International assessment of bioenergy stakeholders research requirements of GIS based biomass analytics

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Abstract

The need for more sustainable energy sources has led to an increase in the use of bioenergy to enhance economic security, lessen environmental impacts and improve social wellbeing. This study aimed to investigate the GIS based biomass research priorities of bioenergy stakeholders. A voluntary survey was distributed internationally to bioenergy stakeholders to discern their usefulness rating for various analytics. The most useful analytic was found to be Economic, followed by Environmental, Product quality and Social assessments. There was a difference between analytic preference and the thirteen countries surveyed or the stakeholder type however, this relationship was not significant.

Introduction

Bioenergy is considered carbon neutral because the emitted at combustion is sequestered again as the biomass regrows [1,2].The production of bioenergy is globally increasing as a result of environment, economic and security concerns [3]. Currently, biomass provides up to fourteen percent of global energy needs, with the potential to provide forty percent by 2050 [4]. It is improbable that climate targets will be achieved without the use of bioenergy [5] as bioenergy burns cleaner and more efficiently than fossil fuels [3]. Substituting biofuel for fossil fuel is more effective and cheaper than reforesting or afforesting, as planting trees only temporarily sequesters carbon [6].

Biomass is any organic material that is obtainable on a cyclic basis including crops, algae and trees [7]. Bioenergy and biofuels can be created using residues that are cheap and underutilised, forestry residues include thinned or deceased trees and the tops or branches of trees [1]. Using thinned wood for bioenergy is beneficial as it allows the remaining trees to grow more efficiently therefore, good forestry management can increase forest health and productivity [1]. Retaining some biomass on the forestry patch is essential for nutrient cycling, soil fertility, soil moisture and erosion mitigation [8].

Geographic information systems (GIS) are beneficial for the bioenergy industry as they can display the spatial distribution of various types of biomass, and select areas that are could be used to produce bioenergy [9,10]. Remote sensing can be used in forestry to estimate the volume of biomass within a region to approximate the amount of bioenergy that could be produced and its economic viability [9,11–13]. The harvesting and transportation costs for different forests can also be estimated using GIS [9,11–15] in addition to the most suitable bioenergy cultivar for a particular location [16].

Stakeholder participation in research regarding bioenergy and GIS is important to increase the relevance and significance of bioenergy studies [17]. Numerous studies have researched the priorities of stakeholders concerning Economic and Environmental assessment however there is a knowledge gap in regards to Social, Product quality assessment priorities [18] and also the comparison between multiple countries. This study aims to address that knowledge gap by surveying biomass stakeholders from numerous countries on their research priorities regarding GIS biomass information. The analysis of survey answers will include a comparison between different analytics as well as assessments between stakeholder types and country of employment.

Methods

RESEARCH METHODS

A voluntary survey was distributed via International Energy Agency (IEA) Task 43 to various stakeholders around the globe through google forms to assess the priorities of biomass stakeholders for GIS based biomass research. Ethics approval for the survey was obtained from the University of the Sunshine Coast prior to the distribution of the survey (ethics approval number A181079). The countries surveyed were Austria, Belgium, Brazil, Canada, Croatia, Finland, Ireland, Italy, New Zealand, South Africa, Sweden, Switzerland and the United States of America (USA). The survey included nineteen questions in the format of Likert scale, multiple choice and open-ended questions to gain demographic information and research priorities. Firstly, stakeholders were asked to identify the most and least useful analytic out of Economic, Environmental, Social and Product quality assessments. Each of these analytics were then divided into several questions and these were rated on a scale of not useful (1) to very useful

(7). This was followed by demographic questions to devise the stakeholder's role in the bioenergy industry, the region of their company and the country they were located in.

STATISTICAL METHODS

Descriptive statistics were created through tables and graphs to represent the percent response for each question. After the results were compiled, SPSS was used to complete statistical analysis on the main responses. To devise the significance of the major analytic preference a chi-squared test was used. A Kruskal-Wallace test was used to test the significance between all the detailed analytic questions and between both country and stakeholder type to major analytic preference.

Results

A total of 34 participants were recorded to respond to the online survey and were in thirteen different countries. The main survey outcome was the major analytic preference of Economic assessment which was prioritised by 53% of participants (Figure 1). Environmental assessment was ranked second with 38% of respondents answering that it was the most useful assessment. The third ranked analytic was Product quality assessment which was prioritised by 5% of respondents. Social assessment was nominated as the priority assessment by 3% of the participants. The difference between major priority analytics was found to be significant ($p<0.0005$) (Appendix 1). The response to the importance of each of the detailed assessments was also significantly different ($p<0.0005$) (Appendix 2).

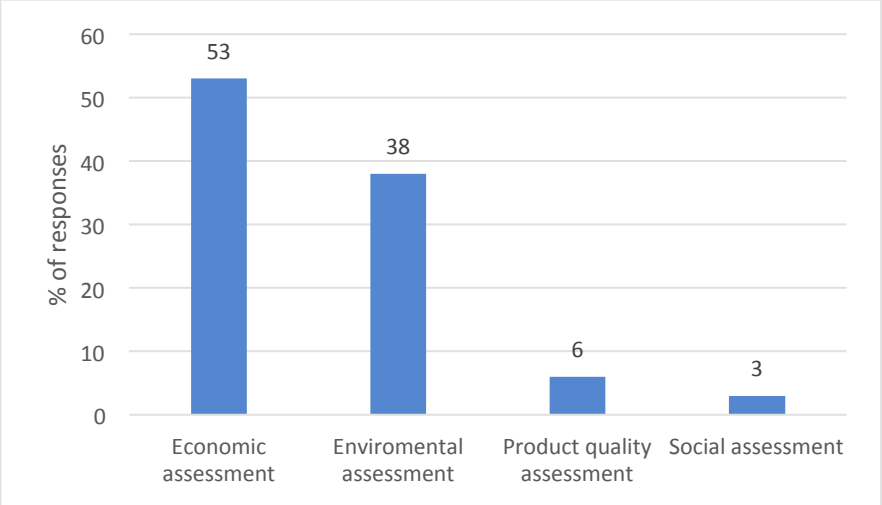

Figure 1: Stakeholders response to the most useful analytic (%)

ECONOMIC ASSESSMENT

The majority of the Economic analytics were rated at 5 or higher (Table 1). Biomass transportation cost of the collected biomass from the road side and landing to a defined point of end user was rated predominately 7 (47%). Biomass collection and processing cost from farm and forest to site scored predominately 7 (44%). The annual availability of biomass by type within the limits of current harvesting technologies and practices was equally rated (32.4%) 5, 6 and 7 on the scale of usefulness. Information and recommendations on supply chain technology options including associated estimates of operational productivity for biomass recovery and delivery was predominately (35.3%) rated a level 6 of importance.

Table 1: Bioenergy stakeholder's prioritisation of different economic assessments

Question	Score of usefulness (%)							Likert score
	1 (Not very useful)	2	3	4	5	6	7 (Very useful)	
The annual availability of biomass by type within the limits of current harvesting technologies and practices	0	0	0	2.8	32.4	32.4	32.4	5.94
Information and recommendations on supply chain technology options including associated estimates of operational productivity (e.g. tonnes per working hour) for biomass recovery and deliver to road side/landing/farm gate.	0	2.9	0	0	32.4	35.3	29.4	5.85
Biomass collection/processing cost ($ per tonne) from farm/forest to road side/landing/farm gate.	0	0	0	14.7	8.8	32.4	44.1	6.06
Biomass transportation cost ($ per tonne) of the collected biomass from the road side/ landing to a defined point of end user.	0	0	2.9	8.8	17.6	23.5	47.2	6.03

ENVIRONMENTAL ASSESSMENT

The Environmental assessments were also rated predominately 5 or higher however, all the questions were ranked not very useful by one participant (Table 2). The availability of each type of biomass considering sustainability ranked most important out of the Environmental assessments, as 44% of respondents rated it very useful. The availability of each type of biomass considering maintaining soil nutrients and reducing fertiliser application was rated predominately very useful (41%). Both availability of each type of biomass in terms of reducing soil erosion risk and compliance with government legislation, was rated lower than the two previous assessments, with 35% and 32% participants respectively rating these analytics as very useful.

Table 2: Percentage score for each Environmental assessment by bioenergy stakeholders

Question	Score of usefulness (%)							Likert score
	1 (Not very useful)	2	3	4	5	6	7 (Very useful)	
Availability of each type of biomass considering maintaining soil nutrients and reducing fertilizers application.	2.9	0	5.9	8.8	32.4	8.8	41.2	5.59
Availability of each type of biomass in terms of reducing soil erosion risk, reducing soil salinity, etc.	2.9	2.9	2.9	17.6	20.8	17.6	35.3	5.44
Availability of each type of biomass considering forest/farm sustainability (future stand/farm growth decline due to biomass recovery).	2.9	0	2.9	8.8	17.6	23.5	44.3	5.85
Compliance of each type of biomass with government legislation for renewable energy.	2.9	0	2.9	14.7	11.8	35.3	32.4	5.67

SOCIAL ASSESSMENT

The ranking for usefulness of social analytics was highly varied (Table 3). The highest ranked assessment was social acceptance and community engagement with the bioenergy sector, which was given a score of very useful by 27% of participants. Both verifying the rural development by bioenergy application and assessment of social wellbeing, occupational injuries, mortalities and disease were given a score of 7 by 21% of respondents. Reducing the oil import and the consumers reaction to change from domestic fuels in bioenergy was rated very useful by 18% of participants.

Table 3: Prioritisation of Social analytics by bioenergy stakeholders

Question	Score of usefulness (%)							Likert score
	1 (Not very useful)	2	3	4	5	6	7 (Very useful)	
Verifying the rural development by bioenergy application/development (e.g. job creation, reduce poverty).	2.9	2.9	8.8	20.6	11.8	32.4	20.6	5.15
Social acceptance and community engagement with bioenergy sector.	2.9	2.9	8.8	17.6	20.6	20.7	26.5	5.18
Reducing the oil import and the consumers reaction to change from domestic fuels (e.g. fossil fuels) into bioenergy (e.g. biofuel).	5.9	5.9	17.6	14.7	8.8	29.5	17.6	4.74
Assessment of social wellbeing, occupational injuries, mortalities and disease.	8.8	8.8	20.6	14.7	14.7	11.8	20.6	4.35

PRODUCT QUALITY ASSESSMENT

The scores given to Product quality assessment were also varied (Table 4). The availability of each type of biomass in terms of reducing soil erosion risk was given a score of 7 by 29% of participants. The availability of each type of biomass considering maintaining soil nutrients and reducing fertiliser application was rated lowest out of all the analytics with 12% of respondents scoring very useful for this assessment.

Table 4: Usefulness score of Product quality assessment by bioenergy stakeholders

Question	Score of usefulness (%)							Likert score
	1 (Not very useful)	2	3	4	5	6	7 (Very useful)	
Availability of each type of biomass considering maintaining soil nutrients and reducing fertilizers application.	0	2.9	11.8	14.7	23.5	35.3	11.8	5.12
Availability of each type of biomass in terms of reducing soil erosion risk, reducing soil salinity, etc.	2.9	2.9	8.8	8.8	23.6	23.6	29.4	5.35

RELATIONSHIP BETWEEN COUNTRY AND ASSESSMENT PRIORITY

Most participants were from South Africa, Italy or Canada and the majority of businesses were located in Western Europe, Africa and North America. Most of countries preferred Economic assessment (7 out of 13) (Table 5). Compared to Canada and USA which had a priority of Environmental assessment; Austria of Product quality; and Belgium, Ireland and South Africa having equal priority of Economic and Environmental assessment. This relationship between country and major analytic was not significant (p=0.21) (Appendix 3).

Table 5: Percentage of responses to major analytic preference classified into countries

	Austria	Belgium	Brazil	Canada	Croatia	Finland	Ireland	Italy	New Zealand	South Africa	Sweden	Switzerland	USA
Economic assessment	0	50	100	17	100	100	100	42.9	100	50	100	100	0
Environmental assessment	0	50	0	66.7	0	0	0	42.9	0	50	0	0	100
Social assessment	0	0	0	0	0	0	0	14.3	0	0	0	0	0
Product quality assessment	100	0	0	17	0	0	0	0	0	0	0	0	0

RELATIONSHIP BETWEEN STAKEHOLDER GROUP AND ASSESSMENT PRIORITY

The stakeholder type was classified into four groups: biomass grower (8.8%), biomass consumer (5.9%), bioenergy investor (8.8%) and others (73.5%). Both biomass growers and biomass consumers were unanimous in their preference of major assessment, with Economic and Environmental respectively (Table 6). The major priority of biomass investors was Environmental analytic, followed by Product quality assessment. Other biomass stakeholders predominately gave priority to Economic assessment, followed by Environmental, Social and Product quality assessment. The relationship between stakeholder group and major assessment priority was not significant (p=0.131) (Appendix 4).

Table 6: Major analytic priority nominated by each stakeholder group (presented as a percentage)

	Biomass grower	Biomass consumer	Biomass investor	Other
Economic assessment	100	0	0	56
Environmental assessment	0	100	75	36
Social assessment	0	0	0	4
Product quality assessment	0	0	25	4

AUSTRALIAN SURVEY

The main results found in the Australian survey was that majority of the stakeholders (70% of participants) chose the economic assessment as the most useful analytic type (Figure 2). Product quality assessment was ranked as second which accounted for 27% of the responses. Environmental assessment was least preferred item for the stakeholders (3% of the responses). The responses to detailed questions related to each type of analytics have been summaries below.

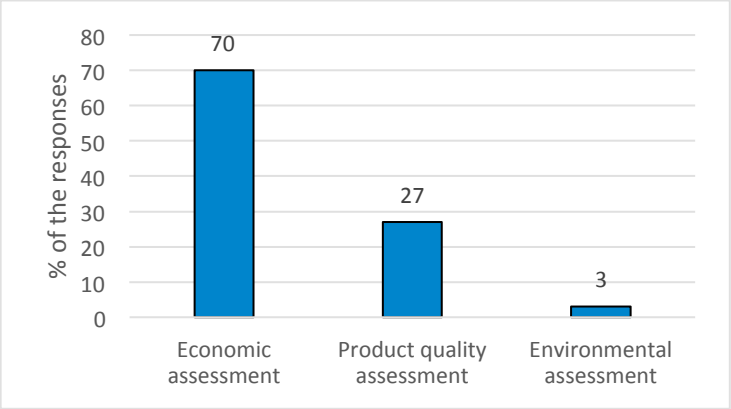

Figure 2. Percentage of the responses for most useful type of analytics

The role of participants within the bioenergy industry was also collected in this survey which included biomass grower (16.7% of participants), biomass consumer (e.g. processor or mill) (13.3% of participants), bioenergy investor (20% of participants) and other (50% of participants). Table 7 summarises the preferences of each group regarding to three types of analytics. These results indicate that most groups (especially growers, investors and consumers) preferred economic assessment to other types of analytics. Product quality assessment was not a preferred analytic for growers, but it was slightly preferred BY consumers, investors and others (Table 4)**.** The location of business of each participant was collected to calculate the percentage of participants for each state/territory which resulted as following; Northern territory (3.3%), New South Wales (6.7%), Queensland (46.6%), South Australia (6.7%), Tasmania (13.3%), Victoria (16.7%) and Western Australia (6.7%).

Table 7. Percentage of the responses of each group for most useful type of analytics

	Biomass grower	Biomass consumer	Bioenergy investor	Other
Economic assessment	100	75	80	63
Product quality assessment	0	25	20	32
Environmental assessment	0	0	0	5

Discussion

The survey revealed that biomass stakeholders prioritise Economic analytics for GIS based research, this prioritisation of Economics is also seen in other studies such as Fawzy and Componation (2015) in the USA, Ghaffariyan (2017) in Australia and Dale et al. (2018) in the USA. Consistent with the highest analytic priority, the detailed analytic rated most useful was the cost of biomass and transportation. The stakeholder priority found in most studies is either Economic or Environmental concerns [15,19,21–25] which was also the result of this study. Shakiba (2015) and Spartz et al. (2015) also observed a high level of Environmental research prioritisation however, some studies did not observe this such as

Ghaffariyan (2017). The detailed analytic with the greatest percentage response of not useful was the assessment of social wellbeing, occupational injuries, mortalities and disease which is consistent with Social analytic having the lowest priority out of the four major analytics.

Generally there is a difference in priorities between different stakeholder types [20,25,26] however, there was no statistical significance observed in this study. Despite this, a difference in the priorities of stakeholder types was observed. None of the biomass investors in this study prioritised Economic assessment, which differs from Ghaffariyan (2017) who observed the majority of biomass investors to prioritise Economic assessments. This difference may have arisen from the varying priorities of the stakeholder's country or the company that the stakeholder is employed by. The biomass consumers rated Environmental assessment to be the most useful assessment which differs from the results of Ghaffariyan (2017) which found biomass consumers to prioritise Economic analytics. All of the biomass growers surveyed preference Economic analytics over other assessments, which was also observed in studies such as Leitch et al. (2013), Shakiba (2015), Wolde et al. (2016) and Gowan et al. (2018). Very few of the stakeholders prioritised Social assessment, which has been observed by Delshad et al. (2010) who found other assessments to be prioritised over Social assessment. It was anticipated that some stakeholder types would prefer a particular analytic however, the hypothesised priorities were not always supported. It was hypothesised that investors would prioritise Economic assessment whereas this study found investors to prioritise Environmental assessment.

A difference was found between countries and major analytic priority, despite this relationship not being significant. This difference in major assessment priority was also found by Shakiba (2015) who compared the biofuel stakeholder priorities between Canada and Belgium.

Comparing an emerging bioenergy industry to a more established bioenergy in Europe displays the contrasts between these two groups of stakeholders. Overall, 60 percent of Western European Bioenergy stakeholders prioritised Economic assessment which is 10 percent less than Australian Bioenergy stakeholders. The prioritisation of Environmental assessment also differed, with 30 percent of Western Europeans prioritising Environmental assessment compared to only 3 percent of Australians. This difference in Economic and Environmental assessments could suggest that initially the profitability of the bioenergy industry is the focus, but as the industry becomes established this focus could change to the environmental impacts of the industry. When comparing the priorities of the different stakeholders in Australia and Western Europe it was observed that both groups of Biomass growers, Bioenergy investors and Others preferred Economic Assessment, whereas the Western European Biomass consumers prioritised Environmental Assessment and Australian Biomass consumers preferred Economic Assessment. Therefore, there are both differences and similarities observed between an emerging and established bioenergy industry.

The study by Ghaffariyan (2017) had a very similar research question and study design therefore, it is interesting to compare the findings of these studies. The results of this study showed a lower priority overall for Economic assessment compared to Ghaffariyan (2017), despite this assessment having the highest preference. Environmental assessment was prioritised by 35% more stakeholders than observed by Ghaffariyan (2017) while the usefulness of product quality assessment dropped from 27% to 6%. All of the Environmental assessments were rated as more useful by the stakeholders and the major analytic preferred by all stakeholder groups was varied, compared to Ghaffariyan (2017) which observed all stakeholder groups to preference Economic assessment. The dissimilar results between these two studies could be a consequence of the different percentages of stakeholder groups surveyed or that Australian biomass stakeholder priorities differ compared to other countries.

Spartz et al. (2015) found the highest ranked Environmental parameter to be Environmental health which was evident among the stakeholders surveyed with US stakeholders rating Environmental health an average of 6 out of 7 on a scale of usefulness. Other studies of US stakeholders have found Economics to be the highest priority [19,21] whereas this study found a unanimous priority of Environmental concerns. One of the US stakeholder social priorities is the creation of jobs [19] which was supported in the reasonably high rating given to the usefulness of verifying the rural development by bioenergy development (for example job creation). Another US stakeholder priority for social assessment is community wellbeing [22], which was not ranked highly in the this study with social wellbeing rated 4 out of 7 on the scale of usefulness. The most important Economic factor for US biomass stakeholders is cost [19,21] which differs from the results in this study which rated cost at medium importance.

One of the main priorities of Canadian governments is meeting legislation targets [25] which is not reflected in the stakeholder priorities as most respondents did not rank this analytic highly. Italy's bioenergy priority is to reduce costs [28] which is supported by this research as the average rating of usefulness given by stakeholders was 6 out of 7. The African biofuel priority is economics [29] which is reflected in the responses of the African stakeholders, in 71% electing Economic assessment as their major priority. The major agricultural goal of Oceania is to increase the profits of the agricultural industry [30], this is supported in the prioritisation of Economic assessment by the New Zealand participant. Sometimes there are conflicting priorities between the agriculture and forestry industries although, in this study that was not found.

Overall, there was a large amount of variation found between the results of this study and the results of other studies. This suggests that there is a large variation of analytic priority between stakeholders, with less variation when comparing countries or stakeholder types. Future IEA studies could research the importance of reaching legislation targets compared to the other analytics.

Conclusion

The most useful research analytic nominated by most stakeholders was Economic assessment followed by Environmental assessment, while few stakeholders gave priority to Product quality assessment or Social assessment. There was no significant relationship found between major analytic preference and either country or stakeholder type however, there were differences observed in these categories. The major outcome in the comparison between an emerging and established bioenergy industry was the similar interest in Economic assessment, with a higher priority of Environmental assessment within established bioenergy industries. The stakeholder groups in both the emerging and established bioenergy regions had similar research priorities. This study addressed the research gap of surveying the importance of Social analytics, the international comparison of bioenergy stakeholder's priorities of GIS based biomass analytics and a comparison between the priorities of an emerging and established bioenergy industry.

Acknowledgement

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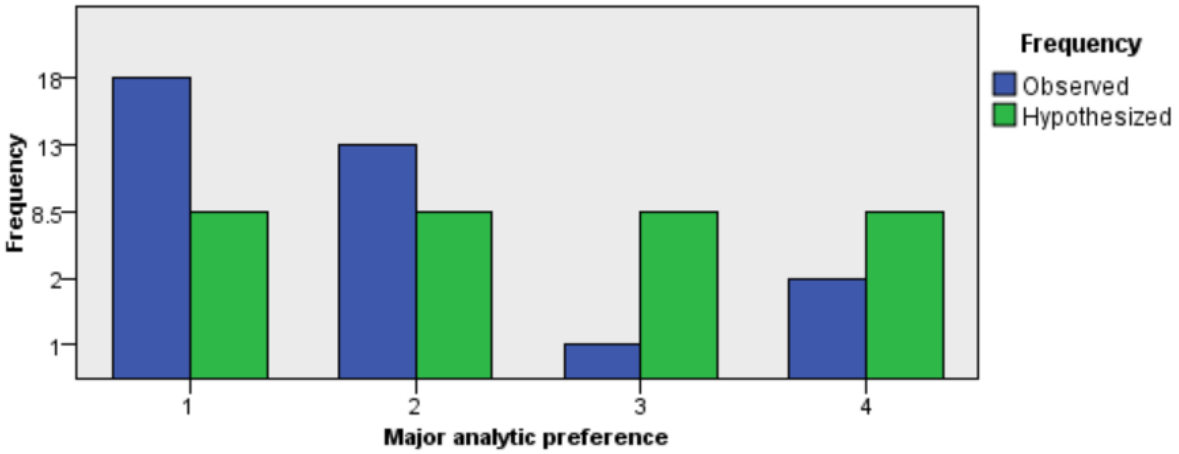
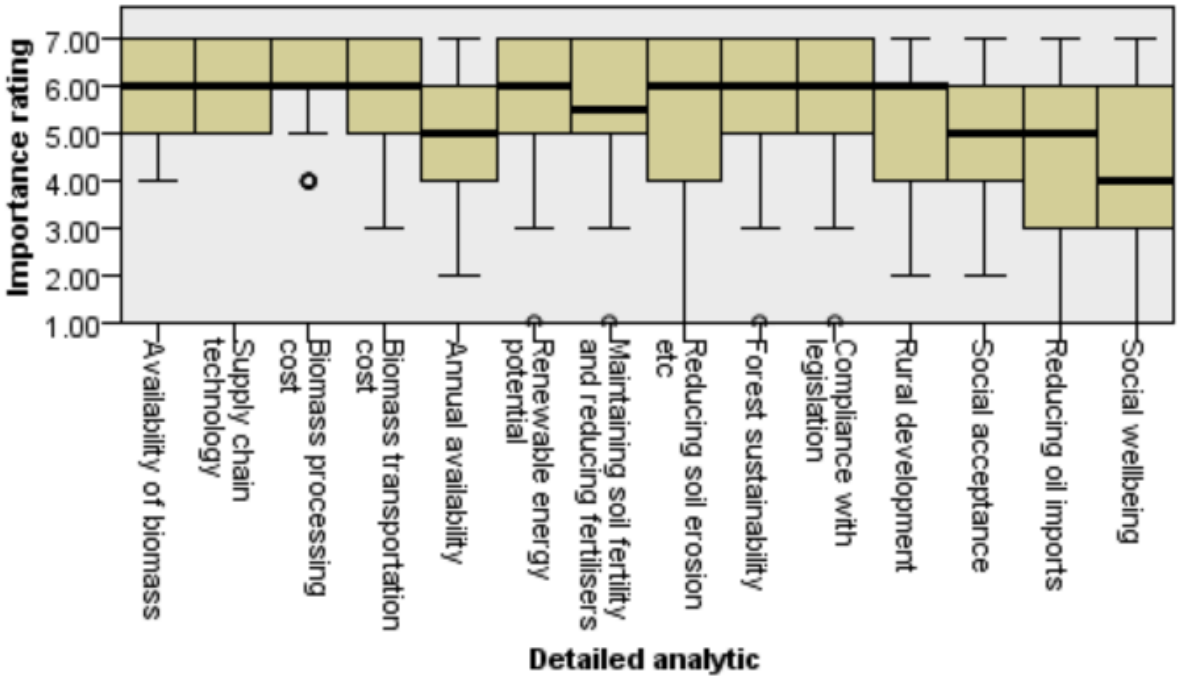
Appendix

Appendix 1: Results from the Chi-squared test for the major analytic preference



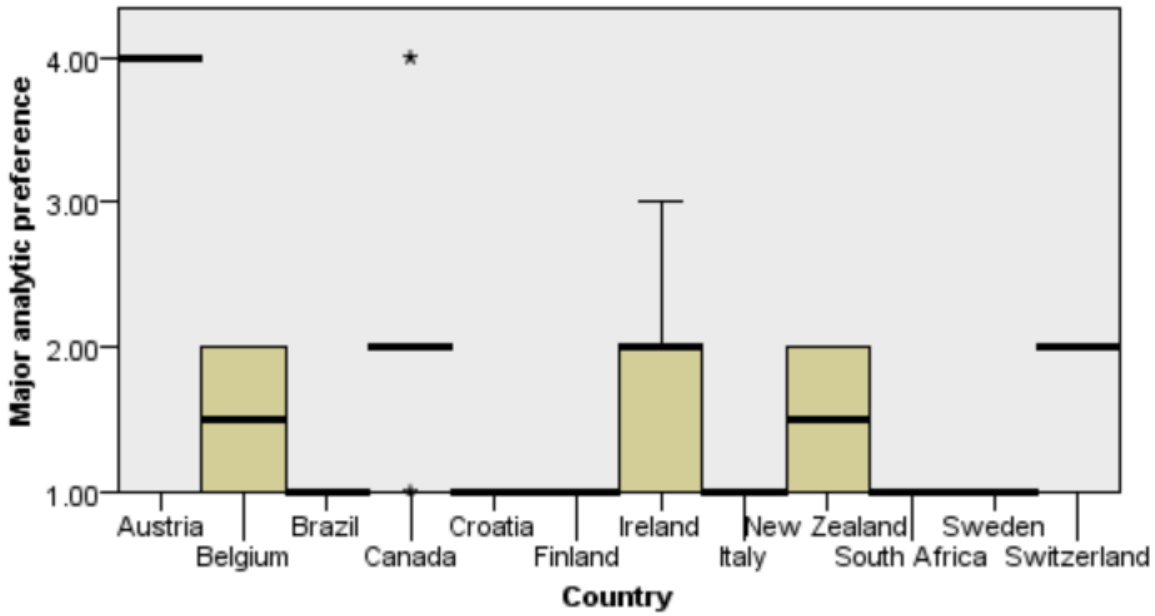
Total N	34
Test statistic	24.588
Degrees of freedom	3
Significance (2-sided test)	0.000

Appendix 2: Results from the Kruskal-Wallace test of the comparison between the detailed analytics



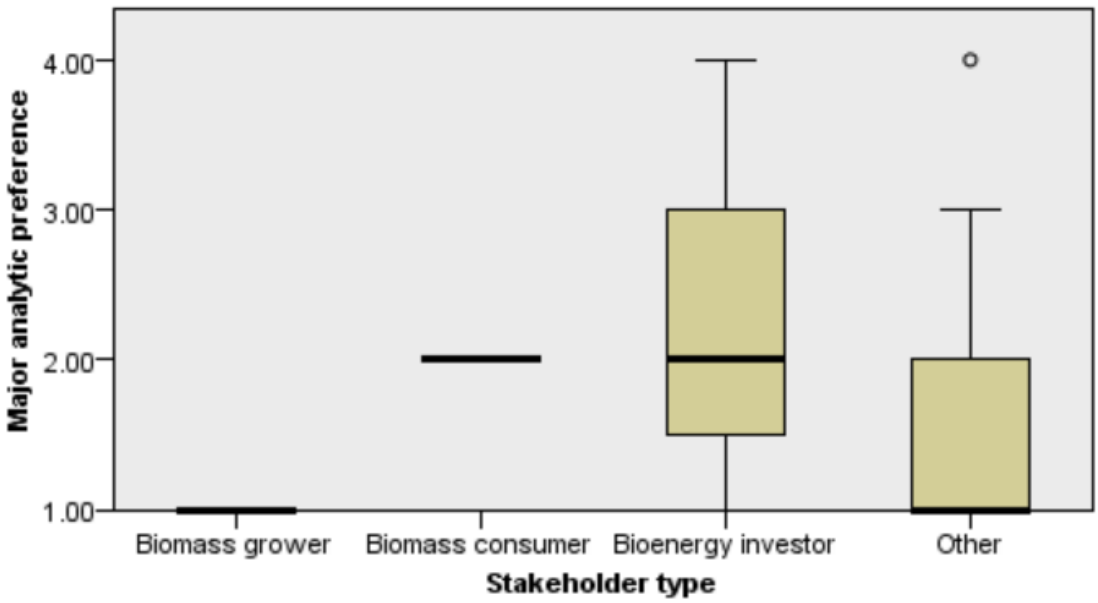
Total N	34
Test statistic	38.502
Degrees of freedom	13
Significance (2-sided test)	0.000

Appendix 3: Results from the Kruskal-Wallace test of the comparison between country and major analytic



Total N	34
Test statistic	14.612
Degrees of freedom	11
Significance (2-sided test)	0.201

Appendix 4: Results from the Kruskal-Wallace test of the comparison between stakeholder type and major analytic preference



Total N	34
Test statistic	5.631
Degrees of freedom	3
Asymptotic significance (2-sided)	0.131