[CONFIDENTIAL]

Farmers' perceptions and intentions alongside the EU-27 to use Bio-based fertilisers: Insights from the Theory of Planned Behavior and Expected Utility Theory.

Sergio Garmendia-Lemus(a,b), Egor Moshkin(a,c), Jeroen Buysse (a), Jurgen Tack (b)
a: Ghent University: Coupure Links 653, 9000 Gent, Belgium.

b: European Landowners' Organization: Rue de Trèves 67, 1040 Bruxelles, Belgium.

c: United Experts: Biezeweg 15a, 9230 Wetteren

*Corresponding author: sergio.garmendialemus@ugent.be (Coupure Links 653, 9000 Gent)

Commented [1]: Check the consistency for terms with Egor's paper. Both papers should have the same terminology.

Commented [SGL2]: statetement
highlight why this methodology is relevant
different sections and
cocnlusion different focus; key finding is that social norm is not importnt whule for other things is important
rational behavior
is it p

Abstract (to be reduced and changed once the rest is approved)

One of the greatest ambitions of the EU is to provide safe and healthy agricultural products with the least environmental impacts. During the last decades, the success and expansion of the agricultural industry is due in large part to the use of mineral fertilisers. However, their usage has come along with significant environmental degradation. One of the present alternatives is the use of newly developed bio-based fertilisers.

Bio-based fertilisers are produced from a diverse range of biological wastes under specific processing technologies. Studies have tested their efficiency and they promise to be as efficient as mineral fertilisers, although it has been discussed in the academic literature that users' acceptance might be lower than expected.

This study was conducted to analyze farmers' perceptions for the acceptance of bio-based fertilisers. We proposed the use of the Theory of Planned Behavior and an extended version with the use of Expected Utility Theory as theoretical framework via the application of an online questionnaire. A total of 332 valid questionnaires were obtained via online survey to farmers across the EU-27.

Our results suggest that the Theory of Planned Behavior (TPB) and the extended version of TPB with Expected Utility Theory (EUT) elements are a useful method for measuring intentions to adopt bio-based fertilisers. It was found that there was a strong correlation between attitudinal perceptions and perceived benefits and risks, which is consistent to what is discussed in literature. Whereas no significant influence from social circles and knowledge was encountered.

Policy makers and the fertiliser industry should focus on promoting and giving information to modify the attitudinal perception of use of bio-based fertilisers with a specific focus on improvements on benefits and minimization of economic risks of use of bio-based fertilisers. Further work for this research should include cross-regional comparison to design specific measures towards the development of the bio-based fertiliser industry more accurately.

1. Introduction

One of the biggest challenges for the agricultural industry is to satisfy the globally growing demand for food with quality and healthy products with fewer inputs, less energy, and lower environmental impacts (Kyttä et al., 2021). To do so, one of the promising practices will imply

changing fertilisation practices and increase the recycling of nutrients from different organic wastes in the form of fertilisers (EC,2019).

Mineral fertilisers have played a key role in high crop yields and economic development for many decades in the agricultural industry. Nevertheless, they are associated with impacts downstream production and use on which stand the use of fossil fuels, natural resources exploitation, nutrient runoff, and accumulation into the environment. (Gaidajis & Kakanis 2021, Chojnacka et al., 2020; Vitousek et al., 2009).

Nutrients in the European Union (EU) context

Aiming for the transition to more sustainable agricultural production systems the EU has pushed initiatives such as the Farm to Fork Strategy and "zero pollution ambition" from the EU Green Deal, promoting the use of locally available nutrients and reduce the dependance of fertiliser imports. (EC,2019; Chojnacka et al., 2020). The EU projects that 30% of the current chemical fertiliser use could be replaced by bio-based fertilisers in the long term. (Chojnacka et al., 2020; Gaidajis & Kakanis, 2021).

The EU has recently revised the Fertiliser Regulation (EC,2019), extending its scope to include fertilising products produced from organic waste streams, which we refer to as "bio-based fertilisers". In this context, bio-based fertilisers are produced from a diverse range of biological wastes under treatment technologies (i.e., thermochemical, physical separation, biological) and can be used as valuable nutrient components in the replacement of mineral sources (Hu et al., 2021). However, harmonization of legislation, quality control, market acceptability, and public perceptions need to be explored for their safe production and use in agriculture.

Previous discussions in adoption have noted that in the agricultural sector, despite the existence of alternatives for farmers, adoption processes are low. This might also be the case for newly bio-based fertilisers. It is of special interest for stakeholders (i.e., developers, policy makers) to understand the factors explaining the adoption of bio-based fertilisers, but there is a lack of studies examining them (Tur-Cardona et al., 2018).

Commented [JB3]: add 1 sentence per lagerkvist, michelson, zhang

We have identified a knowledge gap in terms of the perceptions, knowledge, and role of stakeholders regarding market adoption of multiple agricultural practices, including bio-based fertilisers, as discussed in the latest research (Lagerkvist et al., 2015; Michelson et al., 2021;Zhang et al., 2015). An understanding of the decision-making process and acceptance of bio-based fertilisers will fill this knowledge gap as well as facilitate their development and market inclusion (Rich et al., 2011; Van Loo et al., 2013; Yiridoe et al., 2005). In this study we aim to understand the psychological processes that farmers experience for the adoption of agricultural practices with focus on bio-based fertilisers.

This study begins with a literature review for the identification of intentions, attitudes, behaviors, drivers, and barriers to the adoption of agricultural practices, in particular the use of bio-based fertilisers. After, proposes and executes a qualitative evaluation framework based on latest literature. Farmers alongside the EU are asked on a survey-based experiment about their psychological and economic perceptions of bio-based fertilisers. The proposed framework in this study can be used to underline informational variables that influence the decision of farmers to accept bio-based fertilisers.

2. Literature review

Farmers cannot be expected to have an attitude concerning specific agricultural practices if they have no memory from which an evaluative association can be drawn. These memory representations on a psychological level, are created based on inputs such as the environment and subjective experiences (Lagerkvist et al., 2015). Farmers' willingness to adopt a given agricultural practice might not be equally translated into action (Zhang et al., 2020). This lack of action is an attitude-behavior gap. Farmers would tend to say one thing and do another (Lagerkvist et al., 2015). In this context, despite the existence of alternative bio-based fertilisers the adoption might be lower than expected. (Tur-Cardona et al., 2018). Authors have repeatedly emphasized the need for more studies to investigate the margins at which farmers operate and the role of their subjective beliefs for fertilisers. (Michelson et al., 2021; Michelson et al., 2021; Tur-Cardona et al., 2018; Zhang et al., 2015)

Latest academic sources on understanding farmers' decisions have relied on psychological approaches (Bagheri et al., 2019; Bechini et al., 2020; Doran et al., 2020; Savari & Gharechaee, 2020; Zhang et al., 2020), of which most of them followed the Theory of Planned Behaviour (TPB) (Ajzen, 1991) for their analysis.

The TPB is an extension of Theory of Reasoned Action (TRA) (Ajzen, 1991) and states that behavior results from the intention to engage in a specific action: The stronger the intention, the more likely it is behavior engagement (Steg et al., 2013). The proposed TPB postulates three independent determinants of intentions: attitudes, subjective norms related to behavior, and perceived behavioral control.

1. Attitudes (Att): Reflect the extent to which engaging in a behavior is evaluated positively or negatively. Based on beliefs about the likely costs and benefits of performing certain actions;
2. Subjective Norms (SN): Reflect the extent to which a person believes expectations or pressures upon them to perform or not to perform certain behavior. Social Norms evaluate the importance of the approval or disapproval of the behavior from relevant groups;
3. Perceived Behavioral Control (PBC): Reflect the extent to which a person perceives ease or difficulty of performing a behavior (i.e. resources and opportunities available to a person that some extent dictate the likelihood of behavioural achievement)

We assume that TPB can be a useful tool for the prediction of behavioral intentions for the adoption of newly bio-based fertilisers. The use of psychological approaches clearly matters as evaluating the subjective perceptions on which farmers operate is crucial for targeting adequate marketing interventions.

However, it is presumed that the measurement frameworks such as TPB, must be further expanded as other psychological processes take place. For example, the adoption decision of fertilisers will only be possible when economic and non-economic goals are satisfied (Adnan et al., 2019). We assume that adoption of bio-based fertilisers could have a direct impact on productivity for farmers, on which their economic goals might not be satisfied. Therefore, it is important to understand how farmers assess bio-based fertilisers aiming for the linkage of disciplines on a psychological and economic level. Different evaluation frameworks have been proposed for the linkage of psychology and economic disciplines (see Borges et al., 2019 and Adnan et al., 2017). In general, none of the available proposed methods has aimed to test quantitively for economic and non-economic adoption models in the context of bio-based fertilisers.

A decision to adopt a newly developed technology for farmers might be by comparing their expected utility values with the previous practice. This statement can be framed under the Expected Utility Theory (EUT). According to EUT, farmers will compare the utility of both novel and outdated interventions (i.e., fertilisation methods). We assume that farmers will adopt the new bio-based fertilizes if the expected utility surpasses the utility of the outdated available product (i.e., mineral fertilisers). Farmers therefore are seen as rational decision makers, where they try to optimize their utility from their available resources. (Batz et. al 1999 and cited by Adnan et al., 2017).

Expected Utility Theory (EUT) as Behavioral Predictor of Intentions

Adnan et al., 2017 developed a conceptual framework grounded on the TPB and Expected Utility Theory (EUT) to overcome some of the limitations that appear when just one theory is used. Previous studies have mentioned that perceived benefits, costs, and risks can be tested as explanatory variables for EUT (Borges et al., 2019). For this experiment, we tried to analyze them carefully and take them into account for our own experiment validation.

Within the EUT framework, a large body of literature is dedicated to studying the impact of risk on the farmers' decision to adopt new technology or agricultural practice. As noted by Bocquého et al., 2014, the risk associated with the adoption of new technologies can be a barrier. The risk dimension of EUT can be defined as the farmer's interpretation of the probability of an undesirable outcome for their farm. Risk can range from perceiving no risk at all to perceiving elevated risk (Pennings & Wansink, 2004). Risk perception has a direct negative effect on the likelihood of adoption and expected economic benefits, which might hinder the adoption of a new agricultural practice (Trujillo-Barrera et al., 2016).

Linking EUT and TPB

Borges et al., 2019 underlined strengths and weaknesses from both methods (TPB and EUT) and how the combination of the two may strengthen the final outcomes of conducting a study over using each theory individually. The authors stated that both EUT and TPB models have similar theoretical backgrounds as they are part of the expectancy-value framework. It is widely seen that expected utility is used in economic literature, and TPB is used in social-psychology literature. An important remark is that both theories have failed to find the underlying causes for adoptions.

The two frameworks have their advantages and disadvantages. According to Borges et al., 2019, a remarkable barrier from TPB is the lack of consistency in the methodology between studies on adoptions in agriculture. The second barrier is that TPB does not reveal final behavior but intentions to perform a specific behavior ("attitude-behavior gap"). As a matter of increasing traceability, authors recommend collecting data in different periods of time.

For the EUT, in practice, it captures the 'the most authentic' behavior of farmers, using the concept of revealed preference. However, considers that farmers have the objective to maximize profit, while not considering subjective beliefs. According to Adnan et al., 2017, the combination of TPB and EUT will overcome the limitations when just one theory is used to examine adoption. Thus, according to the above statements, the variable of utility maximization added to the main framework of TPB, potentially would explain behavioral intentions.

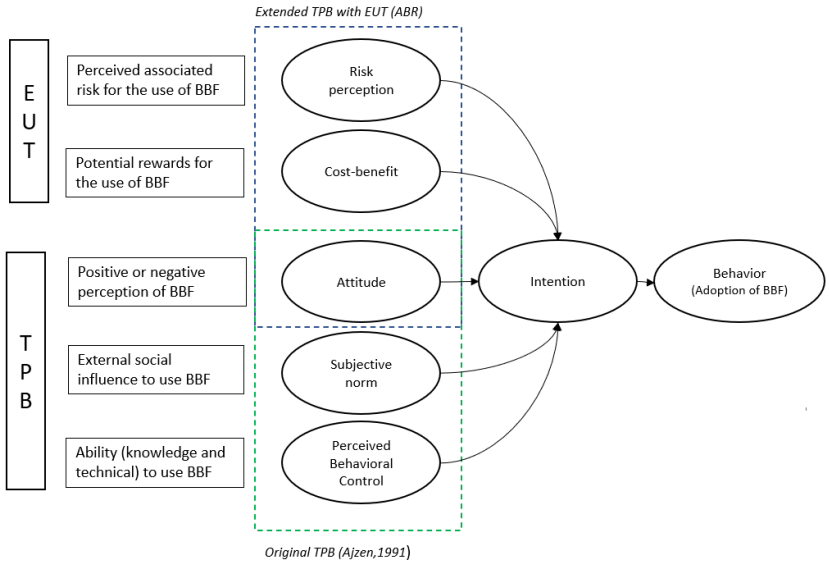


Figure 4. Conceptual framework of the Theory of planned behavior and Expected Utility Theory (Adnan et al., 2017; Ajzen, 1991; Borges et al., 2019)

We hypothesize that an extended version of TPB with EUT would create a model that can predict with better accuracy the underlying mechanisms towards the adoption of bio-based fertilisers alongside the EU. Five main hypotheses of the present study can be defined as follows:

Commented [SL4]: Do you find correct to put those hypothesis?

- Hypothesis 1 (H1). Farmers' attitudes have a significant positive relationship with intentions on the use of bio-based fertilisers
- Hypothesis 2 (H2). Farmers' subjective norms have a positive correlation with intentions on the use of waste-based fertilisers
- Hypothesis 3 (H3). Farmers' perceived behavioral control have a positive correlation with intentions on the use of bio-based fertilisers

Commented [5]: Those are the initial Hypothesis. Might be wise to adjust them according on what we have done so far for more interesting ones...

Cost-benefit and Risk perception are considered one of the elements to consider when adopting new agricultural practices according to scholars under an utility maximization framework. Therefore, an extended version of TPB can be stated where:

- Hypothesis 4 (H4). Cost-Benefit perception in the use of bio-based fertilisers has a positive correlation with intentions on the use of waste-based fertilizers
- Hypothesis 5 (H5). Risk perception in the use of bio-based fertilisers has a positive correlation with intentions on the use of waste-based fertilizers
- Tentative H: Attitudes, Cost-benefit and Risk perception are represent a singular psychological construct (?)

4. Methodology

To analyze farmers' intentions, a structured questionnaire application was selected as a method to gather information to test the acceptance of bio-based fertilisers across the EU. The main part of the survey contained two separate parts: 1) farm characteristics and activities, 2) section to assess the impact of psychological latent constructs on the farmers' intention to adopt bio-based fertilisers and, 3) measuring willingness-to-pay through extended price sensitivity meter methodology. For the measurement of constructs in the second section, items were assessed with a 5-point Likert Scale (1: strongly disagree- 5: strongly agree). For this paper, the focus will be on the first and second part of the survey.

Commented [6]: Shouldn't you mention here that the questionnaire can be found in the appendix? Or is that not allowed?

Commented [SGL7R6]: Might be added as complementary materials to the journal

Study Design and Validity of Instrument

To evaluate indicators, the draft of the questionnaire was reviewed by an expert consultation group that included professors with extensive knowledge in a wide range of agricultural sciences. The first stage of the questionnaire included a testing period between a set of farmers (n=12). The first round of testing provided an opportunity to receive feedback on each survey section.

The testing period ran from the 6th of October 2021 until the 30th of October 2021. After adjustments, the questionnaire was then translated into 19 additional languages: Croatian, Dutch, Danish, Bulgarian, Greek, German, Portuguese, Swedish, Spanish, French, Italian, Polish, Hungarian, Romanian, Finnish, Estonian, Latvian, Lithuanian, and Czech. The translations were cross-checked by native speakers in each country who were familiar with related terminology. The fully translated questionnaire ran from January 2022 until June 2022. All language versions were programmed in the online survey software Qualtrics. The dissemination of the survey was done online through contact databases in the agricultural field from the European Landowners Organization (ELO)and United Experts (UE). To ensure sufficient responses the networks of FertiCycle and REFLOW consortia have been actively used. In addition, the national farmers associations were reached out to provide access to farmers across the EU. Full disclosure of the survey structure can be seen in Table X presented below.

Table X: Factors and corresponding items

Type	Statement	Scale	Type
Control variables			
Occupation	What is your farming type?	1-6	Nominal
Gender	What is your gender?	1-3	Nominal
Age	What is your age?	1-6	Ordinal
Land Extension	What is your land extension?	1-6	Scale
Education	What is your highest degree of education?	1-6	Ordinal
Constructs			
Intentions			
I1	I am willing to participate in a program where that promote to use bio-based fertilizers.	1-5	Ordinal
I2	I am considering to increase the use bio-based fertilizers in the upcoming years if they have similar quality as mineral fertilizers.	1-5	Ordinal

I3	I advise other farmers to use more waste-based fertilizers on their farms.	1-5	Ordinal
I4	I need to change my fertilization strategies towards more environmentally friendly solutions in the upcoming years.	1-5	Ordinal
Attitudes			
A1	I believe that using more of bio-based fertilisers will lead to better environmental outcomes.	1-5	Ordinal
A2	The use of biobased fertilizers use is unpleasant to me.	1-5	Ordinal
A3	I prefer properties of bio-based fertilisers more than conventional mineral fertilizers.	1-5	Ordinal
A4	I agree bio-based fertilisers present a valid alternative to replace the use of mineral fertilizers.	1-5	Ordinal
Social Norms			
SN1	Most people whose opinions are important for me suggest to use more bio-based fertilisers.	1-5	Ordinal
SN2	Agricultural experts / my trusted advisors consider that bio-based fertilizers will be beneficial for my farm.	1-5	Ordinal
SN3	Agricultural product sellers will approve if I use bio-based fertilizers in my farm instead of mineral fertilizers.	1-5	Ordinal
SN4	Authorities in my region promote the higher usage of bio-based fertilizers.	1-5	Ordinal
Perceived Behavioral Control			
PBC1	I have skills and knowledge to apply bio-based fertilizers instead of mineral fertilizers without additional effort.	1-5	Ordinal
PBC2	I have enough information about properties and features of biobased fertilizers that can be used in my farm.	1-5	Ordinal
PBC3	I have a good knowledge of the prices that I pay for the fertilisers that I currently use on my farm.	1-5	Ordinal
PBC4	Existing legal framework interferes with the application of bio-based fertilisers on my farm.	1-5	Ordinal
Benefit Perceptions			
CB1	Bio-based fertiliser will be more expensive than conventional fertilisers.	1-5	Ordinal
CB2	I believe that in order to stay profitable you have to consider fertilizer expenses carefully.	1-5	Ordinal
CB3	Bio-based fertilisers will be beneficial for my farm as it increases soil quality and fertility.	1-5	Ordinal
CB4	Bio based fertilizers will improve yield and therefore, my financial results.	1-5	Ordinal
Risk Perceptions			
R1	I trust quality of bio-based fertilisers.	1-5	Ordinal
R2	Use of bio-based fertilisers will result in nutrient and runoff/losses.	1-5	Ordinal
R3	Bio-based fertilisers will have more stable prices than conventional fertilisers in the future.	1-5	Ordinal
R4	I believe that my current level of fertiliser expenses is too high to maintain in long term.	1-5	Ordinal

Notes: Summary statistics can be found in Appendix XX.

Measurements

By the closure of the survey, a total of 780 people has started the survey. The whole database was cleaned and in total 332 people have finished the survey successfully. Responses were collected from farmers in 22 countries with most responses from France (35) and Portugal (46). Table XX and graph XX presented below give an overview of descriptive statistics from the sample.

Data were analyzed with Excel®, SPSS Statistics, AMOS (software for Structural Equation Modelling), and R Studio. Preliminary cleaning of raw data, table elaboration, and basic descriptive statistics were done in Excel. Then, SPSS was used for flexibility purposes for the assessment and analysis of both AMOS and R Studio. AMOS was used to determine statistical tests such as normality, followed by R which was used for the creation of the measurement models and path analyses using Lavaan R package for Structural Equation Modelling (SEM).

A specific number of questions were asked with inverted scales (A2, PBC4, R2 and R4). Therefore, they had to be corrected for consistency with the rest of the questions. To explore data, a correlation analysis was run to explore the behavior of collected variables. As a result of the analysis, several variables failed to exhibit strong correlation with the analysis. After the preliminary analysis of SEM, due to the lack of significance, several variables were considered redundant for the analysis and were dropped. A correlation plot of variables can be seen in Figure X presented below.

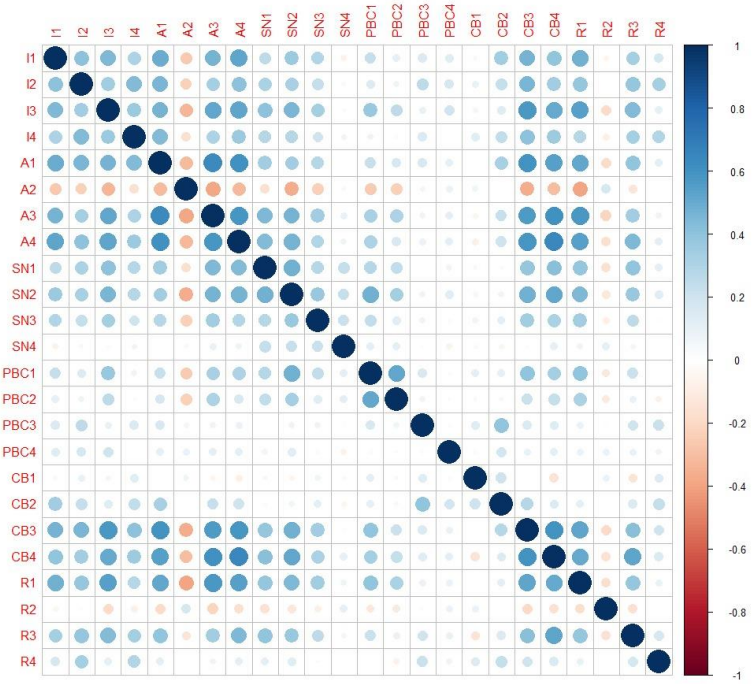


Figure X. Correlation plot of variables (own elaboration R studio)

Results and Discussion

Descriptive Statistics

The results of the individual properties and farmers characteristics are summarized in Table X presented below. A vast majority of the respondents stated to be male (81%). Most of the participants (40%) are above 55 years old followed by the age range from 45-54 years old (28%). In terms of educational degree, participants holding a professional career or higher account up to (74%). A small minority (2%) stated to have basic education. Land extension is greater than 10 hectares for most of the respondents (78%). Respondents owning a private farm accounted to (61%) and owning and renting (21%) and nearly half of respondents (45%) produce field crops. Demographic characteristics of the sample can be seen in Table X.

Occupation	**Number of responses**	**Percent**
A private farm owner	202	61
A large-scale lessee (renter)	8	2
A city resident owning a farm	9	3
Owner and renter	71	21
Agricultural advisor	0	0
Farming type		
Fieldcrops	215	45,8
Horticulture	46	9,8
Wine production	31	6,6
Other permanent crops	72	15,4
Milk production	18	3,8
Other grazing livestock	39	8,3
Granivores	11	2,3
Mixed production	37	7,9
Gender		
Male	269	81
Female	57	17
Prefer not to say	6	2
Total	247	100
Age		
Less than 18 years	1	0
18-24 years	2	1
25-35 years	44	13
35-44 years	58	17
45-54 years	93	28
>55 years	134	40
Land extension		
<0,5 hectares	11	3
0,5-1 hectares	8	2
1-2 hectares	6	2
2-5 hectares	23	7
5-10 hectares	25	8
>10 hectares	259	78
Education		
Basic school	7	2
Highschool	45	14
Bachelor's degree	91	27
Master's degree	131	39
Ph.D. or higher	27	8
Technical school	31	9
Total	**332**	

Table X. Demographic characteristics of respondents (n=332)

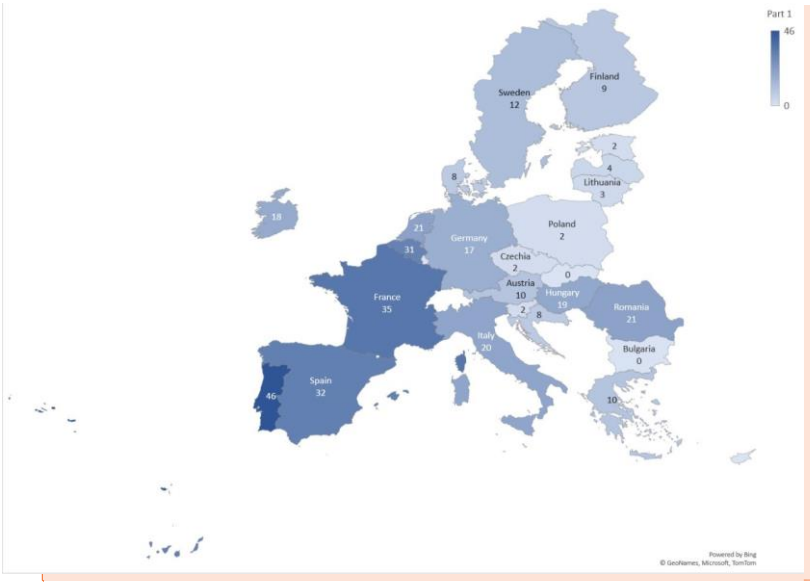


Figure X. Respondents per country (n=332). Own elaboration Q GIS

Commented [8]: A few comments about this map:
- The North arrow is missing
- There is no scale
- Is it necessary to put Bulgaria and Hungary as 0?
- You forgot to input the names of Slovenia, Hungary, Estonia, Denmark, Portugal, Belgium, the Netherlands, Greece, Cyprus, and Latvia.
- What about the non-EU countries? They still exist in Europe even though they were not included in your respondents. You should still put their jurisdictional outlines but you can darken them to highlight they're not included
- You can cut the islands in the Atlantic out as well, to focus on the mainland (+Ireland)

Commented [9R8]: The colour codes are too close to each other, maybe try to find something not colour-oriented? (think of the colorblind/or people who print in B&W)

Commented [10R8]: Also add the figures of every country below, or in a table underneath

Normality Test

Normality was tested using statistical package of AMOS. The results are summarized in tableX. It is observed that the sample fails to exhibit multi-variate normality. Therefore, bias correction in the reported SEM was needed. A bootstrap method was applied to account for issues of non-normality to determine path significance with 1000 iterations. Path significances from the proposed models were used to test the hypothesis formulated for this study.

Normality assesment				
Variable	**Skewness**	**c.r.**	**Kurtosis**	**c.r.**
Intentions				
I1	-0,864	-6,428	0,05	0,186
I2	-1,101	-8,19	0,93	3,459
I3	-0,357	-2,654	-0,565	-2,1
I4	-0,772	-5,745	-0,178	-0,663
Attitudes				
A1	-1,047	-7,792	0,7	2,603
A2	0,455	3,381	-0,705	-2,621
A3	-0,33	-2,452	-0,655	-2,436
A4	-1,01	-7,512	0,309	1,15
Social Norms				
SN1	-0,126	-0,94	-0,401	-1,491
SN2	-0,129	-0,956	-0,203	-0,756
SN3	-0,182	-1,354	-0,432	-1,606
SN4	0,197	1,465	-0,84	-3,124
Perceived Behavioral Control				
PBC1	-0,261	-1,942	-0,943	-3,507
PBC2	-0,029	-0,216	-1,077	-4,006
PBC3	-1,491	-11,092	2,164	8,049
PBC4	-0,325	-2,42	-0,659	-2,452
Cost-Benefit				
CB1	-0,362	-2,69	-0,377	-1,401
CB2	-2,244	-16,693	5,296	19,698

CB3	-0,923	-6,865	0,463	1,722
CB4	-0,073	-0,54	-0,402	-1,494
Risk perception				
R1	-0,3	-2,231	-0,509	-1,894
R2	0,169	1,256	-0,728	-2,706
R3	0,034	0,254	-0,179	-0,665
R4	-0,559	-4,158	-0,479	-1,783

Table X. Normality tests AMOS (include)

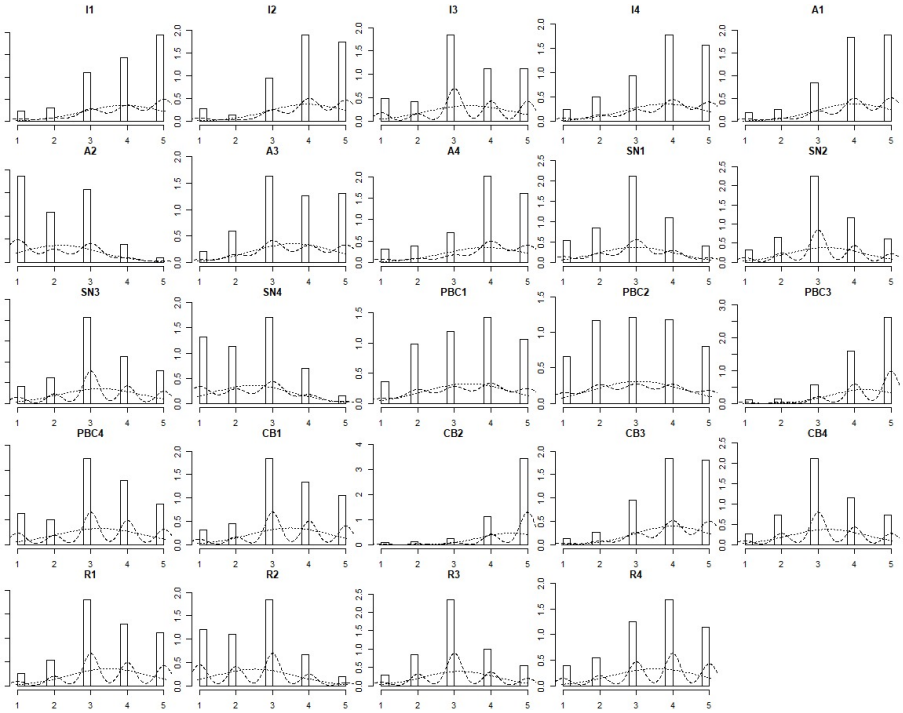


Figure X. Include it or not? Response distribution for different items (Own elaboration. R studio)

Commented [11]: Ask for the non inverted variables graph

Commented [12R11]: Which software was used?

Structural models for evaluation

In this study we wanted to test the relative influence of an extended version of TPB with elements described by the EUT (perceived benefit and risk on intentions) separately. Two main research works (Adnan et al., 2017 and Borges et al., 2019) have worked closely with the extension of TPB using EUT. Both research works agree that attitudes, perceived benefits, and risk come from the same behavioral beliefs, but their proposed structures of the model differ. First, Adnan et al., 2017 proposed a conceptual framework to study farmers' decisions on adoption of green technology. Authors defined attitudes, perception of cost, benefit, and risk as sub-factors of Behavioral beliefs on the same level. By contrast, Borges et al., 2019 defined attitudes, benefits, and risks as a single block of factors stemming from Behavioral beliefs which are in turn affected by external factors such as age, gender, and region of residence.

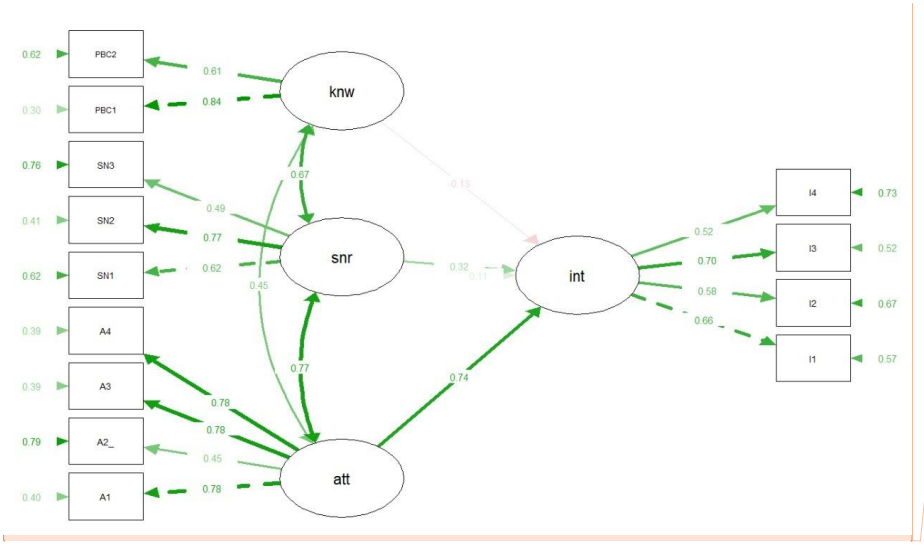
This study includes two different models that test the relative impacts of psycho-economic determinants on the intention to adopt bio-based fertilisers: First, a general Theory of Planned

Behavior model, and secondly, an extended version of TPB with EUT elements such as perceived benefits and risks. The results of the standard model of TPB and extended can be seen in the section below:

General TPB Model

The results show that there is one positive and significant path related to farmers' intentions to use bio-based fertilisers. The path (Attitudes Intentions) coefficients accounted (β=0.74, P>0.00**). Thus, this finding confirms that attitudes are the strongest predictor of intentions for bio-based fertiliser behavioural intentions. The results of structural equation analysis show good fitting of the generic TPB model. Fit indices validate the selection of TPB as a theoretical approach to analyze farmers' intentions to adopt bio-based fertilisers. The chi-square of this model is 146,6 and degrees of freedom (df) 59. The ratio between chi-square and df equals to 2.4, less than the suggested maximum of 2,5. Similarly, Root Mean Square Error (RMSEA) was 0,068 and Comparative Fit Index (cfi) up to 0,39. Summary results from fit indices can be seen in Table X below. The findings indicate that the attitude components explain the greatest part of the variance of intentions to use bio-based fertilisers. The variables of PBC and SN did not have a significant influence on farmers' behavioral intention. The results of the model covariances can be seen in fig. X and summarized in table X below.

Commented [13]: Find reference 2.5



Commented [14]: This is a very complex figure, maybe explains what it does and what it represents?

Figure X. Original TPB with standardized path coefficients (Own elaboration. R Studio)

Extension of TPB with EUT Elements

Commented [15]: capitalisation

While performing a correlation analysis between variables, it was discovered that attitudes, perceived benefits, and risks have strong correlation (higher than 0.9) as can be seen in Figure X. An integration of variables with strong correlation separately in the structural equation model creates issues with multi-collinearity. This made it impossible to integrate them in a model as suggested by Adnan et al., 2017. Therefore, an adjusted approach in the form of second level factor analysis was needed to solve the multi-collinearity issue, however still

retains the possibility to perform the path analysis for each of the measured first level constructs.

This way the combination of Attitudes, Benefits, and Risks (ABR) are combined in a second level factor which is referred as ABR in the analysis. The second structural equation model followed in this study considers a closer structure by the one defined by Borges et al., 2019.

The results of the second model display that the path (ABR→Intentions) is positive and significant and accounted related accounted (β=0.88, P>0.00**). Thus, the finding in this research work confirms that the integration of attitudes, perceived benefits, and risk do belong to the same level of construct as stated in [literature], and all together are the strongest predictor of intentions. The results of structural equation analysis show good fitting of the generic TPB+EUT model. Fit indices validate the selection of the discussed structures of the model in literature as a theoretical approach to analyze farmers' intentions to adopt bio-based fertilisers. Root Mean Square Error (RMSEA) was 0.064 and Comparative Fit Index (cfi) went up to 0.937. Summary results from fit indices can be seen in Table X below. The findings indicate that the extended framework (ABR) explains a larger variance compared to the original TPB. The relative importance of the factor describing attitudes, benefits, and risks (ABR) increases compared to the single attitudes' indicator in the original TPB. Similarly, to the original TPB framework, for the extended version, the variables of PBC, and SN did not have a significant influence on farmers' behavioral intention, according to factor loading data. The results of the model covariances can be seen in fig. X and summarized in table X below.

Commented [SGL16]: Good

Commented [17]: reference the important papers here?

Commented [SGL18R17]: To be added...

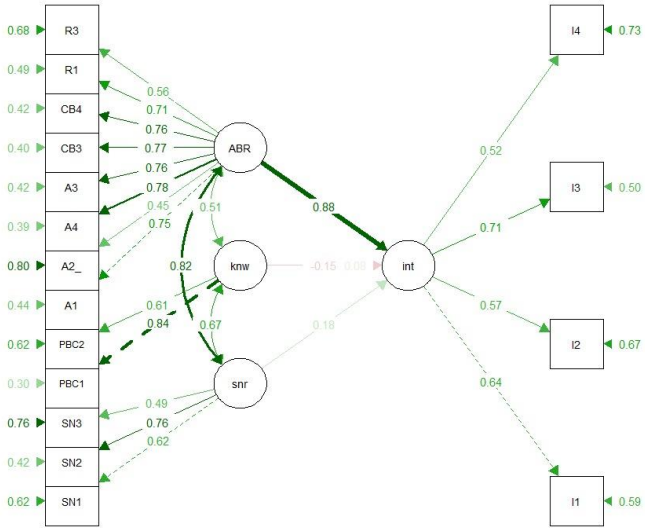


Figure X. Extended version of TPB with standardized path coefficients (Own elaboration. R Studio)

Commented [19]: Which software did you use and what do all the acronyms mean?

Table x. Results of fit of measurement models

Model	cfi	rmsea	chisq	df	srmr
Model 1 (TPB)					
TPB	0,939	0,068	146,635	59	0,052
Model 2 (TPB+EUT)					
TPB+EUT	0,934	0,064	267,735	113	0,05

Table XX. Fit indices of the TPB and extended TPB structural models to measure intentions for the adoption of BBF.

Covariances of models	Estimate	Std. Err	Z-value	P(>lzl)	Std. all
Model 1 (TPB)					
Attitudes	0,704	0,174	4,04	0,00**	0,777
Social Norms	0,331	0,269	1,231	0,218	0,297
Perceived Behavioral Control	-0,099	0,1	-0,988	0,0323	-0,138
Model 2 (TPB+EUT)					
TPB+EUT (ABR as construct)	0,817	0,182	4,491	0,00**	0,881
Social Norms	0,198	0,268	0,737	0,461	0,182
PBC	-0,106	0,084	-1,262	0,207	-0,151

Table X. Results of Structural Equation Models

Hypothesis	TPB	Extended TPB
H1. Attitudes have a positive correlation with intentions	Accept	Accept
H2. Subjective norms have a positive correlation with	Reject	Reject
H3. Perceived behavioral control has a positive correlation with intentions	Reject	Reject
H4. Cost-Benefit perception have a positive correlation with intentions	–	Accept
H5. Risk perception have a positive correlation with intentions	–	Accept

From a theoretical point of view, this study demonstrated that TPB is a useful tool for explaining farmers' intentions to adopt bio-based fertilisers. The significant influence of attitudes aligns with the findings discussed at Doran et al., 2020 on which they stated that attitudes are predictor of intentions, which is the case for bio-based fertilisers.

Since there are different approaches for measuring intentions, and no consensus is defined by scholars in agricultural studies, we approached designing the models based on suggested structures discussed in the latest research (Adnan and Borges). First, the original TPB structure and secondly the extended version of TPB with EUT elements reframe better

(The exteded this is a way to narrow down a common evaluation framework for agricultural studies for extended versions of tpb)

According to the results, the original structure of the TPB explains 88% of total variance of the behavioral intention to adopt bio-based fertilisers. Adding two more variables rooted in the EUT (benefit and risk perception), the enhanced model increased the predictive model for

behavioral intention up to a total explained variance of 92%. As reported in numerous TPB studies previously, we identified attitudes as the strongest predictor of intentions. However, the sole TPB model can be improved by the addition of benefit and risk perception stemming from EUT. Which is consistent with (Savari & Gharechaee, 2020, Adnan et al., 2017; Doran et al., 2020). Interestingly, in our analysis the attitudes, benefit and risk perceptions exhibit strong correlation (>0,9), hinting that in the case of adoption of bio-based fertilisers the three constructs indeed represent the same dimension for behavioral intentions. Therefore, it is crucial to raise awareness on generating and providing information that explicitly remarks the benefits of use of bio-based fertilisers and the risk of use that they represent as those perceptions would be strongly connected to attitudinal perceptions. These results are consistent with previous research discussions (Savari & Gharechaee, 2020,Adnan et al., 2017; Doran et al., 2020).

Commented [20]: What are those results and why do they matter?

"additions for discussion with Jeroen regarding social norms"

-Bagheri (2019), conducred a study to evaluate integrated crop management practices in Iran with the implementation of TPB. They measured ICM (Nutrient management, pest control and financial management). They found out that the strongest path is Social Norms and concluded that there is an existent social pressure among farmers for the adoption of ICM.

Savari (2020): Used the extended TPB with Moral Norms and Risk Perception to measure intentions for safe use of chemical fertilizers.

Studies have extensively tested TPB and have found that is a predictor of behavioral intentions. Social Norms and PBC have been postively correlated with behavioral intentions for several environmental "initiatives" (recycling, environmental behaviors) but not for fertilisers specifically.

Conclusion

With this study, we employed a survey method to understand farmers behavioral intentions to adopt bio-based fertilisers across the EU. The present study is one of the first efforts to test the validity of conceptual frameworks discussed by scholars for farmers adoption decisions. We employed the original structure of TPB and an extended version including variables from EUT. Our findings suggest that both models exhibit a good fit. We determined that in the original structure of TPB, the construct of attitudes is the strongest predictor of intentions, which aligns with discussions found in the majority of the academic literature on the topic. No significant influence was found for Subjective Norms and Perceived Behavioral Control.

Commented [21]: verify acronims

We support the idea that the evaluation of intentions to adopt an agricultural innovation (i.e., newly bio-based fertilisers) must be analysed with an integrated approach and the inclusion of psychological and economic variables. We built on earlier work by testing conceptual frameworks discussed by scholars. While our findings support the theory, it is also important to remark the applicability and importance of the results for designing policy approaches and recommendations for interested sectors on the development and market exploration of bio-based fertilisers. The following is proposed to highlight future policy and research pathways:

- Highlight the quality of bio-based fertilisers with the important benefits they provide (i.e., soil, yield, composition, etc.);
- Focus on generating information that supports a low risk of use and how the change on fertilisation strategies with bio-based fertilisers would reduce economic losses for farmers;

- Encourage development of market mechanisms that ensure price stability of bio-based fertilisers.

Our results suggest that farmers intentions are not driven only by the maximization of profit but also by attitudinal beliefs. These findings bridge a knowledge gap between previous research stating that it is recommended to evaluate behavioral intentions from a multidisciplinary perspective mixing psychological and economical variables. In addition, the findings uncover connection between TPB and EUT and prove the validity of proposed structural models by some of the latest academic research (Adnan et al., 2017 and Borges et al., 2019). Perceptions can differ across different regions, and we collected data unevenly which may lead to bias towards the perceptions in the countries where the larger number of responses were collected. Therefore, it is advised to consider the results taking into account the distribution of the responses. Future research should focus on trying to find differences across different regions and demographics.

This is a first quantitative attempt to evaluate behavioral intentions from psychological-economic perspective for intentions to adopt bio-based fertilisers and it is important to remark that the methodology used in this study is broadly generalizable and may be used for other farming decisions and test the model validity. We used Structural Equation Modelling, and it is important to remark that our proposed model (extended TPB) relies on the theoretical background. Before conducting our analysis, we had no references on which the theory (i.e. extended TPB) were evaluated quantitatively for agricultural innovations. We suggest that further research should reflect on statistical issues that might arise from the proposed models, such as multicollinearity. Further research should discuss general structures for agricultural innovations and find ways to address model structures so that they avoid similar statistical limitations.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study.

Acknowledgements'

This project has received funding from the European Union's Horizon 2020 research and innovative programme under the MSC-ITN grant agreement No. 814258 (REFLOW) and MSC-ITN grant agreement No. 860127 (FERTICYCLE). Authors thank the Projects Team from the ELO for language revisions and comments for the integration of this document.

References

[Missing. To be put at the end]