"Recent developments in applying environmental value chain analysis"

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Recent developments in applying environmental value chain analysis

Abstract

Value chain analysis (VCA) has been increasingly recognized in recent years as an important tool in development and environmental economics. However, the understanding of what a VCA comprises, and how to apply it, has dramatically changed over time. Firstly, the spatial range of value chains has expanded due to the internationalization and globalization process. Secondly, the increased integration of environmental research questions in the VCA requires additional valuation techniques estimating environmental costs and benefits. Thirdly, environmental valuation techniques are increasingly combined with socio-economic value chain tools providing comprehensive data, e.g., sustainability analysis or costs and benefit analysis of certification programs. These developments have strong implications on the choice of analysis method. This paper aims at providing an up-to-date and systematic overview of different accounting methodologies related to value chain analysis. It provides a very good basis for identifying the right methodologies for answering urgent questions around environmental economics.

The variety of VCA application in the field of environmental economics reflects the greatest advantages of the presented methods which are flexibility and adaptability of value chain accounting. Depending on the field of interest, environmental costs and benefits as well as physically measured flows can be assessed, integrated, and evaluated.

Keywords: value chain analysis, environmental economics, mapping, accounting, general equilibrium model.

JEL Classification: Q56, D57, D58.

Introduction

Value chain analysis (VCA) has been recognized in recent years as an important tool in development and environmental research. The peer-reviewed literature[1] using any term related to 'value chain' in the title, abstract or keywords increased steadily over the last 15 years[2]. This notable development of publications signifies the growing interest in VCA. Almost 20% of the papers published in the field of value chains in 2009 were directly related to the environment; 15% covered the international scope of value chains. This trend is assumed to continue.

In the past, the conventional analysis of value chains focused mainly on calculating the value-added and its distribution on different value chain actors. Along with the internationalization, the need of including linkages to up- and downstream value chain stages has been recognized instead of focusing only on a single stage or group of actors. Thus, the spatial range of value chains has expanded considering both the local and global scale. Environmental economics and natural resource management are strongly associated with economic production highlighting the importance of integrating both in the VCA. Hence, the consideration of value chain impact on the environment requires additional valuation methods to include environmental costs and benefits or physical flows of natural resources. Thereby, former economic as well as socio-economic

value chain tools were extended to integrate environmental flows – monetary or physical – to estimate the total economic value of a product instead of only the market value. In contrast, environmental VCA has been adjusted by a monetary component to consider the economic valuation of e.g., environmental impact in the value chain. The purpose of such VCA is to offer comprehensive data, e.g., sustainability analysis, costs and benefit analysis of certification programs[3] or environmental impact assessment on industrial as well as policy level.

With the bearing of environmental concerns on climate change in recent years, methods for environmental VCA have been designed. Tools such as life cycle assessment or material flow analysis and its derived indices like Ecological Footprint or Backpack[4] are applied very often in environmental resource and waste management as well as industrial ecology. Especially in the field of product and process certification, VCA is needed to assess all relevant socio-economic and environmental impacts.

These summarized fields of application show that VCA is not a precisely definable method; it is rather a comprehensive concept for an entire field of different approaches. Indeed, many descriptive handbooks on VCA have been published. Examples are

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[1] Scopus database of peer-reviewed literature including articles, conference paper, editorials and reports (www.scopus.com).

[2] From approximately 140 up to 5915 publications per year (1995-2009) (www.scopus.com).

[3] Certification programs are market-based instruments to achieve different objectives such as environmental sustainability, ISO 14000, labor welfare or food security. Especially environmental labelling often takes separately into account production and processing stages, and a variety of types of environmental aspects: resource and energy use emissions" (Grote et al., 2007, p. 1).

[4] The Ecological Footprint and Backpack will be explained later in chapter 1.3.1.

Kaplinsky and Morris (2002), Roduner (2004), Schmitz (2005), the German International Agency (GIZ) (GTZ, 2007), and the Foreign Investment Advisory Service (FIAS, 2007). However, hardly any review of quantitative measures in the field of VCA is given. Single-step VCA are often based on econometric methods such as the analysis of barriers to entry with respect to certain production activities, determinants of trade and trade intensity, or consumer based surveys on willingness to pay for certified products. This branch of literature is not considered in this study; the same applies to supply chain management which focuses rather on business administration and logistics than on an economic point of view.

This paper aims at providing a systematic overview of different accounting methodologies related to VCA considering the environmental developments. It is based on a critical review of an up-to-date literature from different disciplines. Section 1 classifies the methods including four major parts: (1) value chain mapping; (2) financial VCA by calculating the value added; (3) national accounting tools and its environmental extensions; and (4) environmental-oriented methods resting upon physical accounting. Finally, in the last section conclusions on application and methodological progress are drawn.

1. Classification of value chain methodologies

The origin of VCA is discussed from two different angles: the French 'filière concept' developed in the 1960s and Wallenstein's concept of a 'commodity chain' evolved in the 1970s (Raikes et al., 2000; Bair, 2005). The 'filière concept' targets a structured understanding of economic processes within production and distribution systems (Raikes et al., 2000), though limited to national boundaries (Lauret, 1983). In contrast, Wallenstein's concept aims to explain the global dynamics of the distribution of value chain activities, in particular the international division of labor, in a capitalist world economy (Bair, 2005).

Most cited is Porter's value chain concept evolved in the 1980. The aim was to identify specific activities through which companies may create value by breaking down their activities into value-added to increase competitiveness (Porter, 1985). Porter's concept is applied to the level of individual companies within national boundaries considering geographical agglomeration of interlinked firms and institutions in a particular sector. Wallenstein's commodity chain formed the basis for Gereffi's global commodity chain in the 90s. Gereffi focused on the balance of power embedded in the coordination of globally fragmented but interlinked production systems (Gereffi, 2005). The recent concept of the world economic triangle combines Gereffi's
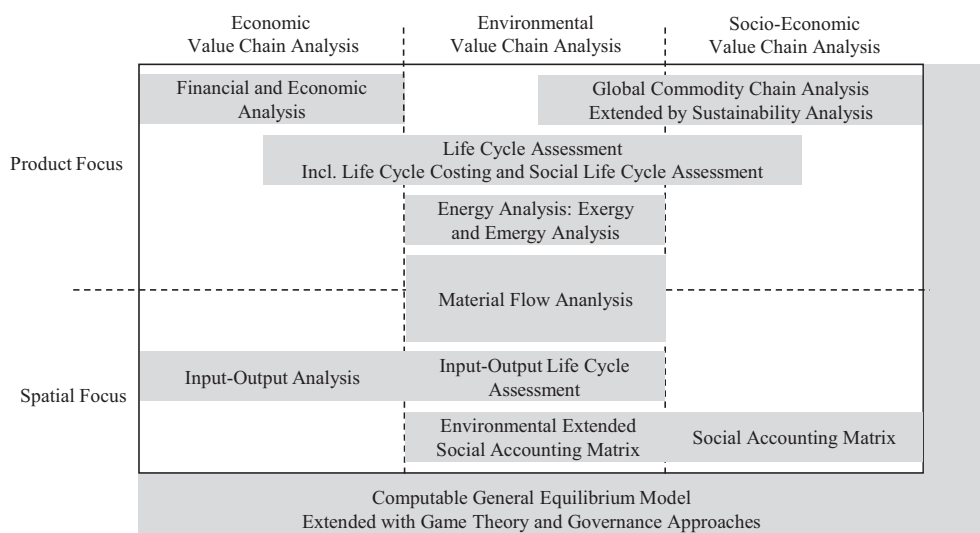
governance and Porter's cluster approach. The underlying assumption that actors, governance and regulation systems determine the scope of action is augmented by a horizontal consideration of cluster effects (Messner, 2002).

All mentioned concepts refer to pure economic analysis of value chains. However, the integration of natural resource consumption and chain-related emissions has received growing attention. Terms like 'greening the value chain' or 'environmental value chain' indicate the importance of environmental issues integrated in the value chain framework (Irland, 2007; Levner, 2007). This is not surprising since all economic activities in value chains are based on natural resources providing all essential inputs as well as the capacity to dispose of emissions and waste.

Kaplinsky and Morris (2002) defined a value chain as a description of "the full range of activities, which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), to delivery to final consumers, and final disposal after use" (Kaplinsky and Morris, 2002, p. 4). The analysis of input-output flows occurs along the entire value chain at a product level or if needed in a regional or national context at a spatial level (Faruk et al., 2002):

♦ Product focus: analyzing the value chain based on a defined functional unit of a good or commodity without being site-specific. The boundaries are specified regarding the inclusion of further up- and downstream value chain stages.
♦ Spatial focus: analyzing the value chain within a definite regional economy, e.g., country, regional, or village specific. The boundaries are defined from a spatial perspective.

In addition to the spatial or product orientation, VCA methods either take principally a (socio)-economic or environmental focus. Economic tools include economic and financial commodity chain analysis as well as tools in the framework of national accounting. The evaluation occurs in monetary terms. Socio-economic VCA additionally incorporates a distributional aspect, e.g., income distribution among households who are employed in a value chain. In contrast to these monetary flows, the environmental VCA measures input-output flows in physical units including, e.g., life cycle assessment, material flow analysis, or energy analysis. Figure 1 shows current VCA tools and its extensions and indicated by crossings over the dashed lines.

	Economic Value Chain Analysis	Environmental Value Chain Analysis	Socio-Economic Value Chain Analysis
Product Focus	Financial and Economic Analysis	Global Commodity Chain Analysis Extended by Sustainability Analysis	
	Life Cycle Assessment Incl. Life Cycle Costing and Social Life Cycle Assessment		
	Energy Analysis: Exergy and Emergy Analysis		
	Material Flow Ananlysis		
Spatial Focus	Input-Output Analysis	Input-Output Life Cycle Assessment	
	Environmental Extended Social Accounting Matrix	Social Accounting Matrix	
	Computable General Equilibrium Model Extended with Game Theory and Governance Approaches		

Source: Own illustration.

Fig. 1. Methodologies for value chain analysis

Altogether, these illustrated methods are pooled under the umbrella of accounting and build the data base for computable general equilibrium (CGE) models. CGEs can be combined with game theoretical approaches and governance models to account for institutional rules of behavior within the value chain. They go beyond the linearity assumption of accounting and allow comprehensive scenario analysis for the value chain under certain policy changes. Before accounting a value chain of interest, the value chain has to be defined and described, called value chain mapping. This is compulsory for economic, socio-economic and environmental VCA.

1.1. Value chain mapping. 'Mapping' the value chain aims at giving an illustrative representation of the identified chain actors and functions being the first step of a VCA. Here, the scope of analysis – or more precisely – the boundaries to other linked value chains are defined where in the actual VCA is being done in the later step. The Food and Agricultural Organization (FAO) (2005a) and Kaplinsky and Morris (2002) describe the way of proceeding in detail. The FAO provides a systematic concept for value chain mapping denoted as a functional and institutional analysis (FAO, 2005a). Herein, a 'preliminary map' provides an overview of all chain actors (institutional analysis) adding then the type of interaction between them (functional analysis). The procedure allows assessing the relative importance of the different stages or chain segments (Rudenko, 2008). Kaplinsky and Morris (2002) propose an 'initial map' including chain boundaries, main actors, activities, connections and some initial indicators of flows' size. Different from FAO (2005a) is the second step, in which the initial map needs to be refined by quantifying key variables such as value-

added and identifying strategic and non-strategic activities. In practice, value chains are certainly more complex compared to this linear conceptual illustration. Multiple links within a chain and various connections to other chains may exist. Some actors may, e.g., collaborate with the same input suppliers or traders denoted as a value chain network (Roduner, 2004).

To assess the complexity of value chains, Clottey et al. (2007) and Kim and Shin (2002) introduced Social Network Analysis originated in social sciences. This method is applied when the chain is more characterized by a network than a linear vertical chain. Special software is available to study the structure of chain networks, e.g., Ucinet[1], AGNA[2] or R[3]. The advantage of Social Network Analysis is to provide not only visual and but also statistical analysis of chain relationships and its strength among actors.

Environmental input-output flows should be also considered in the course of mapping. The aim is to take all requested impacts on natural resources or human beings into account. Natural resources are often considered as production inputs, e.g., energy, water, agricultural land and biodiversity, as well as output, e.g., possible wastes and emissions. Mapping of environmental flows is similar to the boundary definition in Life Cycle Assessment and Material Flow Accounting.

1.2. Economic and socio-economic value chain analysis. Economic and socio-economic VCA are related and thus discussed in one chapter. Whereas

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[1] Ucinet: http://www.analytictech.com/downloaduc6.htm.
[2] AGNA: http://www.geocities.com/imbenta/agna/.
[3] R: http://r-project.org.

the economic VCA assesses the entire value added generated and its impact on growth, the socio-economic highlights distributional aspects within the value chain for instance allocation of inputs for production and distribution of income among the participants. Environmental extensions will be integrated later on to adjust the calculated value added – which is the major indicator in a VCA – for positive and negative environmental benefits and costs.

1.2.1. Financial and economic VCA. Financial and economic VCA – elaborated by the FAO – accounts for expenditures and revenue in all parts of the value chain of interest, also denoted as commodity chain analysis (2005b-c). Similar to the financial cost-benefit analysis, financial VCA – conducted from the perspective of individual agents – determines the financial costs and benefits of the actors of interest. In contrast, economic VCA – conducted from the perspective of the overall economic system (national economy or industrial sector) – analyzes the value chain impact on the national welfare. Both types of analyses are conducted for a defined period, usually one year.

At the center of attention is the calculation of the value-added interpreted as the creation of economic wealth by one or more productive activities (FAO, 2005b). As the term "value" implies, underlying product and input prices are essential for the analysis. While financial analysis is based on actual market prices, economic analysis is based on shadow prices. Consequently, if there are some price distortions in the market, a difference in the estimation between financial and economic analysis will reflect this distortion.

From the calculated agent's value-added several indicators for financial analysis are derived. Important to mention the fact that the overall value-added of the chain is used to identify which stage contributes to the highest share of value-added, which stage to the lowest, and if there is an overall positive value-added. Thereupon, the question may arise, how the created wealth is distributed among the four fundamental chain agents (e.g., the household, financial institutions, government administration, and enterprises). This is a main interest of policy makers, who often aim at households receive a certain share of the profit. Other outcomes are indicators of financial probability, overall efficiency of the chain, processes of price determination, and transfers among agents (FAO, 2005c-d).

The economic impact analysis includes the investigation of upstream-induced effects of productive activities due to the demand for intermediate inputs from the rest of the national economy. In this case, the chain is viewed as an integral part of the national

economy similar to input-output analysis. Indicators are built to evaluate the chain impact in terms of contribution to define development policy objectives such as on wealth and growth. An overview of the various indicators for economic impact analysis is given in FAO (2005c).

Indicators of environmental integration and international trade are not taken into consideration by the FAO methodology. However, concepts to measure costs of degradation as well as benefits summed up in the total economic value of natural resources are not necessarily difficult to integrate, as done in the environmental cost benefit analysis (OECD, 2006).

In fact, the FAO methodology is not frequently cited in empirical studies, but many calculations within VCA are similar to FAO modules since the principle of value-added is a widely applied economic concept. Unfavorable is the fact that the economic impact assessment focuses only on single indicators representing economic importance. Hence, this approach is not able to assess consistently the interdependencies between existing sectors in the economy. This can be achieved by input-output analysis which is integrated in the system of national accounting (Hecht, 2007; CEC et al., 1993).

1.2.2. Greening the national accounts. National accounts contain a rich source of information for economic VCA especially in input-output tables depicting how industries interact with each other in the production process. Input-Output Tables (IOT) allow tracing monetary flows of all goods and services between sectors and industries within an economy. As an ex-post consideration IOT present the database for an Input-Output Analysis (IOA) consisting of a matrix depicting inter-industry relations of an economy. A given input, expressed in a monetary value, is typically stated in the column and its output, also expressed in a monetary value, is listed in its corresponding rows. There are a number of aggregate measures in the national accounts; again, most notably are the value-added and the Gross Domestic Product (GDP) obtained by the respective industrial sectors – a widely used measure of aggregate economic activity in a period. IOA in the framework of national accounting is well-described in the System of National Accounts (SNA) published under the umbrella of the United Nations (CEC et al., 1993; UN, 2008). The criticism concerning current accounting conventions of SNA includes the absence of any allowance for the depletion of natural resources. Due to the absence of any adjustment for degradation of environmental amenity, the GDP is assumed to be overestimated. Thus, a first revision of the SNA implements three possibilities to integrate environmental accounting in the framework of national accounting (CEC et al., 1993, p. 634):

1. Natural resource accounting: physical balancing of natural capital (beginning stock, changes and ending stock); it takes into account material, energy, natural resources and changes in quality attributes.

2. Monetary satellite accounting: expenditures related to environmental protection. Together with these the monetary values of natural resources (such as fishes, forests) , may be derived in order to determine the impacts resulting from a land use change; the aim is the adjustment of the GDP.

3. Welfare oriented approach: targets the question: Who is affected by changes in environmental quality? Not only costs caused by polluters are of interest but also costs borne by affected individuals and producers; the focus is on the well-being of individuals.

Within the SNA framework the […] assets of the natural environment that are – directly or indirectly, actually or potentially – affected by human activities are called natural assets or natural capital" (United Nations, 1993, p. 8); for example natural resource stocks, land and ecosystems. If these "green" elements are valued in monetary terms, it implies additional costs with respect to production activities resulting in the so-called EDP indicator (Environmentally-adjusted Domestic Product), which decreases the value of the GDP. In contrast, physically measured material flows only give information on volume changes. This might sound as a disadvantage, however, the evaluation of resource flows sometimes is critical and miscalculation of the total economic value or costs could lead to a bias. Hence, it might be sometimes worthwhile to measure environmental degradation or pollution only physically. VCA in the scope of IOA is meaningful if sectoral effects need to be considered. However, the high aggregation level of such data might be crucial to researchers.

Three important assumptions constrain IOA. Firstly, the method assumes one single production technology for each product. Secondly, the production is characterized by a linear fixed-coefficient production function, which cannot be altered in any scenario analysis later. Thirdly, IOA does not reflect the distribution of the generated value-added among the different institutional[1] agents: households, companies, and government.

1.2.3. Environmental extended social accounting matrix. In a social accounting matrix (SAM), these agents are integrated in the input-output matrix re-

flecting the interrelationship between income and expenditure flow. This tool was developed in the Seventies for policy analysis to monitor income distribution and poverty reduction. Today it is a part of the SNA. The SAM approach is appropriate for analyzing value chain activities in their social settings providing a consistent conceptual basis for assessing both growth and distributional issues within a single analytical framework. A crucial feature of the SAM is the wide range of possibilities for expanding or condensing the matrix in accordance with specific needs. Besides the calculation of economic indicators, SAM is used to predict the effect of changes in one sector on others by changing the exogenous demand the so-called 'multiplier analysis'. Multipliers summarize the total impact that may follow on a change in a given economic activity; for example, a new manufacturing facility in a value chain or an increasing export activity by a local trader with respect to output, employment, income or value added. The total multiplier effect comprises a direct, indirect and induced component: e.g., a demand for agricultural crops provides direct revenue for the producing farmer in the following season. Second, the farmer may spend the earnings to purchase necessary inputs on the market for agricultural production; the result of this economic activity is called an indirect multiplier effect. In turn, the beneficiaries of these direct and indirect economic activities spend the additional income for unrelated items such as food and non-food items or non-productive assets; this is called the induced multiplier effect.

During the last two decades, researchers started to augment SAMs by additional environmental accounts denoted as, e.g., 'greening the SAM' or 'environmentally extended SAM'. In the environmental extended SAM the focus is on environmental flows and implicit transfers (externalities) not accounted for in the value of monetary transactions (Shiferaw and Holden 2000). In principle, extensions can be presented either in additional rows/columns, or in satellite tables (Alarcon et al., 2000). Practical guidelines for environmental accounting are given by the United Nations (United Nations, 2003) on: (a) accounting for environmentally related transactions; (b) the valuation of natural resource stocks; and (c) valuation techniques for measuring degradation. Martinez de Anguita and Wagner (2010) published a book on 'environmental social accounting matrices' focusing on the integration of forest and its costs and benefits of degradation on a national level (see also, Alarcon et al., 2000). In this regard the authors discuss also the role of the total economic value and its difficulties in measuring.

A SAM can be developed either at national level (macro SAM) or at local level (micro SAM). In-

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[1] In the context of social accounting matrices, the term "institutions" is defined differently compared to the new institution theory. Here, in this context, "institutions are categories of economic actors" (Taylor and Adelman, 2006, p.15).

deed, the SAM at local level is rarely applied, but receives more and more attention due to its possibilities to analyze household interdependencies and their impacts on the environment and derived implications for poverty. The first application of a SAM on village level published in Adelman et al. (1988) with the analysis of the impact of migration on village economies. With regard to the environmental extension of a SAM, Shiferaw and Holden (2000) developed a village SAM framework with the integration of accounts covering soil degradation and external inter-temporal costs of agriculture.

A restrictive assumption of the SAM is that local resources are supposed to be efficiently employed; more precisely there is no underemployment of resources. Secondly, the model assumes constant returns to scale due to the underlying Leontief production function depending linearly on the total output variables. Hence, the amount of each input necessary to produce one unit of a certain output is constant. If the output level of a sector changes, the input requirements change proportionally. Similar to IOA, the linearity of SAM multipliers, their underlying assumption of a Keynesian, demand-driven village economy without resource constraints, and their absence of prices limit their usefulness for many types of analysis. Scenarios with increasing economies of scale or higher efficiency (altering production functions) cannot be considered. In cases where innovative technology allows either input-substitution or greater efficiencies in the use of inputs, impacts to supplying sectors may be critically over- or underestimated due to the assumption of linearity. The same applies to environmental effects.

Consistent data such as social accounting matrices are the basis for mathematical modeling. A noteworthy review on the design and use of village-wide economic equilibrium models based on SAMs is given by Taylor and Adelman (2006).

1.2.4. Computable General Equilibrium models. With regard to VCA, computable general equilibrium (CGE) models are meaningful but complex instruments to analyze multifaceted scenarios. Examples are altering production activities and institutions in response to changes in economic, policy, and environmental variables.

The focus here is on mathematical programming tools covering optimization procedures in the framework of General Equilibrium modeling. CGE models represent the complete economy determining all transactions endogenously based on the socio-economic structure of the SAM. The mathematical model of an entire economic system may be closed or related to external agents via trade. The benchmark situation describes an equilibrium point of the system where all accounts are balanced and all markets are cleared. The standard CGE explains all the payments and receipts displayed in the SAM by mathematical statements. Following the notation of the SAM, the CGE is also characterized by its flexible multi-product, multi-sector, multi-institution disaggregation. Basically, CGE models have been developed to explain the economic performance of countries. Existing applications also cover single regions, villages, or households (Taylor and Adelman, 2006). Impacts of resource constraints on household farm decisions, nonlinearities of production functions, and price effects capturing economic linkages can be taken into account. The standard model is specified in real terms; it is supposed that agents base their multiple decisions on relative prices. However, while the SAM-multiplier model is completely demand-driven, and adjustments are always linear in this model, the behavior of agents might be specified quite differently within the CGE model (Böhringer and Löschel, 2006). The CGE may contain more sophisticated functional forms and non-linear Engel curves that are more consistent with empirical evidence. A further advantageous feature of the CGE is the switch among different activities due to technical progress, and the change of the cost structure. This feature is supported by a special solving procedure, the so-called "Mixed Complementarity Program" (MCP). It notably facilitates modeling of the value chain, where fluctuations and innovations are meaningful and require permanent reorganizations of the chain (Nicholson and Bishop, 2004).

For a comprehensive VCA at household level, Winter et al. (2008) applied a CGE model at the village level to analyze the impacts of an innovative energy value chain on land use systems and degraded forests in the Kakamega District of Western Kenya. A value chain for different wood fuel substitutes such as *Jatropha curcas* was implemented to analyze the impact of its cultivation on the consumption of natural resources, and on income distribution and food security within the village. Combined with a game theoretical approach, simulations illustrate potential benefits of cooperative forest and community land management compared to a situation of unregulated resource competition among stakeholders in the Kakamega District.

In CGE models, often a given objective function has to be optimized, e.g., gross margin or profit, GDP, utility or minimized, e.g., costs or labor time, generating the best configuration under given constraints. Objective functions are usually related to minimize transportation or production costs or the consump-

tion of scarce inputs such as natural resources or maximize production efficiency and profit to increase competitiveness. Traditionally, these problems are solved using linear programming, e.g., simplex algorithm, dynamic programming, or a mixed integer linear programming (Geunes and Pardalos, 2005).

Equilibrium models have been augmented by a game theoretic part in order to analyze governance including the coordination of information and the allocation of profit among actors which play an important role in value chains. Game theory models reflect situations where players make decisions to maximize their own utility, while taking into account that other players are doing the same. This is especially important in equilibrium models including the usage of the global commons such as natural resources or biodiversity or other ecosystem services. Here, institutions (formal or informal) can be used to set constraints in the flow of information, profit or price so that the equilibrium may change compared to the benchmark situation (Winter et al., 2008).

1.2.5. Global commodity chain sustainability analysis. Governance is an important aspect depicting the distribution of power in the value chain as shown in the CGE model. This aspect has been considered in the global commodity chain analysis (GCCA). Governance is defined as "the exercise of political authority and the use of institutional resources to manage society's problems and affairs" (World Bank, 1991). GCCA seeks to explain the institutional mechanisms and spatial organization through which non-market coordination can be achieved (Potts, 2006). The concept of governance itself cannot be evaluated positively or negatively at all. Governance structures are required to transmit information on the settings and to enforce compliance which is assumed to reduce transaction costs among actors, e.g., due to fix contracts, premium prices, or trust. In contrast, dominant actors might also set specific requirements in terms of quality standards or quantities, which might have effects similar to market barriers, because some producers are not able to fulfill the requirements. In order to classify governance in value chains, Gereffi classified three variables: (a) complexity of transactions; (b) the ability to codify transactions; and (c) the extent to which suppliers have necessary capabilities to meet buyers' requirements (Gereffi et al., 2005). However, measurable proxies or indicators need to be specified by the researcher him- or herself. So, GCCA does not measure quantitatively input and output flows at various stages of the life cycle of products; instead, it rather evaluates qualitatively the social relationships and balance of

power between all actors involved in the chain based on single indicators. In this context, the global commodity chain framework has attracted significant attention since the early 1990s (Gereffi, 2005; Raikes et al., 2000).

This rather behavioral concept has been recently extended to a 'Global Commodity Chain Sustainability Analysis' (GCCSA). By determining the distribution of decision-makers across global commodity chains, "it will be possible to identify key leverage points for stimulating changes in private behavior thereby enabling more effective policy intervention" (Potts, 2007, p. 2). The analysis of a GCCSA includes:

♦ Chain mapping.
♦ Supply and demand patterns including trade flows.
♦ Environmental impacts along the chain.
♦ Social impacts along the chain.
♦ International and national policy frameworks.
♦ Supply chain structure including power relationships along the chain.
♦ Policy analysis.

The underlying methods comprise GCCA, life-cycle assessment (LCA), and ecological footprint analysis (EFA). The last two methods LCA and EFA are discussed in the next section under the umbrella of environmental VCA.

1.3. Environmental value chain analysis. Environmental VCA emphasize physical accounting in contrast to economic VCA (Finnveden and Moberg, 2005). Methods to evaluate a potentially harmful output of a value chain or its negative or positive impact on the environment are highly demanded in recent years. Material Flow Analysis including Substance Flow Analysis as a subfield, Life Cycle Assessment and Energy Flow Analysis are noteworthy. The first tool accounts for the product-related output of interest such as CO_2 emissions whereof indicators such as the Material Input Per Service unit or the Ecological Backpack and Footprint are derived. Energy accounting in particular the analysis of energy flows is related to the value chain activities.

1.3.1. Material flow analysis. Material Flow Analysis (MFA) aims at assessing "the flows and stocks of goods and substances in view of a sustainable use of materials, that is, the least overall resource consumption, waste generation, and environmental loadings" (Brunner, 2011, p. 3). This tool is widely applied in the industrial sector to evaluate and improve the resource and waste management along the value chain but also at government level for permissions to construct industrial waste treatment plants (Brunner, 2011). European Environmental Agency (EEA) established MFA in the

framework of the Driving Force-Pressure-State-Impact-Response (DPSIR) scheme[1] developed by the OECD (OECD, 2003).

Besides MFA focusing on all inputs needed to produce a good or a service, the 'Substance Flow Analysis' (SFA) aims at assessing specific – mainly hazardous – substances, either within a region or on a product level in a value chain. However, the method of accounting physical flows remains similar. A review paper has been published by the OECD working group on environmental information and outlooks (WGEIO, 2000).

Since MFA is a physically-oriented analysis, several volume indicators can be quantified. Next to input- or output-oriented indicators, consumption indicators, balance or trade indicators as well as efficiency indicators are applicable. These efficiency indicators are relevant for estimating economic performance in relation to material losses to the environment. The reference point of calculation can be at a site level or product level. The OECD provides an overview of possible indicators and their field of applications (OECD, 2003). For empirical examples conducting MFA, see e.g., Dahlström and Ekins 2006.

Indicators based on the field of material accounting are, e.g., 'the Material Input Per unit of Service' (MIPS). The MIPS concept was originally developed by a team led by Schmidt-Bleek in the 1990s, which aimed at quantifying the use of natural resources during the production of a specified product (Finnveden and Moberg, 2005). After assigning the total material input to the five categories, the ecological backpack is derived. Finally, after accounting the total material input, the indicator is divided by the number of service units; for example the emissions of a car per driven kilometer and driver.

A little different is the ecological footprint applied to both regional and product levels, developed by Rees and Wackernagel (2002), Wackernagel et al. (2004). The indicator measures in adjusted global hectares[2] how much biologically productive land a human population requires to produce its consumption and to absorb its waste under the

prevailing technology[3]. The indicator often is used as a simple information tool to show the unsustainable way of living and overconsumption of individuals, nations and production activities.

Critically is the fact that MFA is not yet a standard procedure. The terms 'materials', 'goods', 'substances', 'materials flow analysis' and 'substance flow analysis' are still used in differing ways (Brunner, 2011). In terms of data uncertainties in MFA, see Danius (2002). In particular, system boundaries and the related processes are chosen on a case by case basis which reduces the comparability of studies. Also the way of measurement of material flows is weakly described in studies and hence decreases the traceability of results (Brunner, 2011). As the next section shows, the same problem occurs to LCA. Since the MFA is applied to build volume indicators assessing natural resource extraction, the method itself is not a tool for impact assessment. Here, LCA is a follow-up method of an MFA; the basic accounting framework of input-output relations in a MFA compared to LCA is very similar (Brunner, 2011). Though, the LCA includes an impact assessment component, which is lacking in the MFA.

1.3.2. Life cycle assessment. In order to assess the environmental impact of a value chain on product level, the framework of LCA has been developed. LCA, often denoted as 'from the cradle to the grave analysis', represents an accounting framework assessing environmental impacts attributable to the value chain activities of a defined product. The analyses focus on the link between the use of inputs (e.g., natural resources) and the related environmental outputs (emissions and waste) of all value chain activities (production, processing, transportation, consumption, and final disposal). LCA is the basis in, e.g., technical, strategic, marketing, and policy decisions (Faruk et al., 2002). The purpose is to build impact indicators, which identify and quantify possible environmental impacts, e.g., the global warming potential, water and land use, or ozone depletion of one unit of production. On this basis, recommendations can be made on which products should be promoted or improved concerning, e.g., production efficiency (Rebitzer et al., 2004). Important to highlight are general problems related to data collection, time, and expertise.

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[1] "The extraction of resources on the input side and the release of emissions and waste on the output side relate to environmental pressures, (sectoral) activities represent driving forces, the flows may change the state of environment which give rise to various impacts and the societal or political response may influence the metabolic situation towards sustainability" (OECD, 2003, p. 18).

[2] The global hectare is a measure of the average biocapacity of any biologically productive areas on the planet. The sum of the world's biocapacity divided it by the number of hectares on the earth's surface results in the biocapacity of one global hectare (Wackernagel, 2004).

[3] www.footprintnetwork.org.
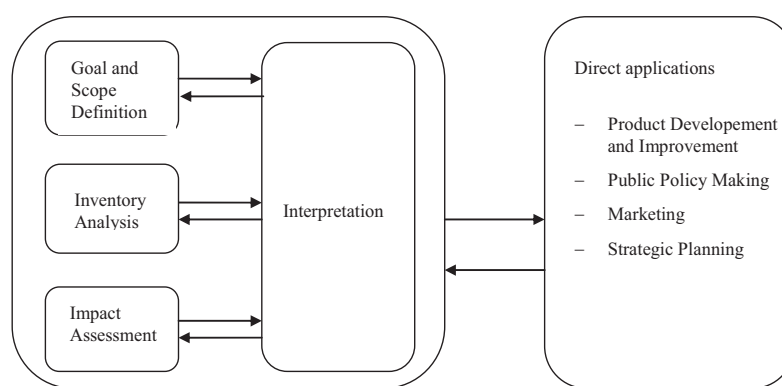
Source: Rebitzer et al. (2004).

Fig. 2. Life cycle assessment framework

However, a major obstacle is the comparability of different studies on the environmental impact of certain products due to different underlying assumptions in the analysis similar to the MFA. Thus, there have been various attempts on standardization and harmonization of LCA. The most commonly applied procedure of LCA – recommended by ISO through its standard ISO 14040:2006 – is illustrated in Figure 2. The proceedings of the single steps according to the ISO series is well described in Rebitzer et al. (2004), Pennington et al. (2004), and Tukker and Jansen (2006).

Applications of LCA are manifold and enjoy an increasing popularity in recent years. For example, keen interest arose with respect to the environmental impact of bioenergy production and the carbon footprint of energy products in general (see Zhiyuan et al., 2004; Mattsson et al., 2000). LCA is also applied to assess the environmental impact of food chains. The focus is predominantly on the carbon footprint (CF) to assess the impact on global warming and climate change. Herva et al. (2011) compiled a comprehensive review on environmental indicators including the carbon footprint. The indicator is expressed in carbon dioxide equivalents and quantifies the total greenhouse gas emissions caused by, e.g., value chain activities. Advantages such as simplicity and intuitiveness of the CF also lead to drawbacks due to the absence of information on other important environmental impacts (Herva et al., 2011).

By definition, LCA does not address economic or social impacts of a product chain. To fill this gap, "*Life Cycle Costing*" (LCC) (Mearig et al., 1999) and "*Social Life Cycle Assessment*" (SLCA) (Dreyer et al., 2006) were developed, whereas the latter is very rarely applied. In addition, "*Life Cycle Energy Assessment*"(LCEA), should be mentioned due to the rising concerns of the environmental impact of energy consumption in a value chain (Kuemmel et al., 1999). LCEA can be interpreted as a variation of energy analysis within the boundaries of a traditional LCA; e.g., the assessments of energy efficiency in production systems e.g. alternative water supply systems (Stokes and Horvath, 2006).

Generally, LCA is evaluated as a "powerful and fairly robust methodological framework" (Rebitzer et al., 2004), but nevertheless there are some critical aspects related to the overall model (Lenzen, 2001; Tukker and Jansen, 2006; Schaltenegger, 1997). LCA is subject to some underlying assumptions; similar to IOA and SAM. LCA is characterized being a strictly linear and static accounting model. Therefore, environmental outputs, e.g., waste and emissions are typically assumed to scale linearly related to the product flows (Rebitzer et al., 2004). However, IOA and LCA also differ in some characteristics (Table 1).

Table 1. Differences between life cycle assessment and input-output analysis

Characteristics	Life cycle assessment	Input-output analysis
Data sources	Unit process data	Economic national accounts
Way of Proceeding	Bottom-up approach	Top-down approach
Commodity unit flows	Physical flows	Monetary valued flows
Level	Micro level	Macro level
Covered life cycle stages	Complete life cycle	Pre-use and consumption stages

Source: Rebitzer et al. (2004).

The importance of the definition of boundaries in the life cycle system is noteworthy, because of having a huge impact on the LCA results and thus on the comparability. Broader boundaries consider more indirect input suppliers and hence, may lead to increasing environmental impacts compared to a more narrow definition. Ignoring these indirect effects by defining rather narrow boundaries can lead to an underestimation of environmental impacts of the considered product. This miscalculation is also denoted as truncation error. To reduce the truncation error, Lenzen (2001) and Tukker and Jansen (2006) suggest the combination of LCA with an IOA, denoted as hybrid LCA approach or input-output life cycle assessment (IO-LCA).

1.3.3. Input-output life cycle assessment. IO-LCA is a specialized subset of the growing field of 'integrated environmental and economic accounting', combining economic input-output data with environmental and resource data from LCA (Rebitzer et al., 2004). The approach is more complete in terms of economy-wide system boundaries also capturing interdependencies of different value chains. However, it lacks process specificity and the differentiation between similar products is very limited (Rebitzer et al., 2004). Therefore, suitable applications for IO-LCA are research questions, where the overall effect of new technologies on a regional or national level has to be analyzed including a rough estimation of the overall environmental impacts. Overview articles worth mentioning are from Hendrickson et al. (1998). The Green Design Institute developed a software tool to conduct an economic IO-LCA (EIO-LCA) based on a database (www.eiolca.net) estimating the overall economic and environmental impacts from producing a certain dollar amount of almost 500 commodities or services. However, the tool is restricted to the United States. The project aims to provide rough guidance on the relative impacts of different types of products, materials, services, or industries with respect to resource use and emissions throughout the U.S.

1.3.4. Exergy and emergy analysis. In general, gaining more information on energy flows along the value chain denoted as energy accounting, plays an important role, e.g., to assess energy efficiency of production activities (Finnveden and Moberg, 2005). There are two important types of energy measures: (a) exergy analysis; and (b) emergy analysis.

Exergy, defined as the quality of energy, measures the ability of an energy source to produce a unit of work. Thus, exergy refers to a thermodynamic unit (e.g., joule) that gives a numerical value to present energy quality (Apaiah et al., 2006). Traditional applications of exergy analysis are focused on the optimization of energy use and the decrease of resource consumption. Calculated indicators are, e.g., the ratio 'exergy input' / 'exergy output' as a measure for energy losses associated with production of an unit of product. Exergy input is the exergy required to produce something, whereas exergy output is the fraction of exergy still contained in the produced substance (Szargut et al., 1988). If exergy analysis is applied to the product level, it is applicable in the boundaries of an LCA (Finnveden and Ostlund, 1997). As exergy is always expressed in the same unit, e.g., 'joule', energy inputs and outputs of each chain are easily comparable. However, also here the same problem

of comparability occurs if different value chain boundaries are defined as in LCA studies.

The objective of emergy analysis is to quantify the energy value of both direct energy supply and material resources (interpreted as indirect energy supply). This implies that all required inputs of material, information, and labor are aggregated using emergy equivalents – expressed in the equivalent solar energy – resulting in the accumulated energy associated with a product (Castellini et al., 2006). Emergy accounting has been developed in the last three decades as a tool for environmental policy. Based on the analysis, several indicators can be developed, e.g., 'transformity', which measures how much emergy is taken to generate one unit of output, regardless of whether or not the input is renewable. However, the indicator 'renewability' takes the percentage of renewable emergy into account used by the system (Cavalett and Ortega, 2007). Studies on emergy analysis have been published by Lefroy and Rydberg (2003), and Cuadra and Rydberg (2006).

Conclusions

The integration of environmental economics in the VCA is a major and important development of the last decade. This fact underlines the motivation to provide an up-to-date and systematic overview of accounting methodologies related to VCA. This paper discussed the application and extensions of (1) value chain mapping as the overall start of a VCA; (2) financial VCA; (3) national accounting tools and their environmental extensions; and (4) environmental emphasized methods resting upon physical accounting such as material accounting, life cycle assessment and energy accounting.

The literature review showed numerous examples and approaches of how environmental research questions may be integrated. On the one hand, purely economic tools became extended by environmental cost and benefits analysis or physically measured satellite systems. On the other hand, principally environmental tools have been developed and augmented by, e.g., a cost component. Even within the GCCA of power distribution among chain actors, environmental impact assessment has been incorporated. The effects of the power relation on value chains natural environment combined with a life cycle approach are in the limelight.

The variety of VCA application in the field of environmental economics reflects the greatest advantages of the presented methods which are flexibility and adaptability of value chain accounting. Depending on the field of interest, environmental costs and benefits as well as physically measured flows can be assessed, integrated, and evaluated. Attention should be paid to

the definition of the system boundaries of value chains. Narrowing the boundaries of the value chain system may eventually lower the costs of analysis but it also affects the results negatively due to the problem of truncation error. The same occurs with respect to the level of aggregation. A high disaggregation level enables a very detailed analysis of the value chain flows and its impact, but also bears higher costs due to a more comprehensive data collection. Here, the analyst has to decide carefully on interests and relevance.

A major disadvantage in the accounting framework is the underlying assumption of linearity which hampers scenario analysis with respect to policy or technology changes. Valuable solutions are the CGE models where the data from input-output tables or social accounting matrices are fed in. Although the difficulty to program these models might scare some people, it enables policy analysis enhanced by institutional settings to allow for changing rules of market participation without following the linearity assumption.

References

1. Adelmann, I., Taylor, J.E. and S. Vogel (1988). Life in a Mexican Village: A SAM Perspective, *The Journal of Development Studies*, No. 25, pp. 5-24.
2. Alarcon, J., Van Heemst, J. and N. De Jong (2000). Extending the SAM with Social and Environmental indicators: An application to Bolivia, *Economic Systems Research*, Vol. 12, Issue 4, pp. 473-496.
3. Apaiah, R.K., Linnemann, A.R. and J.H. van der Kooi (2006). Exergy analysis: A Tool to Study the Sustainability of Food Supply Chains, *Food Research International*, Vol. 39, Issue 1, pp. 1-11.
4. Bair, J. (2005). Global Capitalism and Commodity Chains: Looking Back, Going Forward, *Competition & Change*, Vol. 9, No. 2, pp. 153-180.
5. Böhringer, C. and A. Löschel (2006). Computable General Equilibrium Models for Sustainability Impact Assessment: Status quo and prospects, *Ecological Economics*, No. 60, pp. 49-64.
6. Brunner, P.H. (2002). Material Flow Analysis: Vision and Reality, *Journal of Industrial Ecology*, Vol. 5, No. 2, pp. 3-5.
7. Castellini, C., Bastianoni, S., Granai, C., Dal Bosco, A. and M. Brunetti (2006). Sustainability of poultry production using the emergy approach: Comparison of conventional and organic rearing systems, *Agriculture, Ecosystems & Environment*, Vol. 114, Issues 2-4, pp. 343-350.
8. Cavalett, O. and E. Ortega (2007). Emergy and Fair Trade Assessment of Soybean Production and Processing in Brazil, *Management of Environmental Quality: An International Journal*, Vol. 18, No. 6, pp. 657-668.
9. CEC, IMF, OECD, UN & World Bank (1993). System of National Accounts. Commission of the European Communities-Eurostat, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations and World Bank, Brussels/Luxembourg, New York, Paris, Washington, 711 p.
10. Clottey, V.A., Gyasi, K.O., Yeboah, R.N., Addo-Kwafo, A. and F. Avornyo (2007). The Small Ruminant Production System in Northern Ghana: A Value Network Analysis, *Livestock Research for Rural Development*, Vol. 19, No. 11, Article 167, available at: http://www.lrrd.org/lrrd19/11/clot19167.htm (assessed: February 2009).
11. Cuadra, M. and T. Rydberg (2006). Emergy evaluation on the production, processing and export of coffee in Nicaragua, *Ecological Modeling*, Vol. 196, pp. 421-433.
12. Dahlström, K. and P. Ekins (2007). Combing Economic and Environmental Dimensions: Value Chain Analysis of UK Iron and Steel Flows, *Ecological Economics*, Vol. 58, pp. 507-519.
13. Danius, L. (2002). Data Uncertainties in Material Flow Analysis – Local Case Study and Literature Survey, KTH, Stockholm.
14. Dreyer, L.C., Hauschild, M. and J.Schierbeck (2006). A Framework for Social Life Cycle Impact Assessment, *International Journal of LCA*, Vol. 2, pp. 88-97.
15. FAO. Module 43. Commodity Chain Analysis. Constructing the Commodity Chain, Functional Analysis and Flow Charts. EASYPolAnalytical tools, 2005a. Download: www.fao.org/docs/up/easypol/330/cca_043EN.pdf (accessed: November 2007).
16. FAO. Module 44. Commodity Chain Analysis. Financial Analysis. EASYPol Analytical tools, 2005b. Available at: www.fao.org/docs/up/easypol/331/CCA_044EN.pdf (accessed: November 2007).
17. FAO. Module 45. Commodity Chain Analysis. Impact Analysis Using Market Prices. EASYPol Analytical tools, 2005c. Available at: www.fao.org/docs/up/easypol/332/CCA_045EN.pdf (accessed: November 2007).
18. FAO. Module 46. Commodity Chain Analysis. Impact Analysis Using Shadow Prices. EASYPol Analytical tools, 2005d. Available at: http://www.fao.org/docs/up/easypol/333/cca_046en.pdf (accessed: November 2007).
19. Faruk, A.C., Lamming, R.C., Cousins, P.D. and F.E. Bowen (2002). Analyzing, Mapping, and Managing Environmental Impacts along Supply Chains, *Journal of Industrial Ecology*, Vol. 5, No. 2, pp. 13-36.
20. FIAS Moving toward Competitiveness: A Value Chain Approach. The Investment Climate Advisory Service, Washington, D.C., 2007.
21. Finnveden, G. and A. Moberg (2005). Environmental Systems Analysis Tools – An Overview, *Journal of Cleaner Production*, Vol. 13, pp. 1165-1173.
22. Finnveden, G. and P. Ostlund (1997). Exergies of Natural Resources in Life-Cycle Assessment and other Applications, *Energy*, Vol. 22, Issue 9, pp. 923-931.
23. Gereffi, G., Humphrey, J. and T. Sturgeon (2005). The Governance of Global Value Chain, *Review of Interna-*

tional Political Economy, Vol. 12, Issue 1, pp. 78-104.

24. Geunes, J and P.M. Pardalos (Eds.) (2005). *Supply Chain Optimization*, Springer Verlag.

25. Grote, U., Basu, A.K. and N.H. Chau (ed.) (2007). *New Frontiers in Environmental and Social Labeling*, Physica-Verlag, pp. 1-241.

26. GTZ. ValueLinks Manual. The Methodology of Value Chain Promotion, Eschborn, 2007. Available at: http://www.value-links.de/manual/distributor.html (accessed: December 2007).

27. Hecht, J.E. (2007). National Environmental Accounting – A Practical Introduction, *International Review of Environmental and Resource Economics*, Vol. 1, pp. 3-66.

28. Hendrickson, A., Horvath, A., Joshi, S. and L.B. Lave (1998). Use of Economic Input-Output Models for Environmental Life Cycle Assessment, *Environmental Science & Technology*, Vol. 32, Issue 7, pp. 184A-191A.

29. Herva, M., Franco, A., Carrasco, E.F. and E. Roca (2011). Review of corporate environmental indicators, *Journal of Cleaner Production*, Vol. 19, Issue 15, pp. 1687-1699.

30. Irland, L.C. (2007). Developing Markets for Certified Wood Products, *Journal of Industrial Ecology*, Vol. 11, No. 1, pp. 201-216.

31. Kaplinsky, R. and M. Morris. Handbook for Value Chain Research, IDRC (2002). Download: http://www.ids.ac.uk/ ids/ global/pdfs/VchNov01.pdf (accessed: November 2007).

32. Kim, S. and E.-U. Shin (2002). A Longitudinal Analysis of Globalization and Regionalization in International Trade: A Social Network Approach, *Social Forces*, Vol. 81, No. 2, pp. 445-471.

33. Kuemmel, B., Nielsen, S.K. and B. Sorensen (1999). Life Cycle Analysis of Energy Systems, *European Review*, Vol. 7, No. 3, pp. 421-423.

34. Lefroy, E. and T. Rydberg (2003). Emergy Evaluation of three Cropping Systems in Southwestern Australia, *Ecological Modeling*, Vol. 161, pp. 195-211.

35. Lauret, F. (1983). Sur les études de filières agro-alimentaires, *Économieset Sociétés*, No. 17, p. 5.

36. Lenzen, M. (2001). Errors in Conventional and Input-Output based Life-Cycle Inventories, *Journal of Industrial Ecology*, Vol. 4, No. 4, pp. 127 - 149.

37. Levner (2007). Risk/Cost Analysis of Sustainable Management of Wastewater for Irrigation: Supply Chain Approach. In: M.K. Zaidi (ed.). Wastewater Reuse – Risk Assessment, Decision-Making and Environmental Security. Springer, pp. 33-42.

38. Martínez de Anguita, P. and J.E. Wagner (2010). *Environmental Social Accounting Matrices: Theory and Applications*, London: Routledge, pp. 190.

39. Mattsson, B., Cederberg C., and L. Blix (2000). Agricultural Land Use in Life Cycle Assessment (LCA): Case Studies of three Vegetable Oil Crops, *Journal of Cleaner Production*, Vol. 8, pp. 283-292.

40. Mearig, T., Coffee, N. and M. Morgan (1999). Life Cycle Cost Analysis Handbook – 1st Edition, Department of Education and Early Development, Alaska.

41. Messner, D. (2002). The Concept of the "World Economic Triangle". Global Governance Patterns and Options for Regions. IDS Working Paper No. 173, Institute of Development Studies, Brighton.

42. Nicholson, C.F. and P.M. Bishop (2004). US Dairy Product Trade: Modeling Approaches and the Impact of New Product Formulations. Final Report for NRI Grant, Available at: http://works.bepress.com/cfnichol/16 (accessed: April 2011).

43. OECD (2003). Special Session on Material Flow Accounting. OECD. Working Group on Environmental Information and Outlooks (WGEIO), Paris.

44. OECD (2006). Cost-Benefit Analysis and the Environment – Recent Developments, Paris.

45. Pennington, D.W., Potting, J., Finnveden, G., Lindeijer, E., Jolliet, O., Rydberg, T. and G. Rebitzer (2004). Life Cycle Assessment Part 2: Current Impact Assessment Practice, *Environment International*, Vol. 30, Issue 5, pp. 721-739.

46. Porter, M. (19852004). Competitive Advantage, London: Macmillan.

47. Potts, J. (2007). Global Commodity Chain Sustainability Analysis: Explanations and Examples. IISD Geneva, Available at: http://www.iisd.org/pdf/2007/ global_commodity_chain_examples.pdf (accessed: July 2011).

48. Raikes, P., Jensen M.F, and S. Ponte (2000). Global Commodity Chain Analysis and the French Filiere Approach: Comparison and Critique, *Economy and Society*, Vol. 29, Issue 3, pp. 390-417.

49. Rebitzer, G., Ekvall, T., Frischknecht, R., Hunkeler, D., Norris, G., Rydberg, T., Schmidt W.P., Suh, S., Weidema, B.P. and D.W. Pennington (2004). Life cycle assessment: Part 1: Framework, Goal and Scope Definition, Inventory Analysis, and Applications*, Environment International*, Vol. 30, Issue 5, pp. 701-720.

50. Rees, W. and M. Wackernagel (1992). Ecological Footprints and Appropriated Carrying Capacity: Measuring the Natural Capital Requirements of the Human Economy. Second Meeting of the International Society for Ecological Economics, Stockholm.

51. Roduner, D. (2004). Report on Value Chains: Analysis of existing Theories, Methodologies and Discussions of Value Chain Approaches within the Development Cooperation Sector, LBL, Bern.

52. Rudenko, I. Value Chains for Rural and regional Development: The Case of Cotton, Wheat, Fruit and Vegetable Value Chains in the Lower Reaches of the Amu Darya River, Uzbekistan. Dissertation, University of Hannover, 2008. Available at: http://www.zef.de/fileadmin/webfiles/downloads/projects/khorezm/downloads/Publications/Doctoral_Theses/Rudenko_2008.pdf (access: March 2009).

53. Schaltenegger, S. (1997). Economics of Life Cycle Assessment: Inefficiency of the Present Approach, *Business*

Strategy and the Environment, Vol. 6, pp. 1-8.

54. Schmitz, H. (2005). Value Chain Analysis for Policy-Makers and Practitioners. International Labour Organization. Geneva.

55. Shiferaw, Bekele and Stein Holden (2000). A Social and Environmental Accounting Analysis: An Extended Village SAM for Household-Farms in Ethiopia. Discussion Paper 11/2000, Department of Economics and Social Sciences, Agricultural University of Norway.

56. Stokes, J. and A. Horvath (2006). Life cycle energy assessment of alternative water supply systems, *International Journal of Life Cycle Assessment*, Vol. 11, Issue 5, pp. 335-343.

57. Szargut, Jan, David R. Morris, Frank R. Steward. Exergy analysis of thermal, chemical, and metallurgical processes. Hemisphere Publishing Corporation, 1988.

58. Taylor, J.E. and I. Adelman (2006). Village economies: The Design, Estimation and Use of Village Wide Economic Models. Cambridge: Cambridge University Press, pp. 1-264.

59. Tukker A. and B. Jansen (2006). Environmental Impacts of Products – A Detailed Review of Studies, *Journal of Industrial Ecology*, Vol. 10, No. 3, pp. 159-183.

60. United Nations (1993). Integrated Environmental and Economic Accounting. Handbook of National Accounting, Series F, No. 61, Interim Version, United Nations, Available at: http://unstats.un.org/unsd/publication/SeriesF/Seri esF_61E. pdf. (accessed: May 2011).

61. United Nations (2003). Integrated Environmental and Economic Accounting. Handbook of National Accounting, Series F, No. 61, United Nations, available at: http://unstats.un.org/unsd/envAccounting/seea2003.pdf (accessed: May 2011).

62. Wackernagel, M., White, S. and D. Moran (2004). Using Ecological Footprint Accounts: From Analysis to Applications, *International Journal of Environment and Sustainable Development*, Vol. 3, pp. 293-315.

63. WIGEIO (2000). Special Session on Material Flow Accounting – Papers and Presentations. OECD Working Group on Environmental Information and Outlooks (WGEIO), Paris.

64. Winter, E., Fasse, A. and K. Frohberg (2008). Management Options of Conserving the Kakamega Tropical Rainforest: a Game-Theoretic Village Modeling Approach. Contributed paper for presentation at ISEE Conference, Nairobi.

65. World Bank (1991). Managing Development – The Governance Dimension. Washington D.C., Available at: http://www.wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2006/03/07/000090341_20060307104 630/Rendered/PDF/34899.pdf (accessed: 10.04.2010).

66. Zhiyuan, H., Fang F., DaoFeng, B., Gengqiang, P., and W. Chengtao (2004). Net energy, CO2 Emission, and Life-Cycle Cost Assessment of Cassava-based Ethanol as an Alternative Automotive Fuel in China, Applied Energy, Vol. 78, pp. 247-256.