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Assessment of willingness-to-pay for bio-based fertilisers among farmers and agricultural advisors in the EU

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ABSTRACT

Modern agricultural systems heavily depend on replenishing nutrients in the soils via mineral fertilisers. However, the extensive use and production of mineral fertilisers lead to adverse environmental effects. Furthermore, the raw materials used for the production of mineral fertilisers are unevenly distributed in the world and are susceptible to price fluctuations on the international market. A more circular solution is needed to ensure the sustainable supply of nutrients for agriculture in Europe. Bio-based fertilisers (i.e. fertilisers recycled from various waste streams while avoiding the use of fossil resources) can be a solution. The transition requires significant marketing efforts, but there is very little information on pricing preferences for newly developed bio-based fertilisers. This article aims to fill the gap by performing analyses of willingness-to-pay and price sensitivity using the Van Westendorp pricing technique and its extended version. Our analyses exemplified how the Van Westendorp methodologies can be used to generate insights into the price sensitivity of farmers and agricultural advisors in the EU. The selected methodologies allowed us to consider the 'revenue vs. market share' trade-off and thus distinguish the prices that are needed to gain the largest product market share and the prices that are needed to maximise the revenue from the products. Our results suggest that the price for a bio-based fertiliser at the 30–46% discount compared to the price of an equivalent mineral fertiliser would allow to maximise the market share of the product. Yet, to maximise the revenue the prices can be set equivalent to the ones of the mineral fertilisers. Combined with benchmarking studies and technical economic assessments our results contribute to the understanding of the key aspects needed for the development of marketing strategies and business case analyses for newly introduced products, such as bio-based fertilisers.

1. Introduction

Global agriculture suffers from geopolitical instabilities and market volatility which heavily affect the price and availability of mineral fertilisers, thus creating risk for global food security. It is crucial to ensure a sustainable supply of essential nutrients for agriculture.

Bio-based fertilisers are the products that are derived from organic waste nutrient recovery technologies. Popular recovered material types include ammonium salts as well as struvite, biochar and ash products, which are collectively known as STRUBIAS (Vaneeckhaute, 2021; Shi et al., 2022). These products form a new, rapidly developing market, with great prospect but also with great uncertainty.

Bio-based fertilisers have been shown to be as effective as mineral sources (Numviyimana et al., 2020; Shi et al., 2021). In addition, recent studies have examined the impact of bio-based fertiliser (e.g., biochar) application to various soils on greenhouse gas emissions (GHG). The results have shown that GHG emissions are significantly reduced compared to the application of raw organic forms of waste (Hu et al., 2023; Martínez-Sabater et al., 2022). The development and market introduction of new fertiliser forms will potentially reduce dependence on mineral sources and promote a circular economy and sustainability (Chojnacka et al., 2020; Martínez-Sabater et al., 2022).

The term 'bio-based fertiliser' is ambiguous and is highly debated in the field. Other literature may refer to it as waste-based fertiliser, recycling derived fertiliser or manure-processed product (Smol, 2021; Egan et al., 2022; Tur-Cardona et al., 2018). To avoid confusion, this

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article considers bio-based fertilisers to be fertilisers that are produced according to the principles of the circular economy from various locally available waste streams while avoiding the use of fossil resources as raw materials.

Although bio-based fertilisers are a potential solution for a sustainable supply of nutrients, they still face numerous agronomic and engineering challenges (Marchi et al., 2020). However, even with these problems resolved economic and marketing challenges remain. These present an equally important but totally different task, namely integrating social, economic and political aspects in a fair way to ensure the long-term sustainability of the bio-based fertiliser industry. Huygens et al. (2018) point out that the current market for the recovered nutrients is very small, which emphasizes the effort needed for wider adoption of bio-based fertilisers.

Understanding the market is a key aspect of introducing new products and a new industry needs data to make business decisions. This is especially true for pricing, which is of particular interest to bio-based fertiliser producers (e.g. fertiliser producers, biogas plants and waste management facilities), as it is a pressing challenge to decide whether to introduce or improve current nutrient recovery and reuse technologies (NRR). As NRRs require significant investment, managers need to estimate the potential prices and marketing opportunities for the resulting products to ensure that the technologies are commercially appealing.

Some of the conventional mineral fertiliser producers recently started expressing interest in recovered nutrients in order to incorporate them into their production lines (Fitch, 2022). Although mineral fertiliser producers point out a number of challenges most commonly associated with the quantities and consistency of recovered nutrients, the shift in perspective towards more circular sources is apparent. Therefore, estimating prices for recovered nutrients in order to assess the attractiveness of such a business case is of high interest to the industry.

In general, marketers consider pricing as one of the key components in the marketing mix (i.e. Product, Promotion, Pricing, Place, People, etc.). As noted by Owusu-Bempah et al. (2013) not only does pricing require extensive knowledge of the potential consumer, it also directly impacts on sales and profits. Therefore, a data-driven approach to the development of pricing strategies for bio-based fertilisers is needed.

In the scientific literature, different approaches have been used to assess potential prices for bio-based fertilisers. A popular engineering-based approach involves calculating the price based on the prices of the nutrients contained in the new fertiliser. Maaβ et al. (2014), Evers et al. (2016) obtained pricing information by calculating the price of 1 kg of nutrients based on the data for mineral fertilisers. However, this assumes that the price of the bio-based fertiliser is defined only by amount of nutrients in the fertiliser and the mineral fertiliser market, which is not necessarily the case. Next to the expected amount of nutrients, also their form, concentration and the consistency in quality play a role. Therefore, this approach neglects the demand side of the market, in particular farmers' perceived value and willingness-to-pay for the new products.

An alternative to the engineering-based approach, value-based pricing (i.e. pricing based on the consumers' perception of value) is often regarded by general marketing literature as the most effective and highly recommended method for setting prices and developing marketing strategies (Hünerberg and Hüttmann, 2003; Töytäri et al., 2015).

A few works have utilised a value-based approach for fertilisers by eliciting willingness-to-pay through the contingent valuation method. Using this approach, as demonstrated by Okuma and Isiorhovoja (2017), Zondo and Baiyegunhi (2021) and Tsigkou and Klonaris (2020) it is possible to assess willingness-to-pay and the factors affecting it.

A few articles have assessed the willingness-to-pay for a particular niche category of bio-based fertilisers. More specifically, Pappalardo et al. (2018), Selvaggi (2020); Selvaggi et al. (2021) utilised experimental auction as well as multiple price list methods to explore farmers' willingness-to-pay for digestate in Sicily (Southern Italy). The results obtained highlight the acceptable prices for digestate and can serve as an indicator of the value of nutrients without extensive processing and formulation. However, as the authors note, digestate has the characteristics of a soil improver rather than a fertiliser with low nutrient concentration, greater variability in nutrient context and some variability in mineralisation of organically bound nitrogen. Therefore, it could be deemed as an improved version of manure rather than the higher value products considered in the current paper.

Despite the existence of studies on the topic, as noted above, only very few studies have explored willingness-to-pay for bio-based fertilisers beyond regional niche markets. Bonnichsen and Jacobsen (2021), Tur-Cardona et al. (2018) assessed willingness-to-pay for bio-based fertilisers across a number of European countries with a discrete choice experiment method (DCE). Both works provide valuable insight into the importance of various attributes for the appeal of the new bio-based fertilisers, because the technique is regarded as the most robust in many settings. Notably, the authors elicited willingness-to-pay of products with varying attribute levels through reference to the price of the mineral fertiliser that farmers currently use. The range of products included possibly high-end bio-based fertilisers and products with slightly improved quality compared to manure. These studies used a willingness-to-pay assessment based on the strengths and weaknesses of the bio-based fertilisers including the value of the different attributes of the products. The value of these type of studies is the quantification of how different attributes of the fertiliser products add value and can justify an average price.

However, the DCE approach used does not allow an assessment of market sensitivity to changes in the prices based on varying responses of prices on the same product for each respondent of the study. This makes these studies using DCE more limited in terms of the usability of the insights for pricing strategy development.

Taking into account existing works on the topic, it is apparent that this field of research would benefit from more data on the price potential of bio-based fertilisers. Specifically, the industry would greatly benefit from additional data on the price sensitivities of farmers and agricultural advisors for specific types of bio-based fertilisers, since this information would enable companies to tailor their marketing strategies and better align their product portfolio with customer price perceptions. Additionally, conducting a comparative analysis of the market potential of various bio-based fertilisers would help to identify the most promising products and technologies. Policymakers would also benefit from a deeper understanding of the bio-based fertiliser market, enabling them to create more effective legislation and support measures.

To address the topic, an approach is needed that would allow collection of sufficient data to develop the pricing strategy for the new products with flexibility. In addition, unlike consumer research, data collection among farmers has a number of specific challenges, which was well demonstrated by Pennings et al. (2002). Therefore, a resource-efficient approach is needed to quickly collect sufficient and reliable data across a wide range of countries.

Alternative to DCE, there is Van Westendorp's Price Sensitivity Meter (PSM). PSM is a direct technique for assessment of willingness-to-pay with the assumption that there is a suitable price range for each respondent instead of one price. PSM was first published in Westendorp (1976) and as Lyon (2002) notes, is often applied as an exploratory step for new highly innovative products. In a number of studies PSM has been successfully used to assess willingness-to-pay for various products ranging from innovative fast-moving consumer goods to transformative robot sound (Weinrich and Gassler, 2021; Zhang et al., 2022).

The exploratory nature of the methodology fits the target market of bio-based fertilisers since most of the products either have a rather low representation on the overall fertiliser market or are not yet on the market at all. The model also recognises potential concerns respondents may have about quality, thus it is assumed that there is a price below certain level that will evoke quality concerns and will lead to a lack of willingness-to-pay for the product.

For the purposes of measuring price sensitivity, Van Westendorp's

PSM is the most suitable, as it allows access to information about the perception of multiple possible price points. Also, despite being a direct pricing technique with its inherent bias, as noted by Kloss and Kunter (2016), PSM has a high predictive quality for the optimal product price. Some marketing practitioners also argue that PSM has advantages, as it is easier to communicate to stakeholders, which is a valuable property in the context of new products such as bio-based fertilisers. Additionally, the cognitive burden on respondents is somewhat lower because a whole product is presented instead of a breakdown into its different attributes.

Despite the advantages, PSM also has several limitations that have to be considered. For instance, Lipovetsky et al. (2011) note that respondents can introduce bias as they often overstate their price sensitivity. In addition, the nature of the methodology makes the results very sensitive to the sample size as well as to newly introduced data. Also, in some cases, the price range can be too wide, thus not generating enough information to be of added value for marketing strategy development. The extension of PSM elaborated by Lipovetsky (2006) addressed the limitations of PSM resulting in a concise technique that is easy for respondents to understand, yet yields an additional layer of useful market insights that could be used in the development of pricing strategies.

We do not argue that DCEs were not relevant or that the PSM would be superior. DCEs focus in the value of different attribute levels while PSM focuses on different prices levels for a specific product. Instead, we think it is relevant to see whether the results of the PSM and DCE are consistent in the case of preferences for bio-based fertilisers. The added value of the PSM and its extension is that based on the different price quotes of each respondent on the same product the market penetration using pricing is estimated.

Considering the above, the aim of this article is to improve the understanding of the market potential of bio-based fertilisers by going beyond regular assessment of willingness-to-pay. Our study aims to expand understanding of price sensitivities in the bio-based fertiliser market as well as compare the revenue potentials for a set of currently available or soon-to-be available bio-based fertilisers, thus determining the more promising products. By assessing the views of farmers and agricultural advisors across different regions within the EU, we can uncover potential differences and gain a more comprehensive understanding of the market.

2. Methodology

2.1. Pricing methodology - Van Westendorp Price Sensitivity Meter (PSM)

In the PSM model the respondents are presented with the product and are then tasked to assign four psychological price levels to it. The levels are elicited by asking the following four questions.

At what price would you think the product is:

1. … so inexpensive that it raises concerns about quality (or something else) so that you will not buy it? (Too cheap)
2. … good value? (Cheap)
3. … expensive, but you would still consider buying it? (Expensive)
4. … too expensive so that you would not consider buying it? (Too expensive)

Using the responses to the four pricing questions it is possible to construct 4 cumulative distributions. The interactions between these distributions allow determination of: (1) the acceptable price range comprised of lowest and highest recommended price for the product; (2) the optimal price point (OPP) that indicates the price that would face the least resistance from consumers; (3) indifference price point (IDP) that is a cut-off point for cheap and expensive perceptions of the price. For more details on the methodology refer to Appendix A concisely describing how the output of PSM is generated.

2.2. Extended Van Westendorp Price Sensitivity Meter (EVW)

To overcome the challenges of the original methodology and create an additional layer of insights for making a strategic decision, Lipovetsky (2006) explored the ways of developing statistical tools that could improve the robustness of the technique. Lipovetsky (2006) mentions that to obtain a consistent representation of the Van Westendorp technique another approach can be used.

Lipovetsky (2006) proposes that in place of the four question thresholds, the five states of the price perception ranges can be considered: (1) below Too cheap – Too cheap, (2) from Too cheap to Cheap – Bargain, (3) from Cheap to Expensive – Ok, (4) from Expensive to Too expensive – Premium, (5) Too expensive onwards – Too expensive. Thus, instead of the original cumulative frequencies Q_{TCh}, Q_{Ch} Q_{Ex} and Q_{Tex} the states of the price ranges are used and the percentage of respondents in each state is estimated. The frequency of each state (F_{Tch}, F_{Ch}, F_{Ok}, F_{Ex}, F_{Tex}) is expressed via the original frequencies as follows with *p* reflecting the current prices obtained through the survey:

$$F_{Tch} = 1 - Q_{Tch},\ F_{Br} = Q_{Tch} - Q_{Ch},\ F_{Ok} = Q_{Ch} - Q_{Ex},\ F_{Pr} = Q_{Ex} - Q_{Tex},\ F_{Tex} = Q_{Tex} \quad (1)$$

$$F_{Tch}(p) + F_{Br}(p) + F_{Ok}(p) + F_{Pr}(p) + F_{Tex}(p) = 1 \quad (2)$$

Lipovetsky (2006) notes that although this approach is particularly useful to figure out trade-offs between volume and profit, such evaluations are not precise because of the stochastic nature of the empirical frequency graphs with numerous peaks and gaps. More reliable analytical tools are needed for the statistical evaluation of PSM data.

Based on the approach by Lipovetsky (2006), this article will follow the functional form of the logistic model as illustrated in (3) where *j* is the index for Tch (Too cheap), Ch (Cheap), Ex (Expensive) and Tex (Too expensive).

$$\ln (Q_j / (1 - Q_j)) = a_j + b_j \ln(p) \quad (3)$$

As Lipovetsky (2006) notes, in (3) parameters *a* are defined by the initial conditions for the differential equations and parameters *b* reflect the intensities of transitions between the states.

Logistic models resulting from (3) can be used to calculate modelled cumulative frequencies as illustrated in (4), which avoid the issues inherent in empirical data and allow for statistical testing and calculation of confidence intervals. For more details refer to Lipovetsky (2006).

$$F_{Ok}(p) = Q_{Ch}(p) - Q_{Ex}(p) = 1 / (1 + \exp(-(a_{Ch} + b_{Ch} \ln(p))) - 1 / (1 + \exp(-(a_{Ex} + b_{Ex} \ln(p))) \quad (4)$$

Following this approach five modelled cumulative frequencies can be constructed: Too Cheap, Bargain, Ok, Premium, Too Expensive. By analysing these frequencies, it is possible to distinguish the price points that maximise the Bargain, Ok and Premium price perceptions of the consumers, which is useful when positioning a new product in the market.

More importantly, the output of the EVW distinguishes the percentage of the market willing-to-buy the product at any given price (often termed as ‘Total Reach’), along with potential revenue for each product analysed. It is important to note that revenue in general depends on both price and quantities sold; therefore, the absolute numbers are difficult to obtain. However, ‘Total Reach’ can be used as a proxy for quantity, since it reflects the relative quantity that can be sold. Therefore, by multiplying ‘Total Reach’ and any given price, ‘Relative Revenue’ can be calculated, which is a useful indicator for comparisons between different products, regions or demographics. This way, the methodology allows us to consider the trade-off between market penetration and revenue, thus figuring out (1) the price point that leads to maximum possible market penetration (Reach Maximising Price – where ‘Total Reach’ is maximised) and (2) the price point that leads to maximum possible revenue for the producer (Revenue Maximising Price

Table 1
Summary of analysed bio-based fertilisers.

Bio-based fertiliser	Composition	Market status[a]	Legal status
Ammonium Nitrate (AN)	18% N	Available	The products assumed to be:
Ammonium Sulfate (AS)	7% N, 7% S	Available	• Approved by EU Fertiliser Product Regulations and are safe to use.
Struvite (STR)	5% N, 28% P, 10% Mg	Available	• Not limited to
			170 kg-ha/year N limit defined by the Nitrates Directive
Ash-based fertiliser (ASH)	0% N, 10% P, 12% K, 20% Ca, 7% S, 5% Mg	Available	The products are assumed to be:
Biochar-based fertiliser (BCH)	30% P, 38% Ca	Soon-to-be available	• Approved by EU Fertiliser Product Regulations and are safe to use.
Mixed pelletised fertiliser (MPF)	24% C, 8% N, 1% P, 2% K, 6% S	Soon-to-be available	

[a] At the time of data collection.

– where 'Relative Revenue' is maximised). For more details on how the output of EVW is generated and analysed refer to Appendix A.

2.3. Selected bio-based fertilisers

To utilise the PSM technique, it is necessary to prepare a concise summary of the product being researched. Market research has been performed to identify the current most commonly produced or soon-to-be-available bio-based fertilisers in the EU. A significant part of the information obtained through the market research was explored through the publicly available farmer platform set up in the EU-funded project NUTRIMAN.

The selection was based on the technology availability and potential future market performance, including legal infrastructure, usability, agronomic value and logistics. For the purposes of this study a set of bio-based fertilisers has been selected and summarised in a form of short banners that mimic the offerings that can be found in online fertiliser marketplaces.

2.3.1. Nitrogen-based fertilisers

The market research revealed the prevalent availability of technologies to recover nitrogen in the form of ammonium sulfate (AS) or ammonium nitrate (AN), especially in regions with a high nutrient load (i.e. Belgium and the Netherlands). These bio-based fertilisers resemble the properties and use characteristics of the existing mineral fertilisers. Market research revealed that technologies are available to recover AN and AS in both liquid and crystallised form; however due to wider availability of fertilisers in liquid form in this study these fertilisers are considered in the form of a solution. However, the results can also indicate the potential of crystalised AN and AS.

Taking into account the recently introduced Fertiliser Product Regulations (EU) 2019/1009 (FPR) and the current ongoing discussion on the implementation of CMC15[1] in the FPR along RENURE[2] criteria, AS and AN have the potential for a full legal infrastructure to enter the EU market, thus generating much interest both in the scientific community and industry.

2.3.2. Phosphorus-based fertilisers

Similar to nitrogen-based fertilisers, Struvite (STR) has been identified as a commonly produced and available bio-based fertiliser. The composition of struvite and its properties provide an alternative to Di-ammonium Phosphate (DAP) and Mono-ammonium Phosphate (MAP) as well as superphosphate mineral fertilisers; thus, if produced in a granular form it provides a valid alternative to mineral fertilisers. Companies such as Ostara, with their Crystal Green product, have already been successfully exploring this market over the last decade. Also, similar to nitrogen-based bio-based fertilisers, the upcoming legislative initiatives provide potential for struvite to enter the market and gain wider adoption in the EU.

Currently, different technologies are available for the production of phosphorus-based fertilisers. Among them, popular techniques involve thermo-chemical conversion such as combustion and pyrolysis, producing ashes and chars that are rich in phosphorus. For the purposes of this study, one ash-based fertiliser (ASH) that is currently available on the market has been included along with soon-to-be available biochar-based fertiliser (BCH).

2.3.3. Pelletised mixed fertilisers

Another category of fertiliser products is the mixed fertilisers, which provide an optimal combination of nutrients. For this study, one Pelletised Fertiliser (MPF) has been selected. The product is based on a dried, pelletised digestate mixed with recycled nitrogen, resulting in a circular fertiliser product. The producer claims, *"due to its organic matrix the product enables efficient nutrient utilisation as well as gives long-term positive effects to the soil health, creating a basis for a sustainable production"*. This highlights a different selling point to the regular marketing of traditional fertilisers; thus, the assessment of value perception from the farmers' perspective is interesting in determining the market potential of similar products that are marketed as facilitators for a transition to regenerative agriculture.

Table 1 contains a short summary of the selected fertilisers, their contents, market and assumed legal status. The remaining details on all the selected fertilisers and information provided to the respondents are summarised in Appendix C.

2.4. Farmer survey

To collect the necessary data a farmer survey was conducted. The survey had a twofold objective: 1) to collect data to assess the impact of psychological latent constructs on the farmers' intention to adopt bio-based fertilisers; 2) to measure willingness-to-pay through PSM and its extended version.

The target respondents selected were farmers and agricultural advisors across the EU, since these are the stakeholders who are the final consumers of the fertilisers and decision-makers on their use.

The testing period ran from 6th October until 30th October 2021. After adjustments, the questionnaire was 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 familiar with related terminology in each country. The full translated survey 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. To ensure sufficient responses the networks of FertiCycle and ReFlow consortia have been actively used. In

[1] CMC – Component Material Category, as defined in the Fertiliser Product Regulations (EU) 2019/1009.

[2] RENURE – 'REcovered Nitrogen from manURE', as defined by The Joint Research Centre of the European Commission in Science for Policy report "Technical proposals for the safe use of processed manure above the threshold established for Nitrate Vulnerable Zones by the Nitrates Directive (91/676/EEC)".

Table 2
Socio-demographic characteristics of respondents.

Question	*N*	%
I am/What are the main uses at your ?	**264**	**100%**
A farmer	190	72%
• Fieldcrops	125	49%[a]
• Horticulture	25	10%[a]
• Wine production	11	4%[a]
• Other permanent crops	35	14%[a]
• Milk production	9	4%[a]
• Other grazing livestock	22	9%[a]
• Granivores	7	3%[a]
• Mixed production	23	9%[a]
Agricultural advisor	74	28%
What is the type of your farming system?	**190**	**100%**
Conventional	123	64.7%
Organic	36	18.9%
In transition	19	10%
Other	12	6.3%
Are you male or female?	**190**	**100%**
Male	156	82.1%
Female	29	15.3%
Other	5	2.6%
What is your age?	**190**	**100%**
<18	1	0.5%
18-24	1	0.5%
25-34	29	15.3%
35-44	44	23.2%
45-54	54	28.4%
>55	61	32.1%
Education level	**190**	**100%**
Basic school	3	1.6%
Highschool	22	11.6%
Technical school	19	10%
Bachelor's Degree	53	27.9%
Master's Degree	80	42.1%
PhD	13	6.8%

[a] Multiple choice question, the percentages are calculated based on the total number of respondents selecting the category.

addition, the national farmers' associations were contacted to provide access to farmers across the EU. The survey was fully anonymised and no personal data were collected.

This article will focus on the data collected in the second part of the survey relating to the assessment of willingness-to-pay. In the second part of the survey respondents were sequentially introduced to concise summaries for each selected bio-based fertiliser (details in Appendix C), mimicking potential offers that could be found on the internet. After each summary, the respondents were asked to locate the price slider on a scale from 0 to 1000 EUR per tonne of fertiliser for each of the four pricing questions from the PSM methodology.

Since the survey also covered countries with currencies other than the euro, depending on the stated country of residence, the slider scales were presented in local currencies and recalculated so that the presented range was closely equivalent to 0–1000 EUR per tonne of fertiliser. In the analysis the responses in the local currencies have been recalculated to EUR using the average exchange rates for the period from July 2021 to July 2022 (European Central Bank, 2022). The period was selected to reflect the conditions when the survey was designed, developed and distributed.

Due to the nature of methodology the responses could only be recorded with consistent price preferences (too cheap < cheap < expensive < too expensive). In cases where the respondents failed to follow this principle, the software guided the them to amend their responses accordingly.

3. Results

3.1. Data summary

Despite the challenging nature of data collection among farmers by June 2022 a total of 264 responses had been collected for the assessment of willingness-to-pay. Important to mention that it is rather difficult to represent the whole farming community and certain biases are possible; therefore when examining the results, it is important to consider socio-demographic characteristics. The distribution of responses across the socio-demographic characteristics is presented in Table 2.

A little under three-quarters of the responses were from farmers (72%) with the majority of farmers being male (82,1%), which is expected given that farming is a male-dominated profession, as reported by Eurostat (2022). In the collected sample, primarily older generations are represented, with the majority of respondents (60,5%) aged over 45 years, which is in line with the general age distribution in European farming. Similarly, a larger proportion of farmers have conventional or

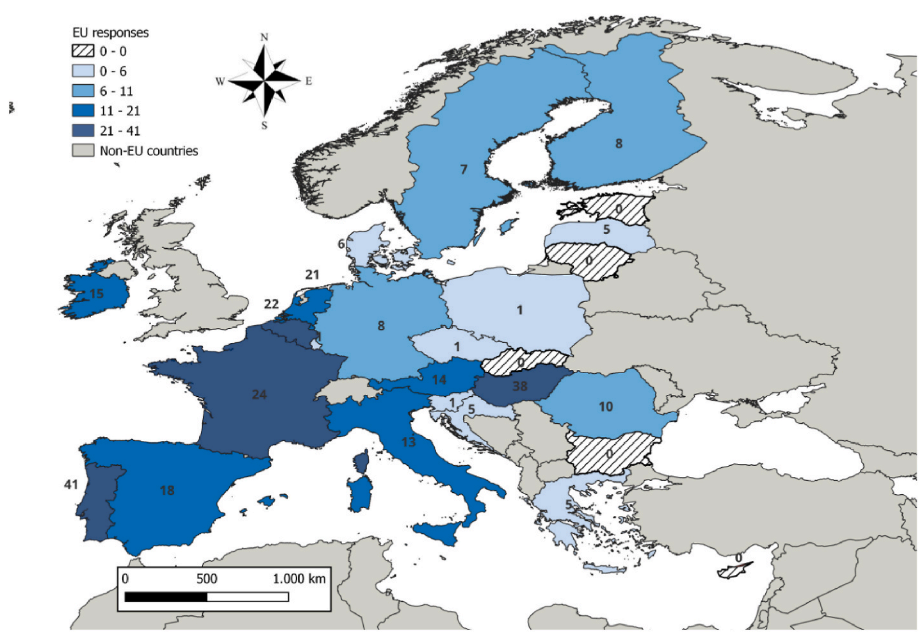

Fig. 1. Map of respondents.

Table 3
Summary statistics for PSM questions.

Question	N	Mean (EUR per tonne)	Std. Dev.	Min	Pctl. 25	Pctl. 75	Max
AN Too cheap	264	137	103	0.01	64	194	613
AN Cheap	264	255	139	3	151	337	814
AN Expensive	264	376	189	5	236	501	947
AN Too expensive	264	521	249	6	339	701	1011
AS Too cheap	264	107	91	0.01	42	152	502
AS Cheap	264	203	130	5	100	289	635
AS Expensive	264	313	186	7	159	416	979
AS Too expensive	264	440	252	9	237	612	1000
STR Too cheap	238	151	112	0.01	68	205	598
STR Cheap	238	272	147	3	155	365	737
STR Expensive	238	380	186	7	240	499	861
STR Too expensive	238	512	242	7	342	668	1000
ASH Too cheap	223	138	112	0.01	54	197	815
ASH Cheap	223	246	142	4	148	325	836
ASH Expensive	223	348	180	7.44	220	462	893
ASH Too expensive	223	471	231	12	304	617	1000
BCH Too cheap	220	144	108	0.01	70	195	566
BCH Cheap	220	253	144	4.39	152	320	809
BCH Expensive	220	358	182	6.51	245	464	895
BCH Too expensive	220	483	234	7.25	310	598	1011
MPF Too cheap	139	112	98	0.01	47	154	497
MPF Cheap	139	209	134	6	120	278	799
MPF Expensive	139	305	173	13	174	410	884
MPF Too expensive	139	424	239	19	231	554	1000

AN – Ammonium Nitrate; AS – Ammonium Sulfate; STR – Struvite; ASH – Ash-based fertiliser; BCH – Biochar-based fertiliser; MPF – Mixed Pelletised fertiliser.

'in transition' farming systems (81,1%) as opposed to organic (18,9%).

Overall, the socio-demographic characteristics of the sample mirror the farming community in the EU; however, the education level is somewhat different. The most prevalent level of education for European farmers is a Bachelor's degree, whereas a relatively large proportion of respondents have Master's degrees. The difference can be partially explained by the fact that more educated farmers are more willing to collaborate in scientific research. Bonnichsen and Jacobsen (2021) also point out that a similar potential bias of respondents is possible.

Fig. 1 Summarises the geographic distribution of the respondents. As illustrated on the map the responses are not homogeneous, yet the regions with different nutrient availability are equally represented, which allows determination of the potential differences in willingness-to-pay.

Table 3 summarises the data used for the PSM methodology. Due to several incomplete responses, the number of observations per selected fertiliser differs. Mixed pelletised fertiliser was added later during the

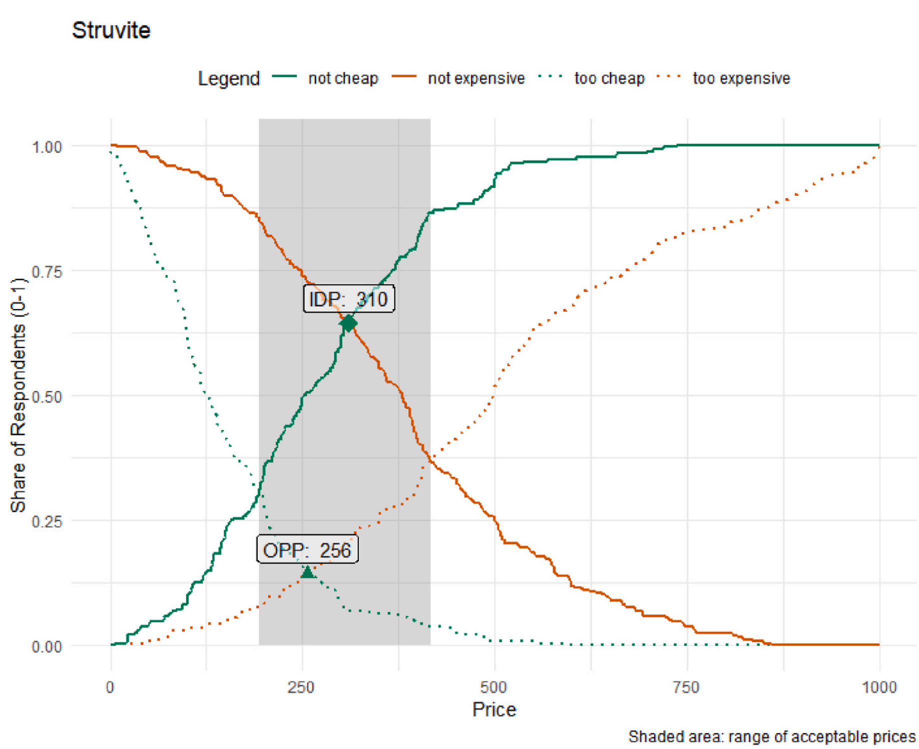

Fig. 2. PSM data output for Struvite.

data collection; therefore the number of observations is significantly smaller than for the rest of the products analysed.

3.2. Output of Van Westendorp Price Sensitivity Meter

To perform the analysis, the package 'pricesensitivitymeter' in RStudio has been used (Alletsee, 2021). Fig. 2 exemplifies the results for struvite. The graphs for the other bio-based fertilisers included in the analysis are presented in Appendix C. Table 4 summarises the data on the acceptable price ranges as well as OPP and IDP for the bio-based fertilisers included in the survey. Note that in Table 4 the number of observations is slightly lower than in Table 3, which is due to certain observations failing to follow the strict 'consistent price preference' rule. Inconsistent observations account for 1–2% of the collected data; therefore filtering them out has no significant impact on the results.

The OPPs are also distinctively different and suitable for comparison. For instance, AN has a value 37% higher than AS indicating a higher perception of value for AN. Interestingly, even though the accepted price ranges for AS and MPF are similar the OPP value of MPF is 15% higher, potentially hinting at higher elasticity of demand for mixed pelletised fertiliser. Also, it is notable that among the analysed phosphorus fertilisers struvite yields the highest values.

3.3. Output of extended Price Sensitivity Meter (EVW)

Fig. 3 Illustrates the resulting modelled frequencies as stated in (4), based on the data collected for struvite (the curves for other analysed fertilisers are presented in Appendix C).

To reflect the fit of the modelled frequencies to the empirical data, the R^2 coefficient of determination has been calculated. The R^2 coefficients, along with the resulting four logistic models for each fertiliser analysed, are presented in Appendix C. The coefficients of determination (above 0.9) indicate a very good model fit, which is similar to Lipovetsky's results and can be explained by the strong theoretical structure of the models for the description of empirical PSM data.

The summary of the output of EVW for the bio-based fertilisers analysed is presented in Table 5. To highlight the statistical robustness of the methodology 95% confidence intervals for the resulting prices have been calculated and presented in Table 5.

The data clearly shows a significant difference between reach maximising and revenue maximising prices as well as the impact of pricing on the market penetration capabilities of the products. AN and struvite yield the highest numbers both for reach (228 EUR and 242 EUR respectively) and revenue maximising prices (418 EUR and 410 EUR respectively), whereas AS and MPF yield the lowest.

For most fertilisers the 'Total Reach' ranges from mid-50% in the case of revenue maximising prices and up to mid-70% for reach

Table 4
Summary of PSM Results (in EUR per tonne).

Bio-Based Fertiliser	Acceptable Price Range	Optimal Price Point	Indifference Price Point	N
Ammonium Nitrate (AN)	179–413	250	300	260
Ammonium Sulphate (AS)	122–336	182	229	260
Struvite (STR)	194–417	256	310	236
Ash-based Fertiliser (ASH)	163–384	228	271	221
Biochar-based Fertiliser (BCH)	183–400	240	286	218
Mixed Pelletised Fertiliser (MPF)	127–341	209	220	135

The acceptable price ranges are wide and can be difficult to interpret; however, the ranges provide a good basis for comparison between the products with STR and AN yielding the highest values, whereas AS and MPF yielded the lowest values.

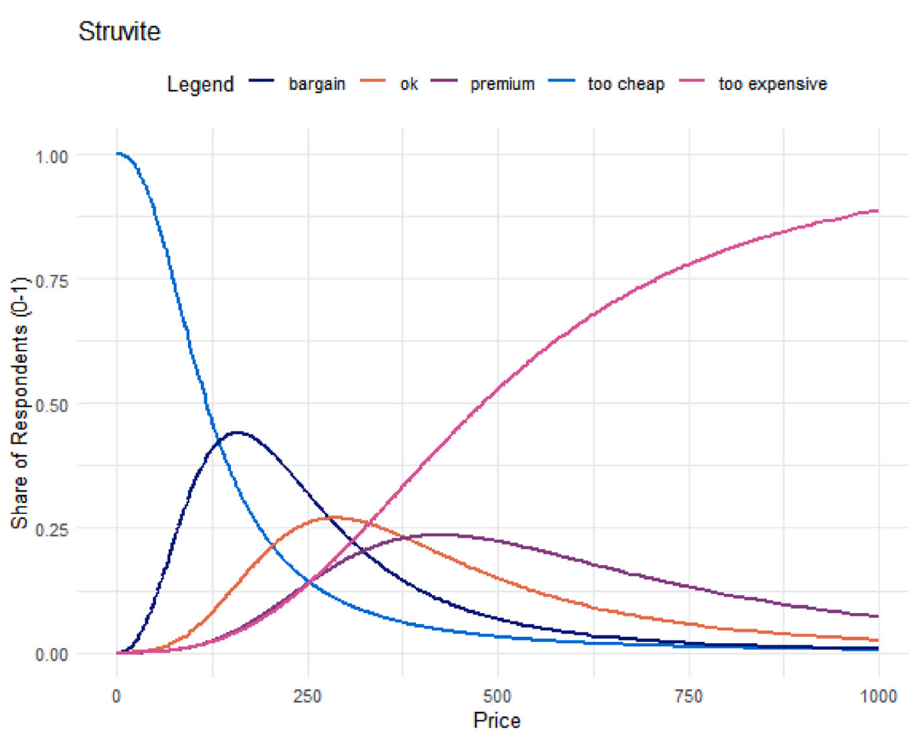

Fig. 3. Logistic cumulative frequencies for Struvite.

Table 5
Summary of EVW results.

Bio-Based Fertiliser/Price	Price (EUR/ton)	Total Reach	Relative Revenue
Ammonium Nitrate			
Bargain	145**	65%	94
Ok	274***	73%	199
Premium	424**	55%	234
Reach Maximising	228**	74%	170
Revenue Maximising	418**	56%	234
Ammonium Sulfate			
Bargain	106**	61%	65
Ok	215**	69%	147
Premium	332**	54%	178
Reach Maximising	173**	71%	122
Revenue Maximising	362**	49%	179
Struvite			
Bargain	159**	63%	100
Ok	286***	70%	200
Premium	423**	54%	229
Reach Maximising	242**	72%	174
Revenue Maximising	410**	56%	229
Ash-based Fertiliser			
Bargain	137**	61%	84
Ok	253**	69%	174
Premium	378**	53%	202
Reach Maximising	213**	70%	150
Revenue Maximising	375**	54%	202
Biochar-based Fertiliser			
Bargain	148**	61%	91
Ok	267**	69%	185
Premium	393**	54%	213
Reach Maximising	226**	71%	160
Revenue Maximising	393**	54%	213
Mixed Pelletised Fertiliser			
Bargain	109*	61%	66
Ok	218*	68%	148
Premium	336*	53%	178
Reach Maximising	176*	70%	123
Revenue Maximising	363*	49%	178

'Price' – price of 1 tonne of the product in EUR.
'Total Reach' – % of market willing-to-buy product at given price.
'Relative Revenue' – product of 'Total Reach' and 'Price', allows to compare revenue potential at given price.
Price 95% Confidence Intervals: '***' ± <5%; '**' ± 5–7%; '*' ± 7–9%.

maximising prices. Interestingly, comparing the 'Relative Revenues' it is evident that to achieve maximum possible market penetration the producers would have to miss out on 25–32% of the potential revenue depending on the fertiliser.

Notably, the results presented in Table 5 are for the full sample across different demographics as well as the regions with different conditions. The analysis of differences requires a thorough review with special attention to the criteria that divide the collected sample. The extended analysis falls outside the scope of this article. However, to avoid concealing the potential differences, the EVW results for the key groups and regions are briefly presented in Appendix B.

3.4. Bio-based vs. mineral fertilisers

To put the obtained results into perspective, comparative analyses were performed. The comparison with traditional mineral fertilisers is particularly interesting, as it allows the competitive position of the newly developed bio-based alternatives to be defined, thus providing useful insights for marketing strategy design as well as for policy development.

For this analysis, only AN, AS, STR and BCH have been used since they are the most similar to current mineral fertilisers on the market. To perform fair comparisons, the prices were compared per kilogram of primary nutrients. The price data for mineral fertilisers were obtained from available online databases (tradingeconomics, IndexMundi). To keep the comparison fair, the prices for mineral fertilisers are averaged for the period from July 2021 to July 2022. The results of the analysis are summarised in Table 6.

The results for nitrogen fertilisers indicate that to ensure maximum 'Total Reach' for recovered AN, the price should be 44% below the price for mineral fertiliser, whereas revenue could be maximised at roughly the same price per kilogram of nutrients as the reference fertiliser. Similarly, for biochar (BCH) market reach can be maximised with a price drop of up to 46% and revenue maximisation is achieved with the prices around the reference, but slightly lower.

The analysis suggests similar findings for struvite, where reach maximising requires a price drop up to 30% compared to the reference fertiliser (DAP), and slightly higher than reference estimations for revenue maximising. It should be kept in mind that in this comparison 1 kg of nutrients includes a combination of nitrogen and phosphorus. It should be noted that the ratio of nitrogen to phosphorus in DAP is different to the one in struvite; therefore, the results are not directly equivalent, but still provide directionally correct insights.

With respect to AS, the results indicate that the price expectations are above the reference. In particular the revenue-maximising price obtained in the analysis is more than twice as high. On the other hand, the reach maximising price is relatively similar to reference fertiliser. However, it is important to note that AS is not exactly similar to the reference fertiliser (UAN) in terms of contents and properties; therefore, the price levels should be compared with caution.

4. Discussion

As noted in the results, although the original PSM methodology has a useful OPP indicator suitable for comparative analyses, it provides a rather wide range of prices for the bio-based fertilisers analysed. In addition, the OPP has a limitation: the optimal in the context of PSM is meant as the price of least resistance, whereas the actual optimal price point may need to be different depending on the marketing objective. In addition, the original PSM methodology relies on empirical data, which makes the resulting numbers sensitive to the sample size and new observations. Furthermore, the use of empirical data makes it impossible to calculate confidence intervals and thus assess the statistical robustness

Table 6
Mineral vs. Bio-based fertilisers.

Fertiliser	Price EUR/tonne	%N	%P	EUR/kg of Nutrient	% of Reference
UAN (reference)	680	30	0	2.27	–
AN Reach	228	18	0	1.27	56%
AN Revenue	418	18	0	2.32	103%
AS Reach	173	7	0	2.47	109%
AS Revenue	362	7	0	5.17	228%
DAP (reference)	667	18	46	1.04	–
STR Reach	242	5	28	0.73	70%
STR Revenue	410	5	28	1.24	119%
TSP (reference)	613	0	44	1.39	–
BCH Reach	226	0	30	0.75	54%
BCH Revenue	393	0	30	1.31	94%

of the results.

The extended methodology (EVW) adds an additional layer of insights by comparing maximum reach and revenue prices, giving more options for creating pricing strategies. Also extending the PSM enables assessment of the statistical robustness of the results.

The maximum reach prices effectively suggest the lowest level at which prices should be set. Since the maximum reach prices are higher than the lowest acceptable prices from the original PSM methodology it narrows the effective range and simplifies the decision on pricing. The addition of the 'Relative Revenue' indicator, along with the comparisons between different bio-based fertilisers allows decision makers to approach pricing with a deeper understanding of the target market and figure out potential future combinations of products that could be put on the market.

The insights presented in this article are particularly useful for producers of bio-based fertilisers, as they offer valuable information on which bio-based fertilisers and technologies have higher market potential. The data output generated by the EVW methodology allows producers planning production of bio-based fertilisers to check what response any chosen price point for the product will cause in the market, thus helping to distinguish more suitable combinations of the products for their product portfolio and assess the viability of their business case. Additionally, EVW allows one to deduce what percentage of those willing to buy the product perceives the selected price as a bargain, ok or premium. This insight can be very helpful in positioning the product in the market as well as adjusting marketing activities to be more effective.

As illustrated in the results, to ensure the most rapid uptake of the products by the market the producers would have to keep the price below the level of mineral fertilisers, notably compromising their potential revenue. Interestingly, the analysis showed that some products require less reduction in revenue compared to others to maximise their market share. For instance, STR required only a 25% reduction in revenue, whereas in the case of AS, it would have to be a 32% reduction. However, the analysis does not consider the additional revenue that may come from lower prices and increased demand (i.e. maximisation of the bargain and ok perceptions). This finding can be of interest to the policymakers since it indicates the extent of potential support that the market needs, either through subsidies to farmers buying bio-based fertilisers or compensation to producers for potential revenue losses.

The comparison of AN and AS clearly indicates a higher willingness-to-pay as well as revenue potential for AN, possibly due to higher nitrogen concentration. However, the producers of bio-based fertilisers point out significant safety risks involved in the production of AN, which along with significantly higher production costs, do not justify the difference in prices between AN and AS, thus making the case for AN production infeasible.

As highlighted in the results section, there is a significant difference between the price per kilogram of N from AS and the reference nitrogen fertiliser (UAN). The difference could potentially be attributed to the differences in composition between AS and UAN (namely, the presence of sulphur) as well as the different uses of the two fertilisers. Additionally, a notable aspect of the methodology is that the revenue-maximising price is essentially defined by the elasticity of demand. For certain respondents, the demand is particularly elastic (i.e. it does not change significantly despite price increases), potentially because they represent the portion of the market requiring low volumes of fertiliser and thus are able to pay higher margins. This effect can be particularly pronounced in the case of AS due to its less common use; however, to state it conclusively, a further analysis with special attention to reference fertiliser prices, as well as different consumer categories in the market, is needed.

As noted by Evers et al. (2016) a popular approach to the estimation of potential prices for bio-based fertilisers is through the cost of the nutrients contained. As the analysis in this article showed, this approach may be somewhat useful, since farmers' willingness-to-pay (in case of revenue maximising prices) mostly follows the prices of nutrients in currently available conventional fertilisers.

Also, comparative analysis with conventional mineral fertilisers indicates that the maximum prices can be set roughly at the level of mineral fertilisers. This finding confirms that, currently, the market potential of bio-based fertilisers is limited by competition with conventional fertilisers. As noted by Buysse and Cardona (2020), due to the high concentration of market power the industry could potentially employ pricing strategies that would reduce the feasibility of the production and sale of bio-based fertilisers. Therefore, upon making a pricing decision, willingness-to-pay analyses should be complemented with benchmarking analyses.

Comparing results to other existing works on the topic, Pappalardo et al. (2018) and Selvaggi (2020) established that farmers in Sicily are willing to pay between 5 and 16 EUR per tonne of digestate. Based on their findings, the cost of a kilogram of N from digestate would range from 0.2 to 0.7 EUR. In contrast, our study indicates that a kilogram of N from bio-based ammonium nitrate would cost around 1.27 to 2.32 EUR. This substantial difference highlights the potential for the increased value of recycled nutrients through additional processing of digestate. However, it is important to note that differences in methodology and socio-demographic characteristics could also contribute to the differences observed, thus any comparisons should be approached with caution.

Tur-Cardona et al. (2018) were able to calculate the price farmers would be ready to pay for bio-based fertilisers relative to the current price paid for traditional fertiliser. Their results suggested that the farmers were ready to pay up to 76,6% of the price of their currently used traditional fertilisers. Similarly, Bonnichsen and Jacobsen (2021) concluded that farmers would need up to a 50% reduction in price compared to currently used mineral fertilisers. These results were partially confirmed in the analysis performed in this article. However, the application of PSM and EVW methodology allows us to perform a deeper analysis with an understanding of multiple price points and corresponding sensitivities of the target market. The results of this article suggest that the indicated drop in prices would only be necessary to achieve maximum market penetration (i.e. reach maximisation), whereas the producers of bio-based fertilisers have the potential to charge prices similar to traditional mineral fertilisers if their goal is to maximise revenues despite the slower uptake by the market.

To the best of the authors' knowledge, the analyses presented in this article have not been performed for bio-based fertilisers. Therefore, this article presents an inherent value to the marketing field for recovered nutrients. However, the limitations of the analyses should be kept in mind when considering the results.

First, farmers are a difficult group to reach, especially in the case of large international surveys. Therefore, the sample size is small relative to the farming community in the EU, which limits the analysis. Also, the response across countries and regions has not been equally active. Therefore, the results could be biased due to local economic, environmental and social circumstances and should be considered with respect to the distribution of responses across the regions in the EU.

In the case of this research, the price perceptions of the respondents must already reflect fertiliser price changes on international markets. However, ideally the analyses should be repeated on a regular basis to account for the non-static nature of price perceptions, especially in the context of current political instabilities and market volatility. The comparative analysis carried out in this article could be extended further through a study that takes into account the changes in prices for mineral fertilisers, as well as the variations in the actual prices paid at the farm gate.

Second, the methodology utilised in this article focuses only on value perception and ignores the costs and competition. Therefore, upon making a price decision, the results should be complemented with competition analysis, as competition often defines the highest prices in the market. In the context of the extended version of Van Westendorp's methodology, this may mean that the total reach and the revenue-maximising prices may be lower. A further study on the impact of competition on the prices of bio-based and mineral fertiliser could be of great interest to the field.

Additionally, our study aimed to provide input on pricing, which is one of the key components of marketing strategies and business case analyses, but it is not exhaustive as the analyses of Product, Placement and Promotion along with other so-called marketing 'P's are needed for a better understanding of the viability of business models for bio-based fertilisers. In addition, a deeper understanding of the psychological aspects leading to the adoption of bio-based fertilisers is needed to better understand the adoption path and further improve marketing strategies.

Finally, the results presented in this article are averaged out, as they illustrate the situation across the wide range of EU member states with differing environmental, economic and social circumstances. Appendix B exemplifies the potential approach to the analysis; however, to uncover all the insights and create tailor-made marketing strategies an in-depth comparative analysis across different regions and demographics is necessary.

5. Conclusions

This paper focused on assessing the market potential of bio-based fertilisers through the assessment of willingness-to-pay and price sensitivity of farmers and agricultural advisors in the EU. Using the extension of the Van Westendorp Price Sensitivity Meter, we explored the impact of different pricing points on the market penetration capabilities of the products as well as the potential revenue of producers.

Our analysis provides the insights to the producers about the market acceptable prices for the bio-based fertilisers and highlights the existence of multiple possible pricing points. Similarly, agricultural advisors may find the results useful to understand the sentiment towards the bio-based fertilisers among their clients. Additionally, the results showcase that certain fertilisers have notably higher potential prices and corresponding market penetration; thus, resulting in higher revenue potential. Yet, in the case of the all bio-based fertilisers analysed, the producers have to give up revenue to improve the market uptake of the products, suggesting that policymaking efforts may be required to support the market in order to accelerate the adoption of bio-based fertilisers.

This article contributes to the marketing field of bio-based fertilisers data on the potential prices and their impact on revenues, which is one of the key aspects needed for financial modelling and business case analyses. Combining the results with production cost estimations, as well as analyses of non-financial aspects of business modelling (i.e. value proposition, supply chain, market segmentations, etc.) would contribute greatly to the development of the bio-based fertiliser industry.

CRediT authorship contribution statement

Egor Moshkin: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Sergio Garmendia Lemus:** Conceptualization, Methodology, Writing – review & editing. **Lies Bamelis:** Supervision, Project administration, Writing – review & editing. **Jeroen Buysse:** Conceptualization, Supervision, Writing – review & editing.

Declaration of competing interest

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 paper.

Data availability

Data will be made available on request.

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Appendix A

Original Van Westendorp Price Sensitivity Meter (PSM) Methodology

To perform the analysis using the Van Westendorp PSM technique, the answers to four pricing questions should be constructed into 4 cumulative distributions: Too cheap, Cheap, Expensive and Too Expensive. The original Van Westendorp's approach also implies 'flipping' Cheap and Expensive distribution to Not Cheap and Not Expensive, thus the final graph resulting as shown in Figure A.1.

The intersection of Too cheap and Not cheap is the point that represents the price where the number of respondents believing the price to be Too cheap and Not cheap is equal. This point is regarded as a start of the acceptable price range or as a point of marginal cheapness (MCP). Setting the price below this point is not advisable as the number of respondents not willing to pay for the product due to the too cheap price and potential perceptions of low quality is too high.

Alternatively, the intersection of Not expensive and Too expensive distributions represents the point where the number of respondents perceiving the price Not expensive and Too expensive is equal. This pricing point is regarded as a highest acceptable price or a point of marginal expensiveness (MEP). Any price above is not advisable since any further increase would lead to a loss of customers' willingness-to-pay due to a too high price.

The intersection of the Too cheap and Too expensive distributions represents the point where the number of respondents believing the price is too cheap and too expensive is equal. This way it is possible to determine the pricing point that will face the least resistance from the customers, thus it is regarded as an Optimal Price Point (OPP).

Finally, the intersection of Not Cheap and Not Expensive distributions is the point that represents the price that equal numbers of respondents consider neither cheap nor expensive. This point is called Indifference Price Point (IDP) and can be used as an indicator of a cut-off point for cheap or expensive perception of the price for the product.

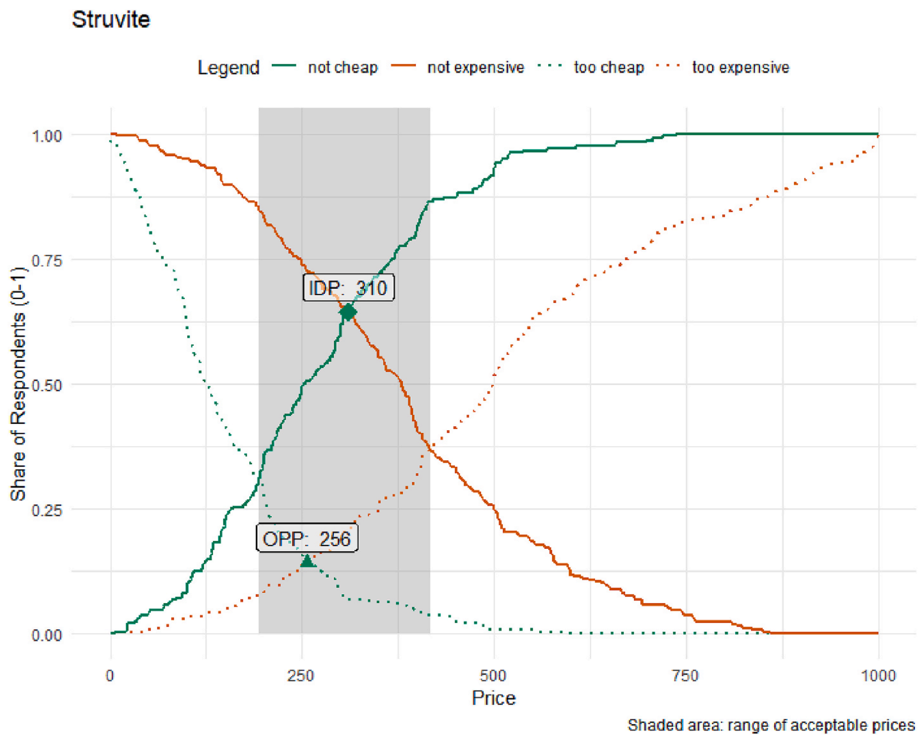

Fig. A.1. Original PSM methodology output for Struvite

Extended Van Westendorp (EVW) Methodology

Figure A.2 illustrates 5 modelled cumulative frequencies following EVW - each line represents the probability of each price point of the continuum to be considered by the customers in one of five ranges. Light blue line represents the probability of price to be considered Too cheap, dark blue – Bargain, orange – Ok, violet – Premium, magenta – Too expensive. With this arrangement the figure contains 2 distributions reflecting the negative price impressions (Too cheap, Too expensive) not leading to the consideration to buy and 3 distributions reflecting the positive price impressions (Bargain, Ok, Premium).

The two distributions reflecting negative impressions are similar to the Too cheap and Too expensive cumulative distributions from the original PSM methodology, although since the data is modelled, the distributions are smoothed out, which allows to locate the interception point easier. The other distributions require a more careful consideration separately.

Figure A.3 summarises the output for the struvite, highlighting the distributions reflecting positive impressions (Bargain – blue, Ok – orange, Premium – violet). The peaks of each distribution represent the pricing points where the share of respondents reaches the highest for each corresponding price perception range. These price points can serve as indicators how the price reflects the positioning in the market for a newly developed product.

The red distribution is the sum of previously mentioned three distributions representing the total percentage of the respondents willing to pay for the product thus representing the potential 'Total Reach' to the market at each particular price point (i.e. % of the market willing to buy the product at given price). Therefore, finding the maximum point of that distribution would yield the price that allows to reach the highest share of the market. This price is referred as market penetration maximising price or reach maximising price and serves as an indicator of optimal price in case the producer wants to expand its market share most rapidly.

However, maximising the market share is often connected with missing out on the revenue. Therefore, since the distributions reflect the demand curves it is possible to construct revenue distribution by multiplying the 'Total Reach' curve values by given price points. The resulting distribution (black line in Fig. 3) indicates what is the 'Relative Revenue' that can be generated at any price point the price continuum (on the secondary axis). Locating the peak point of 'Relative Revenue' curve indicates the price point where the maximum potential revenue for the product is achieved. Although the values of relative revenue are not directly useable, since the actual revenue depends on the quantities sold, nevertheless it serves as a useful indicator of impact of pricing on the revenue.

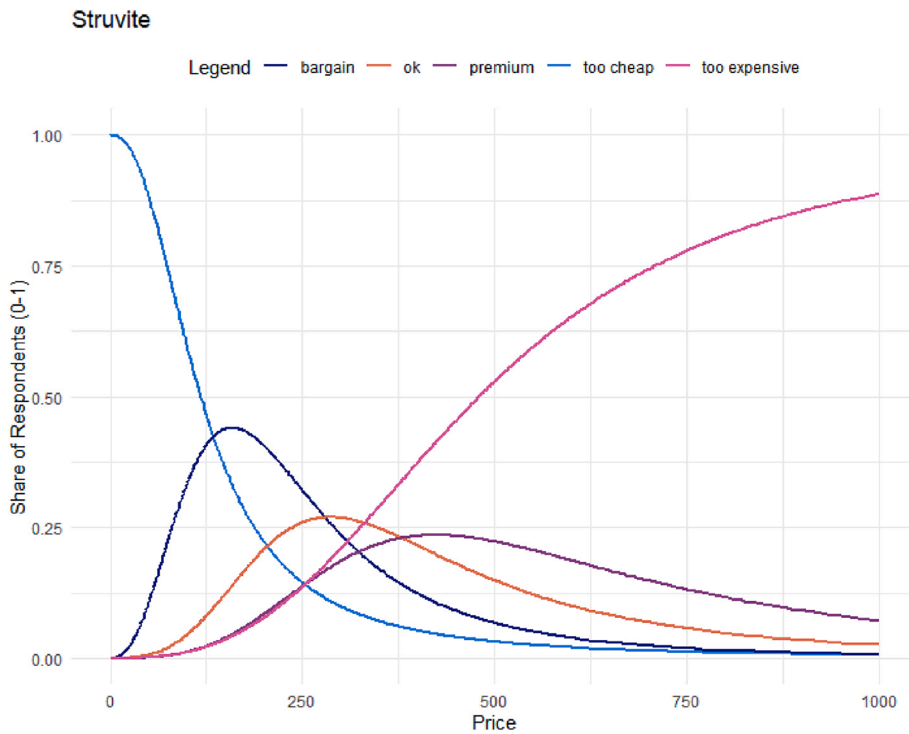

Fig. A.2. Extended van Westendorp Methodology Output for Struvite

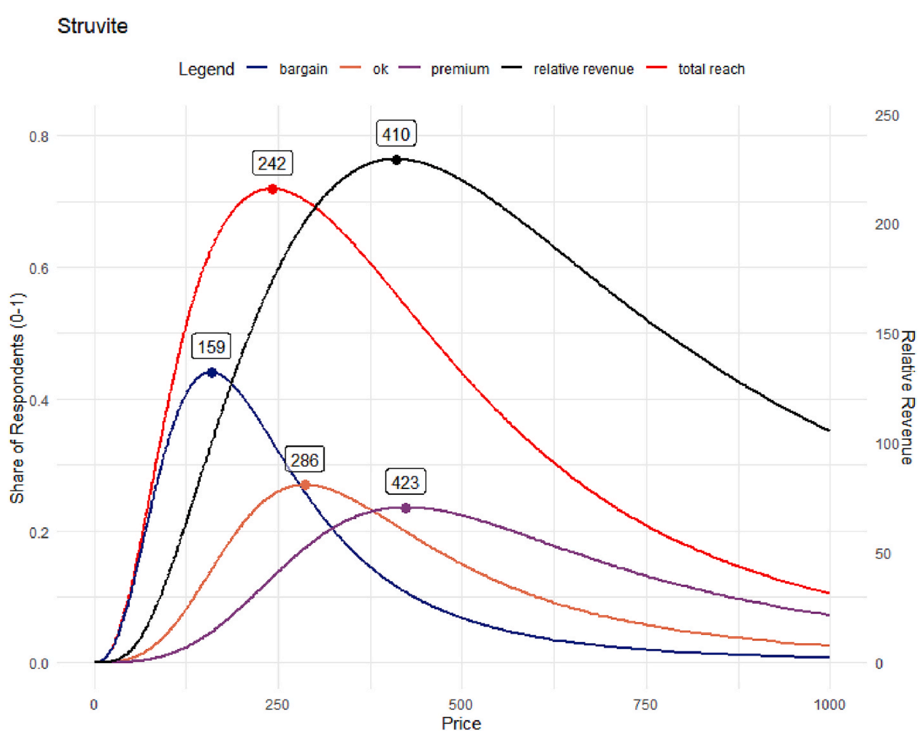

Fig. A.3. Total Reach vs. Revenue for Struvite

Appendix B

The analysis of the willingness-to-pay across the EU should be done with care. The region is represented by wide variety of countries and demographics with different economic and social background. Therefore, an extra care should be taken in the decision how to split the collected sample. The purpose of this appendix is to exemplify the potential approach to comparative analysis across the EU.

The collected sample distinguishes farmers ($N = 190$) and advisors ($N = 74$), since both stakeholders have an impact on the eventual decision of buying the fertilisers. Comparing results between the two groups would contribute to the understanding of different stakeholders' perspectives.

Another potential criterion for separation is the availability of nutrients in the region, which is often defined by the livestock intensity and consequently amounts of available manure. To reflect nutrient availability FADN data was used to determine the amounts of manure available per ha of agricultural land in the regions. In particular the ratio of 'Total Livestock Units' (SE080) and 'Total Agricultural Area for Production' (SE074) could be a good approximation of nutrient availability. Ranking the European countries by this indicator distinguishes 4 groups:

- Group 1 ($N = 66$): Netherlands, Belgium, Denmark, Luxembourg, Ireland, Slovenia
- Group 2 ($N = 77$): Germany, Austria, Spain, France, Italy
- Group 3 ($N = 59$): Greece, Poland, Portugal, Sweden, Croatia
- Group 4 ($N = 62$): Czech Republic, Romania, Finland, Hungary, Latvia

Note, that the EU countries that are not mentioned in the groups above are excluded since no data for them has been collected. In Table B.1 the EVW output is presented for different groups.

Table B.1
EVW Results among Various Sample Groups

Bio-Based Fertiliser/Price	Total			Farmers			Advisors			Group 1			Group 2			Group 3			Group 4		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Ammonium Nitrate																					
Reach Maximising	228	74%	170	215	72%	155	268	81%	218	226	77%	174	217	75%	162	242	70%	169	228	75%	172
Revenue Maximising	418	56%	234	405	53%	215	450	64%	287	404	59%	237	366	59%	215	501	49%	245	453	54%	246
Ammonium Sulfate																					
Reach Maximising	173	71%	122	164	69%	112	199	76%	151	166	75%	124	155	69%	107	201	66%	134	176	71%	125
Revenue Maximising	362	49%	179	351	47%	166	381	56%	213	341	53%	181	331	48%	160	410	48%	196	380	49%	186
Struvite																					
Reach Maximising	242	72%	174	234	70%	164	266	78%	207	229	75%	171	224	77%	173	251	61%	153	269	74%	198
Revenue Maximising	410	56%	229	403	54%	217	426	63%	267	387	59%	228	372	61%	226	466	45%	209	454	58%	263
Ash-based Fertiliser																					
Reach Maximising	213	70%	150	202	68%	138	247	79%	195	199	75%	150	198	73%	145	238	57%	135	221	76%	168
Revenue Maximising	375	54%	202	369	51%	189	384	65%	249	378	55%	210	353	56%	197	430	43%	183	363	61%	222
Biochar-based Fertiliser																					
Reach Maximising	226	71%	160	216	68%	147	256	78%	200	207	71%	147	216	72%	156	224	63%	141	253	75%	190
Revenue Maximising	393	54%	213	390	51%	200	404	63%	256	411	51%	211	357	57%	203	404	48%	192	442	58%	255
Mixed Pelletised Fertiliser																					
Reach Maximising	176	70%	123	175	67%	117	170	77%	131	147	66%	98	194	73%	142	194	70%	135	175	71%	125
Revenue Maximising	363	49%	178	357	48%	170	371	53%	197	460	36%	168	327	58%	188	368	51%	186	341	52%	178

(1): 'Price' – price of 1 tonne of the product in EUR.
(2): 'Total Reach' – % of market willing-to-buy product at given price, allows to distinguish the optimal price to maximise market penetration.
(3): 'Relative Revenue' – product of 'Total Reach' and Price, allows to distinguish the optimal price to maximise revenue.

Appendix C

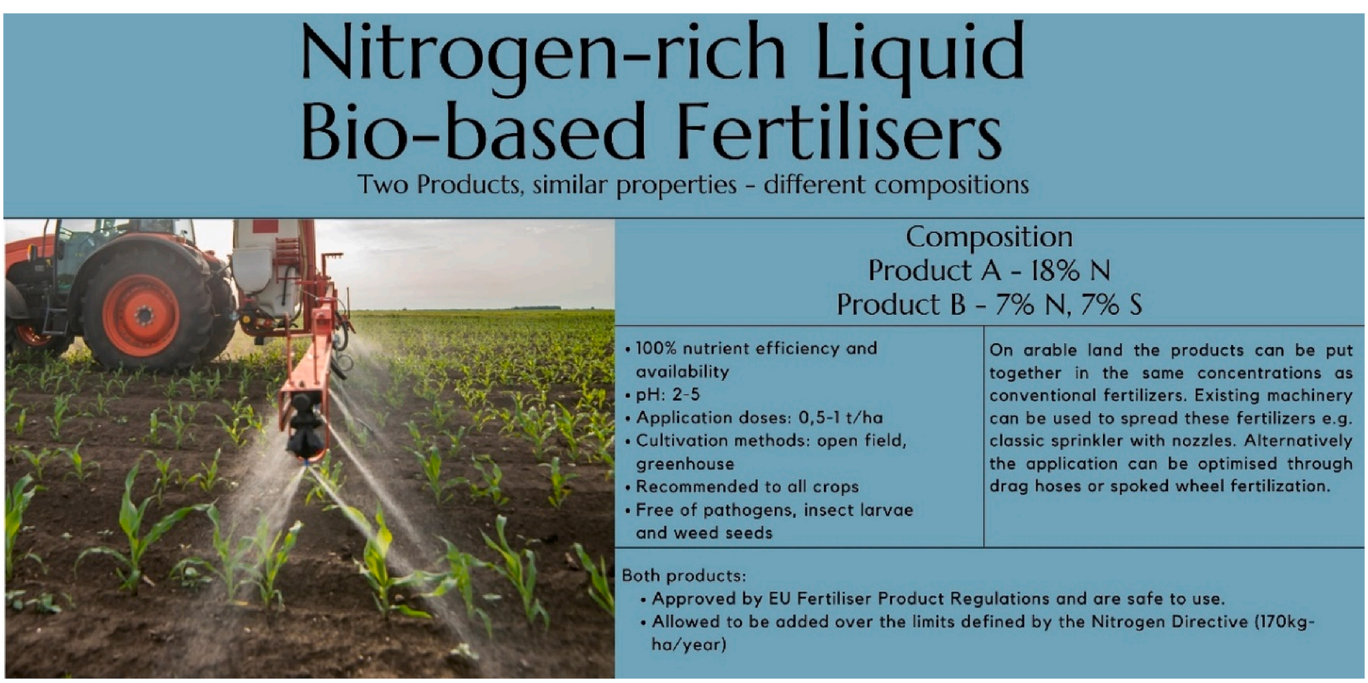

Fig. C.1. Information summary for Ammonium Nitrate and Ammonium Sulfate

Fig. C.2. Information summary for Struvite

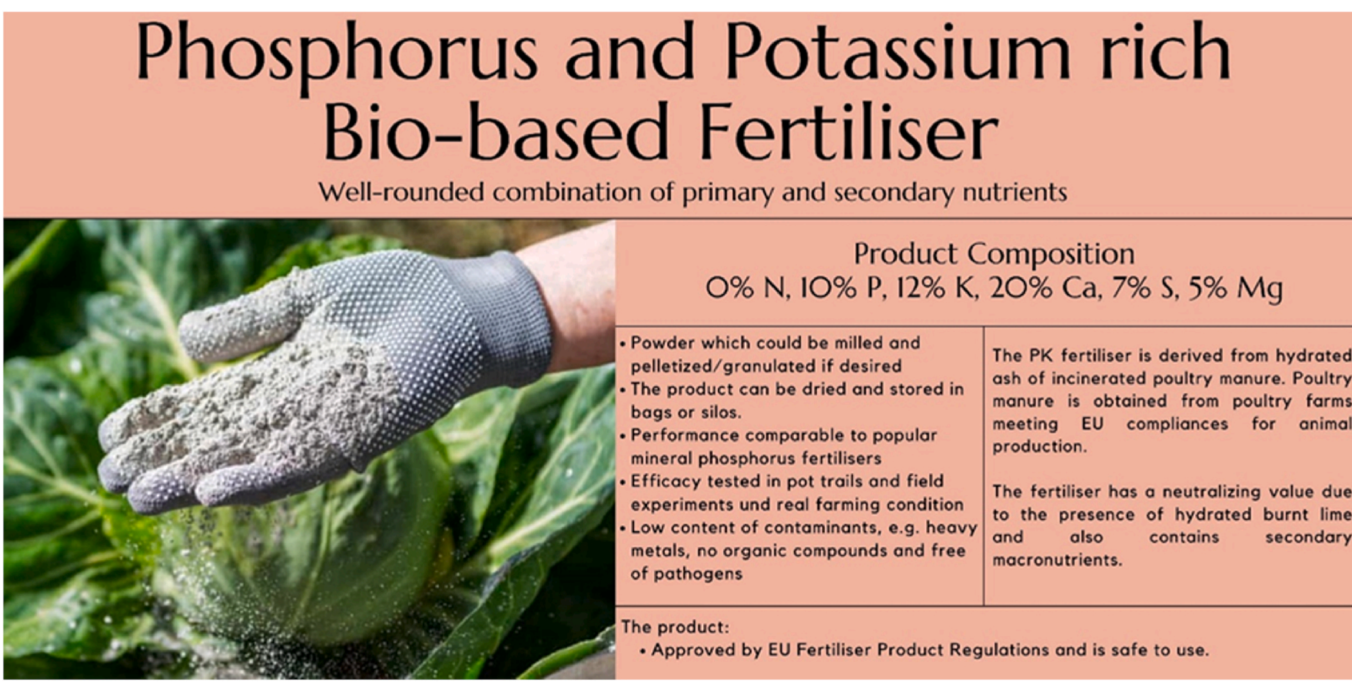

Fig. C.3. Information summary for Ash-based fertiliser

Fig. C.4. Information summary for Biochar-based fertiliser

Fig. C.5. Information summary for Mixed Pelletised Fertiliser

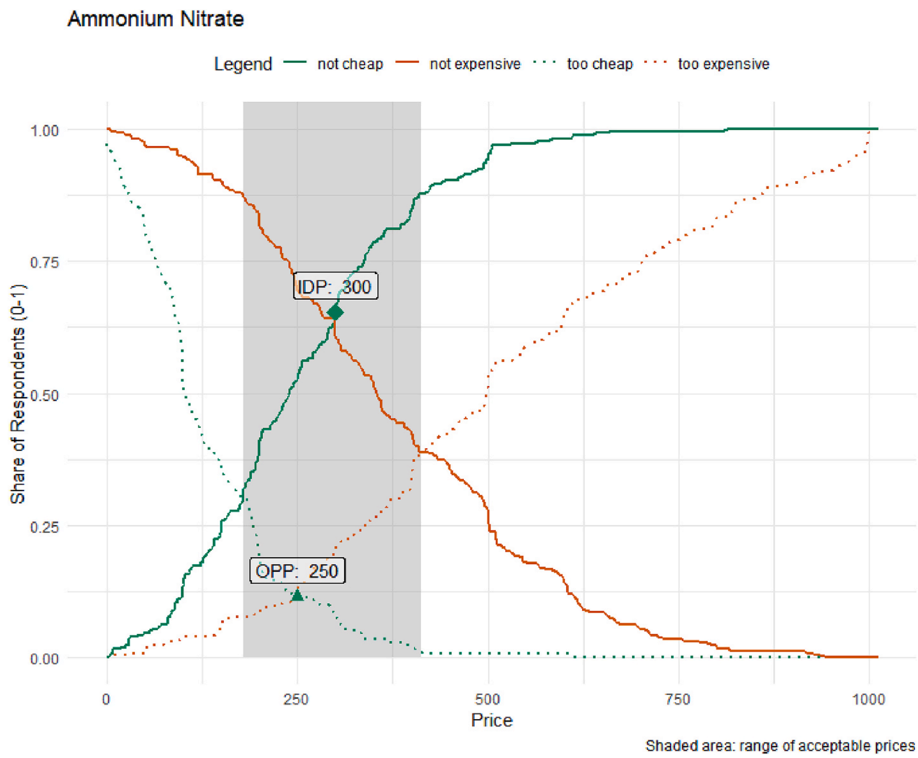

Fig. C.6. Original PSM methodology output for Ammonium Nitrate

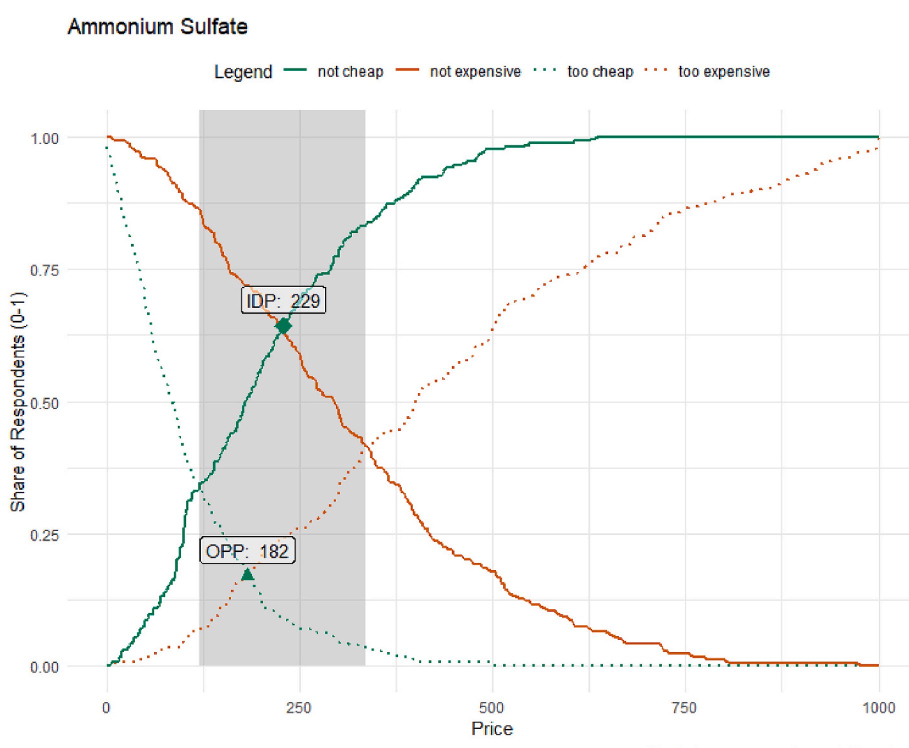

Fig. C.7. Original PSM methodology output for Ammonium Sulfate

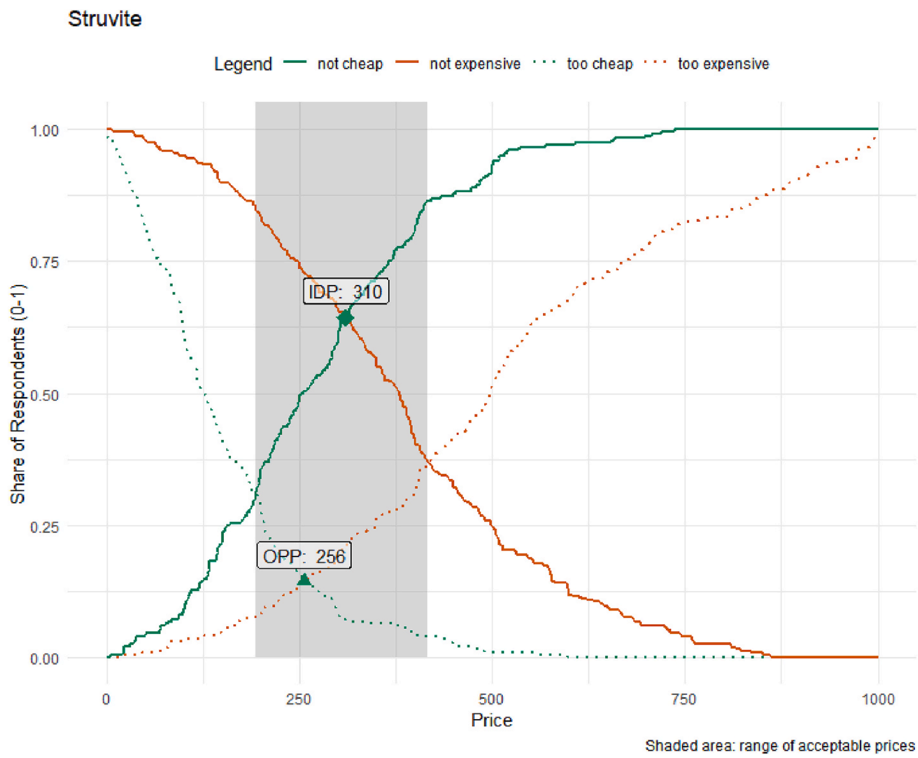

Fig. C.8. Original PSM methodology output for Struvite

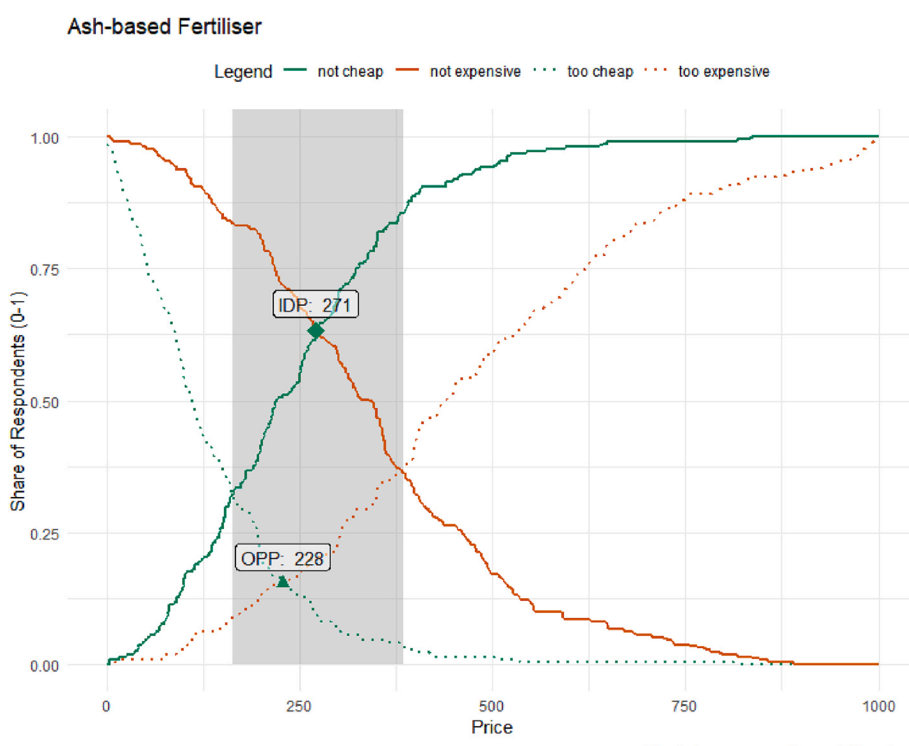

Fig. C.9. Original PSM methodology output for Ash-based fertiliser

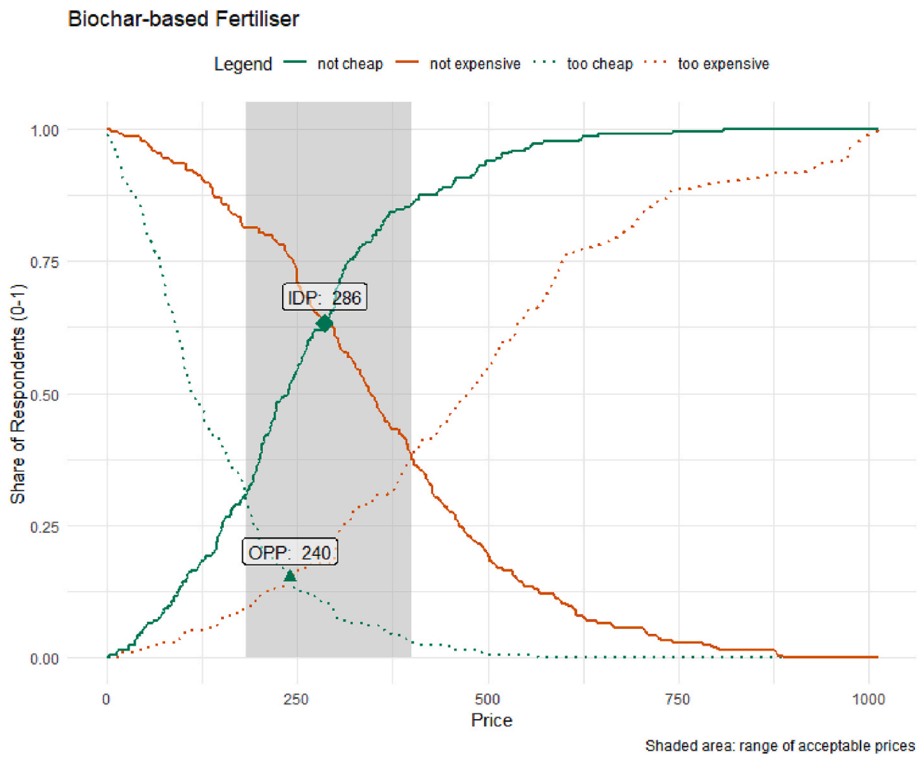

Fig. C.10. Original PSM methodology output for Biochar-based fertiliser

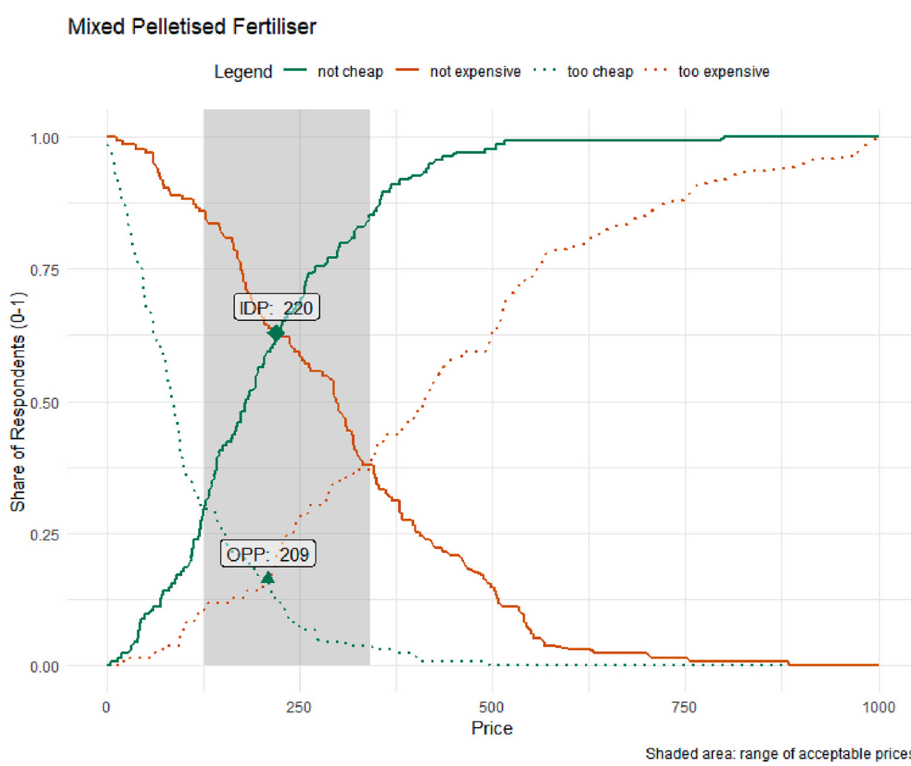

Fig. C.11. Original PSM methodology output for Mixed Pelletised Fertiliser

Table C.1
Logistics regression summaries and R^2

Statistics	Too Cheap (Q_{Tch})	Cheap (Q_{Ch})	Expensive (Q_{Ex})	Too Expensive (Q_{Tex})
Ammonium Nitrate				
Intercept *(a)*	−11.01	−15.73	−16.67	−16.41
Coefficient *(b)*	2.37	2.92	2.86	2.65
R^2	0.986	0.990	0.990	0.992
Ammonium Sulfate				
Intercept *(a)*	−8.95	−12.74	−13.45	−13.7
Coefficient *(b)*	2.06	2.49	2.41	2.3
R^2	0.988	0.991	0.990	0.993
Struvite				
Intercept *(a)*	−11.27	−16.34	−17.50	−17.41
Coefficient *(b)*	2.36	2.98	3.00	2.82
R^2	0.988	0.991	0.989	0.990
Ash-based Fertiliser				
Intercept *(a)*	−10.34	−15.07	−16.20	−16.26
Coefficient *(b)*	2.23	2.82	2.83	2.68
R^2	0.985	0.990	0.989	0.989
Biochar-based Fertiliser				
Intercept *(a)*	−11.24	−15.52	−16.27	−16.37
Coefficient *(b)*	2.39	2.88	2.82	2.68
R^2	0.988	0.991	0.985	0.983
Mixed Pelletised Fertiliser				
Intercept *(a)*	−9.05	−13.3	−13.78	−13.65
Coefficient *(b)*	2.07	2.6	2.48	2.29
R^2	0.990	0.992	0.985	0.987

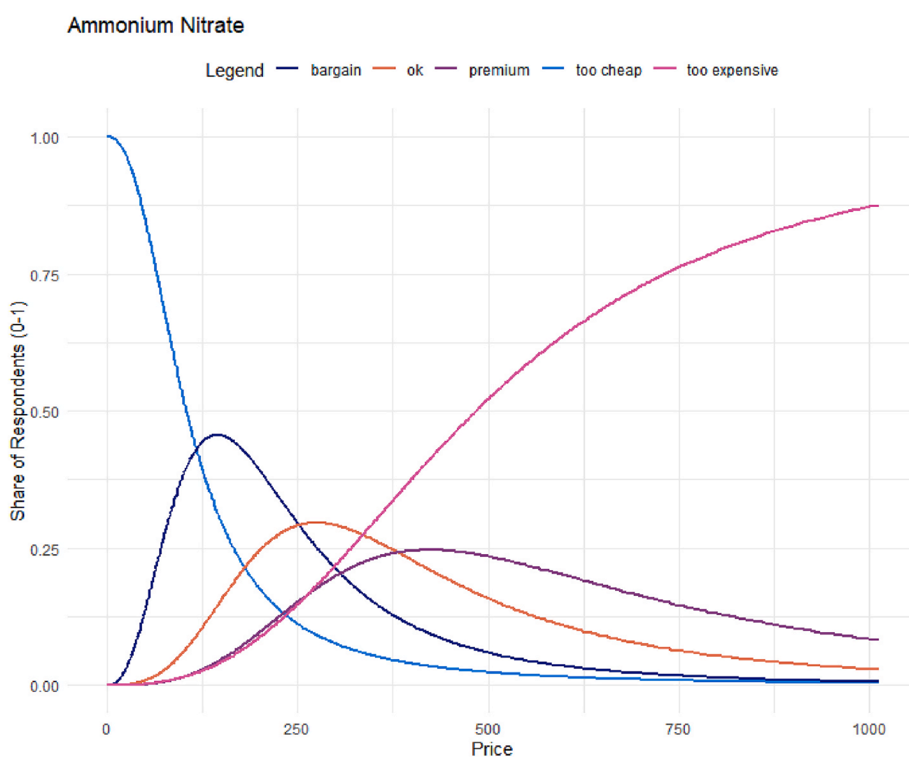

Fig. C.12. Extended van Westendorp Methodology Output for Ammonium Nitrate

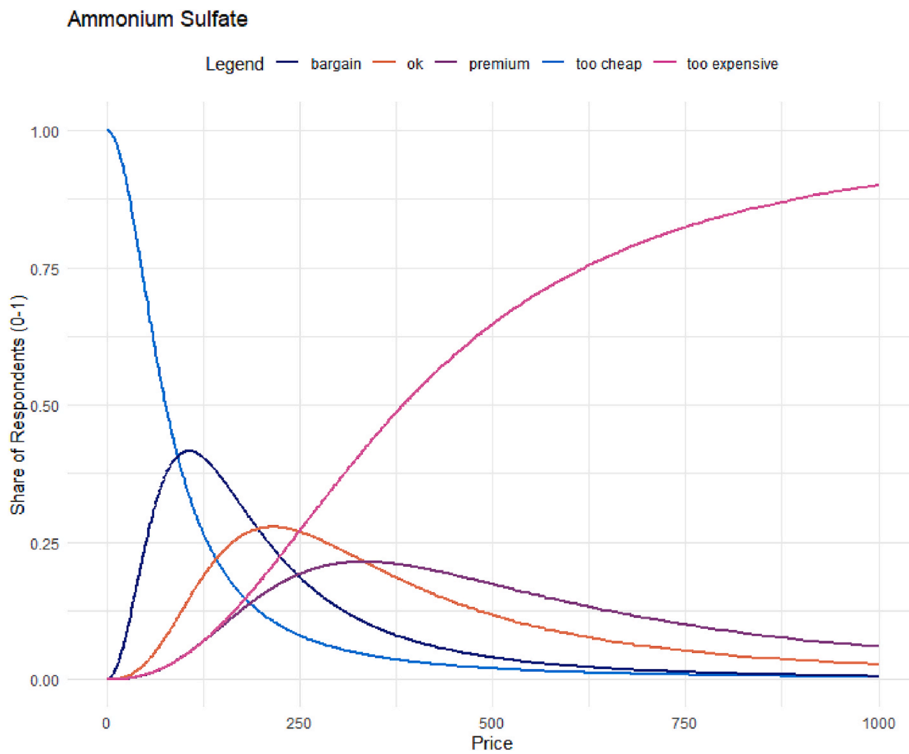

Fig. C.13. Extended van Westendorp Methodology Output for Ammonium Sulfate

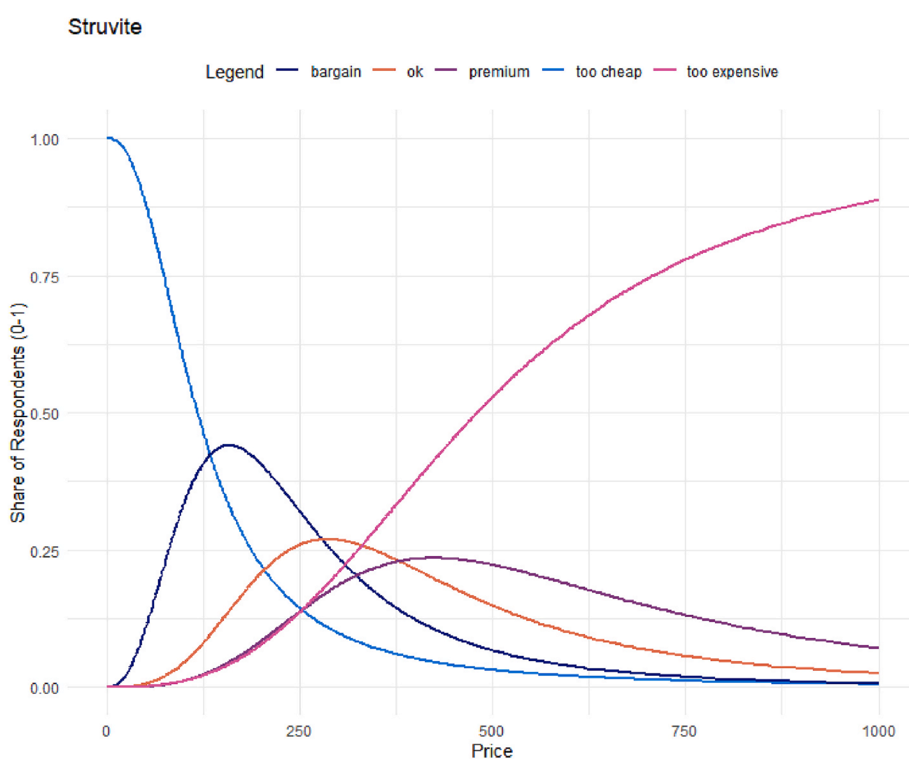

Fig. C.14. Extended van Westendorp Methodology Output for Struvite

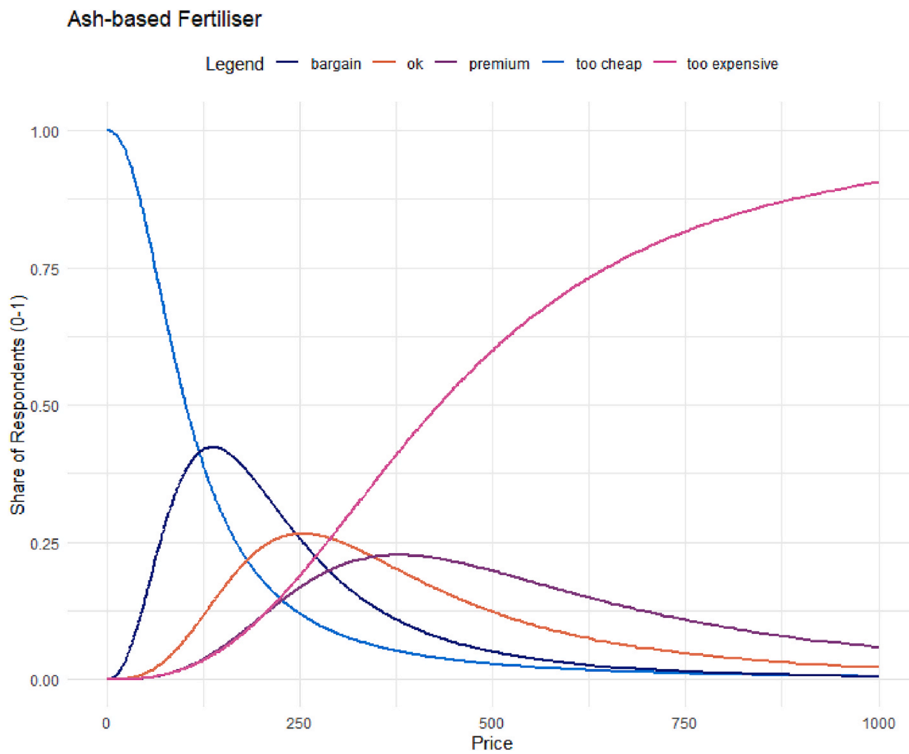

Fig. C.15. Extended van Westendorp Methodology Output for Ash-based Fertiliser

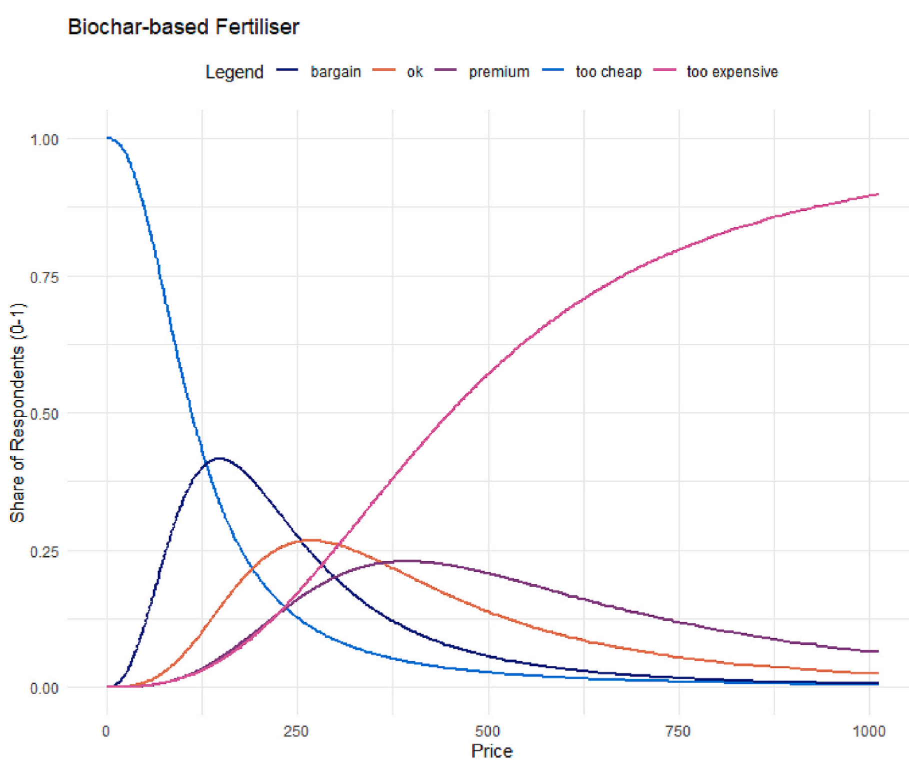

Fig. C.16. Extended van Westendorp Methodology Output for Biochar-based Fertiliser

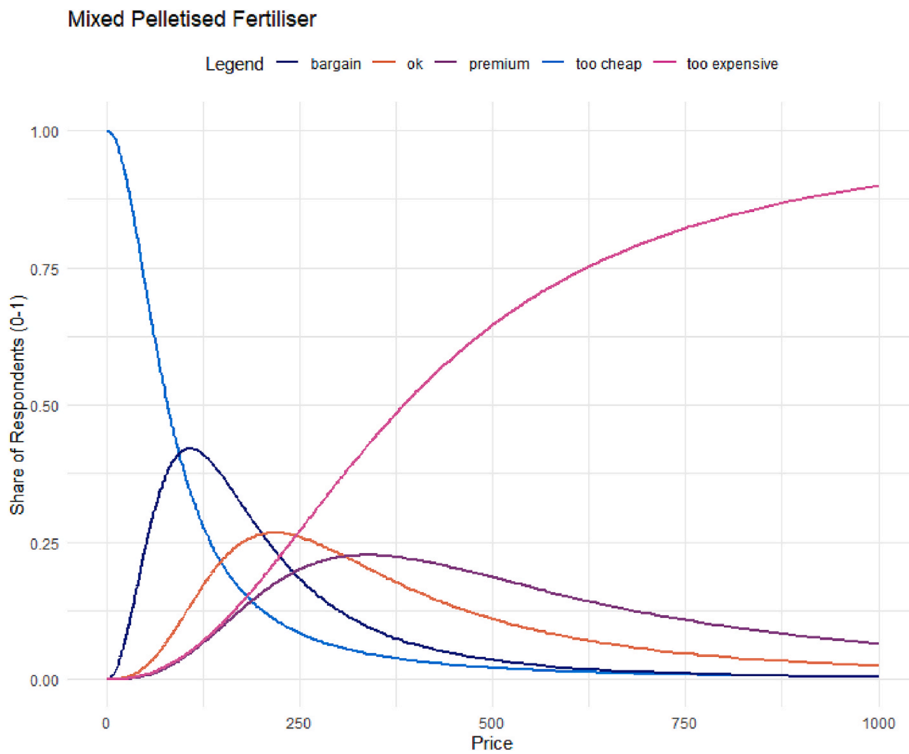

Fig. C.17. Extended van Westendorp Methodology Output for Mixed Pelletised Fertiliser

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