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Executive Summary

The dissemination of the DECOIN toolkit is partly implemented through this D5.3 Report on Case study of the method and tool application. The results gained in the DECOIN toolkit testing are summarised as following benefits and drawbacks.

- The basic idea of integration of MUSIASEM, SUMMA and ASA models provides valuable development direction as the environmental statistics need more statistical computing and analysing in the future.

- The DECOIN toolkit can produce information about unsustainable trends. These findings can be produced also by other methods or deep expertise, but the toolkit eases the analysis greatly.

- The integration of the models is still unfinished and undoubtedly there is need to use much more time and resources for the finalisation of the DECOIN toolkit that was estimated in DECOIN work plan. This development work should be continued.

- There is major challenge to reconcile the spatial and cross-section perspectives of SUMMA and MUSIASEM models with the time-series and dynamic perspective of ASA model.

The development work done within DECOIN project to develop DECOIN toolkit provides for the follow-up research that centres to the actual programming of the prototype software.

Table of Context

1. Introduction

1.1 The DECOIN work plan and objectives

The Development and Comparison of Sustainability Indicators (DECOIN) project deals with sustainable development indicators and the methodology of analyzing inter-linkages between different trends in the EU. According to the DECOIN Description of Work, DECOIN project responds to the EU FP6 SSP Priority “Integrating and strengthening the European Research Area, Scientific Support to Policies”. At the EU policy level, the project will contribute to the renewed EU Sustainable Development Strategy and the 6th Environment Action Programme and the related Thematic Strategies. The DECOIN project The DECOIN project contribute to the research towards a sustainable European knowledge society through the development of the EU framework of Sustainable Development Indicators. Through the methodological work concerning the analytical frameworks the project will help the EU and its Member States to better observe the trends in relation to the different dimensions of sustainability.

Within the DECOIN project The *Advanced Sustainability Analysis* (ASA), the *Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism* (MUSIASEM) and The *Sustainability Multicriteria Multiscale Assessment* (SUMMA approaches are to be developed into a prototype tool which is easy to use and provides reporting features that are required for monitoring and policy making. The DECOIN final work package 5 Dissemination of the results achieved within the DECOIN project, takes place through different channels: web site, publications, presentations in seminars, conferences and meetings, through the Steering Group and Advisory Board and through direct communication with those responsible for monitoring and policy making.

According to DECOIN Description of Work comprehensive monitoring and follow-up of the project outcomes requires a monitoring organisation as well as resources, which are beyond the possibilities of the DECOIN project. However, in the Deliverable 5.3 the DECOIN project will provide a case study with the Statistics Finland to follow up the adoption of the suggested tools and measures. The study will consist of assessment of the methods, tools and indicators from the user perspective. The earlier DECOIN work package 4 has assessed the inter-linkages between trends and provides a prototype tool for the analysis (linking ASA, MUSIASEM and SUMMA). This deliverable aims to adopt the suggested tools and measures into Finnish forest sector in order to assess the usefulness of the prototype DECOIN toolkit.

2 The DECOIN Prototype Toolkit

2.1 Introduction to DECOIN toolkit

DECOIN work-Package 4 had the task to develop and link the three analytical frameworks of ASA, MuSIASEM and SUMMA into a common tool, which can be effectively used to characterize, using integrated sets of indicator, sustainability problems. According to what has been presented in the deliverable 4.3 And 4.4 we can say that this goal can be re-stated by saying that the DECOIN toolkit can be used to generate effective *multipurpose grammars* to be used to represent and study “sustainability issues” in an integrated manner across different dimensions and scales of analysis.

As discussed in previous deliverables, the purpose of the DECOIN Toolkit is not to create a semantically closed, deterministic formal protocol to be used to assess sustainability issues. That is, we are not proposing a "magic box" where it is just necessary to enter a given set of data, then press the "red button" to get the results required to implement sustainability policy. On the contrary, the DECOIN Toolkit has been developed with the explicit goal to keep the relative procedure semantically open. For this reason, we proposed to use the conceptual tool of *multipurpose grammar* which has the explicit goal to provide an aid in the delicate phase of coupling: (A) a given issue definition of sustainability (semantic definition of a problem associated with a semantic definition of the relevant attributes) – a narrative about a sustainability problem; to (B) a given formalization in terms of proxy variables (to quantify the relevant attributes of performance) and data inputs (when defining the tokens) required for the quantitative results. By a wise choice of a combination of semantic and formal categories, it becomes possible to develop integrated set of indicators, which can be effectively employed to deal with the particular sustainability issue which has to be investigated.

By this description it is clear that the DECOIN Toolkit has to be adapted, case by case, to the peculiar characteristics of the sustainability problem to be tackled. It is for this reason, that in the continuation of the DECOIN project into the SMILE project, the DECOIN Toolkit, has been applied to a variety of different cases study: (i) an integrated multi-scale characterization of a small homogeneous region – Catalonia – within EU; (ii) an integrated multi-scale characterization of rural Laos – one of the least developed country in the world; (iii) an integrated multi-scale characterization of Romania – a country still in transition toward full market economy, recently entered in the EU; (iv) an integrated multi-scale integrated characterization of a typology of activity performed within the forestry sector in Finland – a study carried out at the sectoral level; (iv) an integrated multi-scale integrated characterization of a typology of activity performed within the agricultural sector in Campania (Italy) – a study carried out at the sectoral level. From this variety of cases, it is obvious that we could not have used just a single protocol (one size fits all), but we had to tailor the application of the toolkit (which type of approach to use and for which purpose) both on: (i) the specific goal of each one of the cases study; and (ii) the specific characteristics of the investigated system. Availability of data, in some cases, determined the impossibility of using all the 3 approaches in all the cases study.

Therefore, understanding the innovative concepts associated with the DECOIN Toolkit is fundamental to be able to use the proposed tool.

2.2 The DECOIN toolkit models

The main aim in DECOIN project is to include and integrate ASA, SUMMA and MuMIASEM -models to the DECOIN prototype toolkit.

2.2.1 SUMMA

The SUMMA approach (SUstainability Multi-method Multi-scale Assessment) provides a conceptual framework for a system/process evaluation in support to decision-making. In SUMMA the different perspectives are not forced to combine, but retain their full wealth of information, on the basis of which wise decisions can be made, also taking into account important external factors such as social and economic welfare. A full description of SUMMA as well as its integration potential with other approaches is provided in the DECOIN Deliverables D2.2, D3.3and e D4.4.

SUMMA produces intensity and performance indicators at different spatial and time scales and points out the different needs, intensities and performances in resource use. The SUMMA results are also used in the DECOIN toolkit in support of the decomposition analysis of trends and scenarios (ASA) and the identification of socio-economic internal constrains (MuSIASEM) of the investigated system. SUMMA provides a conceptual comprehensive bio-physical framework, in which it is possible to interface the analysis of the dynamics of socio-economic systems with the dynamics of ecological systems. The SUMMA approach is based on a selection of upstream and downstream methods, which offer complementary points of view on the complex issue of resource use performance and environmental impact assessment. The upstream methods used in this approach are based on the adoption of the theoretical concepts of Material Flow Accounting, Embodied Energy Analysis, Exergy Analysis and Emergy Accounting. The downstream method (assessment of downstream impact categories) used in SUMMA approach is based on the rationale given in the CML2 baseline 2000, integrated by other impact assessment methods, depending on the investigated case. The analyzed system or process is considered as a “Black Box”, and a thorough inventory of all the input and output flows is firstly performed on its local scale. It is important to underline that this inventory forms the common basis for all subsequent impact assessments, which are carried out in parallel, thus ensuring the maximum consistency of the input data and inherent assumptions as well as comparability of results. Each individual assessment method is applied according to its own set of rules. The “upstream” methods are concerned with the inputs, and account for the depletion of environmental resources, while the “downstream” methods are applied to the outputs, and look at the environmental consequences of the emissions (sink side). The calculated impact indicators are then interpreted within a comparative framework, in which the results of each method are set up against each other and contribute to providing a comprehensive picture on which conclusions can be drawn.

2.2.2 MuSIASEM

The Multi-Scale Integrated-Analysis of Societal and Ecological Metabolism (MUSIASEM) approach is a multi-purpose meta-grammar which explicitly addresses the challenge of handling the quality checks referring to both “semantic quality” – when dealing with different legitimate perspective about what “sustainability means - and “syntax quality” – when crunching numbers referring to different scales and different disciplinary fields e.g. €, Kg and MJ. The MUSIASEM approach has been developed to provide such a holistic tool. MUSIASEM can establish an effective link among quantitative representations of the interaction of socio-economic systems and ecosystems in terms of congruent relations between:

(1) The intensity of flows – which can be of different nature, such as added values (e.g. Euros), water, commercial energy, food, and other key materials (including books or computer memories) – which can be expressed using the conceptual fund-flow model developed by Georgescu-Roegen per hour of human activity (in relation to a multi-level matrix of the fund human activity) and per hectare of land use (in relation to a multi-level matrix of the fund colonized land); and

(2) A set of relevant components (structures/functions) of the socioeconomic systems defined in the given lexicon (= the given selection of categories adopted in the definition of the multi-level matrices) used to do the accounting of: (i) hours of human activity; and (ii) hectares of land use. These categories [e.g. labour in different economic sectors, leisure time, land used in agriculture, or in residential] will be able to characterize changes in demographic structures, definition of codified

social roles, capital intensity, technical coefficient, life styles (the mix of goods and services produced and consumed in the society).

This integrated representation capable of establishing a bridge between the representation of societal metabolism as perceived inside the black-box (INTERNAL CONSTRAINTS, the interaction of the parts within the black-box) and the representation of societal metabolism as perceived outside the black-box (EXTERNAL CONSTRAINTS, the interaction of the black-box with its context), makes possible to study the interference induced by societal metabolism (the intensity and the overall size of the flows associated with a desirable pattern of metabolism – as perceived by those living in the black-box) with the ecosystem metabolism (the alteration that societal metabolism induced on the flows of matter and energy flowing in the ecosystems embedding the society). This makes possible to link the changes and drivers taking place within the structure of the societal metabolism (inside the black-box) to changes in land covers and land uses.

In quantitative terms MUSIASEM provides a skeleton of expected relations among different flows and the characteristics of different societal elements, defined at different scales, using different analytical disciplines. In this way it establishes a linkage over changes in the values taken by relevant proxy variables useful for economic, social, technical, ecological analysis. A key conceptual tools is *Mosaic Effect Across levels* – how to establish a relation between the characteristics of the ratio of “flow” over a “fund” element (either $/hour, $/ha, or MJ/hour of MJ/ha). In alternative, the ratio of flows (money, energy, materials) per unit of human activity can also be calculated against the fund “land use”. That is the same type of analysis can be obtained by characterizing the typical value of the flows, in different compartments, per unit of area (e.g. hectare) allocated in a given typology of land use. The “mosaic effect” across levels makes it possible to have a parallel analysis of the characteristics of the various elements determining the metabolism of a socio-economic system across different hierarchical levels and scales.

The ultimate goal of the MUSIASEM approach is to keep coherence in the representation of the metabolism of socioeconomic systems across different hierarchical levels (the whole, the parts, sub-parts) and across different dimensions of analysis (flows of added value, energy, matter in relation to requirement of human activity and land uses). To check the congruence of the various representation of performance (the characteristics of the different compartments described at different levels and scales) the MUSIASEM approach uses another key conceptual tool: *Impredicative Loop Analysis*. As explained in other Deliverable, this concept has been developed to deal with the chicken-egg paradox, typical of life. More in general, we can say that when dealing with complex adaptive systems (which are capable of producing themselves through a process of autopoiesis), the characteristics of the parts affect/are affected by the characteristics of the whole and viceversa. When “*Mosaic Effect*” and “*Impredicative Loop Analysis*” are used in combination, it becomes possible to generate a “Sudoku effect” on the resulting integrated system of accounting of relevant flows across hierarchical levels.

The specific functions that the MUSIASEM offers are:

- It can open the ´black box´ and see inside the complex metabolic pattern associated to the functioning of developed socio-economic systems. In this way, it can analyze the effect and implications of changes in those socioeconomic factors determining the modality of consumption and production (interlinkages and trade-offs).
- By adopting a set of categories of human activities it can describe changes in the profile of investments of funds and flows. In this way, it can link demographic changes to structural changes of

the economy. In particular by studying changes in the profile of human time allocation outside Paid Work, it can monitor changes relevant also in relation to the cultural and political realm.

- By adopting a set of categories of land uses (of colonized land) it can describe changes in the profile of investments of funds and flows. In this way, it can link changes in socio-economic variables to changes in land uses (both in the characteristics per hectare and the relative size of the various land uses). The resulting changes in the density of flows of matter and energy per hectare, which are driven by changes in the characteristics of the socio-economic metabolism, can finally be related to the impact on ecological processes.

MuSIASEM imposes biophysical constraints. It examines relations between social and environmental aspects. It is also multiscale analysis that is not time-series based. MuSIASEM produces cross-scale constraints to DECOIN toolkit

2.2.3 ASA

The Advanced Sustainability Analysis (ASA) is a mathematical information system developed by Finland Futures Research Centre. ASA has used decomposition analysis technique to analyse the factors and effects behind structural change in the economy. It focuses on relations between economic and environmental aspects. The ASA model utilises time-series data and takes best into account the national level. ASA is also able to produce scenarios to extend available time-series data. It can be used to analyze economic development from different sustainability points of view. ASA focuses on relationships between changes in environmental, economic and/or social variables that can be measured with any preferred indicator or index. ASA applies decomposition analysis in order to divide the observed environmental, social and/or economic variables (indicators) into different components, contributing factors. The sum of all identified and decomposed factors is equal to the total environmental, social and/or economic change. ASA can also be applied to scenario construction based on a trend (forward) or a target (backward) as drivers of the analysis. The driver can be chosen freely among the identified factors that contribute to the change. ASA uses time series analysis referring to relevant indicators useful to study the changes in performance of the system under investigation. Then, by performing a decomposition analysis, it can suggest hypothesis about driver and possible causes of analyzed trends. The decomposition analysis can integrate variables belonging to different disciplinary back-ground, that is, it can provide an integrated analysis of the link between different indicators of performance. In practise ASA is useful as one wants to analyse reasons to changes in relation to key variable.

2.3 Integrated DECOIN Toolkit

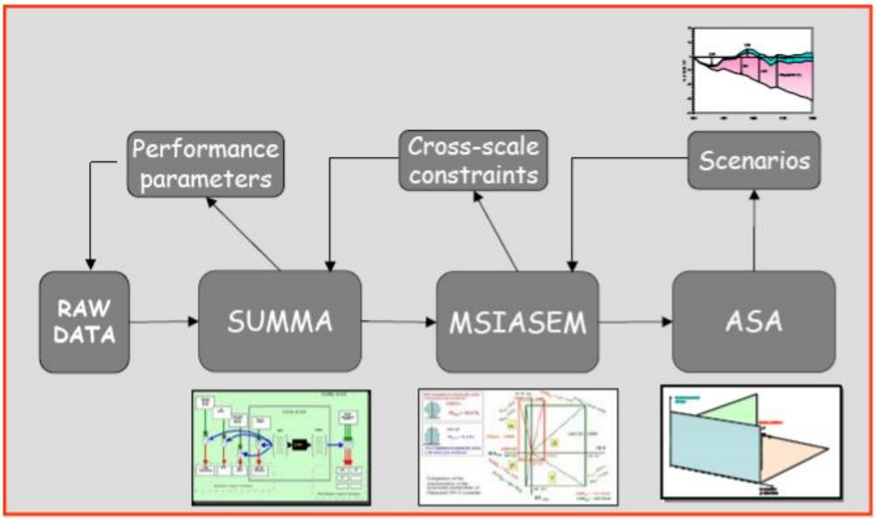
The raw data referring to the interaction of the socio-economic system with its context are collected and entered into the SUMMA approach, where these raw data (tokens) are transformed using several analytical methods into a set of “names” indicators of performance indicating the impact on the environment, the efficiency in using resources in relation to specified goals. By characterizing both upstream and downstream interactions, SUMMA provides an analysis of the relevant flows that enter into and get out of the ´black box´ of socio-economic metabolism:

- The upstream indicators account for the requirement of environmental resources - the pressure on ecological systems on the input side – at different levels.

- The downstream indicators account for environmental consequences that arise because of emissions – the pressure on ecological systems on the output side – at different levels.

When used in an integrated way, the methodology provides an overview of both the ecological constraints and the biophysical (technical) constraints limiting the performance space of socio-economic systems. This is obtained by tracking the embodied input and output, using a system of accounting capable of tracking: (i) the free services provided by the environment; and (ii) the thresholds of environmental loading that should not be passed to respect ecological compatibility.
An overview of the rationale behind this combination is given in Figure1.

Figure 1. The interlinking of the frameworks of the ASA, MUSIASEM and SUMMA tools



The **MuSIASEM** approach complements the gathering of the required data (tokens), in relation to a characterization of the interactions of internal parts (compartments) of the socio-economic system. Then by using these data and some of the data gathered by the SUMMA approach the MUSIASEM approach can generate a representation of the metabolism of socioeconomic systems across different *hierarchical levels*. When dealing with the metabolism of a country, these levels can include (depending on the questions asked):

a) The national level: at this level the analysis deals with the dynamics of the whole economy

b) The Production and Consumption level: at this level the analysis makes a distinction between "production" (activities generating added value, taking place in the paid work sector) and "consumption" (activities taking place in the household sector)

c) Sub-compartments of the production and consumption level: at this level the decomposition of production and consumption patterns continues into sub compartments. Within the production sector different sub-compartments normally are: agriculture, industry, mining and energy sector, services and government. Within the consumption sector different sub-compartments can be: urban versus rural, and then relevant typologies of household types within these two.

The MUSIASEM analysis makes it possible to identify a set of relevant external referents, which are defined at different hierarchical levels and scales for the resulting representation. This makes it possible to check whether the original choice of categories (token and names) adopted in the SUMMA approach results compatible with the research questions and the issue definition adopted for the issue of sustainability. That is how to establish an effective link between the definition of EXTERNAL constraints (generated by the SUMMA approach) and the definition of INTERNAL constraints (generated by the MUSIASEM approach). Put in another way, the MUSIASEM approach provide an additional quality check on the semantic behind the choice of the diagrams and protocols adopted in the SUMMA. The same quality check is provided by the analysis generated by the SUMMA approach on the choice of categories made in the development of the MUSIASEM grammar.

As soon as the analysis performed in the SUMMA and MUSIASEM are considered robust and relevant both in semantic and syntactic terms (relevant for the social actors operating at different scales and congruent in relation to the representation of the socio-economic process across dimensions and scales), the quantitative characterization generated by the combination of SUMMA and MUSIASEM can be used to generate characterization of sustainability issues, at different levels and in relation to different points in time. Then the resulting datasets can be fed into the **ASA** approach. The last step of the ASA analysis, looking for explanations of the represented changes across levels and dimensions, can be used for developing scenarios and make projections in relevance to the main areas of focus. It should also be noted that the ASA approach provides a direct bridge with econometric analysis by making possible to:

a) verify hypotheses over historic series or large samples
b) look for benchmarks values, and
c) verify proposed mechanisms of scaling, by effectuating the decomposition analysis over historic series at different levels

So far the technical integration of the models is still to come, thus in this case study the different models are analysed separately. The ultimate aim of this case study is to test the developed DECOIN toolkit and provide a complementary view of different sustainability problems in various geographical, environmental, social, economic, development and cultural contexts in order to test the different properties and abilities of the new toolkit.

3. Analysing the Finnish Forest sector by means of the DECOIN toolkit

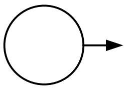
Forests are Finland's most important natural resource. Most of the country is covered by naturally regenerated forests that are in commercial use. Finland has over 26 million hectares of forestry land, accounting for 86 per cent of its total land area. Actual forestland (i.e. productive forest) amounts to 20 million hectares. The Finnish Forestry has been considered as an example of sustainable production sector since the total wood removal does not exceed the annual net primary production. However the forestry has major impact to the biodiversity of the forests. In fact the logging needs of forest industries affected the biodiversity of the forests during last 60-65 years. Also intensive silviculture had negative effects on the diversity of forests, for instance concerning the reduction of the amount of old-growth forests and rotting wood. Thus the way that the commercial forests are managed is of key significance to preserving biodiversity in Finnish nature.

3.1 The DECOIN toolkit system

Diagram in Figure 1 shows the forestry sub-system that provides timber to the Pulp & Paper production sub-system as well as to the market. The subsector of energy production based on forestry and paper industry residues is also shown. Renewable sources (sun, wind, rain, deep heat) are shown as flowing to the system from the left side of the diagram. Energy Systems symbols (Odum, 1996) used in Figures 2 and 3 are described in the next page.

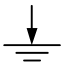
USE OF ENERGY SYSTEM SYMBOLS.
(From: Odum, H.T., 1996. "Environmental Accounting". J. Wiley.)

System Frame:
A rectangular box is drawn to represent the boundaries that are selected.

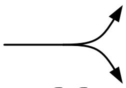


Source:
Any input that crosses the boundary is a source, including pure energy flows, materials, information, genes, services and inputs that are destructive.

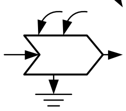
Pathway Line:
Any flow is represented by a line, including pure energy, materials and information. Money is shown with dashed lines.



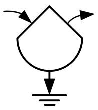
Heat sink:
This symbol represents the dispersal of available energy (potential energy) into a degraded, used state, not capable of further work.



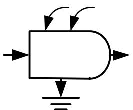
Split:
A pathway that branches represents a split of flow into two of the same type.



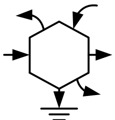
Interaction:
Two or more flows that are different and both requires for a process are connected to an "interaction" symbol. The output of an interaction is an output of an production process, a flow of product.



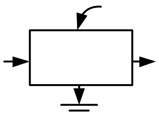
Storage tank:
Any quantity stored within the system is given a "tank" symbol, including materials, pure energy, money, assets, information, image and quantities that are harmful to others. Every flow in or out of a tank must be the same type of flow and mesured in the same units.



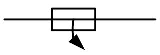
Producers:
"Producer" symbols are used for units on the left side of the systems diagram that receive commodities and other inputs of different types interacting to generate products.



Consumers:
"Consumer" symbols are used for units on the right side of the system diagram that receive products and feedback services and materials.



Miscellaneous Box:
The rectangular box is used for any subsystem structure and/or function.



Small Box:
A very small box on a pathway is used to initiate another circuit that is driven by "force" in proportion to the pathway.

Exchange transaction:
Where quantities in one flow are exchange for those of anoher, the "transaction" symbol is used. Most often the exchange is a flow of commodities, goods or services echanged for money (drawn with dashed lines).

Renewable inflows in Figure 2 go directly in support of the whole investigated system (with specific focus on forestry), and indirectly of the pulp and paper production through timber harvest. In addition to renewable flows, further imported flows from the main economy (fertilizers, chemicals, fuels & electricity, goods & machinery and labor) support forestry sector and pulp & paper production. These human-managed flows are shown as inflowing from top of the diagram.

The system budget, also shown in the Figure, is composed with the money received as income of productive activities (sale of timber and paper products as well possible sale of self-generated energy exceeding local use). Money is used to pay for imported resources, needed to support the system. Money flows are shown as entering from the right side of the diagram and flowing out as payment for services associated to imports. It is important to note that the money paid for resources import only refers to the services associated to such resources, i.e. the indirect labor invested outside of the investigated system to extract and process the raw materials and make processed resources available to the production process (money does not pay nature for its work of production of free resources, but always pays direct and indirect labor of people). In so doing, the performance of the outside economy is indirectly taken into account for within the evaluation of the local system through the emergy supporting the flow of services associated to the imports. As a consequence of accounting for services, each imported flow can be characterized by two emergy values (emergy – a measure of the environmental support - is one of the methods used in SUMMA): (1) the emergy invested by nature in order to actually make a resource (all over the resource life cycle) and (2) a fraction of the emergy supporting the whole economy within which resources are processed and made available to the user. This is indicated in the diagram by the interaction of imported goods and services as well as by the coupling of services with money flows (dashed).

Figure 2. System diagram of Forestry sector and Pulp & Paper production in Finland

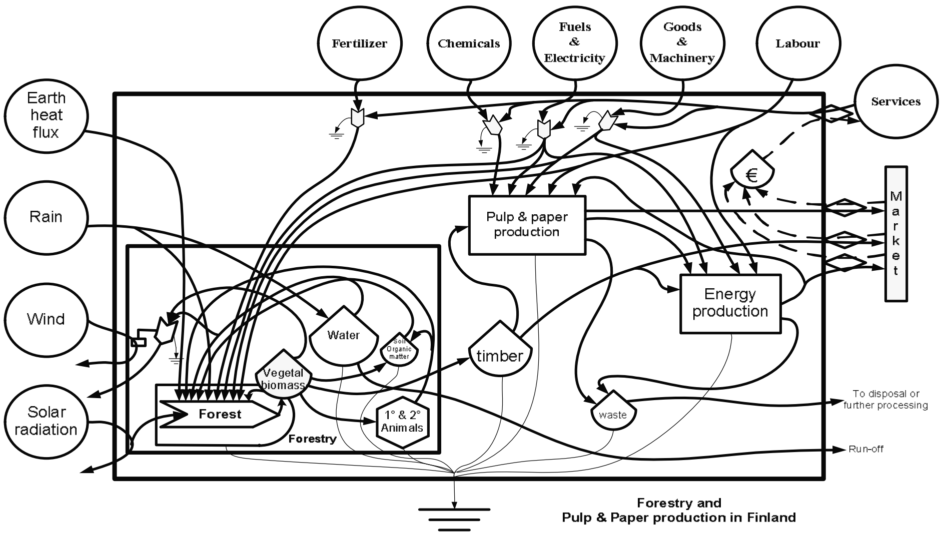
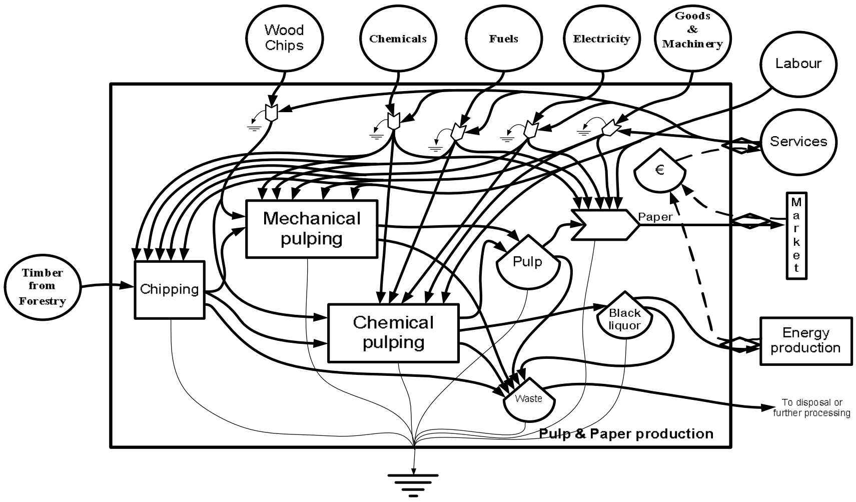


Figure 3. The system diagram of pulp and paper production sector in Finland



The diagram in Figure 3 focuses on the sub-sector of pulp and paper production. After wood chipping (that is usually the pre-treatment step of this kind of production) two treatments are possible for pulping: mechanical and chemical ones. Finally the pulp obtained is treated in order to yield the paper products. Black liquor, toxic residue of chemical pulping, and other waste products are most often recycled to electricity production.

The general purpose of SUMMA evaluation of this study is to estimate the sustainable development of the forestry sector over time. The evaluation is based on data time series in four different years 1991, 1996, 2001 and 2006. The pulp and paper production as well as the energy production from wood residues are not investigated here in details, being outside of the goals of the DECOIN project. However, their evaluation is in progress and will be published as a follow up of the DECOIN project itself in order to fully evaluate the industrial sector connected with the forestry sector. This is an important aspect that cannot be disregarded, due to the fact that wood, pulp & paper as well as selected by-products from the forest ecosystems represent the main economic value of Finland’s forests.

3.2 Application of the SUMMA approach to the Forestry sector in Finland

Table 1 shows the input flows in the investigated years and the total product of Finnish forestry as a whole, quantified as mass (grams of commercial roundwood removals per year), energy (energy content of total commercial roundwood removals) and economic value (generated to sell the commercial roundwood removals), over time.

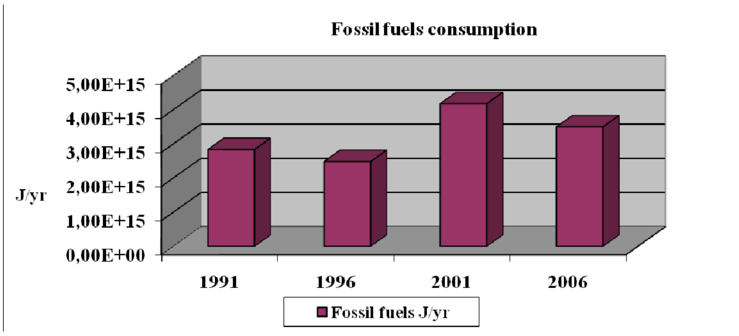
Table 1. Direct supply, land use and product generated of Finnish forestry

Input	Unit	1991	1996	2001	2006
Solar energy received	J/yr	1.13E+14	1.13E+14	1.13E+14	1.13E+14
Wind energy on land	J/yr	4.55E+18	4.54E+18	4.54E+18	4.55E+18
Rainfall (Rain)	g/yr water	1.97E+17	1.97E+17	1.97E+17	1.97E+17
Deep Heat	J/yr	3.07E+17	3.06E+17	3.06E+17	3.07E+17
Total land used for forestry	ha/yr	2.63E+07	2.63E+07	2.63E+07	2.63E+07
Liquid fuels	J/yr	2.84E+15	2.48E+15	4.18E+15	3.50E+15
Machinery	g/yr	4.63E+10	5.63E+10	7.22E+10	7.69E+10
Direct Labor (time units)	hours/yr	5.61E+07	4.75E+07	3.83E+07	3.81E+07
Direct Labor (money equivalent)	€/yr	3.92E+08	3.85E+08	3.49E+08	4.15E+08
Indirect labor (services)	€/yr	4.78E+08	5.19E+08	9.57E+08	1.02E+09
Output					
Mass of forestry production	g/yr	2.75E+13	3.75E+13	4.26E+13	4.06E+13
Energy content of forestry production	J/yr	5.12E+16	6.97E+16	7.92E+16	7.55E+16
Economic value	€/yr	2.09E+09	1.98E+09	2.38E+09	2.51E+09

The input data of the renewable input (sun, wind, rain and deep heat) are, in the evaluated years, the same due to lack of information about environmental data over time (the small variation of renewable data is justified by the forestry land variation). The forestry land is more or less the same in the investigated period with a small decrease (about 1%) from 1991 to 2006.

The main flows to support the production of forestry sector in Finland are machinery and fossil fuels; machinery increases constantly over time while fuel consumption has an oscillating trend (Figure 3) that can be justified by more or less intensive use of machinery due to oscillating wood production. The adoption of more efficient machinery, in terms of less labor needed for machinery use, as well as in terms of more wood processed per hour of machinery activity may also explain the decrease of fuel use in the last years, parallel to an increase of machinery mass.

Figure 4. Fossil fuels consumption



Labor applied to the forestry sector slowly and constantly decreases while in the same time services (indirect labor) increase of about 1% (which means that – considering the uncertainty of some estimates - they are more or less constant). The total mass increases from 1991 to 2001 and decreases in the 2006 by about 1% (again, we might say the such a value can be considered constant, within the uncertainty range). The economic value and the energy content of the product have the same trend of the total mass with a small variation from 2001 to 2006. Of course, the energy content is affected by the typology of wood extracted, while the economic value is affected by the market demand as well as purchasing power of currency in the investigated years.

Table 2 lists extensive and intensive indicators of Material Requirement. Tables 3, 4 and 5 show similar calculations respectively for Airborne Emissions, Embodied Energy, and Emergy Synthesis. Extensive indicators account for the total flow (abiotic matter, water, embodied energy and emergy) supporting the Forest sector. In a way, they provide a measure of the "size" of the system itself, i.e. of how much of a given flow is required to support the systems dynamics, also including hidden flows occurring at larger spatial and time scales. Of course, extensive indicators depend directly on the physical size of the system (total forestry land) and may follow the oscillations of such a size over time. On the other hand, intensive indicators are more independent on the physical size, and provide a measure of efficiency or performance compared to the final product (e.g., more or less material or energy used per unit of product or per unit of time).

Therefore, it is possible to create performance indicators in terms of amount of input (matter, energy, emergy) per gram or joule or € of commercial roundwood removals as well as amount of input per unit time applied or per unit surface of system. When these extensive and intensive indicators are analysed and discussed, the performance of our system can be assessed in depth, and improvement strategies can be designed. This is because the construction of historical series of data offers a powerful tool to assess the role of each input over time (e.g. increased use of machinery, decreased use of direct labor, etc) as well as the changes of system's performance over time, as a more global picture of trends, efficiency, sustainability.

Table 2. Results of Total Material Requirement (large scale) in Finnish forestry sector

Indicators	Unit	1991	1996	2001	2006
Intensive Indicators					
Abiotic Material Intensity per € of product	g/€	7.79E+01	8.57E+01	1.04E+02	9.35E+01
Abiotic Material Intensity per ha	g/ha	6.20E+03	6.46E+03	9.41E+03	8.94E+03
Abiotic Material Intensity per g of Commercial roundwood removals	g/g of product	0.00593	0.00453	0.00580	0.00579
Abiotic Material Intensity per J of Energy content	g/J	3.19E-06	2.44E-06	3.12E-06	3.11E-06
Abiotic Material Intensity per hour of labor	g/hour	2.91E+03	3.57E+03	6.45E+03	6.17E+03
Water Material Intensity per € of product	g/€	7.22E+02	8.24E+02	9.68E+02	8.96E+02
Water Material Intensity per ha	g/ha	5.74E+04	6.21E+04	8.77E+04	8.57E+04
Water Material Intensity per g of Commercial roundwood removals	g/g of product	0.0549	0.0436	0.0541	0.0555
Water Material Intensity per J of Energy content	g/J	2.95E-05	2.34E-05	2.91E-05	2.98E-05
Water Material Intensity per hour of labor	g/hour	2.69E+04	3.44E+04	6.01E+04	5.91E+04
Total Material Intensity per € of product (abiotic+ water)	g/€	8.00E+02	9.10E+02	1.07E+03	9.90E+02
Total Material Intensity per ha (abiotic+ water)	g/ha	6.36E+04	6.86E+04	9.71E+04	9.46E+04
Total Material Intensity per g of Commercial roundwood removals (abiotic+ water)	g/g of product	0.0608	0.0481	0.0599	0.0613
Total Material Intensity per J of Energy Content (abiotic+ water)	g/J	3.27E-05	2.59E-05	3.22E-05	3.29E-05
Total Material Intensity per hour of labor (abiotic+ water)	g/hour	2.99E+04	3.79E+04	6.66E+04	6.53E+04
Extensive Indicators					
Total abiotic material requirement	g/yr	1.63E+11	1.70E+11	2.47E+11	2.35E+11
Total water material requirement	g/yr	1.51E+12	1.63E+12	2.30E+12	2.25E+12

Table 3. Relevant emissions of Finnish forestry sector

	Unit	1991	1996	2001	2006
CO2 released	g CO2/yr	2.80E+11	2.54E+11	4.15E+11	3.56E+11
CO2 per € of product	g CO2/€	1.34E+02	1.28E+02	1.74E+02	1.42E+02
CO2 per ha	g CO2/ha	1.07E+04	9.66E+03	1.58E+04	1.35E+04
CO2 per g of Commercial roundwood removals	g CO2/ g of product	0.0102	0.0068	0.0097	0.0088
CO2 per J of Energy content	g CO2/J	5.47E-06	3.64E-06	5.24E-06	4.72E-06
CO released	g CO/yr	1.09E+09	9.55E+08	1.60E+09	1.34E+09
NOx released	g NOx/yr	3.03E+09	2.66E+09	4.47E+09	3.74E+09
SO2 released	g SO2/yr	4.70E+08	4.27E+08	6.96E+08	5.99E+08
Global unburnt hydrocarbon released	g part./yr	2.91E+08	2.56E+08	4.30E+08	3.60E+08
NO2 released	g NO2/yr	6.54E+06	5.76E+06	9.65E+06	8.11E+06
CH4 released	g CH4/yr	1.52E+07	1.36E+07	2.25E+07	1.92E+07

Table 4. Results of Embodied Energy Requirement (large scale) in Finnish forestry sector

Indicators	Unit	1991	1996	2001	2006
Intensive Indicators					
Oil equivalent intensity per € of product	goil/€	4.22E+01	4.03E+01	5.50E+01	4.46E+01
Oil equivalent intensity per ha	goil/ha	3.36E+03	3.04E+03	4.98E+03	4.27E+03
Oil equivalent intensity per g of Comm. roundwood removals	goil/ g of product	0.0032	0.0021	0.0031	0.0028
Oil equivalent intensity per J of Energy content	goil/J	1.73E-06	1.15E-06	1.65E-06	1.49E-06
Oil equivalent intensity per hour of labor	goil/hour	1.58E+03	1.68E+03	3.42E+03	2.94E+03
Energy Intensity per € of product	J€	1.77E+06	1.69E+06	2.30E+06	1.87E+06
Energy Intensity per ha	J/ha	1.41E+08	1.27E+08	2.09E+08	1.79E+08
Energy Intensity per g of Comm. roundwood removals	J/ g of product	1.34E+02	8.93E+01	1.29E+02	1.16E+02
Energy Intensity per J of product	J/J	0.07	0.05	0.07	0.06
Energy Intensity per hour of labor	J/hour	6.60E+07	7.04E+07	1.43E+08	1.23E+08
Extensive Indicators					
EROI (Energy of products/Total embodied energy applied)		13.84	20.83	14.46	16.08
Total emboded energy applied	J/yr	3.70E+15	3.34E+15	5.48E+15	4.70E+15
Total oil equivalent applied	g oil/yr	8.84E+10	7.99E+10	1.31E+11	1.12E+11

Total energy embodied per unit of product (g, J, €) or per functional unit (ha) or per unit time (hr) oscillates over the investigated period. Such oscillations depend on a multiplicity of factors: smaller production, higher harvest efficiency, higher labor productivity, different market value of wood, etc. How performance is affected by the above factors can be ascertained by proper application of ASA decomposition analysis. A similar behavior is shown by material and emergy indicators with some differences that are specific of the method used. A careful reading of these performance indicators sheds light on the different aspects of the forestry process.

The largest share of imported input to support the Finnish forestry is constituted by fossil fuels that amount to about 90% and by machinery that oscillate around 10% in the investigated period. The total embodied energy investment was 3.70 E+15 J/yr in 1991, steadily increasing to 4.70 E+15 J/yr in 2006. The forestry sector in Finland is mainly addressed to the Pulp & Paper production, not to the energy sector, although the calculated EROI in the range 14-16 to 1 also indicates a potential energy use of at least a fraction of forest production.

Table 5 shows emergy synthesis indicators for the whole system of Finnish forestry, respectively calculated with and without accounting for the emergy that supports labor and services provided to the system. Emergy indicators are calculated with and without accounting for the emergy supporting Labor and Services, that is with and without accounting for the emergy indirectly supplied to the system by the outside economy. Accounting for the emergy associated to labor and services provides an important information about the extent to which the system is dependent on the performance of the outside larger scale (i.e. the performance of the fuel industry, the machinery industry, as well as the global dynamics of the life support system to population). In the investigated years, the larger scale of the economy indirectly supported the forestry sector by supplying about 30% of total emergy needed for the sector activities.

Table 5. Results of Emergy assessment of Finnish forestry sector

Indicators	Unit	1991	1996	2001	2006
Intensive Indicators as such					
Specific Emergy of NPP as such	seJ/g	8.40E+07	8.40E+07	8.40E+07	8.40E+07
Transformity of NPP as such	seJ/J	4.52E+03	4.52E+03	4.52E+03	4.52E+03
Intensive Indicators with Labor and Services					
Specific Emergy of monetary value (with L&S)	sej/€	1.92E+12	2.44E+12	2.33E+12	2.19E+12
Specific Emergy of ha (with L&S)	seJ/ha	1.00E+14	1.31E+14	1.55E+14	1.45E+14
Specific Emergy of unit of Commercial roundwood removals (with L&S)	seJ/ g of product	2.92E+08	2.58E+08	2.60E+08	2.71E+08
Transformity (with L&S)	seJ/J	7.85E+04	6.95E+04	6.99E+04	7.29E+04
Emergy Yield Ratio (with L&S) = U/(F+L+S)		1.18	1.24	1.24	1.21
EIR (with L&S) = 1/(EYR-1)		5.67	4.14	4.20	4.72
Environmental Loading Ratio (with L&S) = (N+F+S)/(R)		2.10	1.56	2.15	2.16
%REN (with L&S) = 1/(1+ELR)		0.32	0.39	0.32	0.32
Intensive Indicators without Labor and Services					
EYR/ELR (with L&S)		0.56	0.79	0.58	0.56
Specific Emergy of monetary value (without L&S)	sej/€	1.26E+12	1.74E+12	1.71E+12	1.52E+12
Specific Emergy of ha (without L&S)	seJ/ha	1.00E+14	1.31E+14	1.55E+14	1.45E+14
Specific Emergy of unit of Commercial roundwood removals (without L&S)	seJ/ g of product	9.59E+07	9.18E+07	9.54E+07	9.41E+07
Transformity (without L&S)	seJ/J	5.16E+04	4.94E+04	5.13E+04	5.06E+04
Emergy Yield Ratio (without L&S) = U*/F		1.92	2.41	1.96	2.08
EIR (without L&S) = 1/(EYR-1)		1.09	0.71	1.04	0.92
Environmental Loading Ratio (without L&S) = (N+F)/(R)		1.09	0.71	1.04	0.92
%REN (without L&S) = 1/(1+ELR)		0.48	0.58	0.49	0.52
EYR/ELR (without L&S)		1.76	3.39	1.89	2.26
Extensive Indicators					
Locally renewable inputs, R (without double counting)	sej/yr	3.01E+20	4.09E+20	4.65E+20	4.44E+20
Locally nonrenewable inputs, N	sej/yr	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Purchased inputs to forestry phase, F (without L&S)	sej/yr	3.27E+20	2.91E+20	4.83E+20	4.09E+20
Direct Labor	sej/yr	1.07E+21	1.05E+21	9.55E+20	1.14E+21
Indirect labor (services)	sej/yr	3.03E+20	3.49E+20	5.17E+20	5.47E+20
Total emergy inputs to forestry phase, U= (R+N+F+L+S)	sej/yr	2.01E+21	2.10E+21	2.42E+21	2.54E+21
Total emergy inputs to forestry phase, U*= (R+N+F)	sej/yr	6.28E+20	7.00E+20	9.48E+20	8.53E+20

Table 5 points out that the Emergy Yield Ratio (Emergy return on emergy investment) increases from 1.18 (1991) to 1.21 (2006) indicating that the analyzed system is no longer a system mainly based on local resources but instead a system that strongly relies on imported emergy sources and the stability of which depends on the availability of such sources at affordable price. The small increase of EYR cannot be considered a sign of better performance, because due to the uncertainty of estimates, the EYR must be considered as more or less constant. Values of EYR lower than 2 are alarming, because they indicate that the process is not exploiting local resources but instead is becoming a conversion process of resources imported from outside. Since EYR is linked to EIR (Emergy Investment Ratio, a measure of the investment cost for local resource exploitation) by the relation EIR= F/(R-N) = 1/(EYR-1), the EIR also decreases slightly, but not significantly. The Environmental Loading Ratio (a measure of the reliance of the system/product on renewable sources) is also more or less stable, increasing slowly by 2.10 in the year 1991 to 2.16 in the year 2006, indicating that the renewable fraction of forestry products oscillates constantly around 32% during the investigated period. If labor and services are not included in the accounting, indicators are different and show a better performance (renewability at about 50% in 2006). While the stability of the whole sector can be considered a good sign also for future management, it cannot be disregarded that the harvested resource is not fully renewable. The latter finding sheds light on the issue of potential use for energy: while the EROI in Table 4 seems to indicate a potential for energy use, emergy data in Table 5 are source of major concern.

Finally, the aggregate environmental Emergy Sustainability Index (ESI= EYR/ELR) calculated with and without labor and services is also more or less stable, but values indicate that the strong dependence of EYR from outside investments (30%) as well as the strong nonrenewability of the system itself (68%) place a significant uncertainty on the overall sustainability of the whole sector. A suitable policy strategy should therefore be the advice of not increasing further the exploitation of Finnish forests, with special focus on trying to avoid forestry for energy. Such a finding, although alarming, is a perfect proof of the need for a multi-method assessment, in order to be able to stress different findings from different methods and reach an informed management decision. Moreover, since several of the calculated indicators are composite indicators, a further disaggregation of their components would be highly illuminating about the driving forces of the investigated trends.

In conclusion, evaluating historical series of the investigated system provided a deep insight into its energy and material basis, its demand for environmental support and sustainability. Our data show that the forestry sector is stable, but shows alarming signs of unsustainability if more extensively exploited.

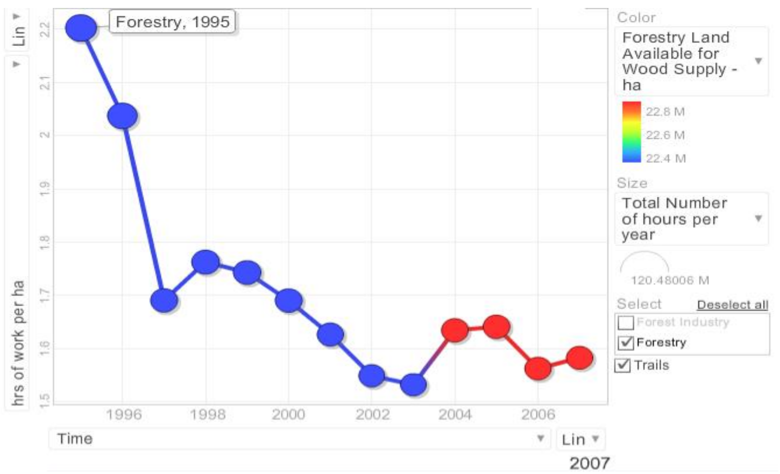
3.3 Application of the MuSIASEM approach to the Forestry sector in Finland

In Finland, the national definition of the ***forestry land*** is made up of ***forest land*** (annual increment of growing stock being at least 1 m^3/ha), ***scrub land*** (growing stock between 1m^3/ha and 0.1 m^3/ha) and ***waste land*** (the annual increment being 0.1m^3/ha). At this point, it is important to point out the particularities of the Scandinavian forests: these measures reveal us the particular low level of growth of the Finnish forests, when we compare these rates with some other countries that also have forest industries. Values for annual increment of growing stock in tropical countries reach 200 m^3/ha. The average waiting period for chopping a piece of land of forest until the trees have grown enough to be commercially viable is 30 years in Finland, meanwhile in tropical countries is around 10 years.

For the application of the MuSIASEM methodology, we will include all the area of *forestry land* (since the distribution of work load for each special categorization of land type is not available). The MuSIASEM will try to track the changes in the number of roundwood removals (in total) and for commercial use (per hour and per hectare) over time. The ownership of forestry land in Finland is distributed such that the State owns 35% (and mainly concentrated in Northern parts of Finland), forest industry companies own 8%, joint or shared (municipal or parish), ownership corresponds to around 5% and the remaining majority, 52% lies under private and non-industrial ownership (Finnish Statistical Yearbook of Forestry, 2005). The amount of time that will be taken into account while analysing the forestry sector is only composed of the hours that are spent for the removal of roundwood and does not include the working time that is required to further process the roundwood.

Initially, the amount of hours of work in forestry has been mapped per hectare over time, so the data is reflecting relative values. As seen, the amount of hours dedicated per hectare has been decreasing over time, until the year 2004, in which the forestry land available for wood supply had increased (illustrated with the colour change) and relevantly, the hours in the year 2004 showed a slight increase (from 34.2 million hours to 37.3 million hours), overall increasing the hours/ha to some extent. The explanation for this decline in the graph will be commented when associating this data with other factors in the following points.

Figure 5. Hours of work in forestry sector per hectare



Following, it is essential to observe the energy use of the forestry sector. Looking at Figure 6, it is seen that there has not been a constant trend in energy consumption of the sector over the years in aggregate terms. Only a very high peak in energy use has been tracked for the year 2001, but we can consider that this peak constitute an exception to the average trend. Another variable that can be tracked is total amount of roundwood removals over time with the colour change of the bubble (as shown in the legend). It is seen that despite no certain increment of energy consumption within the years of 1995-2004, the amount of wood removed has slightly increased.

With figure 7, however, we can see an intensification, energetically, in each hour that is invested for the forestry sector over time. The main difference between figures 6 and 7 is that figure 6 maps energy consumption as an extensive variable, whereas figure 7 maps energy consumption per hour of work in the forestry sector that is able to trace the increase over time. This can be quite the proof of switching over to high machine based roundwood removal techniques, requiring more energy per hour. (i.e. machines overtaking man labour thus decrease in labour hours yet increasing the energy demand per hour). At this point we can relate this factor with the explanation of why the hours spent in this sector were also decreasing (Figure 5), thus the increment in machinery results in less people working in the activity.

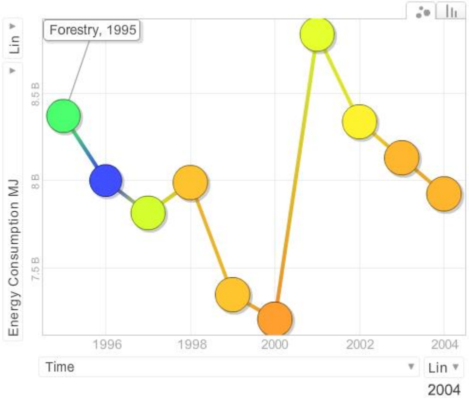


Figure 6. Total Energy Consumption in Forestry Sector over time (colour of bubble illustrating more roundwood removals over time)

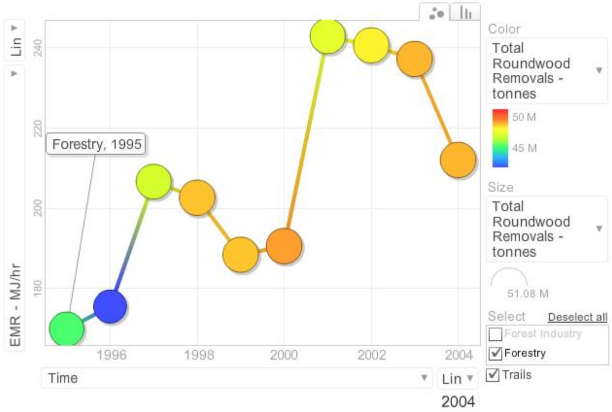


Figure 7. Energy Consumption in Forestry Sector per hour over time (colour of bubble illustrating more roundwood removals over time)

Figure 8 illustrates an image of the mechnical removal of roundwood in the snow-covered forestry areas of Finland.

Figure 8. Illustration of the mechanical removal of roundwood

Imperatively, one must also assess the efficiency of roundwood removal corresponding to of each hour of labour and area of hectare in this respect. As seen in figures 9 and 10, more tonnes of roundwood (both total and commercial) removal have been taking place per hour and per hectare over time. When mapping tonnes of total roundwood removal per hectare and per hour over time as in figure 11, it is seen that there is a trend to the upper right corener of the graph indicating that the process is becoming competent at increasing roundwood removal per hour and per hectare. These facts can be again related with an increment in machinery in the sector.

Figure 9 - The removal of total and commercial roundwood per hour over time

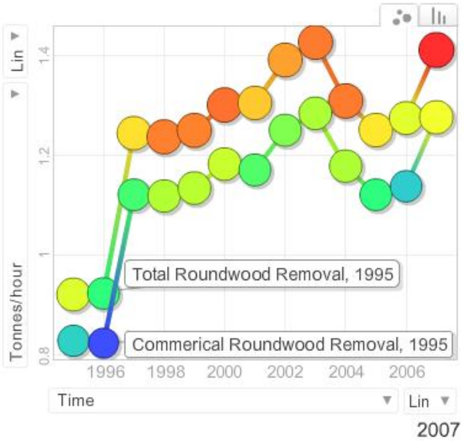


Figure 10 - The removal of total and commercial roundwood per hectare over time

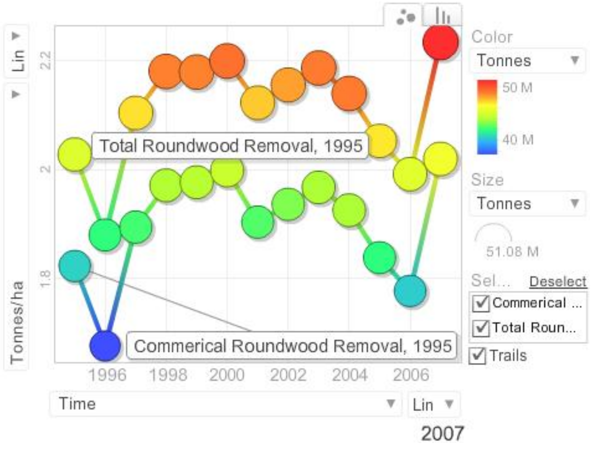


Figure 11. Combing tonne/hectare and tones/hour of roundwood removal (total) over time

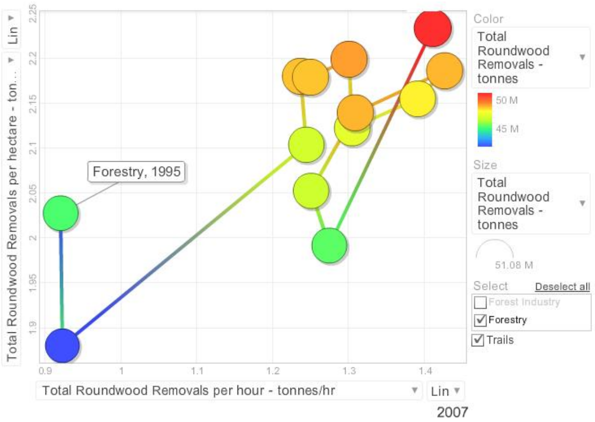


Figure 12. MJ of energy Consumed per tonne of total roundwood removed

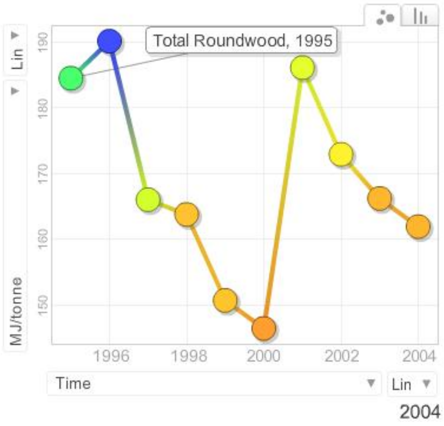
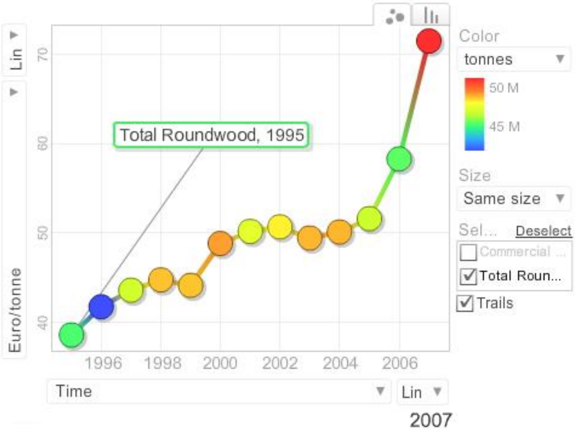


Figure 13. Added Value generated per tonne of roundwood removed



Also, one can look at the benchmarks of energy consumed per tonne of roundwood (total) and added value generated per tonne of roundwood (total) removal. It is also approved with, figures 11 and 12, the amount of energy going into removal of one tonne of roundwood is decreasing until 2000, where it peaks and the re-decreases. And the added value generated per tonne of roundwood (figure 14) is constantly on the increase. It is important to mention here that the prices used in this analysis are already taking into account the inflation effect, because all prices are adjusted to the price of euros in year 2000.

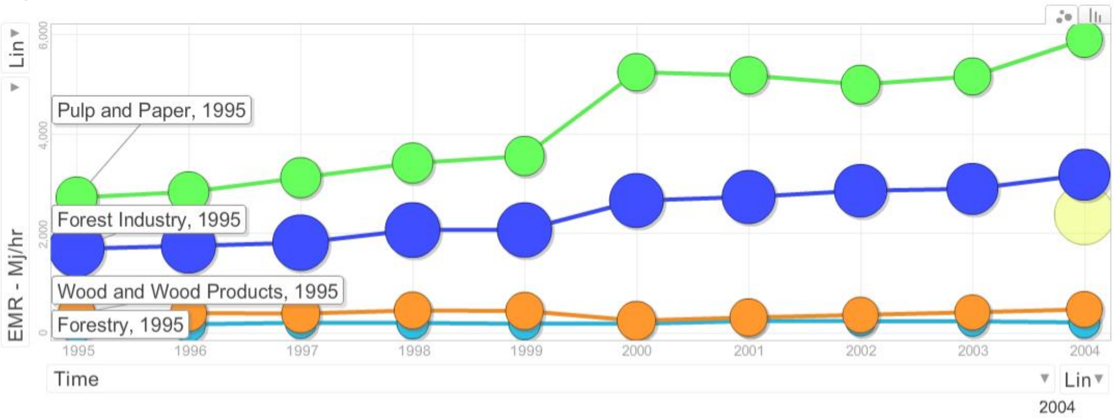
Eventually interpreting the figures above, we can make the following conclusions:

- For every tonne of roundwood removal, less energy (except for the peak in 2001) is being used, hence referring to the conclusion that the process is becoming efficient (less inputs needed for more outputs produced) over time.
- Over time, more energy is going into each hour of work in forestry ultimately, leading to the conclusion that more and more roundwood is being removed per hectare and per hour of work over time. The energy used reflects the level of technical capital (machinery) employed in the activity.
- Moreover, each tonne of roundwood is worth increasingly more over the years, probably due to increasing prices in markets of the type of wood extracted in Finland.

Within the scope of this study, Forest Industries have been regarded as the processes that processes the raw material after the first stage of removal of the roundwood. The pulp and paper industry and the wood and wood products industry will be focused upon, while comparing it to the forestry sector at times. In Finland, in general, it has been regarded that the industrial production has been both very material and energy intensive (Braczyk et al, 1998). Yet, also an interesting fact to bear in mind is that although Finland is plentiful with its forest resources, a quarter of the roundwood utilized by the forest industry had been imported from other countries in recent years, mainly from Russia (yet this amount is expected to decrease in the upcoming years with the prices of imported wood rising substantially) (Finland Forestry Outlook, 2008).

Figure 14 below, shows the amount of energy used in each process of the forest sector per hour that is worked in each specific department. The paper and pulp industry reveals an incredible high value starting from 2725MJ spent in every hour within the paper and pulp industry ending with also an spectacular increment up to 5904MJ/hr. On the other hand, the wood and wood products industry (luckily not as high as that of the pulp and paper) shows a slight change from 394MJ/hr in 1995 and 477MJ/hr in 2004. The forestry sector (including only the process of roundwood removal) as previously illustrated in Figure 7, has also been increasing in energy intensity from 170MJ/hr 212MJ/hr in 2004. Yet the change in the forestry industry itself is quite irrelevant when compared with those of the forest industries. The blue circle of forest industries shows an average value of the pulp and paper and wood and wood products industries together for the energy use per hour, and an aggregate value of the two of hours spent in the sector (represented by the size of the bubble).

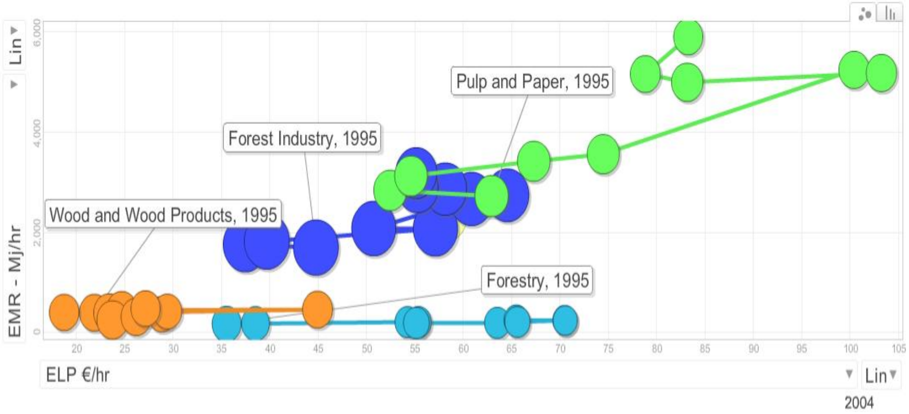
Figure 14. Exsosomatic Matabolic Rates for the Forest Industries (MJ/hr)



Now, in order to be able to observe the trade offs of each sector, it would be relevant to compare the money generated for each sector per hour of work in coordination to the amount of energy that is used that is illustrated in Figure 15.

The pulp and paper industry has an energy throughput of nearly 20 times more than the forestry sector. On the other hand on average, it produces 75€/hr of added value whereas the forestry sector provides 55€/hr of added value. The wood an wood products that have a tenth of the energy consumption of the Pulp and Paper industry, and it only seems to produce 25 € of added value per hour of work. Similarly, the forest industry bubble shows the average of the pulp and paper industry and that of the wood and wood products industry. At least these two sectors have been incrementing the added value per hour along the years without increasing the energy consumption.

Figure 15. Energy consumption per hour vs Added VAlue generated per hour of the Forest Sector's subsectors



The trade offs are clearly illustrated from the figure above. It is now only an issue, open for debate about re-reviewing energy policies for forest industries and reconsidering policy making processes in this direction.¨

3.4 Application of the ASA to the Forestry sector in Finland

The ASA model uses for the decomposition techniques to produce information about factors contributing to environmental burden and thus it explains reasons to different development trends. Since it is very hard to find suitable aggregate measures that describe all environmental hazards, the total carbon dioxide emissions (CO2) have been used as a proxy of environmental burden. In this case study the variables used in ASA model testing are:

- o carbon dioxide (CO2)
- o production volumes (PRO)
- o employment (EMP)
- o value added (VA)
- o working hours (WH)
- o final energy consumption (FEC)

Table 1 presents the equations proposed by Finnish Futures Research Centre for ASA model testing in this particular case study.

Table 16. The equations proposed by FFRC for testing ASA model in this case study

$$CO_2 = \frac{CO_2}{FEC} \times \frac{FEC}{VA} \times \frac{VA}{WH} \times \frac{WH}{EMP} \times EMP \qquad CO_2 = \frac{CO_2}{VA} \times \frac{VA}{WH} \times WH$$

$$CO_2 = \frac{CO_2}{FEC} \times \frac{FEC}{PRO} \times \frac{PRO}{WH} \times \frac{WH}{EMP} \times EMP \qquad CO_2 = \frac{CO_2}{PRO} \times \frac{PRO}{WH} \times WH$$

$$CO_2 = \frac{CO_2}{FEC} \times \frac{FEC}{VA} \times \frac{VA}{EMP} \times EMP \qquad CO_2 = \frac{CO_2}{VA} \times \frac{VA}{EMP} \times EMP$$

$$CO_2 = \frac{CO_2}{FEC} \times \frac{FEC}{PRO} \times \frac{PRO}{EMP} \times EMP \qquad CO_2 = \frac{CO_2}{PRO} \times \frac{PRO}{EMP} \times EMP$$

$$CO_2 = \frac{CO_2}{VA} \times \frac{VA}{WH} \times \frac{WH}{EMP} \times EMP \qquad CO_2 = \frac{CO_2}{VA} \times VA \quad CO_2 = \frac{CO_2}{PRO} \times PRO$$

$$CO_2 = \frac{CO_2}{PRO} \times \frac{PRO}{WH} \times \frac{WH}{EMP} \times EMP \qquad CO_2 = \frac{CO_2}{EMP} \times EMP$$

For testing in this case study the following equation (1) has been selected :

$$(1)\ CO2 = \frac{CO2}{FEC} \times \frac{FEC}{VA} \times \frac{VA}{WH} \times \frac{WH}{EMP} \times EMP$$

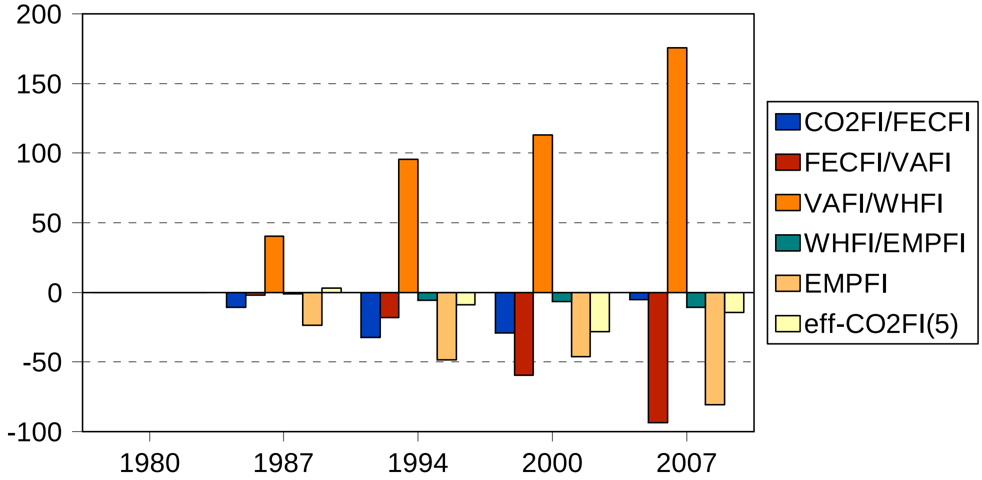
For this case study data about Finnish forest sector from 1980 to 2007 has been collected. This data has been inputted to ASA software and the results presented in Table 17 have been obtained.

Table 17. The ASA analysis results of Finnish forest industry

ASA results table	1980	1987	1994	2000	2007
CO2FI/FECFI	0,00	-10,54	-32,35	-28,96	-5,28
FECFI/VAFI	0,00	-1,81	-18,17	-59,76	-93,45
VAFI/WHFI	0,00	40,56	95,64	113,05	175,97
WHFI/EMPFI	0,00	-1,29	-5,47	-6,60	-10,92
EMPFI	0,00	-23,85	-48,68	-46,13	-80,87
eff-CO2FI(5)	0,00	3,07	-9,04	-28,40	-14,54

The ASA summary table produces results of decomposition analysis in numerical and graphical form. The results are presented as graph in figure 16.

Figure 16. The ASA analysis of Finnish forest industry



According to figure 16 in Forest industry increase in value added indicates increases in production volumes due to more machinery. The energy (of fossil fuels) intensity has decreased indicating shifts to renewable energy use. Use of labour has decreased slightly due to more machinery.

In Finnish forest industry increases in production volumes is the major driving force behind increases of CO2 emissions growth in both pulp and paper as well as in wood industry. All other driving factors have decreasing effects: use of labour, working hours, CO2 intensity of energy consumption etc. In wood industry the CO2 emissions have decreased, but not in pulp and paper industry. In forest industry as a whole, CO2 emissions have decreased only slightly.

4. Experiences from the DECOIN toolkit usage

The Finnish Forestry and Forest sector data provides good testing platform for the DECOIN toolkit. The SUMMA and MuSIASEM results included in this report are produced by the research teams of Parthenope University of Naples (UNIPARTHENOPE) and Autonomous University of Barcelona (UAB). The results produced with ASA model are actually produced by real user, the Statistics Finland team with technical guidance and help from Finland's Futures Research Centre (FFRC). Our experience is that ASA model user interface is in principle easy to adopt and use. Interesting complementary views to different sustainability problems can be generated with relatively easiness.

All DECOIN toolkit models require quite extensive and qualitative precise database. The drafting of relevant diagram on which basis the database was compiled, required both expertise and time. Once the system diagrams were finalised, much of the data desired was not available and it had to be transformed, estimated or even generated artificially. The time spend on statistics compilation exceeded expectations. The DECOIN toolkit provides only as good results as is the quality of input data. As mathematical calculation models they are most sensitive to shortcomings and misinterpretations of data. Furthermore, because of data dependency, the models are unable to discover new unsustainable trends. They only are able to identify unsustainability within existing database. This must be kept in mind when assessing the usefulness of the models.

Within these data constraints, the possibilities to analyse functioning and sustainability of human-economic activities with these models are numerous. Apart expertise to use these models also the translation of results needs deep expertise and background understanding of the sector you are analysing. Thus the DECOIN toolkit is still very much a tool of environmental experts. The results give interesting new insights to reasons behind unsustainable trends. These findings could be obtained also by other methods or deep expertise, but the toolkit eases and speeds the analysis greatly and thus it redeems expectations.

As the integration of the models into DECOIN toolkit is continuing and there is need to use undoubtedly much more time and resources for the finalisation of the DECOIN toolkit that was estimated in DECOIN work plan. The continuation of the development is clearly needed. Based on the experiences of this case study, The DECOIN toolkit should be more clearly focused to produce information on some quite specific unsustainable phenomena. For example in the case of Finnish forest sector, the central issues are the loss of biodiversity and the vitality and regeneration capacities of the forests. Consequently, much more framing of the DECOIN toolkit is required, that would also reduce the resources needed to compile relevant databases on the next case studies.

5. Conclusions

On the basis of he experiences gained within DECOIN project and the DECOIN toolkit testing can be summarised to following benefits and drawbacks.

Benefits include:

1. The basic idea of integration of MUSIASEM, SUMMA and ASA models provides valuable development direction as the environmental statistics need more statistical computing and analysing in the future.

2. The DECOIN toolkit can quite easily produce information about unsustainable trends. These findings can be produced also by other methods or deep expertise, but the toolkit eases the analysis greatly.

The drawbacks include:

3. The integration of the models is still unfinished and undoubtedly there is need to use much more time and resources for the finalisation of the DECOIN toolkit that was estimated in DECOIN work plan. This development work is continuing within the FP7 SMILE project.

4. There is major challenge to reconcile the spatial and cross-section perspectives of SUMMA and MUSIASEM models with the time-series and dynamic perspective of ASA model. This requires new approaches to be adopted.

All in all the development work done within DECOIN project to develop DECOIN toolkit provides for the follow-up research that is this continuing. Since the description and rationales of the toolkit is already done, the next phase must be the actual programming of the prototype software.

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