EIP-AGRI Focus Group

IPM practices for soil-borne diseases

STARTING PAPER

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What is an EIP-AGRI Focus Group?

A focus group forms part of the networking functions of the European Innovation Partnership "Agricultural Productivity and sustainability" (EIP AGRI). This new instrument under the Regulation (EU) No 1305/2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) aims at building bridges between science and practice to find innovative solutions to the challenges rural areas face today.

In this context a focus group is a temporary group of selected experts focusing in a given timeframe on a specific subject which is creating a forum for sharing knowledge and experience on that subject in order to develop concrete recommendations to tackle a certain issue. The group discusses and documents best practices and research results, exploring practical innovative solutions to the problems or opportunities in the field that were listed, and drawing on experience derived from related useful projects. The focus groups catalyse sharing and exchange among actors involved (researchers, farmers, advisers etc.). It then identifies research needs and develops ideas for innovative projects of so-called operational groups (in future, please see the database of operational groups).
These projects may be related to production, processing, consumption, transport, to mention some but not all issues.

The focus group results are to be disseminated by various means and may have implications for possible further directions for research that may help to solve practical problems in the sector.
The tangible output of the work of the focus group is contained in its final report which is to be published after the second – and final – meeting of the focus group.
An EIP-AGRI Focus Group is moderated by DG AGRI and several (usually two or three) experts of the EIP-AGRI Service Point
The output of every EIP-AGRI Focus Group is published on the dedicated website.

Objectives of an EIP-AGRI Focus Group

1. To take stock of the state of the art of practice in the field of the EIP-AGRI Focus Group activity, listing problems and opportunities.
2. To take stock of the state of the art of research in this field, summarizing possible solutions to the problems listed.
3. To identify needs from practice and propose directions for further research.
4. To propose priorities for innovative actions by suggesting potential practical operational groups or other project formats to test solutions and opportunities, including ways to disseminate the practical knowledge gathered.

The output of the focus group will feed into the EIP network which will share the knowledge and practical experience with the wider public.

Introduction on the Focus Group soil-borne diseases

This starting paper will be used at the first meeting of the EIP Focus Group on IPM practices for soil-borne diseases to be held 2 and 3 December 2014, Alicante Spain. It gives a first introduction and overview of the topic and is in this stage therefore preliminary and does not have the pretention to be complete. In the second half of 2015 the focus group will deliver a full report and fulfil the assignment to answer the following question:

How to suppress soil-borne diseases (fungi and nematodes) in vegetable and arable crops and how to enhance cross-fertilisation between different crops and agricultural systems?

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Motivation of the initiative

Soil-borne diseases are major yield-limiting factors and difficult to control. However, applied knowledge on how to use suppression techniques seems to be limited. This focus group will bring together current knowledge of innovative techniques about soil-borne disease (fungi and nematodes) suppression and aims at practical ways to implement related research results while looking at cross-fertilisation of such methods between different vegetables and arable crops and farming systems (open field – greenhouses).

Methyl bromide was one of the most widely used pesticides to control soil-borne diseases. Because of the ozone depleting characteristics of this chemical it was decided to phase it out in 2010 in the developed countries and in 2015 all over the world *(Anonymous, 2009)*. The phase out of MB has been very successful as shown in Figure 1 from the United Nations Environment Programme (UNEP) (Norman, 2008 #24). Also other soil desinfestants like Dichloropropene and Methylisothiocyanate are no longer allowed in more and more European countries. This enhances the need for sustainable and economic alternatives.
It is difficult to collect objective information on the economic impact of soil-borne diseases and the effects of the withdrawal of methyl bromide. One of the tasks of this focus group is the identification of the relevant soil-borne diseases. An estimation of the economic impact will be part of that task.

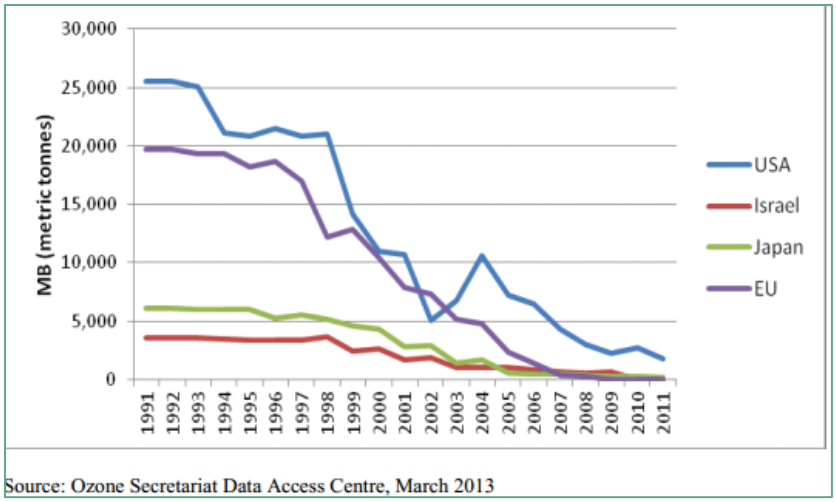

Figure 1. The phase out of MB has been very successful as shown in this figure from the UNEP {Norman, 2008 #24}

Tasks

The Focus Group has the following main tasks:

- Identify the main soil-borne diseases relevant in the EU.
- Identify the key elements that cause such soil-borne diseases and examine how they interact;
  - Identify, assess and compare different IPM systems and techniques (Physical, chemical, biological and other) that suppress soil-borne diseases taking into account the cost-effectiveness in the different systems and crops and explore cross-fertilisation between different crops and agricultural systems
  - Explore strategies for a targeted breeding of cultivars that are more resistant to soil-borne diseases;
  - Identify and compare alternative techniques for soil fumigation that are ready to apply or easily applicable in short term by the farmers, in the framework of the prohibition of the use of methyl bromide;
  - Identify and compare according to the respective arable crop alternative soil-borne disease suppression techniques that are ready to apply or easily applicable in short term by the farmers;
  - Identify farm practices that reduce the pressure of soil-borne diseases;
  - Identify fail factors that limit the use of the identified techniques/systems by farmers and summarise how to address these factors and explore the role of innovation and knowledge transfer in addressing these fail factors.

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How to proceed

In this starting paper the state of the art is given from the perspective of the coordinating expert (Leendert Molendijk) based on a first literature search and personal experience. Based on the inputs of the members of the Focus group, a final report will be written with a complete overview of the state of art and recommendations how to proceed. A first start will be made by an inventory among the experts from which the results will be discussed together with this starting paper at the meeting 2,3 December. As a result of this first meeting, choices will be made on crop/disease combinations and techniques which need more profound exploration by subgroups. In that context, members may volunteer or may be requested to draft "mini-papers" after the first focus group meeting. These documents will provide a deeper analysis of a specific issue (going beyond what had been set out in the discussion paper) but more importantly, they will provide a list of solutions as well as recommendations for further development.
After the second and last meeting of the focus group, the final outcome report should pay particular attention to formulating specific issues that could be taken up by operational groups. It also summarises the gathered knowledge and best practices and lists its sources - lessons learnt, further recommendations, ideas for dissemination etc.

Inventory of the most important soil disease crop combinations

The first step in the inventory of the most important soil disease crop combinations will be by doing an inquiry to all focus group members.

European crops to be evaluated

To make a first selection of crops FAOSTAT has been used to look for the acreage of the crops in the regions of the European union. A second approach is to use the financial importance of a crop as a selection criterion. When crops are selected on their yearly turnover the list is slightly different, see Table 1.

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Table 1. Acreage and turnover of crops in the regions of the European Union (FAOSTAT).

	Crop	Turnover 2004-2006 k$	Crop	Area (hectare)
1	Wheat	17.447.790	Wheat	54.246.541
2	Grapes	13.504.519	Oilcrops Primary	33.929.940
3	Potatoes	12.406.435	Pumpkins for Fodder	29.181.000
4	Tomatoes	7.592.171	Barley	24.379.286
5	Olives	7.476.558	Maize	18.335.325
6	Sugar beet	7.407.782	Sunflower seed	16.027.859
7	Sunflower seed	6.098.928	Rapeseed	8.236.721
8	Apples	6.031.003	Fruit excl Melons,Total	7.360.310
9	Rapeseed	5.285.341	Oats	6.092.694
10	Maize	3.613.275	Potatoes	5.981.823
11	Barley	2.765.309	Olives	4.925.495
12	Vegetables, fresh	2.065.673	Rye	4.543.967
13	Onions, dry	2.053.254	Vegetables&Melons	4.117.619
14	Carrots and turnips	1.937.718	Pulses,Total	3.744.163
15	Peaches and nectarines	1.848.093	Grapes	3.570.708
16	Strawberries	1.787.469	Soybeans	3.446.955
17	Chillies and peppers, green	1.332.067	Sugar beet	3.426.188
18	Plums and sloes	1.298.463	Triticale	3.199.360
19	Lettuce and chicory	1.292.500	Peas, dry	1.968.290
20	Rice, paddy	1.157.917	Apples	1.050.495
21	Cabbages and other brassicas	1.157.691	Treenuts,Total	984.583
22	Oranges	1.101.420	Rice, paddy	688.660
23	Cucumbers and gherkins	1.090.025	Pulses, nes	688.436
24	Pears	1.045.284	Citrus Fruit,Total	541.817
25	Cherries	937.990	Vegetables and roots fodder	512.640
26	Raspberries	878.084	Plums and sloes	511.467
27	Rye	861.377	Tomatoes	506.583
28	Soybeans	854.849	Linseed	485.912
29	Leeks, other alliaceous vegetables	771.615	Cabbages and other brassicas	413.175
30	Tangerines, mandarins, clementines, satsumas	709.971	Onions, dry	384.653

First priority list of the soil-borne diseases of the European crops based on acreage and turnover

Soil-borne pests and diseases are caused by fungi, nematodes, bacteria and viruses. The last mostly transmitted by nematodes or fungi. Fungi, nematodes and viruses transmitted by nematodes seem to have the largest incidence and impact on agricultural crops. Emphasis therefore will be placed on these organisms.

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A preliminary list of soil-borne diseases that will be studied in the Focus group is given in Table 2.

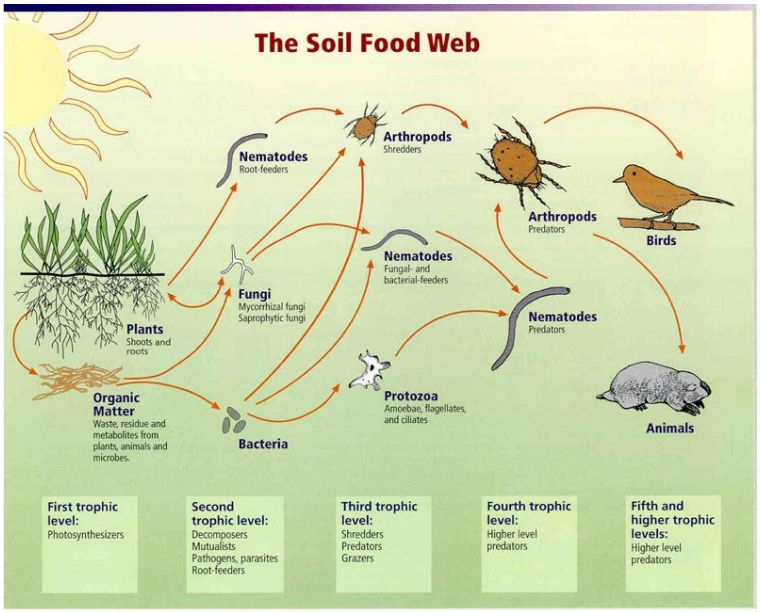
Table 2. A preliminary list of soil-borne diseases that will be discussed in the focus group

	Fungi	Nematodes
1	*Verticillium dahliae*	*Meloidogyne sp*
2	*Gaeumannomyces graminis*	*Pratylenchus penetrans*
3	*Rhizoctonia solani*	*Xiphinema index*
4	*Fusarium spp*	*Globodera sp.*
5	*Pythium spp.*	*Heterodera spp.*
6	*Phytophthora cactorum*	*Ditylenchus dipsaci*
7	*Sclerotinia sclerotiorum*	*Trichodorids and Paratrichodorids*
8	*Sclerotinia cepivorum*	
9	*Plasmodiaphora brassicae*	
10	*Synchytrium endobioticum*	

This selection of crops and diseases is preliminary. Also other criteria are important, e.g. crops-disease combinations where adequate control measures have been developed which can be used as a model for other crops, diseases or agricultural systems. Cross-fertilisation is an important goal of this focus group. This list will be adapted on the basis of the inquiry and priorities can be made during the focus group.

Key elements that cause soil-borne diseases and how they interact

Soil is not just a stacking of mineral parts more or less mixed with organic material. A soil is full of life and a complete ecosystem (see Figure 2. The soil food web. Species that cause soil-borne diseases are just a minority in the whole ecosystem. The presence of these organisms does not automatically lead to crop damage.



Relationships between soil food web, plants, organic matter, and birds and mammals
Image courtesy of USDA Natural Resources Conservation Service
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_food_web.html.

Figure 2. The soil food web

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Soil-borne diseases are a part of soil biology and as such a part of soil quality as a whole. Whether damage is caused depends on the amount of disease present, abiotic soil conditions (humidity, pH, Oxygen, nutrients etc.) the tolerance of the plant and climatic conditions. Everything that improves the vigour of the plant will increase the tolerance to damage. The amount of disease depends much on crop rotation (sequence of the crops). Frequency of growing crops determines the amount of disease especially in the case of specialised organisms with small host ranges (e.g. Potato Cyst Nematodes only propagating on Solanaceae). With polyphagous organisms (e.g. wilting disease, Verticillium dahliae) it is not frequency dependent but the sequence of crops and the number of hosts within the rotation that are decisive elements. To develop a soil health strategy, thorough knowledge on biology and the epidemiology of the diseases is a prerequisite (see Figure 3).

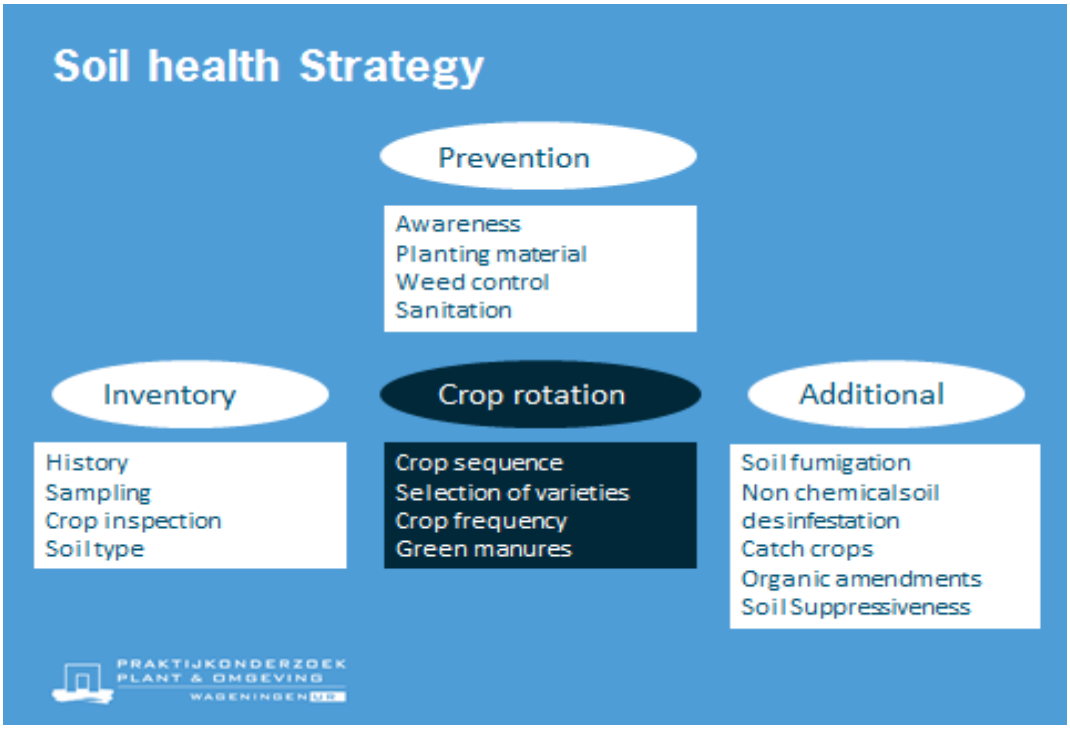

Figure 3. Soil health strategy.

Prevention
Awareness of all participants within the production chain is an important factor. All players within the chain around a crop/field can support to prevent diseases spreading within fields, between farms and over regions/countries. Many soil-borne diseases are spread with seed and planting material. Sanitation and control of propagating material is a first step. Machinery hygiene, cleaning of casks and storages can take away a first contamination. Weeds are hosts of al kind of organisms. Weed control is there for a prevention measure.

Inventory
Based on the epidemiology and biology, a disease risk assessment can be made whether a field is susceptible for introduction (soil type, pH, climatic conditions to survive adverse periods). At harvest products can be checked for symptoms (full field bio assay). Soil sampling can be done to detect pests and diseases in an early stage or to measure the infestation level to estimate crop damage and the economic feasibility of control measures.
Once a field is infested it is impossible to eradicate it and to reach a zero infestation level again. Management can only force infestation levels below damage or detection thresholds by taking the necessary control measures.

Crop rotation
Rotation is an important tool but not the ultimate solution. In the case of polyphagous organisms the sequence is far more important than the cropping frequency. Also the timing of sowing and planting of a crop is part of the rotation planning. Much attention is necessary for the period that the cash crops are not on the

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field. Weed control in the fallow period or the choice of a convenient green manure crop are important elements within the strategy. In some cases resistant varieties are available. In many cases these resistant varieties are partial resistant, this is propagating less than a susceptible one. These partial resistant varieties can be very useful provided that the level of resistance is known.

Additional measures (control measures)
This pillar in the strategy is the safety net but not the starting point. Additional measures are necessary when there are no feasible options within the rotation.

Feasibility of an integral approach

The question has to be raised whether an integral approach can be implemented successfully in most disease crop combinations. Important differences can be expected between arable and vegetable crops in open field systems compared to greenhouses. The level of specialisation of farms with only one or just a small number of crops is a complicating factor. Solutions found in these highly specialized and capital intensive systems will be very helpful for outdoor or less intensive systems. Exchange of knowledge and experience between sectors, countries and cropping systems is of big value and therefor an important topic in the focus group.

Measures generally applied at farm level

The use of certified seed and planting material is a common rule within the European Union. Farm saved seed can be considered as a weakness within the system.
In most cropping systems growers are aware of the importance of crop rotation. Lack of knowledge on host status, epidemiology and damage threshold levels for many soil-borne diseases hamper the effective use of this tool. The small array of profitable crops is another reason that crops are grown in a too high frequency or in a suboptimal sequence. With exception of the Scandinavian countries and Germany most country use(d) fumigants and granular nematicides to control soil-borne diseases. In many cases the use is pre-emptive and not based on decision rules. In Table 3 a first list of active ingredients used in the recent past or still used at the moment. In ***bolditalic*** recent developments are given. The phase-out of methyl bromide as raised the interest of crop protection industries to find new molecules and to develop new products. The first results are entering the market. First admissions are realized in the USA and industry is now in the registration process in Europe.

Table 3. A first list of active ingredients against soil-borne diseases (Labrada, 2008)

	Fumigants	Non fumigants
1	methyl bromide	aldicarb
2	methyl iodide	ethoprofos
3	1-3 dichloropropene	fosthiazate
4	chloropicrine	oxamyl
5	metam sodium	abamectin
6	metam potassium	
7	dazomet	***fluensulfone***
8		***fluopyram***
9	***dimethyl disulfide***	
10	***Iodomethane***	

In Table 4 a first array of non-chemical control measures is given. In ***bolditalic*** recent developments.

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Table 4. A first list of non-chemical measures against soil-borne diseases. (Minuto et al., 2000), Runia, 2004), (Blok et al., 2000), (Siddiqui et al., 2009)

	non-chemical
1	steaming
2	solarization
3	anaerobic soil disinfestation (ASD)
4	inundation
5	biofumigation
6	resistant varieties of culture crops
7	resistant varieties of green manure crops
8	catch crops
9	culture cooking for planting material
10	Enhancement of soil suppressiveness
11	***controlled atmosphere treatment for planting material (CATT)***
12	***cultivit hot air treatment***
13	***Bacillus firmus***
14	***Paecilomyces lilacinus***
15	***Pochonia chlamydosporia***
16	***Pasteuria penetrans***

The first ten non chemical measures are used on different scales in different niches of European agriculture (Martin, 2003). None of them are used on a comparable scale like chemical soil disinfestation. The efficacy of these techniques depends a lot on the target organisms, climatic circumstances and the economic possibilities of the crops. Some of them have the opportunity to be developed to broader applications but seldom to a general control method. It will be tailor made applications. Purpose of the focus group is to describe these tailor made solutions, to identify bottlenecks, to define actions and solutions to overcome these bottlenecks and to define actions to improve implementation in practice.

New developments both in research and practice

On a relative small scale breeders are working on resistant varieties or resistant rootstock (Giannakou Karpouzas, 2003). The focus group will make an inventory onthese programs and the expected developments. In the Netherlands steaming (Runia, 2000) and inundation (Muller, 1989) are traditional methods which were modernized and implemented on a larger scale. Also anaerobic soil disinfestation is moving from the research table to practice encountering all the hurdles that have to be taken (Butler *et al.*, 2014). Biofumigation showed promising results in basic research (Kirkegaard Sarwar, 1998), (Lazzeri Manici, 2000). In practice positive results are reported but it seems this is based on general positive effects of green manure crops and not on the efficacy of disease control (Vervoort et al., 2014).

Decision support systems

Tailor made solutions need a lot of specific data and knowledge to make the right decisions on management of soil health on field level. On many farms many of these data are gathered but not available or used at the moment of decision making. For nematodes a systematic approach has been developed based on the first nematode crop schedules and the strategies from the pre-chemical era (Hijink Oostenbrink, 1968). In the nineties this ideas were further developed (Molendijk Mulder, 1996) and resulted in a qualitative tool on internet www.aaltjesschema.nl (Dutch) which helps farmers to choose the crop sequence within the rotation. Specific for potatoes a quantitative system is available which is used by advisers (Been *et al.*, 2007) (**www.nemadecide.com**). Based on population dynamical models combined with yield damage models the efficacy of control measures can be calculated and scenario comparison helps the farmer/advisor to take the

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economic most profitable decisions. Also to control Sclerotinia an initiative to use a DSS has been taken (Jörg *et al.*, 2006). The focus group will gather information on DSS systems used in the member states and can propose further orientations and developments needed to support implementation in practice.

Fail factors

A first list of fail factors is given in this short overview:

- Too high frequency of profitable crops because of economic reasons
- Lack of awareness and knowledge
  Many soilborne diseases do not show very specific, striking symptoms. Detection is often in a late stage when the area of the infestation has grown out of hand. In many countries there are no routine laboratories where growers can send their soil samples, to check them on soil-borne diseases.
- Up scaling of agriculture. Because of economy and mechanisation the acreage operated by one grower is increasing strongly. The challenge is to intensify the attention per m^2. Technical tools like Geographic Information Systems (GIS) and data exchange via web services could be of help.
- Often the larger acreage is no property but temporarily rented. The incentives to care for the soil in a sustainable way are not present on these 'foreign' soils.
- Brain drain of knowledge
  In many countries there is a lack of education in phytopathology. Less and less people have the skills to work on the topic both, in extension and science
- Free trade of planting material and farm saved seed are accelerating the spread of diseases within and between countries. Certified seed is of help but not good enough from a technical point of view.
- Withdrawal of pesticides. Often with quite a broad working spectrum, are less and less allowed. Instead of a general and quite easy solution for nematodes by applying a nematicide a whole range of detailed and tailor made solutions has to be brought into 'battle'. This is far more complicated and knowledge intensive.

The EIP focus group will evaluate the fail factors in different cropping systems and search for possibilities to overcome these, learning form the different solutions found in different cropping systems. Solutions will always be considered in the total concept of soil management, realizing that the overall yield and quality is a combination of the physical, chemical and biological processes within the growing medium of the plant (see Figure 4).

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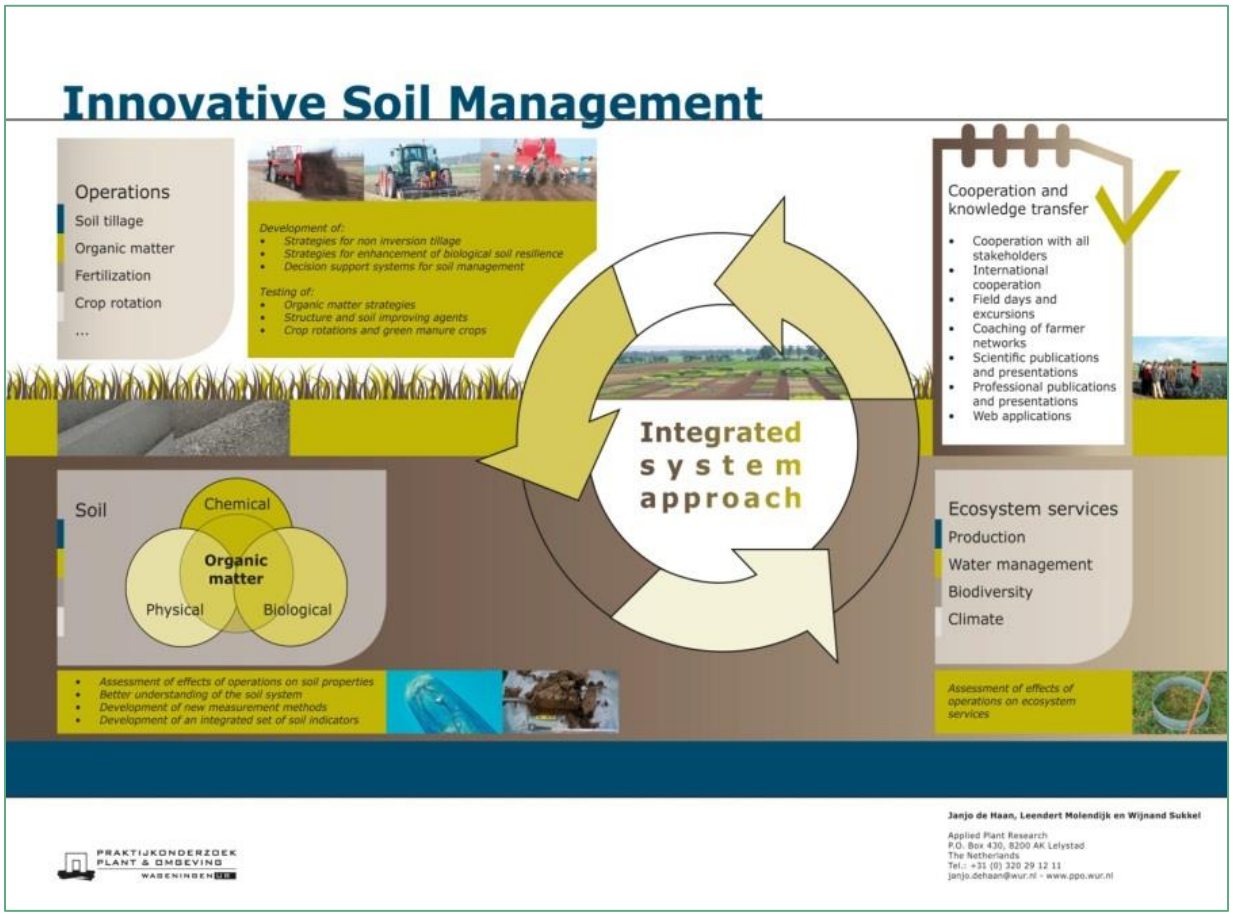

Figure 4. Innovative soil management

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