THE BIOFUEL CONUNDRUM – TOWARDS UNDERSTANDING THE SYSTEMIC INFLUENCE OF AGRICULTURAL AND ENERGY POLICIES ON ENERGY AND FOOD SUPPLIES

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ABSTRACT

This paper complements others that explore the mutually informing use of alternative systems methodologies in building understanding of dilemmas faced by policy makers. We consider the systemic influence of eco, energy and agricultural policies, specifically related to the use of grain crops: to generate biofuels for the energy sector, or to provide raw materials for the food production industry. In doing so, we surface the complexity faced by those charged with determining agricultural and energy policy and provide a constructive illustration of how the CLDs of System Dynamics and Senge's systems archetypes can be used to convey understanding of that complexity and provide a platform for alternative ways of addressing such dilemmas.

Keywords: Multi-methodology, Systems Thinking, Causal Loop Diagrams, Systems Archetypes, Agricultural Policy, Energy Policy.

INTRODUCTION & OVERVIEW

This paper contributes to a series [1] [2] [3] that has explored the use of systems methodologies, particularly the use of different systems representational tools. In this paper, we examine the impact of a set of global and local forces that have resulted in the growth of biofuel 'industry', the consequent substitution of grain-for-food crops by grain-for-biofuel crops, and other related systemic effects on the agricultural and food industries. The biofuel industry has interest in that it sits at the intersection of the agricultural and energy sectors and that it is much influenced not only by governmental policies but by environmental and ecological forces.

This paper seeks to provide a constructive illustration of how systems approaches, and particularly, the use of the Causal Loop Diagrams (CLDs) of System Dynamics (SD), can be used to shed qualitative insight on the systemic nature of these issues. In addition, we seek to demonstrate the promise and value of being able to build and convey understanding of such situations and the inherent dilemmas faced by policy makers and decision makers, through the recognition of commonly occurring systemic structures embedded in the situations. We do so in a manner facilitated by Senge's categorisation of systems archetypes as a basis for identifying such systemic structures [4] [5] [6].

Our demonstration is facilitated through an examination of an illustrative case which we will refer to as the biofuel conundrum. We first provide a brief outline to the development of interest in alternative fuels, specifically biofuels, and then document how the agricultural sector, worldwide, has been led to the planting of grain crops for biofuel purposes, often replacing the use of grain crops within the food supply chain. We note that it is characteristic of dilemmas that different and diverse views of the same problematic situation exist – the nature of undesirable symptoms and effects etc - and seemingly irreconcilable opinions of how they should be addressed.

In this paper, in illustration of our approach to understanding such situations, we first seek to capture and portray aspects of the problems facing policy makers that reflect the seeming continuous and virtuous growth cycles of grain crop planting, and how such cycles may be arrested by natural limiting cycles, redolent of Senge's *Limits to Growth* (LTG) archetype. We then show how the dilemma of whether to substitute grain crops for food with grain crops for biofuels can be beneficially understood in terms of Senge's *Success to the Successful* (STS) archetype, before showing how other external forces may impact on how the systemic relationships unfold.

GLOBAL WARMING, ENERGY AND FOOD

Global Warming – Its Impact on the Energy and Agricultural Sectors

The advent of global warming, and fears of its impact on ecological systems, has resulted in many governments, non-governmental agencies and global institutions instituting policies and being party to treaty agreements, intended to address and ameliorate some of its effects, and to directly address some of the causes, for example, the generation of carbon emissions. However, a lack of consensus on causes, effects and remedies is largely responsible for a lack of concerted or coordinated policy and action on the matter ([7] [8] [9] [10] [11] [12] [13].

Whilst there may be broad agreement on the harm caused by carbon-emissions of fossil-based fuels, or by the clear felling of large tracts of forestry, governments have responded with a mix of policies that mandate or encourage the use of alternative fuels, especially fuels generated from biomass, for example ethanol produced from grain crops or woodchips, or for example, encourage, forest planting. The targets for use of biofuels set by the federal US government, and the accompanying subsidies offered for grain crop planting for the production of ethanol biofuel, sit alongside the mandatory state planting of grain crops and the production of ethanol in China [13]. However, there are fears that the headlong plunge into grain crop planting has, on the one hand, started a virtuous cycle of growth in grain crop planting, whilst on the other hand, another view exists that the growth is not only unstoppable but unwelcome, in terms of its impact on alternative forms of agriculture or on alternative use of grain crops.

The first issue is captured in Fig 1, where a high level macro view of the situation is presented as an illustrative CLD depicting high level effects and perceived cause-effect (C-E) relationships. The second CLD in Fig 2 seeks to capture the impact of the grain crop planting for biofuel production in terms of its consequences for planting for food production – either as grain-based foods, such as bread, tortillas, pasta etc, or grain-fed foods, such as meat, eggs and dairy produce [13] [14] [15]. The third CLD seeks to portray the impact on grain crop planting and food production of wider ecological and economic system forces that drive the demand for food in developing and developed countries [16] [17]. These presentations essentially match the debate and discussion that has been ongoing in the media about different partitions of the problem, and, as such, take their variables from such discussions.

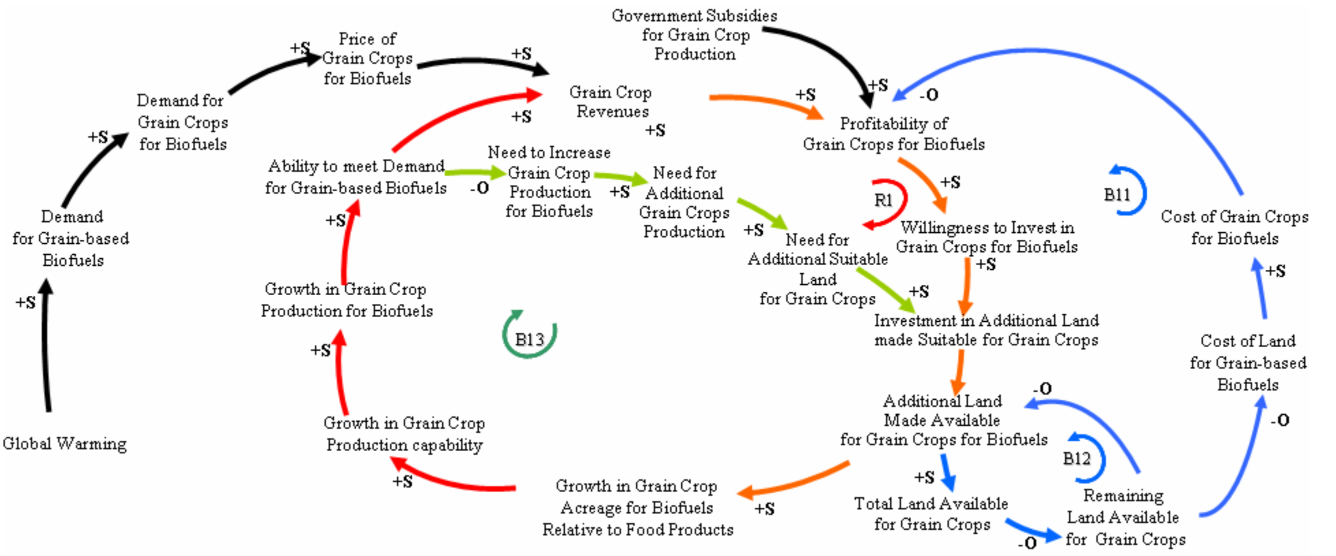
Our representation and analysis of a variety of seemingly divergent issues and views suggests that those views, especially media views, have been limited by the need to offer commentary on digestible chunks of system-wide issues, but in doing so, such commentary fails to surface system-wide matters in a more appropriate fashion. It may be noted that the three CLDs portrayed here address these considerations, and that they have common loops indicating that a single more comprehensive representation may be offered. Whilst space considerations preclude such a presentation in this paper, the CLDs should nevertheless be interpreted and understood as a set.

BUILDING SYSTEMS REPRESENTATIONS

In Figure 1, we note, in particular, that government subsidies may add to the profitability of grain crop planting that drives a motivation to continue to invest in grain crop acreage and planting as a virtuous cycle (see reinforcing loop R1) [18] [19] [20] [21] [22]. However, we also note that such virtuous growth may be restrained or limited by the availability of suitable land for planting, by the cost of such land [23] [24], by saturation or by the cost of production and transportation [25] [26], (see balancing loops B11, B12, B13). We thus note how our CLD structure in Figure 1 can be identified as a modified version of Senge's *Limits to Growth* (LTG) systems archetype.

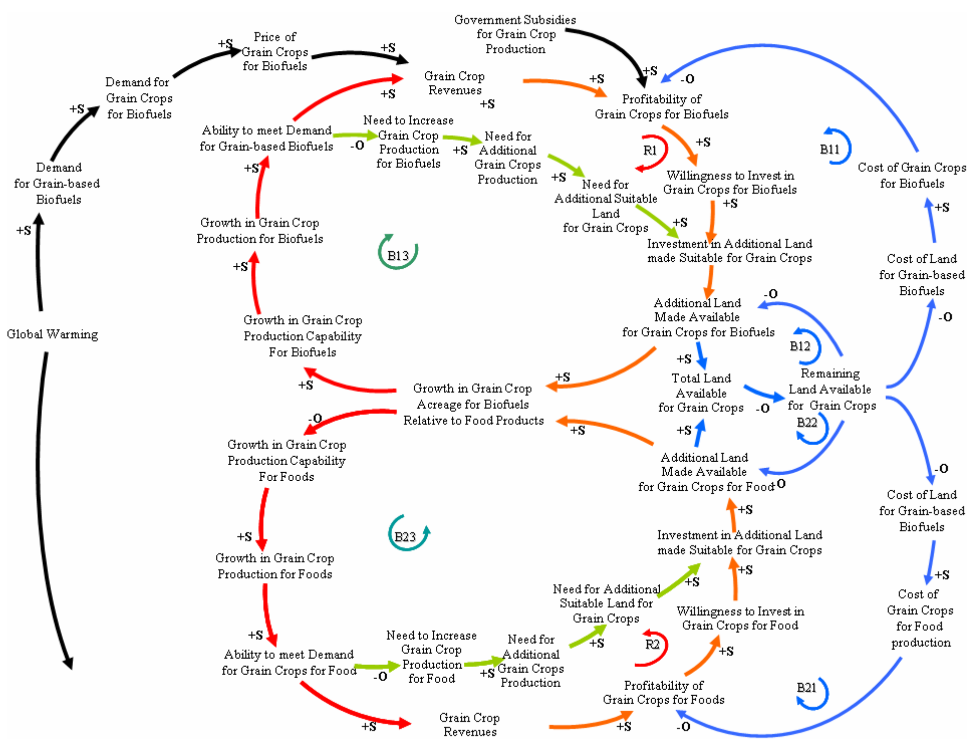
Figure 2 shows how grain crop planting for biofuels may impact on grain crop planting for food products, either by directly replacing the final use of grain crops, or by planting additional acreage for biofuel purposes rather than for food production. We also note how grain crop planting for food production could result in a virtuous cycle, seen as a reinforcing loop (R2), but as with Fig 1, other systemic relationships, shown as balancing loops (B21, B22, B23) could act to limit growth.

FIGURE 1 – AN ILLUSTRATIVE CAUSAL LOOP DIAGRAM (CLD) FOR THE BIOFUELS CASE



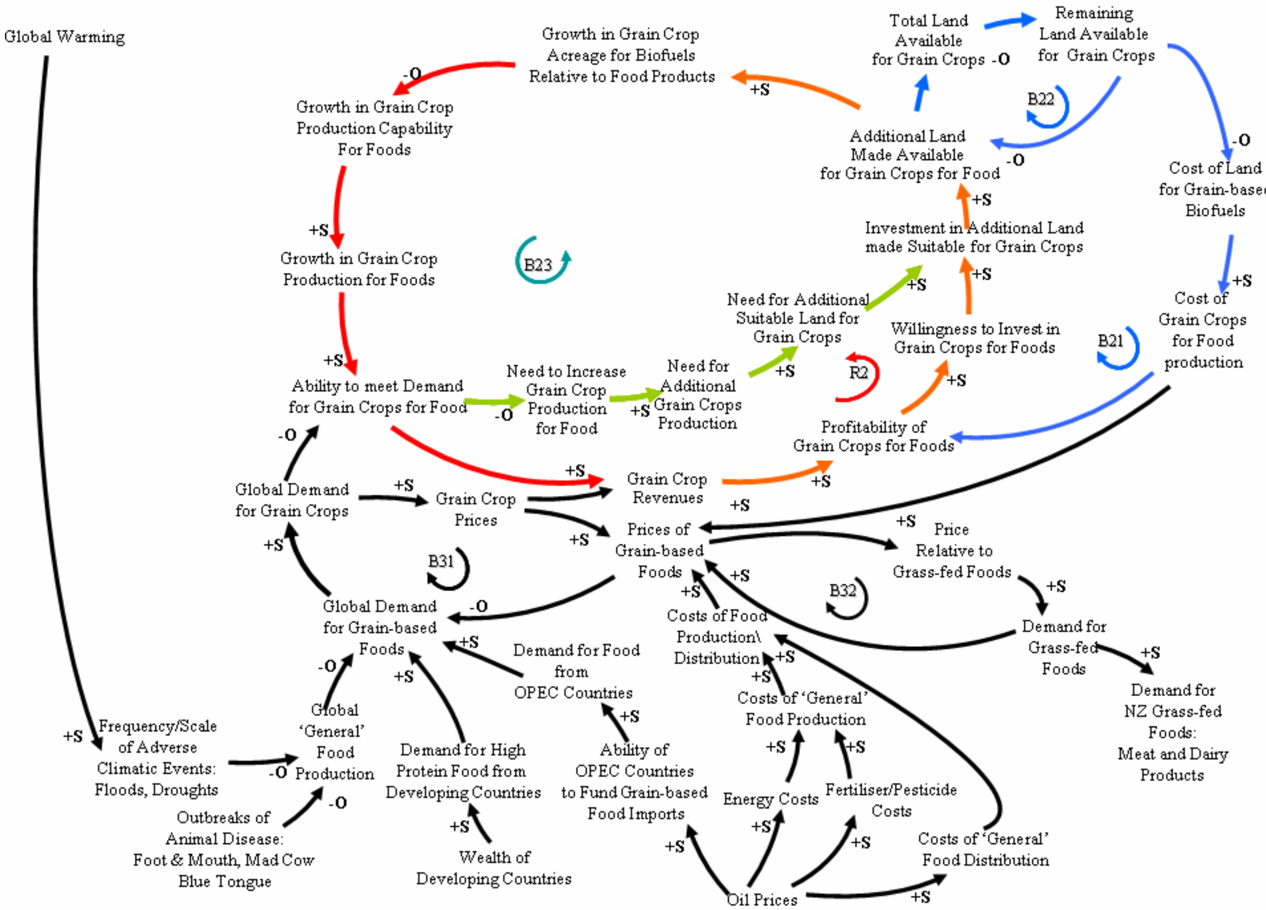
Note that CLD convention requires entities to be described in neutral mode. The + ve S and – ve O annotations then allow relationships to be described in the context of starting or changing conditions. The + ve S annotation indicates that the *more* we do the action at the tail of the arrow, the *more* the effect at the head of the arrow. For example, the *more* we have X, the *more* Y is needed. By contrast, the – ve O annotation indicates that the *more* we do something, the *less* the effect. The double bar // across an arrow denotes a delay – the effect will occur over time or after a time.

FIGURE 2 – CLD SHOWING SUBSTITUTION EFFECTS OF GRAIN CROP USAGE FOR THE BIOFUELS CASE



We note that the systemic structure embracing Loops R1 and R2, reflects the systemic structure of Senge's *Success to the Successful* archetype, where growth in one domain is seen to happen at the expense of growth or success in a related domain which shares a common resource – which in this case, is land suitable for grain crop planting. In such portrayals, we often note the existence of long links within CLD representations, and then, for these representations, interpretation of the CLD will also depend on assumed or implicit logic, and explanation offered via accompanying narrative. It is important to note that whilst a CLD seeks to reflect a holistic view, it can not hope to show all necessary and sufficient logic for all relationships, which would, in this case, be precluded by the size of the paper.

FIGURE 3 – A 3RD ILLUSTRATIVE CAUSAL LOOP DIAGRAM (CLD) FOR THE BIOFUELS CASE SHOWING IMPACT OF EXTERNAL FORCES ON THE DEMAND FOR GRAIN-BASED/GRAIN-FED FOODS



Whilst we have noted that the systemic effects or emergent properties shown in Figures 1 and 2 are redolent of Senge's *Limits to Growth* (LTG) and *Success to the Successful* archetypes, we also note the existence of external factors and forces within a wider system, which system we have not attempted to present in full detail, here. However, some of these forces are shown in Fig 3 as related to global warming and associated effects [13][14] [27] [28], the price of oil [29], the developing wealth of third tier nations [30] etc. An illustrative attempt is made to indicate how such forces impact on the food production system especially as it relates to grain-based and grain-fed foods, such as bacon and eggs [15] [31] [32] or pasta [33]. In particular, we show how the demand for grain-based food products and the growth of grain crop planting for food, may reach a limit where the cost and price structure [34] [35] [36] [37] generates opportunities for producers of grass-fed foods [38] [39] [40] [41] [42].

However, whilst we find the insights from such analyses appealing, thus adding to what we may regard as the seductive existence of such systemic structure within the CLDs, we need to explore or challenge the embedded logic and associated assumptions further. Surfacing such assumptions can raise other questions that may establish or undermine their validity, thus provoking alternative possibilities for solution [43]. Nevertheless, our illustrative analysis and interpretation illuminates how the CLD representations may create a dialogue that can be seen to move the debate from what are effectively sub-systems to a more comprehensive, systematic and systemic approach to understanding the wider system.

DISCUSSION AND CONCLUSIONS

We now summarise how the various systems representations have been applied to the biofuels case, and how insights have emerged from such use, providing improved understanding that may lead to the development of alternative policy options or interventions.

Methodological Insights - The CLD representations of entities and C-E relationships, shown in Figures 1, 2 and 3, are meant to be reflective of the perceived systemic reality of the biofuels case. The separate CLDs, however, can not, on their own, provide a complete understanding of the wider system within which they are embedded, and, additionally, we may note that none explicitly capture any perceived choice for policy intervention other than substitution of grain crops-for-food by grain crops-for-biofuels. Nevertheless, they do allow us to map out the systemic consequences and interactions that may emerge from existing forces and actions. They do so in a manner that reflects the *Limits to Growth* systems archetype of Senge (1990) [6] for Fig 1, and the *Success to the Successful* archetype for Fig 2.

We suggest that construction of CLD diagrams is of value in building understanding of complexity, especially so since an understanding of smaller sub-systems can first be developed, with the linking of such sub-systems diagrams providing the means of developing and conveying an understanding of wider systems issues. In this respect, the categorisation of commonly occurring systems structures developed by Senge can prove to be a considerable aid in surfacing such systemic features in one's own problems.

We foresee benefits in using CLD representations to better diagnose and understand the nature of dilemmas faced by policy makers, and to better understand how and why the emergence of global forces, on the one hand, or the taking of any local action on the other hand, can lead to those unwanted, unintended or unanticipated consequences – which, of course, may undermine our ability to enact chosen or preferred alternatives that may be necessary requirements for achieving overall objectives. Such understanding is necessary to build lasting solutions when confronted by dilemma or conflict.

Problem Insights - In keeping with their purpose, the CLDs, shown in Figures 1, 2 and 3, reveal the prior implicit interconnectedness of variables. Indeed, the CLDs help build an understanding of what we regard as the systemic nature of the relationships. The CLDs not only highlight the dynamic time-based nature of feedback, the existence of balancing (B) and reinforcing (R) feedback loops and side-effects; but also help distinguish between "individual" government or sector behaviour, and systems behavior; between seemingly predictable individual behavior / local outcomes and the systems behavior that may be expressed as the unpredictable or unanticipated "emergent" properties of the system. Additionally, the CLDs may help us recognise how individual or system behavior can lead to unintended, unanticipated, unwanted, yet often patterned and predictable outcomes. Here, for example, we note how additional grain crop planting for biofuels has considerable effect far beyond that intended - which was the development of more environmentally friendly energy. Together, the CLDs in Figs 2 and 3, demonstrate that fears about the seemingly continuous growth of grain crop planting for biofuels may dissipate on developing an understanding of the systemic forces at play that limit or curb such growth – for example, the availability and cost of appropriate land for planting; the consequent growth in global prices for grain and food [22] [23] [24] and their impact on the food value/supply chain [17].

The diagrams capture the systemic interaction, relationships and complexity far more parsimoniously than does any equivalent narrative that also seeks to be comprehensive and exhaustive. However, we recognise that our CLD representations do not capture or reflect the objective of the wider policy making system, and suggest that the conflict representation and resolution process of the systems methodology known as the Theory of Constraints (TOC) can be used to enhance understanding of the problem by surfacing the system's overall goal, and by making explicit alternative actions that are believed to be necessary to achieve the system objectives/goals. Finally, we suggest that, by incorporating the system's goal, the C-E relationships and alternatives in an extended CLD, we can provide an enhanced representation of the dilemma, and a more appropriate platform for decision making.

Nevertheless, our diagrams, individually and collectively, demonstrate the enormity of issues, and the complexity, faced by policy makers. As a consequence, we restate a view that the use of systems representational tools that can further the understanding of policy makers by facilitating, at the very least, some effective qualitative analysis of problems and options, would be beneficial. The deployment of Senge's categorisation of systemic structures as a means of characterising features of problem situations, may also facilitate a common understanding of those problems through a language of systems representation, with systems archetypes providing examples of *de facto* conceptual vocabulary.

In our biofuels case, one conundrum relates to the strength and influence of various C-E loops, and indeed, of the sets of loops that may be depicted as archetypes. For example, we may query whether the limiting loops (B11, B12 and B13) of the LTG archetype in Fig. 1 have a greater influence on the growth loop (R1) than does the reinforcing loop (R2) of the STS loop in Fig 2. In addition, we may question the extent to which the exogenous forces of global warming, and also the production and pricing policies of the Oil Producing Exporting Countries (OPEC), impact on the system represented in Figures 1, 2 and 3.

In conclusion, we suggest therefore that the insights that arise from our use of CLDs and systems archetypes in a mutually informing manner may help build understanding of the inherent systemicity embedded in our problem situation which spans the energy and agricultural sectors, an understanding that will be necessary for the effective management of the global system.

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