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EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY
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Towards zer0 Pesticide AGRIculture: European Network for sustainability (T0P-AGRI-Network)

Synthesis report of Working Group 1. Setting the scene: identifying research gaps and needs

Task 1.1 Analyse research gaps and needs based on an innovative multi-actor approach

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Work Package leader	Dr Ionel Mugurel JITEA
Editors	
Authors	Ionel Mugurel JITEA (UASVMCN) Iulia Sorina DAN (UASVMCN) Iulia Cristina MURESAN (UASVMCN) with contributions from:

Country	Institution	The contributing authors
Armenia	The Faculty of Agriculture and Technology	Bojana PETROVIC
Bulgaria	Agricultural Academy	Violeta BOZHANOVA
Croatia	University of Zagreb Faculty of Agriculture	Renata BAŽOK
France	National Research Institute for Agriculture, Food and the Environment	Christian HUYGHE Thibaut MALAUSA
Germany	University of Würzburg	Sarah REDLICH
Greece	Agricultural University of Athens	Dimitris TSITSIGIANNIS
Kosovo	University of Prishtina Faculty of Agriculture and Veterinary Medicine	Arben MEHMETI

	Latvia	Latvia University of Life Sciences and Technologies, Institute of Plant Protection Research "Agrihorts"	Viktorija ZAGORSKA
	Lithuania	Vytautas Magnus University Agriculture Academy, Agronomy Faculty	Zita KRIAUČIŪNIENĖ
	New Zealand	The New Zealand Institute for Plant and Food Research Limited	Virginia MARRONI
	Portugal	Instituto Superior de Agronomia, Universida de Lisboa	Elisabete FIGUEIREDO
	Romania	The University of Agronomic Sciences and Veterinary Medicine of Bucharest	Gina FINTINERU
	Serbia	Institute for Science Application in Agriculture, Belgrade	Darko JAKŠIĆ
		Environmental Physics Laboratory, Institute of Physics Belgrade, University of Belgrade	Tijana MILIĆEVIĆ
		Institute of Field and Vegetable Crops, Novi Sad	Jordana NINKOV
	UK	Warwickshire College University Centre	Roy KENNEDY
Reviewers	Cecile Detang-Dessendre (INRAE France) (the approach used in the report was established following the STSM carried out by Iulia Dan under the coordination of Mrs. Cecile Detang-Dessendre), Project Consortium		
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1. Objectives

To pave the way for a transition towards zero pesticide agriculture producing enough safe, secure and affordable food, T0P-AGRI-network focus on barriers and opportunities that end-users, i.e. actors in the entire value chain, face in pesticide use so that it can be significantly reduced. By adopting a multi-actor approach in our first working group, we ensure that the experience and knowledge of the relevant actors are considered to cover actual needs. Identifying research gaps and needs together with the non-academic partners and additional stakeholders in WG1, improve the overall impact as we expect enhanced usage of the project results by actors, knowing they were involved in generating them.

Intellectual Output: Analyse research gaps and needs based on an innovative multi-actor approach.

Objectives:

1. Identify barriers and levers for a zero-pesticide agriculture using a common methodology;
2. Collect data from a representative sample of states/regions/situations to have good material for future common scientific publications.

2. Methodology

To identify the barriers and needs in the significant reduction of pesticide use, a multi-actor approach was used. The real identification of the barriers and needs directly from the actors involved in the value chain is necessary to guide towards a correct and beneficial research. Thus, Concept – Knowledge workshops were used to bring together farmers, suppliers of agricultural inputs, advisors, specialists from agro-food industries, researchers, non-academic partners in the consortium, as well as various other interested parties. Such groups shared experiences in pesticide reduction and their expectations regarding the implementation of a zero-pesticide agriculture.

Barriers, needs and good practices were identified for 3 topics of interest, namely technological, social/market and regulations. Each topic is developed by sub-subjects, as follows:

1. Technological:

- Biotechnological (i.e., microbiota, chemical ecology, ecological immunology, plant defences, plan nutrition)
- New cropping systems;
- Precision farming and/or improved decision-making tools;
- Mechanical tools;
- Organic farming;
- Other emerging topics identified with the participants;

2. Social/market:

- Education;
- Advice;
- Consumer behaviour - the value of zero pesticide production;
- Value chain organization;
- Any existing quality signs.
- Other emerging topics identified with the participants;

3. Regulation

Concept – Knowledge workshops (C-K) were carried out on 3 value chains (viticulture, small grains and horticulture). Each country carried out at least one workshop.

2.1. Analytical framework

The reduction of pesticides and a pesticide-free agriculture is not possible without the use and adaptation of innovative systems and technologies through which farmers can reduce their dependence on chemical pesticides, while maintaining healthy and productive agricultural practices. Seen as an innovative system, the transition to zero pesticides it's beneficial both to the environment and to the long-term sustainability of agriculture, because it extends beyond technology or knowledge transfer, and it is associated to the support systems or infrastructures (Klerkx et al., 2012).

The innovation systems approach is a framework that focuses on understanding and fostering innovation in various contexts such as agriculture, technology and economic development. It is considered the interconnection of various actors, organizations and institutions in an innovation ecosystem (Pigford et all, 2018).

The choice to analyse barriers for pesticide reduction from the perspective of innovative systems functions developed by Hekkert et al. (2007), is based on the importance of mapping key activities in these systems and considering how various agricultural innovations can be leveraged to overcome these challenges. The functions of innovation systems, as outlined by Hekkert et al. (2007), refer to the key activities and roles that contribute to the development and diffusion of innovations. These functions help in understanding how innovations emerge and transform existing systems, particularly in the context of sustainability transitions. The seven functions of the innovative system is:

Table 1. Functions of an innovation system

Function	Definition
1. Entrepreneurial activities	Firms using the potential of new knowledge, networks and new markets to experiment with novel technologies, introducing these innovations to the market and investing in production capacity to diffuse the innovations and take advantage of business opportunities
2. Knowledge development	The generation of new knowledge, both tacit (learning by doing) and formal (through research and development)
3. Knowledge diffusion	The exchange of information and knowledge between actors
4. Guidance of the search	Steering the directionality of the innovation process through the articulation of expectations and preferences
5. Market formation	Opening a market for the innovation, for example by means of a protected niche market by raising consumer interest or by creating a level of a playing field through legal, economic and tax-based policy instruments
6. Resources mobilization	Allocating financial and human resources to functions 1 and 2 to allow successful entrepreneurship and learning
7. Creation of legitimacy/counteract resistance to change	Overcoming resistance to changes caused by 1) powerful incumbents with vested interests in the technology, 2) unsupportive legal conditions, 3) unawareness in society regarding the novelty, 4) deeply embedded social norms and habits that are at odds with the novelty in question

Source: Hekkert et al., (2007)

These functions are interrelated and should work in harmony to support innovation. Effective innovation systems can lead to enhanced productivity, competitiveness, and the creation of new solutions and products, which can have positive impacts on an organization, industry or a society as a whole.

By systematically matching the functions of innovative systems to the barriers of reducing pesticide use, we can create a well-informed and strategic approach to promote sustainable and pesticide-free agriculture. This will help address the challenges more effectively and encourage the adoption of innovative solutions in the agricultural sector.

2.2. Data collection

For a uniform data collection from different countries a common guide (annex 1) was created for conducting Concept-Knowledge workshops. It presents the methodology of the organization process, the structure of the group, the topic for the debate and the agenda of the event as well. In addition to this guide an individual digitalised report (annex 2) was created to present results in a common template. Guidelines for the national C-K workshops were sent by email to all members of the Cost Action Working Group 1 (104 members) at the beginning of 2023. A total of 34 countries were included in the emails to implement the national C-K workshops (Figure 1).

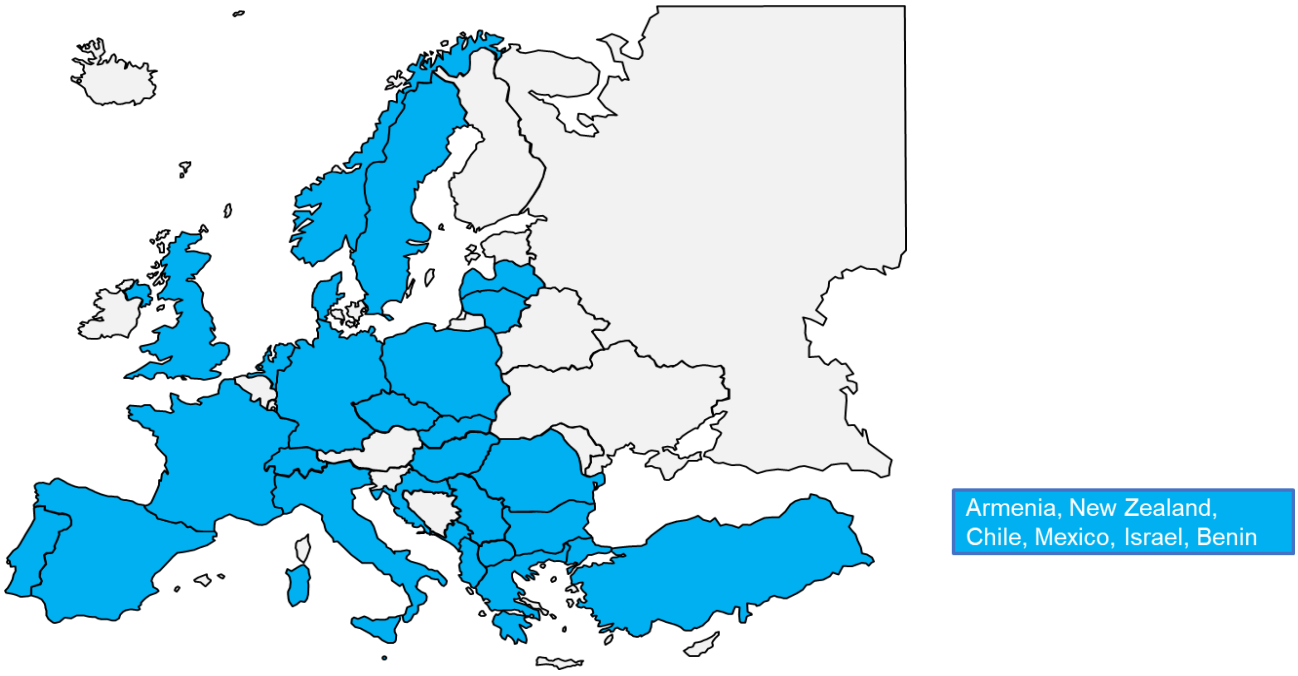

Figure 1. WG 1 member countries

Following these requests 14 countries expressed their intention to implement the national C-K workshops (Figure 2).

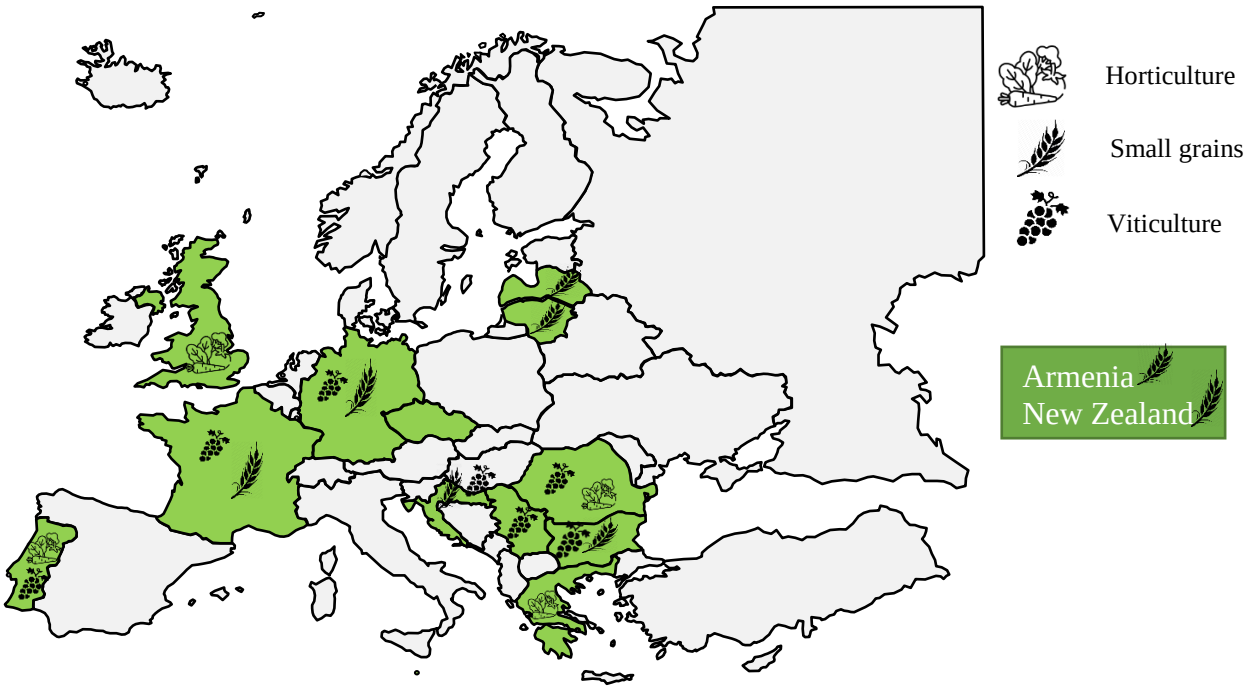

Figure 2. WG 1 National C-K workshops

The national K-C workshops were implemented in 3 agricultural sectors: small grains (8), viticulture (9) and horticulture (4) (Table 2).

Table 2. The situation of C-K workshops in different countries

No.	State	Region	Location	Number of participants	Agricultural sector
1	France	Nouvelle-Aquitaine	Face to face	49	Viticulture
2	Serbia	National	Online	12	Viticulture
3	Romania	Transylvania	Online	12	Viticulture
4	Croatia	National	Face to face	20	Viticulture
5	Kosovo	National	Face to face	N/A	Viticulture
6	Germany	National	Online	13	Viticulture
7	Portugal	North and Centre	Online	9	Viticulture
8		South	Online	9	Viticulture
9	Bulgaria	National	Face to face	19	Viticulture

10	Armenia	Yerevan	Face to face	10	Small grains
11	Lithuania	Baltic	Face to face	133	Small grains (Cereals, Brassiceae, Fabaceous)
12	Croatia	National	Face to face	15	Small grains
13	Bulgaria	Sofia	Face to face	20	Small grains
14	Germany	National	Online	6	Small grains
15	France	National	Online	15	Small grains
16	Latvia	National	Online	12	Small grains
17	New Zealand	National	Online	10	Small grains
18	Portugal	National	Online	14	Horticulture (Vegetable)
19	UK	National	Online	8	Horticulture (Strawberry)
20	Romania	National	Online	17	Horticulture (Vegetable)
21	Greece	Larisa-Thessaly	Face to Face	1000	Horticulture

After the national K-C workshops a Pan European workshop was held with the aim to identify the most stringent barriers towards zero pesticides agriculture. The workshop took place in Cluj-Napoca, Romania on September the 14th, 2023 in a hybrid format (on site and online). There were 8 participants on site, 16 participants online.

2.3. Data analysis

The data analysis was carried out in two stages. In the first stage we identified the barriers, needs and good practices in the three agricultural sectors as they were received in the reports. After that, the prioritization of the results was done based on the results of the Pan European workshops. Moreover, the second stage was about data analysis using the innovative systems functions approach presented above.

4. Results

Following the national Knowledge Concept workshops results were highlighted and are presented in the tables.

4.1. Viticulture

For the viticulture sector the main technological barriers in reducing the use of pesticides refers to the low level of knowledge and information about alternative methods and techniques, their higher cost and the lack of demonstration of their efficiency. These barriers are identified in all the analysed countries. Regarding the needs related to the technological field, these are the development of knowledge about plant immunity, role of the microbiota and agro ecological practices. Increasing the use of varieties with high systemic resistance and advising on the correct use of alternatives are other needs identified in the analysed countries. Several barriers and needs as well as good practices are illustrated in table 3.

Table 3. Technological topic

Barriers	Needs	Levers - good case examples
- Lack of demonstration of the efficiency of technological practices, and as a consequence more scepticism form farmers against these levers (All) - High prices, lack of information, sometimes more complex application and lack of knowledge by farmers to adopt the alternative products and practices (All) - Lack of the resources and available funding schemes for research at regional level (All) - Investment costs in precision farming and mechanical tools (All) - Acceptance of resistant varieties is low (HR, DE, RO, BG) - Lack of the educated producers who may apply the technology (HR, FR, BG) - Lack of funding for new equipment needed for row weed control (HR) - The development of energetically sustainable monitoring sensors (FR) - Biocontrol solutions considered to be costly and ineffective (FR, DE, RO, BG) - The acceptable alternatives to synthetic pesticides (copper,	- To better describe and understand the composition and the role of the microbiota and leaves on grapes (All) - To better understand/research plant immunity (All) - Promote agroecological practices (All) - Training for advisory services (All) - To develop educational & training resources on low-input systems and practices (All) - Productive varieties with higher systemic resistance (All) -Introduction of grapevine varieties that are resistant to diseases and pests (PiWi varieties) (DE, FR, RO, SB, BG) - To use novel research methods (living labs, participatory research) involving stakeholders along the value chain as well as consumers and scientists to achieve realistic and acceptable solutions (DE, RO, BG) - The use of sexual confusion method using pheromones (DE) - More decision support systems using more sensors and artificial intelligence (FR) - Experimentation at the local level because of the meteorological	- Sexual confusion method https://www.stmelf.bayern.de/foerderung/einsatz-des-pheromonverfahrens-zur-bekaempfung-von/index.html - Vitimonitoring by Bavarian State Institute for Viticulture and Horticulture https://www.vitimonitoring.de ; - VITAE project - BIOVINE project - HOLOVITI project - Quinta da Palmirinha https://www.facebook.com/quintadapalmirinha/?locale=pt_PT -AgroSustentável https://www.agrosustentavel.com/ - Herdade do Esporão, https://www.esporao.com/pt-pt/ - Plavinci Winery https://www.plavinci.organic/about/ - Imperator Winery https://www.imperator.rs/ - Maurer Winery https://maurer.rs/en - Bikicki Winery https://www.bikicki.rs/ - NLB / Komercijalna banka has a yearly competition for granting non-

pyrethroids) can be less effective, just as harmful to other organisms as natural enemies and sometimes costly (DE) - Still no demonstration of our capability to extract sufficient amount of copper in soil (FR) - Disease pressure too high and exaggerated amount of invasive diseases under the effects of climate change (DE, RO, PT) - Old vines in vineyards create challenges to modern equipment and technology (PT, RO) - Alternative solutions are difficult to apply in the field, even if it's effective, the number of applications and time they require to apply makes them economically and logistically impossible to use (PT) - Enhanced microbiota supply by wine producers and consumers (FR, RO, PT, CR) - Small number of experts in the field of vine protection, especially in the organic production and supporting the organic production (SB, RO) -Lack of a developed market and specialized facilities and stores for the sale of plant protection products (non-pesticides) (SB) - Unclear guidelines on what is ecological immunology and how it should be defined (SB) - Insufficient organization and interest of local associations of grape and wine producers for seeing new technologies (drones to protect vineyards, meteorological stations, etc.) (SB, RO) - Lack of effective technological solutions for organic grapevine planting material production (BG) - Insufficient application of new plant breeding technologies (NPBT) (BG)	variability between years and what is effective when the pressure is higher (PT) - Increasing the market for pheromone traps, insecticides, other means and methods that would reduce the use of pesticides (SB, RO) - Introduction of new technologies that increase the protection of plants (SB, BG) - Better national and local support for organic production certification (SB, RO) - Arbuscular mycorrhizal fungi (AMF) can be used in production of grapevine planting material (BG)	refundable funds for organic production projects https://www.nlbkb.rs/poljoprivreda/nlb-organic-konkurs - Terra Tangra Winery ttps://terratangra.com/ - Organic winery Orbelus https://www.orbelus.bg/ - Payments for conversion (annual amount per area for table grapes 1352,94 EUR/ha; wine grapes 646,19 EUR/ha). Payments for maintaining organic production (table grapes - 1094,73 EUR/ha; wine grapes - 522,86 EUR/ha) (BG) - Gorun Winery - Bulgaria, produces wines from varieties with increased resistance to fungal diseases (BG) https://www.facebook.com/Gorun Winery/

The main barriers identified in the social and market field in reducing the use of pesticides are related to the low level of knowledge from both farmers and consumers about the benefits of pesticide-free products and the lack of consultation regarding these benefits. The lack of a well-defined market and specific labeling makes the transition difficult. The needs in this field are related to the development of education through curriculum changes and adaptation to current needs, therefore the introduction of quality schemes to increase consumer confidence in these products. Several barriers and needs as well as good practices are illustrated in table 4.

Table 4. Social/market topic

Barriers	Needs	Levers - good case examples
- Lack of knowledge for producers and consumers (All) - Lack of advisory services (All) - Consumer reluctance to change their habits, lack of awareness campaigns (All) - Change of mindset. It is necessary to demonstrate results (All) - Limited budget for employing professionals in the extension service and the poor recognition by responsible administrators (HR) - The level of education of farmers is low and at the same time their age is high so they are not ready to accept new technologies because they are not always able to learn them (HR, RO, KS) - Lack of cooperation between different components of the value chain (DE, RO, KS) - A confusion between zero-pesticide and organic (FR, RO, CR) - There is no governmental support towards this kind of production (except some subsidies for organic agriculture) (SB, RO) - Too many labels limit the knowledge and awareness of the consumer (FR) - Lack of communication between farmer and the final consumer (PT) - The low price paid to the producer does not allow them the use of alternatives (PT, BG) - There is no governmental support towards this kind of production	- To adapt the pedagogic content of the new courses (All) - Farmers need to be trained to use all the advanced techniques and alternatives (All) - Quality schemes which are promoting pesticides free production and pesticides free products (All) - Training the people in the ministry who are responsible for developing and deciding on support programmes (CAP), because sometimes the support programmes do not fully correspond to the practical problems or the possible solutions (HR, RO) - The development of private independent advisory services, developing digital tools for advice. (HR , DE) - Collective and participatory approach for adoption of new practices. Co-design with producers, consumers and citizens (FR) - Fair distribution of the profits along the value chain (PT, BG) - The organization of experimental vineyards and the collection of varieties resistant to diseases and pest attacks, as well as the organization of visits to organic vineyards (SB, DE, RO) - Constant education of consumers through a network of agricultural advisors (SB) - Improving product traceability and stimulating the development of short supply chains (BG)	- Several vocational schools in France - Ecophyto: farmers's groups - "Free from pesticides residues" standard and a Guarantee mark http://www.kladenac.rs/2021/01/29/standard-kvaliteta-bez-ostataka-pesticida/ - Various trainings for agricultural extension services created by the Institute for Application Science in Agriculture. https://www.psss.rs/ - I.Г.1.4. Interventions related to advisory services and technical assistance, particularly regarding sustainable pest and disease control techniques, sustainable use of plant protection products, Sectoral Interventions "Fruit and vegetables" (BG) - Billa's Pesticide Reduction Program www.billa.bg

(except some subsidies for organic agriculture) and no funds for promotion of such products among consumers or policy creators (SB) - Not a well-developed Agricultural Knowledge and Information System (AKIS) (BG, RO) - Existence of unfair trade practices in food labelling (BG)		

The legislative field raises numerous barriers in the reduction of pesticides in agriculture through ambiguous legislation, bureaucracy and the establishment of regulations that are not in accordance with the needs of the actors in the chain. A clear legislation, support measures and a greater collaboration between policy makers and important actors in the chain are necessary levers for the transition to an agriculture without pesticides. In the following table these barriers, needs and good practices are presented in detail.

Table 5. Regulation topic

Barriers	Needs	Levers-good case examples
- Lack of knowledge and interest among administrators who design funding models, and poor connections between them, the scientific community and farmers' associations (All) - Regulators do not communicate directly with farmers, there is a lack of understanding the requirements (All) - Lobbying of the farmers' organization (FR) - Policies are intransigent without adaptation to the reality of the farmers' perspective (PT, RO) - Requirements for those who produce in Europe are different from the requirements for those who produce outside Europe and export to our markets (PT, RO) - Conflict of interest within regulatory organizations and their connections with phytosanitary industry (SB, RO) - Although there is a solid legal framework, many provisions and obligations are not being implemented due to a lack of funds and resources (human and technical) for their full implementation (SB)	- Clear political objectives (All) - The ministry that manages CAP funds must develop funding programmes to help farmers implement alternative measures and reduce pesticide use(All) - Certified planting material guarantees the absence of leafroll virus (HR) - Give researchers access to: phytosanitary treatment records, commercial formulation composition, toxicity/ecotoxicity datasets produced by authorization for industrial market (FR) - Review of the regulations related with the approval of natural control measures (PT) - Improving the level of awareness of farmers and encouraging interest in applying for the subsidies (BG)	- Soil association - cocktail effect https://www.soilassociation.org/causes-campaigns/reducing-pesticides/the-pesticide-cocktail-effect/ - "Further Capacity building in the area of Plant Protection Products and Pesticide Residues" project - INRAE ETTIS VitiREV https://ettis.inrae.fr - REGULATION No. 12 of August 23, 2023 on the terms and conditions for the use of plant protection products https://dv.parliament.bg/DVWeb/showMaterialDV.jsp?idMat=198984 - Updated National Action Plan for Sustainable Use of Pesticides in the Republic of Bulgaria https://www.strategy.bg/StrategicDocuments/View.aspx?lang=bg-BG&Id=876 - Government subsidies through interventions in the Strategic Plan for the Development of Agriculture in Bulgaria 2023-2027 for reducing the use of pesticides: I.B.4 Eco scheme for reducing the use of pesticides; II.A.11. Encouraging the reduction of the use of plant protection products

-Expensive costs for testing alternatives of pesticides and officially registering them (SB, RO, BG) - Under the new law the responsibility for the quality of the planting material lies with the producer and official controls are not provided (BG)		and fertilizers through control in the final product - laboratory analysis for pesticide residues (table grapes) https://www.mzh.government.bg/media/filer_public/2023/01/10/strategicheski_plan_2023-2027_8LjLWGr.pdf

4.2. Small grains

The small grain sector is one of the most important and its transition to zero pesticides raises numerous barriers and needs. In terms of technology the barriers focus on the lack of information and demonstrations of alternatives to the use of pesticides, the lack of resources for investments in digital solutions and precision agriculture. The main needs encountered in this sector are the establishment of demonstration farms that apply the principles of IPP and the creation of effective soil fertilization/growth promotion preparations based on consortia of free-living nitrogen-fixing bacteria, increasing the yield of a wide range of cereals. Several aspects are presented in table 6.

Table 6. Technological topic

Barriers	Needs	Levers - good case examples
- Insufficient information and demonstrations of the alternative to the use of pesticides (All) - Insufficient national funding of fundamental and applied research related to agriculture incl. interdisciplinary studies (All) - Lack of resources for investments in digital solutions and precision farming (All) - The costs of alternative products are higher (HR, DE) - The administrative procedure for granting the financing scheme in the PAC is very complicated (HR - There is no established integrated system for consultations on organic farming (BG) - Lack of skilled labor (BG - Resistant varieties not being competitive in the marketplace (HR) - Farmers' scepticism (HR, LT,NZ) - Not sufficient specialists (LT)	- Dissemination of information and farmers' training in connection with the application of the rules for integrated plant protection (All) - Establishment of demonstration farms applying the principles of IPP in research institutions (All) - Development of microbiological (biological) plant protection preparations with a pronounced insecticidal activity against soil pests of agricultural crops (AR) - Development of a targeted complex bacterial preparation that simultaneously combines both insecticidal and soil-fertilizing/growth-stimulating properties (AR) - Creation of effective soil-fertilizing/growth-stimulating preparations based on consortiums of free-living. nitrogen-fixing bacteria increasing the yield of a wide range of cereals (AR) - Promoting research in the field of soil microbiome in reference to plant growth and health; chemical ecology	-The National Scientific Program "Healthy Foods for a Strong Bioeconomy and Quality of Life" (NNP-FOOD) is being implemented. Within Component 2: *Plant health and safety in food systems* innovative solutions related to the use of biological agents, biopesticides and maintenance of soil fertility were obtained. https://agriacad.bg/bg/science-and-education/programs/nnphrani-2 - Operational groups for joint innovations have been established under sub-measure 16.1 "Support for the formation and functioning of operational groups within the EPI" of the Development Program of rural areas 2014-2020: "Development of innovative biostimulants for the needs of agriculture" https://agri.bg/novini/agroinovatsii-biostimulanti-za-nuzhdite-na-selskoto-stopanstvo

-EU directive about PPP restricts researchers to check the efficiency and spread out information about the microbiological products as the plant protection products, while they are not registered as new active substances. Registration process takes up to 3-5 years (LV) -Funding for the trials, particularly for longer term (NZ)	and in particular door scraper manipulation for sustainable pest insect control. Multidisciplinary collaboration (BG) - Update of Integrated Plant Protection Guidelines (BG) - Breeding programs for resistance (HR) - Advice the users of the digital technologies (DE, FR)	

The reluctance of consumers to change their habits, the lack of awareness campaigns and the lack of knowledge for producers and consumers are the main barriers identified in the reduction of pesticides in the small grains sector. The needs identified in the small grains sector are the education of producers, policy makers and consumers regarding the harmful effects of pesticides on health and the attraction of young people to agriculture in particular to zero-pesticide agriculture. Several elements are illustrated in table 7.

Table 7. Social/market topic

Barriers	Needs	Levers - good case examples
- Consumer reluctance to change their habits, lack of awareness campaigns (All) - Lack of knowledge in the case of producers and consumers (All) - Not a well-developed Agricultural Knowledge and Information System (AKIS) (BG) - The lack of independent advisors, competition with the traders (LT, BG, NZ, DE) - Potential higher costs of products (NZ, LV, DE, HR) - Advice by agrichemical companies and seed providers may be in conflict of interest (NZ)	- To educate producers, policy makers and consumers about the negative effects of pesticides on health (All) - To adapt the didactic content to the new trends (All) - Holding seminars, workshops, television advertisement, free provision of biological preparations for a visual effect (AR) - Quality schemes which are promoting pesticides free production and pesticides free products (BG, HR) - Identify new models for remunerating farmers to support the transition period and share the risk (FR) - Attracting young and not-so-young people to farming (FR, HR) - Develop certification systems that encourage the creation of value (FR) - The attraction of more specialists dedicated to the direct advisory service is needed (LV)	- PI Lithuanian Agricultural Advisory Service, Lithuanian Research Center for Agriculture and Forestry - Billa's Pesticide Reduction Program "Green" label - The product meets the strict criteria of the Billa Pesticide Reduction Program "Yellow" marking - The product meets the legal norms, but does not meet the stricter criteria - Socially responsible initiative of Lidl Bulgaria "You and Lidl for a better life" which funds the good ideas of civil organizations in order to improve the quality of life for people in Bulgaria

Legislative instability, lack of knowledge and interest among administrators who design funding models, weak connections between them and the scientific community, farmers' associations are important barriers for the transition to a pesticide-free agriculture. Clear policy objectives, support farmers to take alternative measures and the development of a public advisory system based on monitoring data, mathematical models for forecasting the emergence and development of economically important pests in strategic agricultural crops are the main needs identified. Several barriers and needs as well as good practices are illustrated in table 8.

Table 8. Regulation topic

Barriers	Needs	Levers-good case examples
- Lack of knowledge and interest among administrators who design funding models, and poor connections between them and the scientific community, farmers' associations (All) - Lack of sufficient objective data to elaborate mathematical models for forecasting the development of key pests in agricultural crops (BG) - Insufficient data on pesticide used in the country (BG, LV) - Rash decisions and deficit of the funding (LV) - High bureaucracy (DE) -Insufficiently objective evaluation system for issuing authorization of PPP candidates for replacement (BG)	-Clear political objectives (All) -Support measures that help and motivate farmers to take alternative measures (All) -Development of public advisory system based on monitoring data and mathematical models for prognosing the occurrence and development of economically important pests in strategic agricultural crops (All) - Upgrade of evaluation system for issuing authorization of PPP candidates for replacement (BG, FR) - Development of a set of electronic registers to track: the movement of plant protection products (PPP) placed on the market and the used ones (BG) - Changing the rules to allow drones to spray (BG) -Reduce regulatory pressure on the primary production sector to give producers more room to manoeuvre (FR) -Increase taxes rather on "non-sustainable" production (FR)	-Government subsidies through interventions in the Strategic Plan for the Development of Agriculture in Bulgaria 2023-2027 for reducing the use of pesticides: I.B.4 Eco scheme for reducing the use of pesticides; II.A.10. Supporting the cultivation of varieties (cereal crops and sunflower) resistant to climatic conditions through integrated production practices;II.A.11. Encouraging the reduction of the use of plant protection products and fertilizers through control in the final product - laboratory analysis for pesticide residues; https://agri.bg/files/documents/2022/12/07/csp-at-a-glance-bulgaria-en.pdf\ - Cooperative models, e.g. Lower Saxony model or funding program cooperative model Brandenburg - Regulation no. 8 of February 23, 2021 on the conditions and order of control of plant protection products, their trade, repackaging, storage and use https://www.ciela.net/svobodna-zona-normativi/view/2137210273/naredba-%E2%84%96-8-ot-23-fevruari-2021-g-za-usloviyata-i-reda-za-kontrol-varhu-produktite-za-rastitelna-zashtita-targoviyata-

		preopakovaneto-sahranenieto-i-upotrebata-im - Updated National Action Plan for Sustainable Use of Pesticides in the Republic of Bulgaria. A simplified procedure for the authorization of low-risk PPP in Bulgaria https://www.mzh.government.bg/media/filer_public/2021/02/24/naredba__5.pdf

4.3. Horticulture

The horticultural sector raises numerous technological barriers regarding the transition to zero pesticides, among them the lack of demonstration for the efficiency of bio stimulants/alternative solutions, the high price for new technologies, equipment and a lot of manual work in horticultural agriculture. To overcome the technological barriers there are some needs related to the development of intelligent spraying systems that automatically detect the plant canopy, adjust the spraying volume and seminars to train agronomists about the nutrient status of each crop, how to interpret, analyse and manage the data from nutrient analysis. Several elements are illustrated in table 9.

Table 9. Technological topic

Barriers	Needs	Levers - good case examples
- Lack of demonstration for the efficiency of biostimulants/solutions(All) - Farmers' scepticism (All) - Lack of resources (All) - High price for the new technologies and equipments (All) - Biological PPPs are very expensive for farmers (All) - More manual labor required in organic horticulture farming (All) - Labor force - little qualified in horticulture cultivation (RO) - Lack of research dissemination for farmers (RO) - Quarantine pests are incompatible with more sustainable solutions and destroy the work (PT) - Natural enemies, parasitoids, entomopathogenic microbes, predators are successful for pest	- Better describe and understand the composition and the role of the microbiota and plant immunity(All) - BioPPPs/biostimulants with wide mode of action that will not depend on plant cultivars and environmental conditions (All) - Pilot farms for the demonstration of IPM schemes, new varieties, agroecological strategies etc. Multiyear experimental stations with long term experiments in Pilot Demo Farms (All) - Seminars to train the agronomists about the nutrient status of each crop and how to interpret, analyse and manage nutrient analysis data (All) - Smart spraying systems that automatically detect the plant canopy and adjust the spray volume. Need for mandatory agricultural spray machinery inspection (All)	- OPTIMA: http://optima-h2020.eu/ (GR) - Retailer – investments in equipment (sensors, metro stations, pest and disease softwares, etc) – 50% support from the investment cost:https://www.lidl.ro/(RO) - Bio&co: https://bio-co.ro/(RO) - Botrytisalert: https://www.botrytisalert.co.uk/ (UK) - Oaklands Fruit Farm: https://www.oaklandsfruitfarm.co.uk/(UK) - Agrii: https://www.agrii.co.uk/ (UK) - Growers associations' advisory systems https://www.tomataza.pt (PT)

control in greenhouses and small farms but not in large fields (GR) -Biological PPPs have low non-stable mode of action that depends on environmental conditions and the used varieties (GR) - There are no biological PPPs registered for all crops (GR)	- The discovery of biological PPPs for the control of viral diseases, soilborne diseases and wood diseases (GR) - The research on RNAi technologies to control plant pests should be intensified (GR) -Use of a combination of mechanical, physical, biological and low-risk chemical control strategies (GR) - Certification of suitable varieties for organic agriculture and rehabilitation of the neglected species (more resilient) (RO, GR) - New technologies for development of the propagation material; use of transgenic plants (GR) - Organization of Living Labs to organise the organic farming (GR, RO) - Use of companion plants for biodiversity augmentation(GR) - Systems of monitoring, forecasting, and warnings for disease outbreaks. Development of advanced mathematical models for prediction of diseases and pests (time series of insect data) in plants based on weather data, phenological stages of hosts/cultivars and pest life cycles (GR,UK) - Mechanical weed control equipment at lower prices (PT)	

Table 10 shows the barriers, needs and good practices in the social field and the market in the horticultural sector. Among the barriers is the fact that citizens are not willing to pay more for products without pesticides, there is a lack of knowledge for producers and consumers, deficiencies in collaboration both between actors from the same category and from different categories (lack of associations) and the lack of specialist consultants. Campaigns to promote and make citizens aware of pesticide-free products and the development of collaboration between agronomists, farmers and industry are among the pressing needs.

Table 10. Social/market topic

Barriers	Needs	Levers - good case examples
- Citizens are not willing to pay more for zero-pesticide products (All) - Lack of knowledge for producers and consumers (All)	- Continuous training of the farmers and agronomists using interactive training media tools on new technologies besides the correct application of IPM schemes in each cultivation (All)	- School 11 Buzău county (didactic greenhouses, circular agriculture, research involvement)

- Lack of growers' associations (All) - Lack of specialized consultants (RO) - Lack of market (RO, UK) - Lack of trust in organic products and zero-pesticide products (RO)	- Advisory Plant Protection by specialists. Need for a Plant protection advisory platforms (All) - Campaigns to promote and raise awareness among citizens regarding zero-pesticide products (All) - Collaboration of agronomists, farmers and the industry (GR, RO) - Operational programs of EU: Connection of researchers and farmers-Translational research from the lab to the field (GR, RO, PT)	

Unclear political objectives and bureaucracy in the registration of biopesticides are the most specific legislative barriers. To overcome these barriers there is a need to develop funding programs (from the CAP) to help farmers implement alternative measures and reduce the use of pesticides. Table 11 presents the elements identified following the workshops held in the partner countries.

Table 11. Regulation topic

Barriers	Needs	Levers-good case examples
- Unclear political objectives (GR, RO) - EU registration for biopesticides based on microorganisms similar to the other pesticides make their registration evaluation too expensive and takes a long time (PT, RO, GR) - Mandatory requirements for EU growers and for growers from non-EU countries exporting their products to EU are not equal (All) - Green Deal will lead to increased cost of production (GR)	- Interaction of legislators, scientists, industry (GR, RO) - Development of funding programs (from the CAP) to help farmers implement alternative measures and reduce pesticide use (GR, RO)	- Specific regulation on public acquisition - to promote the local products (RO)

4.4. Differences between sectors

After presenting the barriers and needs by sector, it can be seen that there are similarities among them. The result being from different culture systems, the main differences identified are related to the production technology. These are presented in the following table along the 3 topics (technological, social/marketing and regulation).

Table 12. Differences between sectors

Technological topic		
Sectors	Barriers	Needs
Viticulture/ Horticulture	- Viticulture is a permanent crop, therefore many solutions that work in small grains cannot be implemented here (e.g. crop rotations, rapid change of crop variety/type from one year to the next) - The control of weeds near the vines (cavaillon in French) - More manual labour required in horticulture farming	- Equipment for row weed control - A lot of plant biomass between rows and possible competition with vines for water - Increasing the soil life (more micro-organisms and more organic matter) for more vine resistance to stress
Small grains	- Lack of knowledge and agro technologies for multi cropping, multifunctional crops. - Expensive implements and machineries are required, economically efficient only in large intensive farms. - Covering vineyards with hail nets alters the microclimate in the canopy. This can change the conditions for pathogen infection and also the occurrence of certain species of insect pests. This is impossible in small grains.	- Suitable trap plants in intercropping with target crops, plant defence stimulators in combination with optimized nutrition.
Social/Marketing topic		
Sectors	Barriers	Needs
Viticulture/ Horticulture	- Low knowledge/acceptance of consumer for alternative, resistant varieties (e.g. PIWIs), because consumer is not used to flavours, does not know variety or is unaware of advantages - Consumers want less or none residues of pesticides but they	- Education and awareness

	do not tolerate defects, spots, russeting	
Small grains	-Processing as a place to create added value	Securing food production
Regulation topic		
Sectors	Barriers	Needs
Viticulture/ Horticulture	-Difficulty in exporting organic wine to some markets because the rules of organic farming are different in various markets	
Small grains	- The rules used for the approval of these new products are the same as for phytopharmaceutical products of chemical origin	

4.5. Prioritization of the results after the Pan European workshop

After identifying the barriers and needs related to the transition to a zero pesticide agriculture based on C-K workshops, they were prioritized in a Pan-European workshop. This workshop was organized in Romania, in September 2023 in a hybrid format, both on site and online. The participants in this workshop were researchers, farmers, input suppliers and advisors. They prioritized the identified technological barriers, the main referring to the efficiency of bio stimulants/alternative solutions regarding the cost/benefit aspect. Furthermore, the main need is related to training for advisory services regarding the use of alternatives and specific zero-pesticide practices. For the social and markets topic, the main barrier is the lack of knowledge for producers and consumers and the need to overcome it by educating producers, policy makers and consumers about the negative effects of pesticides on human health and environment. Regarding the regulation, the main identified barrier is related to the conflict of interests within the regulatory organizations and their connections with the phytosanitary industry. The main need is the development of interaction between legislators, scientists, industry and the establishment of clear political objectives. These results were prioritized after the Pan European workshop resulting in the following:

Table 13. Prioritizing results

Technological topic	
Barriers	*Needs*
Lack in demonstrating the efficiency of bio stimulants/alternative solutions – cost/benefit;	Training for advisory services;
Insufficient national funding of fundamental and applied research related to agriculture incl. interdisciplinary studies;	Implement participatory research methods (living labs) involving all stakeholders from the value chain;
Investment costs in alternative precision farming and mechanical tools;	Experimentation at the local level;

Lack of appropriate solutions/ available resources for farmers;	To make better the national and local support for organic production certification;
Lack of knowledge and agro technologies for multi cropping, multifunctional crops;	To better describe and understand the role of microbiota in production quality;
Alternative protection products registration process take up 3 to 5 years;	To better understand/research plant immunity;
More manual labour required;	Sexual confusion method using pheromones;
Expensive implements and machinery are required, economically efficient only in large intensive farms.	Decision support systems using AI;
	Leaving Labs; Dissemination of information and farmers' training in connection with the application of the rules for integrated plant protection;
	Develop/promote alternative agro-ecological practices;
	To develop educational & training resources on low-input systems and practices;
	Develop new plant varieties with higher systemic resistance for pests and disease;
	Update/adapt the Integrated Plant Protection Guidelines;
Social/ market topic	
Barriers	*Needs*
Lack of knowledge for producers and consumers (lack of farmers' motivation to participate to educational seminars);	Educate producers, policy makers and consumers about the negative effects of pesticides on human health & environment;
Low market drivers;	Quality schemes which are promoting pesticides free production and pesticides free products;
Confusion between zero-pesticide and organic;	To adapt curricula to zero pesticides alternative approaches;
Consumer reluctance to change consumer habits, lack of awareness campaigns;	Fair distribution of the profits along the value chain;
Lack of integration protocols for pesticides free agriculture.	Improving product traceability and stimulating the development of short supply chains;
	Visits of good practice cases;
	Education of children about vegetable production chains; attracting your farmers.
Regulation topic	
Barriers	*Needs*
Conflict of interest within regulatory organizations and their connections with phytosanitary industry;	The interaction of legislators, scientists, industry; clear political objectives;

Mandatory requirements are different comparing the EU products and non-EU products – unfair competition;	Development of funding programs (from the CAP) to help farmers implement alternative measures and reduce pesticide use;
EU biopesticides registration considered to be too expensive and takes a tot of time;	Development of public advisory system based on monitoring data and mathematical models for prognosing the occurrence and development of economically important pests in strategic agricultural crops;
Lack of knowledge and poor connections between the scientific community and farmers community;	Appropriate regulatory framework for ecosystem services of pest control;
Policies are intransigent without adaptation to the reality of the farmer;	Reduce regulatory pressure on the primary production sector to give producers more room to manoeuvre;
Although there is a solid legal framework, many provisions and obligations are not being implemented due to lack of funds and resources (human and technical).	Review/adapt the process of registration and the use of pesticides;
	Give researchers access to phytosanitary treatment records, commercial formulation composition, toxicity/ecotoxicity datasets produced by industry for market authorization;
	Subsidies for consumers.

4.6. Data analysis from the perspective of functions of innovative system

A first conclusion of the analysis of the data from the workshops is that the barriers for the transition to an agriculture without pesticides are similar in the three fields (viticulture, small grains and horticulture).

For each of the 7 functions of the system (see table 1) we first describe the actors that are part of them, then present the barriers that prevent the transition to a zero-pesticide agriculture specific to the function. After this we illustrate the identified needs to be able to move towards a pesticide-free agriculture.

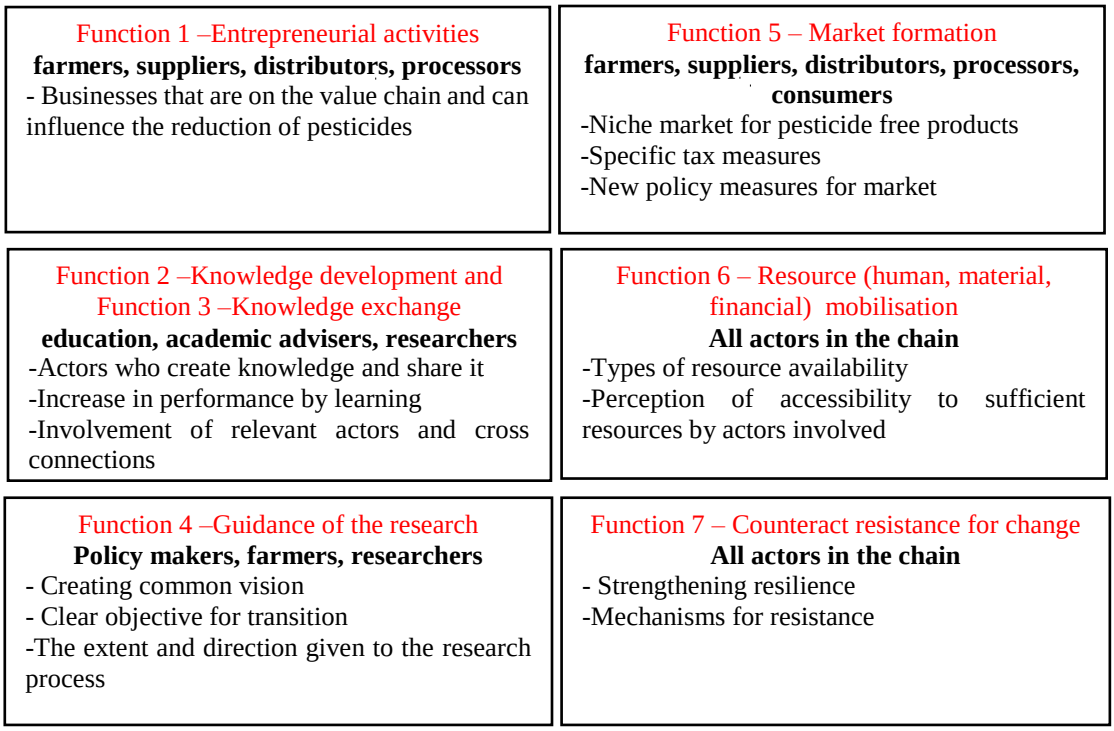

Figure 3. The functions of the innovative system for a pesticide-free agriculture

4.6.1. Function 1: Entrepreneurial activities

This function includes the businesses that operate on the value chain that can influence the reduction of pesticides: farms, agricultural input companies, processing and distribution companies. Their role is essential in the transition for a pesticide-free agriculture, being the key actors that trigger change.

The barriers identified in the K-C workshops within this function focus on three essential aspects:

- the availability and know-how of free-pesticides alternatives;
- the costs in time and money to produce and to use alternative methods.
- the capacity and the adaptability of business to change (especially for farm business).

The lack of knowledge, information and demonstrations regarding the use of alternatives practices lead to farm business scepticism regarding the efficient use of pesticide-free practices. The lack of financial resources for the purchase of new technologies adapted for pesticide-free agriculture is an important barrier, especially for farmers and input suppliers.

The barriers identified upstream the farm relate to the lack of suppliers of alternative products. They are reluctant to adopt new practices because their production cost is high and the approval time by the public authorities to bring the new solutions on the market is also considerably important. The lack of cooperation between the main actors of the chain in developing alternative free-pesticides practices (cooperatives between producers/farmers and other key actors of the value chain) is another important barrier in moving towards pesticide-free agriculture.

The needs identified for this function are primarily related to improving knowledge and information about methods, techniques and alternatives in reducing pesticides for agricultural use. From this need, new business opportunities can arise through the creation of companies that train

farmers to implement such systems as well as through farm advice activities. Another urgent need is the financial support for the transition towards zero pesticides agriculture, which can be implemented through measures to reduce the transition costs provided by the Common Agricultural Policy. These measures must be specific by category of actors (small farms vs large farms) because the size offers have different transition possibilities, besides the different local specific needs. The implementation of a participatory research method (living labs) is based on another real need that should to be carried out to increase farmers' confidence in the alternative approaches.

4.6.2. Function 2 and 3: Knowledge development and exchange

Knowledge development and knowledge dissemination through networks are essential and should be taken into consideration together. These functions include factors such as education at all levels, research and advice. They must work with the main actors (farmers, input suppliers) in the value chain to be able to provide the essential information for the producers moving towards a pesticide-free agriculture.

A first identified barrier is the lack of resources to develop research related methods and alternatives for pesticide-free agriculture. The barrier is also supported by low research prioritization regarding the real needs of the key value chain actors. Another barrier is related to the way of disseminating research results. Many times, the results do not reach the actors directly involved in their use or they are very scientific so that the actors do not know how to use them. This barrier can be highlighted by the lack of participatory research (living labs). To remove these barriers a much closer collaboration between farmers and researchers is needed, using co-learning and co-experimenting processes. The use of new research methods (living labs, participatory research) involving all stakeholders along the value chain is a must in order to achieve realistic and acceptable solutions. Another need is to create platforms for disseminating results for the general public, also some public and private advisory services so that the exchange of knowledge, information is as easy and beneficial as possible.

4.6.3. Function 4: Guidance of the research

This function includes primarily the policy makers who promote actions regarding the reduction of pesticide use (EU policy makers through the European Green Deal) but also the other actors who are directly related to these objectives (farmers, researchers, etc.).

The main barriers are related to a lack of clarity, consistency and coordination between EU, national and local policy makers. Sometimes the EU policy maker’s vision is too ambiguous and therefore not sufficiently clear for the actors involved at a local level.

The second barrier is the lack of cooperation between the key actors of the value chain and policy decision-makers regarding the establishment of legislation to encourage and facilitate the transition, both through regulations and through different measures of public financial support. The needs identified for this function are related to the creation of a clear and concise legislative framework, a more effective cooperation between policy makers and other actors of the value chain.

Policy makers of the development of research relate another need to the financial support, to be able to implement projects based on which to establish priorities and the real vision towards

a pesticide-free agriculture. Another necessity is the financial support of research. Policy makers should collaborate with researchers and support them mainly financially. This support is necessary so that researchers can implement projects aimed to develop alternative measures, but also to research new resistant varieties that farmers can use.

4.6.4. Function 5: Market formation

In this function, the key actors of the value chain involved are: farmers, suppliers, processors, distributors and consumers. The main barriers are: market organization, pricing, product attributes, communication that gets to the final consumer.

The most important barrier is the willingness to pay a premium price for products obtained from pesticide-free agriculture. This can be explained by the lack of consumer information regarding the benefits of these products, but also by the level of education and purchasing power.

Another barrier is the lack of a specific label developed for pesticide-free products. Currently it is difficult to trace products and increase consumer confidence in such products. The lack of communication between the actors of the value chain leads to the lack of cooperation between them, so it is difficult to create a market for pesticide-free products.

To remove the barriers it is necessary to create organizations/associations to inform consumers about pesticide-free products, to enhance cooperation between key actors such as to be able to implement different methods and techniques. This way we can create a payment-based market for environmental services and equitable distribution of profits along the value chain. Another important element is the creation of a quality brand and its labelling to highlight pesticide-free products in order to help develop short supply chains.

4.6.5. Function 6: Resource mobilization

Resource mobilization remains a key challenge. There can be financial, material and human resources. All actors of the value chain are involved in this function. Most of the barriers are related to the financial resources that are not sufficient to help the transition to a pesticide-free agriculture.

All the main actors of the value chain (farmers, suppliers, distributors) show that the main barrier is the lack of financial resource to use for alternatives of pesticides, new technologies and to bear the additional costs or losses incurred due to the non-use of pesticides (risk mitigation). In terms of human resources, the identified barriers relate to the lack of education regarding alternatives in pesticides use, the high age of farmers that makes the adaptation difficult. Another barrier is the lack of both public and private advisers to guide farmers towards preventive techniques, methods and pesticide-free agriculture. The identified needs are related to the development of financial support measures for all levels (farm, market, research) through CAP, and the efficient management of resources by prioritizing needs. These measures must be easy to access and specific for different categories of actors in the value chain, both in terms of size and importance. Regarding human resources there is a need to attract young farmers and educate them towards the development of agriculture without pesticides.

4.6.6. Function 7: Creation of legitimacy

The purpose of the last function is to make an innovation, a new system part of the existing regime. All the actors are part of this function. The barriers are related to conceptual clarity, lower productivity, and feasibility of such a farming system. This approach would be too ambigious for most farmers. The lack of evidence regarding the effectiveness of such alternatives make the actors involved sceptical about their use. The needs to eliminate this barrier are creating a regional living lab to promote resilience, develop public-private partnerships and a clear, explicit national legal framework for all levels.

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