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Land Use and Land-use Changes in Life Cycle Assessment: Green Modelling or Black Boxing?

Michele De Rosa

Aarhus University, Department of Agroecology, Denmark

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ABSTRACT

The assessment of Land Uses and Land-use Changes (LULUC) impacts has become increasingly complex. Sophisticated modelling tools such as Life Cycle Assessment (LCA) are employed to capture both direct and indirect damages. However, quantitative assessments are often incomplete, dominated by environmental aspects. Land uses are a multidisciplinary matter and environmental and sustainable development policies intertwine. Yet, LCAs mostly focus on environmental impacts excluding socioeconomic implications of land occupation. This paper investigates the limitations of current LULUC modelling practices in LCA. Common LCA assumptions harbor value choices reflect a post-positivist epistemology that are often non-transparent to e.g. policymakers. They particularly influence the definition of the functional unit, the reference system and system boundaries, among other LCA methodological choices. Consequently, results informing land policies may be biased towards determined development strategies or hide indirect effects and socioeconomic damages caused by large-scale land acquisitions, such as violation of tenure rights, speculation and displacement. Quantitative assessments of LULUC impacts are certainly useful but should holistically encompass both direct and indirect impacts concerning the environmental and the social science dimension of LULUC. An epistemological shift towards a dialectic approach would facilitate the integration of multiple tools and methods and a critical interpretation of results.

1. Introduction

Mark Twain, the famous American writer, has been attributed with saying, "*Buy land, they do not make it anymore*." With the backdrop of current debates on land-use changes, deforestation and large scale land acquisitions, the quote may appear today to encourage land speculation. Land acquisition, not based on necessity but foresight into its future scarcity, may indeed cause increasing land prices, preventing access to those who do not have alternative sources of livelihood. In contemporary policymaking, it would be labelled as unsustainable development, though Twain would have not been familiar with the concept. The World Commission on Environment and Development (WCED), better known as Brundtland Commission, has popularized sustainability in the modern definition only in 1987. The commission notoriously defined *sustainable development* as a "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" UNWCED Our Common Future, 1987. In 2005, the World Summit on Social Development formalized the three goals of sustainability, the triple bottom line: the three interdependent pillars on which sustainability lies are economic development, social development and environmental protection (United Nations, 2005).

The sustainable development framework has been extensively applied to the food industry and, more broadly, to the agriculture and forestry sector (Pacini et al., 2003; Ridoutt and Pfister, 2010; Čuček et al., 2012). The objective has been to measure the performance of a product or process. However, quantifying the environmental, economic and social performances of several activities occurring along the product chain of an industrial sector is not a trivial task. The complexity of the modern world lies as a backdrop, where a globalized economic system interlinks different socio-political and economic contexts. Several integrated assessment tools for evaluating agricultural systems and land use have been developed since the 1990s to address this complexity (Bezlepkina et al., 2011). Challenges have concerned (1) reaching consensus on methods and procedures to measure the intergenerational effects (temporal dimension), (2) the regional distribution of final impacts (spatial dimension) and (3) identifying the cause-effect relationships between product demand and damages generated (impact pathways). Assessments should cover the entire supply-chain and end-of-life and include indirect effects that occur in different geographical locations because of global impact pathways.

Not surprisingly, Life Cycle Assessment (LCA) gained momentum shortly after the formalization of the sustainable development concept. LCA was born in 1991 (Jensen and Postlethwaite, 2008) as a "cradle-to-grave" environmental assessment framework. After 25 years of constant development, today it is an established science-based comparative

E-mail address: michele.derosa@lca-net.dk.

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assessment tool consisting of a "*compilation and evaluation of inputs, outputs and the potential environmental impacts of a product system through its life cycle*" (ISO, 2006). It is considered by the European Commission as "*the best framework for assessing the potential environmental impacts of products currently available*" (European Commission European Platform on Life Cycle Assessment (LCA), n.d.). LCA is extensively used to assess the environmental performance of agricultural and forestry products (Roy et al., 2009; Dalgaard et al., 2008; Schmidt, 2010). LCA involving Land Use and Land-use Changes (LULUC) have informed to a great number of national agricultural policies (Schmidt et al., 2009; Cherubini and Strømman, 2011) and private investments (Tuomisto et al., 2012; Agusdinata et al., 2011; Yan et al., 2011), as well as European and American biofuel policies (Kim and Dale, 2005; Broch et al., 2013; Vázquez-Rowe et al., 2014). The European Commission sponsors a European Platform on Life Cycle Assessment; it promotes "Life Cycle Thinking" applied also to Life Cycle Costing (LCC) and Social Life Cycle Assessment (SLCA)(UNEP, 2009; Sala et al., 2013a), together forming the backbone of a Life Cycle Sustainability Assessment (LCSA).

Despite the promising developments and improvements in LCA models of LULUC, currently an operational LCSA framework does not exist (Sala et al., 2013a; Sala et al., 2013b). LULUC analyses still concern mainly ecological aspects, poorly addressing the multifunctionality of land and agriculture (Binder et al., 2010). Environmental assessments of land use frequently focus on one or only a few impacts, such as biodiversity loss or carbon footprint (De Rosa et al., 2016a), a simplified environmental LCA accounting for only one impact category: global warming (De Rosa et al., 2016b). The focus on greenhouse gasses (GHG) emission reduction from agriculture and forestry resulted in ad hoc land use policies and carbon credit schemes as the Reduced Emission from forest Degradation and Deforestation scheme (REDD+). One of the most disputed issues remains how to account for both direct and indirect GHG emissions, triggered by land use and occupation. Direct Land-Use Changes (dLUC) are "*changes in human use or management of land within the boundaries of the product system being assessed*," while indirect Land-Use Changes (iLUC) are "*changes in the use or management of land which is a consequence of direct land use change, but which occurs outside the product system being assessed*," as defined by the International Standard Organization (ISO) in 2012(ISO/TS-14067, 2013). Indirect effects can take place both temporally and spatially outside the product system, called "system boundaries" in LCA. Accounting for them requires an understanding of the cause-effect relationships between product demands and actual impacts generated. The attempt to model the impact pathways of globalized production processes has led to highly complex modelling practices (Warner et al., 2014) and the creation of specialist knowledge. Increasingly sophisticated computer-based quantitative assessments have often resulted in loss of studies' transparency, reproducibility and reusability (Pauliuk et al., 2015; De Rosa et al., 2016b).

The '*blackboxing*' critique of technology in science studies — "*the way scientific and technical work is made invisible by its own success*" (Latour, 1999) — has been also made against quantitative modelling in environmental science (Haas, 2011): quantifying sustainability performances implies a particular way of assessing evidences and expertise,(Brickman et al., 1985; Jasanoff, 2005; Duncan, 2008) reflected in decision-making. The specialization of LCA has translated into a wide range of methodological assumptions and uncertainties. The increasing complexity of quantitative LULUC models risks confining the sustainable development discourse in land use studies to a technocratic matter, uniquely addressed by a spiral of incremental methodological improvement. The hidden epistemological choices of models make it difficult to interpret and discuss their results in light of their value-based assumptions (Iofrida et al., 2016). This paper scrutinizes the underlying ontology that has brought about this development. It aims to re-politicize the debate on land use modelling and the damages caused by Land-Use Changes (LUC). The manuscript analyses current practices and limitations in LCA models of LULUC impacts, arguing that the quantification of resource flows and product footprint is socially situated. Decisions with large scale and long-term consequences based on quantitative assessment tools are also prone to biases and qualitative assumptions.

The following presentation of common LULUC methodological disputes does not intend to be (and could not be) exhaustive. There are numerous articles in thematic scientific journals, some cited here, discussing the topic more exhaustively. The illustrative examples provided are instead necessary to discuss with a broader perspective on the ongoing debates. The objectives are, therefore: (1) to examine the relationships among LULUC methodological choices and their relationship to the underlying theoretical framework and (2) to critically analyze how the current development is shaping the scientific debate and its influences on agro-forestry policies, investments and land use practices around the world.

2. The Ontological and Epistemological Foundations of Current LULUC Modelling Practices

As with other disciplines, the rise of quantitative LULUC modelling has been possible thanks to the progresses in information and communication technologies during the second half of the 20th century. These technological developments occurred simultaneously with the rise of Ecological Modernization (Mol and Sonnenfeld, 2000a; Neale, 1997; Christoff, 1996) theories, influenced by the post-positivist approach (e.g. Karl Popper). Like logical positivist, the ontology of post-positivism sees reality as something that exists and can be known, although this knowledge is mediated by human conjectures. Models and theories, that simplify reality in order to understand and control it, reflect these conjectures. While sharing the ontological understanding of positivism, post-positivism differs in its epistemology. Empirical, 'measurable' experiences are still the way reality is known. Nevertheless, because models mediate such measurable experiences, they may not fully mirror reality. Thus, theories and models are held true until they are falsified. Popper called falsification the formulation of beliefs amenable to be proven false. If falsified, models are substituted with new ones informed by new theories. In a broader critique of positivism, Thomas Kuhn later argued that when a whole set of beliefs—an entire *paradigm*—is falsified, a *paradigm shift* occurs. New values are assumed to form a new explanatory framework and a period of regular scientific work—*normal science*—follows (Kuhn, 1970). The rise of the sustainable development framework in the 1990s has often been interpreted as a paradigm change (Sala et al., 2013a) to a more holistic understanding of what shall be sustained. However, in sustainable development discourses the broadening of perspective has not represented a true paradigm shift. Rather, the epistemological understanding of reality as knowable through models (based on observations and human conjectures) has simply expanded tout-court to include non-environmental aspects, such as socioeconomic performances. The development of LCA methodologies and their application to LULUC is a well-fitting example.

LCA analyses are inherently quantitative assessments, aiming to measure and compare the performance and efficiency of production. The concepts of performance and efficiency have also gained considerable attention, simultaneous to the ascendance of Ecological Modernization (Mol and Sonnenfeld, 2000b) and Industrial Ecology as a new scientific field in the last 30 years. The Ecological Modernization and Industrial Ecology general ethos is that new technological improvements would compensate increasing environmental problems and natural resource scarcity. However, the rapid rise of this optimist approach might be due to its accordance to intellectual, political and economic factors, beyond the realm of environmental studies, rather than the result of its robustness as a social theory (Buttel, 2000). Consequently, we could tend to measure only aspects amenable to introducing technological improvements, disregarding other potential damages neutral or