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1 Introduction

1.1 DECOIN and SMILE

The Synergies of Multi-Level Integrated Linkages in Eco-social Systems (SMILE) project seeks to further develop and apply the DECOIN[1] tool kit. This toolkit consists of three models: SUMMA (Sustainability Multi-criteria Multi-scale Assessment); MuSIASEM (Multi-Scale Integrated Analysis Societal Ecosystem Metabolism) and ASA (Advanced Sustainability Analysis). The conceptual basis of the individual DECOIN tools are documented (Ulgiati et al. 2008) for a wide range of previous case studies (Vehmas et al. 2008). The ambition of the SMILE project is to combine these tools into a system of sustainability accounting that provides a useful insights into the dynamics of the sustainability of complex coupled eco-social systems (Giampietro et al. 2009).

Researchers at the Macaulay Institute in Scotland (the authors of this document) have been part of the SMILE consortium since January 2008. The Macaulay share the ambitions of the DECOIN tool developers particularly in developing meaningful profiles of sustainability indicators rather than relying on single (and often exclusively financial) metrics. The DECOIN tools assist analysts in taking a holistic view of sustainability that encompasses the extents and intensities of resource use, the upstream and downstream consequences of actions and the cross scale or spatial flows of resources on which current systems depend for their integrity. The DECOIN tools can also play a useful role in identifying key thresholds within systems beyond which there is the danger of system collapse with attendant loss of resources or other hardships. Participation in SMILE also provides opportunities for international comparisons within the EU to judge the relative performance of regional case study areas.

1.2 Rationale for the Scotland Case Study

The Scotland case study focuses on the role of the researcher(s) as a process manager (Sterk et al. 2006), facilitating a process of challenge, evaluation and refinement of the DECOIN tools and their outputs. The SMILE research is positioned within a much wider literature by the authors and others on using decision aids, including simulation models, with stakeholders (Carberry et al. 2002;Diez & McIntosh 2009;Matthews et al. 2005;Matthews et al. 2008;McCown 2002;McCown et al. 2006;McIntosh et al. 2007;McIntosh et al. 2008).

For research in support of sustainability decision-making stakeholders and scientists are equally fallible in seeing a system through a particular lens, and putting weight on some areas and ignoring others. Sterk *et al.* (2009) note that models play a *heuristic role* to help multiple stakeholders understand complex systems; a *symbolic role* in making issues visible to politicians and a *relational role* by creating a *boundary object* around which a social network can be

[1] http://www.decoin.eu

developed. Our research supports their conclusions that it is the interactive learning involved that facilitates these roles; and that the practice of working with models can be improved.

Our previous findings also reinforce calls to practice sustainability science that takes non-academic knowledge seriously (Carolan 2006) and pays attention to the politics and power relationships involved in any evaluation of a system (Smith & Stirling 2008). The DECOIN tools are extremely powerful at illuminating the constraints on the existing system and the trade-offs that have to be considered when pursuing normative goals of sustainable development. They quantify trade-offs and illustrate whether certain policy goals are feasible and/or desirable. With particular reference to modelling suitability, our results illustrate the importance of having a shared semantic understanding *before* implementing formal representations of a system using inferential, mathematical or simulation models. Our contribution has been to set out an approach to capturing the semantic aspects and how this can be used to 'decode' the model outputs with the stakeholders in later steps; before working around the cycle once more (see Figure 1). These semantic steps are essential if the tools are to be seen as credible, salient and legitimate (Matthews et al 2008).

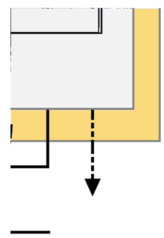

Figure 1: A conceptual model of inclusive model use and development in support of policy

The above approach is being implemented in the Cairngorms National Park (see Section 2 below), which is both an area of land and a new institution for rural sustainable development. Therefore the main policy makers are the staff at the Cairngorms National Park Authority and their partners in delivering the aims of the National Park (Scotland) Act. This deliverable focuses on highlighting the multiple dimensions of the system of interest and the difficulty in representing all facets coherently when there are multiple and contested views regarding both the system and the policy outcomes sought.

The Scottish team represent a wide range of disciplines, experience and technical skills. The team have a strong land-use systems and GIS background, complemented by skills in stakeholder engagement and institutional analysis. However, none of the team have a background in theories of social metabolism. Most of the team have previous experience with computer based Decision Support Systems and research to support policy, making the team well placed in evaluating the utility of the toolkit's application. The key contribution of the Scottish case study, therefore, is to consider the toolkit's utility and address challenges that arise (such as salience, credibility and legitimacy discussed above). A novel, and important, aspect is that the Scottish team are not the developers of the tools. Therefore, our experience of using tools that we have not developed provides a realistic assessment of difficulties of transferring these tools to new groups and applications. A secondary contribution of the Scottish case study is, thus to address the question of the tools' transferability.

1.3 Objectives and Activities

The rationale outlined above, translates into three objectives that seek to give focus to the Macaulay research effort within SMILE. These objectives are:

Objective 1 - Test the transferability of the DECOIN concepts and tools.

Objective 2 – Assess with key stakeholders the utility of the DECOIN outputs and outcomes

Objective 3 - Add *land* as a key factor within DECOIN analyses.

These objectives are to be achieved through the programme of work packages and deliverables set out in Figure 2 and listed below. The activities undertaken to date are:

Familiarisation with the DECOIN tools (WP2)

Scoping of the case study with key stakeholder groups (WP2)

Data gathering and organisation (WP3)

Local Case Study application (WP3 – see Section 2)

D16 – *Local case study progress report (this document)*

Thematic Analysis based on the WP3 case study - (WP4 - Task 4.3)

D28 - The role of economic growth in achieving multiple objectives,

D29 - How synergies and trade-offs occur at different scales

D30 - The role of policy and other actions (links to WP5)

Interfacing with societal/policy processes (WP5 - Task 5.2)

D23 – Utility report on the DECOIN tools.

To date we have made substantial progress on all activities except the Thematic Analysis (Task 4.3). In addition we have participated in four SMILE meetings (hosting one in July 2009). The planned staff time allowance for the first four activities on which we are reporting here was 4 person months. This has not proven to be a realistic estimate of the effort required. While it has been possible to provide substantial support to SMILE activities from other funders it is likely that we will have to revise the scope of the Thematic Analyses to achieve a better match between expectations and resources (see Section 6 of this report).

Figure 2: Scotland case study activities and deliverables

2 Case study area – Cairngorms National Park

The Cairngorms National Park is the largest national park in the UK and was created as a result of the National Park (Scotland) Act in 2003. It covers approximately 3,800 km^2 and is home to approximately 16,000 human residents as well as significant protected habitats and species. National Parks in Scotland are explicitly required to achieve 'sustainable development', as illustrated by the four statutory duties set out in the Park Act:

- To conserve and enhance the natural and cultural heritage of the area;
- To promote sustainable use of the natural resources of the area;
- To promote understanding and enjoyment of the special qualities of the area by the public; and

- To promote sustainable economic and social development of the area's communities.

Therefore, they are not 'wilderness reserves' but fit the IUCN category V (protected landscape). The Cairngorms National Park will alter its boundary in August 2010 to take in a new section to the south-west of the existing boundary (Scottish Natural Heritage 2008).

2.1 Bio-Physical

As shown in Figure 3 below, the National Park contains a variety of ecosystems from the sub-arctic Cairngorms plateau through managed moorlands, pastures and forestry to intensively farmed land in the river valleys.

The Cairngorms National Park

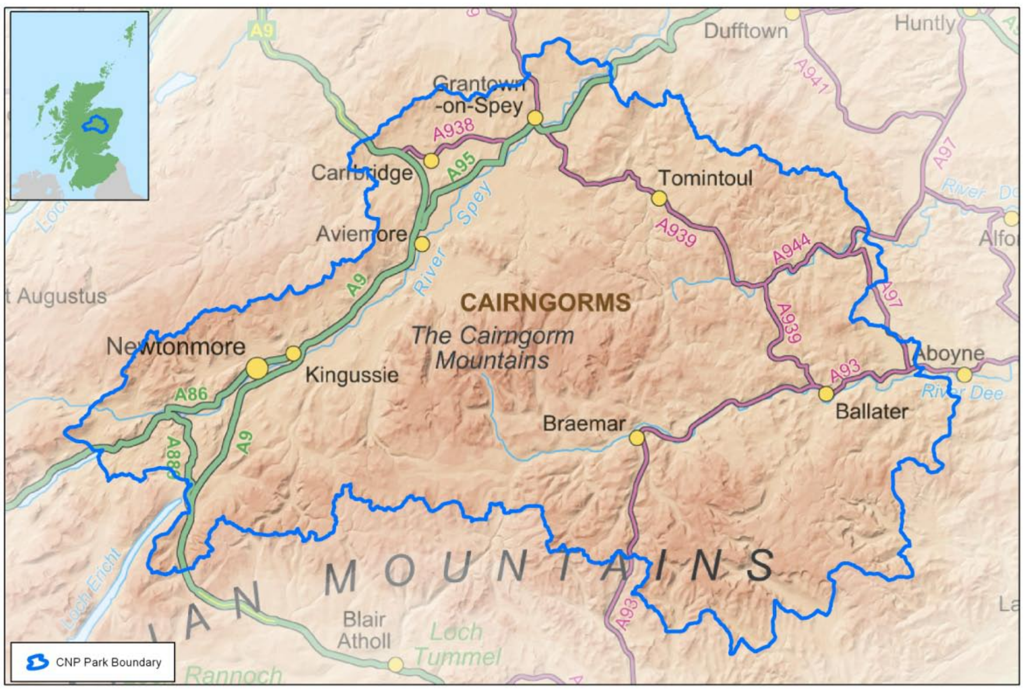

Figure 3: Topographic map of the Cairngorms National Park

The National Park is protected for both its biodiversity and its geodiversity. The mosaic of habitats present, combine to create a unique and highly valued landscape. In 2006, 39% of the National Park was designated for nature conservation and 25% of the area is designated as being of European or International importance for nature conservation. Furthermore, 25% of species on the UK conservation priority species list are found within the National Park. The geological features are of international importance and account for the Cairngorms' inclusion in the Geological conservation review. The Cairngorms provide one of the best preserved examples of post glaciated landscape in the UK.

The headwaters of Scotland's three largest rivers (Tay, Dee, Spey) all rise within the National Park boundaries. Indeed, the water resources are very important to the tourism, recreation, food and drink industries and as a resource for renewable energy. The Dee and the Spey are also protected under the Habitat's Directive, for drinking water abstraction and to protect the economic salmonoid fishery resource.

The Park contains a number of regionally important settlements that service the rural economy in the National Park. The topography means that these communities have traditionally looked away from one another towards the major settlements on the coast or rivers (Aberdeen, Dundee, Perth or Inverness) as the major transport routes detour around the Cairngorms Massif. Therefore, the topography that gives the Park its special and unique features has traditionally divided, rather than united, the residents within its boundary.

2.2 Socio-Economic

The Cairngorms National Park boundary deliberately includes settlements as the National Park is an example of a living protected landscape that is shaped by ongoing human activities.

The population of the Park was 16,252 in 2007, which represents 0.32% of the Scottish population. The population density is 0.04 people per hectare, compared to the Scottish average of 0.65 persons per hectare (based on 2001 census). The age profile indicates that there are less children; less people of a working age and more retired people (aged 65 years or more) than the overall Scottish average; and this profile has been stable from 2001-2007.

In 2001, there were 6738 households. Approximately 63% were home owners, close to the Scottish average. The mean house price in 2007 was £178,541. In 1998, the mean house prices were lower than the Scottish average, but in 2007 they were 20% higher than the Scottish average. However, of those households renting their homes, a much higher proportion rent from private landlords and consequently a lower proportion from public or social housing landlords, than the Scottish average (19% private and 17% social compared to 8% and 29% for Scotland).

The population has been growing steadily since 2003. It is important to recognise that the communities within the Park are heterogeneous, consisting of long-term rural residents whose families have lived in the area for generations as well as recent economic or amenity immigrants attracted by the special qualities of the Park. There are differences by gender, age, class, occupation, land tenure as well as important differences in terms of preferences and attitudes to land use, environmental protection and economic development.

The 2001 census data suggests that the residents of the (pre) National Park had less professional and managerial grade workers than the Scottish average, but also less unskilled and unemployed workers than the average, with a concentration around the C1 (clerical, supervisory/junior management) and C2 (skilled manual worker) grades. The percentage of total population who are income or employment deprived is half that of the Scottish average. There are also lower than average rates for depression, alcohol misuse and drug abuse reported.

The main industries for the Park area (as of 2001) are shown below, with those higher than the Scottish average highlighted in bold:

Sector	**Park % in 2001**	**Scotland % in 2001**
Hotels and Restaurants	**19.4**	13.7
Wholesale and retail	12.6	14.4
Other	**9.8**	5.3
Health and social work	9.7	12.4
Real Estate and Business	9	11.2
Construction	**8.0**	7.5
Manufacturing	7.2	13.2
Education	6.3	7.3
Agriculture, Hunting and Forestry	**5.7**	2.1

There were 21 food and drink processors in the National Park, including seven whisky distillers (whisky being the most valuable Scottish export commodity by volume after oil).

The Park contains, for example, 424 listed buildings and 60 scheduled ancient monuments, as well as many other examples of settlement dating from Neolithic times through to the Victorian hunting lodges and castles. The Park is also the ‘playground’ for local residents, day visitors from nearby Scottish cities and tourists from the UK, Europe and beyond. The recreational facilities support winter sports, long distance walking, water sports, fishing, mountain and road biking and hunting. There are also over 70 visitor attractions and museums in the Park.

It is important to recognise that the Cairngorms is a **National** not a Natural Park. The national aspect has important implications for its function and challenges facing it. The third aim of the National Park (Scotland) Act requires that Scottish national parks promote themselves to the general public. There is an expectation that National Parks are both an asset for all Scottish citizens, but also are an example used to promote Scotland internationally.

2.3 Governance

The Park has a statutory management authority – Cairngorms National Park Authority (CNPA) but unusually, the CNPA are not land owners, regulators or service providers *per se*, but instead seek to coordinate the multiple private, public and voluntary/NGO sector land owners at the local, regional and national (Scottish) level. Approximately 75% of the National Park is privately owned. The CNPA promotes itself as an 'enabling organisation' and aims to act as a coordination and liaison point for the multiple stakeholders involved in managing the National Park. This is quite different from the other Scottish national park (Loch Lomond and the Trossachs) that owns more land and assets and employs many more staff in order to deliver services directly, rather than in partnership.

The CNPA reports to the Scottish Government and are expected to contribute to the Scottish Government's overarching strategic priorities (Scottish Government 2007). The CNPA work with other national level public sector bodies such as: those responsible for nature conservation (Scottish Natural Heritage); Forestry (Forestry Commission Scotland); environmental protection (Scottish Environmental Protection Agency); rural land use (Scottish Rural Inspectorate and Payments Division); cultural heritage (Historic Scotland) and tourism marketing (Visit Scotland). The CNPA also work with, and are lobbied by, national level interest groups representing a wide range of stakeholders, from conservation charities (e.g. World Wide Fund for Nature) through to industry groups (e.g. Scotch Whisky Association, National Farmers Union Scotland). These partners cover the whole of Scotland whereas the CNPA are only responsible for the National Park.

The CNPA works with regional public bodies, namely four (soon to be five) local authorities[2] (Aberdeenshire, Angus, Highland and Moray – with Perthshire and Kinross from August, see Figure 4). Due to the topography, the Cairngorms National Park lies at the junction of these local authority areas, requiring the CNPA to coordinate and liaise across the local government boundaries. The National Park is only a small proportion of the total area for each of the Local Authorities. As with the national stakeholders, the CNPA has to coordinate this group who in turn, have to balance the needs of the National Park with the needs of the areas outside the Park boundary. Other regional stakeholders include public sector enterprise and economic development bodies and industry groupings. The designation of the National Park encouraged the development of two umbrella groups combining existing small private/voluntary groups within the National Park – the Cairngorms Chamber of Commerce and the Association of Cairngorms Community Councils.

The CNPA works with local groups such as destination specific tourism groups and conservation volunteers. These groups represent both communities of place and of interest. The CNPA has set up stakeholder platforms to engage local residents, land owners and business interests in the ongoing management of the Park and delivery of the Park Plan objectives and priorities. Individual land owners are very important stakeholders, and range from individual farmers, through to large estates owned by businesses, to state owned reserves. The CNPA liaises with

[2] In Scotland there is only one level of local government, combining a regional government with municipalities.

research organisations and academics, which provide the ideas and evidence underpinning adaptive management.

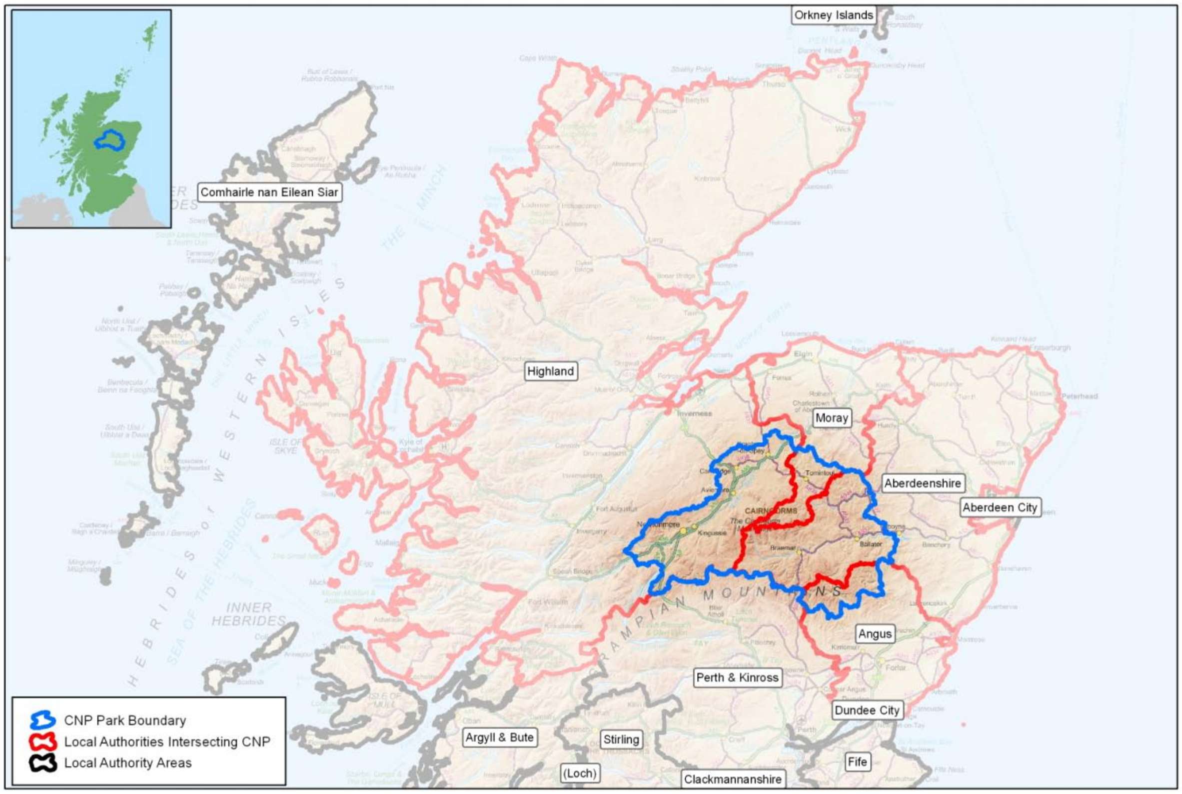

Figure 4: Overlap between the CNP and Scotland's Local Authorities

The National Park Plan also works alongside other existing national and regional plans and policies that influence land use and sustainable rural development. Therefore, in addition to the governance structures put in place by the CNPA, there are numerous existing other local, regional and national stakeholder processes involving those who live in, or influence, the Cairngorms National Park. Therefore, the CNPA is trying to coordinate an extremely cluttered institutional landscape.

The Cairngorms National Park can be thought of as an experiment in the governance of rural sustainable development. It is a new institution that is developing new coalitions of actors who influence how the Park's resources are managed. The new institution of the National Park has few formal sanctions beyond existing national regulations and the land use planning system; and its novel approach to property rights means it has no direct control of the Park's resources. Its limited budget means it relies on capturing national funding schemes (e.g. the Scottish Rural Development Programme) to provide economic incentives. Therefore, the institution relies on educational and voluntary measures to deliver the overall aims. This emphasises the need to generate and maintain a shared symbolic understanding of what the Cairngorms National Park is in order to generate 'buy-in' from the multiple stakeholders. Given the variety of backgrounds and motivations of these stakeholders, developing such a shared and stable concept is an ongoing process.

2.4 Stakeholders for the SMILE Case Study

The main stakeholders for the SMILE Scottish Case study are a subset of those described in the governance section above.

There are two groups of direct stakeholders, meaning those who will be involved in shaping the research process, providing data and evaluating the results. The Scottish research team are the main 'users' of the toolkit and will judge the toolkit's transferability. The CNPA are the main users of the toolkit **results** and therefore the judge of the toolkit's utility in helping to illuminate policy relevant sustainability trade-offs, synergies and trajectories.

There are other indirect stakeholders, meaning those who would be interested in learning more about the research process and the results. These include the Scottish Government, partners delivering the National Park Plan and the wider scientific community. As the CNPA ultimately answer to the Scottish Government, relevant Scottish Government personnel will also be informed of the outcomes of the toolkit application, particularly highlighting where issues with data availability could constrain future sustainability analyses. The CNPA may wish to share the results with their national, regional or local partners where they think the results are of interest and the Scottish team will support this. However, we do not anticipate actively engaging these wider partners due to the fact that these organisations already struggle to resource input to existing National Park stakeholder groups and forums. The results of the toolkit utility and transferability will (and has been) shared with the scientific community via the SMILE project communications and knowledge exchange programme.

2.5 Issues

Section 3.1 below highlights the issues as specifically identified at the start of the SMILE Scottish case study project. However, the Cairngorms National Park Plan (Cairngorms National Park Authority 2007) provides a broader analysis of the main issues that need to be actively managed in order to deliver the vision of a "world-class National Park" by 2030. There are 20 strategic objectives to be addressed over several iterations of the National Park Plan. These are addressed under three headings: Conserving and Enhancing the Park; Living and Working in the Park; and Enjoying and Understanding the Park.

There are seven priorities for action to be addressed by 2012:

- Conserving and enhancing biodiversity and landscapes
- Integrating public support for land management

- Supporting sustainable deer management
- Providing high quality outdoor access
- Making tourism and business more sustainable
- Making housing more affordable and sustainable
- Raising awareness and understanding of the Park

These objectives and priorities for action reflect the outcome of two years of consultation with national, regional and local stakeholder groups, as well as over 150 individual residents. The objectives and priorities are not for the CNPA to deliver alone, but have triggered a variety of partnership projects involving government agencies, private businesses, voluntary groups, charities, research organisations and individual land owners.

3 Case Study

There has been detailed guidance provided on the individual DECOIN tools application. For SMILE, however, the emphasis is on the procedural aspects of how the tools can be used together to deliver case studies of relevance to social or policy processes. Figure 5 is an illustration of the shared conceptual model of how the DECOIN tools are to be applied. There are seven phases to work through, though given the range of different emphases possible within sustainability analyses there are several routes through the process and not all stages are critical to every application. For the Macaulay researchers it is particularly important to understand how to 'close the gap' between the outputs from the tools and the governance processes enacted within the case study. The process as illustrated does not explicitly recognise multiple representations of the system or a participatory process to generate the energy systems diagram, nor does it relate the final outputs back to the initial phases. In other words, the institutional context remains outside the seven steps.

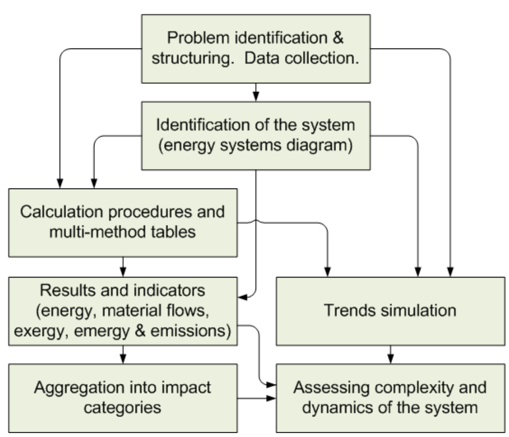

Figure 5: Applying the DECOIN Tools

3.1 Identification of the Problem

For the CNPA it was possible to agree a high level definition of the issue of interest. This was to assess the changes that have occurred since the creation of the National Park. This was intended to be useful to the CNPA both for the evaluation of the Park (due in 2012) and their planning for the next 5-year Park-Plan. By conducting the DECOIN cross-scale analysis it would also be possible to assess if the changes observed within the CNPO were reflective of Scotland as a whole or are more local phenomena. Of course there would remain the issue of disentangling how many of the changes could be attributed to the actions and policies of the CNPA but at least the DECOIN tools were anticipated to provide a more holistic understanding of the sustainability issues.

Within this overall assessment of sustainability the research team (in consultation with other SMILE partners) also identified a series of more specific questions which could be usefully addressed.

Growth - is there an inevitable and irresolvable conflict between growth in economic activity and the preservation of the special qualities of the Park. This is particularly apparent in the tourism and recreation sector where larger numbers of people and development of the required physical infrastructure erodes the special quality or “wilderness” with which the Cairngorms are associated. Within this are several interesting other issues such as - how should the resource use (particularly energy) by tourists be accounted for – at the destination, or where the wealth to purchase the travel was generated?

Dependence - A common perception is that the low levels of population and economic activity within the CNP means low impact, a high quality natural environment and higher than average levels of sustainability. The CNP as a socio-ecological system, however depends on significant flows of resources, financial (wages and pensions), physical (food) and human (skills and services). Particular challenges may occur if the proportion of elderly retirees from urban areas increase, pushing up housing prices and making demands on local care services. The related issue of social exclusion through high levels of second home ownership has been an endemic problem in otherwise successful UK national parks. Conversely a tourism and recreation based economy (perhaps with increased levels of external business ownership) could result in chronic problems of seasonal underemployment for local people, dependence on the importing of migrant labour and net flows of resources out of the CNP.

3.2 Systems Diagrams

There are many possible ways of identifying and characterizing a system. We used a simple process of generating conceptual diagrams to compare and discuss. We generated three diagrams: one developed by the research team from the Macaulay Institute (six people); one developed by a set of managers from the CNPA (five people); and one based on a content and thematic analysis of the key documents describing the national park (one researcher). It was useful to contrast our external view of the system, based on our experiences of visiting the Park, as well as our theoretical understanding of how such systems worked in rural Scotland; with the views of those living, working and managing the Park. The final process used the outputs from a two year strategic planning process that had involved considerable stakeholder involvement (Cairngorms National Park Authority 2007) and could be considered to be a useful proxy for a wider set of views on the Park system.

The first two diagrams were created using a deliberative group process. Working initially in pairs, the participants were asked to write what they thought were the main important components of the Cairngorms system onto post-it notes. Once a reasonable number had been generated, this exercise was stopped and the pairs of participants were given the opportunity to reflect on what they had generated. The entire group then discussed the post-it notes they had generated, grouping duplicate or similar concepts, and identifying any gaps that became obvious. This process started to create higher level groupings. The group then started to arrange the post-it notes onto a large piece of A0 paper to develop a 'systems diagram'. Note this was a rapid participatory process to illustrate the main content of the system and their relationships to one another. During this diagramming stage, 'missing' content was identified and added. There was much debate about how to construct the diagram – do you start from the natural capital or the people? Do you work from left to right or from the centre out? And as a result of discussion and debate, some post-it notes were moved around several times. Furthermore, it became clear how many components were linked in different ways to many other components – illustrating the complexity and the richness of the system. The 'diagram' of post-it notes were then entered onto an Excel spreadsheet and converted into a graphics package called flow-charter, providing an electronic version of the diagrams (see Figure 6). The content of the diagrams is further discussed in Section **Error! Reference source not found.** and full versions of Figure 6 can be found at www.macaulay.ac.uk/smile/).

The content of the post-it notes (representing elements of the system) was classified using several sustainability-oriented coding schemes. The intent here was to try to explore how best to simplify the representation of the system (and its context) to make it tractable whilst not over-simplifying or ignoring important issues. The classification stage allowed us to interrogate the data using concepts, such as *capitals* from the sustainable livelihoods model (Carney 1998); notions of *stocks* and *flows*; whether things were *exogenous* or *endogenous* or heuristics such as PESTLE[3] (Grundy 2006). This step was another opportunity to check that all aspects of the system had been considered.

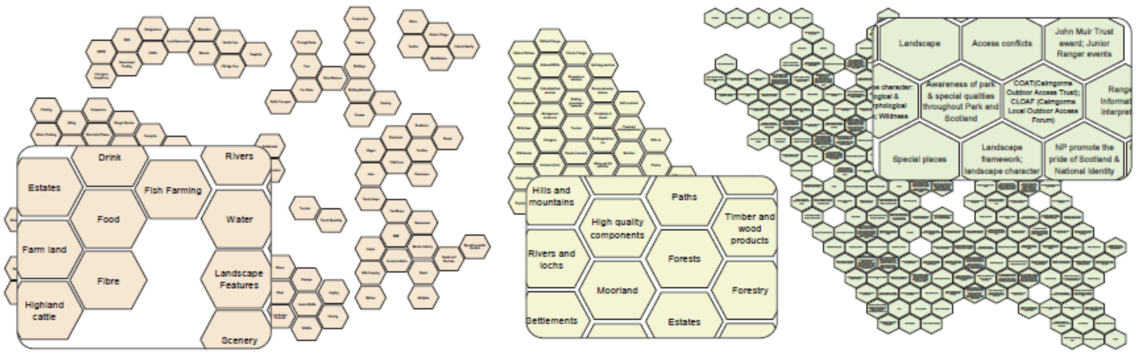

Figure 6: (a) Macaulay diagram; (b) CNPA diagram (c) Content Analysis Diagram

3.3 Formalising - Generating an Energy System Diagrams

The SUMMA tool requires the formalisation of the information generated from these processes into an energy systems diagram (Brown & Ulgiati 2004). The aim is to define the main relationships within a system without the detail overwhelming the structure of the system. The informal systems diagrams presented in Section 3.2 served as the basis for the formal energy systems diagram, although often the higher level clusters, or groups, generated in the diagramming discussions were used rather than the detail on individual post-it notes. It was important to use the field notes, supplemented by the transcript of the CNPA meeting discussions, as a reminder of how the different participants saw the relationships, rather than letting the form of the energy system diagram dictate. In future applications, this step could also be done as part of a deliberative group process.

Figure 7 shows the energy system diagram developed by the Macaulay team for the CNP. The diagram was formalised using Odum's graphical conventions in collaboration with the Parthenope University team. The diagram is read from left to right: with extensive and natural inputs to the system on the far left and increasingly anthropogenic inputs of the system along the top border of the system. The outputs of the system are conventionally found on the right hand edge and the waste exiting the system is indicated along the bottom. It is important to note that the diagram contains several resources such as reputation/image (rep/image) and culture, skills and knowledge that are a serious challenge to include within the formalism in a way that retains the meanings associated with the categories by stakeholders.

[3] PESTLE is Political, Economic, Social, Technical, Legal and Environmental

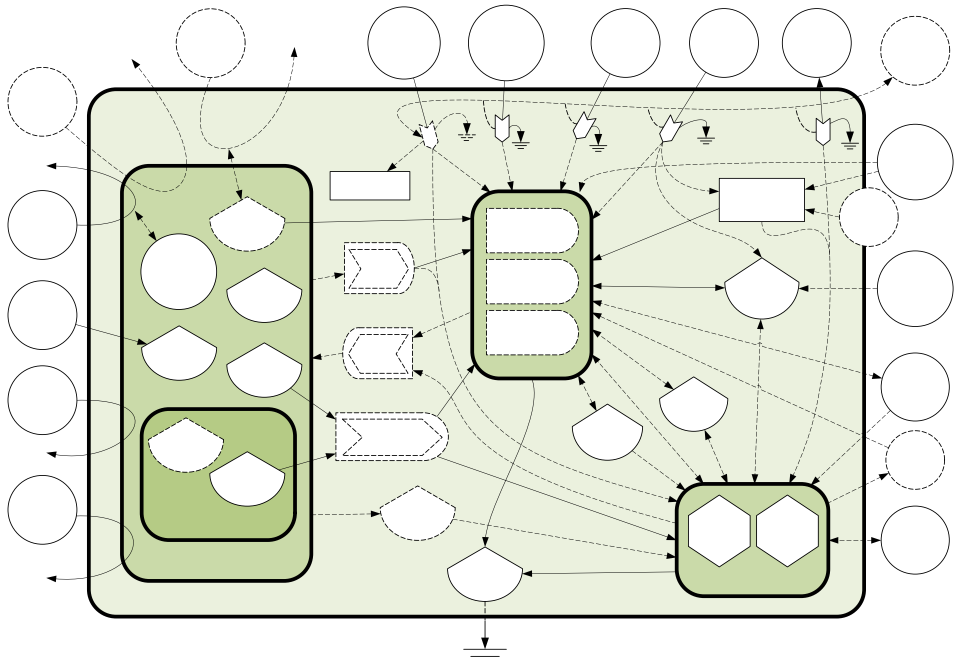

Figure 7: First Energy Systems Diagram for CNP

3.4 Simplifying the Energy Systems Diagram

In consultation with partners at Parthenope University it was decided that in the first instance for the SUMMA based analysis there would be a focus on the production-oriented land-based industries (PoLbI) (agriculture, forestry and sporting estates). The importance of the sector has been variously argued from minimal (gross value added), to marginal (employment), to important (downstream environmental impacts) and finally as crucial (as the management that creates or maintains the landscape/character of the region). In this case the decision to start with the PoLbI reflected the expertise of the research team and their knowledge that there were adequate quality sources of data available. There was also reported (Blackstock pers comm.) to be some difficulty for the CNPA accessing all of the agricultural statistics available for the CNP from other agencies, so the research team were able to act as facilitators. Given the resource constrains on both Italian and Scotland teams and the limitations on the skills of the Scotland team noted previously (Section 1.2) there were also pragmatic reasons for starting from the existing, tested SUMMA model for the agricultural sector in Campania (Ulgiati et al 2008).

Figure 8 illustrates the system components that could be accommodated within the SUMMA analysis at this stage (highlighted) while Figure 9 shows a simplified diagram with only these components.

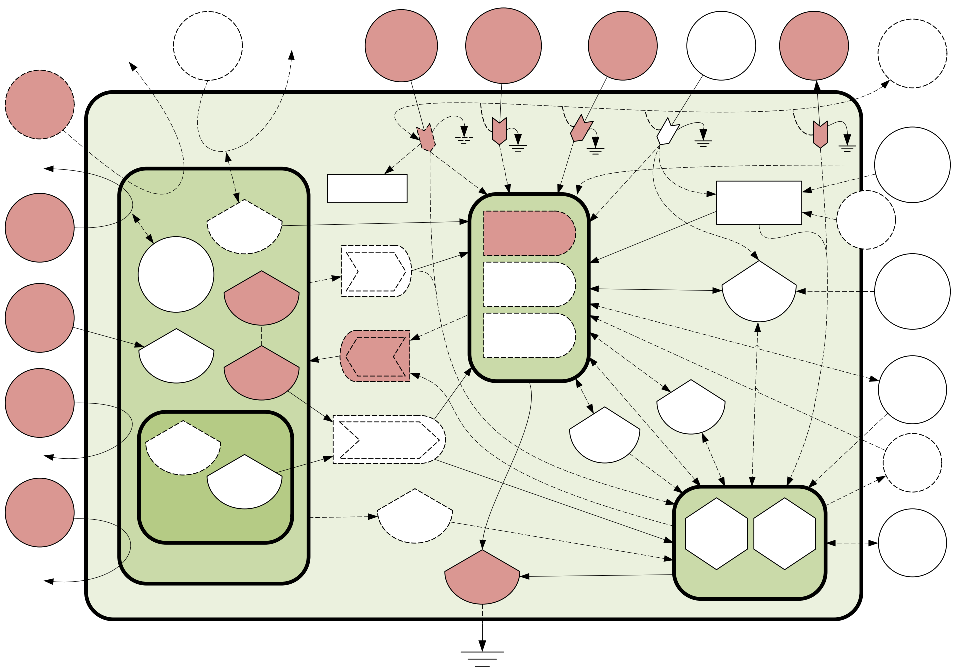

Figure 8: The components included in the CNP and Scotland SUMMA analyses

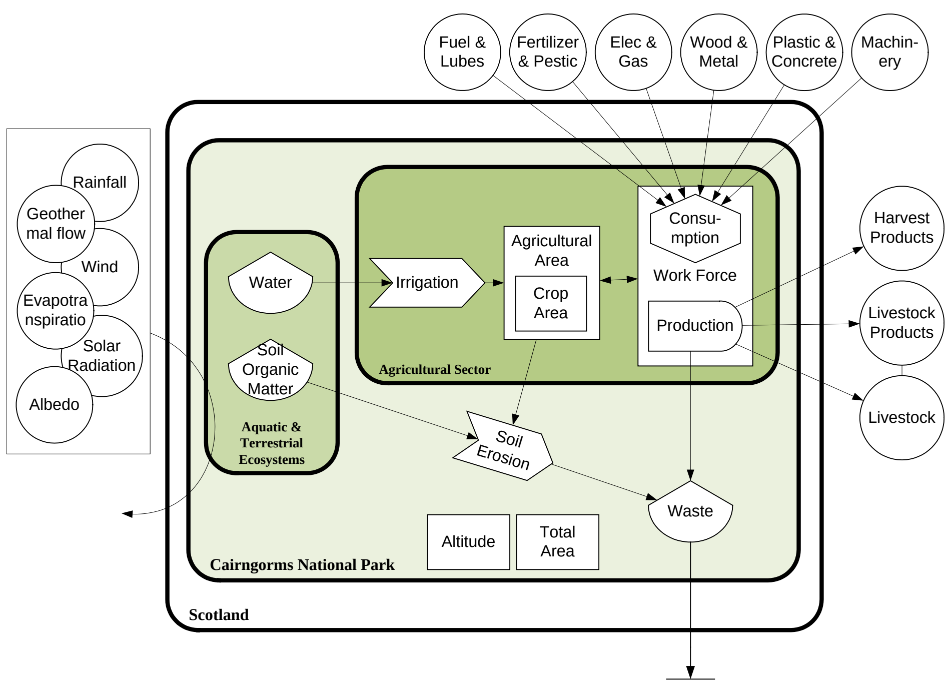

Figure 9: Simplified PBLBI Energy Systems Diagram

For MuSIASEM, the systems diagramming activity serves a different purpose than for SUMMA. The diagram helps in imposing a structure on the semantics categories identified by the research team and the stakeholders, but the MuSIASEM analysis is informed rather than structured by the energy systems diagram. For the CNP case-study the energy systems diagrams are most likely to be useful in guiding decisions on the scope of the n-1 scale MuSIASEM analyses (below the level of the National Parks as a whole).

3.5 SUMMA Data Gathering

As outlined above the SUMMA analysis has in the first instance focused on the POLBI sector. The consequence of this pragmatism is, however, that while the analysis is spatially comprehensive at scale n (CNP) and n+1 (Scotland) it does not explicitly consider supply chain relationships or spill-over effects identified as significant in the systems diagramming. This may limit the salience of the analysis to our main local stakeholders, the CNPA (to be assessed as part of WP4/5 early in 2010).

Given the intention of the Scotland case study is to look at change over the period since the creation of the Park, at least two time periods were needed. To give a wider historical perspective data from an earlier year were also chosen. The dates of the SUMMA analysis were 1991, 2001 (both pre CNP) and 2007 (the most recent year with the most complete and versified statistics). The 1991 and 2001 dates were chose since these are UK population census dates for which the best social and economic data are available. The three dates were the minimum number that allowed the team to asses if since 2003 the changes seen in the CNP were continuations of previous trends (either accelerating or slowing) or saw changes in the direction of trends (some of which may be attributed to the actions or policies of the new institution the CNPA – an aim for D30). While many of the datasets are available annually the resource constraints for this phase of the project and the need to assess the salience of the analysis for stakeholders mean that the minimum number of time intervals was used.

The input data values required are listed in Table 1 (188 values for each 3 time periods and for the two scales). There are specific comments on data sources and specific issues for particular variables in **Error! Reference source not found.**. In general the statistics available for the PoLbI means data quality is very good. Since the Scotland team have access to individual census records for farm holdings on a yearly basis the information on local resources (land use, livestock, labour and machinery) is near comprehensive. Specific productivity and management information tends to be available only at n+1 level (aggregate levels of fertiliser use etc and overall production levels). That said, the identification of sources for some variables proved to be particularly taxing and in many cases the assumption had to be made that local circumstances reflected national averages (deriving totals from average national rates per ha). Such assumptions may not be valid since the CNP is a small area and we know that for some variables there is significant local variation (e.g. in rates for fertiliser application). The area is also marginal in terms of agricultural production, so management may not reflect typical practice. In such instances an assessment of the consequences of such assumptions could usefully be undertaken but would require an automated benchmarking facility (interface and data handling) to be added to the existing SUMMA tools.

Key unresolved issues for the Scotland-CNP SUMMA analysis:

1. The difficulties of cleanly splitting the inputs and outputs of cropping and livestock systems. Since significant amounts of arable crops are used as fodder in Scotland (either from on farm production or as bought in feed) then it is not a simple matter to disentangle fixed/capital asset inputs such as labour, agro-chemicals and machinery.
2. The severe limitations on the energy consumption data (though given government commitments to emission reductions these datasets are becoming more reliable and comprehensive, which of course is no assistance in undertaking analysis of historic trends).
3. The complete absence of information on the use of materials such as steel, plastic, wood and concrete. This is the subject on continuing investigation and has been suggested as a topic for addition to future Agricultural Census forms

Table 1: Input data for the SUMMA comparison of land-based productive sectors in Scotland

Data used in the SUMMA comparison of the land-based production sectors in Scotland (n+1) and CNP (n)		Scotland			CNP		
	£ to € rate ->	1.5192	1.6087	1.4670	1.5192	1.6087	1.4670
Item	**Unit**	**1991**	**2001**	**2007**	**1991**	**2001**	**2007**
Physical Parameters							
Total area of the unit	m2	77,970,681,300	77,970,681,300	77,970,681,300	3,816,539,820	3,816,539,820	3,816,539,820
Total agricultural sector area	m2	39,158,210,800	39,158,210,800	41,477,275,500	1,794,386,400	1,794,386,400	1,794,386,400
Area of the main crops production	m2	211,152,951	226,212,300	311,069,600	1,161,188	1,244,209	1,711,499
Maximum altitude	m	1,343	1343	1343	1,304	1304	1304
Minimum altitude	m	0	0	0	137	137	137
Average altitude	m	105	105	105	521	521	521
Albedo of the land use categories	%	16	16	16	16.5	16.5	22.94
Solar radiation	kcal/m2/year	749654	793907	776433	661,684	700,744	685,321
Wind energy on land	m/s	6.5	6.5	6.5	7	7	7
Wind energy on land	J/m2/year	4.14E+20	4.14E+20	4.14E+20	2.53E+19	2.53E+19	2.53E+19
Total Rainfall in one year	mm/year	1402	1307	1575	883	911	893
Geothermal flow at land surface	mW/m2	38.5	38.5	38.5	38.5	38.5	38.5
Evapotranspiration rate from land	%	40%	40%	40%	40%	40%	40%
Erosion rate of the soil	g/m2/year	200	200	200	200	200	200
% organic matter in soil	%	23.13	23.13	23.13	27.97	27.97	27.97
Water for irrigation (volume of water used)	m^3/yr	5,230,000	5,230,000	5,230,000	na	na	na
Water for irrigation, price	£/ha/mm	£ 3.50	£ 3.50	£ 3.50	£ 3.50	£ 3.50	£ 3.50
	£/m3	£ 0.35	£ 0.35	£ 0.35	£ 0.35	£ 0.35	£ 0.35
	€/m3	€ 0.53	€ 0.56	€ 0.51	€ 0.53	€ 0.56	€ 0.51
Fraction of irrigation water that is evapotranspired	%	40%	40%	40%	40%	40%	40%
Fuel							

Car fuel (diesel and gasoline)	£/yr	£ 12,376,968	£ 12,794,894	£ 13,342,476			
	l/yr	27,262,044	16,946,879	14,044,712			
Ag machinery fuel and oil	£/yr	£ 30,664,179	£ 45,990,938	£ 67,473,633			
Gasoline for agricultural purpose	l/yr	no data	no data	no data	no data	no data	no data
Gasoline price	£/l	£ 0.45	£ 0.76	£ 0.95	£ 0.45	£ 0.76	£ 0.95
Gasoline price	€/l	€ 0.69	€ 1.21	€ 1.39	€ 0.69	€ 1.21	€ 1.39
Diesel for agricultural purpose	l/yr	282,344,444	264,311,111	264,311,111	2,375,469	2,223,748	2,223,748
Diesel price	£/l	£ 0.15	£ 0.20	£ 0.39	£ 0.15	£ 0.20	£ 0.39
Diesel price	€/l	€ 0.23	€ 0.32	€ 0.57	€ 0.23	€ 0.32	€ 0.57
Diesel price	£/yr	£ 42,069,322	£ 52,862,222	£ 103,081,333	£ 353,945	£ 444,750	£ 867,262
Diesel price	€/yr	€ 63,911,714	€ 85,039,457	€ 151,220,316	€ 537,713	€ 715,469	€ 1,272,273
Lubricant for agricultural purpose	l/yr	6,022,989	4,811,111	4,811,111	50,674	40,478	40,478
Lubricant price	£/yr	£ 35,897,011	£ 28,674,222	£ 28,674,222	£ 302,015	£ 241,247	£ 241,247
Lubricant price	€/yr	€ 54,534,740	€ 46,128,221	€ 42,065,084	€ 458,821	€ 388,094	€ 353,909
Electricity for agricultural purpose	kWh/yr	269,650,580	148,503,177	119,530,255	2,268,671	1,249,412	1,005,653
Electricity price	£/kWh	£ 0.0758	£ 0.0809	£ 0.1215	£ 0.0758	£ 0.0809	£ 0.1215
Electricity price	€/kWh	£ 0.1152	£ 0.1301	£ 0.1782	£ 0.1152	£ 0.1301	£ 0.1782
Electricity price	£/year	£ 20,439,514	£ 12,013,907	£ 14,522,926	£ 171,965	£ 101,077	£ 122,187
Electricity price	€/year	£ 31,051,710	£ 19,326,772	£ 21,305,132	£ 261,250	£ 162,603	£ 179,248
Gas (if any) for agricultural purpose	MJ/yr	427,994,318	1,167,704,097	1,033,976,755	3600875	9824329	8699231
Gas (if any) for agricultural purpose	GWh	118.90	324.39	287.24	1.00	2.73	2.42
Gas (if any) for agricultural purpose	m3/yr	10,750,165	29,329,855	25,970,953	90,445	246,763	218,503

Gas price	£/MJ	£ 0.00419	£ 0.00539	£ 0.00895	£ 0.00419	£ 0.00539	£ 0.00895
Gas price	£/yr	£ 1,793,296	£ 6,288,087	£ 9,248,922	£ 15,088	£ 52,904	£ 77,815
Gas price	€/yr	£ 2,724,376	£ 10,115,645	£ 13,568,169	£ 22,921	£ 85,107	£ 114,154
Fertilizers used for the whole agricultural sector:							
Nitrogen (N)	tonne/yr	194,733	227,000	138,000	2612	2835	2028
Nitrogen (N)	kg/yr	1.95E+08	2.27E+08	1.38E+08	2.61E+06	2.84E+06	2.03E+06
Nitrogen (N) price	£/kg	£ 0.36	£ 0.35	£ 0.47	£ 0.36	£ 0.35	£ 0.47
Nitrogen (N) price	€/kg	€ 0.55	€ 0.56	€ 0.69	€ 0.55	€ 0.56	€ 0.69
Phosphate (PO4)	tonne/yr	61,250	81,000	49,000	851	873	696
Phosphate (PO4)	kg/yr	6.13E+07	8.10E+07	4.90E+07	8.51E+05	8.73E+05	6.96E+05
Phosphate (PO4) price	£/kg	£ 0.34	£ 0.32	£ 0.43	£ 0.34	£ 0.32	£ 0.43
Phosphate (PO4) price	€/kg	€ 0.52	€ 0.51	€ 0.63	€ 0.52	€ 0.51	€ 0.63
Potassium (K2O)	tonne/yr	71675	94,000	61,000	977	1019	808
Potassium (K2O)	kg/yr	7.17E+07	9.40E+07	6.10E+07	9.77E+05	1.02E+06	8.08E+05
Potassium (K2O) price	£/kg	£ 0.19	£ 0.20	£ 0.27	£ 0.19	£ 0.20	£ 0.27
Potassium (K2O) price	€/kg	€ 0.29	€ 0.32	€ 0.40	€ 0.29	€ 0.32	€ 0.40
Pesticides used for the whole agricultual sector:							
Fungicides	kg/yr	1,100,462	680,457	746,083	2,451	1,393	1,810
Fungicides price	£/kg	£ 94.41	£ 94.85	£ 101.31	£ 94.41	£ 94.85	£ 101.31
Fungicides price	€/kg	£ 143.43	£ 152.59	£ 148.62	€ 143.43	€ 152.59	€ 148.62
Growth regulators	kg/yr	269,552	192,647	180,165	856	580	667
Growth regulators price	£/kg	£ 95.41	£ 94.85	£ 101.31	£ 95.41	£ 94.85	£ 101.31
Growth regulators price	€/kg	€ 144.94	€ 152.59	€ 148.62	€ 144.94	€ 152.59	€ 148.62
Herbicides	kg/yr	983,135	753,194	676,878	11,606	5,520	2,397
Herbicides price	£/kg	£ 92.33	£ 94.81	£ 105.00	£ 92.33	£ 94.81	£ 105.00
Herbicides price	€/kg	€ 140.27	€ 152.52	€ 154.04	€ 140.27	€ 152.52	€ 154.04
Insecticides	kg/yr	€ 59,646.00	€ 37,024.00	€ 26,083.00	339	257	2,054
Insecticides price	£/kg	£ 91.93	£ 79.81	£ 95.98	£ 91.93	£ 79.81	£ 95.98

Insecticides price	€/kg	€ 139.66	€ 128.40	€ 140.81	€ 139.66	€ 128.40	€ 140.81
Molluscicides	kg/yr	4,226	17,314	14,332	13	26	26
Molluscicides price	£/kg	£ 95.41	£ 94.85	£ 101.31	£ 95.41	£ 94.85	£ 101.31
Molluscicides price	€/kg	€ 144.94	€ 152.59	€ 148.62	€ 144.94	€ 152.59	€ 148.62
Others	kg/yr	4,354,979	5,177,252	1,813,238	88	105	35
Others price	£/kg	£ 93.90	£ 91.84	£ 100.98	£ 93.90	£ 91.84	£ 100.98
Others price	€/kg	€ 142.65	€ 147.74	€ 148.14	€ 142.65	€ 147.74	€ 148.14
Machinery:							
Number of tractors	number	19,818	22,702	42,218	167	191	355
Average weight of tractors	Tone	3	3.71	3.79	3.71	3.71	3.79
Total weight of tractors	tonne	73,514	84,211	160,170	619	708	1,348
Other machineries	number	187,640	214,942	399,719	1,579	1,808	3,363
Average weight of other machineries	tonne	1.37	1.37	1.40	1.37	1.37	1.40
Total weight of other machineries	tonne	256,371	293,673	558,571	2,157	2,471	4,699
Average life time (for tractors)	year	12.5	12.5	12.5	12.5	12.5	12.5
Average life time (for other machinery)	year	13.5	13.5	13.5	13.5	13.5	13.5
Materials							
Plastic (for instance for greenhouse and land cover) used for the agricultural sector	tonne/year	no data	no data	no data	no data	no data	no data
Steel (for instance for crop support or small building) used for the agricultural sector	tonne/year	no data	no data	no data	no data	no data	no data
Wood (for instance for crop support or small constructions) used for the agricultural sector	tonne/year	no data	no data	no data	no data	no data	no data
Concrete (for instance for small construction) used for the agricultural sector	tonne/year	no data	no data	no data	no data	no data	no data
Total cost of the above	€	no data	no data	no data	no data	no data	no data

materials							
Work							
Total Farm worker (only the work for agricultural production avoiding the work related to the industrial transformation of agricultural prodcuts)	n° persons	60,075	68,816	67,155	505	579	565
Total applied labor	hrs/year	91,509,331	91,635,049	84,497,400	866,127	867,317	799,760
Unit labor cost	£/hr	£ 4.36	£ 6.27	£ 7.54	£ 4.36	£ 6.27	£ 7.54
Unit labor cost	€/hr	€ 6.62	€ 10.08	€ 11.06	€ 6.62	€ 10.08	€ 11.06
Sheep							
Market sales	ton/year	84,200	72,000	63,400	1,916	1,638	1,443
Energy content as food calories	kJ/100g	1,046	1,046	1,046	1,046	1,046	1,046
Energy content as food calories	kJ/yr	880,732,000,000	753,120,000,000	663,164,000,000	20,039,188,467	17,135,648,095	15,088,890,129
Energy content as food calories	J/yr	8.81E+14	7.53E+14	6.63E+14	2.00E+13	1.71E+13	1.51E+13
Economic value on the local market that year	£/year	£ 103,380,480	£ 110,080,000	£ 130,600,000	£ 2,352,204	£ 2,504,637	£ 2,971,526
Economic value on the local market that year	€year	€ 157,055,625	€ 177,085,696	€ 191,590,200	€ 3,573,468	€ 4,029,209	€ 4,359,229
Cattle							
Market sales	ton/year	190,100	158,710	190,300	2,236	1,867	2,238
Energy content as food calories	kJ/100g	1,046	1,046	1,046	1,046	1,046	1,046
Energy content as food calories	kJ/yr	1,988,446,000,000	1,660,106,600,000	1,990,538,000,000	23,387,469,295	19,525,645,722	23,412,074,733
Energy content as food calories	J/yr	1.99E+15	1.66E+15	1.99E+15	2.34E+13	1.95E+13	2.34E+13
Economic value on the local market that year	£/year	£ 315,011,061	£ 275,960,000	£ 383,600,000	£ 3,705,060	£ 3,245,754	£ 4,511,781
Economic value on the local market that year	€year	€ 478,564,804	€ 443,936,852	€ 562,741,200	€ 5,628,727	€ 5,221,444	€ 6,618,783
Poultry							

Market sales	ton/year	114,500	136,800	96,200	10	11	8
Energy content as food calories	kJ/100g	589	589	589	589	589	589
Energy content as food calories	kJ/yr	674,405,000,000	805,752,000,000	566,618,000,000	56,037,515	66,951,371	47,081,301
Energy content as food calories	J/yr	6.74E+14	8.06E+14	5.67E+14	5.60E+10	6.70E+10	4.71E+10
Economic value on the local market that year	£/year	£ 62,332,680	£ 92,610,000	£ 74,100,000	£ 5,179	£ 7,695	£ 6,157
Economic value on the local market that year	€year	€ 94,695,807	€ 148,981,707	€ 108,704,700	€ 7,868	€ 12,379	€ 9,032
Pigs							
Market sales	ton/year	58,100	64,700	60,400	17	19	18
Energy content as food calories	kJ/100g	915	915	915	915	915	915
Energy content as food calories	kJ/yr	531,615,000,000	592,005,000,000	552,660,000,000	157,155,456	175,007,883	163,376,756
Energy content as food calories	J/yr	5.32E+14	5.92E+14	5.53E+14	1.57E+11	1.75E+11	1.63E+11
Economic value on the local market that year	£/year	£ 60,954,015	£ 57,770,000	£ 55,600,000	£ 18,019	£ 17,078	£ 16,436
Economic value on the local market that year	€year	€ 92,601,340	€ 92,934,599	€ 81,565,200	€ 27,375	€ 27,473	€ 24,112
Eggs							
Harvest	number	703,000,000	725,000,000	831,000,000	58,414	60,242	69,049
Harvest	ton/year	40,774	42,050	48,198	3	3	4
Energy content as food calories	kJ/100g	596	596	596	596	596	596
Energy content as food calories	kJ/yr	243,013,040,000	250,618,000,000	287,260,080,000	20,192,387	20,824,297	23,868,953
Energy content as food calories	J/yr	2.43E+14	2.51E+14	2.87E+14	2.02E+10	2.08E+10	2.39E+10
Economic value on the local market that year	£/year	£ 27,800,000	£ 24,400,000	£ 30,600,000	£ 2,310	£ 2,027	£ 2,543
Economic value on the local market that year	€year	€ 42,233,760	€ 39,252,280	€ 44,890,200	€ 3,509	€ 3,262	€ 3,730
Milk							
Harvest	litre/year	1,236,591,479	1,200,000,000	1,273,000,000	634,043	615,282	652,711

Harvest	g/year	1,273,689,223,058	1,236,000,000,000	1,311,190,000,000	653,064,604	633,740,033	672,292,552
Energy content as food calories	kJ/100g	274	274	274	274	274	274
Energy content as food calories	kJ/yr	3,489,908,471,178	3,386,640,000,000	3,592,660,600,000	1,789,397,015	1,736,447,691	1,842,081,592
Energy content as food calories	J/yr	3.49E+15	3.39E+15	3.59E+15	1.79E+12	1.74E+12	1.84E+12
Economic value on the local market that year	£/year	£ 246,700,000	£ 245,100,000	£ 264,200,000	£ 126,492	£ 125,671	£ 135,464
Economic value on the local market that year	€year	€ 374,786,640	€ 394,292,370	€ 387,581,400	€ 192,166	€ 202,167	€ 198,726
Wool							
Harvest	ton/year	11,280	9,000	8,000	257	205	182
Energy content as food calories	J/yr	na	na	na	na	na	na
Economic value on the local market that year	£/year	£ 6,500,000	£ 4,000,000	£ 2,400,000	£ 147,894	£ 91,012	£ 54,607
Economic value on the local market that year	€year	€ 9,874,800	€ 6,434,800	€ 3,520,800	€ 224,680	€ 146,410	€ 80,108
Main Crops…							
Barley	Area (ha)	329,114	316,400	320,600	1,327	1,276	1,293
Harvest	ton/year	1,676,000	1,915,700	1,678,000	7,270	8,310	7,279
Energy content as food calories	kJ/100g	1,282	1,282	1,282	1,282	1,282	1,282
Energy content as food calories	kJ/yr	21,486,320,000,000	24,559,274,000,000	21,511,960,000,000	93,205,901,913	106,536,125,475	93,317,126,140
Energy content as food calories	J/yr	2.15E+16	2.46E+16	2.15E+16	9.32E+13	1.07E+14	9.33E+13
Economic value on the local market that year	£/year	£ 145,500,000	£ 198,400,000	£ 222,900,000	£ 586,765	£ 800,098	£ 898,900
Economic value on the local market that year	€year	€ 221,043,600	€ 319,166,080	€ 326,994,300	€ 891,414	€ 1,287,117	€ 1,318,687
Wheat	Area (ha)	109,675	108,900	102,700	6	6	6
Harvest	ton/year	824,000	617,000	832,100	45	33	48
Energy content as food calories	kJ/100g	1,174	1,174	1,174	1,174	1,174	1,174

Energy content as food calories	kJ/yr	9,673,760,000,000	7,243,580,000,000	9,768,854,000,000	529,223,251	390,448,252	562,160,926
Energy content as food calories	J/yr	9.67E+15	7.24E+15	9.77E+15	5.29E+11	3.90E+11	5.62E+11
Economic value on the local market that year	£/year	£ 75,600,000	£ 63,400,000	£ 96,700,000	£ 4,136	£ 3,417	£ 5,565
Economic value on the local market that year	€year	€ 114,851,520	€ 101,991,580	€ 141,858,900	€ 6,283	€ 5,498	€ 8,163
Oilseed Rape	Area (ha)	49,895	36,400	36,300	120	120	146
Harvest	ton/year	161,000	105,900	137,100	387	348	550
Energy content as food calories	kJ/100g	1,078	1,078	1,078	1,078	1,078	1,078
Energy content as food calories	kJ/yr	1,735,580,000,000	1,141,602,000,000	1,477,938,000,000	4,174,157,731	3,755,368,777	5,924,373,509
Energy content as food calories	J/yr	1.74E+15	1.14E+15	1.48E+15	4.17E+12	3.76E+12	5.92E+12
Economic value on the local market that year	£/year	£ 38,600,000	£ 24,700,000	£ 31,400,000	£ 92,835	£ 81,252	£ 125,868
Economic value on the local market that year	€year	€ 58,641,120	€ 39,734,890	€ 46,063,800	€ 141,035	€ 130,710	€ 184,649
Potatoes	Area (ha)	27,032	29,300	29,100	7	7	-
Harvest	ton/year	1,000,000	1,131,900	1,415,700	259	267	-
Energy content as food calories	kJ/100g	298	298	298	298	298	298
Energy content as food calories	kJ/yr	2,980,000,000,000	3,373,062,000,000	4,218,786,000,000	771,678,011	796,641,264	-
Energy content as food calories	J/yr	2.98E+15	3.37E+15	4.22E+15	7.72E+11	7.97E+11	0.00E+00
Economic value on the local market that year	£/year	£ 80,200,000	£ 126,000,000	£ 208,300,000	£ 20,768	£ 29,758	£ -
Economic value on the local market that year	€year	€ 121,839,840	€ 202,696,200	€ 305,576,100	€ 31,551	€ 47,872	€ -
Oats	Area (ha)	27,235	21,300	20,900	71	56	55
Harvest	ton/year	125,000	114,600	123,600	327	299	323
Energy content as food calories	kJ/100g	1,038	1,038	1,038	1,038	1,038	1,038
Energy content as food calories	kJ/yr	1,297,500,000,000	1,189,548,000,000	1,282,968,000,000	3,390,665,631	3,108,562,251	3,352,690,176

Energy content as food calories	J/yr		1.30E+15		1.19E+15		1.28E+15		3.39E+12		3.11E+12		3.35E+12
Economic value on the local market that year	£/year	£	11,900,000	£	13,100,000	£	12,700,000	£	31,065	£	34,198	£	33,154
Economic value on the local market that year	€year	€	18,078,480	€	21,073,970	€	18,630,900	€	47,194	€	55,014	€	48,636
Other Crops (inc Fruit & Veg)	Area (ha)		21,061		22,570		31,056		116		124		171
Harvest	ton/year		528,149		528,149		528,149		1,031		1,031		1,031
Energy content as food calories	J/yr		8.97E+11		8.97E+11		8.97E+11		1.68E+09		1.68E+09		1.68E+09
Economic value on the local market that year	£/year	£	43,630,000	£	93,500,000	£	157,600,000	£	240,235	£	514,828	£	867,774
Economic value on the local market that year	€year	€	66,282,696	€	150,413,450	€	231,199,200	€	364,965	€	828,204	€	1,273,025

3.6 MuSIASEM Familiarisation and Data Gathering

MuSIASEM is significantly different from the other DECOIN tools as it defines a series of principles, approaches and metric types (Giampietro 2004;Giampietro & Mayumi 2000). Implementation of a MuSIASEM analysis therefore entails an initially steeper learning curve[4] for new analysts and a corresponding higher resource requirement. This means that while at this stage there is less material to present in terms of results for the MuSIASEM based aspects, the capacity of the Scotland research team to undertake the analysis independently is greater than for the SUMMA analysis. The nature of the MuSIASEM analysis is such that after this initial investment has been made then there is an incremental increase in complexity and demand for data as the case study proceeds. This allows the analysts to step into the complexity of the interactions within and between systems in an exploratory way. There is, however, the need for great care in deciding which of the multiple avenues available for exploratory analysis are most significant. This cannot always be determined *a priori* and a reflexive process referring back to the issues and key components identified with the stakeholders is necessary to maintain focus and salience.

For the Scotland case study the focal geographical scale is the CNP (n) with Scotland at n+1. Scotland was chosen as n+1 rather than local authority regions since as noted in Section 2.3, the CNP maps onto three local authorities and overall statistics for the authorities do not reflect the portions within the Park. Since one of the aims for the Scotland case study is to explore the role of land as a key factor/constraint in assessing the sustainability of a system then a key n-1 scale disaggregation will be by land use. Previous analyses in developing (Laos) and other countries (i.e. China) have looked at a village and regional-scale land use patterns and enterprise mix, sometimes spatially explicitly (Vehmas et al 2008). These analyses have used the concept of colonised and non-colonised land, but in situations where primary production is either a dominant (Laos) or significant (China) activity for much of the population. Land use in CNP is a key factor in terms of area (all, or nearly all the land is claimed as managed) but in a post-productivism and service/leisure/non-consumption/non-exclusive-use dominated system it will be necessary to develop further the analysis of what is sustainable land use.

The MuSIASEM approach emphasises cross-checking between scales and sectors (the Sudoku effect), partly to overcome issues of missing data, but mainly to gain a better understanding of the dynamics of a system. A key aspect for the CNP analysis is the identification and accounting for external resources (financial, goods and services) that are required to maintain a system, where these resources are being generated (and indeed at what cost – financial or environmental). An emphasis on comparing different scales and aggregations combined with the use of both extent and intensity variables (with external referents) is seen by the research

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[4] Two bi-lateral workshops with the MuSIASEM team have been undertaken 5 days in May 2008, and 3 days in March 2009.

team as being likely to deliver information that is useful for the development of actions and policies to support the CNPA in achieving its objectives. More widely the MuSIASEM approach represents one of the most promising means of making operational the analysis of concepts from the social-ecological systems literature (Gunderson & Holling 2002;Walker & Salt 2007) for example resilience, adaptive cycles, lock-in and the potential for collapse in complex coupled social-ecological systems.

MuSIASEM documentation (Vehmas et al 2008) does provide examples of generic metrics that have been found to be insightful across a range of case studies. As part of building up the Scotland team's expertise with MuSIASEM we have been investigating sources of information needed to support these generic metrics and structuring the available data either in Oracle database tables or GIS layers. Our concern here is the need to generate a capacity within the research team to undertake repeated analyses with stakeholders in a co-learning fashion. Our past experience is that a shared understanding of issues and the analyses required need to be refined over time and that investment in flexible data storage, integration and manipulation capacity is rarely a wasted effort. Previous research has also emphasised that, however robust the analysis, poor presentation of outcomes can reduce comprehension and jeopardise understanding, thus risking inappropriate responses.   Since MuSIASEM type analyses are almost certainly beyond the experience of most if not all policy and management stakeholders then there is a key need to pilot and test the best way to communicate results. Several examples are available from the DECOIN research and we have also been developing/testing simple software tools to assist in visualisation, e.g. the automated creation of the *Impredictive Loop* figures.

There is a generic issue across all the dimensions that published data (often because of confidentiality undertakings) are published as aggregated outputs, often on a changing basis. These changes reflect the need to support particular policy measures but without some standardisation or attention to continuity, the utility of time series data in assessing patterns of sustainability over time can be seriously compromised. Even when no confidentiality issues exist, there is still a tendency to publish headline figures alone rather than making available the much larger datasets that underpin them (and could usefully be aggregated in other ways). This tends to reflect paper-based publishing traditions that have yet to be revised with the greater use of online sources.

The following sections summarise the state-of-play and issues faced for each of the key data types for the MuSIASEM analysis.

3.6.1 Demography

Information is provided in detail by the decadal UK Census (most recently in 2001), this data is available at scales smaller than the CNP (see Figure 10). The Census is supplemented by a wide range of other sources that provide yearly or 5-yearly updates for key policy relevant variables (e.g. Scottish Neighbourhood statistics). The spatial unit for these supplementary surveys are generally larger and sometimes are available only at Local Authority level (which makes them of very limited use for the CNP focused analysis) – see the overlap of LA and CNP in Figure 4. For household data the Census is again an excellent source but the more frequent panel surveys (e.g. British Household Panel Survey) is again available only for larger spatial units. For time use there is a comprehensive survey published every 5 years (The Time Use Survey) but in this case the results are UK wide with some limited age/sex breakdowns. For tourism and recreation numbers there are yearly surveys, with monthly breakdowns both for employment and visitor numbers (as part of the Scarborough Tourism Economic Activity Monitor (STEAM) based analysis for the CNP).

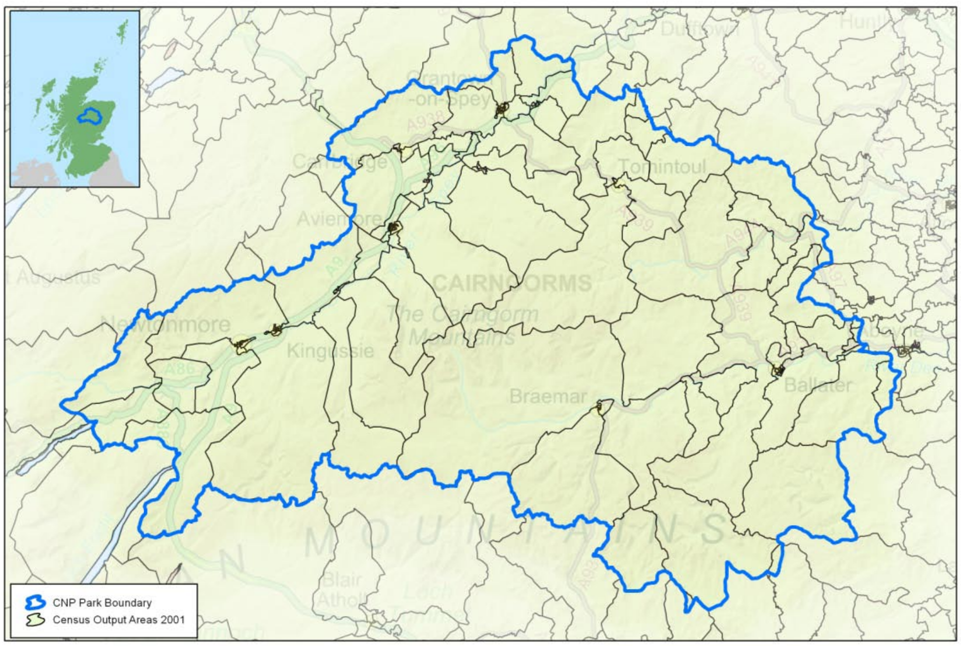

Figure 10: CNP - Census Output Areas

3.6.2 Financial

This presents the biggest dichotomy between highly detailed statistics for some sectors (Agriculture) and/or scales (Scotland-wide) and the seeming complete absence of data in others. For the CNP-scale analysis there is ongoing discussion of using a GRIT[5] based approach to disaggregating (van Leeuwen 2008) some of the National or Local Authority statistics (particularly GVA figures), with SMILE partners from the Vrije Universiteit, Amsterdam), but this does depend on the availability of (ongoing) local survey data from the CNPA.

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[5] Generating Regionalised Input-Output Tables.

3.6.3 Energy

This is the aspect for which the Scotland research team have the least experience so any conclusions drawn are tentative and reflect our experience. Information on energy consumption in either physical or financial terms was quite limited and badly fragmented across a range of agencies/sources (compared for example with the coordination provided by the Agricultural Census). The area, however, is one in which there seems to be significant progress being made, with new datasets becoming available. In no case have we been able to access energy data below the geographical scale of whole-Scotland though some sectoral breakdowns are made (though these tend to be to specific climate change related sectors rather than more standardised divisions). Some effort is being made by Scottish Government to back-calculate previous years so the situation for making historical comparisons is likely to improve somewhat.

3.6.4 Materials

Some accounting of material use by sector and commodity group is available as part of the Scotland Input/Output (I/O) tables. Geographically these tables are limited to an all Scotland scale, are quoted in financial terms (with conversion to physical quantities a non trivial task), and are publically available only for 2001 and 2004. The Scotland team are investigating whether a more recent I/O table is available but not published and when it is planned to update what is a key dataset for other research and policy agencies in Scotland. Particular commodities (wood, deer culled, fish caught etc) can be sourced from individual agencies and organisations but this can be a particularly laborious task and inevitably there are key commodities for which no records exist.

3.6.5 Land

As noted in the SUMMA data gathering section, land use (Figure 11) and related statistics for fixed and variable resources, tenure (Figure 12), and financial support from national government/EU (Figure 13) are well provided for. Where there are more serious issues of data availability are in terms of reliable information on particular management regimes, stocks or changes in semi-natural land covers (see Figure 14) and in species distributions and numbers.

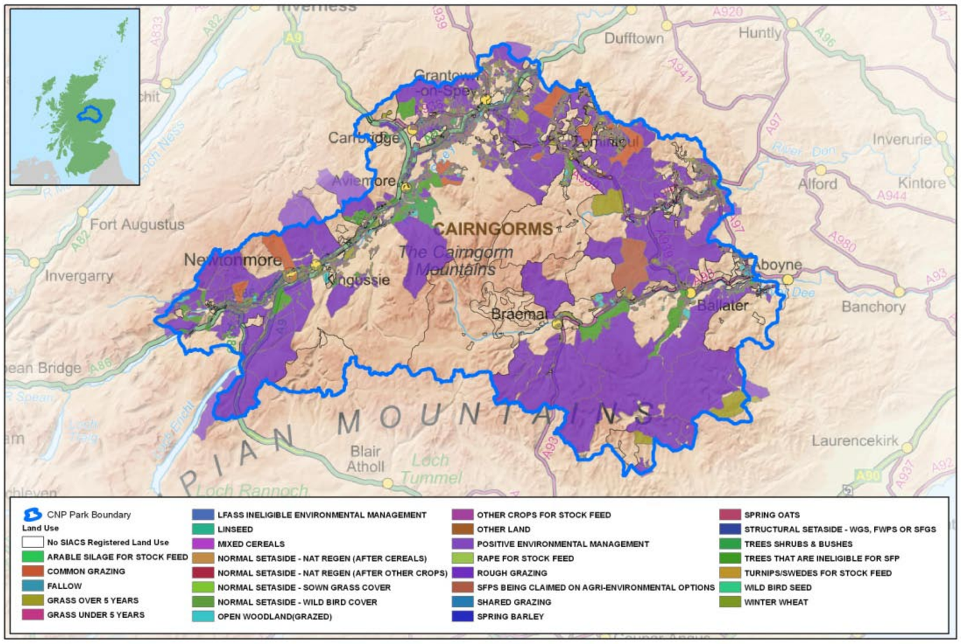

Figure 11: Land Use in the CNP

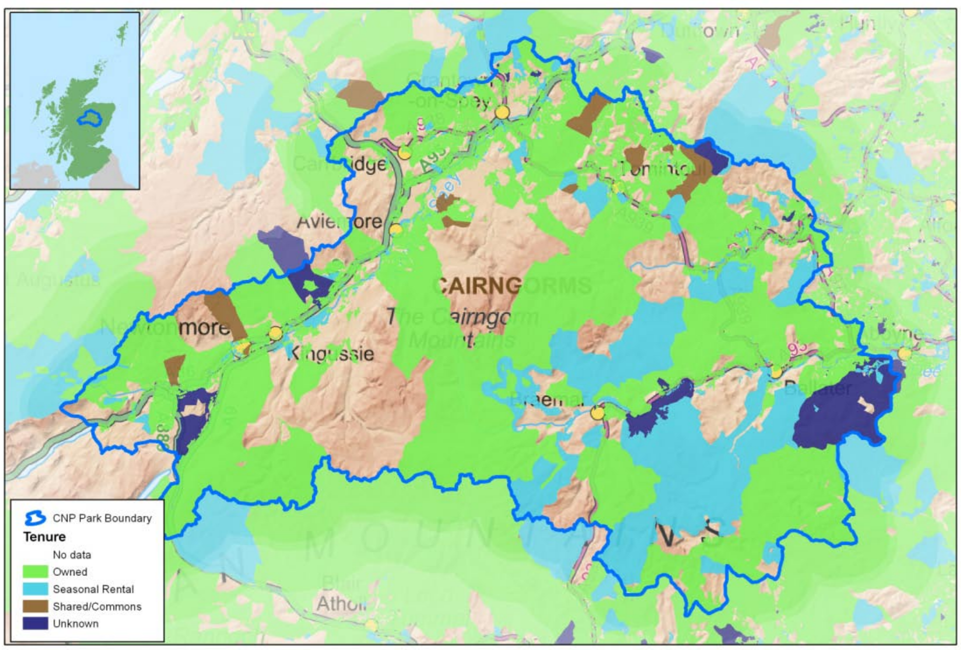

Figure 12: Land Tenure in the CNP

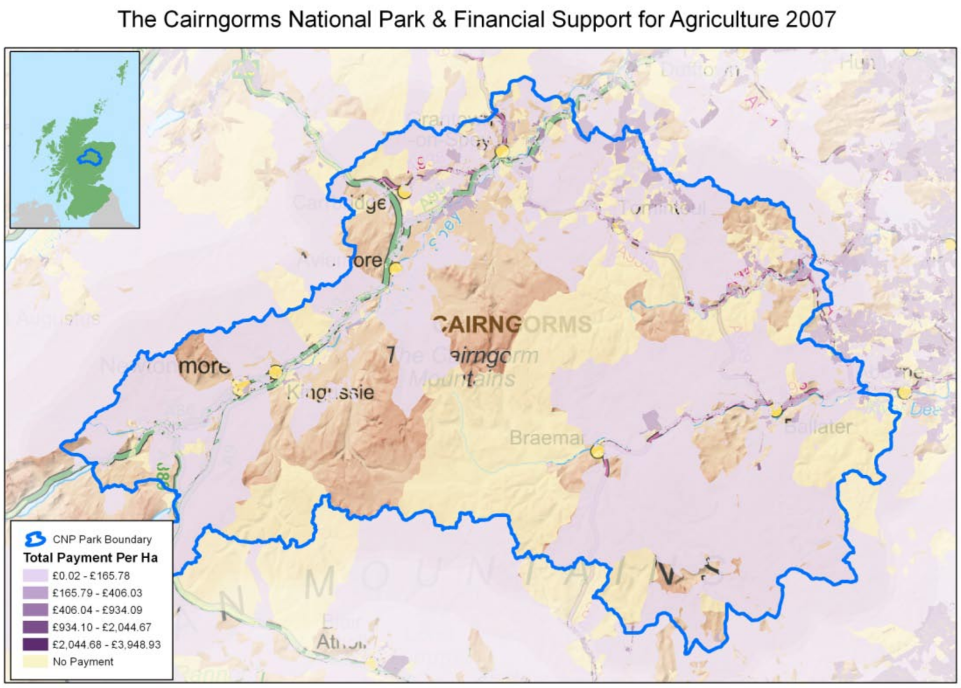

Figure 13: Support Payments per Ha in the CNP

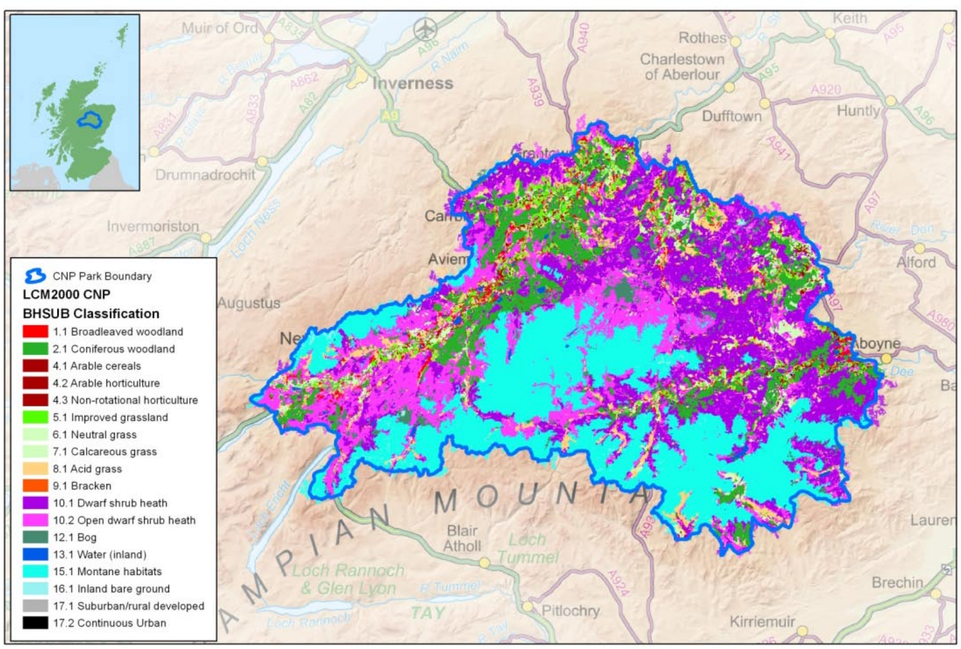

Figure 14: Land Cover in the CNP - from Land Cover GB 2000

3.7 SUMMA Results and Indicators

One of the strengths of SUMMA is in its ability to conduct a full physical accounting of the performance of a system. In particular SUMMA makes available for use in a structured way a multiplicity of technical coefficients from a wide range of sources. These technical co-efficients are the basis on which input data values can be converted into a coherent set of sustainability indicators. SUMMA produces a true multi-parameter systems characterisation from which it is possible to gain a holistic understanding of the functioning of the system of interest. The SUMMA tool is, however, demanding in the range and complexity of the input variables required, and the importance of accuracy in key parameters cannot be overstated. This means that there is a strong dependence on the SUMMA team not only in developing the analytical framework but also in highlighting which input variables are critical and which can bear some uncertainty.

There is a significant challenge (yet to be undertaken) in making meaning from the raw results. In effect how to build a narrative that is both compressive while being comprehensible. The Macaulay team have seen in previous research-based communication in the climate change domain that stakeholders can cope with significant complexity (McCrum et al. 2009). They, however, need to be “stepped into” the issues in a structured way that increases their confidence and enhances the credibility of the data rather than leaves them feeling overwhelmed and the analysis as a “black box”. This process will need to be guided by the experience and knowledge of the SUMMA team allied to the issue/stakeholder knowledge of the Macaulay team. This process will be undertaken as part of the assessment of utility in WP5.

In the interim we are presenting simple views of the initial SUMMA results under the four headings below.

3.7.1 SUMMA - Material Flow Accounting

Figure 15 (below) presents for the crop, livestock and all components of the production-oriented land-based industries (PoLbI) systems, the material intensity factors in terms of abiotic material and water use per unit of economic value (€), per unit of dry matter (g) and per unit of energy (J). The analysis also presents the material intensity of the PoLbI per ha and per year. The ratio of global to locally sourced materials is also presented. The key aspect of interest here is that for the CNP the intensity of resource use is higher than the Scotland average. This reflects the marginal nature of PoLbI in the CNP and is interpreted as reflecting the need for higher levels or inputs to achieve the same outputs or returns. While water availability is unlikely to be a key factor in the CNP (even under climate change) the consequences of the intensity of water use for the sustainability of the CNP need to be investigated further. Finally the global to local ratio needs to be understood better (perhaps as a way of characterising the degree of additional re-localisation that may be possible).

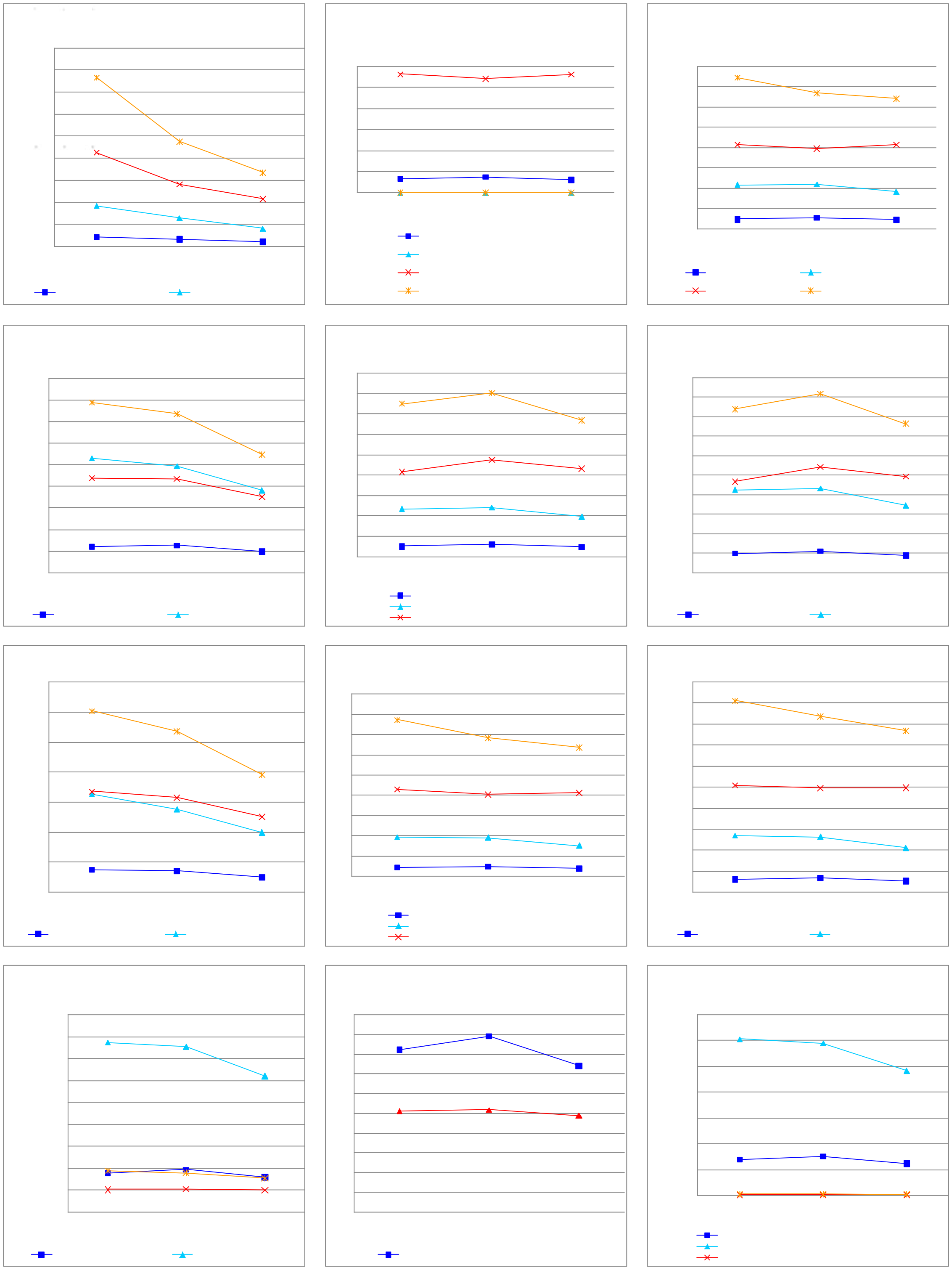

Figure 15: Outputs from SUMMA - Material Flow Accounting

3.7.2 SUMMA- Relevant Emissions

The profile of emissions for the PoLbI of the CNP and Scotland are likely to be influential since emissions reductions have been given a very high profile by Scottish Government (with binding emissions targets proposed in the Climate Change (Scotland) Act published in 2009[6]). While the full interpretation of the SUMMA emissions profiles is beyond the capability of the Macaulay team at present it can be seen even from the first "triple" of graphs that there are interesting contrasts (Figure 16). While total emissions (extent) from the park are very small (Scotland is approximately two orders of magnitude bigger) the rate emissions of CO_2 per ha for Scotland is only three times higher. Indeed in terms of emissions per € it is the park that is seen to be "inefficient" with a higher intensity, reflecting the difficulties of undertaking PoLbI in marginal areas.

[6] http://www.opsi.gov.uk/legislation/scotland/acts2009/pdf/asp_20090012_en.pdf

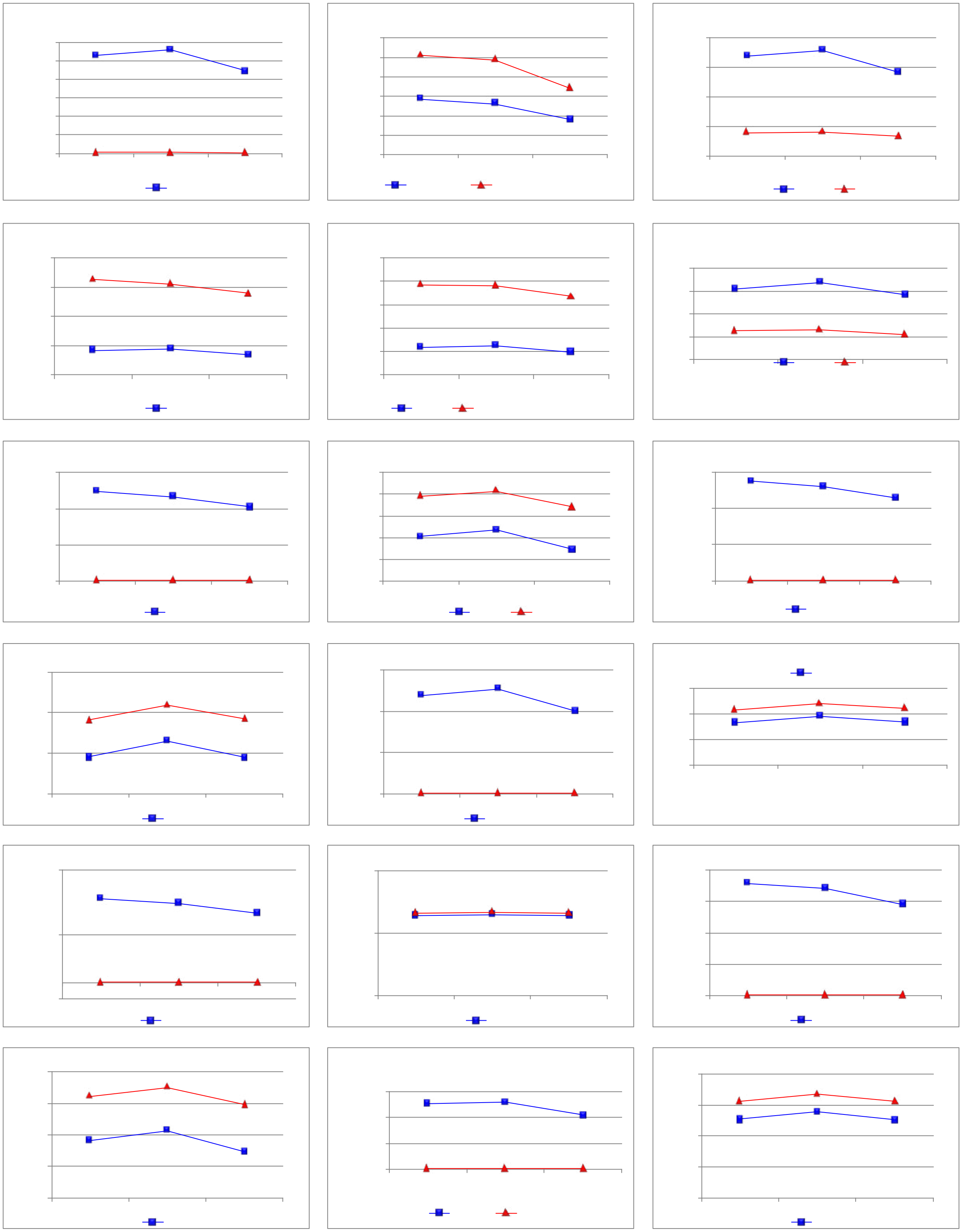

Figure 16: Outputs from SUMMA - Relevant Emissions Analysis

3.7.3 SUMMA - Embodied energy indicators

Figure 17 presents a series of comparisons of the CNP and Scotland in terms of the intensity of energy use. As before, these ratios are presented in terms of per unit of value (€), dry matter (g) and per unit of energy (J). The other side of the ratios is defined either in grams of oil equivalent or Joules. In all cases (as with other indicators) the intensity for the CNP is higher than the average for Scotland reflecting the lower productivity. It is, however, interesting to note the apparent trend for energy intensity to decrease (resulting in an overall improvement in the Energy Return on Investment (EROI). These indicators do, however, need further investigation to determine if it is due to changes in efficiency of resource use or change to the mix of activities or management.

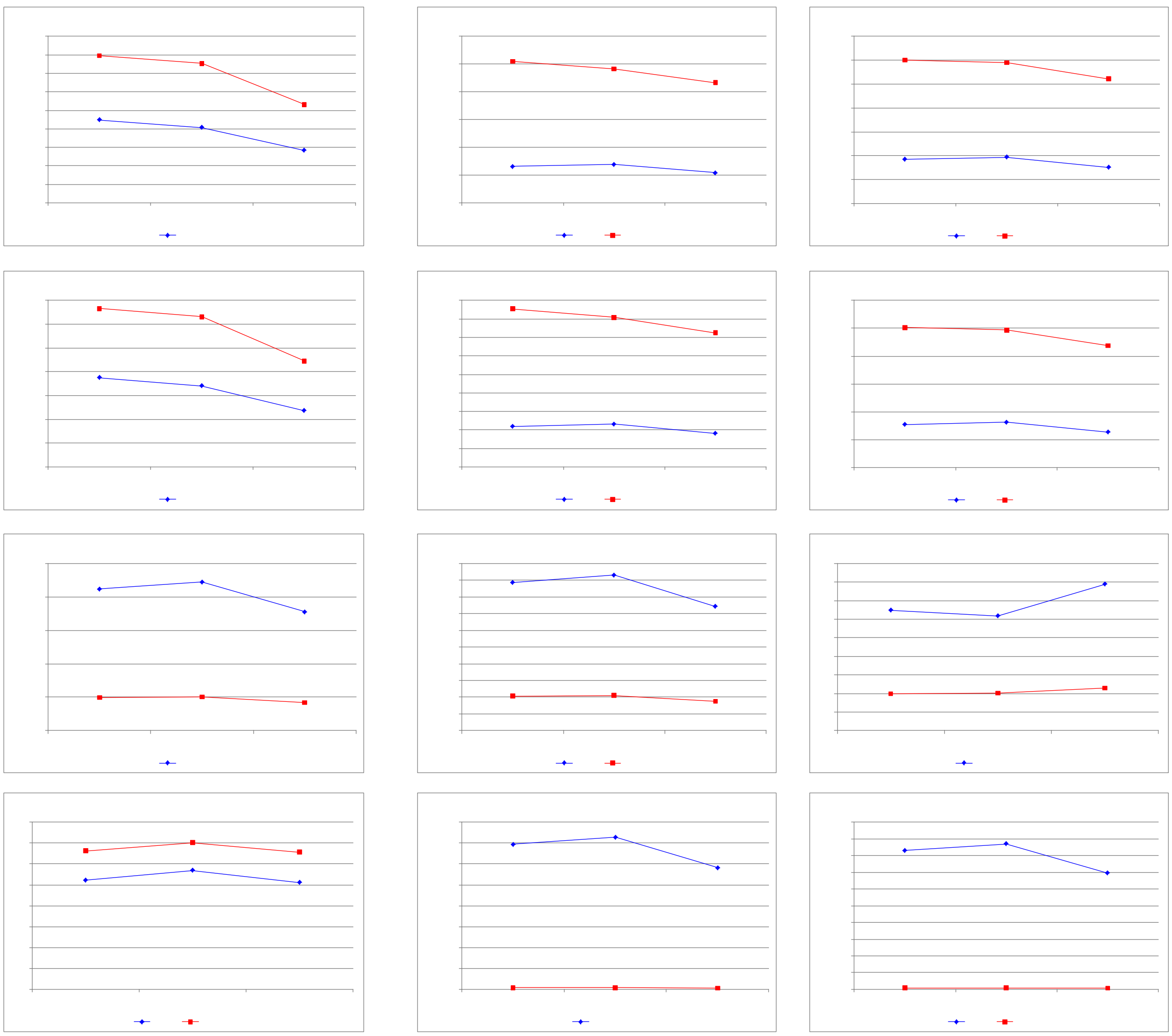

Figure 17: Outputs from the SUMMA - Embodied Energy Indicators

3.7.4 SUMMA - Emergy Indicators

These indicators provide a sophisticated analysis of the overall performance of a system at a global (overall) level. The indicators seek to characterise the systems in terms of the burden (or footprint) that it imposes on the eco-sphere. They take account of free environmental inputs (sunlight, wind etc) as well as the burden embodied in the labour and services that support the particular activities/systems under investigation. The historic burden on the eco-sphere of resource formation is also included within the accounting. Figure 18 presents comparisons for Scotland and the CNP using "headline" emergy indicators. The analysis is presented both with and without the labour and services included. This is particularly important as there remain significant debates over how best to include labour and services in such analyses (SMILE meeting notes). The most significant result at this stage is that the Renewable Emergy Requirement for the CNP is 3x Scotland but still only 6%.

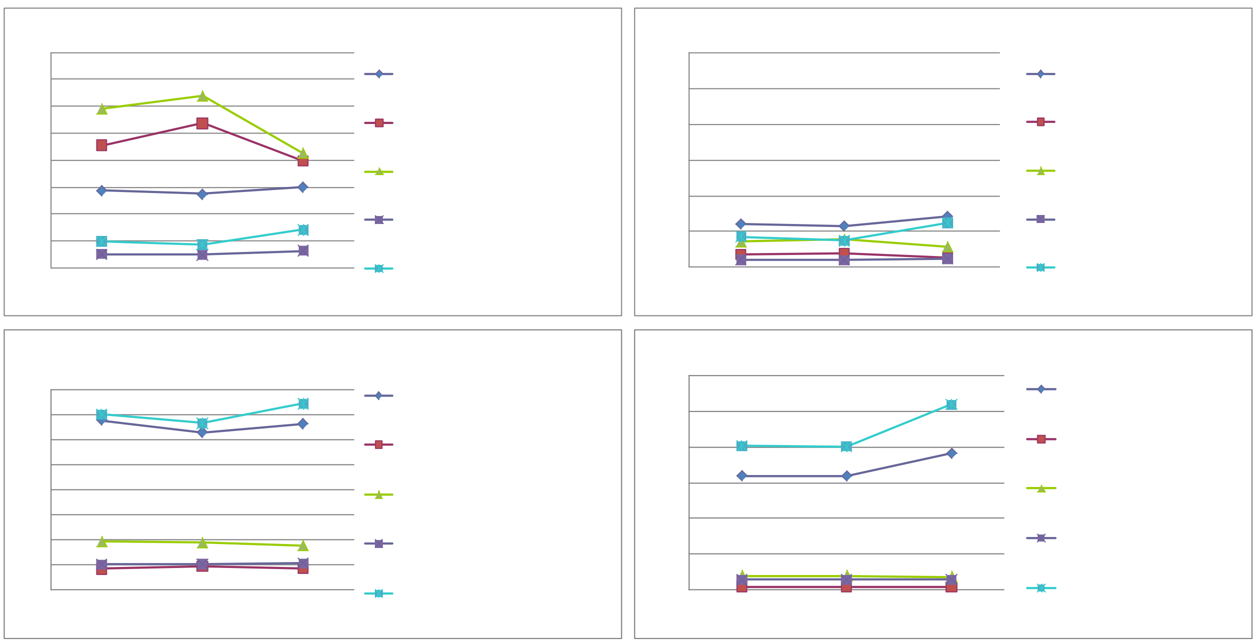

Figure 18: Outputs from SUMMA - Emergy Indicators

3.7.5 Caveats to the SUMMA analysis

It is important to note that the results presented here are provisional since they have yet to be verified through a process of quality control and sensitivity analysis (to be undertaken in SMILE WP4). There are also representational issues to be resolved in understanding how best to reconcile the livestock and crop sectors into a whole systems characterisation. It is also worth noting that there is considerable potential to disaggregate the SUMMA results to smaller geographical scales. Results reported at the whole CNP scale are potentially misleading since the emissions and resource use are in reality concentrated on the most productive land and more intensive land use systems.

3.8 MUSIASEM – Indicative Results

As noted previously the initial available resources and the significant data requirements of the SUMMA analysis means that there has been less progress with the MuSIASEM based part of the case-study. The figures below present some of the initial assessments of Scotland's sustainability at a national or sectoral level for 2007. For each of the Figures there is some limited interpretation but the utility of the analyses is limited by their partial natures (not all sectors are represented) and the lack of external referents standards (e.g. indicator values from other countries/regions) against which to judge the performance of Scotland. It will also be necessary to develop time series of the assessments to allow for interpretation of historical change. Even these limited analyses have, however, raised significant issues of how best to communicate the analysis to stakeholders. We would intend to focus on the development of the MuSIASEM based components of the Scotland case study in 2010-11.

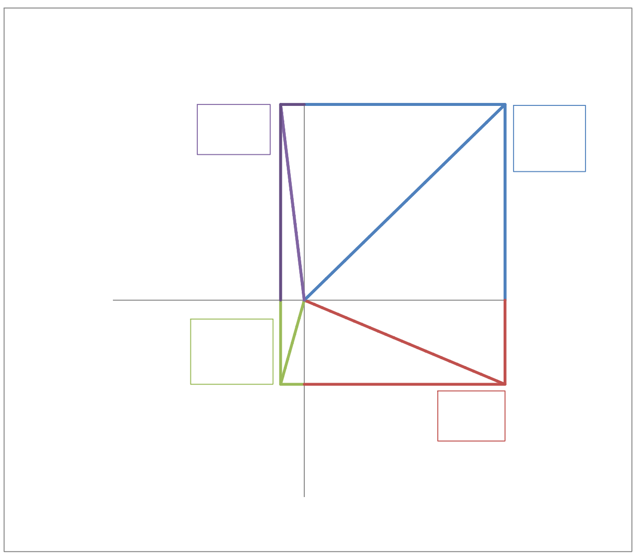

Figure 19: Characterising Scotland's Sustainability - 1. Human Activity and Energy

Figure 19 presents a MuSIASEM diagram relating human activity (a fund) and energy throughput (a flow). The figure shows two ratios – one of the energy intensity of the paid work sector (for Scotland this is ~47MJ/h) and for all activities (13MJ/h). This compares with 150 MJ/h for paid work and 16 MJ/h for the OECD reflecting the post-industrial mix of economic activities typical of NW Europe.

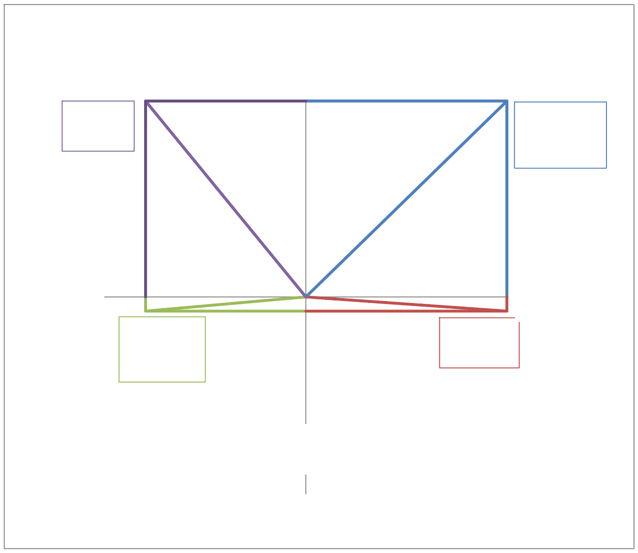

Figure 20: Characterising Scotland's Sustainability - 2. Financial Productivity of Land Use

Figure 20 presents a second MuSIASEM diagram that presents the share of land resources devoted to agriculture and forestry (79%[7]) and the added value for the sector (1.79%). Indeed this would be even lower if the EU subsidies were not included in added-value. This reflects the economic marginalisation of land-based industries in the UK.

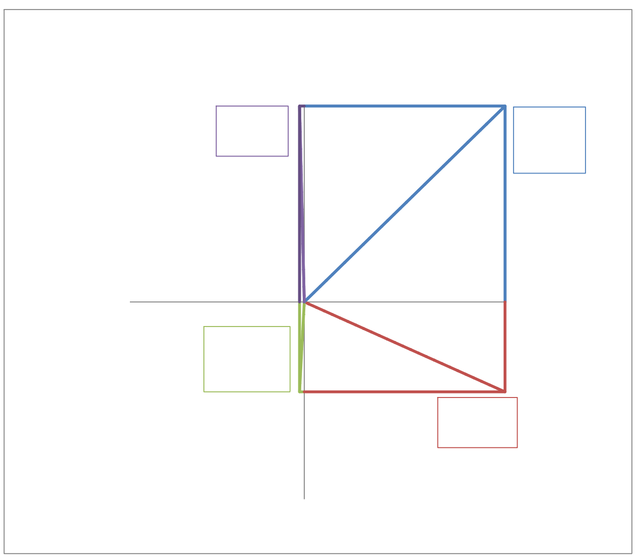

Figure 21: Characterising Scotland's Sustainability - 5. Financial Productivity of Labour (rescaled)

Figure 21 presents the labour productivity for the same sector (agriculture and forestry). While the total fund created by the activity is very small (1.8% of GVA) the high levels of investment in capital machinery mean that the sector is relatively productive on a per hour of labour basis (40£/h of GVA)

[7] Note here the definition of agriculture and forestry encompasses all land managed for sources of food and fibre so that the majority of land will have very low levels of management intensity.

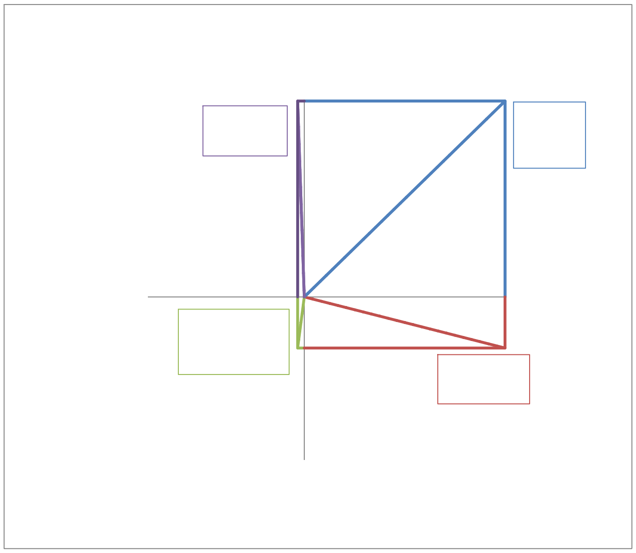

Figure 22: Characterising Scotland's Sustainability - 3. Financial Productivity of Labour in the Public, Education, Health and Other sectors

By contrast the public, education, health and other services sector is very large (26% of GVA) but its productivity as reasonably expected for such a sector is low at 16 £/h. These figures need external referents, however, for a full interpretation of their significance.

3.9 Trends, Simulations and Scenarios Analysis

No activity has been undertaken on trend, simulation and scenarios analysis. The limited availability of time series data, particularly for the n and n-1 scales is likely to limit the potential application of ASA approaches within the CNP case study. There are options for undertaking simple counterfactual analyses using the *Impredictive Loop* analyses as part of the MuSIASEM analysis. The interests of the CNPA are also focused on using the DECOIN tools in a *post hoc* assessment role rather than for future scenarios.

3.10 Deliberation on Policy Issues

As the Macaulay team become more proficient with the SUMMA and MuSIASEM tools and as the case-study becomes more developed, it is intended that there will be a series of meetings with relevant CNPA and other stakeholders to assess the utility of the analyses, how best to communicate the outputs and if it is possible to embed the DECOIN tools into ongoing processes of sustainability assessment. The first of these meeting is scheduled with CNPA officials in spring 2010. This will be undertaken as part of SMILE WP5.

4 Discussion

This section draws attention to the areas where there was difficulty including aspects of the system identified in the diagrams and spread sheets within the formal models in the DECOIN toolkit. If the formal representation of the system is not both coherent and complete, the quantitative outputs will not help us to truly understand system performance.

4.1 Systems diagramming

The elements of the diagrams were categorized as described in section 2.4 above. The researcher's diagram had 107 elements; the CNPA policy makers' diagram had 57 elements; and the content analysis diagram had 212 elements. These differences are a result of the different amount of time taken to construct each diagram and to what degree issues were 'lumped' or 'split'. In terms of classification, the three most interesting areas for potential analysis within our case study are:

- Those that are exogenous in origin but play out in the Park (e.g. policies);
- Those that are endogenous but are also found elsewhere too, as they helped us look at relationships across the system boundary; and
- Those that are unique to the system, which a more generic and deductive framework might miss out.

These elements were put into higher level 'clusters' during the diagram process; to help us abstract from the detail being recorded and identify the relationships within the system; and across the system boundary. These clusters are not 'perfect' but capture the broad output of the workshop/process that we underwent. Using a process of comparing and contrasting the elements and clusters from each diagram; alongside the field notes recorded during the workshops and as the content analysis was being done; the authors identified a set of clusters that reflect the content of all three diagrams. They are listed below (in alphabetical order):

- Governance & Land Tenure;
- Habitats and Species;
- History & Culture;
- Knowledge, Skills, Management;
- Land Use & associated industries;
- People (multiple types);
- Settlements & Infrastructure; and
- Tourism & Recreation.

Some of the external factors that influence the elements of the CNP system were listed as the economic context, institutions, climate change, and regional effects such as proximity to major settlements (e.g. Inverness).

We have learnt three lessons from this diagramming process. Firstly, the outputs of the process will reflect the world views of who participates. It is vital to carefully record how participants generate and 'map' the components of the system – it is the meanings embodied in these choices that are important rather than the categories themselves (Kesby et al. 2007). This process could be done with more sets of stakeholders but represents the maximum investment we could afford to make within this deliverable. We recommend that a more complete process is provided for in the timescale of future projects.

Secondly, we could have used other deductive sustainability frameworks, such as Tabara & Pahl-Wostl's (2007) or Newell *et al.*'s (2005) approaches to analyse the diagrams. These conceptual models were, perhaps, too different to be compatible with the formal models to act as checks on the analysis. However, using alternative frameworks for assessing sustainability would provide another lens on whether the DECOIN energy systems diagram does capture enough of the complexity of socio-ecological systems required for sustainability science.

Thirdly, the discursive approach to our diagramming created an '*unholy mess of different types of concepts and often composite issues within one post-it note*' (field notes). Therefore, our analysis had to deal with things that were incommensurable; at different resolutions; and many were repetitions of similar things, yet not the same. This demonstrated the richness and complexity of the system and its many possible interpretations but did not help with the classification system. It raised an epistemological issue about whether to represent what the post-its said or whether to abstract early on, to come up with a more manageable set of categories for classification.

The analysis of why such problems occurred returns to the way sustainability is conceptualised and presented. Stocks and flows are useful concepts for bio-economic modelling but this approach has some challenges. Firstly, it does not take an interpretive approach whereby people interpret the same component in different ways and secondly, it does not capture the institutional aspects that enable a stock to become a flow. This problem of how to handle the transformative nature of human aspects of a complex socio-ecological system also pertains to the capital coding. It was important to consider how some of the capitals are stocks that are generated *by* flows; whilst others are stocks that *generate* the flows. Working within a framework of strong sustainability means that relationships between components have different weightings or directionality and are not equally substitutable. As the body of work on natural resource and sustainability governance suggests, understanding how and why different elements of the system are valued and are given different weightings by different actors is fundamental to making choices about how to manage a system.

Indeed, the DECOIN toolkit conceptualises sustainability quite differently from the more popular approaches to local rural sustainable development that focus on indicators of natural, social and economic capital that are meaningful and recognisable to local people and policy makers (e.g. charismatic species, examples of local culture, success of local industry). The toolkit seems to put more emphasis on the abiotic and biotic materials underpinning a socio-ecological system than on the ecological communities visible within the system. An example of this is the fact that the protected species and habitats that give the CNP its special qualities are more or less invisible within the model structures and the resulting analysis. This difference may be a strength; in that the toolkit makes the foundations for sustainability more visible, but may also make it less accessible – something to be explored in WP5.

4.2 Using the DECOIN tools to assess the CNP

Our analysis based on the diagrams and the capital classifications suggests the following tentative conclusions for the application of MuSIASEM and SUMMA. SUMMA adopts an explicit focus on the bio-physical thresholds of any socio-ecological system. There are important seasonal variations within the system in terms of demand for stocks and the direction and strength of the flows. For example, climate can be an important enabling and constraining factor for the tourism and agricultural sectors but these seasonal dynamics may not be captured by the 'snap shot' approach of MUSIASEM or the indicators within SUMMA. In terms of the human system, there are different types of tourists whose behaviour has implications for the consumption of resources in the Park. There are different residents, and there are also the second home owners who have to be accounted for. Tourism, second home owners and residents also have implications for the stock and flow of housing and the resources used within this sector. Much of the public management of land is funded by the tax payer – this has implications for capital flows but is also another kind of human actor to consider. This can be handled by MUSIASEM but it is less clear how to account for this in SUMMA.

The main employment is provided by government/services, tourism/recreation and agriculture/forestry. The first two are particularly reliant on economics at the N+1 (Scotland) level and draw on stocks held at N+1 as well as within the Park. Agriculture & Forestry are reliant on markets at N+1 level. The Cairngorms National Park is a dissipative system (a sink) in economic and energy terms. It uses monies generated through taxes and directed by government – so the analysis will have to account for how public monies are spent in the productive and service sectors; and ensure there is a feedback loop to these capital sources outside the Park. There are inter-relationships between services and tourism – particularly in terms of the provision of retail, hospitality and human services. There are conflicts between the provision of services for different types of tourism e.g. ski resorts versus wilderness trekking. There is a limited inter-relationship between tourism and farming (e.g. the use of local food products is being promoted by the Park Authority). Field sports are a high value sector associated with land management, although it is unclear whether these activities should be allocated to agriculture or tourism.

These findings highlight the importance of understanding the non-consumptive use of land and the land's multi-functionality. Our findings ask us to account for land that is simultaneously used for different purposes, with different stakeholders benefiting from these uses. This finding led the tool developers to realize that we needed a formal representation of the link between land use and landscape. Currently, the tools, whilst trying to deliver a systems level view of sustainable development, tend to focus on consumptive use of resources - what resources are used rather than how land use is enacted and what meanings are attached to these practices. For example, MuSIASEM does not indicate 'quality' of land use but generates metrics for its outputs and its intensity variables that might be a proxy for these 'qualities'. But these model outputs cannot answer the normative questions of: What is to be sustained? For whom? At whose cost? And who benefits?

There are marked differences in land tenure in different parts of the Park with implications for the economic mix and use of resources. Again, it is essential to link sustainability assessment to the insights from institutional analysis as different forms of property rights have implications for how resources are mobilized and managed. Management arrangements and policy objectives are also very important in understanding the historical pattern of the system metabolism and in thinking about how different future options might be delivered; but it is not clear how these can be incorporated into the formal models. The ratio between the land area and the number of human actors utilising the land resource (residents and tourists) means that stakeholders believe the stocks are less pressurised than in other parts of the UK – this could be explored using metrics generated by SUMMA and MuSIASEM. This perception, that the park system is under less pressure than other areas, could be contrasted with the perception that it is a dissipative system. It gives rise to questions of why the rest of Scotland should support this 'haven' if this situation is shown to exist.

4.3 Success factors as identified in DECOIN D4

Earlier work within DECOIN proposed several success factors associated with using the DECOIN toolkit and this section compares some of these with the findings from our Cairngorms Case study.

4.3.1 Understanding and agreeing the issues for analysis

It is important to achieve a shared definition of the issues that the toolkit is addressing, and to understand where there is no agreement, and the reasons for this. This step is essential as it will impact on the way that any results are interpreted and explain different meaning attached to the data analysis. This stage not only provides an analysis of the social actors' perceptions, but also a chance to improve the researchers' understandings of the system and ensure that all important elements are identified. The initial findings from the diagramming process (and work undertaken for step one of WP5 methodology) indicate there is a variety of views of what the issues are, which are the priorities and what the toolkit could or should be used for. The DECOIN guidance suggests that the toolkit will help define reality and inform the actors' world views. However, taking a co-constructive approach to socio-ecological system would suggest there are many interpretations of the material reality, and it is necessary to work with these multiple knowledge processes rather than try to enforce a shared 'correct' view of reality.

4.3.2 Data management

It is important to invest time in managing the quantity, organisation and quality of the data to be used within the toolkit. The case study has highlighted the large amount of data required for the SUMMA application and the resources required to organise the datasets so that meaningful analysis can be carried out. Likewise, there is a need for quality control on the data inputs, such as ensuring congruence, accuracy, pedigree of source. However, such metadata is not always available. Sections **Error! Reference source not found.** and **Error! Reference source not found.** above describe the work involved in data management for DECOIN and the numerous gaps that exist in data sets. This has implications for both the utility and transferability of the toolkit, as regardless of the first step outlined above, the availability and quality of the data sets up path dependencies regarding what can be analysed using the toolkit. An obvious example is the lack of an ASA application as there is a lack of suitable time series data at the scale of the CNP.

4.3.3 Data analysis using the toolkit

The guidance highlights the need to calculate indicators that give an overview of the system function; and the importance of illustrating both intensity and extensity factors over time. As discussed above, the choice of indicators should be guided by the social actor's perceptions of the system (the semantics) but often is constrained by the data available. The toolkit tends to require analysis of a predefined set of indicators that fit both the data available and the structure of the formal models. As Section 4.3.1 highlights, there are many aspects of the semantic view of the CNP system that cannot, have not or were not analysed as the tools could not handle them or data were not available. Again, the impact of this 'gap' between semantic and formal approaches can be assessed as part of the utility analysis in WP5. The guidance also highlights the need for quality control on the outputs of the toolkit, including the use of sensitivity analysis. This is very important in terms of achieving credibility with stakeholders, as it indicates to what extent results are an artefact of the assumptions and parameters used in the modelling approach and therefore how well the tools represent possible realities. Equally, the toolkit approach can help with a process of social learning, by asking stakeholders to look at their system in a new light and understand the factors that explain how it is performing. The benchmarking of the system across scales and between places can be very powerful in illustrating how a system works, and how it could be improved.

5 Conclusions

The operational use of the DECOIN tools would represent a radical recasting of the (conceptually limited) sustainability debate that exists. This means that there is a substantial "gap" to be closed between the DECOIN developers and the likely users of the tools or their outputs. Our early indications are that, at least conceptually, this gap can be overcome with staff who have professional responsibility for sustainability issues and with higher level representatives of stakeholder groups. What is less certain is how best to make the tools and their outputs salient, credible and legitimate to the wider stakeholder community.

In a similar fashion it is clear that the Macaulay team will continue, for some of the tools (e.g. SUMMA), to depend on the expertise of the DECOIN developers. This dependence means that the Macaulay team will not in the near future be in a position to independently undertake substantial modifications to these tools to support specific local analysis. Within SMILE this is not an issue since the Parthenope University team have been very supportive but it makes longer term use of SUMMA more difficult without investing in staff with appropriate skills and experience.

Finally, as with all toolkits and models, it is necessary to be wary that the data and tools are shaped by the issues not the other way round. This is particularly challenging with the DECOIN tools since they are a very rich source of novel concepts and capabilities and have the potential to have a really positive impact on how the debate on sustainability is conducted.

6 Implications for further work

Despite supplementing the resources available to the Macaulay SMILE team there has been a substantial time overrun for WP2 and WP3 (the reasons for which have been outlined). Given the strengths and interests of the Macaulay team we would not wish to limit out activities within WP5 (the assessment of utility with CNPA). Given the fixed resources available, the implication is that we will have a more limited capacity than expected to deliver activities within WP4 (the thematic analysis). We therefore need to consider if all the ambitions can be met, and if as seem likely they cannot, then wherever it is best to tackle all issues planned at limited depth or focus on one in detail?

Appendix 1 – Commentary on SUMMA Input Data Quality

Table 2: Data sources and comments on input parameters for the SUMMA analysis

Data Sources for the SUMMA analysis		
Item	**Unit**	**Notes /Sources**
Physical Parameters		
Total area of the unit	m2	Area of CNP_Park_Boundary.shp (***Park Established 2003***). Area of Scotland_Boundary.shp
Total agricultural sector area	m2	Area of SIACS shapefiles for 2001 and 2007 where PREDOM_LU <> ' ' (2007 increase reflects greater coverage of SIACS polygons)
Area of the main crops productions within the Park (barley, wheat, ecc.)	m2	Totals based on individual crops detailed below
Maximum altitude	m	Stats from CNP-DEM-Ex dataset
Minimum altitude	m	Stats from CNP-DEM-Ex dataset
Average altitude	m	Stats from OS Dem Statistics dataset
Albedo of the land use categories	%	National figures calculated from Land Cover GB and associated Albedos. CNP Stats calculated on the basis of PREDOM_LU and Albedo rates per category.
Solar radiation	kcal/m2/year	CNP observed data converted from MJ m2 day to kcal m2 year. Scotland data extracted as average from Midas dataset. Needed to use 2004 data for 2007 due to lack of SR data for 2007
Wind energy on land	m/s	East 10 knots avg, Highland 14 knots avg, West 15 knots avg, Islands 14 knots so average of around 13 knots (or 6.5m/s)
Wind energy on land	J/m2/year	Area * windspeed cubed * density of air (1.225) * kinetic energy (0.5) multiplied up from a second to a year
Total Rainfall in one year	mm/year	Mean Scotland 1914-2007 = 1415 mm yr Source is SG website. Aviemore mean 1984-95 = 1003
Geothermal flow at land surface	mW/m2	Global Heatflow Database of the International Heat Flow Commission range 37-40
Evapotranspiration rate from land	%	7.12E+15 J/year. % rate is about 40% of rainfall is evapotranspired
Erosion rate of the soil	g/m2/year	This is not a very well understood measurement so simply assuming the 2t/Ha/year mentioned in SNH doco http://www.snh.org.uk/publications/on-line/advisorynotes/43/43.htm

% organic matter in soil	%	Calculated as a weighted average from Carbon field in qmsoils_2008_PC_Carbon
Water for irrigation (volume of water used)	m^3/yr	Based on CJC Consulting Evaluating the Economic Impact of Abstraction Controls on High and Medium Volume Water Users in Scotland - Report for the SEERAD Water Environment Unit
Water for irrigation, price	£/ha/mm £/m3 €/m3	EA abstraction rates vary between £18 - £40 per hectare Source: SAC FMH, under potatoes - e.g p30 for 2008/09 Note: 1Ha at 1mm depth <=> 10x10^9 mm3 <=> 10m3 (assuming 1m3 = 1x10^9 mm3)
Fraction of irrigation water that is evapotranspired	%	40% based on ET rates from grass
Fuel		
Car fuel (diesel and gasoline)	£/yr	Data from Sustainability Request document - Bruce Golding (SG). Using 2006 data for 2007. CNP figures taken as a proportion of Scotland based on number of workers.
	l/yr	Derived
Ag machinery fuel and oil	£/yr	Data from Sustainability Request document - Bruce Golding (SG). Using 2006 data for 2007. CNP figures taken as a proportion of Scotland based on number of machines.
Gasoline for agricultural purpose	l/yr	Derived from total cost and cost per litre
Gasoline price	£/l	http://www.ukpia.com
Gasoline price	€/l	Derived from above
Diesel for agricultural purpose	l/yr	CNP derived from ratio of tractor numbers
Diesel price	£/l	Farm Management Handbook https://statistics.defra.gov.uk/ http://www.ukpia.com/
Diesel price	€/l	Derived from above
Diesel price	£/yr	Derived from above
Diesel price	€/yr	Derived from above
Lubricant for agricultural purpose	l/yr	CNP derived from ratio of tractor numbers
Lubricant price	£/yr	Based on tractor transmission fluid £149 for 25lr (Terralus UTTO Biodegradable Tractor Transmission Fluid)
Lubricant price	€/yr	Derived from above
Electricity for agricultural purpose	kWh/yr	Back calculated from known price per kWh and total spend
Electricity price	£/kWh	http://www.berr.gov.uk/energy/statistics/publications/prices/tables/page18125.html

Electricity price	€/kWh	Derived from above
Electricity price	£/year	Data from Sustainability Request document - Bruce Golding (SG). Using 2006 data for 2007. CNP figures taken as a proportion of Scotland based on number of workers.
Electricity price	€/year	Derived from above
Gas (if any) for agricultural purpose	MJ/yr	CNP values woprked out on basis of proportion of workforce
Gas (if any) for agricultural purpose	GWh	Convert using 1 GJ = 277.8kWh (UK Energy Statistics 2003)
Gas (if any) for agricultural purpose	m3/yr	Convert GWh to kWh then convert: 1 cubic metre of gas = 11.06kWh (UK Energy Statistics 2003)
Gas price	£/MJ	Data from FMH. 2001 taken as mean of initial 0.691p then 0.386p; 2007 taken as mean of initial 1.185p then 0.604p.
Gas price	£/yr	Derived from above
Gas price	€/yr	Derived from above
Fertilizers used for the whole agricultural sector:		
Nitrogen (N)	tonne/yr	Brittish Fertiliser Usage Survey 2007
Nitrogen (N)	kg/yr	Derived from above
Nitrogen (N) price	£/kg	SAC - Farm Management Handbook
Nitrogen (N) price	€/kg	Derived from above
Phosphate (PO4)	tonne/yr	Brittish Fertiliser Usage Survey 2001
Phosphate (PO4)	kg/yr	Derived from above
Phosphate (PO4) price	£/kg	SAC - Farm Management Handbook
Phosphate (PO4) price	€/kg	Derived from above
Potassium (K2O)	tonne/yr	Brittish Fertiliser Usage Survey 2001 (rates for 1991)
Potassium (K2O)	kg/yr	Derived from above
Potassium (K2O) price	£/kg	SAC - Farm Management Handbook
Potassium (K2O) price	€/kg	Derived from above
Pesticides used for the whole agricultual sector:		
Fungicides	kg/yr	Fungicides - British Pesticide Usage Survey
Fungicides price	£/kg	Fungicides price - DEFRA
Fungicides price	€/kg	Derived from above

Growth regulators	kg/yr	Growth regulators - British Pesticide Usage Survey
Growth regulators price	£/kg	Growth regulators price- DEFRA
Growth regulators price	€/kg	Derived from above
Herbicides	kg/yr	Herbicides - British Pesticide Usage Survey
Herbicides price	£/kg	Herbicides price- DEFRA
Herbicides price	€/kg	Derived from above
Insecticides	kg/yr	Insecticides - British Pesticide Usage Survey
Insecticides price	£/kg	Insecticides price - DEFRA
Insecticides price	€/kg	Derived from above
Molluscicides	kg/yr	Molluscicides - British Pesticide Usage Survey
Molluscicides price	£/kg	Molluscicides price - DEFRA
Molluscicides price	€/kg	Derived from above
Others	kg/yr	Others - British Pesticide Usage Survey
Others price	£/kg	Average of the above prices
Others price	€/kg	Derived from above
Machinery:		
Number of tractors	number	December Ag census & 2002 Scot Econ Ag Report. For 1991 and CNP assume same proportions as workers.
Average weight of tractors	ton	Derived.
Total weight of tractors	ton	December Ag census & 2002 Econ report and manufacturers spec sheets. For 1991 & CNP assume same proportions as workers.
Other machineries	number	December Ag census 2007. Assume same proportions for rest.
Average weight of other machineries	ton	Derived.
Total weight of other machineries	ton	To be derived from December Ag census and manufacturers spec sheets. For 1991 & CNP assume same proportions as workers.
Average life time (for tractors)	year	Data from Sustainability Request document - Bruce Golding (SG).
Average life time (for other machinery)	year	Data from Sustainability Request document - Bruce Golding (SG).
Materials		
Plastic (for instance for greenhouse and land cover) used for the agricultural sector	ton/year	No data
Steel (for instance for crop support or small building) used for the agricultural sector	ton/year	No data

Wood (for instance for crop support or small constructions) used for the agricultural sector	ton/year	No data
Concrete (for instance for small construction) used for the agricultural sector	ton/year	No data
Total cost of the above materials	€	No data
Work		
Total Farm worker (only the work for agricultural production avoiding the work related to the industrial transformation of agricultural prodcuts)	n° persons	1991, 2001 Scot figure from econ report 1992, 2003. 2007 figures from JAC. 1991 and 2001 CNP figures assume 2007 proportions.
Total applied labor	hrs/year	1991 Scot figure from econ report 1992. 2007 figures from JAC. 1991 and 2001 CNP figures assume 2007 proportions.
Unit labor cost	£/hr	Economic Report on Scottish Agriculture 1994, 2006, 2008.
Unit labor cost	€/hr	Derived from above
Sheep		
Market sales	ton/year	Scottish figs from Econ Report on Scottish Ag 1994, 2003, 2008. CNP figs calculated from the CNP/Scot proportion in JAC as at 2007
Energy content as food calories	kJ/100g	Food Standards Agency http://www.food.gov.uk/science/dietarysurveys/dietsurveys/
Energy content as food calories	kJ/yr	Derived from above
Energy content as food calories	J/yr	Derived from above
Economic value on the local market that year	£/year	Scottish figs from Econ Report on Scottish Ag 1994, 2003, 2008. CNP figs calculated from the CNP/Scot proportion in JAC as at 2007
Economic value on the local market that year	€year	Derived from above
Cattle		
Market sales	ton/year	Scottish figs from Econ Report on Scottish Ag 1994, 2003, 2008. CNP figs calculated from the CNP/Scot proportion in JAC as at 2007
Energy content as food calories	kJ/100g	Food Standards Agency http://www.food.gov.uk/science/dietarysurveys/dietsurveys/
Energy content as food calories	kJ/yr	Derived from above
Energy content as food calories	J/yr	Derived from above
Economic value on the local market that year	£/year	Scottish figs from Econ Report on Scottish Ag 1994, 2003, 2008. CNP figs calculated from the CNP/Scot proportion in JAC as at 2007
Economic value on the local market that year	€year	Derived from above
Poultry		

Market sales	ton/year	Scottish figs from Econ Report on Scottish Ag 1994, 2003, 2008. CNP figs calculated from the CNP/Scot proportion in JAC as at 2007
Energy content as food calories	kJ/100g	Food Standards Agency http://www.food.gov.uk/science/dietarysurveys/dietsurveys/
Energy content as food calories	kJ/yr	Derived from above
Energy content as food calories	J/yr	Derived from above
Economic value on the local market that year	£/year	Scottish figs from Econ Report on Scottish Ag 1994, 2003, 2008. CNP figs calculated from the CNP/Scot proportion in JAC as at 2007
Economic value on the local market that year	€year	Derived from above
Pigs		
Market sales	ton/year	Scottish figs from Econ Report on Scottish Ag 1994, 2003, 2008. CNP figs calculated from the CNP/Scot proportion in JAC as at 2007
Energy content as food calories	kJ/100g	Food Standards Agency http://www.food.gov.uk/science/dietarysurveys/dietsurveys/
Energy content as food calories	kJ/yr	Derived from above
Energy content as food calories	J/yr	Derived from above
Economic value on the local market that year	£/year	Scottish figs from Econ Report on Scottish Ag 1994, 2003, 2008. CNP figs calculated from the CNP/Scot proportion in JAC as at 2007
Economic value on the local market that year	€year	Derived from above
Eggs		
Harvest	number	Econ Report on Scottish Ag 1994, 2004, 2008. CNP data based on poultry proportions.
Harvest	ton/year	Assumes 58g medium egg. CNP data based on poultry proportions.
Energy content as food calories	kJ/100g	Food Standards Agency http://www.food.gov.uk/science/dietarysurveys/dietsurveys/
Energy content as food calories	kJ/yr	Derived from above
Energy content as food calories	J/yr	Derived from above
Economic value on the local market that year	£/year	Econ Report on Scottish Ag 1994, 2004, 2008. CNP data based on poultry proportions.
Economic value on the local market that year	€year	Derived from above
Milk		
Harvest	litre/year	Econ Report on Scottish Ag 1994, 2004, 2008. No CNP data. CNP proportion based on dairy farm proportion 2007 = 147 / 286698
Harvest	g/year	Density of milk 1030g/lr
Energy content as food calories	kJ/100g	Food Standards Agency http://www.food.gov.uk/science/dietarysurveys/dietsurveys/

Energy content as food calories	kJ/yr		Derived from above
Energy content as food calories	J/yr		Derived from above
Economic value on the local market that year	£/year		Econ Report on Scottish Ag 1994, 2004, 2008. No CNP data. CNP proportion based on dairy farm proportion 2007 = 147 / 286698
Economic value on the local market that year	€year		Derived from above
Wool			
Harvest	ton/year		Econ Report on Scottish Ag 1994, 2004, 2008. CNP data based on sheep proportions.
Energy content as food calories	J/yr		Wool is not food!
Economic value on the local market that year	£/year		Econ Report on Scottish Ag 1994, 2004, 2008. CNP data based on sheep proportions.
Economic value on the local market that year	€year		Derived from above
Main Crops…			
Barley	Area (ha)		Econ Report on Scottish Ag 1992, 2006, 2008. CNP from JAC (1991, 2001 assume 2007 proportion)
Harvest	ton/year		Econ Report on Scottish Ag 1992, 2006, 2008. CNP from JAC (1991, 2001 assume 2007 proportion)
Energy content as food calories	kJ/100g		Food Standards Agency http://www.food.gov.uk/science/dietarysurveys/dietsurveys/
Energy content as food calories	kJ/yr		Derived from above
Energy content as food calories	J/yr		Derived from above
Economic value on the local market that year	£/year		Economic Report on Scottish Agriculture 1992, 2006, 2008. (1991, 2001 assume 2007 proportion)
Economic value on the local market that year	€year		Derived from above
Wheat	Area (ha)		Economic Report on Scottish Agriculture 1992, 2006, 2008. (CNP Figures from SIACS where PREDOM_LU = Spring Wheat or Winter Wheat))
Harvest	ton/year		Derived from above
Energy content as food calories	kJ/100g		MAFF Feed Comp red book
Energy content as food calories	kJ/yr		Derived from above
Energy content as food calories	J/yr		Derived from above
Economic value on the local market that year	£/year		Economic Report on Scottish Agriculture 1992, 2006, 2008.
Economic value on the local market that year	€year		Derived from above
Oilseed Rape	Area (ha)		Economic Report on Scottish Agriculture 1992, 2006, 2008. (CNP Figures from SIACS where PREDOM_LU = - Rape for Stock Feed)
Harvest	ton/year		Economic Report on Scottish Agriculture 1992, 2006, 2008.

Energy content as food calories	kJ/100g	MAFF Feed Comp red book
Energy content as food calories	kJ/yr	Derived from above
Energy content as food calories	J/yr	Derived from above
Economic value on the local market that year	£/year	Economic Report on Scottish Agriculture 1992, 2006, 2008.
Economic value on the local market that year	€year	Derived from above
Potatoes	Area (ha)	Economic Report on Scottish Agriculture 1992, 2006, 2008. (CNP Figures from SIACS where PREDOM_LU = Seed Potatoes or Ware Potatoes)
Harvest	ton/year	Economic Report on Scottish Agriculture 1992, 2006, 2008.
Energy content as food calories	kJ/100g	Food Standards Agency http://www.food.gov.uk/science/dietarysurveys/dietsurveys/
Energy content as food calories	kJ/yr	Derived from above
Energy content as food calories	J/yr	Derived from above
Economic value on the local market that year	£/year	Economic Report on Scottish Agriculture 1992, 2006, 2008.
Economic value on the local market that year	€year	Derived from above
Oats	Area (ha)	Econ Report on Scottish Ag 1992, 2006, 2008. CNP from JAC (1991, 2001 assume 2007 proportion) (*NB Area claimed for CNP SIACS 2007 = 69.94Ha, for 2001 = 44.76Ha where PREDOM_LU = Spring Oats)*
Harvest	ton/year	Econ Report on Scottish Ag 1992, 2006, 2008. CNP from JAC (1991, 2001 assume 2007 proportion)
Energy content as food calories	kJ/100g	MAFF Feed Comp red book
Energy content as food calories	kJ/yr	Derived from above
Energy content as food calories	J/yr	Derived from above
Economic value on the local market that year	£/year	Economic Report on Scottish Agriculture 1992, 2006, 2008. (1991, 2001 assume 2007 proportion)
Economic value on the local market that year	€year	Derived from above
Other Crops (inc Fruit & Veg)	Area (ha)	2007 figures estimated from JAC results and consultating FMH. Econ Report on Scottish Ag 1992, 2006, 2008. CNP from JAC (1991, 2001 assume 2007 proportion)
Harvest	ton/year	Calculated from IACS data that isn't barley, wheat, oilseed rape, potatoes or oats
Energy content as food calories	J/yr	Calculated from IACS data that isn't barley, wheat, oilseed rape, potatoes or oats
Economic value on the local market that year	£/year	Economic Report on Scottish Agriculture 1992, 2006, 2008. (1991, 2001 assume 2007 proportion)
Economic value on the local market that year	€year	Derived from above

References

Brown, M. T. & Ulgiati, S. 2004, "Energy quality, emergy, and transformity: H.T. Odum's contributions to quantifying and understanding systems.", *Ecological Modelling*, vol. 178, no. 1-2, pp. 201-213.

Cairngorms National Park Authority 2007, *Cairngorms National Park Plan* [online] http://www.cairngorms.co.uk/resource/docs/publications/CNPA.Paper.301.National_Park_Plan_2007.pdf [accessed 2-2-09].

Carberry, P. S., Hochman, Z., McCown, R. L., Dalgliesh, N. P., Foale, M. A., Poulton, J. N. G. H., Hargreaves, D. M. G., Cawthray, S., & Hillcoat, N. 2002, "The FARMSCAPE approach to decision support: farmers', advisers, researchers' monitoring, simulation, communication and performance evaluation", *Agricultural Systems*, vol. 74, pp. 141-177.

Carney, D. 1998, *Sustainable rural livelihoods: what contribution can we make?* DfID, London.

Carolan, M. S. 2006, "Science, expertise, and the democratisation of the decision-making process.", *Society and Natural Resources*, vol. 19, pp. 661-668.

Diez, E. & McIntosh, B. S. 2009, "A review of the factors which influence the use and usefulness of information systems.", *Environmental Modelling and Software*, vol. 24, no. 5, pp. 588-602.

Giampietro, M. 2004, *Multi-scale integrated analysis of agroecosystems* CRC Press, Boca Raton, Florida.

Giampietro, M. & Mayumi, K. 2000, "Multiple-scales integrated assessments of societal metabolism: Integrating biophysical and economic representations across scales", *Population and Environment*, vol. 22, no. 2, pp. 155-210.

Giampietro, M., Serrano, T., & Sorman, A. 2009, *Tool Manual*, DECOIN: Development and Comparison of Sustainability Indicators, Project No 044428, FP6-2005-SSP-5A, Deliverable D4.4 of WP4.

Grundy, T. 2006, "Rethinking and reinventing Michael Porter's five forces model.", *Strategic Change*, vol. 15, pp. 213-229.

Gunderson, L. H. & Holling, C. S. 2002, *Panarchy: Understanding transformations in human and natural systems* Island Press, Washington.

Kesby, M., Kindon, S., & Pain, R. 2007, "'Participatory' approaches and diagramming techniques," in *Participatory Action Research*, Routledge, London, pp. 144-166.

Matthews, K. B., Rivington, M., Buchan, K., Miller, D. G., & Bellocchi, G. 2008, "Characterising and communicating the agro-meteorological implications of climate change scenarios to land management stakeholders.", *Climate Research*, vol. 35, no. 1, pp. 59-75.

Matthews, K. B., Schwarz, G., Buchan, K., & Rivington, M. 2005, "Wither agricultural DSS?", A. Zerger & R. M. Argent, eds., Modelling and Simulation Society of Australia and New Zealand, pp. 224-231.

McCown, R. L. 2002, "Locating agricultural decision support systems in the troubled past and socio-technical complexity of 'models for management'. (Special issue: Probing the enigma of the decision support system for farmers: learning from experience and from theory)", *Agricultural Systems*, vol. 74, no. 1, pp. 11-25.

McCown, R. L., Brennan, L. E., & Parton, K. A. 2006, "Learning from the historical failure of farm managment models to aid managment practice. Part 1. The rise and demise of theoretical models of farm economics.", *Australian Journal of Agricultural Research*, vol. 57, pp. 143-156.

McCrum, G., Blackstock, K. L., Matthews, K. B., Rivington, M., Miller, D. G., & Buchan, K. 2009, "Adapting to climate change in land management: the role of deliberative workshops in enhancing social learning.", *Environmental Policy and Governance*, vol. 19, pp. 413-426.

McIntosh, B. S., Giupponi, C., Voinov, A., Smith, C., Matthews, K. B., Monticino, M., Kolkman, M. J., Crossman, N., Van Ittersum, M. K., Haase, D., Haase, A., Mysiak, J., Groot, J. C. J., Sieber, S., Verweij, P., Quinn, N., Waeger, P., Gaber, N., Hepting, D., Scholten, H., Sulis, A., van Delden, H., Gaddis, E., & Assaf, H. 2008, "Bridging the gap: developing tools for environmental policy and management," in *State of the Art and Futures in Environmental Modelling and Software*, T. Jakeman et al., eds., Elsevier.

McIntosh, B. S., Seaton, R. A. F., & Jeffrey, P. 2007, "Tools to think with? Towards understanding the use of computer-based support tools in policy relevant research.", *Environmental Modelling and Software*, vol. 22, pp. 640-648.

Newell, B., Crumley, N., Hassan, E. F., Lambin, C., Pahl-Wostl, C., Underdal, A., & Wasson, R. 2005, "A conceptual template for integrative human-environment research", *Global Environmental Change*, vol. 15, pp. 299-302.

Scottish Government 2007, *The Government Economic Strategy*, Scottish Government [online] http://www.scotland.gov.uk/Publications/2007/11/12115041/8, Edinburgh.

Scottish Natural Heritage 2008, *Report on the proposal to extend the Cairngorms National Park into Perth and Kinross*, Scottish Natural Heritage [online] http://www.snh.org.uk/strategy/sr-adnp03.asp.

Smith, A. & Stirling, A. 2008, *Social-ecological resilience and socio-technical transitions: critical issues for sustainability governance*, [online] http://www.steps-centre.org/PDFs/STEPS%20Working%20Paper_Transitions.pdf [accessed 2-2-09].

Sterk, B., Leeuwis, C., & Van Ittersum, M. K. 2009, "Land use models in complex societal problem solving: Plug and play or networking?", *Environmental Modelling & Software*, vol. 24, no. 2, pp. 165-172.

Sterk, B., Van Ittersum, M. K., Leeuwis, C., Rossing, W. A. H., Van Keulen, H., & van de Ven, G. W. J. 2006, "Finding niches for whole-farm design models - contradictio in terminis?", *Agricultural Systems*, vol. 87, no. 2, pp. 211-228.

Tabara, J. D. & Pahl-Wostl, C. 2007, "Sustainabiltiy Learning in Natural Resource Use and Management", *Ecology and Society*, vol. 12, no. 2 [online] http://www.ecologyandsociety.org./vol12/iss2/art3/.

Ulgiati, S., Zucaro, A., Bargigli, S., Franzese, P., Raugei, M., Vehmas, J., Luukkanen, J., Pihaljamaki, M., Giampietro, M., Gamboa, G., Lobo, A., Sorman, A., & Waldron, T. 2008, *Documentation - User and client documentation for the DECOIN tools*, SMILE: Synergies in Multi-scale Inter-Linkages of Eco-social systems, Project No 217213, FP7-SSH-2007-1, Deliverable 3 of WP2.

van Leeuwen, E. 2008, *Town Today: Contemporary Functions of Small and Medium-sized Towns in the Rural Economy [Phd Thesis],* Vrije Universiteit, Amsterdam.

Vehmas, J., Luukkanen, J., Pihaljamaki, M., Ulgiati, S., Zucaro, A., Franzese, P., Raugei, M., Giampietro, M., Gamboa, G., Lobo, A., Sorman, A., & Waldron, T. 2008, *Demonstration - Example for each of the DECOIN tools*, SMILE: Synergies in Multi-scale Inter-Linkages of Eco-social systems, Project No 217213, FP7-SSH-2007-1, Deliverable 4 of WP2.

Walker, B. H. & Salt, D. 2007, *Resilience Thinking: Sustaining Ecosystems and People in a Changing World* Island Press, Washington, DC..