The evolution of Life Cycle Assessment and its application to the bamboo ecosystem in Vietnam
Timothy Morozgalski (Environmental Science)

Introduction
This paper describes how Life Cycle Assessment (LCA) of products and processes has developed into something more comprehensive for today’s ‘socially responsible’ society, and evolved from consideration of exclusively environmental impacts to include wider socio-economic concerns. It considers whether an LCA incorporating these wider concerns has anything to offer the Sustainable Livelihoods Approach (SLA), which is a developmental technique supporting poverty alleviation programmes. The arguments are then applied to the bamboo ecosystem in Vietnam, as an example of poverty alleviation based on sustainable ecosystem exploitation. The use of LCA as a socio-economic tool (the so-called Social LCA or S-LCA) represents the culmination of its evolution from the purely environmental into the widest possible application. Venturing into the realms of socio-economics presents challenges in data collection and presentation but places the technique firmly at the forefront of sustainability toolkits. It is therefore necessary to plot the development of LCA to the current status.

Evolution of LCA
The early stages of LCA can be traced back to the late 1960s and early 1970s when environmental awareness was in its infancy and an increase of wasteful by-products meant that there was a need for calculating these valuable industry systems by the primitive means of a flowchart, which we would now call an LCA (Boustead 1996). Weidema (2010) claims that an LCA’s original purpose was to analyse energy consumption and Basset-Mens and van der Werf (2007) describe LCAs as normalised methodology, which can assess the environmental impact of a product along its life cycle and typically calculate resource or energy consumption.

Therefore, originally, an LCA was a general environmental impact assessment tool (E-LCA) which evolved, introducing separate categories to reflect new uses for LCAs. For example, in order to assess environmental impacts, specific impact factors were subsequently created and a method of calculation was simultaneously developed. There are now eight impact categories within the inventory analysis of an LCA, based on the International Standards Organisation (ISO) approved methodology (ISO/TR 14047; 2003 [E]), including: Acidification, Ecotoxicity, Eutrophication/Nitrification, Climate Change/Global Warming, Human Toxicity, Depletion of Abiotic/Biotic Resources, Stratospheric Ozone Depletion and Photo-Oxidant formation (Azapagic et al. 2004). ISO 14040
defines the process of an LCA which includes: the Life Cycle Inventory analysis (LCI) phase, the Life Cycle Impact Assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA (ISO 2006).

The process of understanding these impact factors led to Life Cycle Costing (LCC), as businesses tried to assess the financial, time and resource costs of the above impact factors. For example, the amount of pollution which was caused by their distribution methods, i.e. Lorry carrying (X) amount of goods at (Y) miles per gallon and the cost (Z) per gallon or CO₂e (Carbon Dioxide equivalent).

Figure 1 shows the 4 stages of an LCA and from the basic layout of the schematic (its function is simple yet effective), whilst Table 1 describes the four components in more detail (Elcock 2007).
These examples illustrate that changes have occurred within the design, functionality and application of LCAs, particularly within the last decade. In particular, the expansion of the impact factors into new areas has driven the evolution of LCA.

Figure 2 is a representation of an LCA that shows the life cycle of a production line in a clear manner and an obvious progression of a production line (in a clockwise direction). Therefore, the function of the LCA is clear and can be utilised in such a way to gather data on each component to provide information for the four stages of the LCA. Here, ‘cradle to grave’ means from the extraction of raw materials through to final disposal, whilst the ‘cradle to cradle’ approach implies reuse/recycling of the final product rather than disposal.

<table>
<thead>
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<th>TABLE 1 LCA Components</th>
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<tr>
<td><strong>Component</strong></td>
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<td>Goal Scope and Definition</td>
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<tr>
<td>Life-cycle Inventory (LCI)</td>
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<td>Life-cycle impact assessment (LCIA)</td>
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<td>Life-cycle Interpretation</td>
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Once the impact factors, life cycle costing, evaluation of an LCA and its components were complete, a new approach progressed into understanding each attribute within an LCA and its direct consequence.

Life Cycle Attribute Assessment (LCAA) uses existing life cycle models to assist in the aggregation of data about process attributes across product systems and offers a way to summarise attributes of a product life cycle or company supply chain (Norris 2006).

**Attributional and Consequential LCA**

Brander et al. (2008) not only highlighted that there was a change emerging within LCA approaches which they defined as Attributional LCA (A-LCA) and Consequential LCA (C-LCA), but also that each one had different applications. The A-LCA can be recognised as a typical LCA where each attribute of the LCA has an input along a product line (emissions, ore etc.), whilst C-LCA helps to inform consumers and policy makers of the indirect impacts of a process (consequence). For example, Brander et al. (2008) explained that C-LCA was a more comprehensive and thorough approach to understanding the impacts of each attribute in an LCA with boundaries that are more far-reaching than that of a typical LCA. One of the strong points of the C-LCA approach is that its application can be focussed on social, environmental, economic or product-based assessments. By looking at both direct and indirect impacts one could obtain a ‘truer’ picture as all the data is included. There could
also be an argument that there is benefit from a hybrid (yet to be realised) and integrating the two
would be a better option.

Due to the relative speed of the LCA evolution there have been many similar approaches which will
not be included in this paper, although they have contributed in some way to the development
(Global Reporting Initiative, Sustainability Reporting, Areas of Protection (AoP), Life Cycle
Management, Cost-Benefit Analysis (CBA) and so on). However, there is one approach which has
contributed to the ‘thinking’ of LCAs that concerns the impacts of a product or business – the three
or four ‘P’ approach. There are many interpretations of this model, but the categories are commonly
People, Planet, Profit and Product, with variations around the theme of Environmental, Economical
and Social categories (Crul and Diehl 2008). The Triple Bottom Line (Figure 3) has emerged as a
popular conceptualization and reporting ‘vehicle’ for articulating corporate social, environmental,
and economic performance and is arguably the most accepted impact review model within ‘green’ or
‘socially responsible’ businesses since the 1990s (Brown et al. 2006).

Another late contribution to the LCA evolution which will be described in this paper is a concept
called Life Cycle Impact Assessment (LCIA). It can be best described as a C-LCA approach to analysing
a company’s impacts on a socio-economic level. The concept was developed into a framework by
Jolliet et al. (2004) and the idea of understanding the impacts of each process were considered to be
revolutionary (Weidema 2010).
An E-LCA rarely, if at all, included elements of human or social assessment. However, E-LCAs usually have some element of human welfare included within them. For example, Azapagic et al. (2004) noted that the impacts of persistent chemicals on air, land and water lead to human, animal and ecosystem damage. Therefore, human impacts can in some way be measured and accounted for within an LCA. However, including societal elements into LCAs is difficult as they are not necessarily measurable or physical attributes and are therefore difficult to accurately quantify (Azapagic et al. 2004).

These approaches to LCA have culminated in the idea of a Social or Societal Life Cycle Assessment (S-LCA) and this paper will now look at this new concept/framework to assess its application, test its approach and conclude if it is capable of truly assessing social ‘needs’.

S-LCA aims to assess the social and socio-economic impacts of all life cycle stages that are familiar to an LCA and is a systematic process using best available science in order to collect best available data, and report about, social impacts (positive and negative) in product life cycles from extraction to final disposal (Benoît et al. 2010).

In 1993 the Society of Environmental Toxicology and Chemistry (SETAC) produced a document entitled: ‘Guidelines for Life-Cycle Assessment: A “Code of Practice”’. Since then, many environmental management tools have helped to initiate the idea of a social welfare impact category into an LCIA (Benoît et al. 2010). The concept is somewhat of a hybrid as it uses a similar framework to traditional LCAs and the concept can be used to assess social impacts of a corporation, a Non-Governmental Organisation (NGO) or process.

According to Benoît and Mazijn (2009) there are five main stakeholder categories within an S-LCA: workers/employees, local community, society (national<global), consumers (all stages) and value chain actors. Within those; there are many subjective impact categories such as child labour, fair salary, equal opportunity, migration, secure living conditions and technology development. The feasibility of integrating social aspects into LCAs seems challenging but it could prove to be a rewarding exercise. Grieshammer et al. (2006) discussed this topic further and concluded that there are many hurdles to overcome in order for S-LCA to be comprehensive and needed:

- to improve the data situation (qualitative, semi-quantitative and/or fully quantitative)
• carry out more case studies (provide various scenarios in order to highlight areas of improvement)
• establish an accepted social indicator list (including impact categories)
• a connection with CSR (GRI, SA 8000, ILO, OECD Guidelines for MN enterprises etc.) needs to be realised and implemented

It cannot be ignored that there is a harsh subjective nature to many social assessment methods which can be found within S-LCA methods. Objective indicators are designed to measure impacts (i.e. wages, working hours), which were established and effective for E-LCAs whereas subjective indicators focus on the experiences or feelings of the relevant S-LCA ‘user’ (i.e. assessing the wealth of society as a broad notion) (Jorgensen et al. 2010). It is difficult to assess how the concept will achieve these tasks and it seems near impossible to truly measure the 'needs' of such complex creatures (humans) and their ever more complex social environments. Some research needs are shown below in Table 2.

Table 2. Research needs in S-LCA (adapted from Benoît et al.2010)

<table>
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<tr>
<th>S-LCA</th>
<th>Research needs</th>
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<tr>
<td>General</td>
<td>Case studies&lt;sup&gt;a&lt;/sup&gt;</td>
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<td></td>
<td>Educational material</td>
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<td></td>
<td>Tools development</td>
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<td>Documentation and communication</td>
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<td></td>
<td>Product utility and social acceptability</td>
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<td></td>
<td>Stakeholder approach</td>
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<td>Model development</td>
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<td>Review process</td>
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<td>Goal and scope</td>
<td>Product utility</td>
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<td>Consequential LCA</td>
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<td>Inventory Analysis</td>
<td>Documentation of system boundaries</td>
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<td>Methodological sheets&lt;sup&gt;a&lt;/sup&gt;</td>
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<td></td>
<td>Development of database</td>
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<td>Impact Assessment</td>
<td>Methodologies</td>
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<td>Areas of protection</td>
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<sup>a</sup> Priorities
The two most pressing research needs are: case studies (such as bamboo culture in Vietnam) and the development of methodological sheets for inventory analysis.

Figure 4 shows the criteria which could be used to define an E-LCA and an S-LCA for bamboo culture in Vietnam, illustrating the difficulties in the latter in comparison to the former.

On the right hand side of the illustration it is clear that there are too many ‘important’ social issues to address and also that these issues may arise in more than one step of a process. Take food and water for example, the security, quantity and quality of food and water must be present at the agricultural, manufacturing and distribution phases. The argument is this: how would one accurately assess each social criterion of a complex business process without leaving out other equally ‘important’ areas of social impacts? Does the subjective nature detract from the comprehensiveness of this method?

The amount of research currently going into S-LCAs is a positive sign that this maybe the future for social assessment tools. However, one of the most disheartening quotes from the feasibility of S-LCA
reporting is that the methodology will need about five to ten years development in order for it to become suitable for treating social aspects (Griesshammer et al. 2006).

We will now look at an established methodology within the Corporate Social Responsibility (CSR) field and see where it coincides with S-LCA meet and if they can benefit, improve or work with one another.

The Sustainable Livelihoods Approach (SLA) was developed in the late 1980s and is a framework which provides a generic schematic of various, ‘capitals’, which can help stakeholders, NGOs, multilateral organisations and policy makers to understand the livelihoods of the poor and the potential impacts (positive and negative) of a commercial activity (i.e. Human, Social, and Physical Assets) (DFID 2001).

Although it is described as a framework it could be better described as a philosophy to which businesses should try to adhere. The Department For International Development (DFID 1999) released a paper called ‘Sustainable Livelihoods Guidance Sheets’, which explains each phase of their complex framework/model in order for a business to achieve a better sense of CSR.

Figure 5: The Sustainable Livelihoods Framework
One must acknowledge that this framework does address more issues than an LCA and, as a result, it is far more complex and does not show any clear progression as traditional LCAs do. The two frameworks (LCA and SLA) appear to be worlds apart, yet recently they seem to be becoming more confluent.

SLA offers a more empathetic approach to commercial activity (by focusing on the poor), LCA, by contrast, seems more business-like in its approach.

One of the strengths of an SLA is that it highlights complex and important issues which are often overlooked by developers. Also, an SLA is more focused around people (usually poverty-stricken) and can provide a multifaceted perspective to all stakeholders. However, the serious limitations of the SLA framework will now be argued (due to its already complex nature) and that an S-LCA may be able to adjust, assess and advise on modern dilemmas where the SLA seems obsolete and inflexible.

**Similarities between SLA and S-LCA**

For any comparison or similarities to be noticed it is important to assess the goals of each concept:

- E-LCA aims to assess the negative environmental impacts
- S-LCA aims to assess positive and negative social impacts
- SLA allows the user to consider important issues which effect poor people

It can be seen that E-LCA and S-LCA have the same framework but the latter lacks statistical input similarly to the SLA. Also, the intentions of SLA and S-LCA appear to coincide, yet, only the latter attempts to assess social impacts and there is an obvious gap in the SLA in quantifying social impacts (which S-LCA is trying to achieve).

The capital assets described in SLA find application within the S-LCA framework. For example; the human, social, natural, physical and financial assets categories are useful and welcome additions to S-LCA as it lacks these criteria. Currently, the S-LCA has to assess and justify each addition into the social framework and this can explain why certain aspects are, or are not, included (for example, include fair trade and not assess living conditions?)

**SLA applications and some limitations of the concept**

Neely et al. (2004) applied the SLA concept in twelve countries with similar rural-poor projects. They were able to show (not quantify) that the impacts of their work with the rural poor were having a
positive impact. They did not use SLA directly but used indicators from it (i.e. assets, vulnerability and income diversification etc.) to provide evidence of positive change and to assess, inform, and improve social well-being. However, this also highlights the difficulty of providing statistical information with regards to social assessment, which begs the question: is it possible to use a SLA simultaneously with an S-LCA to help discover an accurate representation of social impacts?

Discussion on S-LCA and SLA competition

Benoît and Mazijn (2009) admit that their paper only acts as a ‘skeleton’ for developing this idea and highlights the need for S-LCAs to be researched in order for it to act as a comprehensive, stand alone social impact assessment tool. However, importantly, Benoît and Mazijn (2009) highlight that S-LCAs can engage stakeholders to improve social and socio economic conditions of production and consumption. Therefore, for that reason, S-LCAs seem to be the favoured option for future projects.

As the S-LCA tool is such a new and unproven concept, it is hard to assess its effectiveness and there is an urgent need for applications of this concept (Benoît and Mazijn 2009). In addition, due to the lack of quantifiable data that can be entered and retrieved from this schematic, it is hard to see how it can be a stand-alone tool at present. For example, if there was some way of entering social numerical data into computational software (as there is for carbon emissions or production line waste i.e. SimaPro), then the figures would be invaluable to NGO and government projects alike. Benoît and Mazijn (2009) admit that it is nearly impossible to quantify all social impacts, but even so, data quality and integrity in the socio-economic sphere are as important as in an E-LCA. Benoît and Mazijn (2009) therefore include factors such as: the validity, completeness, accessibility and relevance of the data, appropriateness of the measurement methods, the documentation, and finally an assessment of the uncertainty associated with the methodology.

Application of S-LCA: Bamboo in Vietnam

Bamboo was worth two billion USD (United States Dollars) according to the global exports of raw bamboo and rattan in 2007 (INBAR 2009), yet its total market size for 2006 was estimated at seven billion USD (Marsh and Smith 2007). Vietnam has a long history of growing bamboo and has around 69 native species (Bystriakova et al. 2001) which is valued at around two hundred and fifty million USD in 2007 (Marsh and Smith 2007). However, due to unprofessional methods of farming, deforestation and a lack of long term planning there appears to be a need for an improved approach. The application of an S-LCA to a project in Vietnam could prove beneficial to all stakeholders involved as there are currently many opportunities to grow and utilise bamboo.
There are many types of application for bamboo and Lobovikov et al. (2009) state that the raw material can be used in around 1,500 commercial products, thus creating a high amount of jobs (especially in rural areas) and around 75% benefit the poor, farmers, and local workers. Bamboo Grove (2008) give some examples of how bamboo can be used; practical agricultural application (irrigation pipes, fencing, trellis etc.), construction material (lumber, roofing, scaffolding etc.), and furniture or crafts (chairs, tables, sofas, frames, blinds etc.) making it a versatile and advantageous crop.

The Centre for Sustainable Development (CSD) at UCLan (University of Central Lancashire) and Professor Diep Thi My Hanh (Vietnam National University, Ho Chi Minh City) wish to implement S-LCA studies into bamboo projects in Vietnam for two purposes. Firstly, by using S-LCA frameworks and similar tools, they aim to assess the impact of the bamboo ecosystem in rural poverty alleviation. Secondly, due to its high growth rate, bamboo is able to sequester carbon from the air and this will enable Vietnam to take part in Carbon Trading schemes, extol its bamboo processes and enhance water/air quality, prevent soil erosion and have other beneficial impacts on communities and the country.

In order for this project to be successful, the needs of the people must first be defined; this will be done through questionnaires and surveys of local areas. Once the data highlights a significant area in need of improvement (e.g. access to sanitation, education levels, fair trade etc.), the goal and scope of an S-LCA can be set. Due to the lack of case studies and incompleteness of the S-LCA model it is unclear what the qualitative and quantitative results will be. However, this project has two main aims (poverty alleviation and optimum carbon sequestration) and will be using an S-LCA to assess these.

One argument must be put forward regarding the subjective nature of sociological studies. Due to time and money constraints, not all aspects of social needs can be included into any social assessment tool. Can one justify whether health or education is more important or does one have to include both in the study? In which case, how much is too much?

Blengini and Busto (2009) describe an LCA example for rice cultivation in Italy which is readily applicable to bamboo cultivation in Vietnam. Their traditional LCA has input and output quantities illustrated by various categories and subcategories. For example, within the agricultural production phase there are seven subsystem categories which can all be assessed individually to assess, quantify
and therefore improve any aspect within a pre- or post-production phase. However, it can be seen that it lacks any societal input into this schematic. van der Lugt et al. (2010) address each step along a traditional LCA, but their work lacks detail on agricultural processes and considers Eco-Costs (Production Systems, impacts on biodiversity and the carrying capacity of the earth) rather than social impacts. They highlight that the growth and manufacturing of bamboo has positive and negative impacts on the community which relate directly to social aspects, accepting that whilst not included in their work it is of importance.

There are vital necessities that poor and vulnerable households need in Vietnam, including (IFAD, 2008):

- Food security and diversification (at the household level)
- Water, sanitation, schools and clinics (at community level)
- Access to infrastructure, processing facilities, agricultural inputs and technology (at national level)

A brief synopsis of the aims of IFAD (2008) in Vietnam is:

i. improve community infrastructure (linked with markets and national infrastructure)
ii. strengthen the capacity of farmers’ organisations
iii. develop and transfer appropriate technology (leading to lower costs, higher productivity and post harvest activities, livestock and forestry production)
iv. facilitate access to financial services
v. develop skills for farm and non-farm activities

At this point, it is important to find out how IFAD were able to assess the needs of the people. Did they use SLA or S-LCA?

Unfortunately, it is not obvious as to how they gathered their results and there were no references to social assessment tools. However, the terminology used throughout their meticulous project in Vietnam sounds reminiscent of an SLA. They use words such as ‘vulnerability’, ‘assets’, ‘Strength Weakness Opportunity’ and ‘Threats (SWOT) analysis’, all of which are familiar in the SLA approach (IFAD 2008). The problem is: if SLA offered IFAD a complete framework for assessing social needs, then is there room for S-LCA? On the other hand, the insight gained by IFADs work in Vietnam suggests a systematic approach to their research. It seems as if their paper merely depicts the problems that Vietnam has, and not how they assessed the country.
Today, IFAD uses a Management for Development Results (MfDR) approach, which develops a Country Strategic Opportunities Programme (COSOP). It is hard not to see the resemblance to SLA and LCA in their framework. However, it could be argued that this new framework does not really offer much improvement, detail and representation of all stakeholders (especially social impacts to the urban and rural poor).

Conclusions
This paper has shown that LCAs have evolved into innovative social assessment tools and can no longer be classified as just flowchart illustrations of a business process and the traditional LCA has a new counterpart with a big responsibility. S-LCAs, as discussed in this paper, are still under constant development, research and scrutiny and its practitioners are aiming to achieve something which is socially more wholesome, empathetic and potentially rewarding. The SLA could be seen as a forerunner or stimulus to S-LCAs. The gaps that are left by SLAs are tentatively filled by S-LCAs, to some extent. What we are seeing is the dawn of a new way of assessing social needs with a focus on those who rarely get it – the poor. UCLan plans to apply this study into S-LCAs to growing bamboo in Vietnam. With regards to S-LCAs, the project will hopefully achieve the following:

- Allow the models, theories and project to be developed (and, most importantly, tested)
- Provide numerical complications (quantitative and qualitative) to help resolve the uncertain aspects of the model
- Give the model a timescale (of years) to adapt and apply altering and updated theory to create a more coherent plan of what a S-LCA can and cannot do
- Provide a proposal for some generally accepted sets of indicators, schematics and rules

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