NoAW project

Innovative approaches to turn agricultural waste into ecological and economic assets

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1.2. Revision history

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PU Public	**PU**
CI Classified, as referred to Commission Decision 2001/844/EC	
CO Confidential, only for members of the consortium (including the Commission Services)	

2. Summary

Background	The H2020 project NoAW has as its goal to contribute to a 'near zero-waste society' by promoting a circular economy in which agricultural waste, by- and co-products are turned into eco-efficient bio-based products with direct benefits for the environment, economy and society. The WP2 overall objective is to develop innovative and robust approaches and tools adapted to the assessment and determination of optimal agro-wastes management strategies. The objective of WP2 is also to aid decision support regarding agro-waste upgrading strategies. The decision support shall inform decision makers on three levels: product, farm and region.
Objectives	The objective of this deliverable is to create a framework for how several evaluation methods can be applied on one case study. This will show how results from different methods can complement each other, to reach new insights that could not be gained by application of one individual method. The aim is also to create a framework for how methods can be combined into hybrid tools. By combining methods, stakeholders will be provided with high quality decision support, and will also yield important knowledge for future studies.
Methods	The following steps have been done: • Development of a step-wise procedure to apply several evaluation methods on one case study • Description of framework for combination of methods
Results & implications	The application of different assessment methods will give results that cannot be generated by applying only one method. Results from the different methods will be compared and combined. This will help to avoid sub-optimisation and undesirable trade-offs that could occur otherwise. In this delivery we show that using several methods requires careful planning and close communication between the different research groups. It is important that a common ground of terminology is decided upon and that there is an agreement on the basic principles of case study set-up. It is also important to acknowledge that the research questions and the approach to the case study will somewhat differ between the methods. Furthermore, a plan for joint data collection and management is needed, as well as a plan for the communication of results. Several different opportunities for combining methods into hybrid tools were identified: (1) Combining Territorial Metabolism and Life Cycle Assessment (TM-LCA) allows for process-based environmental impact modeling at a regional scale. (2) Several add-on elements are possible for the TM-LCA method e.g. approaches to dynamic systems and multiple-criteria decision analysis. (3) A combination of Computational social choice and Argumentation permits to support decision based on validated preferences.

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3. Introduction

General introduction:

The H2020 project NoAW has as its goal to contribute to a 'near zero-waste society' by promoting a circular economy in which agricultural waste, by- and co-products are turned into eco-efficient bio-based products with direct benefits for the environment, economy and society. The focus is to study residues from grape cultivation, wine production and cereal cultivation as raw material for production of bio-active molecules, chemicals, building-blocks and materials.

The WP2 overall objective is to develop innovative and robust approaches and tools adapted to the assessment and determination of optimal agro-wastes management strategies. The objective of WP2 is also to give decision support regarding agro-waste upgrading strategies. The decision support shall inform decision makers on three levels: product, farm and region. The following tasks are included in WP2:

- Task 2.1 - Identification of relevant attributes and definition of NoAW agro-wastes systems boundaries
- Task 2.2 - Hybridizing LCA and TM to enable agro-wastes life cycle early guidance and assessment
- Task 2.3 - Multi-criteria evaluation in strategic environmental assessment of agro-waste management plans
- Task 2.4 - Evaluation of case studies and guidance for decisions within the project

The approach in WP2 is to use existing methods and tools, but to combine and/or adapt them to be better suitable for the NoAW context. The advantage is that the application of several methods for assessment of agro-waste upgrading strategies will give a multifaceted picture of the systems. This will prevent the sub-optimization or undesirable trade-offs that could be a side effect of only using one assessment method or only including one level. This systems overview will facilitate new innovative thinking and identify sustainable business opportunities. The challenge is how to, in practice, apply several methods to specific cases, to present and compare the results and draw relevant conclusions. The outcome of WP2 is intended to generate both high-quality research and results useful for industry and other stakeholders. Stakeholders on three levels, product, farm and region, will be approached and their views and priorities regarding agro-waste upgrading strategies will be included.

Objectives of Deliverable:

According to DOA the D2.1 deliverable should describe: "Foundation for the work to be performed in Task 2.2, Task 2.3 and Task 2.4." Based on this we have formulated two specific aims, described below.

The first aim of this deliverable is to create a framework for how several methods can be applied on one case study. This will evidence how results generated from different methods can be combined to reach new insights, which cannot be gained by application of one individual method. By this, a larger group of stakeholders can be addressed. In case of contradictory results, we will investigate the difference and how it impacts the case study. We will also identify when and why certain methods are not applicable or cannot be combined. This deliverable explains the process for applying multiple methods to one case study, including processes for joint data collection and data management, mainly addressing task 2.3 and 2.4.

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The second aim of this deliverable is to create a framework for how methods can be combined. By combining methods, stakeholders will be provided with high quality decision support. This facilitates new thinking, and the systems overview will help in identifying business opportunities that contribute to sustainable development. From a research point of view, the development of hybrid methods is also interesting as new insights are gained. The experience of how a combination of methods can be applied will also yield important knowledge for future studies. This deliverable lays out the process for integration of methods to hybrid tools, mainly addressing task 2.2.

The common case study:

In this deliverable, the case study will not be described in detail, the aim is rather to set out the methodological framework. However, all methods in WP2 will be applied to one specific case study to provide a baseline and to test and improve the methodology. The first specific case study is the LCA assessment of Winery Aleksandrovic (VA) in Serbia; a NoAW project partner. The approach will then be applied on wine production in Languedoc Roussillon in France. After this first case study, the methodology will be used to assess technologies for agro-waste upgrading developed within the NoAW-project and in different regional context.

Methods used in the project (WP2):

In Table 1 (p. 9-10) a brief overview of the methods applied in WP2 is presented. This gives a first indication of the advantages and disadvantages and the possibilities of the methods to complement each other. A more comprehensive description can be found in the NoAW Milestone *MS5 - Attributes and system boundaries defined*.

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Table 1. Overview of applied methods in WP2

Method	Important documents to describe the method	Typical questions answered by the method	Data used (quantitative, qualitative etc.)	Common indicators	Advantages with method	Disadvantages with method
Life Cycle Assessment (LCA)	ISO 14040[1] ISO 14044[2]	What is the potential environmental impact of a product or process through its life cycle?	Quantitative data. Specific data if available, generic data if compatible with the goal and scope of the study	Global Warming Potential (GWP, kg CO2-eq) Acidification potential (AP, kg H+ eq) etc.	Assesses the environmental impact of products and processes through the entire life cycle, upstream and downstream of production including the end-of-life.	Product-focused and data intensive Only quantitative aspects are considered Results for one case may differ depending on the choice of system boundaries
Territorial Metabolism – LCA (TM-LCA)	Sohn et al 2018[3]	What is the potential environmental impact (and scale of impact) of the implementation of alternative value chains in a production-shed based territory?	Quantitative data. Specific if available.	Global Warming Potential (GWP, kg CO2-eq)	Territorial Metabolism – LCA (TM-LCA)	Can be data intensive, especially when optional complications such as LCC, MCDA, and system dynamics are included.

[1] ISO (2006) Environmental Management -Life Cycle Assessment- Principles and Framework ISO 14040
[2] ISO (2006) Environmental Management -Life Cycle Assessment -Requirements and Guidelines, ISO 14044
[3] Sohn, J., Croxatto Vega, G., Birkved, M., A Methodology Concept for Territorial Metabolism – Life Cycle Assessment: Challenges and Opportuni-ties in Scaling from Urban to Territorial Assessment, Procedia CIRP,Volume 69, 2018, Pages 89-93, ISSN 2212-8271, https://doi.org/10.1016/j.procir.2017.10.005.

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Method	Important documents to describe the method	Typical questions answered by the method	Data used (quantitative, qualitative etc.)	Common indicators	Advantages with method	Disadvantages with method
Computational social choice	Brandt et al 2016[4]	Preference aggregation using different voting rules	Qualitative data about stakeholders' preferences	Final ranking score depending on the used voting rule	Quantitative score allows to compare alternative and support decision	Does not permit to take into account underlying reasons for preferences
Argumentation	Phan Minh Dung (1995)[5]	Reasoning with contradictory information and opinions thanks to arguments	Qualitative data about stakeholders' arguments	Maximal consistent subsets of arguments	Argumentation permits to check and validate the preferences	Does not permit directly to support decision as it focuses on assessing arguments validity (is an argument supported and logically sound?) and not on what is the best decision to be made based on the valid supporting and contradicting arguments

[4] Brandt, F., Conitzer, V., Endriss, U., Lang, J., & Procaccia, A. D. (Eds.). (2016). Handbook of computational social choice. Cambridge University Press.
[5] Phan Minh Dung (1995) "On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming, and n–person games". Artificial Intelligence. 77 (2): 321–357. doi:10.1016/0004-3702(94)00041-X.

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Method	Important documents to describe the method	Typical questions answered by the method	Data used (quantitative, qualitative etc.)	Common indicators	Advantages with method	Disadvantages with method
Multi Criteria Decision Analysis (MCDA) - TOPSIS	Hwang and Yoon (1981)[6] , Yoon (1987)[7] , Hwang, Lai, and Liu (1993)[8]	What is the best alternative amongst a set of alternatives given a set criteria.	Quantitative	Performance score, rank	Widely used method easy to use and implement, mimics human thinking, and has a low rank reversal compared to similar methods	Potential for over-interpretation or misinterpretation of normalized and weighted results.
Multi-criteria Evaluation (MCE) in Strategic Environmental Assessment (SEA) of Waste Management Plan (WMP)	Josimović et. al (2015)[9]	What is the potential territorial impact of the Waste Management Plan (including new valorisation routes) on environment	Quantitative data, mostly from Vinery Aleksandrovic (Case Study). Specific if available, general if compatible with the goal and scope of the study	Indicators for the assessment of territorial impacts on: water, soil, air, waste, noise, etc.	Optimal solutions in the WMP in the context of the environmental protection	Subjectivity in the process of evaluation.

[6] Hwang, C.L.; Yoon, K. (1981). Multiple Attribute Decision Making: Methods and Applications. New York: Springer-Verlag
[7] Yoon, K. (1987). A reconciliation among discrete compromise situations. Journal of Operational Research Society. 38. pp. 277–286.
[8] Hwang, C.L.; Lai, Y.J.; Liu, T.Y. (1993). "A new approach for multiple objective decision making". Computers and Operational Research. 20: 889–899.
[9] Josimović, Boško et. al (2015)[9]. “Multi-Criteria Evaluation in Strategic Environmental Assessment for Waste Management Plan, A Case Study: The City of Belgrade”. Waste Management 36, pp. 331-342. DOI: 10.1016/j.wasman.2014.11.003

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Previous attempts of combining methods

This section gives a brief review overview of similar research that has been performed.

Argumentation-social choice:

To the best of our knowledge, the application of argumentation into computational social choice with the objective of improving decision support through the aggregation of validated preference relations is a relatively new domain. However, it should be noted that many problems on the intersection of computational social choice and argumentation are weakly related to our work. Most of the approaches in this research area are theoretical and place themselves in the argumentation context in order to deal with the problem of collective argumentation, i.e. how we should rationally deal with justifications taken as abstract entities when several agents are present. In this kind of work, the problem is to aggregate individual argumentation frameworks into a collective one in a general way, i.e. in a way that could be used in any kind of application context. In this kind of approach, the problem is to aggregate individual argumentation frameworks into a collective one. The aggregation mechanisms provided to solve the problem rely on social choice, i.e. voting rules. An informative survey is provided by Bodanza et al[10]. In NoAW, we want to do the reverse, that is we want to use argumentation to validate preferences before aggregating them.

TM-LCA:

LCA is a mature sustainability assessment method in use for several decades. However, applying LCA to large systems or regions is a developmental area of the methodology. Urban metabolism (UM) coupled with LCA has been previously used to assess material flows of a city and can be an effective tool to benchmark the environmental performance of cities[11]. UM lacks specific direction for larger scale assessments, it uses material flow to arrive at environmental impacts but does not incorporate upstream or downstream flows. Or, in other words, UM draws a system boundary at the edge of a city (or urban growth boundary, or whatever other usually contiguous politically defined unit of definition of urban area as desired) whereas TM-LCA draws its system boundary at the production-shed (the area affected by changes in a value chain) for the system being assessed. There is not really a basis of comparison on scale but theoretically, UM could assess the largest urban area in the world down to a single person town and TM-LCA could theoretically assess the largest global supply chain down to the smallest production line. TM-LCA essentially uses UM methodology, while offering direction to approach the problem of scale, thereby becoming useful for assessment at a larger scale[12].

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[10] Bodanza G., Tohmé F. and Auday M.(2017)Collective argumentation: A survey of aggregation issues around argumentation frameworks. Argument \& Computation, 8:1, p. 1-34

[11] Goldstein, M. Birkved, M.-B. Quitzau, and M. Hauschild, (2013) "Quantification of urban metabolism through coupling with the life cycle assessment framework: concept development and case study," Environ. Res. Lett., vol. 8, no. 3, p. 35024

[12] Sohn J., Croxatto Vega G., Birkved M. (2018), A Methodology Concept for Territorial Metabolism – Life Cycle Assessment: Challenges and Opportunities in Scaling from Urban to Territorial Assessment, Procedia CIRP,Volume 69, Pages 89-93, ISSN 2212-8271, https://doi.org/10.1016/j.procir.2017.10.005

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4. Results

4.1. Process for applying multiple methods to one case study

In order to evaluate a common case study with different methodologies, a number of steps need to be followed. We have developed a procedure for this, described below.

Step 1: Agree on terminology, which is important for the basic understanding and communication. Here we have identified a number of important terms for the project:

In the EU-legislation, the only clear definition that is given is that between product and waste. The main document for this is the Waste Directive (2008/98/EC)[13]. In this directive, the definition is rather straight forward, if something can be sold as a product with or without further treatment it is a product, if not it is a waste. By-products and co-products are not defined. Some clarifications to the waste directive have been made[14]. In this project we used these definitions.

- **Product:** all material that is deliberately created in a production process. In many cases it is possible to identify one or more primary products which is the principal target of the production process
- **Production residue:** a material that is not deliberately produced in a production process and may or may not be a waste.
- **By-product:** a production residue that is not a waste. A by-product is a sellable product that is the result of a production process for which the primary aim is not the production of that product. A by-product may require further treatment to increase the market value
- **Case study** – an assessed system or value chain. While WP2 is focused on assessment case studies, the term can have different meanings depending on the user. When combining methodologies, it is important to agree on the meaning of case study. It is also necessary, the system boundaries and the content. This second step, agreement, is described in further detail below.
- **Decision support tool** – the methodology or assessment procedure that can be applied to obtain structured information on (sustainability) impacts, useful for making well-informed decisions. In WP2, this will be applied to agro-waste upgrading strategies. The technologies in NoAW and waste treatment strategies in different regions will serve as case studies to prove the methodology and to generate results. Results will be unique to a specific case, but we strive to develop methodologies that can be applied broadly and adaptable according to specific needs. A decision support tool is not necessarily a computer-based tool. However, some tools e.g. a dynamic LCAs will be developed and used to generate specific information. The principles for the methodology will be published and available to the public.

[13] Directive 2008/98/EC of the European Parliament and the Council of 19 November 2008 on waste and repealing certain directives

[14] Communication from the commission to the council and the European Parliament on the Interpretive Communication on waste and by-products. Brussels, 21.2.2007, COM(2007) 59 final

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Step 2: Agree on the basic principles of case study set-up. In this WP we have agreed on the following basic principles for the case studies:

- Value chains assessed should be comparable and representative within the NoAW context
- Sufficient data must be available
- Relevant questions regarding case studies are asked and answered
- Studies cover all kinds of scenarios needed (Baseline, background and chosen case)
- Studies allow comparison between different value chains and technologies
- A regional perspective should be applicable in all studies

Step 3: Define case study details:

- Technological system
- System boundaries; geographical-time, level; farm-territory-region-product,
- Impact categories included in study
- Handling of wastes, by-products, and co-products.

Step 4: Formulate alternative scenarios to be compared. For the common case study for which several methods are applied, the research question will somewhat differ. It is important to be clear about this when comparing results. The research questions to be answered by the different methods for the case study Winery Aleksandrovic:

- **LCA:** What is the effect of residues and different waste management options on the environmental performance of wine? What is the effect of residues and different waste management options on the environmental performance of the vineyard?
- **ARG:** How is it possible to help design waste management scenario based on preferences expressed by the stakeholders for current and future products?
- **MCE:** How will the MCE method for evaluation of impact of agro-waste management plan affect the defining of optimal strategies of waste management (on regional level) in correlation with environmental and socioeconomic indicators of sustainability? Can the extrapolated data from VA (amount of organic and packaging waste) be applicable at the regional/national level (Oplenac vineyards or wider)?
- **TM-LCA:** What is the effect of implementing different waste management options on the environmental performance of a wine producing territory?

Step 5: Work out a plan for joint data collection and management:

- **Identification of critical data:** Data is a crucial issue for environmental assessments. All methods used in WP2 need data and the data must be of sufficient quality. For each group, necessary data and type of data were identified and collected in a table. It was made visible for all researchers what needs there are and when needs overlap, which facilitates the data collection and the collaboration regarding data collection. Examples of tables for identification of data needs are presented in Annex 1.

- **Data collection and collaboration:** Once data has been identified, there is a need to collaborate on the collection of data when possible. Making the data collection process as efficient as possible is not only necessary for the environmental assessments but also to facilitate for technology developers, farmers, industry etc. who provide the data.
- **Management of data:** Data must be stored in a safe manner, both regarding confidential information but also considering long-term storage of the data so that it is available in the future. It is important to ensure easy access to collected data for all those researchers involved in the project.

Step 6: Plan the communication of results

- Common publications (Described in MS9)
- Development of decision support guidance, within and outside project
- Communication with stakeholders

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4.2. Integration of methods to Hybrid tools

TM-LCA:

By combining Territorial Metabolism – Life Cycle Assessment (TM-LCA), we can analyze how the regional and dynamic perspective affects the results of the LCA for implementation of biorefining technologies in the treatment of wine and vineyard by/co-products.

A framework for the methodological approach is described in Sohn et al.[15] This framework for the development of background system modeling allows for process-based environmental impact modeling at a regional scale. This is accomplished through the coupling of methods derived from UM applied at a territorial level with the impact assessment methods in LCA. In the context of the NoAW project, the TM-LCA framework creates the opportunity for direct assessment of environmental impacts, incorporation of system dynamics, and the use of multi-criteria decision analysis for the assessment of various value chains, which have been proposed for the treatment of winery wastes. By evaluating a producer-shed based territory through the TM-LCA method, this study will have the opportunity to provide decision support for the potential implementation of the various value chains proposed within the NoAW project.

TM-LCA +

Several add-on elements are described in the formulation of the TM-LCA method. These combined TM-LCA methods are dubbed TM-LCA+, and they include approaches to dynamic systems and multiple-criteria decision analysis, among others. Within the WP2 TM-LCA based assessments, the inclusion of MCDA for applying weighting factors will be explored using computational social choice and argumentation methods and tools. This will be used to generate regionalized weighting profiles to provide tailored and transparent decision support in the form of single score indicators which are presented alongside midpoint indicators from LCA for the various cases assessed in WP2.

TM-LCA combined with Argumentation and MCDA will make it possible to take into account in a generic manner the specificities of studied regions in TM-LCA. Is it possible to provide contextualized indicators to decision makers based on the prioritization of mid-point indicators from LCA using computational social choice and argumentation methods and tools?

Computational social choice - Argumentation

Combination of Computational social choice and Argumentation permits to support decision based on validated preferences. The aggregation mechanisms provided to solve the problem normally rely on social choice, i.e. voting rules. In NoAW, we want to do the reverse, that is we want to use argumentation to validate preferences before aggregating them.

[15] Joshua Sohn, Giovanna Croxatto Vega, Morten Birkved, A Methodology Concept for Territorial Metabolism – Life Cycle Assessment: Challenges and Opportunities in Scaling from Urban to Territorial Assessment, Procedia CIRP,Volume 69, 2018, Pages 89-93, ISSN 2212-8271, https://doi.org/10.1016/j.procir.2017.10.005.

5. Conclusions

The results show that using several methods requires careful planning and close communication between the different research groups. It is important that a common ground of terminology is decided upon and that there is an agreement on the basic principles of case study set-up. It is also important to acknowledge that the research questions will differ between the methods. Furthermore, a plan for joint data collection and management is needed, as well as a plan for the communication of results.

Several different opportunities for combining methods into hybrid tools were identified: (1) Combining Territorial Metabolism and Life Cycle Assessment (TM-LCA) allows for process-based environmental impact modeling at a regional scale. (2) Several add-on elements are possible for the TM-LCA method e.g. approaches to dynamic systems and multiple-criteria decision analysis. (3) A combination of Computational social choice and Argumentation permits to support decision based on validated preferences.

In conclusion, using several methods and in some cases combining these methods, can give a broader base of information and facilitate new thinking. Decision makers in R&D, industry, policy and civil society will be able to make more informed decisions to guide waste-resource recovery strategies and minimize impacts on water, air and soils and hence contribute to a sustainable development.

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6. Partners involved in the work

The partners that have been involved in this work are RISE, DTU, INRA and IAUS with support from IFV and VA.

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7. Annexes

Annex 1. Identified data needs of the groups involved in WP2

Table A1. Examples of data needs related to raw material generation in Wineries.

	Quantitative					
Task (Partner)	waste/co-product production	Spatial Definition	Production	Material inputs	Economic data	
2.1 (INRA)	Y	Y	Y	Y	Y	
2.2 (DTU, RISE)	Q, T, S	A, L	Q, S	T,Q,O	Y	
2.3 (IAUS)	Q, T, S	A, L, etc.	Q, S	T,Q,O	?	
2.4 (RISE, DTU)	Q, T, S	A, L	Q, S	T,Q,O	Y	
	Qualitative					
Task (Partner)	waste/co-product production	Spatial Definition	Production	Material inputs	Value chain	Present treatment methods
2.1 (INRA)	E, P, J	E, P, J	E, P, J	E, P, J	E, P, J	E, P, J
2.2 (DTU, RISE)	Y		Y	Y	Y	Y
2.3 (IAUS)	Y		Y	Y	Y	Y
2.4 (RISE, DTU)	Y		Y	Y	Y	Y

Y	Yes
Q	Quantity
T	Type
S	Seasonality
A	Area
L	Location
O	Origin
C	Composition/characterization
E	Exhaustive list of alternatives
P	Preferences (ordering)
J	Justifications

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Table A2. Examples of data needs for assessment of technologies for upgrading of agro-wastes.

	Quantitative				
	Material consumption	Energy consumption	Capital goods	Outputs	Economic Data
2.1 (INRA)	Y	Y	Y	Y	E, P, J
2.2 (DTU, RISE)	T,Q	T,Q	T,Q	T,Q	Y
2.3 (IAUS)					
2.4 (RISE, DTU)	T,Q	T,Q	T,Q	T,Q	Y

	Qualitative						
	Material consumption	Energy consumption	Capital goods	Outputs	Value chain	Conventional production methods	Scale
2.1 (INRA)	E, P, J	E, P, J	E, P, J	E, P, J	E, P, J	E, P, J	Y
2.2 (DTU, RISE)	Y	Y	Y	Y	Y	Y	Y
2.3 (IAUS)							
2.4 (RISE, DTU)	Y	Y	Y	Y	Y	Y	Y

Y	Yes
Q	Quantity
T	Type
S	Seasonality
A	Area
L	Location
P	Origin
C	Composition/characterization
E	Exhaustive list of alternatives
P	Preferences (ordering)
J	Justification

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Table A3. Examples of needs of spatial data.

Quantitative

	Geographical definition of case study area	Position of production facilities	Terrain data (elevation)	Land coverage	Nature and cultural protected areas	Location of waste treatment facilities	Population (distribution, statisticsm employment)	Future plans for the area
2.1 (INRA)								
2.2 (DTU, RISE)								
2.3 (IAUS)	Q, T, S	A, L, etc.	Q, S	T,Q,O				?
2.4 (RISE, DTU)	A	A, L		T,Q		A, L		Y

Qualitative

	Geographical definition of case study area	Position of production facilities	Terrain data (elevation)	Land coverage	Nature and cultural protected areas	Location of waste treatment facilities	Population (distribution, statisticsm employment)	Future plans for the area
2.1 (INRA)								
2.2 (DTU, RISE)								
2.3 (IAUS)	Y		Y	Y	Y	Y		
2.4 (RISE, DTU)	Y	Y		Y		Y		Y

Y	Yes
Q	Quantity
T	Type
S	Seasonality
A	Area
L	Location
O	Origin
C	Composition/characterization
E	Exhaustive list of alternatives
P	Preferences (ordering)

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