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Editorial

Resilience capacities as perceived by European farmers

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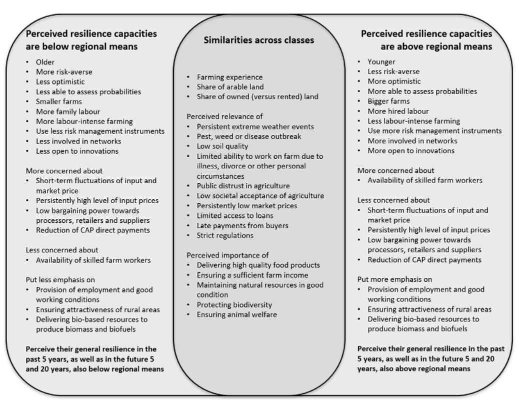
HIGHLIGHTS

- We investigate how European farmers perceive robustness, adaptability, and transformability of their farms.
- Our results indicate mutual dependence between the three perceived resilience capacities.
- Two groups of farm(*er*)s are revealed based on the resilience capacities: all three below and all three above regional means.
- Each group shares characteristics, such as labour input, risk aversion, and perceived importance of private and public goods.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: The ability of a farm to cope with challenges is often conceptualised as resilience. Although improving resilience of farms is a major policy goal in the European Union, the current state of resilience is often unknown. Previous resilience assessments have been based either on pre-defined indicators or on perceptions. In particular,

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empirical research of perceived resilience is still limited and usually restricted to one specific resilience capacity, one challenge, or one function.

OBJECTIVE: We investigate how European farmers perceive resilience capacities of their farms. Extending beyond previous research, we cover all three resilience capacities (robustness, adaptability, and transformability), consider a broad range of short-term shocks and long-term stresses, and include multiple functions. Furthermore, we analyse farms from diverse farming systems across Europe and investigate whether farms and farmers with similar perceived resilience capacities share characteristics.

METHODS: We address the complex nature of resilience capacities by accounting for multiple scales formulated as analytical steps of a resilience assessment framework. More specifically, these are 'resilience of what' (farms and farming systems), 'resilience to what' (challenges), 'resilience for what purpose' (functions), and 'what enhances resilience' (resilience attributes). These steps guided the development of a survey with farmers across eleven European farming systems. Based on three indices for each farmer indicating perceived robustness, adaptability, and transformability of their farms, we identified two classes of farmers with particularly strong and weak resilience profiles respectively. Using nonparametric Mann-Whitney *U* tests, we furthermore compared other parameters collected via the survey across the identified classes.

RESULTS AND CONCLUSIONS: Our data sample outputs two classes of similar size characterised by all three perceived resilience capacities being above (below) regional average. This finding suggests that the perceptions of robustness, adaptability, and transformability are mutually dependent. Furthermore, we found that farmers who perceive their resilience above the regional averages are characterised by lower risk aversion, greater focus on providing public goods, a higher number of implemented risk management strategies, more active involvement in networks, and greater openness to innovation.

SIGNIFICANCE: The revealed links between particular characteristics of farms and farmers and different levels of perceived resilience capacities can support policy-makers in developing more targeted resilience-enhancing strategies, as well as in understanding farmers' responses to challenges. Finally, our results can serve as a basis for further research, e.g., for formulating and testing hypotheses on causal effects between perceived resilience and its components, and on links between perception- and indicator-based resilience assessments.

1. Introduction

Europe's agricultural sector faces large environmental, economic, social and institutional challenges. The ability of farms and farming systems to cope with these challenges can be conceptualised as resilience (Meuwissen et al., 2019). Improving resilience in agriculture is a major policy goal of the European Union (EU Commission, 2020). However, the current state of resilience is often not known, and hence interventions cannot be designed and prioritised appropriately (Peerlings et al., 2014). In this paper, we provide insights into perceived resilience capacities based on a large-scale survey of 974 farmers in 11 European regions. Following Meuwissen et al. (2019), we distinguish between three resilience capacities —— robustness, adaptability, and transformability —— that ensure the provision of private and public goods in the face of increasingly complex and accumulating shocks and stresses. Although other actors also contribute to the functions of farming systems, this paper focuses on farms and farmers and assesses the three resilience capacities suggested by Meuwissen et al. (2019) at this level. Accordingly, robustness is the capacity of a farm to withstand stresses and (un)anticipated shocks. Adaptability is the capacity to change the composition of inputs, production, marketing and risk management in response to shocks and stresses but without changing the structures, feedback mechanisms or identity of a farm. Transformability is the capacity to significantly change the internal structure and feedback mechanisms of a farm in response to either severe shocks or enduring stresses that make business as usual impossible or undesirable.

Existing literature describes two types of resilience assessments: (i) resilience assessments based on pre-defined indicators (e.g., Cabell and Oelofse, 2012), and (ii) perceived-resilience assessments (e.g., Grothmann and Patt, 2005; Marshall and Marshall, 2007; Jones and D'errico, 2019). Resilience assessments based on pre-defined indicators rely on the observation of key socioeconomic and ecological variables (FAO, 2016; Bahadur and Pichon, 2017) that are usually defined by researchers rather than by the farming system actors (Jones, 2018). While these resilience assessments may draw on locally collected data, they often rely on statistical relationships at an aggregated scale (Clare et al., 2017). Furthermore, indicator-based resilience assessments are context-specific. Assessing the resilience of a specialised Belgian dairy farm requires different indicators than for a mixed family farm in North-East Romania. Therefore, it is difficult to compare and synthesise resilience assessments across different farming systems. Another major limitation of indicator-based resilience assessments is the difficulty to identify and include all relevant traits and indicators — ranging from economic and geophysical to sociocultural and political factors — that influence resilience (Cutter et al., 2008; Meuwissen et al., 2020). Conceptualizing, operationalising, and measuring all these indicators can be very demanding. For instance, the FAOs resilience assessment tool SHARP (Self-evaluation and Holistic Assessment of climate Resilience of farmers and Pastoralists) comprises over 100 sub-indicators (FAO, 2020).

Recently, resilience assessments based on stakeholder perception have attracted increased interest (Lockwood et al., 2015, Béné et al., 2014, Jones and Tanner, 2017, Perrin et al., 2020). Perceived resilience relies on a farmer's cognitive and affective valuation of his or her capacity to anticipate, buffer, adapt, and transform the farm in response to a short-term shock or a long-term stress (Jones and Tanner, 2017). Perceived-resilience assessments allow for cross-farming system comparison if the same statements are applicable in different contexts, i.e., if the same survey statements can be used across farming systems. The reader should note though that perception-based resilience assessments should not be considered as an alternative but rather as a complement to indicator-based assessments (Jones and D'errico, 2019). Both methods combined provide a robust base for designing resilience-enhancing policies and interventions, since perception-based resilience assessments reveal information about a wide range of socio-economic, psychological and institutional factors and their contribution (Jones and Tanner, 2017). In contrast to indicator-based resilience assessments, previous empirical research of perceived resilience has been mostly limited to one specific resilience capacity (e.g., Grothmann and Patt, 2005; Marshall et al., 2014), one challenge (e.g., Smith et al., 2012; Komarek et al., 2020), or one function (e.g., Seo, 2010). Furthermore, there is a lack of large-scale resilience assessments that compare multiple farming systems .

Against this background, this paper aims to assess all three perceived resilience capacities, covering a broad range of short-term shocks and long-term stresses, considering multiple functions, as well as capturing and analysing current resilience perceptions of farmers in eleven European farming systems. Our contribution is twofold. Firstly, we provide insights into three perceived resilience capacities (i.e., robustness, adaptability and transformability) of European farmers using a unique data-set with broad coverage of different regions and farm types. Second, we include a wide range of challenges that farmers perceive (i.e., economic, environmental, social and institutional), and consider multiple functions of farming (i.e., the provision of both private and public goods). In this way, we provide unique insights into the perceived resilience of farms and farmers, and we investigate factors that might potentially explain heterogeneity in perceived resilience capacities. However, due to data limitations and different survey modes, we do not compare perceived resilience capacities across farming systems or farm types.

The remainder of this paper is structured as follows. Section 2 provides the conceptual background. Section 3 introduces the farm survey and the eleven farming systems. Section 4 presents the methodology that is used for analysis of collected data, as well as our empirical results. Section 5 discusses the results and concludes with suggestions for further research.

2. Conceptual background

Concepts of coping, adaptation, and transformation are not unique for resilience frameworks and used in other studies, e.g. of sustainable livelihoods and farm management. Resilience thinking stresses the dynamics and complexity of a system's response to a challenge (Folke et al., 2010), as well as the circumstances that predefine required capacities (Darnhofer, 2014; Meuwissen et al., 2020). In this regard, an empirical analysis of farming system resilience is challenging due to the wide range of potentially relevant shocks and stresses, and heterogeneity of farms and farmers who experience them (Peerlings et al., 2014). In the following paragraphs we introduce the theoretical and empirical background of our approach.

First, we follow several previous studies suggesting that the contextual, dynamic, and complex nature of the resilience capacities can be better understood through the analysis of multiple scales that are formulated as analytical steps of a resilience framework (e.g., Darnhofer, 2014; Herman et al., 2018; Meuwissen et al., 2019). More specifically, we follow the steps proposed by Meuwissen et al. (2019), namely 'resilience of what', 'resilience to what' (challenges), 'resilience for what purpose' (functions), and 'what enhances resilience' (resilience attributes and enabling or constraining context). The first step defines and describes the farm and farmer of interest, including farm specialisation, size, farming experience, amount of available land and labour resources. Step 2 identifies economic, environmental, institutional, and social challenges ('resilience to what') and ensuing current and potential threats. It is important to note that these challenges are often interdependent. Furthermore, we distinguish between short-term shocks (e.g., price volatilities or short-time labour deficits due to sickness) and long-term stresses (e.g., changing consumer preferences or climate change). Step 3 specifies the functions, i.e. the public and private goods provided. Private goods are the marketable products and services, in particular food, fibre, and energy. Public goods are qualities and values which are not remunerated through markets, for example the provision of animal welfare beyond statutory requirements, contributions to attractive rural areas, and biodiversity. The final step defines resilience attributes and describes the resilience-enhancing or -constraining context. The Resilience Alliance (2010) suggests five generic principles to define resilience attributes: (i) diversity; (ii) modularity; (iii) openness; (iv) tightness of feedbacks; and (v) system reserves. Information on a farm's or a farmer's characteristics (step 1) also informs the assessment of resilience attributes. For instance, long farming experience constitutes a system reserve, i.e., accumulated human capital, while a broad portfolio of farm products and services contributes to a system's diversity.

Second, based on the previous findings, we hypothesise and test if farmers with similar perceived resilience capacities share characteristics. These hypotheses are based, among others, on theories of decision-making under risk (Scholz et al., 2012) and farm management (Darnhofer, 2014). Risk perception and risk attitude contribute to explaining adaptive behaviour (e.g., Grothmann and Patt, 2005; Clayton et al., 2015; Jianjun et al., 2015). Furthermore, decision-making under risk usually implies consideration of simultaneous and conflicting objectives, e.g., expected returns vs. level of risk. The literature on empirical assessment in the resilience context similarly acknowledges the existence of multiple and often conflicting objectives (Plummer and Armitage, 2007), and farmers' characteristics have been linked to their responses to challenges. For instance, Peerlings et al. (2014) found that large specialised farms run by young farmers with higher levels of education were less likely to implement any adaptation strategies when facing a challenge. Since farmers' behaviour is largely shaped by perceptions, we test if these characteristics can be framed by the 'resilience of what' (functions) and 'what enhances resilience' (attributes and context) questions posed by Meuwissen et al. (2019). In addition, we included an obervation by Adger (2000), who links social resilience to innovation but emphasises that the causal relationship is unclear – a resilient environment might enhance the willingness to innovate; or openness to innovation might enhance perceived resilience capacities. Finally, individual involvement in social networks may also influence perceived resilience (Smith et al., 2012) and constitute a resilience capacity.

Previous research on perceived resilience used either surveys or focus groups for data collection (see e.g., Brusset and Teller, 2017; Clare et al., 2017). Surveys are suitable to assess individual rather than group perceptions. In the field of psychological resilience and wellbeing, several resilience-perception scales have been suggested (e.g., Wagnild, 2011; Liebenberg et al., 2013). Some empirical examples from the field of socio-economic resilience are also available (e.g., Nguyen and James, 2013), yet, as mentioned above, they are usually limited to one resilience capacity, one challenge, or one function.

3. Survey design and data collection

Based on the conceptual and methodological background outlined above, we designed a questionnaire consisting of 13 parts (see Appendix 1). In the first part, the respondents were asked about characteristics of their farm ('resilience of what'), including specialisation, size, number of animals, and employed labour. The second part continued with the risk management strategies that have been used in the last five years. In order to limit the time required for filling in the survey, we did not ask about exact coverage of each risk management instrument, but only whether it was used or not. Parts 3 and 5 of the survey dealt with perceived future challenges ('resilience to what') and combined an open question (part 3) and a 7-point-Likert-type item battery for a pre-defined list of challenges (part 5). The two parts were separated on purpose, in order to minimise the influence on responses to the open question. The fourth part of the survey aimed at the perceived importance of functions ('resilience for what purpose') and asked respondents to prioritise eight pre-defined functions by distributing 100 points between them. The sixth part of the survey aimed at the perception of the three resilience capacities by asking farmers to assess the relevance of a number of statements based on a 7-point-Likert-type items (see Table 1) following examples from the literature (e.g., Nguyen and James, 2013; Jones and D'errico, 2019; Slijper et al., 2020). The statements are in line with the four components of resilience suggested by Marshall et al. (2007, 2009), namely (i) perception of risk; (ii) ability to plan, learn, and reorganise; (iii) perception of ability to cope with change; and (iv) level of interest in adapting to change. This part also suggested three illustrative examples for the three resilience capacities (see Appendix 1).

Parts 7 and 8 focused on resilience attributes, namely on farmers' involvement into formal and informal networks, as well as their willingness to adopt innovations, and asked the respondents to self-assess both based on 7-point-Likert-type items. Part 9 asked about perceived resilience dynamics. In this case, we did not distinguish between the

Table 1
Statements included in the farm survey to assess the three perceived resilience capacities based on the 7-degree-Likert scale (1 = strongly disagree … 7 = strongly agree).

Robustness			Adaptability			Transformability		
Rob1	After something challenging has happened, it is easy for my farm to bounce back to its current profitability.	+	**Adap1**	If needed, my farm can adopt new activities, varieties, or technologies in response to challenging situations.	+	**Trans1**	For me, it is easy to make decisions that result in a transformation.	+
Rob2	As a farmer, it is hard to manage my farm in such a way that it recovers quickly from shocks.	–	**Adap2**	As a farmer, I can easily adapt myself to challenging situations.	+	**Trans2**	I am in trouble if external circumstances would drastically change, as it is hard to reorganise my farm.	–
Rob3	Personally, I find it easy to get back to normal after a setback.	+	**Adap3**	In times of change, I am good at adapting myself and facing up to agricultural challenges.	+	**Trans3**	After facing a challenging period on my farm, I still have the ability to radically reorganise my farm.	+
Rob4	A big shock will not heavily affect me, as I have enough options to deal with this shock on my farm.	+	**Adap4**	My farm is not flexible and can hardly be adjusted to deal with a changing environment.	–	**Trans4**	If needed, I can easily make major changes that would transform my farm.	+

+ and – represent positive and negative contribution to resilience capacity indices respectively that were accordingly converted.

three resilience capacities, but did refer to different time horizons, namely current resilience, resilience in the past five years, five years into the future and twenty years into the future (Table 2). The aim of these additional questions on resilience dynamics was to check whether the three indices reflecting the three perceived resilience capacities were good proxies for overall perceived resilience. In addition, if there was an association between the three perceived resilience capacities (Table 1) and general perceived resilience (Table 2), we aimed to check whether it was constant with regard to the perception of resilience in the past, present and future. More specifically, we aimed to capture current perceived resilience with perceived behavioural control (e.g., the upper four rows in Table 2), following previous studies on perceived resilience (e.g., Grothmann and Patt, 2005; Béné et al., 2014). Perceived behavioural control reflected personal capacities and constraints and their influence on behaviour (Hagger and Chatzisarantis, 2005), which we combined with a proxy for knowledge (the fifth row in Table 2).

In part 10 of the survey, respondents were asked to evaluate their own ability to handle probabilities based on a 7-point-Likert-type item battery. Part 11 aimed to assess whether respondents held pessimistic or optimistic expectations for their farms. For this purpose, the survey introduced a definition of a good (bad) year, namely when the gross annual farm income is at least 30% higher (lower) than expected. Next, participants were asked to assess the probabilities of the next year being good or bad, as well as the probabilities of at least one of the next 10 years being good or bad. Part 12 of the survey aimed to capture how farmers perceived their own risk preference. Respondents were asked to assess their willingness to take risks (Dohmen et al., 2011) and to compare on 7-point-Likert-type items their willingness to take risks with other farmers in terms of risks to (i) production; (ii) marketing and prices; (iii) finances; (iv) innovation; and (v) farming in general. Importantly, high values on the comparative scales do not necessarily indicate that respondents are risk-prone, but perceive themselves as less risk-averse than their peers. The final part of the survey included demographic questions, such as the farmer's gender, age, and education.

Table 2
Statements included in the farm survey to assess perceptions of current, past, and future general resilience based on a 7-degree-Likert scale (1 = strongly disagree, 7 = strongly agree).

Current general resilience	Resilience1	If I wanted to, it would be easy for me to deal with agricultural challenges on my farm.	+
	Resilience2	It is mostly up to me whether or not I can deal with the challenges on my farm.	+
	Resilience3	I have a lot of control about agricultural challenges affecting my farm.	+
	Resilience4	For me, it is difficult to deal with the challenges that affect my farm.	–
	Resilience5	I know a lot about agricultural challenges on my farm.	+
Past general resilience	Resilience6	If I consider the last 5 years, my farm has often experienced negative consequences of agricultural challenges.	–
Future general resilience	Resilience7	For the next 5 years, I expect my farm to be resilient to agricultural challenges.	+
	Resilience8	For the next 20 years, I expect my farm to be resilient to agricultural challenges.	+

+ and – represent positive and negative contribution to resilience capacity indices respectively that were accordingly converted.

The questionnaire was translated into the local language by the respective project partner (forward-translation) and back to English by someone who had not seen the original (English) survey (blind back-translation, cf. Brancato et al., 2006). This procedure helps to identify ambivalent words or phrases that might lead to incorrect interpretations (Hilton and Skrutkowski, 2002). A pilot survey was conducted in Poland and Bulgaria in spring 2018 and the results were used to revise some of the questions. Hence, the data from Bulgaria and Poland are based on slightly different statements. Consequently, we assume a regional fixed effect and do not run a cross-country comparison of data as explained below. The survey in the other nine case studies took place between July 2018 and January 2019 via various distribution methods which responded to local circumstances and limitations (Table 3). For instance, in the Spanish farming system farms are located in remote areas with low access to internet; and hence, we opted for face-to-face surveys. The online survey was expected to take 30 minutes to complete; face-to-face or phone interviews took longer. Participation in the survey was voluntary. In some farming systems, participation was promoted by offering material rewards. For example, in the Dutch farming system, 24 vouchers, each worth €25, as well as one Samsung tablet, were raffled among the respondents (Slijper et al., 2020). In total, 996 responses were collected, of which 24 were omitted from the analysis because of missing values on the three resilience capacities (Table 3). The data sample is published in Slijper et al. (2021).

We selected eleven farming systems across Europe to conduct the survey (Figure 1). The focus of the farming system in Flanders, Belgium are dairy farmers, who were at the time slowly recovering from a price crisis, increasing production rapidly. The mixed farming system in Altmark in East Germany also includes dairy and livestock production and represents a typical agricultural structure of Eastern Germany after unification. As a heritage of land reforms during the socialist period (1945–1989), 5.3% of the farms in the Altmark manage more than 1000 ha each and cultivate close to 33% of the agricultural land (STALA, 2018). The farming system in Bourbonnais, France has been traditionally dominated by beef production with an average farm size of 88 ha. The Spanish survey covered two farming systems: extensive sheep farming in Huesca and extensive beef farming in Sierra de Guarradama (Comunidad de Madrid). The farming system in Southern Sweden includes the high value livestock egg and poultry sector. The focus of the farming system in Northeast Bulgaria is arable farms (mainly wheat). The farming system in the East of England covers highly productive

Table 3
Overview of sample size and distribution methods across the farming systems.

Farming system	Data collection				Sample size	Response rate
	Face-to-face	*Telephone*	*Mail*	*Online*		
BE				Applied	220	0.05
BG	Applied				30	1.00
FR	Applied	Applied		Applied	50	Unknown[a]
DE				Applied	30	0.29
IT	Applied			Applied	60	0.75
NL				Applied	30	Unknown[a]
PL	Applied		Applied	Applied	70	0.06
RO	Applied				122	1.00
ES	Applied				120	0.96
SE		Applied	Applied	Applied	64	0.36
UK		Applied			200	0.07
				Total	**996**	

[a] The response rate remains unknown because it is undeterminable how many farmers were reached and recruited through online advertisement via various agricultural publishers.

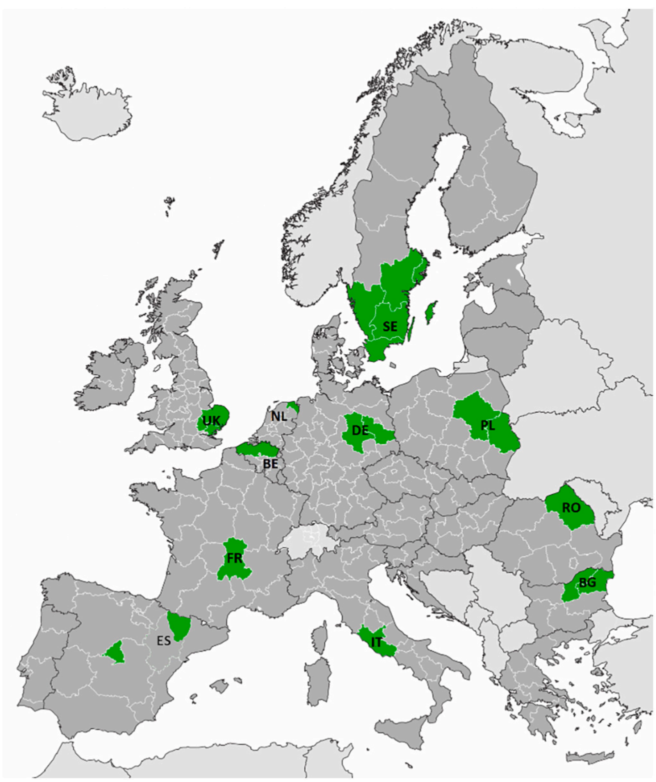

Fig. 1. Selected farming systems: BE — dairy farming in Flanders; BG — large-scale arable farming in Northeast Bulgaria; DE — arable farming with livestock in Altmark; ES — extensive sheep and cattle grazing in Huesca and Sierra de Guarradama; FR — extensive beef cattle system in Bourbonnais (France); IT — small-scale hazelnut production in Lazio; NL — intensive arable farming in Veenkoloniën; PL — Fruit and vegetable farming in the Mazovian region; RO — small-scale mixed farming in Northeast Romania; SE — high-value egg and broiler systems in South Sweden; UK — arable farming in the East of England.

lands and contributes more to the UK's agricultural gross value added than any region. Production includes a variety of crops (cereals, industrial crops, potatoes, sugar beet), with cereals (especially wheat and barley) covering almost half of the farmed area. The farming system in the Mazovian region, Poland, includes two groups of farms: (i) fruit production from trees, shrubs and bushes and (ii) production of outdoor (ground) vegetables. The farming system in Lazio, Italy focuses on hazelnut farms which deliver high-quality products compared with the international competitors. The vast majority of farms in the farming system in Veenkoloniën, the Netherlands, are either specialised in arable crops (60%), such as starch potato, sugar beet, and winter wheat, or grazing livestock (34%) (CBS, 2019). The farming system in Northeast Romania covers mixed farms, 95% of which work on less than 5 ha. The usual livestock on farms is dairy cows, poultry, sheep, pigs, and equidae. The sample aimed to cover a broad range of different farming systems. We deliberately included heterogeneous case studies in terms of size, specialisation, organisational forms, climatic conditions, and political frameworks. We assume a regional fixed effect in order to minimise potential regional bias, as explained in the following section.

4. Data analysis and results

4.1. Data preparation

Likert-scale item batteries used in the survey served as a basis for composite indices of respective parameters, e.g., for current robustness, adaptability, and transformability, as well as current, past, and future resilience. More specifically, we calculated means of the respective statements. To test the reliability and validity of our measurement model for these composite indices, we used confirmatory factor analysis (see Appendix 2 for greater detail). Several Likert-scale items – mainly negatively-worded items (e.g., Rob2, Adap4 and Trans2 in Table 1) – were not included into the composite indices because their factor loadings were too low or did not discriminate enough between constructs. The formulas for resulted composite resilience indices can be seen in Fig. 5.

In order to account for differences across farming systems in terms of farm specialisation, survey mode, cultural factors, macro-economic and legal frameworks, as well as small differences in the statements for the assessment of the three perceived resilience capacities (i.e., between the pilot and regular versions), we standardised all data by dividing each observation by a farming system's average, so that parameter values below or above 1 indicate that they are below or above the farming system's mean respectively. The reader should note that due to lack of data (e.g., indicators for resilience capacities) we did not use any additional statistical source for standardisation, but relied solely on the survey sample (see Fig. 2). Due to standardisation, we could not directly compare observations across different farming systems; we could only say, for instance, that they were above farming systems' means. Furthermore, due to standardisation, any variable does not represent a certain perceived level but a perceived level relative to its farming system's mean. For instance, a variable being below one indicates that its perceived level is below the farming system's mean, regardless if the farming system's mean is especially high or low.

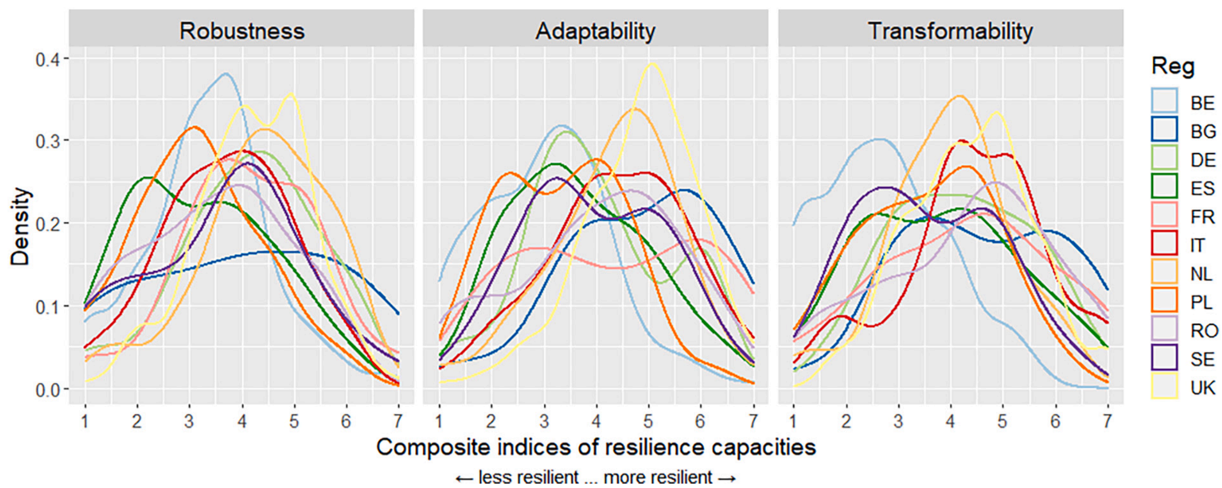

Fig. 2. Smoothened probability density functions for the composite indices of the three resilience capacities across farming systems.

4.2. Descriptive results

Fig. 2 displays the three perceived resilience capacities before standardisation across the eleven farming systems. The findings indicate great heterogeneity between the cases. For instance, the Spanish and Belgian farming systems are characterised with right-skewed distributions, especially for robustness and transformability. In contrast, the French and British farming systems show left-skewed distributions, especially for robustness and adaptability. Such difference between farming systems might be explained by heterogeneity in considered farming systems or patterns of perception and supports our decision to account for regional fixed effects. Within each farming system, however, the three density functions look similar and hint towards mutual relationship between the three resilience capacities.

Figs. 3 and 4 below illustrate non-standardised perceived relevance of a pre-defined list of challenges in the coming twenty years. Long-term economic stresses are perceived as most relevant, yet persistent extreme weather events and reduction in direct payments of the CAP are seen as equally important. Interestingly, perceptions of short-term market and input price fluctuations, low bargaining power against suppliers, strict regulations, as well as pest, weed or disease outbreaks display quite narrow distributions across all eleven farming systems. In contrast, perceived relevance of sick labour and limited availability of skilled labour are scored heterogeneously. The complete summary statistics of the survey sample can be found in Appendix 3.

4.3. Latent variable model for the three resilience capacities

We used a latent variable model[1] for analysis of the standardised data for the three resilience capacities (see, e.g., Hickendorff et al., 2018 for a methodological overview; and Palma et al., 2017, Novikova et al., 2017, Ikiz et al., 2018, and Wu et al., 2020 for recent examples of empirical application). Latent variable models are used to divide a heterogeneous set of observations into a number of homogeneous subclasses based on unobserved (latent) characteristics, which can reveal patterns in the subgroups (Hickendorff et al., 2018). Thus, this econometric technique allows identifying classes in terms of how farmers perceive resilience capacities and also explaining their class membership (Fig. 5). More specifically, we assumed that some latent (unobserved) variables explained the heterogeneity in the survey data regarding respondents' revealed combinations of the three perceived resilience capacities.

The latent variable analysis suggested the model specification EVE,2 (i.e., two classes with **E**qual volume, **V**arious density contours, **E**qual orientation in space) to be optimal for the follow-up analysis (Fig. 6; see Appendix 4 for greater details). The analysis of our data sample resulted in two groups of almost similar size (51% and 49%). The bigger group is characterised by values for all three resilience capacities above 1 with respective means of 1.11, 1.13, and 1.24 for standardised robustness, adaptability and transformability. Members of this group mostly perceive resilience capacities above their farming system's average. The other group is characterised by values for all three resilience capacities below 1, with respective means of 0.89, 0.86, and 0.76 for standardised robustness, adaptability and transformability. Members of this group mostly perceive resilience capacities below their farming system's average.

It is worthwhile to mention that due to very small differences in test statistics we also considered other model specifications of two or three classes, as documented in Appendix 4. These other model specifications were rejected due to too uneven distribution among groups, such that too small groups (less than 10% of the total survey sample) did not allow any further analysis. Yet, they led to similar mutual dependence between perceived resilience capacities, i.e., all three being below, above, or around the regional means.

4.4. Characteristics of lower and higher perceived-resilience groups

Having identified the two groups based on the combination of perceived resilience capacities, we compared them in terms of their other attributes, such as characteristics of farm and farmer (i.e., 'resilience of what'), perceived challenges (i.e., 'resilience to what'), perceived importance of functions (i.e., 'resilience for what purpose'), applied risk management strategies, openness to innovation, and involvement in networks (i.e., 'what enhances resilience'). Here, we emphasise again that when referring to values of a variable being lower (higher) in one of the groups, it is meant that the value of the standardised variable, i.e., relative to the farming system's mean, is lower (higher). We neither report nor compare farming systems' means. In order to compare distributions of each attribute among groups, we used nonparametric Mann-Whitney *U* test (also known as Mann-Whitney-Wilcoxon test or Wilcoxon rank-sum test). Low *p*-values (here, 0.10 is

[1] A latent variable model assumes that each class is centred around a mean with an increased density of observations near the mean. Yet, deriving classes in the data sample requires a number of initially unknown inputs, including the number of classes, as well as geometric features of classes (Celeux and Govaert, 1995). More specifically, volumes, shapes, and orientation can be equal (E) or varying among classes (V). In this regard, EEV stays for a model, which ensures that all the classes are of the same density (equal volume) and the similar density contours (equal shape), but their orientation in the space may vary.

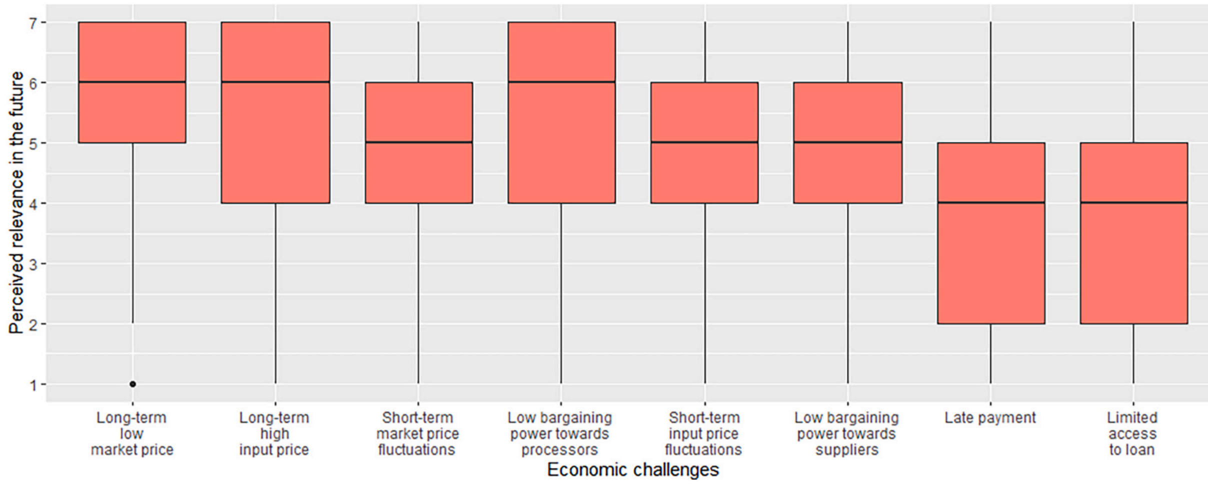

Fig. 3. Perceived relevance of pre-defined economic challenges in the next 20 years, ordered by mean average.
Note: Each box displays the first (the lower frame) and the third (the upper frame) quartiles, as well as the median (the horizontal line in the box).

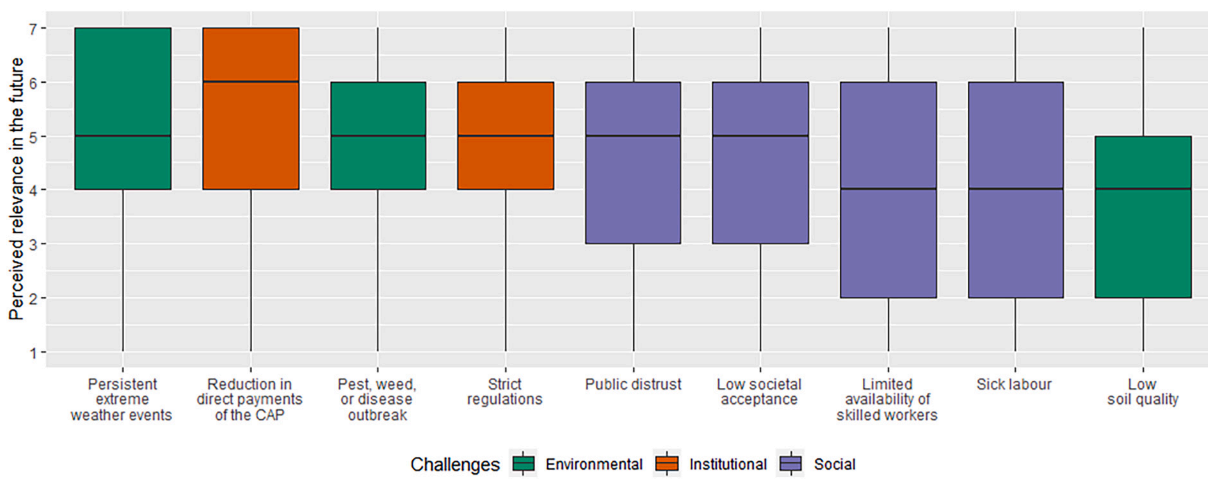

Fig. 4. Perceived relevance of pre-defined environmental, institutional, and social challenges in the next 20 years, ordered by mean average.
Note: Each box displays the first (the lower frame) and the third (the upper frame) quartiles, as well as the median (the horizontal line in the box).

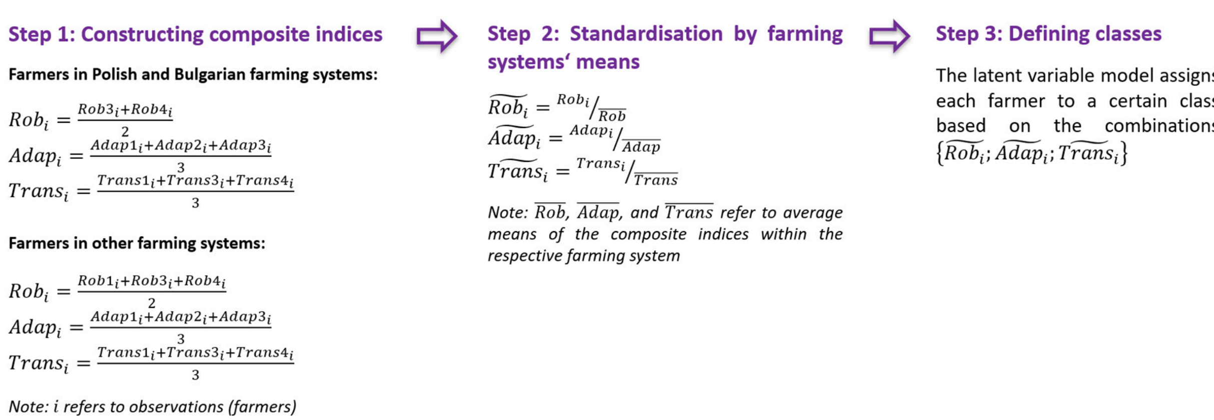

Fig. 5. Overview of the latent variable analysis.

assumed to be the threshold significance level) mean that the Null-hypothesis, i.e., the probability of X being greater than Y, is equal to the probability of Y being greater than X, can be rejected; in other words, the two compared distributions are different. The analysis indeed revealed a number of characteristics that distinguish the groups as presented below and in Fig. 7. The complete results of the Mann-Whitney *U* tests, as well as means and medians across each group, can be found in Appendix 5.

The group with perceived resilience capacities below farming system's average includes generally older, more risk-averse farmers with

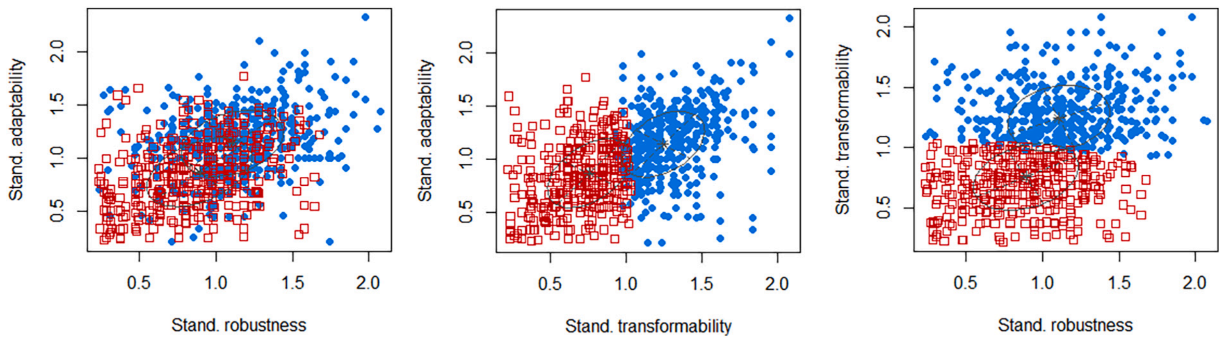

Fig. 6. Distribution of observations among two identified classes.

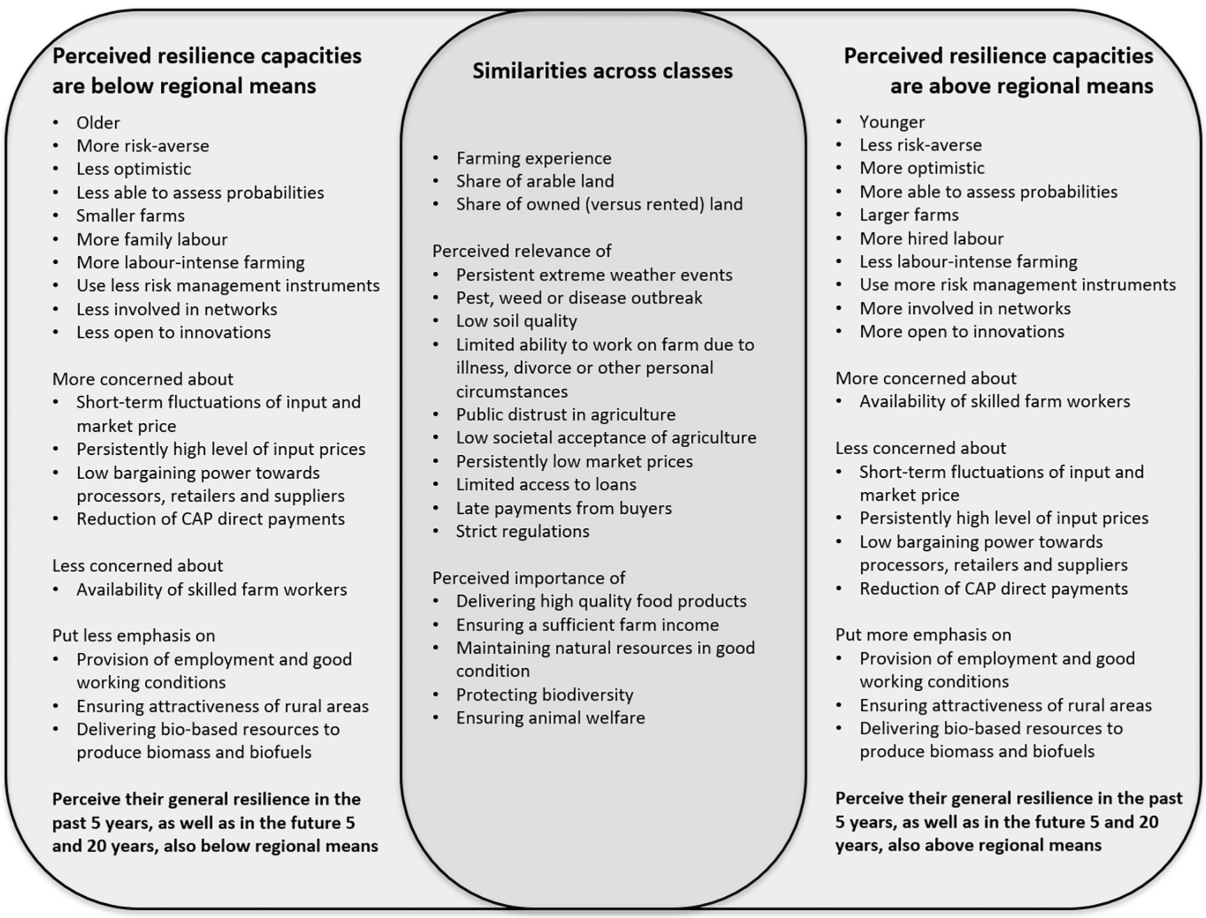

Fig. 7. Revealed differences and similarities across two classes.

rather pessimistic expectations about good years in the future and lower self-assessed ability to handle probabilities. The farms in this class are smaller, rely more on family labour and on more labour input per hectare (partly explained by smaller sizes of these farms). Farmers in this class are more concerned about short-term fluctuations and persistently high levels of input prices, short-term fluctuations of market prices, low bargaining power against processors, retailers and suppliers, as well as reductions of CAP direct payments. Furthermore, farmers in this group put less emphasis on the provision of public goods, in particular on the provision of employment and good working conditions for employees (probably due to a lower share of hired labour) and on ensuring attractiveness of rural areas for agro-tourism and residence, combined with less emphasis on delivering bio-based resources to produce biomass and biofuels. Farmers in this group assess themselves as less involved in networks and as rather reluctant towards innovations. The latter might explain that farmers in this group also have less concerns than the other group about limited availability of skilled farm workers. Finally, farmers from this group use less risk management instruments. Regarding general resilience, our results indicate that farmers with perceived resilience capacities below their farming system's average also score their past, current, and future general resilience below their farming system's respective average.

Although a significant difference in farmers' age between the two classes emerged, no significant difference could be found in terms of their farming experience, which indirectly hints towards farmers with perceived resilience above farming system's averages to enter farm business at younger age than farmers from the other group. Furthermore, no significant difference was identified in terms of share of arable land and share of owned (versus rented) land. Perception of many pre-defined challenges was similar across the two groups. This refers to all environmental challenges, the majority of social challenges, as well as half of economic and institutional challenges. The following challenges were perceived similarly in both groups: persistent extreme weather events; pest, weed or disease outbreak; low soil quality; limited ability to work on farm due to illness, divorce or other personal circumstances; public distrust in agriculture; low societal acceptance of agriculture; persistently low market prices; limited access to loans; late payments from buyers; and strict regulations. Furthermore, the probabilities of a bad year to happen were perceived similarly in both classes, although farmers with perceived resilience capacities above farming system's average were more optimistic regarding good years to occur. Finally, five out of eight pre-defined functions were perceived similarly important by respondents in both groups: delivering high quality food products, ensuring a sufficient farm income, maintaining natural resources in good condition, protecting biodiversity, and ensuring animal welfare. However, none of the pre-defined resilience attributes (i.e., risk management instruments, networks and openness to innovation) was found to be similar across the two groups.

5. Discussion and conclusion

Our explorative analysis provides insights into resilience capacities and its components as perceived by farmers across Europe. Based on a large-scale survey we identified two distinct groups with perceived resilience below and above their farming system's average. The distinctive attributes of the two groups are in line with previous research. More specifically, younger age (in line with Peerlings et al., 2014), lower risk aversion, more optimistic expectations, greater focus on provision of public goods, higher number of implemented risk management strategies, more active involvement in networks (in line with Smith et al., 2012), and openness to innovations (in line with Adger, 2000) were found to be linked to perceived resilience above the respective regional mean. Yet, the revealed associations raise further research questions about causal relationship. For instance, lower risk aversion might cause higher perceived resilience capacities; yet, it is also possible that a resilience-enhancing environment allows farmers to take more risks or that risk-prone farmers overestimate the resilience of their farm business. Previous research suggests that support for risk management (Spiegel et al., 2020), knowledge networks (van den Brink et al., 2014) and social learning (Karpouzoglou et al., 2016) are promising to improve resilience. These particular factors were also identified in our analysis as correlated with perceived resilience. Nevertheless, our results allow for the development and testing of hypotheses on determinants and outcomes of resilience perception. Future studies could investigate determinants of perceived resilience capacities, building on the set of factors that we have identified. If confirmed, these determinants would inform researchers and policy-makers on perceived resilience capacities based on observed characteristics of farms and farmers without conducting time- and effort-demanding assessments of perceived resilience capacities.

Next, our analysis gives ground for the idea that the three perceived resilience capacities – robustness, adaptability, and transformability – are mutually dependent and mutually reinforcing. This result implies that improving one resilience capacity might require improving the other two, and hence provides valuable insights for resilience-enhancing policies. For instance, adaptability or transformability in the longer term might require robustness in the short term. The result also leads to another interesting question, namely which resilience capacity would be employed to respond to a challenge. More specifically, it remains unclear what drives farmers to transform or adapt, or to enhance robustness, or to do nothing. Previous literature dealing with adaptation strategies and their determinants shed some light on this, e.g., claiming that behaviour depends on the type of challenge, as well as on an enabling or constraining environment (Meuwissen et al., 2020). Yet, there is still potential for further research, in particular with respect to perceptions and expectations of farmers. We would like to emphasise, however, that our analysis is focused on resilience capacities as perceived by farmers, who might not sharply distinguish between the three resilience capacities and hence scoring all three similarly. The same applies to perceived past, current, and future resilience capacities, as it might be fairly difficult to predict resilience capacities in 20 years from now, or one might simply extrapolate the presence into the future. Indeed, our reliability and validity tests revealed little difference between perceived resilience in five and in twenty years. It is also important to highlight that even those farmers who reported low resilience capacities in the past were still around. Yet, the fact that improving resilience capacities is perceived to take a long time, if confirmed in future research, would highlight the importance of immediate resilience-enhancing actions to cope with future challenges.

Finally, links between perception- and indicator-based resilience capacities remain unclear. Can we claim that farmers who *perceive* to have greater resilience will be indeed more resilient if challenges arrive or accumulate? Even if there are substantial discrepancies between different resilience assessments, farmers do respond to challenges based on their perceptions. Hence, the question is whether the perception to be resilient is an accurate assessment or whether it works, for example, as a self-fulfilling or a self-defeating prophecy. In this regard, perception-based resilience assessment is crucial, e.g., for simulating responses to resilience challenges. The debates on different methods for resilience assessment become even more relevant when referring to resilience dynamics. Indicator-based resilience assessments can mainly capture experienced resilience and use past observations to make inference about future resilience capacities. Perception-based resilience assessments might advance here by including perceptions and reasoning about the future. Yet, we again stress that perception-based resilience assessments shall be seen as complements to indicator-based assessments and vice versa. Although previous research has compared methods of resilience assessment, it has barely addressed resilience dynamics – and in particular interlinkages between different resilience capacities over time. We recommend focusing on the links between perception-based and indicator-based approaches and their impacts on decision- and policy-making. In particular, future research should investigate whether policies shall target resilience perceptions at all. Once links between the two methods of resilience assessments have been further elaborated, it might be easier to target and monitor resilience capacities based on retrospective indicators, knowing how exactly it would affect forward-looking perceived resilience.

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Declaration of Competing Interest

There is no conflict of interest.

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Appendix A. The survey

1. Your farm

Respondent number

For how many years have you run your own farm?	__ years
What is your main agricultural specialisation?	1☐ Crops 2☐ Horticulture 3☐ Dairy 4☐ Specialist pigs 5☐ Specialist poultry 6☐ Other grazing livestock (sheep, goats, beef, and cattle rearing and fattening) 7☐ Mixed activities 8☐ Other: ____________
How much livestock do you keep on your farm for commercial usage? Please indicate the number of animals you keep on your farm. In case you do not keep any livestock on your farm, please tick the box "No livestock on my farm".	☐ No livestock on my farm ___ sows ___ fattening pigs ___ dairy cows ___ fattening calves ___ fattening bulls ___ heifers (breeding or fattening) ___ broilers ___ laying hens ___ horses ___ sheep (including ewes) ___ goats Other: ___ _________ ___ _________
Is your farm conventional or organic?	1☐ Conventional 2☐ Organic 3☐ Converting from conventional to organic 4☐ Other: ____________
Which legal form is most applicable to your farm? [Local partners add here most relevant ownership types]	1☐ 2☐ 3☐ 4☐ 5☐ 6☐ Other: ____________
What is the total size of your farm? This includes both rented and owned land.	___ ha of land
Of which how many hectares are arable land?	___ ha of arable land
Of which how many hectares are pasture?	___ ha of pasture
How many hectares of land do you own?	___ ha of owned land
How many hectares of land do you rent?	___ ha of rented land
What is the average number of (unpaid) family members working on your farm? Please express in full time equivalents (FTE). A FTE corresponds to 8 working hours for each working day of the year.	___ FTE of unpaid family labour
What is the average number of workers you hire to work on your farm? Please express in full time equivalents (FTE). A FTE corresponds to 8 working hours for each working day of the year.	___ FTE of hired labour

2. Risk management strategies

Which of the following have you been implementing in **the last 5 years**? Please tick the boxes of **all** the risk management strategies you have been implementing in the last 5 years.

My on-farm strategies	
☐ Maintained financial savings for hard times	☐ Used market information to plan my farm activities for the next season
☐ Had low debts or no debts at all to prevent financial risks	☐ Diversified in production (e.g. mixed livestock and crop farming or a combination of several crops or animals)
☐ Invested in technologies (e.g. irrigation or hail nets) to control environmental risks	☐ Diversified in other activities on my farm (e.g. agri-tourism, on-farm sales, nature conservation, or renewable energies)
☐ Implemented measures to prevent pests or diseases (e.g. strict hygiene rules)	☐ Improved cost flexibility (e.g. renting land instead of buying, temporal labour contracts instead of permanent contracts)
☐ Worked harder to secure production in hard times	☐ Improved flexibility in the timing of my production (e.g. to deal with seasonality)
☐ Had an off-farm job (either myself or a family member)	☐ Opened up my farm to the public (e.g. open farm days)
☐ [CS specific on-farm strategy]	☐ [CS specific on-farm strategy]

My risk-sharing strategies with others	
☐ Cooperated with other farmers to secure inputs or production (e.g. buy inputs together, share machinery, or exchange land)	☐ Learned about challenges in agriculture (e.g. farmer group, consultant, or agricultural training)
☐ Member of a producer organisation, cooperative or credit union	☐ Bought any type of agricultural insurance [insert CS specific examples, e.g. crop, hail, yield, or livestock insurance]
☐ Member of an (inter)branch organisation (e.g. collaborate with value chain actors such as processors, retailers, and technology providers)	☐ Used production or marketing contracts to sell (part of) my production
☐ Had access to a variety of input suppliers (e.g. feed, seed, fertiliser, or finance suppliers)	☐ Hedged (part of) my production with futures contracts
☐ [CS specific risk sharing strategy	☐ [CS specific risk sharing strategy]

3. Future challenges in agriculture and strategies to deal with these challenges

1.

2.

3.

3a. Considering the **next 20 years**, what do you expect to be the 3 most important challenges on your farm?
3b. Considering the **next 20 years**, what do you expect to be your 3 most important strategies to deal with challenges on your farm?

1.

2.

3.

4. The essential functions of your farm

The following question asks you to distribute a total of 100 points between 9 potential functions of your farm. The more points you distribute to a function, the more important the function is for your farm. If a function is not important at all, then you should distribute 0 points to this function. How would you distribute 100 points among the following functions?

If you can think of an important function of your farm that is not listed below, you can add it under "Other, please specify" and distribute points to this function as well.

	Number of points
Deliver high quality food products	
Deliver bio-based resources (e.g. hemp, wood) to produce biomass and biofuels	
Ensure a sufficient farm income	
Provide employment and good working conditions for my employees	
Maintain natural resources (e.g. water, air, soil) in good condition	
Protect biodiversity	
Ensure the attractiveness of rural areas in terms of agro-tourism and residence	
Ensure animal welfare	
Other, please specify:	

Please check carefully if the total number of points adds up to 100.

5. Challenges in agriculture

Considering **the next 20 years**, to what extent do you think that the following events will be challenging for your farm? Please circle your answer on a scale of 1 (not challenging at all for my farm) to 7 (very challenging for my farm).

(1) Not challenging at all for my farm	(7) Very challenging for my farm
Price challenges	
Persistently high input prices (e.g. fertiliser, feed, seed)	1 - 2 - 3 - 4 - 5 - 6 - 7
Input price fluctuations (e.g. fertiliser, feed, seed)	1 - 2 - 3 - 4 - 5 - 6 - 7
Persistently low market prices	1 - 2 - 3 - 4 - 5 - 6 - 7
Market price fluctuations	1 - 2 - 3 - 4 - 5 - 6 - 7
Value chain challenges	
Low bargaining power towards processors and retailers	1 - 2 - 3 - 4 - 5 - 6 - 7
Low bargaining power towards input suppliers (e.g. fertiliser, feed, seed suppliers)	1 - 2 - 3 - 4 - 5 - 6 - 7
Financial challenges	
Limited access to loans from banks	1 - 2 - 3 - 4 - 5 - 6 - 7
Late payments from buyers	1 - 2 - 3 - 4 - 5 - 6 - 7
Production challenges	
Persistent extreme weather events (e.g. floods, droughts, frost)	1 - 2 - 3 - 4 - 5 - 6 - 7
Pest, weed, or disease outbreaks	1 - 2 - 3 - 4 - 5 - 6 - 7
Low soil quality	1 - 2 - 3 - 4 - 5 - 6 - 7
Personal and personnel challenges	
Limited availability of skilled farm workers	1 - 2 - 3 - 4 - 5 - 6 - 7
Limited ability to work on the farm due to illness, divorce or other personal circumstances	1 - 2 - 3 - 4 - 5 - 6 - 7
Institutional challenges	
Strict regulations (e.g. environmental, animal welfare, or competition)	1 - 2 - 3 - 4 - 5 - 6 - 7
Reduction in direct payments of the Common Agricultural Policy (CAP)	1 - 2 - 3 - 4 - 5 - 6 - 7
Societal challenges	
Public distrust in agriculture	1 - 2 - 3 - 4 - 5 - 6 - 7
Low societal acceptance of agriculture	1 - 2 - 3 - 4 - 5 - 6 - 7
Country specific challenges	
[CS specific challenge(s)]	1 - 2 - 3 - 4 - 5 - 6 - 7

6. The resilience of your farm

To deal with agricultural challenges, it is important that your farm is resilient. We distinguish three types of resilience.

6a. The first resilience type is robustness. This explains how well your farm **absorbs shocks and how likely it is that your farm recovers fast from these shocks.**

Example: *A baker wants to earn a decent income. Currently he faces extremely high wheat prices. The ability to earn a decent income, even when the wheat prices are extremely high, makes the baker robust.*

To what extent do you agree or disagree with the following statements? Please circle your answer on a scale of 1 (strongly disagree) to 7 (strongly agree).

(1) Strongly disagree	(7) Strongly agree
After something challenging has happened, it is easy for my farm to bounce back to its current profitability	1–2 - 3 - 4 - 5 - 6 - 7
As a farmer, it is hard to manage my farm in such a way that it recovers quickly from shocks	1–2 - 3 - 4 - 5 - 6 - 7
Personally I find it easy to get back to normal after a set back	1–2 - 3 - 4 - 5 - 6 - 7
A big shock will **not** heavily affect me, as I have enough options to deal with this shock on my farm	1–2 - 3 - 4 - 5 - 6 - 7

Example: *To deal with extremely high wheat prices, the baker adjusts his production strategy by changing the bread composition. He uses less wheat and more cheaper grains to produce his bread. This is adaptability.*

6b. The second resilience type is adaptability. This explains how easy you can **adjust or change your farm.**

To what extent do you agree or disagree with the following statements? Please circle your answer on a scale of 1 (strongly disagree) to 7 (strongly agree).

(1) Strongly disagree	(7) Strongly agree
If needed, my farm can adopt new activities, varieties, or technologies in response to challenging situations	1–2 - 3 - 4 - 5 - 6 - 7
As a farmer, I can easily adapt myself to challenging situations	1–2 - 3 - 4 - 5 - 6 - 7
In times of change, I am good at adapting myself and facing up to agricultural challenges	1–2 - 3 - 4 - 5 - 6 - 7
My farm is **not** flexible and can hardly be adjusted to deal with a changing environment	1–2 - 3 - 4 - 5 - 6 - 7

6c. The third resilience type is transformability. This explains how easy you can and how willing you are to **radically change or reorganise your farm.**

Example: *The baker thinks that it is time for a radical change. He decides to open a tearoom as part of his bakery. Next to selling bread, the baker serves coffee, tea, and cake to customers in his tearoom. This radical change shifts the business focus of his bakery. This is transformability.*

To what extent do you agree or disagree with the following statements? Please circle your answer on a scale of 1 (strongly disagree) to 7 (strongly agree).

(1) Strongly disagree	(7) Strongly agree
For me, it is easy to make decisions that result in a transformation	1–2 - 3 - 4 - 5 - 6 - 7
I am in trouble if external circumstances would drastically change, as it is hard to reorganise my farm	1–2 - 3 - 4 - 5 - 6 - 7
After facing a challenging period on my farm, I still have the ability to radically reorganise my farm	1–2 - 3 - 4 - 5 - 6 - 7
If needed, I can easily make major changes that would transform my farm	1–2 - 3 - 4 - 5 - 6 - 7

7. Network

To what extent do the following statements apply to you? Please circle your answer on a scale of 1 (does not apply to me at all) to 7 (strongly applies to me).

(1) Does not apply to me at all	(7) Strongly applies to me
I know a lot of other farmers in my region	1–2 - 3 - 4 - 5 - 6 - 7
Concerning farming, I often interact with neighboring farmers	1–2 - 3 - 4 - 5 - 6 - 7
Farmers in my region tend to support each other when there is a problem	1–2 - 3 - 4 - 5 - 6 - 7
I know a lot of agricultural professionals, experts, or value chain actors	1–2 - 3 - 4 - 5 - 6 - 7
When I attend agricultural events and meetings, I interact a lot with professionals, experts, or value chain actors	1–2 - 3 - 4 - 5 - 6 - 7
I feel I can receive support from agricultural professionals, experts, or value chain actors in my network	1–2 - 3 - 4 - 5 - 6 - 7

8. Innovation

To what extent do the following statements apply to you? Please circle your answer on a scale of 1 (does not apply to me at all) to 7 (strongly applies to me).

(1) Does not apply to me at all	(7) Strongly applies to me
Compared to other farmers, I am among the first to try out a new practice on my farm	1–2 - 3 - 4 - 5 - 6 - 7
I like to try out all kinds of new technologies or varieties	1–2 - 3 - 4 - 5 - 6 - 7

9. Your ability to cope with agricultural challenges

To what extent do you agree or disagree with the following statements? Please circle your answer on a scale of 1 (strongly disagree) to 7 (strongly agree).

(1) Strongly disagree	(7) Strongly agree
If I wanted to, it would be easy for me to deal with agricultural challenges on my farm	1–2 - 3 - 4 - 5 - 6 - 7
It is mostly up to me whether or not I can deal with the challenges on my farm	1–2 - 3 - 4 - 5 - 6 - 7
I have a lot of control about agricultural challenges affecting my farm	1–2 - 3 - 4 - 5 - 6 - 7
For me, it is difficult to deal with the challenges that affect my farm	1–2 - 3 - 4 - 5 - 6 - 7
I know a lot about agricultural challenges on my farm	1–2 - 3 - 4 - 5 - 6 - 7
If I consider the **last 5 years**, my farm has often experienced negative consequences of agricultural challenges	1–2 - 3 - 4 - 5 - 6 - 7
For the **next 5 years**, I expect my farm to be resilient to agricultural challenges	1–2 - 3 - 4 - 5 - 6 - 7
For the **next 20 years**, I expect my farm to be resilient to agricultural challenges	1–2 - 3 - 4 - 5 - 6 - 7

10. Handling probabilities

To what extent do you agree or disagree with the following statements? Please circle your answer on a scale of 1 (strongly disagree) to 7 (strongly agree).

(1) Strongly disagree	(7) Strongly agree
It is often helpful to see percentages on the weather forecast (e.g. a 45% chance on rain).	1–2 - 3 - 4 - 5 - 6 - 7
I am good in working with percentages.	1–2 - 3 - 4 - 5 - 6 - 7
Information expressed using numbers is often useful.	1–2 - 3 - 4 - 5 - 6 - 7
If the market price increases by 15%, I am good in figuring out what the new market price will be.	1–2 - 3 - 4 - 5 - 6 - 7

11. Bad and good years

11a. Bad years occur in farming. In a bad year, your yearly gross farm income is **at least 30% lower** than you expected.
Please express your answer as a percentage between 0% and 100%. The higher the percentage, the more likely it is that a bad year occurs.

How likely do you think it is that next year will be a bad year for your farm?	___ %
How likely do you think it is that your farm will face **one or more** bad year(s) in the coming **10 years?**	___ %

11b. Good years also occur in farming. In a good year, your yearly gross farm income is **at least 30% higher** than you expected.
Please express your answer as a percentage between 0% and 100%. The higher the percentage, the more likely it is that a good year occurs.

How likely do you think it is that next year will be a good year for your farm?	___ %
How likely do you think it is that your farm will face **one or more** good year(s) in the coming **10 years**?	___ %

12. Willingness to take risks

12a. How do you see yourself: are you generally a person who is fully prepared to take risks or do you try to avoid taking risks? Please circle your answer on a scale of 0 (not at all willing to take risks) to 10 (very willing to take risks).

(0) Not at all willing to take risks	(10) Very willing to take risks
0–1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 - 10	

12b. To what extent do you agree or disagree with the following statements? Please circle your answer on a scale of 1 (strongly disagree) to 7 (strongly agree).
I am willing to take **more** risks than other farmers in terms of...

(1) Strongly disagree	(7) Strongly agree
Production	1–2 - 3 - 4 - 5 - 6 - 7
Marketing and prices	1–2 - 3 - 4 - 5 - 6 - 7
Financial risks	1–2 - 3 - 4 - 5 - 6 - 7
Innovation	1–2 - 3 - 4 - 5 - 6 - 7
Farming in general	1–2 - 3 - 4 - 5 - 6 - 7

13. Education and other personal information

What is your year of birth?	_ _ _ _
What is your gender?	☐ Male
	☐ Female
What is your expectation for the succession of your farm?	☐ I have no expectations
	☐ I expect a family member to take over the farm (e.g. son, daughter, brother)
	☐ I expect to sell the property

(*continued on next page*)

(*continued*)

	☐ I expect to give up the tenancy ☐ Other, please specify________
What is your highest completed educational degree? [Farming system-tailored scale should be added]	☐ No education ☐ Primary school ☐ Secondary school ☐ Undergraduate ☐ Graduate
Did you complete any agricultural education or training?	☐ Yes ☐ No

This is the end of the questionnaire. Please check carefully if you have answered all questions. Thank you very much for your participation! If you want to receive a summary of the questionnaire results, please leave your email address below.

Email address: ____

Appendix B. Reliability and validity of Likert-scale items

Likert-scale item batteries served as a basis for composite indices of respective parameters, e.g., for current robustness, adaptability, and transformability, as well as current, past, and future resilience. More specifically, we calculated means of the respective statements. To test the reliability and validity of our measurement model for robustness, adaptability and transformability, we used confirmatory factor analysis and divided our sample over all respondents from Bulgaria and Poland on the one hand, and the 9 other countries on the other hand. This was done because in Bulgaria and Poland, a pilot version of the survey was administered, after which some, albeit minor, changes to the 12 items were made. For this reason, the data from Bulgaria and Poland cannot be combined into a single confirmatory factor analysis. For both separate datasets, we calculated a number of fitness indices for model fit, convergent validity and discriminant validity and evaluated these values against standard threshold for good validity and reliability (Hair et al., 2010; Malhotra and Dash, 2011). For the 9 countries, Table 4 shows the reliability and validity of the proposed item structure. It is clear that this model suffers from both convergent validity and discriminant validity issues. Composite reliability (CR) of both robustness and adaptability is below 0.50, while average variance extracted (AVE) for transformability and adaptability islower than the maximum shared variance (MSV), and both transformability and adaptability have higher correlation with another factor than the square root of their AVE. This indicates convergent validity problems for robustness and adaptability, as well as problems in discriminating transformability from adaptability. Additionally, this model has only mediocre model fit.

Table 4
Validity and reliability of the proposed item structure (9 countries).

	CR	AVE	MSV	MaxR(H)	R	T	A
R	0.706	0.402	0.355	0.769	0.634		
T	0.778	0.490	0.536	0.847	0.491	0.700	
A	0.812	0.531	0.536	0.867	0.596	0.732	0.729

X^2/df = 5.700 (p = 0.000); CFI = 0.939; RMSEA = 0.072.
R = Robustness; A = Adaptability; T = Transformability; CR = composite reliability; AVE = average variance extracted; MSV = maximum shared variance; MaxR(H) = maximum reliability.

All items with low factor loadings were gradually removed and after each step, the validity and reliability were checked. Inspection of the factor loadings suggest problems with all three negatively worded items (Rob2, Adap4 and Trans2). After removal of these items, the validity and reliability were confirmed (Table 5).

Table 5
Validity and reliability of the final item structure (9 countries).

	CR	AVE	MSV	MaxR(H)	R	T	A
R	0.763	0.518	0.342	0.766	0.719		
T	0.831	0.622	0.506	0.847	0.476	0.789	
A	0.845	0.647	0.506	0.869	0.585	0.711	0.804

X^2/df = 3.368 (p = 0.000); CFI = 0.984; RMSEA = 0.051.
R = Robustness; A = Adaptability; T = Transformability; CR = composite reliability; AVE = average variance extracted; MSV = maximum shared variance; MaxR(H) = maximum reliability.

For Poland and Bulgaria, the proposed item structure suffered from the same validity and reliability problems (Table 6). There is a convergent validity issue for R and the AVE is too small (less than 0.05). There are discriminant validity issues with all three constructs, with all three having an AVE which is less than its MSV, and correlations with another construct which is higher than the square root of its AVE.

Table 6
Validity and reliability tests for initial hypothesized item structure (Poland and Bulgaria).

	CR	AVE	MSV	MaxR(H)	T	R	A
T	0.767	0.529	0.630	0.907	0.727		
R	0.726	0.425	0.630	0.836	0.794	0.652	
A	0.837	0.570	0.627	0.891	0.792	0.713	0.755

X^2/df = 1.948 (p = 0.000); CFI = 0.918; RMSEA = 0.098.
R = Robustness; A = Adaptability; T = Transformability; CR = composite reliability; AVE = average variance extracted; MSV = maximum shared variance; MaxR(H) = maximum reliability.

We gradually removed items with low factor loadings and continued checking validity and reliability using the same method. Also, here, the items that were negatively worded had factor loadings that were too low or did not discriminate enough between constructs. Additionally, item Rob1 had to be removed as well; so, the final item structure here is a model where robustness measured by Rob2 and Rob3, adaptability by Adap1, Adap2 and Adap3, and transformability by Trans1, Trans 3 and Trans4 produced adequate validity and reliability (Table 7).

Table 7
Validity and reliability of the final measurement model. (Poland and Bulgaria).

	CR	AVE	MSV	MaxR(H)	T	R	A
T	0.877	0.705	0.635	0.908	0.840		
R	0.816	0.690	0.615	0.830	0.784	0.831	
A	0.846	0.650	0.635	0.880	0.797	0.712	0.806

X^2/df = 1.550 (p = 0.068); CFI = 0.981; RMSEA = 0.075.
R = Robustness; A = Adaptability; T = Transformability; CR = composite reliability; AVE = average variance extracted; MSV = maximum shared variance; MaxR(H) = maximum reliability.

The same tests for other variables generated the following results: For the composite index of current general resilience, only Resilience1, Resilience2, and Resilience3 shall be used, while Resilience4 (a negatively worded item) and Resilience5 (an item about general knowledge about challenges at the farm) shall be removed. As for future general resilience, the reliability and validity tests revealed no difference between Resilience7 (an item concerning the next 5 years) and Resilience8 (an item concerning the next 20 years).

Appendix C. Summary statistics

	Variable definition as in the survey	Mean (st.dev.) in the sample	References
Farmer's characteristics			
	Age, years	50.50 (12.45)	
	Farming experience, years	24.32 (14.16)	
	Share of male farmers	90%	
(Tailored scale for each farming system with 1 being the lowest level of education, or no education, and 6 being the highest level of education)			
	Education level 1, share of farmers	6%	
	Education level 2, share of farmers	9%	
	Education level 3, share of farmers	36%	
	Education level 4, share of farmers	26%	
	Education level 5, share of farmers	21%	
	Education level 6, share of farmers	3%	
	Share of farmers having completed any agricultural education or training	73%	
Farm's characteristics			
	Share of farmers having no succession expectations	25%	
	Share of farmers expecting a family member to take over the farm (e.g. son, daughter, brother)	49%	
	Share of farmers expecting to sell the property	6%	
	Share of farmers expecting to give up the tenancy	3%	
	Share of farmers having other succession expectations	18%	
	Share of farms specialized on crops	31%	
	Share of farms specialized on horticulture	3%	
	Share of farms specialized on dairy livestock	17%	
	Share of farms specialized on pigs	0%	
	Share of farms specialized on poultry	0%	
	Share of farms specialized on other grazing livestock (sheep, goats, beef, and cattle rearing and fattening)	6%	
	Share of farms specialized on mixed activities	29%	
	Share of farms having other agricultural specialisation	13%	
	Share of farms having no livestock	29%	
	Number of livestock units per farm (among farms having livestock)	154.81 (372.06)	
	Number of livestock units per hectare (among farms having livestock)	3.93 (23.14)	
	Share of conventional farms	93%	
	Share of organic farms	5%	
	Share of farms converting from conventional to organic	1%	
	Share of farms with other farming practices	1%	
	Size, hectares	244.87 (558.59)	

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	Variable definition as in the survey	Mean (st.dev.) in the sample	References
	Share of arable land	74%	
	Share of pastures	26%	
	Share of owned land	55%	
	Share of rented land	45%	
	Family labour per farm, full time equivalents (FTE). One FTE corresponds to 8 working hours for each working day of the year	14.30 (71.72)	
	Hired labour per farm, FTE	9.23 (51.51)	
Major challenges in the next 20 years (1 = not challenging at all for my farm … 7 = very challenging for my farm)			
Economic	Persistently low market prices	5.61 (1.54)	Meuwissen et al., 2001, Flaten et al., 2005, Lien et al., 2006, Van Winsen et al., 2016, Meraner and Finger, 2019
	Persistently high input prices (e.g. fertiliser, feed, seed)	5.23 (1.59)	
	Market price fluctuations	5.22 (1.47)	
	Low bargaining power towards processors and retailers	5.16 (1.72)	
	Input price fluctuations (e.g., fertiliser, feed, seed)	4.82 (1.59)	
	Low bargaining power towards input suppliers (e.g., fertiliser, feed, seed suppliers)	4.77 (1.72)	
	Limited access to loans from banks	3.58 (1.88)	
	Late payments from buyers	3.64 (1.87)	
Environmental	Persistent extreme weather events (e.g., floods, droughts, frost)	5.24 (1.56)	
	Pest, weed, or disease outbreaks	4.92 (1.65)	
	Low soil quality	3.91 (1.79)	
Institutional	Reduction in direct payments of the Common Agricultural Policy (CAP)	5.17 (1.88)	
	Strict regulation (e.g., environmental, animal welfare, or competition)	4.84 (1.84)	
Social	Public distrust in agriculture	4.72 (1.88)	
	Low societal acceptance of agriculture	4.53 (1.94)	
	Limited availability of skilled farm workers	3.97 (2.14)	
	Limited ability to work on the farm due to illness, divorce or other personal circumstances	3.95 (1.97)	
Functions (Distribute 100 points among the pre-defined functions; the more points are assigned, the more important the function is)			
Private goods	Deliver high quality food products	25.69 (17.37)	
	Deliver bio-based resources (e.g., hemp, wood) to produce biomass and biofuels	2 (5.39)	
	Ensure a sufficient farm income	31.59 (20.84)	
Public goods	Provide employment and good working conditions for employees	6.95 (9.14)	
	Maintain natural resources (e.g. water, air, soil) in good condition	10.93 (9.81)	
	Protect biodiversity	6.95 (7.01)	
	Ensure the attractiveness of rural areas in terms of agro-tourism and residence	3.69 (5.59)	
	Ensure animal welfare	10.98 (12.37)	
Risk literacy (1 – strongly disagree … 7 – strongly agree)			
	It is often helpful to see percentages on the weather forecast (e.g. a 45% chance on rain)	5.37 (1.62)	
	I am good in working with percentages	5.17 (1.54)	
	Information expressed using numbers is often useful	5.53 (1.42)	
	If the market price increases with 15%, I am good in figuring out what the new market price will be	5.57 (1.48)	
Risk preferences			
Self-assessment question (0 – not at all willing to take risks … 10 – very willing to take risks)			
	How do you see yourself: are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?	5.65 (2.36)	Dohmen et al., 2011
Business statements (1 – strongly disagree … 7 – strongly agree)			
	I am willing to take more risks than other farmers in terms of production	4.23 (1.6)	Meuwissen et al., 2001, Meraner and Finger, 2019
	I am willing to take more risks than other farmers in terms of marketing and prices	4.06 (1.59)	
	I am willing to take more risks than other farmers in terms of financial risks	3.67 (1.73)	
	I am willing to take more risks than other farmers in terms of innovation	4.27 (1.73)	
	I am willing to take more risks than other farmers in terms of farming in general	4.34 (1.53)	
Probabilities of a 'good' (i.e., yearly gross farm income is at least 30% higher than expected) and a 'bad' (i.e., yearly gross farm income is at least 30% lower than expected) year to happen (0%–100%)			
	How likely do you think it is that next year will be a bad year for your farm?	42.7 (20.34)	Based on the OECD definition of "severe loss" (e.g., Finger and El Benni, 2014)
	How likely do you think it is that your farm will face one or more bad year(s) in the coming 10 years?	59.08 (26.2)	
		46.01 (21.39)	

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	Variable definition as in the survey	Mean (st.dev.) in the sample	References
	How likely do you think it is that next year will be a good year for your farm?		
	How likely do you think it is that your farm will face one or more good year(s) in the coming 10 years?	59.38 (25.68)	
Resilience capacities *(1 – strongly disagree … 7 – strongly agree)*			
Robustness	After something challenging has happened, it is easy for my farm to bounce back to its current profitability	3.74 (1.53)	
	As a farmer, it is hard to manage my farm in such a way that it recovers quickly from shocks	4.14 (1.62)	
	Personally I find it easy to get back to normal after a set back	3.82 (1.57)	
	A big shock will **not** heavily affect me, as I have enough options to deal with this shock on my farm	3.56 (1.7)	
Adaptability	If needed, my farm can adopt new activities, varieties, or technologies in response to challenging situations	3.65 (1.82)	
	As a farmer, I can easily adapt myself to challenging situations	3.94 (1.7)	
	In times of change, I am good at adapting myself and facing up to agricultural challenges	4.21 (1.59)	
	My farm is not flexible and can hardly be adjusted to deal with a changing environment	3.67 (1.73)	
Transformability	For me, it is easy to make decisions that result in a transformation	3.88 (1.79)	
	I am in trouble if external circumstances would drastically change, as it is hard to reorganise my farm	4.07 (1.74)	
	After facing a challenging period on my farm, I still have the ability to radically reorganise my farm	3.88 (1.69)	
	If needed, I can easily make major changes that would transform my farm	3.67 (1.75)	
Current general resilience	If I wanted to, it would be easy for me to deal with agricultural challenges on my farm	4.2 (1.52)	
	It is mostly up to me whether or not I can deal with the challenges on my farm	4.91 (1.64)	
	I have a lot of control about agricultural challenges affecting my farm	4.08 (1.67)	
	For me, it is difficult to deal with the challenges that affect my farm	3.79 (1.61)	
	I know a lot about agricultural challenges on my farm	4.89 (1.46)	
	If I consider the last 5 years, my farm has often experienced negative consequences of agricultural challenges	4.16 (1.68)	
Past resilience	For the next 5 years, I expect my farm to be resilient to agricultural challenges	4.67 (1.48)	
	For the next 20 years, I expect my farm to be resilient to agricultural challenges	4.4 (1.59)	
Risk management strategies *(=1 if applied in the last 5 years; =0 otherwise; we report share of farms having applied each risk management strategy)*			
On-farm risk management strategies	Maintained financial savings for hard times	55%	Meuwissen et al., 2001, Flaten et al., 2005, Lien et al., 2006, Van Winsen et al., 2016, Meraner and Finger, 2019,
	Had low debts or no debts at all to prevent financial risks	46%	
	Invested in technologies (e.g. irrigation or hail nets) to control environmental risks	34%	
	Implemented measures to prevent pests or diseases (e.g. strict hygiene rules)	56%	
	Worked harder to secure production in hard times	59%	
	Had an off-farm job (either myself or a family member)	34%	
	Used market information to plan my farm activities for the next season	44%	
	Diversified in production (e.g. mixed livestock and crop farming or a combination of several crops or animals)	37%	
	Diversified in other activities on my farm (e.g. agri-tourism, on-farm sales, nature conservation, or renewable energies)	32%	
	Improved cost flexibility (e.g. renting land instead of buying, temporal labour contracts instead of permanent contracts)	25%	
	Improved flexibility in the timing of my production (e.g. to deal with seasonality)	31%	
	Opened up my farm to the public (e.g. open farm days)	14%	
Risk-sharing strategies	Cooperated with other farmers to secure inputs or production (e.g. buy inputs together or share machinery with other farmers)	36%	
	Member of a producer organisation, cooperative or credit union	48%	
	Member of an (inter)branch organisation (e.g. collaborate with value chain actors such as processors, retailers, and technology providers)	16%	
	Had access to a variety of input suppliers (e.g. feed, seed, fertiliser, or finance suppliers)	49%	
	Learned about challenges in agriculture (e.g. farmer group, consultant, or agricultural training)	49%	
	Bought any type of agricultural insurance	33%	
	Used production or marketing contracts to sell (part of) my production	30%	
	Hedged (part of) my production with futures contracts	20%	
Involvement into networks			

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	Variable definition as in the survey	Mean (st.dev.) in the sample	References
(1 – does not apply to me at all … 7 – strongly applies to me)			
Informal	I know a lot of other farmers in my region	5.61 (1.39)	Schneider et al., 2012, Sol et al., 2013, Moschitz et al., 2015, Hunecke et al., 2017
	Concerning farming, I often interact with neighboring farmers	5.08 (1.61)	
	Farmers in my region tend to support each other when there is a problem	4.41 (1.72)	
Formal	I know a lot of agricultural professionals, experts, or value chain actors	4.97 (1.59)	
	When I attend agricultural events and meetings, I interact a lot with professionals, experts, or value chain actors	4.68 (1.72)	
	I feel I can receive support from agricultural professionals, experts, or value chain actors in my network	4.78 (1.67)	
Openness to innovations			
(1 – does not apply to me at all … 7 – strongly applies to me)			
	Compared to other farmers, I am among the first to try out a new practice on my farm	4.04 (1.75)	
	I like to try out all kinds of new technologies or varieties	4.17 (1.79)	

Appendix D. Choice of the latent variable model and definition of classes

The analytical approach suggests constructing multiple latent variable models with different parameters and comparing them, e.g., based on the Bayesian Information Criterion (BIC) and the Integrated Completed Likelihood (ICL) criterion. Both criteria quantify goodness-of-fit of a model and are hence used for model selection, including the selection of optimal number of classes (Schwarz, 1978; Biernacki et al., 2000). Our analysis was conducted using the *mclust* package in R (the R code is available in supplementary materials), which is designed for latent variable analysis of continuous data (Fraley et al., 2012). We started with comparing different model specifications with 1 to 9 classes based on Bayesian Information Criteria (BIC) and Integrated Completed Likelihood (ICL). Both BIC and ICL suggest a range of model specifications with 1–3 classes under Top-3 and rather small differences in BIC and ICL between the model specifications (Table 8).

Table 8
Comparison of the three best model specifications w.r.t. Bayesian Information Criteria and Integrated Completed Likelihood.

Best Bayesian Information Criteria values:				Best Integrated Completed Likelihood values:			
	VVE,2	VVV,2	EVE,3		EEE,1 / EVE,1 / VEE,1 / VVE,1 / EEV,1 / VEV,1 / EVV,1 / VVV,1	VEV,2	VEV,3
BIC	−1629.39	−1641.18	−1659.02	ICL	−1691.98	−1711.63	−1829.84

Note: the model specifications should be read as follows:

- The first letter stays for the volume (E – equal; V – variable);
- The second letter stays for the shape of the density contours (E – equal; V – variable);
- The third letter stays for the orientation of the covariances (E – equal; V – variable);
- The number after comma stays for the number of classes.

We did not consider model specifications VVE and VVV, since both score low in terms of ICL for two or more classes (beyond Table 8). Due to little difference in BIC and ICL across model specifications, we compared both VEV and EVE in terms of constructed classes and possibility for follow-up analysis. In order to confirm the optimal number of classes for a particular model specification, we carried out a likelihood ratio test (LRT) comparing a model specification with n classes against the same model specification with $n + 1$ classes; more specifically, we used bootstrap to obtain the null distribution of the LRT statistics (LRTS) (Mclachlan, 1987). The procedure resamples LRTS from the fitted model with replacement from the observed data and outputs a p-value for the LRTS. Low p-values (here, 10% is assumed to be the threshold significance level) indicate that a model with $n + 1$ classes cannot be rejected to fit better.

The bootstrap procedure indicated that three classes could not be rejected for both model specifications. Yet, both VEV,2 and VEV,3 output too unequal distribution among classes (95.4% - 4.6% for 2 classes; 92% - 4.5% - 3.5% for 3 classes), which would not allow any follow-up comparison of the classes. The same holds for EVE,3 (78.2% - 12% - 9.8%). In this regard, EVE,2 was selected for follow-up analysis.

Appendix E. Results of the Mann-Whitney *U* tests

All tests and calculations were performed to standardised values, i.e., values relative to the mean average of the respective farming system. Hence, a value above one means that it is above the farming system's average; and vice versa. Low p-values (here, 0.10 is assumed to be the threshold significance level) mean that the Null-hypothesis, i.e., the probability of X being greater than Y is equal to the probability of Y being greater than X, can be rejected.

General resilience.

	Class	
	Above average	Below average
Current resilience *(the higher the more resilient)*		

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	Class	
	Above average	Below average
Mean	1.10	0.89
Median	1.08	0.90
p-value of Mann-Whitney U test	0.00	
Resilience in the last 5 years *(the higher the more resilient)*		
Mean	1.06	0.94
Median	1.04	1.00
p-value of Mann-Whitney U test	0.00	
Resilience in the next 5 years *(the higher the more resilient)*		
Mean	1.07	0.93
Median	1.07	0.95
p-value of Mann-Whitney U test	0.00	
Resilience in the next 20 years *(the higher the more resilient)*		
Mean	1.07	0.93
Median	1.12	0.90
p-value of Mann-Whitney U test	0.00	

Risk preferences.

	Classes	
	Above average	Below average
General risk preferences *(the higher the more risk-loving / less risk-averse)*		
Mean	1.08	0.91
Median	1.14	0.98
p-value of Mann-Whitney U test	0.00	
Risk preferences relative to other farmers in terms of production *(the higher the more risk-loving / less risk-averse)*		
Mean	1.09	0.90
Median	1.09	0.94
p-value of Mann-Whitney U test	0.00	
Risk preferences relative to other farmers in terms of marketing and prices *(the higher the more risk-loving / less risk-averse)*		
Mean	1.08	0.91
Median	1.11	0.92
p-value of Mann-Whitney U test	0.00	
Risk preferences relative to other farmers in terms of financial risks *(the higher the more risk-loving / less risk-averse)*		
Mean	1.1	0.89
Median	1.15	0.88
p-value of Mann-Whitney U test	0.00	
Risk preferences relative to other farmers in terms of innovation *(the higher the more risk-loving / less risk-averse)*		
Mean	1.11	0.89
Median	1.1	0.83
p-value of Mann-Whitney U test	0.00	
Risk preferences relative to other farmers in terms of farming in general *(the higher the more risk-loving / less risk-averse)*		
Mean	1.09	0.9
Median	1.13	0.95
p-value of Mann-Whitney U test	0.00	

Farmer characteristics.

	Classes	
	Above average	Below average
Age *(the higher the older)*		
Mean	0.99	1.01
Median	1.00	1.03

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	Classes	
	Above average	Below average
p-value of Mann-Whitney U test	0.05	
Farming experience		
(the higher the longer)		
Mean	0.99	1.01
Median	0.98	0.96
p-value of Mann-Whitney *U* test	0.87	
Ability to handle probabilities		
(the higher the more able)		
Mean	1.03	0.97
Median	1.06	1.00
p-value of Mann-Whitney U test	0.00	

Farm characteristics.

	Classes	
	Above average	Below average
Share of arable land		
(the higher the greater)		
Mean	1.00	1.00
Median	1.09	1.09
p-value of Mann-Whitney U test	0.54	
Share of owned land versus rented		
(the higher the greater)		
Mean	0.98	1.03
Median	1.11	1.11
p-value of Mann-Whitney U test	0.47	
Farm size in acreage		
(the higher the bigger)		
Mean	1.17	0.82
Median	0.75	0.67
p-value of Mann-Whitney U test	0.01	
Share of family labour versus hired		
(the higher the greater)		
Mean	0.94	1.08
Median	1.05	1.05
p-value of Mann-Whitney U test	0.01	
Use of labour per hectare		
(the higher the more)		
Mean	0.97	1.03
Median	0.69	0.81
p-value of Mann-Whitney U test	0.01	

Economic challenges.

	Classes	
	Above average	Below average
Persistently high input prices (e.g. fertiliser, feed, seed)		
(the higher the more challenging)		
Mean	0.96	1.04
Median	1.04	1.04
p-value of Mann-Whitney U test	0.00	
Input price fluctuations (e.g., fertiliser, feed, seed)		
(the higher the more challenging)		
Mean	0.96	1.04
Median	0.98	1.06
p-value of Mann-Whitney U test	0.00	
Persistently low market prices		
(the higher the more challenging)		
Mean	0.99	1.01
Median	1.04	1.08
p-value of Mann-Whitney U test	0.32	

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	Classes	
	Above average	Below average
Market price fluctuations		
(the higher the more challenging)		
Mean	0.98	1.02
Median	0.96	1.06
p-value of Mann-Whitney U test	0.01	
Low bargaining power towards processors and retailers		
(the higher the more challenging)		
Mean	0.97	1.03
Median	1.02	1.14
p-value of Mann-Whitney U test	0.00	
Low bargaining power towards input suppliers (e.g., fertiliser, feed, seed suppliers)		
(the higher the more challenging)		
Mean	0.98	1.02
Median	0.98	1.03
p-value of Mann-Whitney U test	0.06	
Limited access to loans from banks		
(the higher the more challenging)		
Mean	1.01	0.99
Median	1.03	0.99
p-value of Mann-Whitney U test	0.89	
Late payments from buyers		
(the higher the more challenging)		
Mean	1.01	0.99
Median	1.03	1.03
p-value of Mann-Whitney U test	0.61	

Social challenges.

	Classes	
	Above average	Below average
Limited availability of skilled farm workers		
(the higher the more challenging)		
Mean	1.05	0.95
Median	1.11	0.94
p-value of Mann-Whitney U test	0.00	
Limited ability to work on the farm due to illness, divorce or other personal circumstances		
(the higher the more challenging)		
Mean	0.98	1.02
Median	0.99	1.00
p-value of Mann-Whitney U test	0.20	
Public distrust in agriculture		
(the higher the more challenging)		
Mean	0.99	1.01
Median	1.06	1.06
p-value of Mann-Whitney U test	0.48	
Low societal acceptance of agriculture		
(the higher the more challenging)		
Mean	0.99	1.01
Median	1.03	1.03
p-value of Mann-Whitney U test	0.61	

Environmental challenges.

	Classes	
	Above average	Below average
Persistent extreme weather events (e.g., floods, droughts, frost)		
(the higher the more challenging)		
Mean	1.01	0.99
Median	1.02	1.02
p-value of Mann-Whitney U test	0.40	

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	Classes	
	Above average	Below average
Pest, weed, or disease outbreaks		
(the higher the more challenging)		
Mean	0.99	1.01
Median	1.04	1.08
p-value of Mann-Whitney U test	0.33	
Low soil quality		
(the higher the more challenging)		
Mean	1.00	1.00
Median	1.02	1.02
p-value of Mann-Whitney U test	0.86	

Institutional challenges.

	Classes	
	Above average	Below average
Strict regulation (e.g., environmental, animal welfare, or competition)		
(the higher the more challenging)		
Mean	0.99	1.01
Median	0.95	1.12
p-value of Mann-Whitney U test	0.18	
Reduction in direct payments of the Common Agricultural Policy (CAP)		
(the higher the more challenging)		
Mean	0.96	1.04
Median	1.01	1.13
p-value of Mann-Whitney U test	0.00	

Optimistic and pessimistic expectations.

	Classes	
	Above average	Below average
How likely do you think it is that next year will be a bad year for your farm?		
(the higher the greater the probability)		
Mean	0.97	1.03
Median	1.04	1.04
p-value of Mann-Whitney U test	0.32	
How likely do you think it is that your farm will face one or more bad year(s) in the coming 10 years?		
(the higher the greater the probability)		
Mean	0.99	1.02
Median	0.95	0.98
p-value of Mann-Whitney U test	0.27	
How likely do you think it is that next year will be a good year for your farm?		
(the higher the greater the probability)		
Mean	1.05	0.95
Median	1.03	0.97
p-value of Mann-Whitney U test	0.01	
How likely do you think it is that your farm will face one or more good year(s) in the coming 10 years?		
(the higher the greater the probability)		
Mean	1.04	0.96
Median	1.03	0.95
p-value of Mann-Whitney U test	0.02	

Functions.

	Classes	
	Above average	Below average
Deliver high quality food products		
(the higher the more important)		
Mean	0.99	1.01

(*continued on next page*)

(*continued*)

	Classes	
	Above average	Below average
Median	0.89	0.93
p-value of Mann-Whitney *U* test	0.42	
Deliver bio-based resources (e.g., hemp, wood) to produce biomass and biofuels		
(the higher the more important)		
Mean	1.27	0.71
Median	0.00	0.00
p-value of Mann-Whitney U test	0.00	
Ensure a sufficient farm income		
(the higher the more important)		
Mean	0.97	1.03
Median	0.87	0.98
p-value of Mann-Whitney U test	0.12	
Provide employment and good working conditions for employees		
(the higher the more important)		
Mean	1.12	0.87
Median	0.60	0.00
p-value of Mann-Whitney U test	0.00	
Maintain natural resources (e.g. water, air, soil) in good condition		
(the higher the more important)		
Mean	1.02	0.98
Median	0.90	0.89
p-value of Mann-Whitney U test	0.19	
Protect biodiversity		
(the higher the more important)		
Mean	1.02	0.97
Median	0.98	0.81
p-value of Mann-Whitney U test	0.24	
Ensure the attractiveness of rural areas in terms of agro-tourism and residence		
(the higher the more important)		
Mean	1.10	0.89
Median	0.00	0.00
p-value of Mann-Whitney U test	0.02	
Ensure animal welfare		
(the higher the more important)		
Mean	0.93	1.07
Median	0.70	0.75
p-value of Mann-Whitney U test	0.19	

Attributes.

	Classes	
	Above average	Below average
Involvement into formal networks		
(the higher the more active)		
Mean	1.06	0.94
Median	1.08	0.98
p-value of Mann-Whitney U test	0.00	
Involvement into informal networks		
(the higher the more active)		
Mean	1.03	0.97
Median	1.05	1.01
p-value of Mann-Whitney U test	0.00	
On-farm risk management instruments applied in the last 5 years		
(the higher the more instruments)		
Mean	1.04	0.96
Median	1.03	0.91
p-value of Mann-Whitney U test	0.02	
Risk-sharing instruments applied in the last 5 years		
(the higher the more instruments)		
Mean	1.09	0.90
Median	1.09	0.88
p-value of Mann-Whitney U test	0.00	
Openness to innovations		
(the higher the opener)		

(*continued on next page*)

(*continued*)

	Classes	
	Above average	Below average
Mean	1.12	0.88
Median	1.14	0.89
p-value of Mann-Whitney U test	0.00	

Appendix F. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.agsy.2021.103224.

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