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IPM Decisions

Deliverable 5.3 – Interactions between end-user characteristics and structural and performance features of assessed DSS

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Contents

1 Public Summary

Incentives and barriers to adoption of IPM decision support systems (DSS) by farmers and farm advisors, identified through analysis of questionnaire data, were linked to structural and performance characteristics of IPM DSS. Approaches to overcome each identified barrier and to use incentives for DSS adoption were suggested.

2 Executive Summary

The deliverable reports on the results achieved in WP5, Task 5.3. The results are based on the usable outputs of Task 5.1 (Deliverable 5.1: A catalogue of structure and performance profiles for all included DSS) and the end-user characteristics that affect the adoption of IPM DSS. The latter were identified through questionnaires answered by participants (farmers and farm advisors) in the IPM Decisions workshops in 12 European countries (O5.2). The reported results serve the following two objectives of the IPM decisions project: (i) to understand which levers can be used to increase the uptake of DSS for the different identified user segments (ii) to link the identified incentives and barriers to the IPM DSS characteristics in order to provide additional knowledge on the interactions between user requirements and the characteristics of the assessed DSS that can be used by problem owners (e.g. DSS developers, IPM decisions platform developers) to search for appropriate potential solutions (approaches) to overcome the identified barriers or use the identified incentives to increase the adoption of IPM DSS. Attached to this document is an interactive catalogue of 80 DSS described with selected characteristics that influence users' decision to use or not use IPM DSS and associated with proposed approaches to address the identified barriers and incentives to DSS adoption. This catalogue can be further used to support achieving the objectives set out in Task 5.4. It can also be used to prioritise the further integration of DSS into the IPM Decisions platform.

IPM DSS are not widely adopted by farmers and farm advisors, despite the fact that various DSS have been developed for IPM for three decades. After all this time, many farmers and farm advisors still do not use DSS or even know that such tools exist.

The reasons for the low use of DSS on IPM are on both sides: on the side of the users (e.g. many of them do not have trust in the tools developed, others are not convinced that DSS can help solve their problems, and some feel that they lack the information technology skills to use DSS.) and on the side of the developers (e.g. the tools are too complex to use, not relevant to farmers' problems, not validated for their location). It is therefore crucial to address the problem (i.e. the low use of DSS in IPM) holistically.

An attempt was made to explore the reasons for the relatively low use of IPM DSS both on the side of the users as well as on the characteristics of DSS. Two complementary approaches were used to analyse the questionnaire data to identify incentives or barriers to the adoption of IPM DSS. The results of both analyses were linked to the structural and performance characteristics of DSS. This comprehensive analysis allowed us to develop a list of practical approaches to improve the uptake of IPM DSS among farmers and farm advisors in Europe.

3 Introduction

The eight principles of Integrated Pest Management (IPM) provide a set of internationally recognised processes for ensuring sustainable crop production, and form part of the EU's Sustainable Pesticide Use Directive (SUD 2009/128/EC)[1]. According to the third principle, management decisions should be supported through use of forecasts, economic threshold or other IPM Decision Support Systems (DSSs) [1]. Despite many IPM DSS being available across agricultural sectors, including some excellent examples of well tested and implemented systems [2], uptake by farmers and their advisers remains low. Uptake has been constrained by numerous factors, associated with either the technical development and availability of systems, or the way in which farmers and their advisors are engaged with during development and end product launch. The latter frequently results in DSS being either rejected by potential users, or the outputs of the system are not perceived as sufficiently trustworthy to influence pest management decisions.

Decision Support Systems provide farmers with reliable scientific data, promote innovation, and reduce wastage [3] – [5]. The agricultural sector faces the challenge of a growing global demand for food, while preserving biodiversity, combating climate change and ensuring that production is sustainable and economical [6]. The decisions associated with pest management can be among the most difficult that farmers and their advisors face during the growing season [7]. Applying pesticides when the actual risk of pest damage is low rarely leads to acute repercussions but has chronic impacts on the long-term sustainability of crop production and the health of the surrounding ecosystem [8]. Conversely, farmers can experience substantial economic losses where pest infestations are left unchecked and go on to cause widespread crop damage [9]. The main purpose of a DSS is to enable users to make more effective decisions. For the outputs to be trusted, DSSs must not only be reliable, but also clear in their limitations and assumptions [10]. Currently, the common types of IPM DSS used are tactical systems, supporting decisions on when to monitor crops for pest activity and when action may be required to prevent economic losses, such as monitoring systems, forecasting systems and thresholds [11]. Monitoring systems report actual occurrences of given pests at a defined spatial scale. Pest forecasts are based on algorithms that model a given pest's ecology from climatic and/or agronomic inputs to predict the likelihood of infestation and/or the risk to the crop [12]. Together these provide farmers and their advisers with an insight into the current and future risk of infestation in their region, supporting decisions on whether further crop monitoring is required [13]. Economic thresholds are based on the potential for a given pest to cause economic damage to the crop and are a final assessment of the need to act [7]. A majority of IPM DSS require user inputs such as field

[1] Parliament, E. Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides. Off J Eur Union 2009, 309, 71-86.

location, soil type and structure, climate data, and agronomic details such as sowing date and crop variety. Based on these data the DSSs algorithms are run, and the system outputs potential strategies (decision aids/treatments) that the farmer can choose from [14]. Outputs range from a relative assessment of the risk of infestation and/or economic damage, to specific recommendations for pest management measures or when the use of pesticides would be most effective.

3.1 Current uptake of IPM DSS

Over the last three decades, there is a growing concern that even though agricultural DSSs are available for farmers, they are neither fully utilised nor appropriate for the complexity of the daily decisions farmers face [15]–[17]. In weed management, for example, some DSSs determine the density of weeds at which a control treatment will provide an economic return [18]. Economic thresholds such as this are highly valued by farmers and have been developed for many pests [19], [20], however they can be difficult to develop and establish in farming practice [7].

From inception, most DSSs are primarily designed to handle farm and crop production data. The weakness of this approach is that the role of the farmer, and other auxiliary factors, are minimised or left out completely. User characteristics are, however, key factors influencing the adoption and application of DSS [21]. The data-focused nature of DSS is an understandable by-product of developers' efforts to optimise their DSS to work with certain types of pests and crops, making them specific and detailed. In contrast, farmers prefer to have a broader view, reflecting the polyvalent spectrum of day-to-day decisions they face [10]. Van Meensel et al. [22] conclude that some DSS are overwhelmingly complex, the terminology and functions are not only unsuitable but often irrelevant to the final user. Other DSS may be simple, but the Graphical User Interface (GUI) is too complex, either by poor design, or due to the high frequency of changes made by developers to optimise their product. Therefore, if farmers interact with a few complex systems, it can lead to a community level perception of all DSS being too complicated to be of value. In addition, many DSSs lack a proven track record of their effectiveness in farming. This is in part explained by the agricultural DSS development cycle, in which systems are a culmination of a short term (3-5 year) research project. Often, the main activities involve coding and GUI design, instead of demonstrating the economic and environmental benefits the system offers. A focus on algorithm development, and optimal GUI design, with omission of the influence of user behaviours has led to a dismal adoption and general lack of trust in agricultural DSS to date among farmers.

3.2 Improving uptake and trust in IPM DSS

Decision making and technological adoption theories provide useful insights into the low rates of adoption of agricultural DSSs. The theories of adoption of new farming practices have been extensively documented, identifying the factors influencing the adoption of farming technology [23], [24]. Conventionally, decision-making process theories identify three main factors: farmer, technological and institutional characteristics [25]. A review by Kumar et al. [26] identified the source of information, technological features, economic factors, farm characteristics, institutional and sociodemographic factors significantly influencing the adoption of farming technologies. In this study, farmer and farm-related characteristics collected during workshops across Europe were used to assess the factors influencing the uptake and trust in IPM DSS. A revised analytical framework outlining the interactions between end-user characteristics and structural performance features of assessed DSS in the decision-making process involving technological adoption by users at the farm is presented. Other decision-making processes include a psychological process in addition to the factors identified above. As suggested by Davis [27] in the Technology Acceptance Model, technology acceptance and usage are determined by the perceived usefulness and the perceived ease of use. Perceived usefulness is the utility gained from improving one's work performance due to the use of a certain technology, whereas perceived ease of use is related to the effort required to use a certain technology [28].

3.3 Structural and performance features of assessed DSS

The structural and performance characteristics of decision support systems play an important role in the user's decision whether or not to use a system [31]-[37]. Barriers to the use of IPM DSS by farmers, farm advisors and other users can arise for a variety of reasons, such as infrastructure requirements, relevance of DSS to users, type of outcomes DSS provides, language barriers, price and the like. To effectively address the identified incentives and barriers to DSS adoption in IPM among farmers and farm advisors in Europe, the identified barriers and incentives have to be linked with the characteristics of already developed DSS. Such a linkage would enable a holistic approach to addressing the barriers and leveraging the identified incentives for DSS adoption in IPM. This would support the European Union's objectives of i) reducing the risks of pesticide use (European Green Deal (Commission, 2022)[2]), ii) use pesticides more sustainably (Farm to Fork Strategy (Commission, 2020)[3]), and iii) strengthen biodiversity conservation efforts (Biodiversity Strategy (Commission, 2020a)[4]).

[2] Commission, E. The European Green Deal, COM(2019) 640 final. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions 2019.
[3] Commission, E. Farm to fork strategy: for a fair, healthy and environmentally-friendly food system, COM(2020) 381 final. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 2020.
[4] Commission, E. EU Biodiversity Strategy for 2030 Bringing nature back into our lives, COM(2020) 380 final. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions 2020a.

4 Methodology

4.1 Assessment of user characteristics

A questionnaire survey was administered to 149 farmers from 12 European countries (Table 1), eliciting personal, farm and farm equipment characteristics that influence the adoption and trust in DSS. The survey was designed in consultation with a team of experts working closely with the IPM Decisions Network.

Table 1: Number of total responses, per country and workshop

Country	Number of Farmers
France	6
Greece	22
Lithuania	9
Denmark	4
Italy	37
Slovenia	14
United Kingdom	24
Sweden	11
Finland	9
Germany	9
Holland	4
Total	149

The questionnaire was completed by farmers in national workshops. The workshops were held face-to-face between December 2019 and March 2020. A further round of national workshops was carried out online between January and March 2021, where a second questionnaire was administered to farmers. This was used to assess the perceived relative importance of the variables from the analysis of the first questionnaire. Each question of this complementary questionnaire focused on the variables used as explanatory variables in the econometric model derived from the first questionnaire. Each question in the second questionnaire had three options to choose from: “not important at all,” “important to some extent,” and “very important”.

The models were developed under the hypothesis that the characteristics of the farmer (e.g., education, gender, exposure to marketing, etc.), farm and farm equipment (e.g., crop specialisation, legislation, output, total acreage, etc.) are likely to have a direct effect on the decision to the use DSS or not and the level of trust in DSS.

Considering the binary nature of the first explained variable (yes, no), we adjusted a logit model with robust standard errors clustered at the country level. In addition to this, we have been also interested in knowing the reasons why farmers do or do not trust DSS. Since farmers' trust is an ordinal variable taking values from 1 to 7, an ordered-logit model with robust standard errors clustered at the country level was used for the estimation. Regarding the variables used in the models, particular attention has been paid to multicollinearity issues. While there is no specific test for multicollinearity, special attention has been paid to several warning signals such as the model stability, the variance inflation factors (VIF) and the correlation of the estimated coefficients. Table 5 displays the coefficients and average marginal effects of the logit estimation of the DSS use rate in the two first columns. It also displays the coefficients of the ordered-logit estimation of the trust level in column 3. Marginal effects of this model are available upon request.

4.2 Variables and descriptive statistics of questionnaire data

The variables fall into three main categories: personal information about the farmer; farm characteristics and characteristics of the technology at the farm. In line with the General Data Privacy Policy, respondents were free to exclude any information they did not wish to share but were encouraged to provide as much information as possible. Consequently, there were missing observations for some variables resulting in an uneven dataset. A summary of the responses to questions eliciting the characteristics of the respondents and their farms is provided in Table 2.

The characteristics of the farmers in Greece, Italy, the United Kingdom and Slovenia are summarised in Table 3. An overview of all the variables created from the questionnaire is provided in Table 4 (see also Appendix A).

Table 2: Percentage of answers related to the main variables (N=149)

Age			Type of farm	
18 to 25	7.4%		Conventional	40.5%
25 to 35	25.5%		Integrated	29.4%
35 to 50	27.5%		Organic	9.2%
50 to 60	29.5%		Biodynamic	0.6%
60 or more	10.1%		Not indicated	20.2%
Highest degree attained			Farm size	
Vocational	40.3%		Under 5HA	10.1%
Bachelor	27.5%		5 to 10 HA	2.7%
Masters	17.4%		10 to 30 HA	18.1%
PhD	4.7%		30 to 60 HA	14.1%
Others	6.7%		Over 60 HA	54.4%
Average income (euros per year)			Access to speed internet	
Under 20K	21.5%		No	10.1%
20 to 35K	20.8%		In the office only	38.6%
35 to 50K	20.1%		Also in the fields	52.3%
50 to 75K	12.1%			
Over 75K	22.1%			
Gender			Already tried using a DSS	
Male	80.5%		Yes	60.4%
Female	18.8%		No	24.2%
Not indicated	0.7%		Not indicated	15.4%

Table 3: Characteristics of farms per country

		EL* (22)	SE (11)	IT (37)	SI (14)	UK (24)
Farm size	Under 5HA	5	0	0	10	0
	5 to 10 HA	0	0	3	1	0
	10 to 30 HA	11	0	4	2	0
	30 to 60 HA	0	0	14	0	0
	Over 60 HA	7	11	16	1	24
Type of farm	Conventional		10	19	3	19
	Integrated		1	12	9	5
	Organic		2	12	3	4
	Biodynamic		0	1	0	0
	Not indicated		0	1	0	1
Access to high-speed internet	No	1	0	4	2	5
	In the office only	13	3	12	5	9
	Also, in the fields	8	7	21	7	10

**The Greek workshop did not include the type of farm in their version of the questionnaire*

4.3 Questionnaire data analysis

Questionnaire responses were analysed to identify and measure the relationship between the adoption and trust in the guidance of DSS, and other explanatory variables. Logit and ordered logit models were used to estimate the relationship between these two main dependent variables and the other explanatory variables mentioned in the previous section. The analysis was conducted using Stata version 14.2 for MAC OS and Windows. Explanatory variables were inspected prior to analysis following the protocol described in Zuur et al. [29]. Special attention has been paid to several warning signs of multicollinearity such as the model stability, the variance inflation factors (VIF) and the correlation of the estimated coefficients. The coefficients and average marginal effects of the logit estimation of the DSS use, and coefficients of the ordered-logit estimation of the trust level are provided in Table 5. Marginal effects of this model are also included in the output table.

Since farmers' uptake of IPM DSS is binary in our case (either they use or do not use IPM DSS), a logit model was used to analyse this response variable, with robust standard errors clustered at the country level. Since farmers’ trust is an ordinal variable taking values from 1 to 7, an ordered-logit model with robust standard errors clustered at the country level is used for the estimation.

4.4 Assessment of DSS characteristics

To identify structural and performance characteristics, which influence users' decision to use or not to use IPM DSS, we used the output of the deliverable 5.1 of this project: "A catalogue with structural and performance feature profiles for all included DSS" (Debeljak et al., 2021) where 80 DSS for IPM in Europe are described with over 55 structural and performance characteristics. The characteristics are structured in the first hierarchical typology for IPM DSS that are applied in Europe. Their structural and performance characteristics were addressed from the following four aspects, and complemented with descriptive information of included DSS (e.g., name of DSS, country of development, region of focus etc.):

1. Information about the target user of the assessed DSS and the spatial, temporal and technical constraints for the problem in question.
2. Information about the decision problems that are addressed by the assessed DSS and decision alternatives that the assessed DSS can provide.
3. Information on the decision analysis method used by the assessed DSS and the required input data.
4. Information on the required knowledge that the end-user needs for the use of the assessed DSS.

A detailed description of the methodology for IPM DSS in Europe is provided in deliverable 5.1 of this project, including its attached Excel file with description data of assessed DSS [38].

Following the mapping of the existing DSS for IPM in Europe (deliverable 4.9 of this project) [39] and DSS typology (deliverable 5.1 of this project) [38], the barriers and incentives identified in this project (and described in sections 3.1 and 3.2) were linked with the structural and performance characteristics of the assessed DSS for IPM in Europe.

5 Results and discussion

The results of the analyses identified several associations between farm and farmer characteristics, and the uptake of and trust in IPM DSS.

5.1 Drivers of farmer uptake of IPM DSS

Farm size ($p = 0.003$) shows a positive and significant effect on the DSS use rate. Adoption is more is more likely to occur on larger farms, with all other parameters remaining equal. The reason for the positive impact of farm size on DSS use could be that with a larger area to manage, farmers are less likely to routinely monitor and track potential infestations without the help of DSS. Also, the staff of a large farm may disagree on pest management, in such cases DSS can be used as a coordination tool.

Regarding the personal characteristics of the farmer, it is apparent that education level does not have a significant effect on the likelihood to adopt DSS. Farmers with a higher level of education do not necessarily have an advantage in terms of better connections to researchers and developers, and better access and visibility of systems available in comparison to farmers with lower levels of education. Also, the probability to use a DSS increases with the willingness to pay for a DSS ($p = 0.06$).

Concerning the characteristics of the farm, crop specialisation does not seem to have a significant impact on adoption.

5.2 Drivers of farmer trust in IPM DSS

Farmers reporting to work on larger farms tend to show a significantly higher level of trust towards DSS ($p = 0.089$). Modern farming is complex and as such, wireless technologies and automated interventions are suited to cope with agricultural demand.

While farmers that have been exposed to simple advertising show a significantly lower level of trust towards DSS ($p= 0.017$), farmers who attended regular DSSs use demonstrations trust DSS significantly more ($p = 0.091$). Simple advertising may not induce trust probably because of the lack of direct engagement. Demonstrations allow farmers to see DSSs in action and allow them to see where it can fit with their existing processes. It also enables farmers to see others' trust in the system, and gives an opportunity to ask questions, clarify limitations, and discuss with peers.

Table 4: Logit and logit ordered estimations of the DSS use rate/trust level among farmers

	DSS use	Marginal effects	Trust in DSS
Age	-0.3130	-0.0014	0.0708
	(0.8383)	(0.0372)	(0.2877)
Education	0.9394	0.0416	-0.1135
	(0.8358)	(0.0411)	(0.3509)
Male			0.9412
			(0.7668)
Farm size	1.9586***	0.0868*	1.5428***
	(0.7242)	(0.0479)	(0.4977)
Income	0.4728	0.0210	-0.6402
	(0.8793)	(0.0379)	(0.2417)
Arable crops	-1.3841	-0.0614	0.5275
	(1.8344)	(0.0899)	(0.7326)
Animals	-1.9412	-0.0861*	-0.9417
	(1.2763)	(0.0502)	(1.3434)
Orchards	-0.3542	-0.0157	-0.0693
	(0.8995)	(0.0411)	(1.0066)
Vegetables	1.2412	0.0550	0.1678
	(1.8206)	(0.0858)	(0.9133)
Flowers	-1.7192	-0.0762	-0.4341
	(2.1400)	(0.0964)	(1.5444)
Vineyards			2.6697*
			(1.3821)
Integrated farm			0.2420
			(0.5543)
Legislative requirement	-3.3239*	-0.1474	-0.1473
	(1.7390)	(0.1000)	(0.9309)
Speed internet	2.1461	0.0952	
	(1.3685)	(0.0767)	
Need IT teaching	0.4794	0.0213	2.3923
	(1.0878)	(0.0508)	(1.5169)
Willingness to pay	2.3434**	0.1039*	
	(1.0806)	(0.0515)	
Already used DSS			0.1757
			(0.3415)
Exposed to marketing			-3.3659**
			(1.5381)
Exposed to demonstrations			2.0298*
			(1.1053)
_cons	-6.6491**		
	(2.6576)		
N	90	90	68

*Std Errors to the nearest four d.p. in parenthesis. Significance level: *p<0.1, **p<0.05, ***p<0.01*

When we focus on individual drivers of DSS adoption, we find an interesting effect of the farmer´s risk aversion on DSS adoption (Table 5). The more risk averse a farmer is, the more likely it is that he or she will adopt a DSS. This responds to a theoretically ambiguous expectation of this effect because risk aversion may, in theory, work both against adoption (due to a farmer´s perceived risk of not using a DSS properly or because of lack of trust in the DSS) and in favour of it (if the risk of crop loss is considered). Further results of this model confirm that older and more educated male farmers are more likely to adopt a DSS, whereas the farm's income plays no significant role. Access to high-speed internet and the farmer's perceived need for IT education increase the likelihood of DSS adoption. Finally, vineyard and flower growers and those animals on the farm all increase the likelihood of DSS adoption.

5.3 Interactions between end-users characteristics and structural-performance features of DSS

Barriers and incentives to adoption of DSS are often dealt with at the individual level, with narrow focus either on user specifics or on DSS characteristics. Our approach follows broader, holistic approach which overcome barrier and/or benefit using specific incentive for their realisation. By combining different methods of questionnaire data analysis (ie. machine learning supplemented by non-parametric statistics (barriers); logit and ordered logit models (incentives), we were able to obtain complementary results and connect identified barriers and incentives with structural performance of IPM DSS characteristics. Based on these connections, 13 codes of solution approaches were proposed, each related to identified barrier or incentives (Table 6;Table 7). Interactive table with all detail information for the assessed DSS is provided as Excel file attachment to this pdf document (Appendix).

Table 6 shows that some of the barriers and incentives are well addressed by DSS developers. A good example of this is the language of the DSS interface. 96% of the DSS in the catalogue are available in the national language of the country where they were developed, which facilitates usability by removing language barriers. In addition, 56 % of the DSS in the catalogue are also available in English, which enables their use in neighbouring countries and also internationally. During the development of the IPM Decisions platform, possible language barriers that could lead to a lower uptake of the platform were taken into account and solved very well, as all DSS included in the platform and the platform itself were translated into 12 languages of the participating countries.

Some of the identified barriers and incentives are insufficiently addressed, such as the type of target crop for which DSS can be used. Vine growers and ornamental plant growers have expressed a desire to use such DSS, but not many of the assessed DSS in the catalogue relate to these target crops.

Table 5: DSS adoption

UseDSS1yes	Coef.	Std. Error.	t-value	p-value	[95% Conf	Interval]	Sig
Gender x_age	2.956	1.128	2.84	.005	1.398	6.247	***
Gender x edu	.31	.172	-2.11	.035	.105	.92	**
Income	2.257	1.283	1.43	.152	.741	6.875	
Arable crops	3.964	5.484	1.00	.32	.263	59.68	
Animal	.081	.098	-2.08	.038	.008	.867	**
Orchards	2.626	2.948	0.86	.39	.291	23.711	
Vineyard	.054	.051	-3.07	.002	.008	.348	***
Vegetables	9.587	11.516	1.88	.06	.91	100.967	*
Flowers	.001	.002	-2.57	.01	0	.166	**
Legislative Requirements	1.212	1.063	0.22	.826	.217	6.761	
High speed internet	23.36	36.85	2.00	.046	1.061	514.284	**
IT teaching needed	.001	.002	-2.73	.006	0	.14	***
WTP	2.35	3.227	0.62	.534	.159	34.664	
Risk aversion	44.383	63.404	2.66	.008	2.699	729.802	***
Constant	.049	.119	-1.24	.213	0	5.675	
Mean dependent var		0.906		SD dependent var		0.293	
Pseudo r-squared		0.492		Number of obs		96.000	
Chi-square		18.728		Prob > chi2			0.176
Akaike crit. (AIC)		60.358		Bayesian crit. (BIC)			98.824

*** p<.01, ** p<.05, * p<.1

Table 6: Summary of the identified barriers and incentives, the associated DSS characteristics and the percentage of assessed DSS that have a characteristic with a positive influence for DSS use.

Barriers		Incentives	Related DSS characteristics		Catalogue D5.1 status		Code
Advisors	**Farmers**	**Farmers**	**DSS typology**	**DSS characteristic**	**Positive value**	**%**	
Southern Europe: Crop specific requirements and expectations from DSS. Special attention needs to be paid to crop types.		Vineyard, vegetable and flower growers and having animals on the farm all increase the likelihood of DSS adoption.	**Decision problem** > **Plant protection** > *Key target crops*	Vegetables	Yes	34	1
				Vineyard	Yes	10	2
				Ornamentals	Yes	6	3
Northern Europe: Many only have internet access in the office, but not in their clients' fields.	Southern Europe: Poor access to high-speed internet.	Access to high-speed internet increase the likelihood of DSS adoption.	**Decision analysis** > **Implementation**	Access to DSS	Online	85	4
	Northern, Central and Southern Europe: Lack of trust in DSS. South Europe: Low expectation for DSS to improve productivity.	Demonstration strategies are more effective building trust, rather than advertising (favouring references to facts as opposed to branding strategies).	**Decision analysis** > **Implementation**	Access to references	Yes	64	5
Central Europe: Perceived complexity of DSS; easy to use systems are preferred.		Farmer's perceived need for IT education increase the likelihood of DSS adoption.	**Decision analysis** > **Implementation**	Login required	No	48*	6
			Decision analysis > **Implementation** > *Language*	National	Yes	96	7
				Available in English	Yes	56	8
			Decision analysis > **Data required** > *Weather*	Obtaining weather data	Automatic OR Not required	45	9
			Final outcomes > **Output**	Map	Yes	41	10
				Text	Yes	23	11
				Numerical / Categorical	Yes	44	12
Central Europe: Low willingness to pay for DSS, and low price of DSS are preferred.		Farmers who are more willing to pay are more likely to use DSS	**Decision analysis** > **Implementation** > *Price*	Free	Yes OR Limited	70	13

**Online DSSs, which do not require login.*

The proposed approaches to overcoming the identified barriers and using the identified incentives can be further specified to make them applicable to different developers and their specificities. For example, for the IPM Decisions platform developed under this project, it is suggested to increase efforts to include more DSS for vegetables, vines and ornamentals, as there is a strong interest among potential users to use these systems, while for DSS developers it is suggested to focus on the sectors mentioned above when developing new products. Each of the approaches listed in Table 7 can be achieved in different ways, depending on the resources available. Some of the approaches can only be adopted by certain roles (e.g. grants and subsidies for the development/use of advanced DSS can only be provided by policy makers, and minimising registration requirements can only be implemented by DSS developers).

Table 7: Key broad approaches to overcome identified barriers or exploit identified incentives to IPM DSS uptake among farmers and farm advisors.

Code	**Key approaches**
1, 2, 3	- Develop/include additional DSS for vegetables, vineyards and ornamentals.
4	- Reduce dependence of DSS use from speed of and/or access to internet.
5	- Raise users' awareness of the benefits of DSS, - Stimulate the sharing of positive experiences among farmers, - Stimulate developers to provide evidence of efficiency of their DSS, - Increase trust.
6	- Minimise login requirements.
7, 8	- The necessity of the national language is well addressed in our project (translation of the platform)
9	- Minimise manual input of weather data to support user friendliness of the DSS
10, 11, 12	- Increase the effectiveness of communicating DSS results to end users
13	- Grants/subsidies for development/use of advanced (payable) DSS, - Developers should offer free trial versions.

6 Conclusion

This deliverable discusses the results of our work package, namely understanding the interactions between the characteristics of users (farmers, farm advisors) and the structural and performance characteristics of DSS that influence the adoption of IPM DSS by farmers and farm advisors in Europe.

We analysed the data using two complementary methodological approaches. We combined the results of both approaches to find links between the characteristics of the DSS (Deliverable 5.1 of this project) and the identified incentives and barriers. This comprehensive analysis enabled us to produce a list of practical approaches to enhance the DSS uptake in IPM. In addition, an interactive Excel spreadsheet (Appendix) is attached to this file to facilitate further exploitation of the obtained results.

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8 Appendix

Interactive Excel table with detailed information about the associated characteristics which support and encourage the use of Decision Support Systems developed for use in Integrated Pest Management.