are vulnerable to leaching or runoff into watercourses and groundwater. Cover crops are able to utilise some of the residual N & P following outdoor pigs and provide winter cover to prevent nutrient losses via runoff and erosion. A recent demonstration trial at North Farm, Spetisbury, near Blandford in a sensitive nitrate area looks into how cover crops could be used after pigs to reduce nitrate leaching.

3. Field Information

Soil type:	Silty clay loam over chalk
Previous field management:	Harvest 2015: Winter wheat September 2015-September 2016: Outdoor farrowing pigs, housing: arcs with straw bedding
Cover crop establishment:	Drilled 21st September. No pre-cultivations, Seed box mounted on cultivator.
Cover crops plots:	Oil Radish Westerwolds Turnip Rape Kings Mix: Turnip Rape & Oats Control (bare soil)

Plot Layout:



4. Results and Discussion

4.1 SMN Results

The graph below displays the Soil Mineral Nitrogen (SMN) in the autumn and the spring. The autumn SMN shows how much residual Nitrogen there is left in the soil going into the winter and which has the potential to leach. As expected autumn SMN figures are higher than other autumn SMNs on similar soils over chalk. On average there was 298kgN/ha residual N in the autumn. Between plots, the values ranged from 222 - 339kgN/ha. This could be due to the variability of stocking in the field, eg: the time of year that pigs were put out to an area of the field, feeding and housing locations.

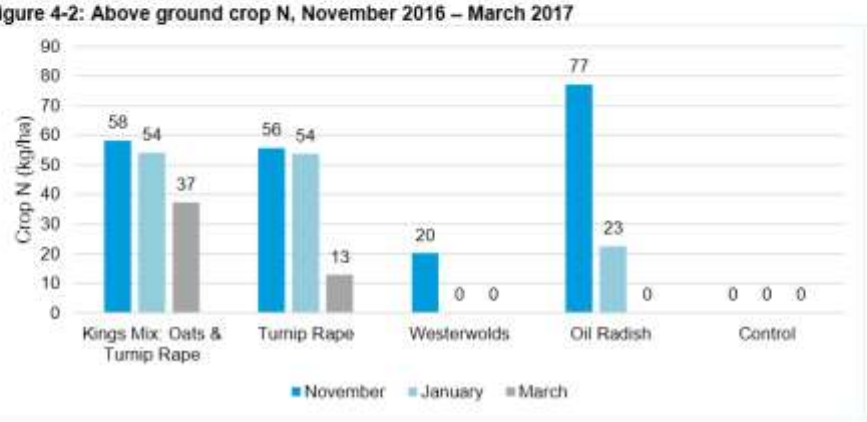
Figure 4-1: Autumn & Spring SMN (kgN/ha)

The spring SMN shows what N was left in the soil. The dry conditions over the winter meant leaching was lower than average across the whole region. Consequently, losses in the control plot were lower than expected. Had winter rainfall been higher it is certain that nitrate leaching would also be higher.

4.2 Crop Tissue

Crop tissue samples were also taken to measure N uptake in the crops. The brassica crops were highly responsive to the residual N, with significantly high crop N uptake, compared with other later drilled brassica cover crops. Mild conditions allowed the crops to continue to grow throughout the winter months. Up to 70kgN/ha may be in the crops before grazing by sheep in January. With current fertiliser prices it is expected that the value of the nitrogen in the cover crop is approximately £30/ha.

Figure 4-2: Above ground crop N, November 2016 – March 2017



4.3 Soil Nitrogen Supply

The table below summarises the SMN and crop tissue results, added together they produce a Soil Nitrogen Supply (SNS) index, which can be used to determine fertiliser recommendations. Where cover crops are incorporated it is expected that half the nitrogen released will be available to the following crop. With total nitrogen supplies over 120kgN/ha, there is scope to reduce spring N fertiliser significantly. AHDB recommend that where SNS exceeds 160kgN/ha, the crop should be treated as a 160kgN/ha crop.

Table 4-1: SNS Summary, Samples taken 13th March 2017

Plot/ Crop	SMN (kgN/ha) March 2017	Crop N (kgN/ha) Spring 2017*	Available Crop N	SNS (kgN/ha) **	SNS Index	RB209 recommendation for spring barley (kgN/ha) ***
Oil Radish	220	70	35	255	6	0
Control	224	0	0	224	5	0-30
Westerwolds	131	30	15	166	5	0-30
Turnip Rape	108	70	35	143	4	30
Kings Mix: Oats & Turnip Rape	126			161	5	0-30
Field Average	***162***	***70***	***35***	***197***	***5***	***0-30***

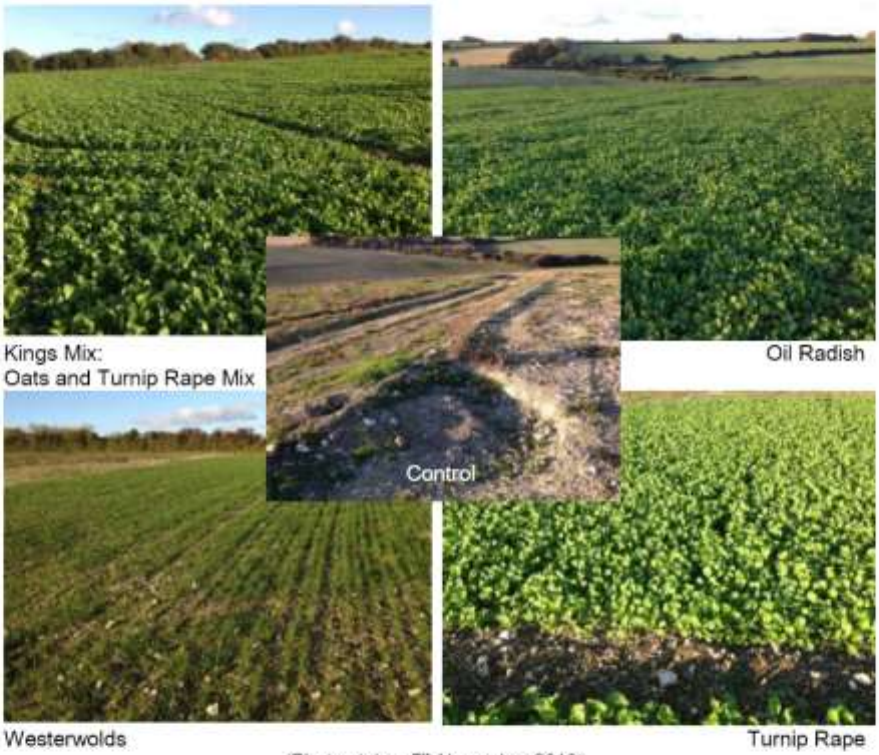
* for the purposes of these calculations crop N is estimated, as the data set is not truly representative for the crops, due to grazing and spraying off before sampling

** According to the method in RB209: SMN + Crop N + Estimate of additionally available N (assumed to be 0 for the purposes of these calculations)

*** RB209 recommendations for spring barley in kgN/ha on other mineral soils are- SNS 0: 160, SNS 1: 140, SNS 2: 110, SNS 3: 70, SNS 4: 30, SNS 5: 0-30 SNS 6: 0

4.4 Photos

The photos below also demonstrate how much green cover was present going into the winter compared to the control plot, which helps to mitigate against soil erosion and avoid cross compliance failure. Even the Westerwolds, where cover is less than the brassicas, the green cover is providing significant protection from erosion.



(Photos taken 7th November 2016)

5. Conclusions & recommendations for future work

SMN values alone do not provide enough evidence of how well cover crops reduce nitrate leaching. However, with crop N readings of up to 70kgN/ha in the autumn after a late drilling it is clear to see that the brassica cover crops are very responsive to the high N residuals after outdoor pigs. They also provided sufficient ground cover to reduce the risk of soil loss through erosion. SMN and crop tissue results alone are not enough to draw any sound conclusions. Further work would need to be carried out in the future, using other data collection methods such as porous pots and also increasing number of replicates and control plots over a number of winters to account for the varying winter weather conditions.

14 Annex 1: Full-factsheets

No.	Title of factsheet
1	Integrated management of Tobacco Rattle Virus (TRV) in potato production (1): General information
2	Integrated management of Tobacco Rattle Virus (TRV) in potato production (2): Control methods
3	Integrated management of Tobacco Rattle Virus (TRV) in potato production (3): Which cultivar to choose?
4	Allelopathy: a tool for an Integrated Weed Management. Application to resistant Black grass (Alopecurus myosuroides Huds.)
5	Application of wood ash fertilizer for enhanced forest growth
6	Recycling of wood ash as fertilizer
7	Methods to avoid weed reseeding
8	Catch crops to reduce N leaching
9	Chaff recovery
10	Combine inter-row hoeing and intra-row herbicide treatment on the same tool
11	Combine row crop sowing and herbicide band-spraying
12	Combination of rape and temporary plant cover
13	Improving “Superior Bread” and “Improver Wheat” quality through late mineral fertilization
14	Integrated Management of Botrytis pathogens causing neck rot in onion production
15	Irrigation scheduling with matric soil water potential sensors
16	Unmanned aerial vehicle for monitoring crop biomass
17	Low Volume spraying (LVS)
18	Matric soil water potential sensors for soil water status monitoring
19	How to set up a forest owner group
20	How to persuade the owners to set up a forest owners group
21	How to develop a joint Management Plan
22	Methods, approaches and mechanisms for valuing ecosystem services

15 Annex 2: Mini-factsheets

Key to Themes:

1. ROT: Crop rotation, soil cover management and integrated pest management.
2. ECO: Eco-system and social services in agriculture and forestry.
3. SOIL: Soil management as an integrated agro-ecological system.
4. WATER: Water management in agriculture and forestry.
5. CHAIN: Integrated supply chain services and tools, innovative farm management.
6. WASTE: Recycling and smart use of biomass and food waste, in particular waste generated during primary production.

Theme	Title
1. ROT	Alley cropping: field crops associated with woody crops
1. ROT	Application of air sampling in early plant disease detection
1. ROT	Applications of zeolites to crop protection
1. ROT	Autonomous robot for weed control
1. ROT	Biochar effects on plant health
1. ROT	Competitive cereals cultivars: part of an integrated weed management
1. ROT	Control of Scots pine blister rust (Cronartium flaccidum)
1. ROT	Early fruit-zone leaf removal in grape production
1. ROT	Flame weeding
1. ROT	Herbicide-tolerant varieties
1. ROT	Insect pest monitoring based on pheromone-baited traps
1. ROT	Integrated management of Potato early dying
1. ROT	Integrated pest management of the large pine weevil, Hylobius abietis, on Scots pine
1. ROT	Management of bacterial wilt in potato production
1. ROT	Management of Fusarium oxysporum cepae in onion production
1. ROT	Management of Sclerotium cepivorum in onion production
1. ROT	Management of the nematode Ditylenchus dipsaci in onion production
1. ROT	Mating disruption based on pheromone and semio-chemical use
1. ROT	Nozzles to reduce spray drift
1. ROT	Permanent grass cover in perennial crops to limit environmental impacts of pesticides
1. ROT	Pheromone-based 'lure and kill' technique in long-term pest management
1. ROT	Pheromone-based mass trapping of forest pests
1. ROT	Plant disease management by stimulating crop residue decomposition
1. ROT	Quantitative resistant cultivars
1. ROT	Remote monitoring of pheromone-baited traps
1. ROT	Rhizoctonia solani management in potato production
1. ROT	Role of chitosan-derived products in plant protection
1. ROT	Snail and slug integrated management
1. ROT	Soil solarisation: a non-chemical method to manage soilborne pests
1. ROT	Sprayer with recovering panels (tunnel sprayer)
1. ROT	Stale and false seedbed technique
1. ROT	Steam weed control
1. ROT	Tobacco Rattle Virus (TRV) management in potato production
1. ROT	Trap cropping in integrated insect pest management
1. ROT	Trap plants to control cyst nematodes
1. ROT	Use of Ampelomyces spp. against grapevine powdery mildew

1. ROT	Use of variety mixtures in disease management
1. ROT	Using of biofumigation in order to manage soil-borne pests
1. ROT	Vibration mating disruption
1. ROT	Weed harrowing in cereals
1. ROT	Weed management through annual field crops intercropping
2. ECO	Impact of wood ash fertilisation on carbon sequestration
2. ECO	Setting up a Forest Owners' Group
2. ECO	Valuation of forest ecosystem services
3. SOIL	Adaptation of conservation tillage to rice systems
3. SOIL	Aerial imagery to improve nitrogen fertilisation management
3. SOIL	Animal behaviour analysis using remote tracking (GPS and accelerometers)
3. SOIL	Application of anhydrous ammonia with nitrapyrin, a nitrification inhibitor
3. SOIL	Application of nitrogen fertilizers with 3,4 dimethylpyrazole phosphate (DMPP), a nitrification inhibitor
3. SOIL	Application of urea with urease (NBPT) and nitrification (DCD) inhibitors
3. SOIL	Bio strip till
3. SOIL	Biochar application to improve soil quality and fertility
3. SOIL	Biochar as a forest fertiliser
3. SOIL	Buffer strips to prevent soil erosion
3. SOIL	Catch crops to reduce nitrogen leaching
3. SOIL	Combined electric conductivity, organic matter and pH measurement for soil mapping
3. SOIL	Cover crops for livestock grazing
3. SOIL	Decision Support System (DSS) for manure management at a farm scale
3. SOIL	Decision Support System (DSS) for nitrogen management at a field scale in arable crops
3. SOIL	Direct sowing into living mulch/permanent cover
3. SOIL	Estimate of dry matter content of harvested crop
3. SOIL	Estimate the composition of animal manure
3. SOIL	Fertigation Decision Support System (DSS)
3. SOIL	Fertigation in apple orchards
3. SOIL	Fertigation using mineral or separated liquid manure in drip and sprinkler irrigation
3. SOIL	Forest machinery driving on unfrozen soft soils
3. SOIL	Formulations of phosphorus fertilisers to improve phosphorus availability in calcareous soils
3. SOIL	Grazing management for conservation and restoration of landscape heterogeneity
3. SOIL	Hand-held sensor to improve N fertilisation management
3. SOIL	High density apple orchards
3. SOIL	Improved fertiliser spreading techniques by Variable Rate Technology (VRT)
3. SOIL	Improving “Superior Bread” and “Improver Wheat” quality through late mineral fertilization
3. SOIL	Increase fertilization efficiency combining fertilizers and zeolite
3. SOIL	Intercropping of N fixing crops and other crops to improve N use efficiency
3. SOIL	Leaf color charts to determine nitrogen fertilizer needs of crops
3. SOIL	Manure solid-liquid separation equipments and techniques
3. SOIL	Minimizing water pollution through the use of P efficient crop plants
3. SOIL	Minimum tillage techniques
3. SOIL	Natural gamma-radiation measurement for soil properties determination
3. SOIL	No-till cultivation systems (sod seeding) to improve soil fertility

3. SOIL	Nutrient availability from polymer-coated controlled release fertilisers through analysis of kinetic of nutrient release
3. SOIL	On-farm composting techniques for organic fertiliser production
3. SOIL	Partially acidulated phosphate rock (low-cost partially soluble phosphorus)
3. SOIL	Polymer coated phosphorus fertilizers formulations
3. SOIL	Regional management of animal waste through exchange of animal manure to equilibrate soil fertility at a regional scale
3. SOIL	Satellite imagery to improve nitrogen fertilisation managements
3. SOIL	Sensors for monitoring nutrient status in the root zone
3. SOIL	Side dressing fertilization in band of maize with cattle or pig slurry
3. SOIL	Site-specific assessment of harvested product with yield sensors
3. SOIL	Site-specific variable-depth tillage
3. SOIL	Slow-release of boron through co-granulation with MAP
3. SOIL	Slurry injection
3. SOIL	Soil analysis with Near-Infrared Spectroscopy (NIRS)
3. SOIL	Soil Electrical Conductivity measurement as a precision farming tool
3. SOIL	Stocking-rates to comply with soil protection from erosion in grazing systems
3. SOIL	Termination of cover crops (timing, roller crimper, appropriate mixture choice, etc.)
3. SOIL	Ulexite and colemanite used as slow-release boron sources
3. SOIL	Use of biodegradable mulching
3. SOIL	Use of acidic additives to reduce phosphorus solubility & ammonia loss from manure
3. SOIL	Use of algae with biostimulating and activator functions
3. SOIL	Use of biostimulants to overcome stress situations
3. SOIL	Use of brash mats to prevent forest soil compaction
3. SOIL	Use of clay minerals coating (e.g. zeolite) to improve nitrogen and phosphorus fertilizer efficiency
3. SOIL	Use of DGPS-RTK to apply manure positioned in bands in maize
3. SOIL	Use of Light Detection And Ranging (LiDAR) to estimate herbaceous crop biomass
3. SOIL	Use of microbial community plant interaction to restore agroecosystem functions
3. SOIL	Use of mulching with recycled paper
3. SOIL	Use of mycorrhizal fungal plant interaction to restore ecosystem functions
3. SOIL	Use of nanoparticles fertilizers to stimulate growth and yield of plants
3. SOIL	Use of zeolite to improve soil fertility
3. SOIL	Vertical tillage
3. SOIL	Visual evaluation of soil structure
4. WATER	A new farm equipment to install and retrieve surface drip irrigation laterals
4. WATER	Aerated wastewater irrigation reservoirs/lagoons
4. WATER	Automation of pressurized irrigation systems based on soil water status sensors
4. WATER	Best farm practices to protect water bodies from agricultural pollution
4. WATER	Best practices for land drainage design, realization and management
4. WATER	Best practices for the realization and management of farm ponds for irrigation use
4. WATER	Best practices to reduce evaporation from on-farm water reservoirs
4. WATER	Biodegradable drip irrigation tapes
4. WATER	Bio-drainage for reclamation of salt-affected waterlogged areas
4. WATER	Constructed wetland for the treatment of agriculture wastewater
4. WATER	Control wind sensors to drive sprinkler irrigation
4. WATER	Crop and soil sensor data fusion to delineate homogeneous management zones
4. WATER	Decision support models to optimize the cropping-plan decision in irrigated farms

4. WATER	Deficit irrigation to reduce irrigation water consumption
4. WATER	Delineation of homogeneous management zones through electromagnetic sensors
4. WATER	Drip irrigation system in paddy crop
4. WATER	Farm rainwater roof harvesting systems for irrigation use
4. WATER	Floating treatment wetlands for the treatment of agriculture wastewater
4. WATER	Furrow diking to increase soil water infiltration
4. WATER	Gravel-mole drainage systems
4. WATER	Ground Penetrating Radar (GPR) to detect soil water content
4. WATER	Hydropowered pumping systems to reduce irrigation energy costs
4. WATER	Integration of fish and shrimp farming into harvestable crops and irrigation networks
4. WATER	Irrigation scheduling based on ground-based infrared thermometry
4. WATER	Irrigation scheduling based on matric soil water potential devices
4. WATER	Irrigation scheduling based on soil water content sensors
4. WATER	Irrigation scheduling based on the FAO soil water balance approach
4. WATER	Matric soil water potential devices for monitoring soil water status
4. WATER	Mole drainage systems
4. WATER	Olive mill wastewater reuse in irrigation
4. WATER	On-farm automation of gate structures in surface irrigation systems
4. WATER	On-farm compact wastewater treatment systems
4. WATER	On-farm hydropower generation
4. WATER	Partial root zone drying to reduce irrigation water consumption
4. WATER	Photovoltaic pumping systems to reduce irrigation energy costs
4. WATER	Reverse-osmosis water desalination for use in agriculture
4. WATER	Sensor data fusion (optical and electromagnetic) for measuring soil properties
4. WATER	Soil and crop management to decrease irrigation water consumption
4. WATER	Soil management practices to increase soil water holding capacity, decrease soil evaporation and improve soil infiltration
4. WATER	Sprinkler rainguns with integrated wind sensors
4. WATER	Sub-surface drip irrigation to reduce irrigation water losses
4. WATER	Ultrasonic insect and animal repellents to protect drip tape
4. WATER	Ultrasound wastewater treatment technique for reuse in agriculture
4. WATER	Ultraviolet wastewater treatment technique for reuse in agriculture
4. WATER	Use of biodegradable mulches (biopolymers) to decrease soil evaporation
4. WATER	Use of sensors to monitor the water table depth
4. WATER	Using flow rate sensors to detect breaks in irrigation systems
4. WATER	Using UAV thermal imagery to assess crop water status
4. WATER	Variable Frequency Drive pumps to ensure optimum energy consumption in pressurized irrigation systems
4. WATER	Variable rate sprinkler irrigation technologies: individually controlled sprinklers (center pivot and rainger)
4. WATER	Volumetric soil water content sensors for monitoring soil water status
4. WATER	Wastewater reuse in short rotation plantation
4. WATER	Water control structures to manage timing and amount of water leaving the drained fields
4. WATER	Water table control to optimize irrigation water management
4. WATER	Wireless Sensor Networks (WSNs) to monitor irrigation management variables
5. CHAIN	Adaptive forest management to reduce storm risk
5. CHAIN	Advanced Forest Fire Fighting

5. CHAIN	Bricks made from wood ash
5. CHAIN	Buffer strips as a bioenergy source
5. CHAIN	Cascade use of wood biomass
5. CHAIN	Certification of non-wood forest products
5. CHAIN	Commercial potential of non-wood forest products
5. CHAIN	Decision Support Systems and tools to optimize the provision of forest goods and services.
5. CHAIN	Decision Support Systems to optimize forest management
5. CHAIN	Decision Support Systems to optimize provision of non-wood forest products
5. CHAIN	Decision support tools for Forest Risk Management
5. CHAIN	Evaluating the commercial potential of wild edible fungi
5. CHAIN	Forest management to adapt to climate change impact
5. CHAIN	Forest management to combine wood production and nature conservation ("integrative management")
5. CHAIN	Fruit harvesting robots
5. CHAIN	Grazing management to reduce forest fires risk
5. CHAIN	Harvesting on steep slopes
5. CHAIN	Improved methods for branding agroforestry-derived products
5. CHAIN	Methods for assessing the net wood volume in wood stacks
5. CHAIN	Multi tree harvester head in geometric thinning for precommercial and (early) thinnings
5. CHAIN	Optimization of perennial grasses for biomass production
5. CHAIN	Optimized forest biomass supply chain management
5. CHAIN	Precise calcium nutrition as part of the potato quality management
5. CHAIN	Reduce fire risk through improved forest management
5. CHAIN	Short rotation coppice (SRC) integrated in an alley cropping systems as a source of woody biomass
5. CHAIN	Sustainable innovative mobilisation of wood
5. CHAIN	The impact of wood ash fertilisation on berries and mushrooms
5. CHAIN	The role of appropriately arranged trees in reducing nitrate leaching and soil runoff and associated phosphorus loss
5. CHAIN	The use of intercrops in agroforestry to encourage pollinators and prevent soil erosion
5. CHAIN	The use of trees to enhance animal welfare in poultry systems
5. CHAIN	The use of trees to increase biodiversity in arable cropping systems
5. CHAIN	Tools to adapt forests to climate change
5. CHAIN	Use of LIDAR to improve forest management
5. CHAIN	Use of LIDAR to reduce inventory costs
5. CHAIN	Use of Light Detection And Ranging (LiDAR) remote sensing to measure aboveground biomass in tree biomes
6. WASTE	Ammonia stripping from manure
6. WASTE	Anaerobic digestion in a small scale digester
6. WASTE	Application of wood ash fertilizer for enhanced forest growth
6. WASTE	Biogas from solid biomass
6. WASTE	Bio-oil production from forest biomass
6. WASTE	Co-digestion of agricultural wastes
6. WASTE	Combination of anaerobic digestion and struvite precipitation to produce biogas and fertilizer products from pig manure
6. WASTE	Combined use of ultrafiltration and reverse osmosis to concentrate liquid manure
6. WASTE	Compost from hair residue from slaughterhouses
6. WASTE	Digestate from olive mill effluent as nutrient source

6. WASTE	Estimate biogas production from agricultural biomass
6. WASTE	Ethanol production from ligno-cellulosic biomass
6. WASTE	Fractionation of olive mill wastes
6. WASTE	Improve forest planting success
6. WASTE	Micro scale digestion for production of biogas
6. WASTE	Mobile pyrolysis plant for forest residues
6. WASTE	Nutrients recovered from wastewater treatment
6. WASTE	Pelletised dried manure
6. WASTE	Phosphorus recovery from agricultural residues
6. WASTE	Processing manure to increase the use efficiency of nutrients
6. WASTE	Producing pest- and pathogen free compost with disease suppressing activity from plant based waste
6. WASTE	Recycling nutrients from sewage sludge
6. WASTE	Recycling of wood ash as fertilizer
6. WASTE	Reduction of the content of toxic organic compounds in sewage sludge
6. WASTE	Safe application of waste water and sewage sludge in short rotation plantations for wood production
6. WASTE	Slurry tank coverage
6. WASTE	Treatment of organic waste to improve soil quality
6. WASTE	Use of agricultural residues as mycelium growing substrate
6. WASTE	Use of crop residues in anaerobic digestion
6. WASTE	Use of wood ash in a short rotation coppice
6. WASTE	Valorisation of food waste by transformation into animal feed at low cost and low energy input
6. WASTE	Wastewater treatment for irrigation and fertigation
6. WASTE	Whey as layer and broiler feed