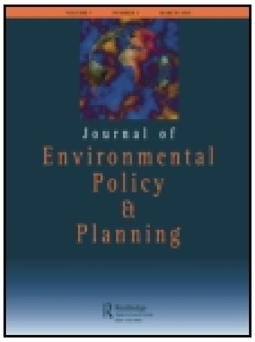

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Identifying Transition Capacity for Agri-food Regimes: Application of the Multi-level Perspective for Strategic Mapping

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ABSTRACT *In this paper, agri-food systems are discussed in the context of a set of socio-technical transitions principles, with a focus on energy, materials and practice elements that have the potential to promote sustainable outcomes across the system. This paper aims to develop an integrated approach for regime analysis, informed by emerging knowledge on socio-technical transitions. The application of the multi-level perspective (MLP) as a heuristic framework to structure descriptions of the multi-dimensional transition contexts of contemporary agri-food regimes is explored. To do this, the paper aims to elaborate the MLP by proposing an integrated means through which complex transition dynamics can be mapped across: (a) energy and material flows and (b) social practices which shape, direct and determine these energy and material flows. This approach is labelled strategic regime mapping (SRM). The paper forwards insights from the development of SRM and discusses the role of strategic mapping of key points across the regime. By combining insight on the conceptualization of dynamic and globally interconnected socio-technical systems with specific observations on contemporary agri-food systems, the paper provides insight into the mapping of transition capacity across agri-food systems, as well as highlighting the significant challenges associated with such an undertaking.*

KEY WORDS: Agri-food systems, socio-technical, sustainable, transitions, multi-level perspective, policy

1. Introduction

The ontological assumption of this paper is that the 'trilemma challenge' posed by global climate change and increasing energy scarcity combined with an increased

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demand for food and food production resources requires significant investigation of current approaches, policy and practice, as well as urgent research to foster innovation and systems change. Key challenges as the twenty-first century progresses will be to maintain and increase current levels of food production, to protect these levels of production from adverse environmental impacts, including climate change impacts and to mitigate the adverse impacts of production on the environment, including emissions reductions. Comprehensive approaches are required to achieve this. This paper looks in particular at a conceptualization of agri-food systems as a socio-technical regime, with technical, practice and social elements. This paper aims to develop an integrated approach for regime analysis, informed by emerging knowledge on socio-technical transitions. In particular, the application of the so-called multi-level perspective (MLP) as a heuristic framework to structure descriptions of the multi-dimensional transition contexts of contemporary agri-food regimes is explored. To do this, the paper aims to elaborate the MLP by proposing an integrated means through which complex transition dynamics can be mapped across: (a) energy and material flows and (b) social practices which shape, direct and determine these energy and material flows. This approach is labelled strategic regime mapping (SRM). To date, MLP has been seen primarily as a means to understand how niches can influence the regime. In this paper, we see the MLP as a means for regime actors to develop a strategic understanding of the three levels of landscape, regime and niche, and to strategically develop responses to future and emerging dynamics affecting the regime. There is an implicit recognition that, from a policy perspective, conceptual perspectives adopted on the regime are likely to affect both descriptive understandings and normative recommendations. The paper forwards insights from the development of the SRM approach and reflects on the use of socio-technical concepts in the analysis of agri-food systems, identifying key advantages and highlighting avenues for future research. Through this focus on the application of the MLP in agri-food regime analysis, the paper aims to stimulate debate on the challenges and opportunities for a transition to sustainability across the agri-food regime more broadly, and on the role that transitions theories can play.

2. Context

2.1 *A MLP on Transition*

Socio-technical transitions are defined as 'major technological transformations in the way societal functions such as transportation, communication, housing and feeding are fulfilled' (Geels, 2002). Since the late 1990s, a significant body of literature has emerged on socio-technical transition (STT) (Geels, 2002; Kemp, 1994; Schot & Geels, 2007). Central to this, body of theory is the argument that policy shifts to longer term perspectives and approaches are critical for environmental sustainability (Geels, 2011; Kemp *et al.*, 2007). Critical to the development of STT theory are the concepts of technical regimes and the idea of technological paradigms and technological trajectories (Dosi, 1982). These ideas were developed further by Rip and Kemp (1998) who explored STT and the concept of evolutionary niches, highlighting the role of protected spaces to encourage experimentation and innovation. One fundamental conceptual construct which underpins STT theory is the MLP (Geels, 2002; Kemp, 1994; Rip & Kemp, 1998). The MLP distinguishes three levels of heuristic, analytical concepts which combine as a

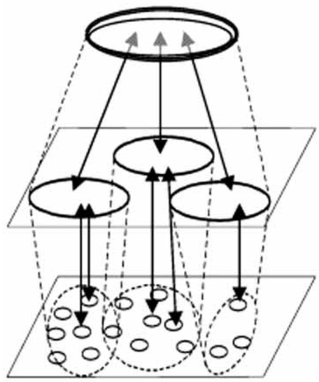

Figure 1. The MLP after Nykvist and Whitmarsh (2008) and Geels (2002).

nested hierarchy to create a socio-technical system (Crabbé *et al.*, 2013). These are: landscape, regime and niches (Figure 1 after Nykvist & Whitmarsh (2008)).

Landscape represents the overarching level, created by a combination of complex macro-level elements including wars, economic development, climate change, oil prices, political dynamics together with wider cultural and normative values (Geels, 2002). The *landscape* level is typically the most stable of the three levels of the MLP described, and because of this is regarded as being exceptionally difficult to change (Geels, 2011).

A *regime* is defined as the articulation of a current social paradigm sum of current practices, beliefs, methods, technologies, behaviours, routines and rules for societal functions (Rip & Kemp, 1998). Due to the presence of established practices, rules and artefacts, the regime exhibits certain obduracy and can be considered to be path dependent (Switzer *et al.*, 2013). In fact, these factors form a deep and embedded structure which is characteristically difficult to change due to lock-in and stability characteristics (Geels, 2011).

Niches are protected spaces which represent significantly different approaches to the existing technological regime. In *niches*, alternative rules, behaviours, practices and wider social elements can develop, or can be 'incubated' (Elzen & Wieczorek, 2005). In this paper, the MLP is applied as a structuring mechanism for the analysis presented herein. While the niche level is critical in any understanding, there is a body of recognized emerging literature in this area, including work by Hall (2000), Murdoch (2000), Morgan and Murdoch (2000), Smith (2007), von Hippel (2001) and Asheim and Coenen (2005).

2.2 *Application of the MLP in Transitions Research*

Regime analysis can be conducted in different ways, depending on the conceptualization of the regime to begin with. Geels (2004) has suggested regimes to contain three distinct elements: systems (resources and material aspects), actors involved in maintaining and changing the system and the rules and institutions, which guide actor's perceptions and activities. The study of distributed electricity generation by van der Vleuten and Raven (2006) empirically applies these distinctions to study effects of lock-in and change in this regime in Denmark. By contrast, Smith (2007) uses regime dimensions as identified by Geels (2002) as an analytical heuristic for regime analysis. Two different approaches highlight how the conceptualization of the MLP can differ, and how this difference can be significant for the types and outcomes of analysis. These approaches are strategic niche management (SNM) and transitions management (TM).

Both SNM and TM approaches are concerned with change at the regime level, which place emphasis on innovation at the niche level (Smith, 2007). SNM literature focuses on understanding the early adoption of new technologies with high potential to contribute to sustainable development (Schot & Geels, 2008). SNM can be regarded as both a research model as well as a policy tool (Smith & Raven, 2012). TM, by contrast, is presented as a governance approach based on the perspective of regimes as complex adaptive systems. TM typically applies a cyclical process of searching, experimenting and learning (Rotmans & Kemp, 2008) and emphasizes the importance of creating visions before starting experiments (Schot & Geels, 2008). While SNM develops an evolutionary approach aimed at overcoming lock-in and promoting socio-technical diversity, TM focuses more on goal-oriented modulation, thereby placing greater emphasis on the role of strategic envisioning (Schot & Geels, 2008). While not explicitly stated, the MLP as applied in SNM has to date primarily focused on market-based understandings where supply-demand dynamics are to the fore, for example the work by Kwon (2012), Romijn *et al.* (2010) and Verbong *et al.* (2010). In TM, a range of elements of societal systems is incorporated, including material infrastructure, the macro economy, demography and the natural environment at the socio-technical landscape level, dominant practices, rules and shared assumptions at the regime level and individual actors and technologies and local practices at the niche level (Rotmans *et al.*, 2001). TM therefore addresses some factors that SNM underplays (Schot & Geels, 2008). These differences are important to acknowledge prior to discussion of the application of MLP to agri-food regime analysis.

3. Approach

The central focus of this paper addresses the regime level of the MLP of agri-food systems. The paper aims to elaborate the MLP by proposing an integrated approach for analysis of regimes, labelled SRM. A TM perspective of the MLP is applied, whereby emphasis is placed on the role of strategic envisioning. However, the paper is not a study of TM in agri-food systems per se, goal-oriented modulation is not addressed for example. The paper aims to elaborate the MLP by proposing a means of mapping complex transition dynamics across: (a) energy and material flows and (b) social practices which shape, direct and determine these energy and material flows. The context for study is firstly described, in a brief discussion of the socio-technical landscape of agri-food systems, including a discussion of the challenges with encapsulating this within current MLP framings. Characteristics of the agri-food socio-technical regime are then discussed, including the need for new approaches in regime conceptualization and modelling. The SRM approach is articulated, including a discussion of the challenges of applying MLP in agri-food transitions studies, and the challenges with integrating different ontologies such as social practice theory (SPT) with the MLP. Finally, potential application, policy implications and future directions of the SRM approach are forwarded. A body of literature has already emerged on the niche level of agri-food regimes, including work by Smith (2006); Patankar *et al.* (2010) and Lebel *et al.* (2010) and this level of the MLP is not addressed in detail in this paper. In terms of the scope of study, the literature on MLP does not prescribe how broad or narrow the empirical topic should be delineated. Geels (2011) argues that the regime concept is an inherently flexible concept that can be applied to empirical topics of different scope (primary fuels or entire electricity systems). This flexibility is one of the primary attractions for application of the MLP in agri-food systems research. The agri-food regime, like most real-world complex systems, is not characterized by neatly defined, easily identifiable boundaries; for analysis purposes, narrowly defined boundaries are likely to underestimate complexity and oversimplify reality. In the context of globalized supply chains, simple delineation of regime by food type or by region of production, a 'tomatoes' regime or an 'Italian tomatoes' regime, for instance, is problematic and likely to be not particularly useful. For the purposes of this paper therefore, the inherent flexibility of the regime concept is recognized, so that the delineation of the agri-food regime can occur in several ways, and according to the requirements of the particular agri-food regime elements under consideration. In this regard, the developed SRM approach is forwarded as a first-stage, strategic engagement with the dynamic, intertwined and multi-dimensional challenges which a transition of the agri-food regime to a more ecologically sustainable equilibrium demands. This is achieved through an analysis of existing literature, augmenting emerging work to expand the applicability of socio-technical principles to agri-food systems research. The paper is structured around two research questions:

(1) How can the MLP be elaborated for application in agri-food systems research?
(2) What is the implication of including multiple perspectives in the analysis of regimes?

4. Elaboration of the MLP for Agri-Food Regime Analysis

4.1 *The Changing Landscape of Global Agri-Food Systems*

There is a wealth of research reported in the literature which addresses landscape factors of significance to the agri-food socio-technical system, of which a brief overview is provided here. A defining feature of contemporary agri-food systems is the extension of food supply chains across the globe, aided by the considerable resources of corporate agri-business and, increasingly, by the retail sector (McMichael, 2004). Agri-food systems are 'spreading eastwards, concentrating, globalizing' and there is a fundamental altering of internal relations within the system (Rayner *et al.*, 2008). A clear trend in all parts of the food system is the high levels of horizontal (between similar companies) and vertical (along the supply, production and processing chain) integration among food-related businesses. Indeed, the globalization process implies that a vertically integrated food supply chain that links input suppliers, producers, processors, distributors and retailers becomes essential for meeting the changing demand requirements as efficiently as possible (Pingali, 2007). Horizontal and vertical integration of companies in the food system are therefore increasing dramatically (Acres, 2010; Fresco, 2009). Global trade has also allowed human relationships with food to move beyond a 'local and seasonal' model (Acres, 2010). With market globalization and convenient transportation choices, more and more food types have become available during seasons when they were typically absent (Marlow *et al.*, 2009), resulting in a severing of the link between diet, the local availability of resources and local habits (Pingali, 2007). Rapid economic growth and increases in income and trends of urbanization and globalization are leading to a dramatic shift of Asian diets away from staples and increasingly towards livestock and dairy products (Pingali, 2007). While world population is projected to increase by 50% from 2000 to 2050, it is estimated that meat production will increase by 100%, with associated ecological consequences[1] (Aiking, 2011). These pressures are additional to, but linked with, issues such as population growth, urbanization and industrialization, economic growth and land use changes and water scarcity (Khan *et al.*, 2009). In this context, global climate change and nutritional transition are already placing new pressures on food production systems. Climate change impacts on the stability of primary production may subsequently affect food manufacturing and trade (Tirado *et al.*, 2010). Direct impacts on food production through changes in agro-ecological conditions may be compounded by indirect effects on growth and distribution of incomes, and demand for agricultural produce as a result (Schmidhuber & Tubiello, 2007). Dominant perspectives in conventional agricultural science and development programmes have until recently implicitly assumed a stable and an almost indefinitely resilient environment, where resource flows could be controlled and nature would return to a steady state when human stressors were removed (Thompson & Scoones, 2009). Such perspectives fit with the original view of the landscape level as being typically the most stable of the three levels of the MLP (Geels, 2011). However, it is evident from this brief review of literature that the available evidence suggests that the landscape level for agri-food systems is in fact characterized by increasing volatility, with a series of interlinked and cascading issues which present serious challenges to present configurations of agri-food regimes. Such volatility has not been sufficiently recognized by relevant academic disciplines. Recent debate on the development of the MLP may ensure that transitions scholars are becoming better equipped to deal with volatility of this type. For example, Geels (2011) acknowledges that the landscape level has been criticized as being a residual analytical category, whereby a myriad of contextual influences are crudely grouped together. Geels (2011) suggests a number of changes to address this issue, which could serve to make the landscape level more conceptually useful. Firstly, the landscape level can be made more dynamic by applying van Driel and Scot's (2005) more differentiated view of landscapes, including: factors that do not change, or only change very slowly, rapid external shocks and long-term changes in a particular direction. Further differentiation could be made by identifying those landscape developments that help stabilize existing regimes, and by determining the relative influence of stabilizing and destabilizing landscape developments. Geels (2011) also suggests that the influence of regime shifts on landscape changes and mechanisms of reverse causality could be further elaborated. Such changes to the landscape level of the MLP are urgently required for agri-food regime analysis, for the following reasons:

- Issues such as climate change are dynamic and evolving. Since the industrial revolution, climate has moved from a factor that changed slowly, to a factor changing in a particular direction. It is likely in the coming century that climate change will represent a source of rapid external shocks in the form of droughts, water shortages and extreme weather events. The dynamism of factors such as climate change at the landscape level therefore needs to be acknowledged and factored into MLP analysis.

- A temporal component to landscape conceptualizations would aid in this, allowing delineation between long-term, short-term, chronic and acute landscape factors.
- The agri-food system represents an ideal arena to investigate the influence of regime shifts, such as lower fossil fuel consumption and reduced emissions, on landscape changes, such as the rate of climate change. While the views of Shove and Walker (2007) in this context are recognized, in that the outcomes of actions are unknowable, the system unsteerable and the effects of deliberate intervention inherently unpredictable, nevertheless this does not represent a legitimate reason to maintain current functioning, or clearly established regime dysfunction, in the face of overwhelming challenges. As noted by Rotmans and Kemp (2008), we can do things that help to achieve better futures, even in the face of perplexing complexity and overwhelming uncertainty. A reduction of emissions across the entire agri-food system represents a simple example of such an action.
- The idea of regime stability or regime resilience is also very apt for agri-food regime analysis. The MLP could be applied in this regard, not to analyse shifts in the current regime in response to niche level innovations, but to consider what innovations are required to maintain stable regime functioning in the face of the aforementioned volatility and increasing disruption from the landscape level.

4.2 *Challenges with Agri-Food Socio-Technical Regime Articulation*

Socio-technical regimes are typically defined as relatively stable configurations of institutions, techniques and artefacts, as well as rules, practices and networks that determine the development and use of technologies (Rip & Kemp, 1998; Smith *et al.*, 2005). A focus on regimes recognizes that organizations and technologies are embedded within wider social and economic systems (Rip & Kemp, 1998). Socio-technical systems are thus conceptualized as clusters of aligned elements, such as technical artefacts, knowledge, markets, regulation, cultural meaning, rules and infrastructure (Kern, 2012). As socio-technical regimes have become the focal unit of analysis, the policy challenge is to transform them into more sustainable configurations (Smith *et al.*, 2005). Despite a large and growing literature, there has been a dearth of research which systematically identifies or analyses the meso-level socio-technical regimes said to be central to stability and change in socio-technical systems (Genus & Coles, 2008). From an agri-food policy perspective, while there is a growing recognition among international and national bodies of the role of regulatory institutions in addressing current patterns and levels of consumption (Mont, 2004), the concept of the agri-food system itself is poorly reflected in institutional terms (Fresco, 2009). Notwithstanding occasional overlaps, the fields of agriculture, food processing, nutrition, marketing and consumption are still ‘miles apart’ (Fresco, 2009). There are currently no international organizations or intentional governance structures to ensure the long-term, equitable use and sustainable management of phosphorus resources in global agri-food systems, for example (Cordell *et al.*, 2009). At present, there is also a dearth of research on strategic aspects of risk management for agri-food systems in the face of climate change, energy resource scarcity and available mineral and water resources (Acres, 2010). Furthermore, Thompson and Scoones (2009) argue that current equilibrium-centred views provide inadequate insight into the dynamic character of agri-food systems, particularly in an era of global economic and environmental change.

Improving the sustainability of the agri-food system requires a comprehensive and integrated understanding of the relationships between food consumption behaviours, processing and distribution activities and agricultural production practices (Heller & Keoleian, 2003). Coherent policy approaches for the promotion of sustainable agri-food systems must take the entire process into consideration (Infante Amate & González de Molina, 2013), and must also deal with socio-economic complexities, including the cultural dimensions of consumption and short- and long-term implications of production and consumption practices (Rayner *et al.*, 2008).

In the context of these debates, this paper forwards the SRM approach as means of first-stage engagement with these issues for decision-makers in the agri-food arena. While assessment is being increasingly viewed as a critical element to aid in the shift towards sustainability, (Pope *et al.*, 2004), major difficulties remain with assessment for sustainability, not least the growing number of sustainability-related methods, tools and concepts (Hallstedt *et al.*, 2010). Decision-makers face the challenge of selecting appropriate tools from an ever increasing range, and applying these at suitable spatial, temporal and institutional scales. These challenges are further pronounced for the all-encompassing regime concept. Strategic approaches are critically important in this regard. Strategic approaches can raise awareness of potential impacts of activities at the earliest stages of design and planning, and can challenge deeply embedded assumptions in the search for progressive solutions to ecological impacts of projects (Carter *et al.*, 2009), or of wider systems. Bina *et al.* (2011) forward strategic assessment approaches as a medium to facilitate conversations among policy-makers, environmentalists and the public, as opposed to strictly defined assessment tools, for example. The paper responds to the clear need for strategic approaches which consider the system as a whole, and which engage with sustainability appraisal at the strategic level of agri-food systems. Two approaches are forwarded to describe and evaluate those defining characteristics of the agri-food socio-technical regime, following Smith *et al.*'s (2005) argument that an analytical and normative engagement with the complexities of governing sustainable systems innovation needs a more explicit and detailed articulation of conceptual tools. The goal of these approaches is to distinguish more clearly between different elements critical for regime transition and to provide systems characterizations which are reflective of different contextual elements and descriptive understandings of the system. The approaches include *Energy and Material Flow Mapping*, and *Socio-Technical Practice Mapping*. Figure 2 illustrates this in the context of the MLP heuristic framework.

4.3 *Energy and Material Flow Mapping*

In conventional food-system management processes, energy is considered as only a small part of the total cost of production. It is not considered as a core business in the agri-food industry and as a result, is not generally a priority in daily management (Muller *et al.*, 2007). However, agri-food systems in the advanced economies depend on large inputs of high-quality energy resources to maintain their characteristic high levels of productivity (Patterson, 1984). Possibilities for reconciliation of food production with environmental quality lies in addressing

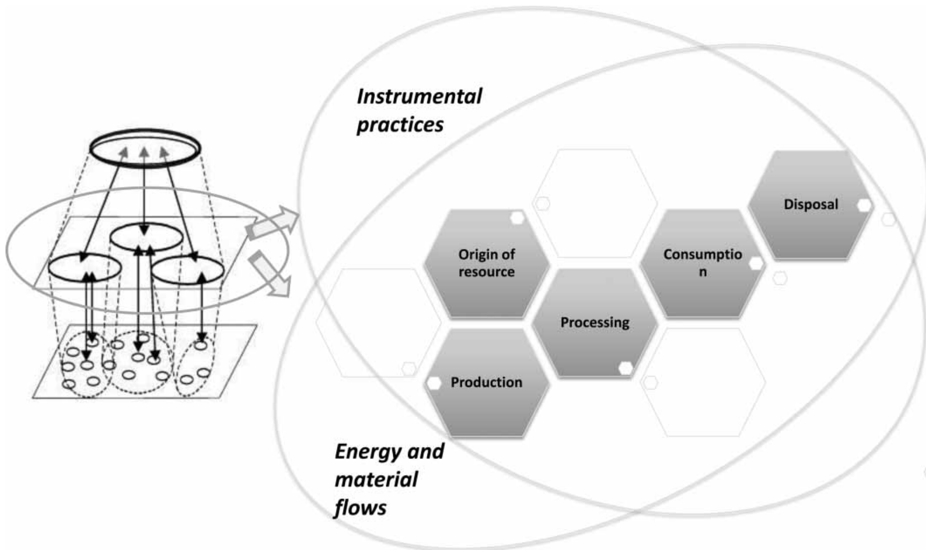

Figure 2. SRM using the MLP.

the link between production and material and energy throughput, particularly through more efficient use of land, water and energy inputs (Khan *et al.*, 2009; Picton & Daniels, 1999). This role of energy must therefore be understood and taken into account when making decisions concerning resource allocation, if levels of productivity are to be sustained in the coming decades (Patterson, 1984). Such an approach needs to be applied throughout the food production process, from raw materials' extraction to final disposal or reuse of waste materials. Following from this, Figure 3 presents the agri-food socio-technical regime, as viewed through an Energy and Material Flow Mapping Model. Figure 3 has been developed after ideas forwarded by Muller *et al.* (2007), Sarkis (2003) and Sobal *et al.* (1998).

From Figure 3, the conceptually most evident way of immediately reducing energy use from food production processes would be to reduce the amount of waste being produced throughout the system, particularly at the final distribution and consumption phases. A reduction in food waste would have an effect on the whole food supply chain, in direct relation to the amount of energy used for producing the wasted food (Wallgren & Höjer, 2009). The extents to which wastes continue to arise, and the quantities requiring ultimate disposal, remain as stresses upon the environment (Fehr *et al.*, 2002).[2] The food chain produces Greenhouse gas (GHG) emissions at all stages in its life cycle for example, from the farming process and its inputs, through to manufacture, distribution, refrigeration, retailing, food preparation in the home and waste disposal (Garnett, 2011). Food that is not consumed or used in some other beneficial way in effect represents a waste of all of the resources that were used in its production and distribution, including water and energy resources (Ridoutt *et al.*, 2010).

Efficient use of inputted energy resources is therefore vital in terms of increasing crop production, water productivity, the economic competitiveness of food production and environmental sustainability (Khan *et al.*, 2009). The recycling and reuse of materials represent an important, albeit part, alieviation of environmental stresses (Pentreath, 2000). A closing of nutrient cycles associated with

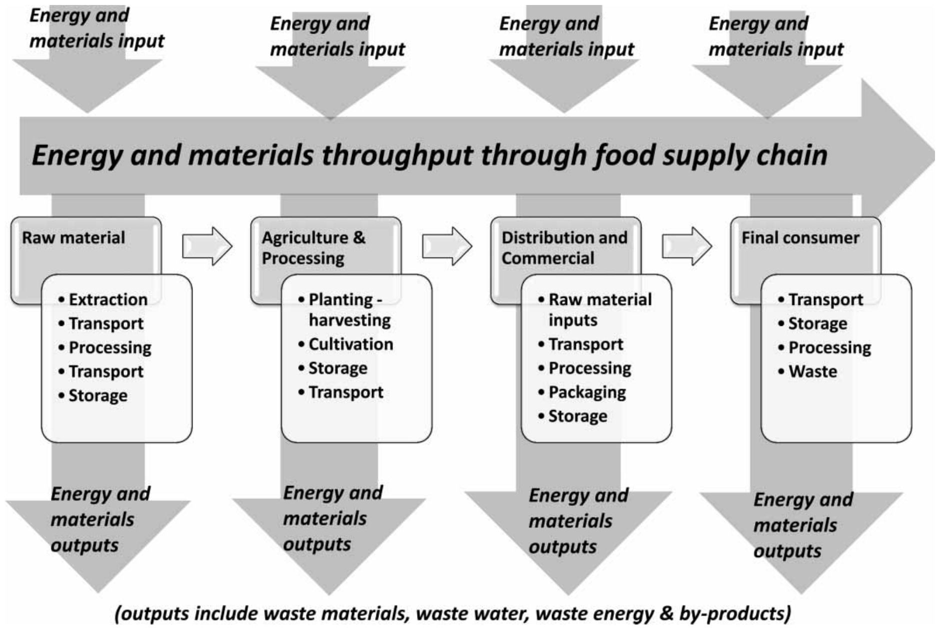

Figure 3. Agri-food socio-technical regime, energy and material flow mapping model after schematics by Muller *et al.* (2007), Sarkis (2003) and Sobal *et al.* (1998).

agri-food systems decreases dependence on synthetic fertilizer production in the first instance, and may help to address overall levels of waste through resource reuse, such as the use of compost as crop fertilizer (Tilman *et al.*, 2002). From a policy perspective, energy could be forwarded as a unit of management across the agri-food system to achieve such goals. There is a case for final consumer awareness raising in this context, including mandatory reporting of the environmental impact per unit of final product, for instance (Gadema & Oglethorpe, 2011).[3] Economic savings may also be forthcoming from such measures. Research by Lee and Okos (2011) has shown the economic feasibility of applying measures to reduce water usage, waste water production and energy consumption in a food processing system, reporting significant environmental and economic savings potentials. The Energy and Material Flow Mapping model demonstrates that links between waste, energy and carbon need to be far more explicitly acknowledged across the agri-food system. This needs to occur firstly at the level of the basic understanding of regime functioning, before effective policy instruments can be developed. In this regard, the forwarded mapping model can be developed based on a series of narrative descriptions from key stakeholders across the system. A characterization of waste, energy and carbon profiles across individual stages of the production and consumption process represents a first stage in this process, and a means of identifying those aspects which, for example, a detailed life cycle assessment would yield maximum policy relevant insights and understandings.

4.4 *Integrating SPT Concepts with the MLP*

Despite shared concerns with sustainability and with systemic understandings of innovation, both MLP approaches and SPT have been developed as discrete and in some respects, mutually exclusive bodies of literature (Hargreaves *et al.*, 2013). To date, the application of practice approaches to sustainability transitions has largely focused on final consumption and changes in what people do in their everyday lives, including the work of Shove and Walker (2007), Walker and Shove (2007) and Watson and Shove (2008). However, practice-based approaches have yet to systematically consider processes of production in sustainability transitions research (McMeekin & Southerton, 2012). This represents a significant gap in the literature, particularly from the point of view of agri-food systems research. Practices are of instrumental importance, particularly in view of the many normative associations which inform judgements along the agri-food system; notions of hygiene, expectations of quality, ethical issues around waste and the use of resources, for example. In this regard, discreet sets of practices can be located along the agri-food supply chain, which have an instrumental effect on issues of resource efficiency, waste and environmental impact. There is a need to develop appropriate means of co-locating practices with materials and energy flows at particular points of the regime. Which practices matter, which are significant and which can be addressed effectively to influence associated energy and materials flows represent critical questions for agri-food sustainability.

Where SPT focuses attention on the horizontal dynamics of practices that cut across multiple regimes as they follow circuits of reproduction (Hargreaves *et al.*, 2013), the MLP has by contrast paid very little attention to final consumption and remains an approach that foregrounds the importance of technological change (McMeekin & Southerton, 2012). Within the MLP, agency, behaviour and the instrumental influence of practices across myriad activities, including and additional to consumption (extraction, processing, storage, transport, retail and distribution) are important aspects of socio-technical regimes, which require further consideration. Geels's (2004) structure of socio-technical systems, rules/institutions and actors does provide for agency within an MLP framework. These ideas are applied and elaborated on by Elzen *et al.* (2011), whose concept of normative orientation offers a promising avenue for crossover between SPT and MLP approaches. However, while the overarching schema of the MLP is well suited to understanding connections between production and consumption, the dynamics of practices such as final consumption remain poorly represented (McMeekin & Southerton, 2012). There remains a debate in the literature on the compatibility of SPT and MLP approaches. Integrative efforts potentially conflate distinct analytical approaches and units of analysis, transitions in regimes in MLP versus transitions in practice in SPT, for example (Hargreaves *et al.*, 2013). Geels provides an in-depth discussion of such issues arguing that a micro-focus, flat ontology and complexifying epistemology complicates the crossover of relationist approaches such as practice theories with the MLP (Geels, 2010). There remains a great diversity in practice approaches, however, as discussed by Gram-Hanssen (2011). Warde's practice theory (Warde, 2005) has a more 'structured' view of agency which is potentially more compatible with MLP approaches than practice theory approaches with 'flat' ontologies, for example. Recent literature, including the work by Hargreaves *et al.* (2013) and McMeekin and Southerton (2012), suggests that viable crossover may be possible between practice theory and the MLP. The question remains, why is this desirable? Why not apply MLP and SPT as different slices of a complex reality? The view of this paper is in agreement with that of Hargreaves *et al.* (2013), that appropriate consideration of the points of intersection between regimes and practices offers vital insights into processes that can serve to hinder (or potentially help) sustainability transitions. This paper therefore argues that a mapping of practices in conjunction with a mapping of energy and material flows can identify critical points of intersection between these domains. These intersection points represent locations of strategic importance in a TM view of the agri-food regime.

4.5 *Socio-Technical Practice Mapping*

The application of behavioural approaches in consumption studies is part of a general wave of renewed interest in practice theory (Røpke, 2009). Practices are embedded in a range of socio-technical systems which constitute a diversity of institutions, regulations, infrastructures and technologies. They are also framed and shaped by the norms and values of the societies and contexts in which they take place (Moloney *et al.*, 2010). Next to the routine consumption practices of everyday life, there are practices implied at higher systemic levels, in the reproduction of markets, in politics and throughout the workings of civil society (Spaargaren, 2011). In this regard, practices can be considered in isolation, or can be considered as part of larger groups or interrelated sets of behaviours (Moloney *et al.*, 2010). Wider social systems can be described as relations between actors, organized as repeated social practices and reproduced and transformed by actors, for instance (Røpke, 2009). Figure 4 presents the agri-food socio-technical regime, as viewed through the Socio-Technical Practice Mapping Model, developed from ideas forwarded in these literature sources.

In the socio-technical regime heuristically shown in Figure 4, all segments or nodes of production—consumption chains and networks can be characterized according to the associated practices at that point (Spaargaren, 2011). Spaargaren (2011) distinguishes between the upstream practices of mining, processing, storage, transport, retail and distribution for example and the downstream

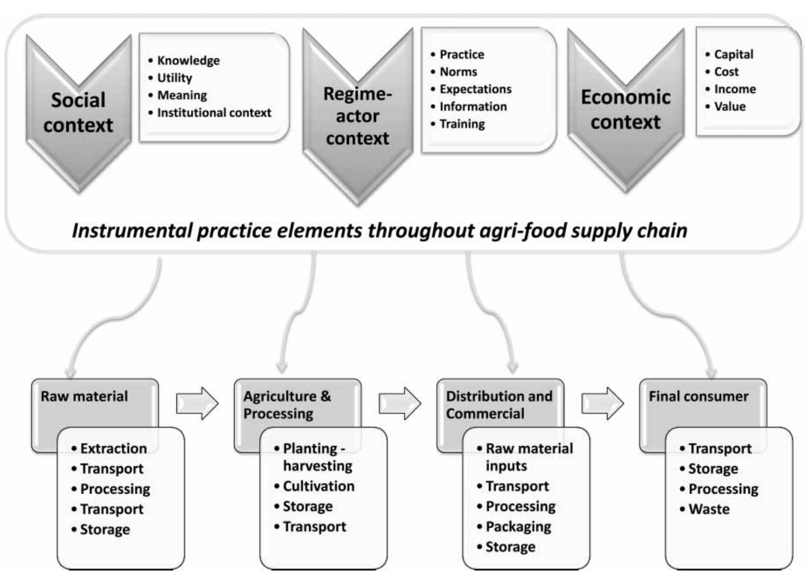

Figure 4. Agri-food socio-technical regime, socio-technical practice mapping model after Spaargaren (2011), Røpke (2009), Moloney *et al* (2010), Stephenson *et al.* (2010) and Sobal *et al.* (1998).

practices of buying, storing, consuming, (re)using and recycling. In terms of downstream practices, consumers not only push food innovation by their behaviour but also pull the process by their wants and needs, drivers which are further informed by awareness through education and the media (Earle, 1997). In the advanced economies, societal norms and expectations represent a considerable driver of food waste, for example. Major supermarkets, in meeting consumer expectations, will often reject entire crops of perfectly edible fruit and vegetables at the farm because they do not meet exacting marketing standards for their physical characteristics, such as size and appearance (IMechE, 2013). Controlling and reducing the level of wastage of this type are frequently beyond the capability of the individual farmer, distributor or consumer, since it depends on factors related more to societal, political and economic norms (IMechE, 2013). Against this, there is a growing, albeit limited, demand for environmentally sustainable food produce.[4] The macro-trend of global dietary transition is also influenced at all levels by norms and expectations (Spaargaren, 2011), and food cultures once thought to be resilient appear to be rapidly changing in the face of such pressures (Rayner *et al.*, 2008). Understanding of the overall needs, views and attitudes of society is therefore crucial to understanding agri-food regimes (Pentreath, 2000). More specifically, there is a growing need for policy-makers to gain a better understanding of everyday consumption practices (Spaargaren, 2011). According to the Socio-Technical Practice Mapping Model presented here, practices represent a basic ontological unit for analysis. Practice inputs, including means of implementing cultivation, processing and storage procedures, norms and expectations which shape wholesale and retail activities, and the behaviour of end consumers need to be recognized as having instrumental importance to the functioning of the agri-food system. Practices shape the character of the agri-food regime across production and consumption activities, and play a critical role in determining the future development and evolution of the regime. Behavioural and practice elements represent a central focus for any policy efforts to foster a transition to a sustainable, low-impact agri-food regime. In this context, Socio-Technical Practice Mapping may be applied to help explain behaviour at critical points in the regime. An initial mapping exercise of this type may be applied to identify important behavioural drivers for targeted interventions. The mapping approach also provides a framework for empirical research on the impact of interventions.

5. Application

The failure of many policies and management efforts to change the course of economic and societal systems towards more sustainable directions shows that there has been a lack of a sense of direction, vision and overall goal (Korhonen, 2007). One issue has been an over reliance on reductionist methodologies and tools, including narrowly defined indicators, across single scales or dimensions and for limited time-horizons (Gasparatos *et al.*, 2008). By contrast, the socio-technical approach to transitions is broader than other approaches to sustainable development (Geels, 2012). This paper has explored the use of the MLP, and in particular the regime concept to bring forth hidden but pervading aspects of agri-food-systems. Through application of the SRM approach, the conceptualization, visualization and communication of multi-layered and complex system functioning and dynamics are possible. Elements of materials and energy use and practice inputs can be recognized as having instrumental importance to the functioning of the system, while the role of practitioners in defining the system is made explicit. The integration of MLP with SPT elements ensures that a multi-dimensional, multi-disciplinary approach is maintained, and that individual, narrowly defined issues or areas of interest are not prioritized over a comprehensive view of the system as a whole.

A mapping of practices in conjunction with a mapping of energy and material flows can identify locations of strategic importance in a TM view of the agri-food regime. By co-locating materials and energy flows and practices as key components of the regime, an explicit engagement with these elements in the understanding and subsequent management of the regime in question is engendered. Table 1 provides an overview of the application of the SRM approach for the investigation of multi-dimensional aspects of agri-food sustainability, taking the case of food waste across the system as one avenue of application. The table provides a summary of indicative uses of SRM in this context across production and processing, consumption and disposal stages of the agri-food regime, indicating issues of importance and avenues for future research.

The application of the SRM approach, informed and structured by the socio-technical MLP concept, has three key advantages for agri-food systems research, particularly in the context of the debates discussed in Section 4. These are:

- The conceptualization of complex system functioning through multi-dimensional perspectives
- The co-location of 'hard' energy and material flow issues with 'soft' socio-technical practice issues at points of strategic importance across the agri-food regime
- The subsequent targeting and direction of appropriate assessment techniques and policy responses

The articulation of the agri-food regime through SRM can help with the development of strategic, targeted and scientifically informed appraisals of sustainability at key points of the system. As the theme of sustainability is intrinsically multi-sectoral, this suggests that effective appraisals should likewise be based on multidisciplinary approaches (Ravetz, 2000). Strategic level assessments of this kind, directed by SRM, have the potential to act as mediating instruments, bridging problem perceptions with technical solutions and facilitating the integration of environmental values into decision-making processes (Vicente & Partidário, 2006). For example, a key challenge is the expedient transfer of relevant expertise to where it is needed, and the development of a political and social environment which encourages both the transfer and adoption of relevant ideas to take place (IMechE, 2013). In addition, there is a need for policy integration, which is reflective of the vertical and horizontal integration of companies discussed in Section 4.1. Özerol *et al.* (2012) argue that the governance of natural resources calls for approaches that transcend fragmented single-sectoral approaches. Governance measures which are multi-pronged, involving technologies, institutions and regulatory measures are therefore required (Khan *et al.*, 2009). Barber (2007) and Spaargaren (2011) highlight policy integration potentials, whereby production and consumption are conceptualized as part of an interdependent cycle of activities, around which issues, initiatives and strategies cluster. The SRM approach presents significant potential for decision-makers to address these challenges. From a materials flow perspective, the Institution of Mechanical Engineers argue that there is a world-wide potential to provide 60–100% more food by

Table 1. Application of SRM for the investigation of multi-dimensional aspects of food waste across agri-food systems

	Energy and material flow mapping	Socio-technical practices mapping	Integrated SRM
System-wide application	Helps understand **what** and **where** food is being wasted throughout the supply chain and what the energy and emission implications of this are	Helps understand **why** the practice of wasting food is occurring at different levels throughout the supply chain	Understand **how** targeted policy interventions can reduce food waste and its emissions at key points throughout the supply chain
Production and processing	Understand the energy and emissions implications of low-intensity cultivation techniques versus high-intensity techniques *Example*: with consideration given to resulting yield loss quantities and the drivers behind those losses	Understand cultures of wholesale and retail decision-makers in shaping and directing food markets *Example*: with regard to the rejection of large quantities of fresh fruit and vegetables because of imperfect appearance as well as the disposal of trimmings resulting from standardized manufacturing processes	-Obtain a wider societal understanding of food losses and impacts *Example*: links between consumer derivation of value for food products and understandings of food waste -Play a leading role in encouraging research into food losses in farms -Change regulations on specific marketing standards for misshaped fruit and vegetables -Pass legislation to provide tax credit to farmers who donate excess produce
Consumption	Economies of scale in food provision, particularly with regard to environmental impacts and issues of local versus globally sourced materials *Example*: increased food waste along long supply chains because of long transportation and storage times required	Understand drivers of unsustainable consumption patterns and attitudes to food waste in residential and commercial sectors *Example*: insufficient purchase planning; confusion around food labelling dates; careless attitudes towards food of those who can afford to waste; and belief that food waste is not an environmental problem as it is biodegradable	-Influence market norms and expectations -Update public procurement rules for catering and hospitality to consider waste -Promote behavioural change through awareness campaigns to inform the public how to avoid wasting food -Enforce clarification on date labels to help raise consumer awareness and knowledge

(*Continued*)

Table 1. Continued

	Energy and material flow mapping	Socio-technical practices mapping	Integrated SRM
Disposal	-Identification of wasted energy and material flows constituent in food waste materials -Emissions implications of food waste disposal and recovery *Example*: comparisons of composting versus anaerobic digestion, versus incineration	Understand the design aspects scripting behaviour of food disposal, including packaging elements *Example*: packaging that absorbs the hormone ethylene to slow down fruit ripening to extend shelf life	-Guide policy directions to address food waste, including technical aspects, links to other policy arenas (climate change), need for innovation support etc -Providing separate collection of food waste for both residential and commercial sectors -Improved waste management -Addressing regulations around using food waste for animal feed -Improve the consistency of reporting on the food waste figures and waste categories

simply eliminating losses, while simultaneously freeing up land, energy and water resources for other uses (IMechE, 2013). SRM can inform a first-stage articulation of waste and inefficiency issues across the system, identifying, for example, where energy use can be reduced and directing where more in-depth technical analysis should be conducted to better inform policy responses. In addition, the practice and behavioural elements underpinning all stages of production and consumption in the agri-food regime are made explicit and recognized in instrumental terms by the approach.

The SRM approach is not forwarded as a definitive model of agri-food systems. No single framework or model could effectively encompass all facets involved in the complex socio-ecological agri-food system, or precisely predict systems dynamics across large temporal and spatial scales. There is a vast body of literature on multiple facets of agri-food systems and all of it cannot be appropriately addressed within the scope of a single paper. Frewer *et al.* (2011) examine what is known about consumer responses to food-related technologies that have been associated with different levels of consumer rejection, for example. Other issues include a rapidly changing governance context (Le Heron, 2003), the changing nature of agri-food supply chains in the face of high-tech information systems (Salin, 1998) and the impact of information technologies on markets, processes and management systems (Schiefer, 2004). Rather, the paper has aimed to further elaborate dimensions of the existing literature on energy and materials flows and practices, building on emerging work to further interrogate the applicability of socio-technical principles to agri-food systems research. The paper has sought to add to debate on comprehensive understandings of evolving ecological, economic, social and political conditions, as called for by Thompson and Scoones (2009). The developed SRM approach affords benefits to researchers because of its broad, system-wide focus and consideration of multiple perspectives and for policy-makers, a means to effectively develop a first-stage engagement with these complexities, whereby multiple alternative policy pathways, across a range of scales and domains can be potentially identified and explored.

6. Conclusions

Contemporary agricultural practices, while undoubtedly economically efficient in some regards, have incurred significant costs related to environmental degradation. Technological advances and globalization have shaped an agri-food regime that is economically, socially and environmentally unsustainable in the long term. This agri-food regime is also increasingly vulnerable to a range of increasingly prevalent landscape level risks in the short-to-medium term. In this context, the transition to a sustainable, low carbon future presents a dauntingly complex issue, involving technical, political, social and theoretical aspects. Such a transition necessitates an exploration of new ways of production and consumption, new technologies and innovations and new regulatory and institutional infrastructures to coordinate the change. This paper has explored the elaboration and use of the MLP heuristic framework as a means to better conceptualize agri-food systems. The forwarded SRM approach can be applied to assess the current state of the agri-food socio-technical system, characterize the dynamic nature of pressures and challenges facing the system and can enable a strategic direction of policy approaches and assessment techniques targeted at various points in the system. The comprehensive mapping of the entire agri-food system can also facilitate a more rigorous appraisal of the sustainability credentials of new innovations. The SRM approach is not advanced as a definitive model of agri-food systems. Rather, the developed approach identifies the advantages of applying socio-technical concepts to agri-food systems research. Future work will apply SRM to identify those locations across the agri-food regime where more in-depth theoretical and empirical analysis is required to further develop ideas of socio-technical transition. A number of case studies, across international jurisdictions, will serve to further develop the insights from this paper and will provide a means of validating the arguments forwarded. It is clear from analysis that theoretical approaches remain underdeveloped, particularly in terms of the broader understanding of linkages between food production, food-related waste and energy and wider bodies of knowledge on consumption behaviour and sustainable practice. There is an obvious lack of empirical research underpinned by a lack of data. An ambitious programme of research is required to further examine the ecological, fiscal, regulatory, infrastructural and institutional dimensions of agri-food systems, together with aspects of innovation and stakeholder interaction which a transition to sustainability would require. More broadly, while this paper has explored the use of an elaborated MLP as a means of engaging with complexity in agri-food systems, further enquiry of this type would prove valuable for future research into the sustainability of other complex and dynamic systems.

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Notes

1. Marlow *et al.* (2009) report on the higher ecological cost of an animal-based diet, citing the disproportionate impacts of meat production systems on biodiversity loss, freshwater depletion and climate change for example. Furthermore, Aiking (2011) highlights the crucial role that meat and dairy production play in overstepping 'planetary boundaries', including absorptive capacity and pollution threshold levels for key issues.
2. Every year, an estimated 1.3 billion tonnes of the food produced for human consumption worldwide is lost or wasted. In industrialized countries, significant waste occurs at the consumption stage, while in low-income countries, food losses take place primarily during the early and middle stages of the supply chain (FAO, 2012).
3. Gadema and Oglethorpe (2011) argue that the establishment of effective linkages between food policy and food market actors to drive a targeted and coherent carbon-labelling policy is needed, which would provide consumers with the opportunity to make informed choices.
4. Demand for food products with low-ecological impact is predicted to strengthen considerably in the coming decade (Fresco, 2009).

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