



Research article

Do pro-environmental values, beliefs and norms drive farmers' interest in novel practices fostering the Bioeconomy?



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ABSTRACT

A transition towards a bio-based economy is accompanied by a growing demand for biomass resources as fossil fuels need to be replaced for the more sustainable production of consumer goods, chemicals and energy. To increase the supply of renewable biomass and avoid a conflict with food production, currently underutilized by-products (i.e. leaves, stems) from horticultural production could be valorised as feedstock. The success of this approach depends on farmers' willingness to adopt novel practices like the collection and treatment of plant leaves. However, literature on factors influencing farmers' decisions to adopt novel practices aimed to foster the Bioeconomy is limited. This paper addresses this gap by exploring drivers of farmers' interest in the valorisation of by-products. To this aim, the Value-Belief-Norm theory was used and expanded by contextual factors, such as the perceived market demand for biomass and future environmental policies. A survey with German fruit and vegetable farmers ($N = 96$) has been carried out and data have been analysed with a Structural Equation Model. Findings suggest that the Value-Belief-Norm theory is a relevant framework for the agricultural domain to predict farmers' interest in the valorisation of horticultural by-products. Results further indicate that an internal ecological worldview is potentially relevant for farmers' perception of contextual conditions aimed to foster the Bioeconomy. These outcomes could have managerial and policy implications associated with the identification of potential lead users to trigger the diffusion of innovative sustainable practices and generally foster the Bioeconomy.

1. Introduction

Our society currently faces several environmental challenges such as climate change, waste production and industrial pollution. In order to tackle these issues, the economic system needs to abandon the 'take-make-dispose' principle and move towards a circular bio-based economy to enable the needed sustainability transition (McCormick and Kautto, 2013; Golembiewski et al., 2015). Therefore, scholars and policy makers suggest that renewable biomass resources, as opposed to ecologically harmful fossil fuels, need to be utilized for the more sustainable production of energy, chemicals and materials (Bugge et al., 2016). However, the transition is subject to several challenges, most notably associated with the adoption behaviour of agents along the emerging bio-based value chain (Carraresi et al., 2018). In this context, policy makers tend to have a misleadingly instrumental view of the role of farmers, i.e. only as technical providers of biomass (Rossi and Hinrichs, 2011; Schmidt et al., 2012). In fact, beyond the financial and pro-environmental benefits that are envisioned, farmers also have their

own distinct perspectives on the suitability of novel practices fostering the Bioeconomy, perspectives which are often marked by scepticism and uncertainty (Rossi and Hinrichs, 2011). However, it is more generally the case that the factors shaping their interest in those practices are still not well understood (White and Selfa, 2013). Against this background, the paper addresses the research gap by examining drivers of farmers' interest in the valorisation of horticultural by-products as an example for practices fostering the Bioeconomy.

Horticultural by-products (i.e. vegetable leaves), which tend to be currently underutilized, have the potential to be valorised as feedstock for a wide range of bio-based products (Godoy-Durán et al., 2017). Thus, the utilization of by-products increases the availability of biomass while avoiding a conflict with food production (Boehlje and Broering, 2011). Moreover, residues of fruit and vegetable production are rich in health-promoting active components, which can be extracted and used as ingredients in several products (e.g. cosmetics or dietary supplements) (Pleissner et al., 2016). Even after prioritizing these uses, residual biomass can be further utilized for less quality-intensive purposes

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such as energy production (Allen et al., 2013).

When adopted by farmers on a large scale, the valorisation of by-products is expected to contribute to the alleviation of negative consequences for the ecosystem, such as the broad dependency on fossil resources, mitigation of climate change impacts, and the shift away from the linear “take-make-dispose” economy (Golembiewski et al., 2015; Pleissner et al., 2016). Thus, this novel practice can also be understood as a type of pro-environmental behaviour.

However, from the perspective of farmers, the valorisation of horticultural by-products requires a new level of engagement, given that by-products have to be collected, dried and then delivered to bio-refineries or industrial partners for further processing (Keegen and Kretschmer, 2013). These potential changes in organisational procedures lead to high uncertainty among farmers, so that they still have to define their attitudes towards the practice to valorise by-products (Rossi and Hinrichs, 2011). To form an attitude, which is seen as a precondition to adopt or reject novel technologies or practices, individuals need to collect information about potential costs and benefits of the innovation (Rogers, 2003). The motivation to gather more information about novel sustainable practices is in turn driven by rather stable pro-environmental values, beliefs and normative concerns (Steg and Vlek, 2009). Therefore, this study drives upon the value-beliefs-norm (VBN) theory of environmentalism (Stern et al., 1999) to predict farmers' motivation to collect information about the valorisation of by-products. Moreover, farmers' motivation may also be facilitated or constrained by contextual factors such as the market demand for biomass, agricultural subsidies or infrastructure (Bloomberg New Energy Finance, 2010; Bröring et al., 2017). Therefore, it is pivotal to examine both internal and contextual conditions as well as the interaction between them in order to understand farmers' interest in valorising by-products.

The objectives of this paper are thus threefold. First, it applies the VBN theory to assess the relationship of pro-environmental values, beliefs and norms vis-à-vis fruit and vegetable farmers' motivation to learn more about valorising by-products. Second, it examines farmers' perceptions of the pro-environmental effectiveness of the process and, moreover, their understanding of the contextual factors that are most relevant to the transition towards a Bioeconomy as additional contextual antecedents of farmers' interest to valorise by-products. Third, the paper explores the nature of the interaction between ecological worldviews and farmers' perceptions of contextual factors. Thereby, this study contributes towards the more comprehensive understanding of factors shaping farmers' interest to valorise by-products as a practice aimed to foster the Bioeconomy.

2. Review of literature

2.1. Theoretical framework

In the innovation-decision process, individuals move from the knowledge stage, in which they notice an innovation for the first time, to the persuasion stage, in which they form an attitude towards the innovation, to the final decision to adopt or reject (Rogers, 2003). As the practice of valorising horticultural by-products is still relatively unknown, fruit and vegetable farmers will be situated in the knowledge stage. In this case, their perceptions of the innovation as well as the motivation to gather more information are likely to be (unconsciously) driven by their relatively stable values and general beliefs (Hassinger, 1959; Schwartz and Bilsky, 1987; Rogers, 2003).

One widely utilized theoretical foundation for studying these stable internal factors, the VBN theory of environmentalism, is provided by Stern et al. (1999), aiming to explain why individuals decide to engage in a range of pro-environmental behaviours. The model postulates a causal chain in which the effect of values on pro-environmental behaviour is mediated by individual beliefs and personal norms. As a result, each variable is assumed to not only influence the next variable in the series, but might also potentially affect other variables down the chain

(Stern, 2000). More specifically, relatively stable altruistic and self-interest values are assumed to reinforce an ecological worldview which, in turn, can activate individual awareness of those negative consequences of environmental threats for themselves, others, and the biosphere (Stern and Dietz, 1994). Further, if individuals become more aware of consequences involved, this is predicted to activate individuals' perceived ability to reduce these environmental threats, which then strengthens their personal norm to undertake pro-environmental actions (Stern et al., 1999; Stern, 2000). To distinguish between different types of pro-environmental behaviour, Stern et al. (1995, 1999) have also considered the effect of openness-to-change and traditional values on individual's decision-making. More generally, those individuals who are most excited about novelties will be more likely to adopt innovations than individuals who are sceptical about changes (Rogers, 1963, 2003).

2.2. Current state of research

Recent studies have integrated a more social science-informed perspective in order to explain farmers' decisions to adopt pro-environmental practices. For example, studies have shown that farmers' internal attitudes are a crucial determinant of the adoption of practices such as water conservation (Yazdanpanah et al., 2014), maintenance of ecological focus areas (Menozzi et al., 2015), manure separation technology (Gebrezgabher et al., 2015), and use of minimum tillage and row planting (Zeweld et al., 2017). This paper utilizes the framework of the VBN theory which is shown to be relevant for domains ranging from the acceptability of energy policies (Steg et al., 2005) and recycling behaviour (Aguilar et al., 2013) to willingness to pay for park conservation (López-Mosquera and Sánchez, 2012). Support for its application to the agricultural domain has also been found for farmers' intention to adopt practices related to both natural resource management (Seymour et al., 2010) and land management (Price and Leviston, 2014).

However, farmers' pro-environmental behaviour is also influenced by contextual factors such as policy incentives and farm- and management-related characteristics (Knowler and Bradshaw, 2007; Bartowski and Bartke, 2018). According to Horbach (2008), contextual factors facilitating or hampering the diffusion of environmental innovations can be organised in three main groups: i) market pull ii) regulatory push and iii) technology push. Regarding the first of these, the diffusion of environmental innovations can be pulled by the market, e.g. owing to expectations that the innovation is likely to be profitable. For instance, the increased environmental awareness among consumers leads to a growing demand of sustainable products and services (Pavitt, 1984). In the Bioeconomy context, the so far limited consumer understanding of the benefits of bio-based products may reduce the market demand of biomass and, in turn, the profitability of valorising by-products (Allen et al., 2013). Second, the broad regulatory climate has been shown across several sectors to influence the diffusion of environmental innovations (Horbach et al., 2012). Farmers in the European Union currently do not receive any financial incentives for the collection and/or transport of their by-products. Instead, extant policy initiatives have mainly focused on uses for bio-energy, and with limited attention to potential applications for bio-chemicals and bio-materials (Bloomberg New Energy Finance, 2010). Finally, technology developments which lead to more affordable innovations with improved functionality or novel technological capabilities are likely to facilitate a more rapid implementation (Horbach, 2008). In the case of horticultural by-products, research uncovering the potential application fields for bio-active components is still ongoing (Pleissner et al., 2016). Moreover, existing infrastructure and logistical processes for the transport and storage of biomass are often either unavailable or inefficient (Bröring et al., 2017).

These contextual barriers and the lack pro-environmental values, beliefs and norms might reduce farmers' willingness to engage in the

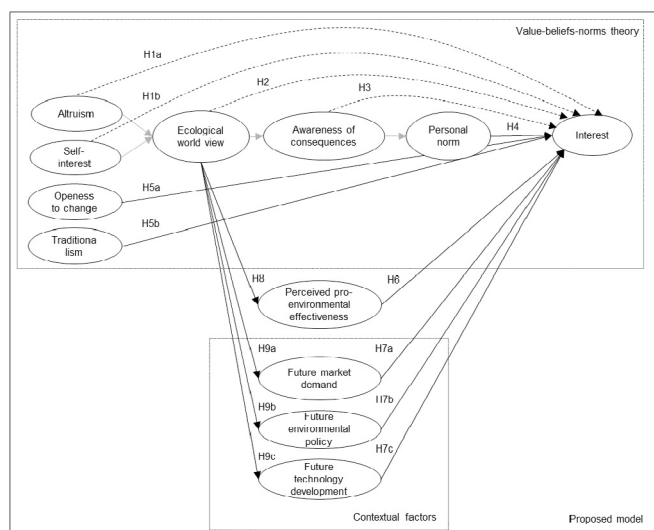


Fig. 1. Conceptual model and hypotheses (dashed arrows indicate indirect effects).

valorisation of by-products (Rossi and Hinrichs, 2011). However, the impact of these factors is still not empirically tested which is the aim of this paper.

3. Conceptual model and hypotheses

The final dependent variable in this study captures farmers' *interest* to gather more information about valorising by-products. In specific, this is seen as a precondition for the formation of an attitude towards this innovation and, in turn, ultimately making a decision about whether or not to adopt this practice (Rogers, 2003; Wolske et al., 2017). The conceptual model is presented in Fig. 1 and the hypotheses are listed in Table 1.

Based on Stern (2000), it is hypothesised that *altruistic values* and *self-interest values* affect –positively and negatively, respectively – the *ecological worldview* of farmers which, in turn, is positively related to the *awareness of consequences* vis-a-vis climate change, the current dependency on fossil resources, and the reliance on a linear “take-make-dispose” economy (H1a, H1b, H2). *Awareness of consequences* of these environmental threats is specifically understood to activate the *personal norm* to act (H3) and finally farmers' *interest* to collect information about valorising by-products (H4).

Empirical studies in the context of central Europe have shown that farmers, compared to the general public, are more likely to be sceptical towards innovations and not so interested in novelty for its own sake

(Baur et al., 2016). Therefore, value profiles of farmers might be the reason for the slow uptake of pro-environmental agricultural innovations (Baur et al., 2016), e.g. because they are more “traditional” by nature. For example, in the case of Dutch farmers, their innovativeness has been found to positively affect their decision to build a sustainable stable (Kemp et al., 2014). Due to the novelty of attempts to valorise by-products, this study also aims to capture innovativeness through the variables of *openness-to-change values* and *traditionalism* (Schwartz and Bilsky, 1987; Stern et al., 1998); which, respectively, can be hypothesised to be positively and negatively related to farmers' interest in valorising by-products (H5a, H5b). Furthermore, assessing the innovativeness of farmers also serves to identify lead users who adopt innovations earlier than their followers (Rogers, 2003).

If individuals are aware of the negative consequences of their behaviour, they are more likely to perceive a moral obligation to change their behaviour (Stern et al., 1999; Stern, 2000). However, it is important that individuals also believe that they are able to alleviate these negative consequences by their actions (Stern et al., 1995). In this regard, Rajendran et al. (2016) found that the more farmers perceive sustainable agricultural practices to have pro-environmental benefits (e.g. via reduced impact of chemical pesticides), the more willing they will be to adopt them. Therefore, farmers who expect the valorisation of by-products to have positive effects on the environment are assumed to be more interested to learn more about these practices (H6).

Moreover, several empirical studies indicate that the perceived profitability of pro-environmental agricultural practices (e.g. soil conservation) and the existence of policy measures like subsidies positively influence farmers' adoption decisions (Knowler and Bradshaw, 2007; Baumgart-Getz et al., 2012; Rajendran et al., 2016). Based on the main contextual factors influencing the diffusion of environmental innovations identified by Horbach (2008), those farmers who believe that the *market demand*, *environmental policy* measures and *technology developments* will evolve in favour of the Bioeconomy, are assumed to be interested in collecting information about valorising by-products (H7a, H7b, H7c).

These external conditions such as the future market demand for biomass or pro-environmental effectiveness of valorising by-products are likely to be perceived and evaluated differently by farmers owing to the influence of individual values and beliefs (Guagnano et al., 1995). This process can be explained using the concept of selective perception, which describes the potential for bias in how information is likely to be subjectively perceived and differently evaluated based on one's existing value system (Hassinger, 1959; Rogers, 2003). This has not yet been applied in relation to farmer decision-making however. Nonetheless, the stability and generality of values and beliefs across a range of domains means that they can also serve as the foundation for attitude formation towards unknown agricultural practices and future

Table 1

List of hypotheses.

H1a	Farmers' <i>altruistic values</i> have a positive indirect effect on their <i>interest</i> to learn more about the valorisation of by-products.
H1b	Farmers' <i>self-interest values</i> have a negative indirect effect on their <i>interest</i> to learn more about the valorisation of by-products.
H2	Farmers' <i>ecological worldview</i> has a positive indirect effect on their <i>interest</i> to learn more about the valorisation of by-products.
H3	Farmers' <i>awareness of consequences of environmental threats</i> has a positive indirect effect on their <i>interest</i> to learn more about the valorisation of by-products.
H4	Farmers' <i>personal norm</i> has a positive direct effect on their <i>interest</i> to learn more about the valorisation of by-products.
H5a	Farmers' <i>openness-to-change values</i> have a positive direct effect on their <i>interest</i> to learn more about the valorisation of by-products.
H5b	Farmers' <i>traditionalism values</i> have a negative direct effect on their <i>interest</i> to learn more about the valorisation of by-products.
H6	Farmers' perception of pro-environmental effectiveness of the new practice has a positive direct effect on their <i>interest</i> to learn more about the valorisation of by-products.
H7a	Farmers' beliefs about the <i>market demand</i> of biomass in the future has a positive direct effect on their <i>interest</i> to learn more about the valorisation of by-products.
H7b	Farmers' beliefs about <i>future environmental policies</i> in favour of the Bioeconomy has a positive direct effect on their interest to learn more about the valorisation of by-products.
H7c	Farmers' beliefs about <i>future technology developments</i> in favour of the Bioeconomy has a positive direct effect on their interest to learn more about the valorisation of by-products.
H8	An <i>ecological worldview</i> positively affects farmers' perceived <i>pro-environmental effectiveness</i> of valorising by-products.
H9a	An <i>ecological worldview</i> positively affects farmers' beliefs about the <i>market demand</i> of biomass in the future.
H9b	An <i>ecological worldview</i> positively affects farmers' beliefs about <i>future environmental policies</i> in favour of the Bioeconomy.
H9c	An <i>ecological worldview</i> positively affects farmers' beliefs about <i>future technology development</i> in favour of the Bioeconomy.

developments in the Bioeconomy (see Stern et al., 1995). Thus, an ecological worldview is expected to affect farmers' perceptions of the pro-environmental effectiveness of valorising by-products and of future external developments favouring the Bioeconomy (H8, H9a, H9b, H9c).

4. Methodology

A questionnaire survey was designed for fruit and vegetable farmers across Germany to identify those factors driving their interest to learn more about the valorisation of by-products. Data have been collected in August 2017 via telephone interviews, in cooperation with Kleffmann Group, a provider of agricultural market research services. Fruit and vegetable farmers throughout Germany were randomly selected from an internal database and received incentives for participation.

4.1. Measures

Before creating the survey, the hypotheses were validated on the basis of qualitative data from five interviews with fruit and vegetable farmers. Inspired by Wolske et al. (2017), the scale used to measure farmer *interest* consists of five items capturing the motivation of learning more about advantages and disadvantages of the practice from other farmers or companies and the intention to talk to companies that might be willing to collect their horticultural by-products.

Concerning the independent variables extracted from the VBN-theory, validated scales from the literature were adopted and adjusted (Stern et al., 1999; Diekmann and Preisendörfer, 2016; Wolske et al., 2017). All items are measured on a Likert scale from 1 to 7, where 1 = do not agree at all, and 7 = absolutely agree.

In order to measure farmer perception of the pro-environmental effectiveness of valorising by-products, three items were developed to capture the expected impact on climate change, the dependency on fossil resources, and the circular economy. For variables representing farmer beliefs about external influences, items were created by drawing on the three main contextual factors influencing the diffusion of environmental innovations identified by Horbach (2008). For example, the variable *future market demand* included items about future demand of biomass residuals as well as pressure from food retailers and consumers. All these measures are presented in Table 2.

4.2. Evaluation of the measurement model

In order to test the relationships between the latent constructs, Partial Least Squares Structural Equation Modelling was applied (PLS-SEM) and the software Smart-PLS 3.0 was used for the analysis. The constructs in this study are based on a reflective measurement model as all indicators are assumed to be caused by the construct and, therefore, are interchangeable and correlated with each other (Hair et al., 2014). The complete structural model is illustrated in Fig. 2. To test the fit of the reflective measurement model to the empirical data, reliability and validity of the constructs were evaluated using those measures suggested by Hair et al. (2014) (Appendix A). The majority of the indicators used for the final structural model had outer loadings with an acceptable level of (at least) 0.7. Moreover, while a few indicators had loadings between 0.5 and 0.7, they were retained in the model due to their contributions to content validity (Hair et al., 2014). All other indicators with lower levels of outer loadings and indicator reliability were deleted.

Composite reliability was also used to test for internal consistency (Hair et al., 2014; Weiber and Mülhhaus, 2014), and with acceptable values, i.e. above 0.7, found for all variables. Further, to assess convergent validity, the average variance extracted (AVE) was calculated for each construct. The values of AVE for all constructs are above the level of 0.5, while the value for *future market demand* is close to 0.5. This indicates that more than 50% of the variance of indicators can be explained by the construct (Hair et al., 2014). Making use of the Fornell-

Larcker Criterion to examine divergent validity (Fornell and Larcker, 1981), it was tested whether the square root of each construct's AVE is greater than its correlations with other latent variables. Results indicate that all constructs meet this criterion, thus suggesting that they are sufficiently distinct from each other in the path model (Appendix B).

4.3. Estimation of the structural model

Before assessing the significance of the relationships between the latent constructs and the overall predictive accuracy of the structural model, the variance inflation factor (VIF) was calculated for the independent variables to assess potential collinearity. According to Hair et al. (2014), collinearity is revealed through VIF values below 0.2 and above 5. Hence, the data are not affected by collinearity, given that the VIF values in the model range from 1.36 (*future environmental policy*) to 2.83 (*awareness of consequences*). Finally, a bootstrap resampling procedure was applied with 5000 sample sets to calculate confidence intervals for parameter estimates.

4.4. Sample characteristics

In total, from 285 contacted farmers who fulfilled the requirements of this study; 101 were ultimately willing to participate (response rate of 35%). Due to missing values exceeding 10% of responses, five participants were removed from the dataset (Hair et al., 2014), leading to a final sample of 96 respondents.

The average age of farmers in the sample is 57 years ($SD = 15.25$, $range = 19-87$), and the majority of the respondents are male ($n = 90$). Mean farm size is 67.89 acres ($range = 1.75-630$), with the median annual turnover between 250,000€ - 500,000€. Descriptive results show that half of the farmers in the sample are rather motivated to learn more about valorising by-products ($Mdn = 4.80$, $M = 4.45$, $SD = 1.73$).

5. Results

Before testing the various hypotheses, it was first examined whether or not the data support the assumption that the VBN variables are organised in a causal chain. As stated in the theory, altruism positively ($\beta = 0.46$, $p \leq 0.00$) and self-interest negatively ($\beta = -0.20$, $p \leq 0.10$) affect the strength of ecological worldviews. Furthermore, farmers' ecological worldview then has a positive influence on their awareness of consequences of negative threats ($\beta = 0.56$, $p \leq 0.00$), which in turn positively affects the strength of personal norms to act in order to protect the environment ($\beta = 0.42$, $p \leq 0.00$). According to these results, each variable indeed determines the next variable in the succession, thus demonstrating that the causal chain of the VBN model is applicable in the context of this study.

The results for the direct and indirect effects of the exogenous variables on the endogenous variable *interest* are presented in Table 3. Model 1 includes the variables from the VBN-theory, to which *perceived pro-environmental effectiveness* of valorising by-products was added to form Model 2, followed by the beliefs about external factors to form Model 3. To assess whether the added exogenous constructs in Models 2 and 3 have a substantial impact on the ability to explain the endogenous variable, the effect size was calculated. Following Cohen (1988), values of $f^2 \geq 0.02$, $f^2 \geq 0.15$, and $f^2 \geq 0.35$ represent small, medium and large effects, respectively (Cohen, 1988).

Model 1 explained 23% of the variance in farmers' *interest* to learn more about valorising by-products. Results show that *altruism* ($\beta = 0.19$) and *awareness of consequences* ($\beta = 0.19$) both indirectly influence the endogenous construct, whereas *personal norms* ($\beta = 0.46$) have a more direct effect on interest. The variables *self-interest* and *ecological worldview* do not have a significant (indirect) impact. In accordance with extant literature on innovation management (Jansson, 2011; Pino et al., 2017; Wolske et al., 2017), *Openness-to-change* ($\beta = 0.33$) has a

Table 2
Indicators of latent variables.

Latent variables (Sources)	Indicators	
Interest (Wolske et al., 2017)	I_1	If I knew a farmer from my region who already collects horticultural by-products, I would be interested in learning more about the advantages and disadvantages.
	I_2	If I knew a company that recycles horticultural by-products, I would be interested to get more information.
	I_3	I am interested in contacts to other farmers who already collect horticultural by-products.
	I_4	I am interested in contacts to companies that take my horticultural by-products.
	I_5	The likelihood is very high that I will look for more information about the valorisation of my horticultural by-products in the future.
Altruism (Stern et al., 1999)	A_1	A world at peace
	A_2	Social justice
	A_3	Equality among men
	A_4	Environmental protection
	A_5	Unity with nature
	A_6	Respecting the earth
Self-Interest (Stern et al., 1999)	SI_1	Authority and right to lead
	SI_2	Having an impact on other people
	SI_3	Wealth
Openness-to-Change (Stern et al., 1999)	OC_1	A varied life
	OC_2	Exciting experiences
	OC_3	Curiosity
Traditionalism (Stern et al., 1999)	T_1	Honoring elders
	T_2	Family
	T_3	Self-discipline
Ecological world view (Diekmann and Preisendörfer, 2016)	EA_1	It worries me when I think of the environmental conditions our children and grandchildren are likely to face.
	EA_2	Environmental problems are greatly exaggerated by environmental activists (R)
	EA_3	The majority of people are not acting environmentally friendly
	EA_4	If we go on like this, we will soon experience a major ecological catastrophe
	EA_5	When I read newspaper reports or television broadcasts about environmental problems, I often become outraged and angry
	EA_6	There are limits of growth that our industrialized world has already crossed or will reach very soon
Awareness of Consequences (Stern et al., 1999)	AC_1	Do you think that the “take-make-dispose” economy, where residuals are not being recycled, will cause problems for you and your family in the future?
	AC_2	Do you think that the “take-make-dispose” economy will cause problems for other people in the future?
	AC_3	Do you think that the “take-make-dispose” economy will cause problems for animals, plants and the biosphere in the future?
	AC_4	Do you think that climate change will cause problems for you and your family in the future?
	AC_5	Do you think that climate change will cause problems for other people in the future?
	AC_6	Do you think that climate change will cause problems for animals, plants and the biosphere in the future?
	AC_7	Do you think the dependency of our economy on fossil resources like oil or coal will cause problems for you and your family in the future?
	AC_8	Do you think that the dependency of our economy on fossil resources will cause problems for other people in the future?
	AC_9	Do you think that the dependency of our economy on fossil resources will cause problems for animals, plants and the biosphere in the future?
Personal norm (Stern et al., 1999)	PN_1	Farmers like me should participate in a circular economy where residuals and by-products are valorised.
	PN_2	I feel a sense of moral responsibility to work against climate change.
	PN_3	I feel a personal obligation to alleviate the dependency of our economy on fossil resources.
Perceived pro-environmental effectiveness (Stern et al., 1999)	EE_1	If horticultural by-products from my farm get valorised, I will contribute to foster the circular economy.
	EE_2	If horticultural by-products from my farm get valorised, I will contribute to fight against climate change.
	EE_3	If horticultural by-products from my farm get valorised, I will contribute to reduce the dependency of our economy on fossil resources.
Future market demand (Horbach, 2008)*	MD_1	In the future, the general demand for biomass will increase.
	MD_2	In the future, it will be profitable to collect horticultural by-products and sell them to companies.
	MD_3	In the future, consumers will expect farmers to operate more sustainably.
	MD_4	In the future, food retailers will request farmers to operate more sustainably.
Future environmental policy (Horbach, 2008)*	EP_1	In the future, there will be laws to regulate the valorisation of horticultural by-products.
	EP_2	In the future, subsidies for the collection of horticultural by-products will come into place.
	EP_3	In the future, there will be a growing number of policy measures to promote the industrial valorisation of horticultural by-products.
	EP_4	In the future, it will be prohibited to leave or put horticultural by-products on the field.
Future technology developments (Horbach, 2008)*	TD_1	In the future, transport and storage processes between farmers and chemical companies will become more efficient.
	TD_2	In the future, there will be technical solutions to harvest fruits and by-products such as leaves at the same time.
	TD_3	In the future, scientists will identify further application fields for horticultural by-products.
	TD_4	In the future, the extraction process of valuable components from horticultural by-products will become more efficient.

Note: * we developed indicators ourselves on the basis of Horbach (2008).

positive impact on farmers' *interest* to learn more about valorising by-products. However, *traditionalism* has no significant impact. Generally speaking, the results of this study congruent with the theoretical prediction of Stern et al. (1999) that relatively stable values and general beliefs have an indirect impact on farmers' decision making (Price and Leviston, 2014).

Regarding Model 2, the inclusion of the additional variable results in an explained variance of 31%, thus adding a further 8% compared to Model 1. In specific, *perceived pro-environmental effectiveness* has a positive and significant impact on farmers' *interest* to learn more about valorising by-products ($\beta = 0.33$). Overall, the additional variable is found to have a medium effect-size on the endogenous variable ($f^2 =$

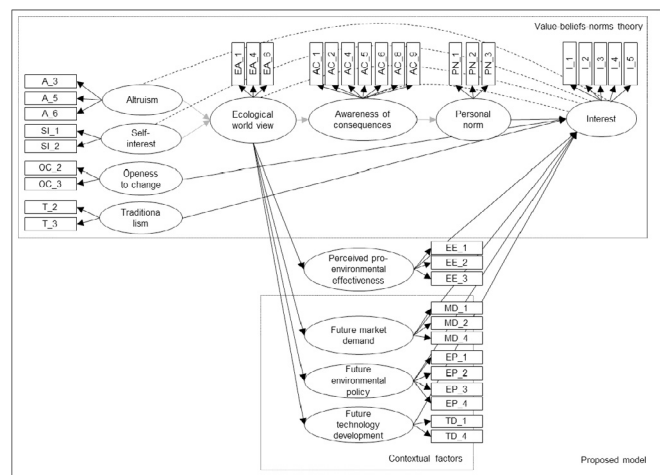


Fig. 2. Structural model and measurement model.

Table 3
Results of the structural equation model.

Hypotheses	Constructs	Model 1	Model 2	Model 3
H1a	Altruism ^a	0.19*	0.16*	0.18*
H1b	Self-Interest ^a	−0.08	−0.08	0.08
H2	Ecological worldview ^a	0.06	0.10	0.25*
H3	Awareness of consequences ^a	0.19**	0.15**	0.16**
H4	Personal norm	0.46***	0.35***	0.38**
H5a	Openness-to-change	0.33***	0.30**	0.33***
H5b	Traditionalism	0.20	0.20	0.14
H6	Perceived effectiveness		0.33***	0.28**
H7a	Market demand			0.37**
H7b	Environmental policy			0.08
H7c	Technological development			−0.20*
	R ²	0.23	0.31	0.41
	f ²		0.11	0.16

Note: *p ≤ 0.1; **p ≤ 0.05; ***p ≤ 0.01; f² = (R² included – R² excluded)/(1 – R² included).

^a Modelled to have an indirect effect on farmer interest.

0.11). This provides support for the presumption of Stern et al. (1999) that it is necessary for individuals to not only be aware of negative consequences for the environment but to also believe in their ability to alleviate these threats through their actions.

Finally, Model 3 explains 41% of the variance in farmers' interest to learn more about valorising by-products, with addition of the three external factors offering a further 10% of explained variance. The f² value (0.16) moreover indicates that the inclusion of these variables had a medium effect on explaining the overall variance in farmers' interest. Compared to Model 2, ecological worldview has a significant (indirect) effect on farmer interest (β = 0.25). Looking at the contextual factors, future market demand exercises a positive and significant effect on interest (β = 0.37), indicating that those farmers who believe that valorising by-products will be profitable in the future are generally more motivated to collect the information necessary to make a decision. This finding is broadly consistent with the agricultural economics literature, wherein it is indicated that the perceived profitability of an innovation is a driver for adoption behaviour (Cary and Wilkinson, 1997; Morgan et al., 2015). In contrast, the analysis reveals a (moderately) negative relationship between perceived future technology development (β = −0.20) and farmers' interest. One explanation could be that these farmers are more likely to think that developments of science and technology are able to offer broad solutions for environmental problems (Huesemann, 2001), and thus pro-environmental practices

are not needed. Moreover, there is no evidence of a relationship between farmer perceptions of future environmental policy and their interest in valorising by-products, which conflicts with previous studies (Baumgart-Getz et al., 2012; Rajendran et al., 2016). Indeed, all in all, the only contextual factor able to predict farmer interest in valorising by-products is future market demand, that is, how strong the market for such products is likely to be in the future. In comparison to the factors of the VBN framework, the overall explanatory power of these contextual factors is notably lower. Therefore, while it is crucial to continue exploring the contextual factors on decision-making, agri-environmental research is needed more urgently into the relevance of altruistic values and pro-environmental beliefs for understanding farmer behaviour.

Furthermore, to assess the interaction between internal and contextual factors, the path coefficients were calculated between ecological worldviews and farmers' beliefs about external factors. This analysis illustrates that farmer perceptions of the pro-environmental effectiveness of valorising by-products is both positively and significantly related to the strength of their ecological worldviews (β = 0.24, p = 0.03). Furthermore, beliefs about future market demand (β = 0.28, p = 0.10) as well as future environmental policy (β = 0.24, p = 0.03) are also both positively related to their ecological worldviews. These positive relationships show that an ecological worldview of farmers has a strong indirect effect on their overall interest in investing time to research these practices. By contrast, the path between ecological worldview and future technology development is found to not be significant, perhaps due to the fact that technology developments related to valorising by-products are not generally driven by environmental concern but rather efficiency.

However, despite positive associations between an ecological worldview and contextual factors (e.g. MD and EP) the direction of causality still remains to be investigated. In this vein, a growing body of research in the behavioural sciences suggests that internal factors such as emotions and interpersonal knowledge shape how people and objects in the external world are perceived and evaluated (Baum and Gross, 2017; Otten et al., 2017). As such, internal factors like pro-environmental beliefs can indeed be expected to act in concert with and strengthen the perception and evaluation of the broader contextual developments.

6. Discussion

The first objective of this study was to examine the influences of values, beliefs and norms on levels of farmer interest in practices aimed to foster the Bioeconomy. The results of this study provide evidence that the VBN theory is indeed a useful framework to understand the interest of German farmers in learning more about valorising by-products. In fact, the amount of the variance in farmers' interest explained by the VBN model is similar to studies that have previously applied the model to consumer research (Steg et al., 2005; Wolske et al., 2017). Regarding the second objective, the results show that farmer perceptions of both the pro-environmental effectiveness of valorising by-products and of contextual factors additionally explain their interest in learning more about these innovative practices. By measuring farmers' interest, operationalized as a behavioural intention to gather more information, the open gap towards the next step in the decision process in which individuals already have a predefined attitude and come to an adoption decision was closed (Kaplan, 1999; Rogers, 2003). Indeed, empirical studies found that after collecting information about novel practices farmers are also more likely to adopt these practices (McNamara et al., 1991; Llewellyn et al., 2007; D'Emden et al. 2008). However, the main contribution of this study is that farmer perceptions of contextual factors are inextricably connected to the strength of their ecological worldview, thus indicating a relationship between external circumstances and internal belief systems (Guagnano et al., 1995).

6.1. Limitations and further research

The motivation to learn more about valorising by-products is a necessary but not sufficient condition for farmers to adopt related agronomic practices. Therefore, future studies need to examine factors that might be more relevant for the later stages of adoption decisions, in which farmers finally make an adoption decision. At the early stages, when the innovations are relatively unknown, general values can offer broad guidance, but as soon as farmers develop specific beliefs about the advantages and disadvantages of an innovation, it is likely that attitudes will become more relevant for adoption decisions (see Rogers, 2003). In this case, the theory of planned behaviour might be a useful framework to understand farmers' decisions as it assumes that attitudes are one of the main antecedents of individual behaviour (Ajzen, 1985, 1991; Steg and Vlek, 2009). The impact of farmers' attitudes on their decision to adopt or reject could then quantitatively be tested by conducting discrete choice experiments. In this study, it was not possible to identify whether or not individuals truly collected more information, let alone ultimately adopted the relevant practices. Thus, future empirical studies need to conduct longitudinal studies. By following farmers over several years, it would be possible to explore actual behaviour. Longitudinal studies or experiments could also help to provide further support of causal relationships between internal and contextual factors in the domain of farmers' decision making.

Moreover, the sample may have suffered from self-selection bias because only 35% of contacted farmers were willing to participate in the study. Thus, the results could be different for those farmers who did and did not participate, influenced by altruism or trust in research institutions. As a result of such self-selection and the relatively small sample size of 96 farmers, it cannot be assumed that the sample is fully representative of German fruit and vegetable farmers. Moreover, environmental values and beliefs about Bioeconomy practices might vary across regions and sectors according to the culture shared by farmers from generation to generation (Schultz and Zelezny, 1999) and, e.g., according to national policy contexts (Prokopy et al., 2015). As this is the first study that applies the VBN framework to the Bioeconomy domain, future studies would be highly desirable to replicate the results with other Bioeconomy practices and in other countries.

Finally, the more exploratory character of this study also leads to two limitations. First, the items used to form measures of VBN variables are translated from other domains and thus applied to the agricultural context for the first time. Also, given that additional indicators have been created to capture farmer beliefs about appropriate contexts for the future valorisation of by-products, convergent validity tests are still missing. Second, although the traditional VBN model was enlarged with more relevant variables, the results might still be affected by omitted-variable bias. For example, farmers' decision to gather more information about the valorisation of by-products might also be influenced by social norms (Zeweld et al., 2017). For these reasons, future research needs to validate the measurement and structural models of this study by using a larger sample size and other examples of practices in the context of the Bioeconomy.

6.2. Policy and managerial implications

This study has three major implications for policy makers and managers who aim to foster the diffusion of novel Bioeconomy practices among farmers. First, the findings indicate that farmers who are more altruistic, aware of environmental consequences, open to change, and with a stronger ecological worldview are more likely to be interested in valorising by-products. These characteristics can thus be used to develop a profile of the farmers who are most likely motivated to collect more information, and therefore potentially to adopt novel practices. In this vein, both policy initiatives and market-entry strategies are likely

to be more promising if they target farmers with characteristics matching this profile. For example, farmers who have already adopted organic farming practices are shown to be more driven by social and moral concerns (Mzoughi, 2011), while those farmers who have already implemented innovative practices are also generally more open to change (Kemp et al., 2014). Therefore, organic and innovative farmers could act as beneficial target groups for identifying lead users who might be more willing to implement novel practices related to the valorisation of by-products (Hippel, 1986) and/or act as “opinion leaders” to influence their fellow colleagues and communities to adopt these practices (Case, 1992; Rogers, 2003).

Second, although values and beliefs are relatively stable across time and context, interventions to, e.g., strengthen farmers' openness to change, altruism, and ecological worldviews could help to stimulate interest in agricultural practices aimed to foster the Bioeconomy. One possibility to cultivate openness to change and pro-environmental values among farmers might be to organise public-private partnerships and workshops in which people with different perspectives discuss sustainability issues and novel agricultural practices (Ngutu and Recke, 2006; Carraresi et al., 2018; Luís et al., 2018). More fundamentally, schools and universities need to offer environmental education programs to influence internal beliefs (Pooley and O'Connor 2016). For instance, outdoor activities such as hiking and camping have been shown to foster an increased perceived connectedness with nature, and thereby promoting a more ecological worldview (Schultz, 2000). Third, the results show that farmers are more likely to be interested in the valorisation of by-products if they believe that this practice effectively reduces environmental threats. Therefore, any companies who want to convince farmers to participate in the Bioeconomy transition need to not only communicate the financial benefits but also establish the broader environmental relevance of these practices. In this context, greater information about the beneficial environmental impact of novel practices throughout the supply chain (e.g. by means of a life-cycle assessment) could serve as both valuable information and additional motivation for farmers to undertake the necessary changes.

6.3. Concluding remarks

In sum, the results of this study indicate that the VBN theory is a relevant framework for the agricultural domain to predict farmers' interest in the valorisation of horticultural by-products. Actually, the findings point towards the existence of an interaction between an internal ecological worldview and the perception of external conditions such as future environmental policies and technology developments. Thus, internal beliefs are potentially relevant by signalling how farmers perceive both the external world and how they evaluate the suitability of conditions for the implementation of practices aimed to foster the Bioeconomy. As a result, this study underlines the importance of pro-environmental beliefs for the transition towards a bio-based economy and highlights them as an interesting avenue for further research in this domain.

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Appendix A. Results for the evaluation of the measurement model

Variables	Indicators	Loadings	Composite reliability	AVE
Altruism	A_3	0.81	0.79	0.56
	A_5	0.71		
	A_6	0.73		
Self-Interest	SI_1	0.72	0.84	0.73
	SI_2	0.97		
Openness-to-change	OC_2	0.96	0.75	0.62
	OC_3	0.56		
Traditionalism	T_1	0.54	0.76	0.52
	T_2	0.70		
	T_3	0.87		
Ecological worldview	EA_1	0.84	0.84	0.64
	EA_4	0.81		
	EA_6	0.75		
Awareness of Consequences	AC_1	0.73	0.91	0.60
	AC_2	0.74		
	AC_4	0.80		
	AC_5	0.85		
	AC_6	0.82		
	AC_8	0.77		
Personal norm	AC_9	0.71	0.89	0.73
	PN_1	0.78		
	PN_2	0.88		
Perceived pro-environmental effectiveness	PN_3	0.90	0.95	0.86
	EE_1	0.90		
	EE_2	0.94		
Future market demand	EE_3	0.94	0.73	0.49
	MD_1	0.62		
	MD_2	0.87		
Future environmental policy	MD_4	0.55	0.81	0.52
	EP_1	0.63		
	EP_2	0.64		
	EP_3	0.87		
Future technology developments	EP_4	0.72	0.81	0.69
	TD_1	0.93		
	TD_4	0.72		
Interest	I_1	0.86	0.93	0.72
	I_2	0.86		
	I_3	0.88		
	I_4	0.86		
	I_5	0.80		

Appendix B. Correlation of latent constructs

Constructs	1	2	3	4	5	6	7	8	9	10	11	12
1 Altruism	–											
2 Self-interest	0.20	–										
3 Openness to change	0.30	0.48	–									
4 Traditionalism	0.48	0.26	0.14	–								
5 Ecological worldview	0.41	–0.11	0.10	0.07	–							
6 Awareness of consequences	0.48	0.08	0.20	0.24	0.63	–						
7 Personal norm	0.52	–0.02	0.11	0.19	0.51	0.61	–					
8 Environmental effectiveness	0.42	0.29	0.23	0.22	0.24	0.35	0.45	–				
9 Future market demand	0.28	0.12	0.11	0.24	0.28	0.16	0.31	0.15	–			
10 Future environmental policy	0.20	0.14	–0.00	0.14	0.24	0.02	0.13	0.07	0.56	–		
11 Future technology developments	0.06	0.14	0.09	0.07	–0.06	–0.16	0.19	–0.04	0.52	0.40	–	
12 Interest	0.14	0.05	0.27	0.16	0.12	0.13	0.40	0.34	0.34	0.16	0.08	–

References

- Aguilar, A., Magnien, E., Thomas, D., 2013. Thirty years of European biotechnology programmes: from biomolecular engineering to the bioeconomy. *N. Biotechnol.* 30, 410–425. <https://doi.org/10.1016/j.nbt.2012.11.014>.
- Ajzen, I., 1985. From intentions to actions: a theory of planned behavior. In: Kuhl, J., Beckmann, J. (Eds.), *Action-control: from Cognition to Behavior*. Springer, Heidelberg, Germany, pp. 11–39.
- Ajzen, I., 1991. The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* 50, 179–211. [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T).
- Allen, B.R., Keegan, D., Elbersen, B., 2013. Biomass and bioenergy in the wider land-use context of the European Union. *Biofuels, Bioprod. Biorefin.* 7, 207–216. <https://doi.org/10.1002/bbb.1359>.
- Bartowski, B., Bartke, S., 2018. Leverage points for governing agricultural soils: a review of empirical studies of European farmers' decision-making. *Sustainability* 10, 3179. <https://doi.org/10.3390/su10093179>.
- Baum, C.M., Gross, C., 2017. Sustainability policy as if people mattered: developing a framework for environmentally significant behavioral change. *J. Bioecon.* 19, 53–95. <https://doi.org/10.1007/s10818-016-9238-3>.
- Baumgart-Getz, A., Prokopy, L.S., Floress, K., 2012. Why farmers adopt best management practice in the United States: a meta-analysis of the adoption literature. *J. Environ. Manag.* 96, 17–25. <https://doi.org/10.1016/j.jenvman.2011.10.006>.
- Baur, I., Dobricki, M., Lips, M., 2016. The basic motivational drivers of northern and central European farmers. *J. Rural Stud.* 46, 93–101. <https://doi.org/10.1016/j.jrurstud.2016.06.001>.

- Bloomberg New Energy Finance, 2010. Next-generation Ethanol and Biochemicals: What's in it for Europe? https://www.dsm.com/content/dam/dsm/cworld/en_US/documents/bloomberg-nextgeneration-ethanol-and-biochemicals-whats-in-it-for-europe.pdf, Accessed date: 16 February 2017.
- Boehlje, M., Broering, S., 2011. The increasing multifunctionality of agricultural raw materials: three dilemmas for innovation and adoption. *Int. Food Agribus. Manag. Rev.* 14, 1–16.
- Bröring, S., Baum, C.M., Butkowski, O., Kircher, M., 2017. Kriterien für den Erfolg der Bioökonomie. In: Pietzsch, Joachim (Ed.), *Bioökonomie für Einsteiger*. Springer, Berlin, pp. 159–175.
- Bugge, M., Hansen, T., Klitkou, A., 2016. What is the bioeconomy?: a review of the literature. *Sustainability* 8, 1–22. <https://doi.org/10.3390/su8070691>.
- Carraresi, L., Berg, S., Bröring, S., 2018. Emerging value chains within the bioeconomy: structural changes in the case of phosphate recovery. *J. Clean. Prod.* 183, 87–101. <https://doi.org/10.1016/j.jclepro.2018.02.135>.
- Cary, J.W., Wilkinson, R.L., 1997. Perceived profitability and farmers' conservation behaviour. *J. Agric. Econ.* 48, 13–21. <https://doi.org/10.1111/j.1477-9552.1997.tb01127.x>.
- Case, A., 1992. Neighborhood influence and technological change. *Reg. Sci. Urban Econ.* 22, 491–508. [https://doi.org/10.1016/0166-0462\(92\)90041-X](https://doi.org/10.1016/0166-0462(92)90041-X).
- Cohen, J., 1988. *Statistical Power Analysis for the Behavioral Sciences*. Lawrence Erlbaum Associates, Hillsdale, NJ.
- D'Emden, F.H., Llewellyn, R.S., Burton, M.P., 2008. Factors influencing adoption of conservation tillage in Australian cropping regions. *Aust. J. Agric. Resour. Econ.* 169–182. <https://doi.org/10.1111/j.1467-8489.2008.00409.x>.
- Diekmann, A., Preisendörfer, P., 2016. Green and greenback. *Ration. Soc.* 15, 441–472. <https://doi.org/10.1177/1043463103154002>.
- Fornell, C., Larcker, D.F., 1981. Structural equation models with unobservable variables and measurement error: algebra and statistics. *J. Market. Res.* 18, 382–388. <https://doi.org/10.2307/3150980>.
- Gebregabher, S.A., Meuwissen, M.P.M., Kruseman, G., Lakner, D., Lansink, Oude, Alfons, G.J.M., 2015. Factors influencing adoption of manure separation technology in The Netherlands. *J. Environ. Manag.* 150, 1–8. <https://doi.org/10.1016/j.jenvman.2014.10.029>.
- Godoy-Durán, Á., Galdeano-Gómez, E., Pérez-Mesa, J.C., Piedra-Muñoz, L., 2017. Assessing eco-efficiency and the determinants of horticultural family-farming in southeast Spain. *J. Environ. Manag.* 204, 594–604. <https://doi.org/10.1016/j.jenvman.2017.09.037>.
- Golembiewski, B., Sick, N., Broering, S., 2015. The emerging research landscape on bioeconomy: what has been done so far and what is essential from a technology and innovation management perspective? *Innovat. Food Sci. Emerg. Technol.* 29, 308–317. <https://doi.org/10.1016/j.ifset.2015.03.006>.
- Guagnano, G.A., Stern, P.C., Dietz, T., 1995. Influences on attitude-behavior relationships. *Environ. Behav.* 27, 699–718. <https://doi.org/10.1177/0013916595275005>.
- Hair, J.F., Hult, G.T., Ringle, C., Sarstedt, M., 2014. *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*. SAGE, Los Angeles.
- Hassinger, E., 1959. Stages in the adoption process. *Rural Sociol.* 52–53.
- Hippel, E. von, 1986. Lead users: a source of novel product concepts. *Manag. Sci.* 32, 791–805. <https://doi.org/10.1287/mnsc.32.7.791>.
- Horbach, J., 2008. Determinants of environmental innovation - new evidence from German panel data sources. *Res. Policy* 37, 163–173. <https://doi.org/10.1016/j.respol.2007.08.006>.
- Horbach, J., Rammer, C., Rennings, K., 2012. Determinants of eco-innovations by type of environmental impact - the role of regulatory push/pull, technology push and market pull. *Ecol. Econ.* 78, 112–122. <https://doi.org/10.1016/j.ecolecon.2012.04.005>.
- Huesemann, M.H., 2001. Can pollution problems be effectively solved by environmental science and technology? An analysis of critical limitations. *Ecol. Econ.* 37, 271–287. [https://doi.org/10.1016/S0921-8009\(00\)00283-4](https://doi.org/10.1016/S0921-8009(00)00283-4).
- Jansson, J., 2011. Consumer eco-innovation adoption: assessing attitudinal factors and perceived product characteristics. *Bus. Strat. Environ.* 20, 192–210. <https://doi.org/10.1002/bse.690>.
- Kaplan, A.W., 1999. From passive to active about solar electricity: innovation decision process and photovoltaic interest generation. *Technovation* 19, 467–481. [https://doi.org/10.1016/S0166-4972\(98\)00128-X](https://doi.org/10.1016/S0166-4972(98)00128-X).
- Keegan, D., Kretschmer, B., 2013. Cascading use: a systematic approach to biomass beyond the energy sector. *Biofuels, Bioprod. Biorefin.* 193–206.
- Kemp, R., Nijhoff-Savvaki, R., Ruitenburt, R., Trienekens, J.H., Omta, S., 2014. Sustainability-related innovation adoption: the case of the Dutch pig farmer. *J. Chain Netw. Sci.* 14, 69–78. <https://doi.org/10.3920/JCNS2014.0240>.
- Knowler, D., Bradshaw, B., 2007. Farmers' adoption of conservation agriculture: a review and synthesis of recent research. *Food Policy* 32, 25–48. <https://doi.org/10.1016/j.foodpol.2006.01.003>.
- Llewellyn, R.S., Lindner, R.K., Pannell, D.J., Powles, S.B., 2007. Herbicide resistance and the adoption of integrated weed management by Western Australian grain growers. *Agric. Econ.* 36, 123–130. <https://doi.org/10.1111/j.1574-0862.2007.00182.x>.
- López-Mosquera, N., Sánchez, M., 2012. Theory of Planned Behavior and the Value-Belief-Norm Theory explaining willingness to pay for a suburban park. *J. Environ. Manag.* 113, 251–262. <https://doi.org/10.1016/j.jenvman.2012.08.029>.
- Luís, S., Lima, M.L., Roseta-Palma, C., Rodrigues, N., Sousa, L., Freitas, F., Alves, F., Lillebø, A.I., Parrod, C., Jolivet, V., Paramana, T., Alexandrakakis, G., Poulos, S., 2018. Psychosocial drivers for change: understanding and promoting stakeholder engagement in local adaptation to climate change in three European Mediterranean case studies. *J. Environ. Manag.* 223, 165–174. <https://doi.org/10.1016/j.jenvman.2018.06.020>.
- McCormick, K., Kautto, N., 2013. The bioeconomy in Europe: an overview. *Sustainability* 5, 2589–2608. <https://doi.org/10.3390/su5062589>.
- McNamara, K.T., Wetzstein, M.E., Douce, G.K., 1991. Factors affecting peanut producer adoption of integrated pest management. *Rev. Agric. Econ.* 13, 129. <https://doi.org/10.2307/1349563>.
- Menozzi, D., Fioravanti, M., Donati, M., 2015. Farmer's motivation to adopt sustainable agricultural practices. *BioBased Appl. Econ.* 4, 125–147. <https://doi.org/10.13128/BAE-14776>.
- Morgan, M.I., Hine, D.W., Bhullar, N., Loi, N.M., 2015. Landholder adoption of low emission agricultural practices: a profiling approach. *J. Environ. Psychol.* 41, 35–44. <https://doi.org/10.1016/j.jenvp.2014.11.004>.
- Mzoughi, N., 2011. Farmers adoption of integrated crop protection and organic farming: do moral and social concerns matter? *Ecol. Econ.* 70, 1536–1545. <https://doi.org/10.1016/j.ecolecon.2011.03.016>.
- Ngutu, M., Recke, H., 2006. Exploring farmers' innovativeness: experiences with the adaptation of water-saving technologies for small-scale vegetable production around marsabit mountain in northern Kenya. *Exp. Agric.* 42, 459–474. <https://doi.org/10.1017/S0014479706003851>.
- Otten, M., Seth, A.K., Pinto, Y., 2017. A social Bayesian brain: how social knowledge can shape visual perception. *Brain Cognit.* 112, 69–77. <https://doi.org/10.1016/j.bandc.2016.05.002>.
- Pavitt, K., 1984. Sectoral patterns of technical change: towards a taxonomy and a theory. *Res. Policy* 13, 343–373. [https://doi.org/10.1016/0048-7333\(84\)90018-0](https://doi.org/10.1016/0048-7333(84)90018-0).
- Pino, G., Toma, P., Rizzo, C., Miglietta, P., Peluso, A., Guido, G., 2017. Determinants of farmers' intention to adopt water saving measures: evidence from Italy. *Sustainability* 9, 77. <https://doi.org/10.3390/su9010077>.
- Pleissner, D., Qi, Q., Gao, C., Rivero, C.P., Webb, C., Lin, C.S.K., Venus, J., 2016. Valorization of organic residues for the production of added value chemicals: a contribution to the bio-based economy. *Biochem. Eng. J.* 116, 3–16. <https://doi.org/10.1016/j.bej.2015.12.016>.
- Pooley, J.A., O'Connor, M., 2016. Environmental education and attitudes. *Environ. Behav.* 32, 711–723. <https://doi.org/10.1177/0013916500325007>.
- Price, J.C., Levinson, Z., 2014. Predicting pro-environmental agricultural practices: the social, psychological and contextual influences on land management. *J. Rural Stud.* 34, 65–78. <https://doi.org/10.1016/j.jrurstud.2013.10.001>.
- Prokopy, L.S., Arbuckle, J.G., Barnes, A.P., Haden, V.R., Hogan, A., Niles, M.T., Tyndall, J., 2015. Farmers and climate change: a cross-national comparison of beliefs and risk perceptions in high-income countries. *Environ. Manag.* 56, 492–504. <https://doi.org/10.1007/s00267-015-0504-2>.
- Rajendran, N., Tey, Y.S., Brindal, M., Ahmad Sidique, S.F., Shamsudin, M.N., Radam, A., Abdul Hadi, A.H.I., 2016. Factors influencing the adoption of bundled sustainable agricultural practices: a systematic literature review. *Int. Food Res. J.* 23, 2271–2279.
- Rogers, E.M., 1963. What are innovators like? *Theory Into Pract.* 2, 252–256. <https://doi.org/10.1080/00405846309541872>.
- Rogers, E.M., 2003. *Diffusion of Innovations*, fifth ed. Free Press, New York.
- Rossi, A.M., Hinrichs, C.C., 2011. Hope and skepticism: farmer and local community views on the socio-economic benefits of agricultural bioenergy. *Biomass Bioenergy* 35, 1418–1428. <https://doi.org/10.1016/j.biombioe.2010.08.036>.
- Schmidt, O., Padel, S., Levidow, L., 2012. The bio-economy concept and knowledge base in a public goods and farmer perspective. *BioBased Appl. Econ.* 1, 47–63. <https://doi.org/10.13128/BAE-10770>.
- Schultz, P.W., 2000. New environmental theories: empathizing with nature: the effects of perspective taking on concern for environmental issues. *J. Soc. Issues* 56, 391–406. <https://doi.org/10.1111/0022-4537.00174>.
- Schultz, P.W., Zelezny, L., 1999. Values as predictors of environmental attitudes: evidence for consistency across 14 countries. *J. Environ. Psychol.* 19, 255–265. <https://doi.org/10.1006/jenvp.1999.0129>.
- Schwartz, S.H., Bilsky, W., 1987. Toward a universal psychological structure of human values. *J. Pers. Soc. Psychol.* 53, 550–562. <https://doi.org/10.1037/0022-3514.53.3.550>.
- Seymour, E., Curtis, A., Pannell, D., Allan, C., Roberts, A., 2010. Understanding the role of assigned values in natural resource management. *Australas. J. Environ. Manag.* 17, 142–153. <https://doi.org/10.1080/14486563.2010.9725261>.
- Steg, L., Vlek, C., 2009. Encouraging pro-environmental behaviour: an integrative review and research agenda. *J. Environ. Psychol.* 29, 309–317. <https://doi.org/10.1016/j.jenvp.2008.10.004>.
- Steg, L., Dreijerink, L., Abrahamse, W., 2005. Factors influencing the acceptability of energy policies: a test of VBN theory. *J. Environ. Psychol.* 25, 415–425. <https://doi.org/10.1016/j.jenvp.2005.08.003>.
- Stern, P.C., 2000. New environmental theories: toward a coherent theory of environmentally significant behavior. *J. Soc. Issues* 56, 407–424. <https://doi.org/10.1111/0022-4537.00175>.
- Stern, P.C., Dietz, T., 1994. The value basis of environmental concern. *J. Soc. Issues* 50, 65–84. <https://doi.org/10.1111/j.1540-4560.1994.tb02420.x>.
- Stern, P.C., Kalof, L., Dietz, T., Guagnano, G.A., 1995. Values, beliefs, and pro-environmental action: attitude formation toward emergent attitude objects. *J. Appl. Soc. Psychol.* 25, 1611–1636. <https://doi.org/10.1111/j.1559-1816.1995.tb02636.x>.
- Stern, P.C., Dietz, T., Guagnano, G.A., 1998. A brief inventory of values. *Educ. Psychol. Meas.* 58, 984–1001. <https://doi.org/10.1177/0013164498058006008>.
- Stern, P.C., Dietz, T., Abel, T., Guagnano, G.A., Kalof, L., 1999. A value-belief-norm theory of support for social movements: the case of environmentalism. *Hum. Ecol. Rev.* 6, 81–97.
- Weiber, R., Mühlhaus, D., 2014. *Strukturgleichungsmodellierung*. Springer, Berlin, Heidelberg.
- White, S.S., Selfa, T., 2013. Shifting lands: exploring Kansas farmer decision-making in an era of climate change and biofuels production. *Environ. Manag.* 51, 379–391. <https://doi.org/10.1007/s00267-012-9991-6>.
- Wolske, K.S., Stern, P.C., Dietz, T., 2017. Explaining interest in adopting residential solar

- photovoltaic systems in the United States: toward an integration of behavioral theories. *Energy Res. Soc. Sci.* 25, 134–151. <https://doi.org/10.1016/j.erss.2016.12.023>.
- Yazdanpanah, M., Hayati, D., Hochrainer-Stigler, S., Zamani, G.H., 2014. Understanding farmers' intention and behavior regarding water conservation in the Middle-East and North Africa: a case study in Iran. *J. Environ. Manag.* 135, 63–72. <https://doi.org/10.1016/j.jenvman.2014.01.016>.
- Zeweld, W., van Huylenbroeck, G., Tesfay, G., Speelman, S., 2017. Smallholder farmers' behavioural intentions towards sustainable agricultural practices. *J. Environ. Manag.* 187, 71–81. <https://doi.org/10.1016/j.jenvman.2016.11.014>.