Exploring Environmental Tradeoffs in Soft Commodity Production

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TABLE OF CONTENTS

INTRODUCTION

Global production of food, feed, fiber, and bio-based fuel commodities is essential to economic development and human well-being. These 'soft' commodities, so named because they are grown and not mined (WWF, 2012a), support basic human needs and sustain a growing population and economy. However, trends indicate that natural ecosystems are unable to support projected global demand for resources, and are already under strain from increasing consumption, dietary shifts, a rising middle class, and overall economic growth (WWF, 2012b). This suggests that the future will see increasing market price volatility, changes in production and consumption patterns, and unpredictable supply chain shocks within the soft commodity market. These changes will ripple throughout the business sector, governments, and civil society with profound economic, social, and environmental consequences.

In the face of increasing uncertainty in soft commodity markets, businesses have a strong incentive to enhance the sustainability of their supply chains. Indeed, a long-term sustaining business model and natural resource conservation are often strongly intertwined. As freshwater becomes scarcer, for example, apparel manufacturers will face supply pressures and rising prices for thirsty cotton, while freshwater species will experience severe habitat degradation and loss. Overfishing will both harm the long-term prospects of companies sourcing fish products and result in significant loss of biodiversity. These examples illustrate that businesses and conservation groups would be well-served to identify where their goals overlap, and to work in partnership toward achieving those goals for mutual benefit.

TRANSFORMING MARKETS: *THE 2050 CRITERIA*

The World Wildlife Fund created the Market Transformation Initiative (WWF, n.d.a) to engage the private sector in thinking critically about how to alter soft commodity supply chains to achieve beneficial business and conservation outcomes. The Market Transformation Initiative focuses on partnering with major companies to promote market changes in the key soft-commodity sectors of forests, agriculture, aquaculture, fisheries, and bio-energy that ultimately result in beneficial conservation and business outcomes. By influencing major corporations' decisions regarding commodity sourcing, WWF seeks to have a large-scale impact across thousands of suppliers and large areas of land.

The approaches WWF has taken to influence and encourage positive change in commodity markets include engaging in multi-stakeholder initiatives to develop sustainable product standards and certifications, creating partnerships with key corporate stakeholders, and promoting sustainable commodity investment. WWF's long-standing efforts in these areas have resulted in the establishment of successful multi-stakeholder groups such as the Forest Stewardship Council (FSC), Marine Stewardship Council (MSC), and Roundtable on Sustainable

Palm Oil (RSPO) intended to provide guidance and encourage the adoption of best practices in commodity sourcing (WWF, n.d.b). WWF has also established ongoing partnerships with corporations from Coca-Cola to Avon in the areas of water use, protection of tropical forests, and other key conservation issues (WWF, n.d.c).

A major milestone in this work was the publication of *The 2050 Criteria: Guide to Responsible Investment in Agricultural, Forest, and Seafood Commodities,* which examines high-priority global commodity sectors through the lens of ten major environmental and social themes. At its core, the report provides high-level guidance to investors and other financial actors on making responsible investments in soft commodities sectors. At the same time that global production of these soft commodities is critical to social and economic development, it is also severely damaging to the natural environment. Responsible investments, then, have the potential to foster sustainable production and ensure that the earth's natural resources can provide for humanity into the future.

BEYOND *THE 2050 CRITERIA*: SUSTAINABLE SOURCING

Whereas *The 2050 Criteria* sheds light on using investments as a means to transform markets, there is also opportunity to promote market transformation by encouraging businesses to change their existing sourcing practices, product formulations, and product designs. By reformulating a product to use a commodity with a smaller environmental footprint or by sourcing more sustainably grown products, companies can achieve significant reductions in the environmental and social impacts of their supply chains. Not only does sustainable sourcing reduce the impact of the specifying supply chain, but increasing demand for sustainably grown commodities will hopefully help stimulate growth in sustainable production and ultimately transform the soft commodity market. This report intends to build on the information provided in *The 2050 Criteria* by providing a decision-making framework for partner corporations to improve their sourcing practices.

At the crux of a sustainable sourcing approach is the fact that there are choices related to the economic, social, and environmental factors involved in commodity production. Economic and market-oriented choices, including cost, taste, and performance, have traditionally guided product design and formulation. Commodity sourcing may also involve choices about social factors, such as labor practices and cultural acceptance of a given input. Finally, and what will serve as the focal point of the following report, commodity sourcing has a broad range of choices related to environmental factors like greenhouse gas emissions, water use, and biodiversity impact. These types of choices may be mutually supportive: a firm uses a low-environmental impact material that also reduces cost. They may also become tradeoffs: a firm chooses an input that increases costs but decreases environmental impact. Ultimately, firms must make decisions about which of these factors to prioritize according to their goals, values, and standards.

Sustainable sourcing is an undoubtedly complex endeavor for a business, as it involves efforts to not only meet desirable environmental and social criteria, but to meet often rigid product design standards and cost specifications as well. Indeed, economic and market factors that are core to traditional product design—cost, performance, taste, appearance, regulatory compliance—will understandably often take precedence over environmental and social factors in product design and formulation. It is clear that a more sustainable substitute for any given input must not compel a firm to compromise on product performance. Nonetheless, businesses may find opportunities for flexibility to use substitutes and alternatives, or to even eliminate certain inputs, by prioritizing and making the economic, social, and environmental choices that come with commodity sourcing. Choosing performance and water use, for example, as the primary factors in designing a product creates an opportunity to seek out commodity inputs that both reduce water use and maintain performance. In other words, firms may elect to optimize the economic, social, and environmental performance of their products through their commodity sourcing practices for mutual business and conservation benefit.

COMMODITY SOURCING AND ENVIRONMENTAL TRADEOFFS

Acknowledging the critical importance of product performance, this report is intended for businesses who are seeking to address the environmental impacts of their products through their commodity sourcing practices. Although social criteria such as human rights and labor issues are paramount to sustainable production, this report will focus on the environmental dimensions of sustainability because of the clear connection between the business and conservation implications of commodity production. Specifically, we will examine commodities in the context of 6 environmental indicators- metrics used to assess the environmental impact of an activity. These include greenhouse gas emissions, acidification potential, eutrophication potential, water use, biodiversity impact, and land-use change. By employing indicators as a lens through which to examine commodity sourcing practices, companies can begin to identify more sustainable inputs that can be substituted for existing inputs during product design and formulation.

However, even when a business has the flexibility to reduce environmental impacts of its products through more sustainable commodity sourcing, selecting the most “sustainable” commodity input is not always a straightforward endeavor. Commodity production varies widely in terms of environmental impacts, and a particular product may perform better in some impact areas and worse on others. For example, while redesigning a product to use an alternative fiber may result in lower greenhouse gas emissions than the previous design, it may also increase water usage or result in significant land-use change. As a result, the more “sustainable” choice is not immediately apparent, and decision-makers may be challenged to determine how to best prioritize and weight these countervailing outcomes to achieve their combined sustainability and business goals.

This report aims to provide further analysis and guidance to companies on sustainable soft commodity sourcing, building on *The 2050 Criteria*. Specifically, the report will examine commodity sourcing through the lens of tradeoffs—the impacts or benefits that are sacrificed or gained in changing sourcing practices. Tradeoffs will be considered along four dimensions. First, a business might consider the tradeoffs between sourcing one **commodity or an alternative commodity**. For example, an apparel company may examine the tradeoffs in replacing some of the cotton in its products with an alternative fiber such as jute by considering whether jute has a relatively smaller environmental footprint as compared to cotton. Second, a company may consider tradeoffs in sourcing from different **geographies**. For example, a procurement officer may compare the GHG emissions associated with sourcing palm oil from one country where land-use change has already occurred versus from another where it is currently happening. Third, a company could consider tradeoffs in sourcing commodities grown using different **production methods**. For example, a company sourcing fishmeal may consider the impacts of purchasing fishmeal produced from wild-caught versus aquaculture-grown fish. Finally, a company will apply the meta-lens of **indicators** to its assessment of the other tradeoff dimensions. For example, a company seeking to reduce GHG emissions will prioritize that indicator in making sourcing decisions, whereas a company seeking to lower water usage will make decisions on the basis of water usage indicators. Once the indicator of interest has been established, a company will then select whether a geographic, production method, or commodity-based approach to reducing GHG emissions or water usage would be appropriate.

To further illustrate the dimensions of these four tradeoff dimensions, Table 1 presents a tradeoffs matrix with example considerations within each category.

TABLE 1: TRADEOFF DIMENSIONS

		Commodity	**Geography**	**Production method**
Indicator	**GHG emissions**	Does corn or wheat production produce more GHGs?	Does sugarcane-based biofuel production in the US or Brazil result in greater GHG emissions	Does organic production emit lower GHGs
	Water use	Does cotton or jute production use more water	In which countries does cotton production result in the least strain on water resources	Does organic cotton production use less water
	Acidification	Does cotton or jute production have greater potential for acidification	Do production methods of paper fiber in one country result in greater acidification potential than in another?	Does organic production of cotton reduce eutrophication potential
	Eutrophication	Does cotton or jute production have greater potential for acidification?	In which countries is eutrophication from crop production a significant problem?	Does organic production of cotton reduce eutrophication potential
	Biodiversity impact	Does palm or coconut oil have greater implications for biodiversity?	Where should fiber be sourced from to reduce biodiversity impacts?	Is sourcing wood from plantations or natural forests lead to less biodiversity loss?
	Land-use change	Which seed oil commodity has the greater land-use change impacts?	Does producing beef in certain countries have greater implications for land-use change?	Does organic production result in greater land-use change?

PROJECT GOALS AND OBJECTIVES

To help business decision-makers make the most responsible resourcing choices, it is clear that further analysis is needed to more deeply examine and understand the complex interactions of these commodity systems, the relative impacts of each commodity, and, crucially, the tradeoffs inherent in responsible commodity sourcing. To that end, this goal of this project is to create a report that explores five soft commodity groups within the context of the geographies and methods of production through the lens of six environmental indicators: acidification, eutrophication, greenhouse gas emissions, water use, land-use change, and biodiversity impacts.

The primary objective of this project is to create a report that translates the scientific research and analysis of environmental tradeoffs into information and guidance for business decision-makers who are seeking ways to reduce the environmental impacts of their soft commodity supply chains. Whereas there are ample scientific studies and analyses performed on the relative impacts of commodity production, practical guidance on how to utilize this information has been less than forthcoming. As a result, the potential influence of scientific information on decision-making may be underutilized because that information is disparate and sometimes challenging to digest. This report aims to bridge the gap between science and action by synthesizing science into meaningful information that can be incorporated into decision making. Businesses in particular may benefit from this guidance as they seek to respond to increasing public demand for corporate stewardship of the planet.

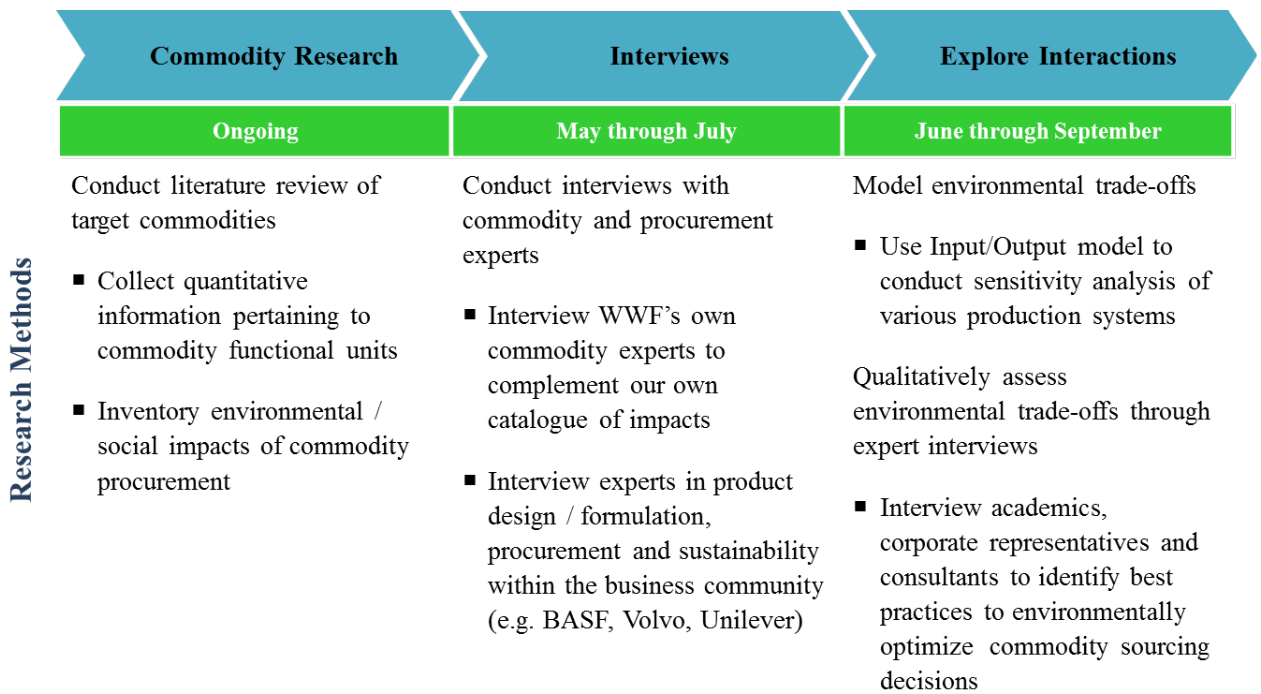
Specifically, the resulting report is aimed at three types of decision-makers operating at different stages of the product development process: namely those in product design, product formulation, and procurement. For product designers and formulators, understanding tradeoffs between different commodities, geographies, and business practices and their impacts may facilitate the development of products that use low-impacts materials from the outset, or that replace high-impact materials with low-impact substitutes in product re-design or re-formulation. A consciousness of these issues at inception can direct research dollars and solidify patents associated with materials that have a better environmental profile than others. Those in procurement who are sourcing the commodities that go into products can benefit from insights into the origin and production method of those commodities and can influence production practices through their specifications, sending rippling effects through supply chains globally. Other business decision-makers at different points along the cycle of bringing a product to market may benefit from understanding where the impacts of that product might be more severe – how to communicate about that and how to mitigate those potential unintended consequences.

Ultimately, this report is designed to provoke decision makers at all levels to consider the complex environmental implications of their supply chains and to take action to address these implications in a meaningful way. It is imperative that businesses address the inherent risk in soft commodity supply chains if they are to prepare for an increasingly constrained resource future and greater supply chain variability and volatility. We hope that this information and the ideas it provokes will spread between decision-makers in procurement, product design, corporate strategy, finance, risk management, and every department in between. Businesses must plan and act now to be meaningful partners in stewarding finite resources and in ensuring their own business success into the future.

RESEARCH METHODOLOGY

As displayed in Figure 1 below, the research methodology for this project followed three threads: 1) researching commodities within five overarching commodity groups along six indicators to identify tradeoffs along four dimensions (commodity, geography, production practice, and indicator) 2) conducting research on what businesses are already doing with regard to environmental tradeoffs in their commodity supply chains, and 3) using the method of input/output analysis to model the impact of tradeoffs across environmental indicators.

FIGURE 1: RESEARCH METHODOLOGY



RESEARCH SOURCES

To perform in-depth research on commodity groups and individual commodities, information and data was collected from scientific studies, databases managed by national and international organizations, and interviews with commodity experts. The primary source of scientific data on environmental impacts was Life Cycle Assessment (LCA) studies of commodity groups and individual commodities which examine environmental impacts of commodity production. Life Cycle Assessment (LCA) is one tool frequently used by industry to assess the environmental impacts that occur at each stage of a product during its life cycle from “cradle to grave”. For example, today more than 180 of Fortune 500 companies report on their indirect supply chain greenhouse gas emissions, known as scope 3 emissions, by using hybrid LCA analyses (Risz and Reich-Weiser, 2013). While there are many variations and additions to the basic assessment, LCA analyses are generally categorized as either attributional or consequential assessments. Attributional LCAs highlight the impacts associated with the production and use of product at a specific point in time, while consequential LCS identify environmental consequences of a proposed change in a system. Proper LCA procedure is guided by a family of environmental management standards known as ISO 14000, which were developed by The International Organization of Standardization in 1996 (Citation).

The United Nations Food and Agriculture Organization (FAO), as well as World Bank and United States Department of Agriculture databases on agricultural production served as the main sources of data and statistics on commodity production.

COMMODITY RESEARCH

The initial phase of the research for this project centered on collecting data about commodity groups and individual commodities, including environmental and social impacts of commodity production and procurement, as well as the functional units most widely used to measure impacts for each commodity (e.g. calorie, kg, CO_2 equivalent, and so on).

Based on the commodities detailed in *The 2050 Criteria*, WWF identified five priority commodity groups as the focal point for the research for this report, with the Fiber and Protein groups being subdivided into two distinct categories. A description of each commodity is provided in Table 2.

TABLE 2: COMMODITY GROUPS

Commodity group	Commodities identified	Description
Grains	Wheat, Maize, Barley, Rice	Grown for human consumption or animal feed
Oilseeds	Soy, Palm, Rape	Grown for conversion into oil for human consumption or industrial use
Biofuels and Bioplastics	Corn grain, Sugarcane, Wheat	Grown for conversion into biofuels or bioplastics, namely ethanol
Fiber	Apparel Fiber: Cotton, Jute, smaller crops	Grown to process into fiber for textiles and other applications
	Timber/Pulp Fiber: Hardwood (tropical and non-tropical), softwood	Natural or plantation-based harvest for processing into pulp or wood products
Protein	Terrestrial Meat: beef, poultry, pork, sheep	Animal protein for human consumption
	Fisheries and Aquaculture: farmed or wild fish, shrimp, mollusks	Fishery protein obtained from wild sources or grown using aquaculture methods
	Other: Eggs, milk, cheese	Animal-based sources of protein for human consumption

ENVIRONMENTAL INDICATORS

Six key environmental indicators were identified by WWF to guide the analysis of environmental tradeoffs in commodity production for this project (WWF, 2012). Table 3 provides a description of each indicator as well as the most common functional unit encountered in research.

TABLE 3: ENVIRONMENTAL INDICATORS

Indicator	Description	Common Functional Unit
Greenhouse Gas Emissions	Emission of heat-trapping gases from energy production, industry, agriculture, and other sources	CO_2 equivalents
Acidification Potential	The potential for the release of hydrogen into soil, resulting in pH change, usually from agricultural and industrial processes	SO_2 equivalents
Eutrophication Potential	The potential to introduce nutrients into water that cause excessive biomass growth and resulting toxicity to aquatic life, usually from nitrate and phosphate runoff from industrial and agricultural sources	PO_4 equivalents
Water use	The use of freshwater resources for agricultural production	M^3 (cubic meters)
Land-use change	The conversion of land from one use to another; here, conversion of land for agricultural use	No single metric
Biodiversity impact	The consequences of agricultural production on species biodiversity	No single metric

DIMENSIONS OF ENVIRONMENTAL TRADEOFFS

Finally, the research and analysis of environmental tradeoffs in commodity production for this project will be evaluated along four dimensions: commodity, geography, production practice, and indicator. Table 4 provides a description of each dimension, a sample question that a business might consider, and assumptions underlying the way in which a business would employ this tradeoff dimension as a lens for its sourcing decisions.

TABLE 4: TRADEOFF DIMENSIONS

Tradeoff Dimension	Description	Sample question	Assumptions
Commodity	The relative environmental impacts of a commodity and an alternative within the same commodity group (e.g. palm and soy oil) for consideration in product redesign or reformulation	Would replacing palm oil with soy oil in a given product result in reduced environmental impacts along a given set of indicators?	Reasonable substitutability between a commodity and an alternative; flexibility in product design and/or formulation
Geography	The relative environmental impacts of producing a given commodity in different production regions for consideration in sourcing and procurement decisions	Would sourcing cotton from the US or China result in reduced environmental impacts along a given set of indicators?	Knowledge of commodity origin; ability to specify commodity origin in sourcing decisions
Production practice	The relative environmental impacts of producing a given commodity employing different methods of production	Does the grass-fed or feedlot method of beef production result in reduced environmental impacts along a given set of indicators?	Knowledge of production method; ability to source commodities based on production methods
Indicator	Used in conjunction with other tradeoff dimensions to understand the relative impacts of commodity sourcing decisions. Includes a comparison both between indicators (e.g. tradeoff between water and land-use impacts of a decision) and within a given indicator (e.g. water-use impacts of different decisions)	*Within an indicator:* what are the water-use implications for sourcing corn versus wheat for use in a product? *Between indicators:* Does sourcing corn from one geography or another reduce water-use but result in greater land-use change?	

As discussed in the introduction above, the 'indicator' dimension serves as a meta-lens through which to evaluate tradeoffs within the other three dimensions. Indicator tradeoffs cannot be examined in isolation, but are rather a way of analyzing the outcomes of decision-making using the other evaluation dimensions. As such, a company can use indicators are an important tradeoff dimension and can help a company prioritize its environmental values and goals to guide decision making along the other three dimensions. This requires that a company selects an indicator or a set of indicators through which to examine its sourcing decisions.

NOTE ON SOCIAL IMPACTS IN SOFT COMMODITY SOURCING

It is important to acknowledge that in addition to the environmental consequences, there are also significant social implications linked to soft commodity production, including consequences for labor and working conditions, human health and safety, and land rights issues. The social implications of commodity production add yet another dimension to this tradeoffs analysis, as what is the most environmentally beneficial decision is not necessarily also the most socially optimal decision. Many companies already make these types of tradeoffs regularly. They may weigh, for example, the benefits to the local economy of a large-scale agricultural development project against the land-use change and water use environmental implications of the project. Given that corporations have limited resources to allocate to the numerous environmental and social issues their operations may pose, it is reasonable that they may focus on addressing higher-level tradeoffs between social and environmental outcomes, and not dive more deeply into looking at specific environmental tradeoffs.

While acknowledging that companies are actively balancing environmental and social tradeoffs, this report is intended to provide guidance to those companies that do want to engage more deeply on the environmental dimension. Therefore, the scope will be limited to examining environmental tradeoffs in soft commodity production, and will not delve into the social implications of production. Nonetheless, research into the social dimensions of commodity production is warranted, and this report may provide a basis for future exploration into this important topic.

INTERVIEWS

Companies that hold improved sustainability as a management objective are at varying stages of developing internal decision-making criteria and tools to guide analysis of the impacts of their commodity sourcing practicing. Companies like BASF, Alcan, and Volvo have sophisticated tools to address many environmental parameters. Some companies are currently developing or adopting these types of decision-making tools while others analyze information without considering trade-offs (Schatsky, 2012).

To understand whether and how environmental tradeoffs figure in corporate decision-making for supply chain sustainability, interviews were conducted with over 10 companies identified by WWF from a broad range of industries engaged in soft commodity sourcing. The interviews were conducted with individuals from product formulation, commodity procurement, and sustainability departments. The interview questions, presented in Appendix A, were designed to draw out the decision-making criteria, tools and processes, and challenges companies have in addressing the environmental impact of the commodity impacts of their products. Ultimately, the results of the interviews provide a baseline for the state of tradeoffs analysis in corporate commodity sourcing and served to guide the project in formulating relevant and meaningful guidance for companies on the environmental impacts of their sourcing practices. The “Interviews” section of this report discusses in detail the results of the interviews.

MODELING TRADEOFFS: ENVIRONMENTAL INPUT-OUTPUT ANALYSIS

The final stage of research for this project was to examine the dynamic interactions between soft commodity systems, and in particular to model the expected or unexpected consequences of altering commodity sourcing practices. Because they use the same inputs—land, water, agricultural chemicals, labor—commodity systems are necessarily interrelated, and changes in one system can have consequences on another. This adds an additional layer of complexity to evaluating environmental tradeoffs along the dimensions of geography, production practice, commodity, and indicator. This project intended to use the technique of environmental Input-Output analysis to add additional depth to the analysis of environmental production by modeling the dynamic interactions between soft commodity production systems and the consequences of sourcing decisions in terms of environmental indicators. The "Model" section of this report provides a detailed discussion of the I/O modeling technique and the results of I/O analysis for this project.

REPORT OUTLINE

The key findings and analysis of the research and interviews conducted for this project will be presented in five sections below. Section 1 will detail how businesses are currently engaged in decision-making focus on environmental impacts of their products or services. Section 2 presents the key research findings of each commodity group, including production methods, environmental impacts, market information and certifications and standards. In Section 3, scenarios are presented for each tradeoff dimension through the lens of a commodity group to provide businesses with examples of what decision-making guided by environmental impacts might look like in practice. Section 4 addresses key challenges that businesses may face in trying to make procurement and sourcing decisions based on an analysis of environmental impact tradeoffs. Finally, Section 5 presents challenges faced by the project team and opportunities for improvement in the research surrounding environmental impact tradeoffs, input-output modeling, and sustainable procurement and sourcing.

SECTION 1: CURRENT BUSINESS PRACTICES IN ENVIRONMENTAL IMPACT TRADEOFFS ANALYSIS

EXISTING BUSINESS FRAMEWORKS FOR ENVIRONMENTAL IMPACT ANALYSIS

Every day humans make hundreds of decisions, some of which are trivial, and others that have significant influence on our lives with serious impacts on our health, the environment, and society. When we make a decision we chose one option over another and every option is associated with benefits and consequences. As individuals we have developed strategies to evaluate our possibilities quickly and efficiently. However, simple pro and con tactics can fail us when tradeoffs exist. In a tradeoff situation the positive and negative consequences of each alternative outcome may be equal in number, but different in quality. In each outcome one quality is lost in return for gaining another. For example when wondering if you should bike or drive to work you realize that biking is the slower but healthier option, while driving is the faster yet unhealthier choice. In this case a trade-off must be made between health and time. There is a benefit and a drawback for each option and a compromise between your health and time must be made. How do we prioritize goals and make decisions considering the tradeoffs? For individuals making these difficult decisions will likely reflect individual values, habits, and situational factors. However, for large unwieldy corporations complex decisions fraught with tradeoffs can be difficult to comprehend and navigate.

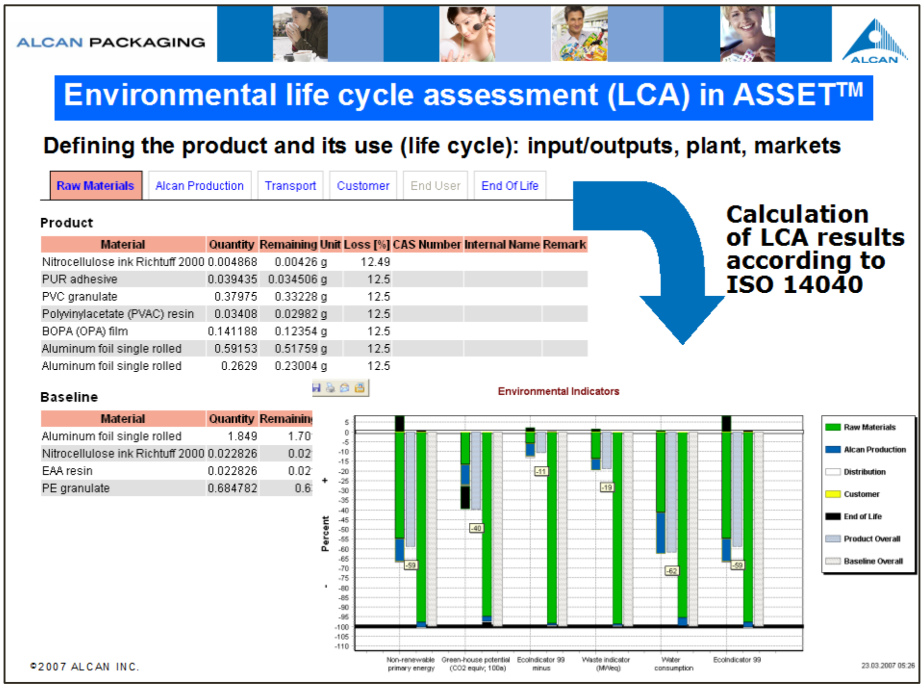
Similar to individuals, companies make decisions based on values, yet companies are often comprised of multiple business units and departments with diverse and sometimes conflicting priorities. While a focus on environmental concerns is a growing trend for companies, the most pressing sustainability issues can quickly become unclear if data is muddled and environmental interests are lost among the company's broader goals (see interview section for further discussion on current state of companies). Synthesizing a comprehensive corporate strategy and decision framework that includes environmental sustainability can be a complicated endeavor. Creating such a holistic frame may require the strenuous task of ranking goals across the entire business matrix of a company. Currently very few organizations utilize such comprehensive decision-making frameworks to incorporate environmental impacts into strategic direction. This section serves as an overview of existing environmental assessment tools and a summary of broader decision making frameworks.

Traditionally, company values and priorities are geared towards maximizing profit. This is compounded for public companies that are held accountable to shareholders who are often looking for short term financial gains. Department managers and executives play a critical role in decision-making and developing comprehensive and sound frameworks. Executives are increasingly involved in the process as company reputation and success are becoming linked with sustainability as the public grows increasingly concerned with environmental issues.

As companies embrace ideas of environmental sustainability (Ioannu, 2013), they are increasingly establishing sustainability departments and “green” goals or commitments. In order to achieve their goals, emphasis has been placed on assessment and monitoring of environmental impacts through the whole life cycle of products from raw material extraction, processing, manufacturing, distribution, consumer use, and disposal or recycling.

While many companies utilize LCA research and even conduct their own studies, some companies have taken assessment a step further by fully incorporating LCA departments and tools into their business. Before being purchased by Amcor in 2009, the packaging company Alcan developed an LCA based tool known as the Alcan Sustainability Stewardship Evaluation Tool or ASSET. The ASSET tool compares environmental impacts of packaging products that provide similar services and perform equivalent functions (see figure 2). Each set of comparable products forms a “family” of comparison products and within each family one product is chosen as a baseline comparison for the other products. The assessment compares both quantitative environmental LCA results and qualitative environmental, social, and economic issues of each product. A summary of results is displayed in a matrix and each product is given an impact profile. Although Alcan is now owned by Amcor, the company still uses the technique internally. In 2012 alone Alcan utilized the ASSET tool with over 800 LCA studies (Amcor, 2014). While this approach has worked well for the packaging company, companies in different industries and commodity categories have their own set of unique challenges.

FIGURE 2: EXAMPLE OF LCA INPUTS IN THE ASSET TOOL USED TO COMPARE ENVIRONMENTAL INDICATORS OF DIFFERENT PRODUCTS



Although challenging without sophisticated systems like Alcan's, companies attempt to translate the results of environmental assessments into action in order to meet established sustainability goals. Companies typically define their success by meeting sustainability metrics that have been defined internally as well as established by third parties like the Global Reporting Initiative (GRI) and The Sustainability Consortium (TSC). Initiatives like GRI and TSC provide companies with LCA research, procedural guidance of sustainability reporting, and management standards. There are also numerous roundtable and council efforts for specific industries that establish sustainability principle and criteria (P&C) metrics for companies. These organizations include efforts such as The Roundtable for Sustainable Palm Oil and the Forest Stewardship Council and are typical organized groups of diverse industry stakeholders that develop standards for the production of specific raw commodities like tree fiber, palm oil, beef, marine fish, and biomaterials. However, as companies have begun to catalog and assess environmental impacts they have found it difficult to translate these results into broader company decisions and improvement without a comprehensive decision framework to navigate tradeoffs and the greater goals of the company.

LIMITATIONS OF EXISTING TOOLS

There are very few examples of organizational tools that inform business decisions by systemically analyzing impacts and considering tradeoffs across the entire company. Techniques exist to facilitate this process, but a universal framework has not been created and many of the existing tools are fraught with drawbacks. The following section reviews techniques of normalization, weighting, life cycle impact assessment (LCIA), multi-criteria analysis and practical examples of such applications. Advantages and weakness of each will also be discussed.

While life cycle analysis is an extremely helpful tool for companies, it does not directly render business decisions. LCA can compare the impacts of different products across multiple midpoint and endpoint indicators; however the results are difficult to communicate to non-LCA practitioners and can be deceiving depending on the procedure utilized. Various LCA methods and additional applications can aid in the communication and utility of results although no one method is unilaterally accepted.

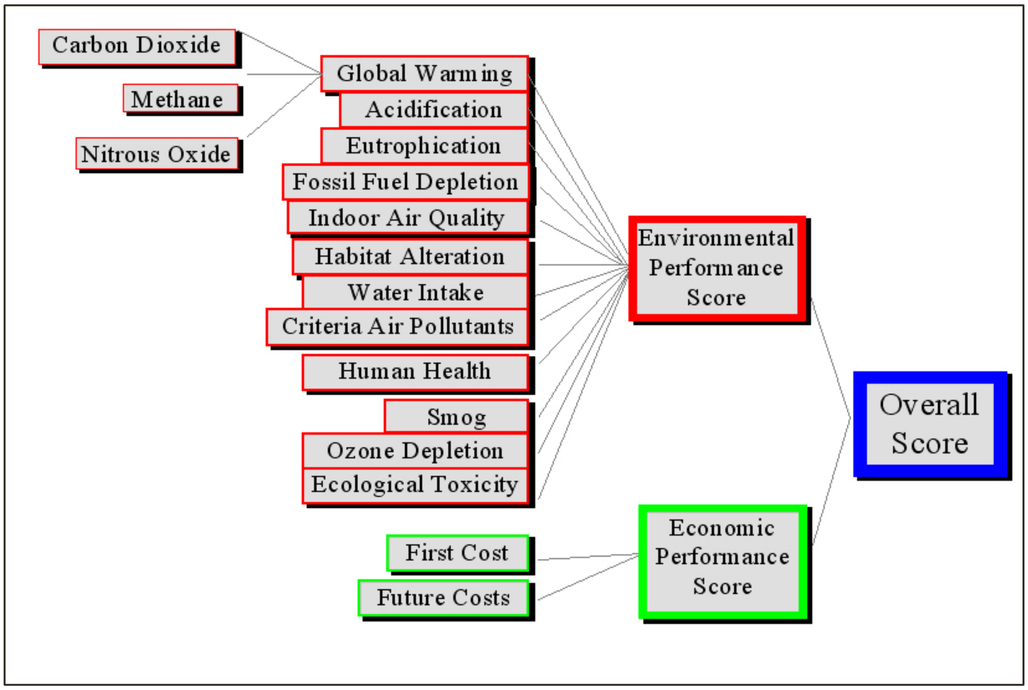
Normalization is a practice in LCA by which the resulting impacts are compared to a common baseline, usually the annual resource use and emissions produced by a reference population in a given region during a particular year (Van Hoof et. al., 2013). This helps users understand the significance of the impact relevant to the overall system. For example, without normalization the GHG emissions produced from a company processing 1 kg of steel in Germany may appear to have the largest impacts when compared to water and land use consequences. However, after comparing all impacts to the overall European pollution resource extraction and pollution levels the results may reveal that CO2 emissions actually make the smallest contribution to the overall system. Without normalization a company may focus on improving a particular impact, without understanding its proportional relevance to society. Although the ISO regards normalization as an optional step, many consider normalization a technique that can provide decision makers with the most relevant indicators potentially helping them establish priorities for improvement strategies (Van Hoof et. al., 2013).

Although normalization is regarded as helpful, researchers select their normalization method from a variety of approaches. For example, endpoint normalization per damage category, midpoint normalization per midpoint, and endpoint normalization with relative contribution of normalized midpoint utilize different approaches. Each method normalizes the results by using a slightly different formula. The variations are based on what part of the indicator, endpoint or midpoint), is included in the normalization equation. By choosing different normalization methods different impacts appear more or less relevant to the reference system. While it may be helpful for a company to normalize their data, it is equally important to have a LCA practitioner and system that can understand the differences of each method and communicate the findings to decision makers.

Practitioners can take LCA results a step further by applying weights to the indicators. Some researchers regard weights as an effective application that acts as a link between the quantitative results of an LCA and the value-based choices of decision makers (Gloria et. al., 2007). The process involves applying a predetermined multiplicative numeric value to the LCA indicator results in order to “weight” each impact according to its significance. The process is similar to the normalization process in that it highlights the relative importance of the impact categories, however the weights are typically based on the researchers experience and not a formal reference system. However, while weighting may illuminate the importance of various environmental impacts, some argue that the process is too subjective (Van Hoof et. al., 2013).

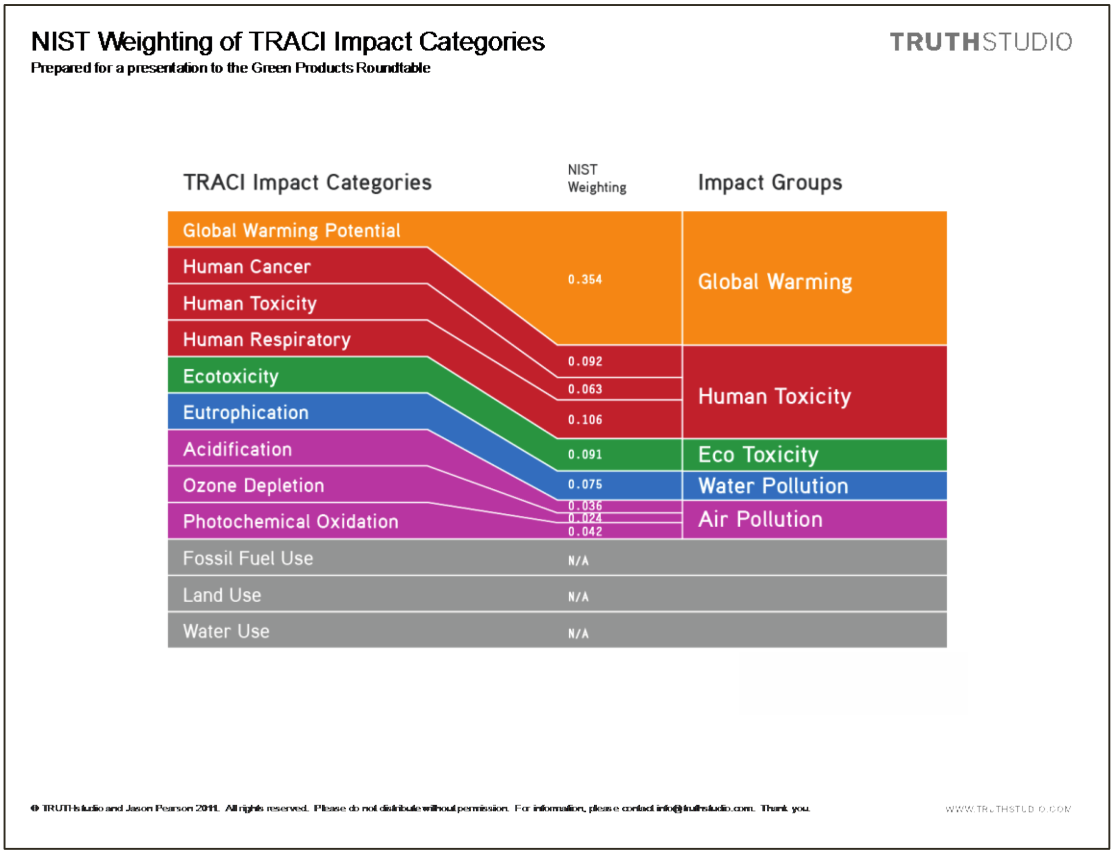
Despite the polarized opinion on weighting, there are companies and organizations that use the application. The engineering laboratory of the National Institute of Standards and Technology (NIST), an agency of the U.S Department of Commerce, has developed a weighting software known as BEES **– B**uilding for **E**nvironmental and **E**conomic **S**ustainability. The online tool was designed for builders, designers, and product manufactures to support environmentally purchasing of building products in the United States. The software allows users to compare the environmental and economic performance data of 230 building products and helps purchasers select cost effective and environmentally preferable products (National Institute of Standards and Technology, 2009). The BEES software measures the environmental performance of products by utilizing an LCA approach and economic performance measured by the standard ASTM life cycle cost method (covers the costs of initial investment, replacement, operation, maintenance and repair, and disposal). The environmental and economic performances are combined into an overall performance score using the ASTM standard for Multi-Attribute Decision Analysis (see figure 3 for the BEES model) (National Institute of Standards and Technology, 2009).

FIGURE 3: THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST) BEES MODEL



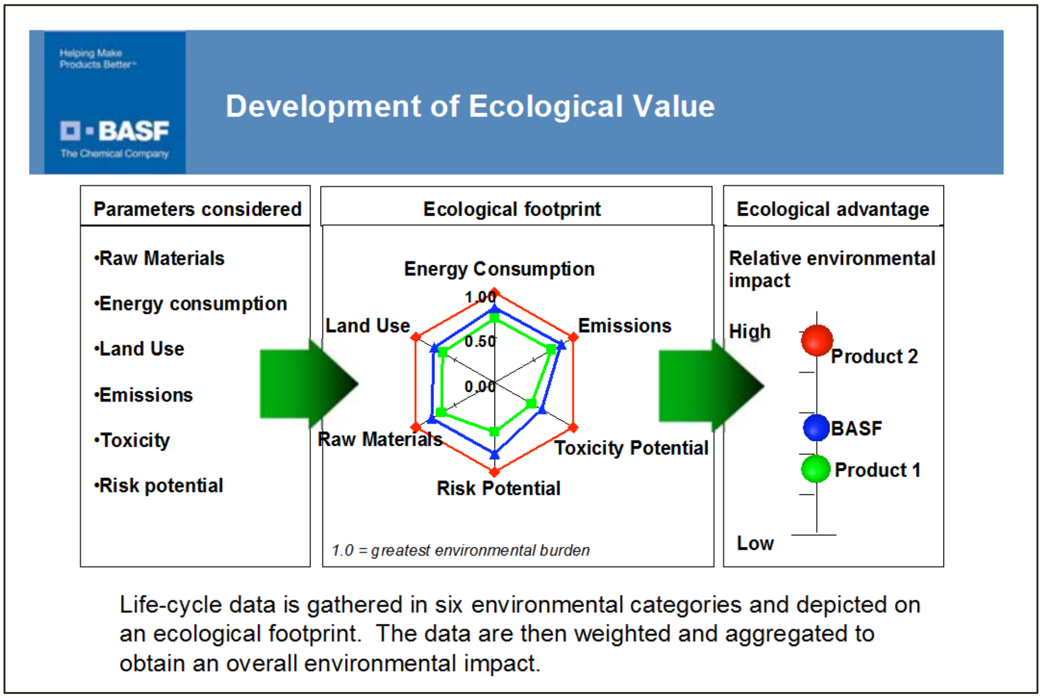
The NIST BEES model utilizes weights to aggregate the environmental score of the product performance. The model calculates environmental performance based on twelve environmental and human health impact categories, largely based on the U.S EPA's Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) with one additional category – indoor air quality (Gloria et. al., 2007). (The TRACI tool will be discussed more in depth in the LCIA methodology section). Previous versions of the software utilized generalist perspective to establish weights for environmental performance, but the most recent version uses a more elaborate weight determination process. "The new weight set was created by a multi-stakeholder panel via the AHP method, and is a synthesis of panelists' perspectives on the relative importance of each environmental impact category in BEES. The weight set draws on each panelist's personal and professional understanding of, and value attributed to, each impact category. While the synthesized weight set may not equally satisfy each panelist's view of impact importance, it does reflect contemporary values in applying LCA to real world decisions, and represents one approach others can learn from in producing weight sets. The new weight set offers BEES users an additional option for synthesizing and comparing the environmental performance of building products and making purchasing decisions" (See figure 4 for a visual of the NIST weighting compared to TRACI impact categories).

FIGURE 4: A VISUALIZATION OF THE NIST WEIGHTING SYSTEM BASED ON U.S EPA TRACI IMPACT CATEGORIES



Similar to Alcan's ASSET tool the chemical company BASF has a software tool that creates sustainability profiles for various chemical inputs and products by aggregating LCA data. However, unlike the ASSET tool the BASF's Eco-Efficiency analysis involves weighting impacts similar to the NIST BEES approach (see FIGURE 5).

FIGURE 5: BASF ECO-EFFICIENCY ANALYSIS INSTRUMENT



Regardless of the method, a comprehensive tool needs to be supported by business intelligence software and clear access to data. "Firms need to support the analysis and application of information captured in order to make operational decisions. Say for marking seasonal merchandise or providing certain recommendations to customers, firms need right access to information quickly. Implementing smarter business processes is where BI influences and impacts the bottom line and returns value to any firm….It is essential to have a system for establishing the status of a business at any moment in time in relation to its performance objectives. An important component of this investment is in BI" (Sahay et al). In the research for this report, there was a clear gap in access to software tools and transparent data. These restrictions will be discussed in greater detail in the limitations chapter.

INTERVIEWS WITH CORPORATE DECISION-MAKERS

Further supporting a need for the current report, companies have widely varying views on how they define "tradeoffs." As evidenced in a series of interviews with product design and procurement professionals within a variety of industries, tradeoffs mean different things to different decision makers. Some companies are looking at the tradeoffs between environmental impacts for alternative inputs during the design phase of their products, while others are more concerned with the tradeoffs of consumer preferences for "sustainable" compared to price and environmental impact. Still others are more interested in working with existing suppliers to improve sustainability rather than considering alternative inputs and view tradeoffs only within a single commodity product.

A number of common themes regarding tradeoffs resonated in the interviews. First, many decision makers voiced the complexity associated with considering tradeoffs and the potential for such complexity and lack of clarity to result in inaction. While some interviewees alluded to not truly understanding how to evaluate tradeoffs between commodities during decision making, a greater number referenced the lack of data resolution as the primary reason for not examining tradeoffs more closely. Further, even when some data is available, it is very site specific and heavily weighted on measuring easily quantifiable impacts like greenhouse gas emissions while lacking attention towards impacts such as biodiversity. Interviewees noted that even studies that address a spectrum of environmental impacts often ignore the important economic and social impact trade-offs that might be at play within that decision as well.

A second common theme was the need to understand where tradeoffs truly exist within the lifecycle of a product. Interviewees discussed the importance of focusing improvement efforts on the appropriate places and whether the scale of the tradeoff is substantial enough to warrant attention. This issue can be illustrated by a recent study on laundry detergent which showed that unlike many household products, whose lifecycle impacts are often concentrated in the raw material and production phases, most of detergent's lifecycle impacts stem from the customer's hot water use (Martin & Rosenthal, 2011). As a result, a company has a greater potential for improving its product by creating and promoting cold-water alternatives rather than examining the tradeoffs between alternative ingredients. This case study demonstrates the importance of understanding of the lifecycle impacts of each product before decisions to improve them can be made.

Lastly, since most of the companies interviewed were consumer facing companies, they voiced a struggle of how to accurately and efficiently communicate tradeoffs to their customers. More specifically, as consumers begin to demand more sustainable products, there is a gap in understanding for what that truly means for environmental impacts areas. For example, many customers are looking for recycled fiber products, such as for paper. However, depending on the method of production, creating white paper from recycled materials is not only the lowest potential reuse for the product, but is actually more resource dependent than using virgin fibers (Ostle, 2011). Similarly, within the livestock industry there are frequently tradeoffs between animal welfare concerns such as grass-fed or cage-free and the associated environmental impacts (Pelletier, 2010). As consumers are confronted with increasing numbers of certifications and labeling changes, communication about tradeoffs, if not done carefully, can serve to confuse rather than inform customers about product sustainability.

Despite all of the challenges and concerns listed above, there are companies who are currently addressing the complex issues of environmental trade-offs. Several companies interviewed use a series of lifecycle analyses to evaluate potential changes to their products or packaging. The results of the LCA information are also weighed against broader company interests such as price, customer preferences, and publicly stated sustainability goals to ultimately make a decision. One illuminating example was of a company who decided to change the packaging type of one of their products to reduce environmental impact even though the new packaging was not recyclable, which was in direct conflict with their zero waste goal, forcing them to compromise on one goal to achieve another. While there is rarely a clear answer, environmentally conscious companies are beginning to have these critical conversations to make meaningful changes to their products. However, even the most forward thinking companies expressed that thinking about and making decisions regarding tradeoffs was a struggle for their company. As more companies' sustainability programs continue to evolve, the issues of tradeoffs in decision making will increasingly arise. This report aims to highlight a subset of potential tradeoff decision types and potential frameworks with which to address them to assist even the most progressive companies.

FRAMING THE QUESTIONS: HOW SHOULD DECISION-MAKERS APPROACH TRADEOFFS?

Before a company embarks on an analysis of environmental, social, and economic tradeoffs, it must clearly define the problem. Regardless of the business' situation it is imperative the company clearly articulate the problem in order to decisively enhance the sustainability of their supply chain. If the problem is not explicitly defined the decisive solution may be irrelevant. Although seemingly a minor step, problem definition is an essential keystone that serves as a tangible reference for companies in the midst of complex prioritization, data acquisition, result analysis, and decisive execution.

Defining the Problem – There are multiple approaches to problem definition, but in general a company can begin by listing the following:

- The company values, commitments, and goals
- Known issues of concern of the product or commodity of interest

Likely the company already has a list of internal sustainability goals; economic, environmental, and social. These values and goals need to be emphasized and considered when pinpointing the main problem. These goals can illuminate the current status of the company and help establish areas of greatest concern and ultimately priorities. For example The Kellogg Company has recently committed to the environmental goal of eliminating deforestation from their palm oil supply chain "As part of its new commitment, Kellogg's will require that by Dec. 31, 2015, all its suppliers be able to trace palm oil back to plantations that can be independently verified as compliant with the company's principles for protecting forests, peat lands and communities, as well as meet the standards for RSPO certification." (Petru, 2014)

Questioning Assumptions and Exploring all Impacts – However, while internal goals help define the problem and strongly drive a company's final decision it is helpful to keep an open mind and challenge the assumptions underlying these commitments. Especially when establishing the companies environmental goals. Established decision making frameworks that contain subjective weights may also need to be revaluated as new information and assumptions that go into the framework change.

For example, a company that prioritizes the reduction of GHG emissions in its formal sustainability goals may define the problem as "What oilseed (palm, rapeseed, or soy) has the lowest GHG emissions at the farm level?" After conducting an assessment or literature review the company would search the data particularly for the GHG impact and the results would dictate what oilseed the company will source. However, although the results of additional impact areas may seem irrelevant and confusing they are just as important to analyze. These additional results may help bolster the company decision to continue prioritizing GHG emissions, but may also highlight the importance of an additional driver or threat such as land use change or biodiversity loss. The normalization stage may help reveal that certain impact areas have higher relative impacts, and the company may consider reorganizing their priorities and redefining their problem statements in the future. This will also fuel conversation around the issue of tradeoffs in business indicators – which indicators are really the most important? Is this a cut and dried issue or is their greater complexity? Issues cannot be prioritized until there is a clear understanding of the impacts and problems behind the environmental indicators. Issues cannot be prioritized until there is a clear understanding of the impacts and problems behind the environmental indicators.

Unclear goals – If a company does not have clear environmental priorities, the research and development department may have more freedom to explore various environmental impacts, but may have greater difficulty actually defining the problem or justifying its approach against economic and social goals. In this case a product-centric approach may be helpful (e.g. reducing the environmental impact of product X). While this report only focuses on impacts associated with the production of raw commodities, it is important to conduct full sustainability assessments to highlight impacts at all stages. In the absence of company priorities, the problem statement can be established from a general overview of the scientific literature.

Examples of question formulation – Once the known concerns and company values are thoroughly considered the problem statement should be formed as a <u>specific question</u> that needs to be answered or decision that needs to be made. Potential unknowns or unintended consequences should also be considered to anticipate potential for mitigation or the need to shift priorities

For example, if a company is sourcing beef and has a commitment to lower GHG emissions there problem statement may be:

- Which country of origin or which production practices could we source from that would provide the lowest GHG footprint for beef production at no additional cost? Are there any unintended consequences of this decision and can we mitigate those?

Additionally seed oil may be required for a new instant noodle box product and the noodle company has a commitment to global water security. There are several seed oils that can be substituted in the product. For this scenario the question may be:

- Between soy, rape, and palm oil – which seed oil has the smallest water footprint at less, equal to, or marginally higher cost? What geography and production practices for vegetable oils are associated with a lower water impact? Are there any consequences of this decision that could be potentially damaging to local economies or other watersheds? Can we mitigate those consequences?

Conclusion – Company goals and known impact information will drive the problem definition and decision-making process involved in improving the sustainability of company's soft commodity supply chain. Anticipation of unknowns and conflicting priority goals are an added challenge, but are manageable with normalization, weighting, and tools to analyze unintended consequences. Establishing a companywide decision-making framework may also help organize the information, prioritize goals, and facilitate a final decision. Weighing tradeoffs can be difficult, but a solid problem definition acts as a guiding light and allowing for a more holistic and informed conclusion.

SECTION 2: RESEARCH FINDINGS

COMMODITY CATEGORIES: FINDINGS FROM RESEARCH

The WWF's *2050 Criteria*, provided a clear picture of each commodity group's environmental and social impacts. However, to understand how tradeoffs occur requires a broader context than *The 2050 Criteria* provides. Because differences in production method, geography, or between commodities can create tradeoff scenarios, understanding key market and production factors helps to illuminate the origins of tradeoff decisions within a given commodity group.

To begin to understand of tradeoff scenarios, each commodity group is described below according to their respective market structures, production processes, geographies of major production and consumption, environmental impacts, as well as environmental certifications. Within each commodity group a unique combination of tradeoff scenarios exist due to geography, substitutability, or differing production methods, and the analysis below highlights where those tradeoff decisions are likely to exist.

FIBER (APPAREL AND TEXTILE USE)

Commodity	Total Annual Production (tons)	Top 5 Producing Countries	Top 5 Importing Countries	Primary Uses
Cotton (lint)	32,795,096	China, India, USA, Pakistan, Brazil	China, Turkey, Bangladesh, Indonesia, Vietnam	Textiles, apparel
Jute	3,506,964	India, Bangladesh, China, Uzbekistan, Nepal	India, China, Pakistan, Nepal, Brazil	Textiles, packaging
Sisal	236,208	Brazil, Kenya, Tanzania, Mexico, Madagascar	N/A	Textiles, pulp and paper, biogas from waste
Flax	283,385	France, Belarus, Russia, China, United Kingdom	China, Belgium, Netherlands, Lithuania, Poland	Textiles, rope
Others: Hemp, Ramie, Abaca, Kapok				

Data source: FAOStat (2012)

PRODUCTION

Natural fibers including cotton, jute, and other alternative fibers, are grown around the world in a range of different climates with varying production methods. Cotton, the most prominent natural fiber, is a somewhat drought-tolerant crop that can be grown in arid and wetter biomes depending on the application of irrigation and other techniques to optimize production. Globally, about half of cotton cultivation is irrigated (Chapagain and Hoekstra 2005), and chemical application is common both in production and harvest (Kooistra 2006) though organic production is on the increase due to growing demand from consumers and retailers (Organic Trade Association 2010). Once harvested, the cotton plant is separated into the lint, which is used for textiles and other applications, and the seed. Once processed, the lint is spun into yarn, dyed and woven into textiles for apparel and other uses. As cotton is by far the predominant natural fiber used by nearly everyone in the world in some application, alternative fibers must be adequately substitutable (as a replacement) or complementary (as a supplement) if they are to gain market share from cotton.

Jute is an alternative fiber that thrives in the humid tropics. Although traditionally used for applications like sacking and twine, jute can be combined with fibers like cotton or wool in apparel and textiles. Current production of jute is comparably less intensive than cotton production, employing traditional methods like intercropping, rain-watering and low agrochemical use (International Jute Study Group 2003). Upon harvest, fibers are extracted and spun into yarn for various uses.

A host of other alternative natural fibers are produced using traditional (i.e. non-intensive) methods largely in the tropics, including sisal (from the agave plant), abaca (from a banana-like plant native to the Philippines), and ramie (a bush native to the Malay Peninsula). Flax and hemp are also grown globally as alternative textile fibers. All of these follow a similar path of cultivation, harvest, retting (a process of separating the useful fibers from the waste products), processing and spinning into yarn or thread to weave into textiles or for use in other applications.

MARKET

Cotton is a globally significant crop, with an estimated 2.5% of total arable land devoted to cotton production worldwide (International Trade Centre, n.d.). The apparel and textile industry is a major end consumer of cotton, though raw cotton may be first imported and processed into textiles in certain regions before being sent elsewhere for cutting and sewing into garments or other products. Recently, large retailers such as H&M, Nike, and Wal-Mart have moved toward sourcing more organic cotton in response to consumer demand and increasing attention to the environmental impacts of cotton production.

Jute could theoretically replace or supplement cotton in some textiles, though it is currently used largely for sackcloth, packaging, and other such uses. The UN FAO expects demand for jute to increase with the growing consumer demand for natural fibers, although jute is also being replaced by synthetic materials like polypropylene in some applications (FAO 2014).

Most other natural fibers are currently in very low production compared to cotton that their use as a substitute is not feasible unless major investments are made in their cultivation. However, the UN FAO looks at jute, ramie, and abaca as “future fibers” with significant growth potential (FAO 2014).

Ultimately, consumer pressure may play a role in the success or failure of alternative fibers. Growing awareness of and demand for “eco-friendly” products may stimulate demand in less environmentally-impactful fibers. At the same time, consumer lack of familiarity with such fibers and a strong identification with cotton may push growth in organic cotton rather than a move toward alternative fibers.

ENVIRONMENTAL IMPACT

The sheer amount of land devoted to cultivating cotton hints at the significant environmental consequences of production. One of the greatest environmental impacts of cultivation is water usage. Globally, approximately 53% of cotton land (representing 73% of production) is irrigated, and an estimated 2.6% of global freshwater resources are devoted to cotton cultivation (Chapagain and Hoekstra 2005). This impact varies significantly with geography; production increases water stress in already water-scarce regions such as Pakistan and Uzbekistan, whereas more water-rich areas such as the southeastern US are less affected. GHG emissions are also significant, with an estimated 0.3-1% of global GHG emissions resulting from cotton cultivation (International Trade Centre 2011). Acidification and eutrophication resulting from heavy agrochemical use contributes to cotton’s environmental footprint as well, though this can be mitigated to some extent through organic production. Land-use change is also a major concern; as land becomes degraded from intensive farming, farmers may seek to bring new land into production. Moreover, less intensive organic production may have lower yields and actually require more land. All of these impacts have consequences for biodiversity, as habitats are eliminated or degraded.

Jute and other alternative fibers are considered to have far lower environmental impacts, requiring less water and much lower application of agrochemicals to produce (UN FAO 2014). However, it is important to consider that these crops may require more processing and therefore could have greater impacts in the processing phase than cotton. Further, the yields of these crops may be lower per given unit of land, thereby requiring a greater amount of land to produce enough fiber for a unit of textile, for example. Given that these alternative fibers are currently produced in very small amounts largely using traditional methods, it remains to be seen whether increased demand and accompanying growth in production would lead to increased mechanization and use of agrochemicals and irrigation techniques.

STANDARDS OR CERTIFICATIONS

The cotton supply chain is considered one of the more complex commodity supply chains, with the product passing through a multitude of different geographies and actors between the cultivation and use phase of the cotton life cycle (WWF 2012). As a result, companies have relied largely on organic certification as a proxy for environmental sustainability and Fair Trade as a proxy for social sustainability. To encourage companies to improve their cotton supply chains, the World Wildlife Fund and corporate partners also established the Better Cotton Initiative, which aims to improve the cotton supply chain for, producers, consumers, and the environment.

FIBER (TIMBER, PULP, AND PAPER USE)

Commodity	Total Annual Production (M^3)	Top 5 Producing Countries	Top 5 Consuming Countries[1]	Primary Uses
Hardwood[2]	771,269,208	Brazil, United States, China, Indonesia, Russia	China, India, Finland, Sweden, Belgium	Wood flooring, pallets, furniture, cabinets
Softwood	1,029,473,983	United States, Canada, Russia, China, Sweden	China, Germany, Austria, South Korea, Japan	Residential construction,
Tropical Hardwood	176,949,121	Indonesia, Brazil, India, Malaysia, Nigeria	China, India, Japan, South Korea, Thailand	Furniture, flooring, cabinets
Others: Bamboo, Kenaf, agricultural residues, logging residues				

Data source: FAOStat, International Tropical Timber Organization (2012)

[1] Values presented represent imports; consumption data not available
[2] Industrial roundwood, includes tropical

PRODUCTION

Tree forests provide the majority of the fiber used for timber, pulp, and paper, with some raw material being provided by bamboo, kenaf and other non-wood sources (Garcia et al 2009). Hardwoods (generally from deciduous trees) and softwoods (generally from coniferous trees) are harvested either from primary- or secondary-growth forests, or from managed tree plantations (silviculture). In the case of virgin forests, forests are thinned and then trees are harvested and sent to sawmills or other processing facilities to produce board timber, paper pulp, and other products. Harvest may involve clearcutting—harvesting all trees in a given area—or selective logging—harvesting only particular logs either for quality or sustainability.

Silviculture is a far more managed process in which land is prepared and planted with often a single species of tree. The saplings are fertilized and treated with other agrochemicals to ensure survival and optimal growth, and then harvested when the trees are adequately mature (Garcia et al 2009). In both cases, trees are harvested to produce high-quality timber as well as logging residues including branches, resins, and bark, which can be used for a variety of purposes. Silvicultural practices differ widely by geography depending on species of tree planted, soil type, water and nutrient availability, and other factors.

The production of tropical hardwoods often involves logging of virgin rainforests and other ecologically sensitive tropical forests. Like with non-tropical hardwoods and softwoods, tropical logging may involve either selective logging or clearcutting. Clearcutting may be followed with land burning to prepare it for agricultural use or tree plantations (Union of Concerned Scientists 2012).

Substitutes for wood as a source of paper pulp include kenaf, hemp, bamboo, and others. Generally these crops are planted in fields or plantations, harvested at maturity, and processed to separate the fibers that can be used in paper-making and other pulp applications. Whereas kenaf thrives in a tropical climate, bamboo and hemp are more tolerant of a multitude of climates and may be grown more widely as a result (Paper Task Force 1996).

MARKET

Global consumption of wood is sensitive to economic fluctuations and long-term market changes, particularly in the developed world. For example, the economic recession of 2008 resulted in lower rates of new housing construction, decreasing overall demand for wood. At the same time, trends toward electronics and away from paper use have decreased demand for paper to some extent. Nonetheless, demand for timber and pulp has continued to rise in the developed world (United Nations Forestry and Timber Section 2013). Africa, and Latin America, and particularly Asia have all seen steady growth in forest product consumption, with Asia and Latin America also showing increased exports of wood (UCS 2012).

Changing environmental and trade regulations and trends also affect the market for wood products. International regulations are in place to regulate trade in illegally logged wood, which has helped to stimulate growth in wood certification. Indeed, the percentage of the world's certified forest area has now reached 10% (UCS 2012). Moreover, as forestry (whether planting new forests or preserving existing ones) becomes an attractive method of carbon sequestration, sustainable forestry will only grow in prominence and may ultimately affect demand for wood (United Nations Forestry and Timber Section 2013).

Currently alternative fibers comprise less than 10% of fiber in paper and packaging (Pollock 2011). The market for alternative timber and pulp fibers has the potential to grow as companies like Kimberly-Clark and others dive more deeply into the environmental impacts of their supply chains and seek for less impactful alternatives.

ENVIRONMENTAL IMPACT

Broadly speaking, wood is considered a renewable resource that can be grown under a very wide range of climates and growing conditions. Growth of hardwoods and softwoods, whether in virgin forests or tree plantations, provide significant environmental benefits including carbon sequestration and the provision of wildlife habitat. Nonetheless, the environmental impacts of wood production can be minimal or vast, varying largely by production method and geography.

For instance, harvest of virgin hardwoods and softwoods results in significant loss in biodiversity, effective release of carbon that was previously stored in the tree mass, and potentially in land-use change unless the forests are replanted. On the other hand, natural forests do not require irrigation or agrochemical application, improving their environmental profile on both water use and acidification and eutrophication potential. Tree plantations, on the other hand, often require agrochemicals to ensure sapling survival and growth, which contribute to acidification and eutrophication (Garcia et al 2009). Further, plantations often plant non-native tree species that require irrigation and may contribute to water stress in the areas in which they are located. Finally, plantations may be associated with land-use change, as the area for the plantation may have previously been forestland that was cleared.

Considering the distinctions between hardwood and softwood production impacts, the differences are tied less to forest or plantation production methods for each and more to the processing to prepare the wood for use, namely drying. Because hardwoods are denser and have a higher moisture content, hardwood is more energy-intensive to process (Bergman and Bowe, 2008 and 2010), which is associated with higher GHG emissions.

The environmental impacts of alternative paper and pulp fibers are largely tied to yield potentials. For instance, kenaf has higher fiber yields per unit area than softwoods and less is required to make a ton of paper (Paper Task Force 1996). As a result, land-use change implications for producing kenaf may be lower than for softwood plantations. Similarly, bamboo, as a rapidly-growing highly renewable fiber source, has far lower land-use implications than traditional timber (Thomas and Liu, 2013). At the same time, annual crops may require greater agrochemical use, provide lower biodiversity benefits, and potentially require more water depending on where they are grown (Paper Task Force 1996). Both bamboo and kenaf, for example, are associated with higher herbicide use than softwood, and kenaf has significantly higher water use (Thomas and Liu, 2013).

STANDARDS OR CERTIFICATIONS

Proper management is critical to reducing the environmental impacts of hardwood and softwood production. Well-managed harvest of virgin forests may have a better environmental profile than a poorly managed plantation; a well-managed plantation will have a better environmental profile than clearcutting a virgin forest. Certifications are one way to verify that best management practices have been employed.

Forest Stewardship Council: an organization that works to promote environmentally sound, socially beneficial and economically prosperous management of the world's forests through certification that rests on 10 principles and 57 criteria on environmental impacts, human rights, management and monitoring, and other key areas (FSC, n.d.).

Programme for the Endorsement of Forest Certification (PEFC): PEFC is the world’s largest certification program with over 240 million hectares certified. The certification program shares common environmental criteria with FSC and others but includes strong measures on indigenous and small landholder rights and takes a bottom-up, locally-driven approach to certification (PEFC, 2012).

GRAINS (HUMAN CONSUMPTION AND ANIMAL FEED)

Commodity	Total Annual Production (tons)	Producing Regions	Consuming Regions	Primary Uses
Corn (Maize)	872,066,770	USA, China, Brazil, Mexico, Argentina	USA, China, European Union, Brazil, Mexico	Livestock feed, biofuels, human consumption
Rice	719,738,273	China, India, Indonesia, Viet Nam, Thailand	China, India, Indonesia, Bangladesh, Vietnam	Human consumption
Wheat	670,875,110	China, India, USA, France, Russia	China, European Union, India, USA, Russia	Human consumption, livestock feed
Barley	132,886,519	Russia, France, Germany, Australia, Canada	European Union, Russia, Saudi Arabia, Canada, Turkey	Human consumption, livestock feed
Others: Sorghum, Rye, Millet, Oats				

Data Source: FAOStat, USDA (2012)

PRODUCTION

Cereal grains represent hundreds of millions of hectares of agricultural production across the world and can be grown in a wide expanse of climatic regions, in varying levels of drought conditions, and at a range of altitudes. However, in most cases production methods are fairly similar. Grains are grown on large designated agricultural fields with the help of some combination of irrigation, fertilization, and pesticide and/or herbicide use. Some production methods such as no-tillage or conservation tillage have become popular in crops such as corn to reduce environmental impact on the soil and GHG emissions (West and Marland, 2002). Even with these practices the majority of environmental impact of grains takes place during the production, rather than processing stage of the product.

Once harvested the grains are each graded and milled before consumption or use. Wheat and rice must both be dried and husked and wheat is typically ground into flour whereas rice requires minimal additional processing. Corn, given its wide range of uses, from fuel to sweetener, has particularly diverse processing options. Corn may be cracked, ground, or fermented depending on its final use (Clay, 2002). Grains are then transported, often via rail, to storage or final use locations.

MARKET

There is a wide range of industries involved in the market for commodity grains. The end uses are primarily processed foods (such as breads and cereals), commercial meat production, and biofuels. There are several secondary industries within the supply chains that also have significant market influence, such as grain aggregators and millers. These mid-supply chain players are often large-scale companies due to the capital intensive nature of most milling operations that require economies of scale for profitability. This is particularly true for grain destined to urban areas or for export. Companies in the agricultural inputs industries such as fertilizer and seed are also very important players within this commodity group market.

Unlike groups like oilseeds, whose products from different crops are functionally very similar, grains are often used for very different products and may be affected by functionality differences, consumer tastes, or geographic availability. For example, the substitutes for corn being used for high fructose corn syrup (HFCS) are not actually other grains, but rather other sweeteners such as sugarcane or sugar beet. Grains used for livestock feed are largely interchangeable by function; however, transportation cost is a primary driver of feed costs resulting in regionally grown crops being the primary input for livestock feed. As a result, evaluating grain tradeoffs on the basis of production method or geography of production is frequently more feasible than in comparison to other crops within the commodity group.

The demand for cereal grains is growing for all crops due to increasing population, rising incomes (which results in more meat consumption and therefore demand for livestock feed), and government policies promoting biofuels. Emerging customer concerns about GMO grains is also a trend within the market, particularly in more developed economies outside of the US.

ENVIRONMENTAL IMPACT

Given the number of acres on which cereal grains are grown globally, land-use and habitat conversion are a serious environmental impact for the commodity group. Though the productivity per hectare of cereal grains has increased dramatically, allowing for the same land to provide grains for a growing population, there are still some areas where previously conserved or undisturbed land is now being farmed for cereal grains (Clay, 2002). As the demand for cereal grains grows, especially in developing countries, the impacts of grain production on land use and biodiversity loss will be a crucial concern (Weins, 2011).

Cereal crops are also a large consumer of freshwater through irrigation the flooding of rice paddies. As drought conditions become more common in grain producing areas, it is likely that the water use through irrigation will increase. Water use for cereal grains varies by crop (on a global average wheat and barley use more than rice and corn (Pfister, 2011)), geography, and production method so understanding the source of the grains is very important in assessing its water use impact.

In addition to water use, the use of agrichemicals has a huge impact on water quality. Runoff of herbicides and pesticides has been linked to human and wildlife health concerns while runoff of fertilizers contributes to the eutrophication of bodies of water, which can permanently change their ecosystems.

Cereal grains also contribute to global warming through two primary methods. Fertilizer use contributes to global warming through the emission of nitrous oxide, a powerful greenhouse gas, which is off gassed from the fields directly into the air. In addition, rice fields that are continuously flooded release methane into the atmosphere and actually make up between 10 and 30 percent of the global methane production (Clay, 2004).

Most of these environmental concerns have mitigating practices that can be performed by growers such as increasing the productivity per hectare, optimizing fertilizer and chemical use, low impact irrigation, and no-till practices. The variation in farming practices across the world makes the geography of sourcing an important tradeoff decision within this category. Additionally, companies can work with their supply chain to ensure the use of more sustainable farming practices to improve their inputs when a tradeoff decision cannot be made.

STANDARDS OR CERTIFICATIONS

Currently no major sustainability standards or certifications exist for cereal grains besides certified organic. A few no-till certifications exist for some grains, but they are regionally specific, not recognized by consumers, and do not have significant market share.

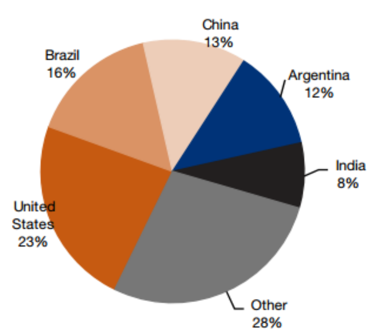
OILSEEDS

Commodity	Total Annual Production (tons)	Top 5 Producing Countries	Top 5 Importing Countries	Primary Uses
Palm, Oil	50,198,781	Indonesia, Malaysia, Thailand, Colombia, Nigeria	India, European Union, China, Pakistan	Culinary, cosmetic, industrial (e.g. lubricants), biodiesel, livestock feed
Palm Kernel	14,657,454	Indonesia, Malaysia, Nigeria, Thailand, Colombia	European Union, Nigeria, Philippines	Culinary, cosmetic, industrial, biodiesel, livestock feed
Rapeseed	65,068,240	Canada, China, India, France, Germany	China, European Union, Japan, Mexico, United Arab Emirates	Culinary, livestock feed biodiesel, fertilizer
Soybeans	241,841,416	USA, Brazil, Argentina, China, India	China, European Union, Mexico, Japan, Taiwan	Culinary (including meat & dairy alternatives), cosmetics, industrial, biodiesel, livestock feed
Sunflower seed	37,449,403	Ukraine, Russian Federation, Argentina, China, France	Turkey, European Union, Egypt, United States, Morocco	Culinary, livestock feed, fuel
Other Important Oilseeds: Coconut, Cottonseed, Groundnut, Olive				

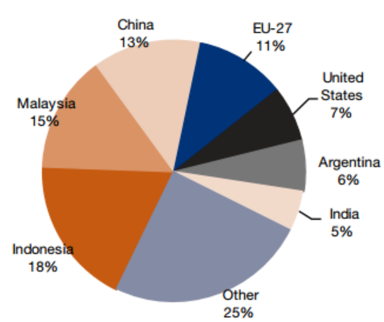
Data source: FAOStat and USDA Foreign Agricultural Service (2012)

Note that with the exception of 'palm, oil,' commodity data listed refers to the parent crop and not the derivative oil or meal

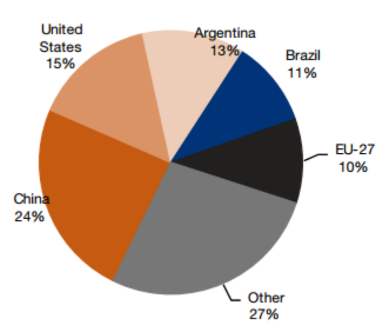
Oilseed production by country



Vegetable oil production by country



Meal production by country



***Source:** Global Markets Research – Oilseeds Industry Review (Mathews 2010)*

PRODUCTION

The term ‘oilseed’ refers to any seed crop that yields oil. This diverse class of commodities is produced in a variety of biomes throughout the world. Soybeans, the most produced oilseed by volume, are predominantly cultivated in the Western Hemisphere particularly the US, Argentina and Brazil but are successfully grown in many other regions with hot summers and sufficient precipitation (Mathews 2010). More than half of global soybean production now comes from genetically modified seed more than any other crop (Worldwatch Institute 2014).

Although initially cultivated in West Africa, oil palm is now grown in tropical climates throughout the globe, but nearly 90% of total production comes from just two countries: Malaysia and Indonesia (Mathews 2010). The scale of plantations can vary dramatically but tend to be substantial with plantations in Southeast Asia ranging in size from 400 to more than 70,000 hectares (Clay 2004). Unlike some other oil crops, harvesting palm fruit is a labor intensive practice and the Malaysian and Indonesian palm industries alone employ millions of workers (WWF 2012).

Rapeseed, particularly the low uric acid cultivar canola, is another major oilseed. A member of the mustard family, rapeseed is grown primarily in EU nations with significant production in Canada and India as well. The European biofuel market demand drives demand (Mathews 2010). Currently more than 5% of global rapeseed production is genetically modified and this percentage is expected to increase (Worldwatch Institute 2014).

The oil and meal content of the various oilseeds can differ significantly, which informs end-use applications. While processing varies based on the type of oilseed used, oilseeds typically go through a milling stage that involves a mechanical and / or solvent extraction process generating oil and meal/cake co-products (Sanz Requena et al. 2011). Oils can then be refined according to the appropriate end-use application. For food applications this might include neutralizing, bleaching, and deodorizing the oils to promote certain flavoring, color, and odor profiles (Schmidt 2010).

MARKET

Distinct markets exist for both the oilseed oil and meal co-products. Oilseed meal is predominantly used in animal feed in the cattle, poultry, and pork livestock industries. Growth in the oilseed market, both for oil and protein meal, is largely being driven by increased consumer and industrial demand in China. The westernization of diets in other developing nations and the shift away from trans fats in developed economies are also significant factors in the market’s growth (Mathews 2010).

Over the past several decades consumption of vegetable oils has grown nearly three times faster than the world wheat market (Mathews 2010). Vegetable oils are used in a number of culinary, cosmetic, and industrial applications. Common culinary applications include use as cooking oil, as a salad dressing base, and as a flavoring or shortening agent. For several of the major culinary uses, the major vegetable oils (e.g. palm, soy, rape, sunflower) are generally substitutable, with seed oil from crops of higher lauric acid concentrations (e.g. palm kernel and coconut) being less interchangeable (Schmidt and Weidema 2008). Vegetable oils are widely used in cosmetics as a base for lipstick and as a key component of soaps and perfumes (Mathews 2010). From an industrial standpoint, seed oils are frequently used in the production of paint and as a manufacturing lubricant, solvent or detergent (Schmidt and Weidema 2008). Growth in the industrial use of vegetable oil has outpaced human consumption in recent years due largely to heightened global demand for biodiesel (Mathews 2010).

ENVIRONMENTAL IMPACT

Oil crop production, particularly oil palm in Southeast Asia and soy in the Cerrado region of Brazil remains a critical threat to biodiversity as significant production takes on or near land with high conservation value. Between 2005-2010 nearly 30% of forest loss in Malaysia and Indonesia was due to further development of oil palm plantations and processing facilities exerting enormous pressure on several rare and endangered species. In addition to biodiversity impacts, oilseed production results in significant greenhouse gas emission due to both land conversion and crop cultivation (WWF 2012). CO_2 emissions associated with logging and draining peat soils, often to prepare for palm plantations, make up nearly 60% of Indonesia's total CO_2 emissions (Wetlands International 2013).

The use of pesticides and fertilizers during oilseed cultivation can also have significant environmental impacts. Agrochemical use in oilseed cultivation is responsible for nitrate leaching (Manik and Halog 2013) and eutrophication of downstream ecosystems, although loss of nitrogen to groundwater per hectare is frequently less for oilseeds than major alternative arable crops (Van der Werf 2004). Soil erosion, particularly with regards to soy and oil palm production, is another key environmental concern for this commodity group (Clay 2004).

STANDARDS OR CERTIFICATIONS

Roundtable on Sustainable Palm Oil (RSPO): an international organization that monitors the social, environmental, and economic impacts of palm oil production.

Roundtable on Responsible Soy (RTRS): a multi-stakeholder initiative to ensure the responsible production, processing, and trading of soy.

The Roundtable of Sustainable Biomaterials (RSB): an international initiative and certification for renewable fuels and biomaterials in general.

BIOFUELS

Commodity	Total Annual Production (tons)	Producing Regions	Consuming Regions	Primary Uses
Sugarcane	1,832,541,194	Brazil, India, China, Thailand, Pakistan	India, EU, China, Brazil, United States	Direct and indirect human consumption. Bio-energy.
Corn Grain	872,066,770	U.S., China, Brazil, Mexico, Argentina	U.S., China, European Union, Brazil, Mexico	Direct and indirect human consumption. Bio-energy.
Wheat	670,875,110	China, India, U.S., France, Russia	China, European Union, India, U.S., Russia	Direct and indirect human consumption. Bio-energy.
Cellulosic (switch grass, rice straw, corn stover, bagasse)	N/A	N/A	N/A	Bio-energy, animal feed, building materials, fertilizer.

Data Source: FAOStat, USDA (2012)

PRODUCTION

Production methods for biofuels depends on the type of feedstock sourced. Generally sugar and starch crops follow a pathway from harvest to milling and hydrolysis for sugar conversion then to fermentation and distillation to ethanol. But not all sugar and corn crops are harvested and produced in the same manner. For example, the ideal production environment of sugarcane is biomes with wet and warm seasons followed by cold and dry seasons, which makes parts of Brazil ideal for production. In contrast, corn production requires a temperate climate, such as found in parts of the American Midwest.

Cellulosic feedstocks transform into diesel through a gasification process. Though this method is still cost ineffective, many scientist and regulators see it as the most promising pathway for biofuel generation. From a production perspective, the advantage of cellulosic feedstocks is that they can be grown on marginal or degraded land and use parts of the plant unsuitable for human consumption.

MARKET

The most significant market driver of biofuel production is renewable mandates from governments. Currently these mandates regulate the percentage of ethanol that must be mixed into fossil-fuel based gasoline for use in commercial and passenger vehicles. Countries such as Brazil, the U.S., and throughout the European Union follow such mandates.

From a consumer perspective, the feedstock used to create the biofuels is indistinguishable. Whether the biofuel is derived from corn or sugarcane or cellulosic is immaterial to the driving experience. However, government mandates may regulate the use of particular feedstocks. For example, renewable fuels in the U.S. must be derived from corn-based ethanol in order to count towards the renewable fuel standards designed by the Environmental Protection Agency.

Often biofuel production must compete with other market demands for the feedstock. For example, sugarcane can either be turned into ethanol or sugar for human consumption. A combination of market signals (such as price) and government regulation drive the balance between these competing demands.

ENVIRONMENTAL IMPACT

The most significant environmental impact in terms of the desired outcome of biofuels is the reduction of GHG emissions. However, some feedstocks require more energy inputs to generate equivalent amounts of ethanol output. Corn-based ethanol shows less GHG reductions per unit output as compared with sugarcane and cellulosic-based fuels. In fact, some studies demonstrate that corn-based ethanol may not lead to any GHG emissions as compared with fossil-fuel based gasoline.

In addition to GHG emissions, other environmental impacts are important to the production of biofuels: air quality (from fuel combustion), land-use change impacts (from the displacement other agricultural production), soil quality (from agricultural production), water quality and availability (from agricultural production and ethanol processing).

STANDARDS OR CERTIFICATIONS

The Roundtable of Sustainable Biomaterials (RSB): an international initiative and certification for renewable fuels and biomaterials in general.

Roundtable on Sustainable Palm Oil (RSPO): an international organization that monitors the social, environmental, and economic impacts of palm oil production.

Roundtable on Responsible Soy (RTRS): a multi-stakeholder initiative to ensure the responsible production, processing, and trading of soy.

Forest Stewardship Council (FSC): a U.S. based non-profit that promotes “environmentally sound, socially beneficial, and economically prosperous” use of the world’s forests.

TERRESTRIAL PROTEIN

Commodity	Total Annual Production	Producing Regions	Consuming Regions	Primary Uses
Cattle (Meat)	63,288,582.09	United States, Brazil, China, Argentina, Australia	United States, Brazil, European Union, China, Argentina	Direct Human Consumption
Chicken (Meat)	92,811,674.49	United States, China, Brazil, Russia, Mexico	China, United States, European Union, Brazil, Mexico	Direct Human Consumption
Pig (Meat)	109,122,021.08	China, United States, Germany, Spain, Brazil	China, European Union, United States, Russia, Brazil	Direct Human Consumption
Sheep (Meat)	8,470,267.17	China, Australia, New Zealand, Sudan, India	N/A	Direct Human Consumption
Cow Milk (Skimmed)	116,136,049.46	United States, Germany, France, New Zealand, Russia (skim)	European Union, India, United States, China, Russia	Direct Human Consumption
Cow Cheese **Whole** (Skimmed)	16,837,378.68 (2,283,337.85)	United States, France, Germany, Italy, Netherlands (whole)	N/A	Direct Human Consumption
Sheep Cheese	684,371.04	Greece, China, Spain, Syrian Arab Republic, Italy	N/A	Direct Human Consumption
Goat Cheese	457,401.15	Sudan, France, Greece, Spain, Niger	N/A	

Data Source: FAOStat, USDA (2012)

PRODUCTION

Production methods for protein commodities depend on the type of livestock and agricultural management utilized. Regardless of production process larger animals generally require more resources and time to produce the final protein commodity due to their unique physiological characteristics. For example a chicken may only take 6 weeks to reach slaughter size, while a heifer cow may take months or years to reach slaughter size (UNH Extension). Globally the vast majority of animals reared for the production of meat are raised utilizing conventional intensive farming techniques (World Watch Institute). A 2007 FAO report estimates that about 67 percent of poultry meat, 50 percent of eggs, and 42 percent of pork is produced from factory farming

(FAO, 2007). Generally intensive farming techniques allow for a faster growth rate and efficient use of space and resources. Livestock is kept in specially designed enclosures usually in large numbers in order to maximize production per unit area. The livestock is systematically transported through the life cycle phases of rearing, feeding, and slaughter. Each commodity requires different lengths of time and involves unique stages of processing. For example chicken broilers are fattened in grow-out houses, while cattle may be sent to pasture for back grounding before being transported to an intensive enclosed feedlot. In general longer-lived animals can have a more complex production cycle. In North America the traditional beef cycle typically includes a cow-calf suckling/grazing period, and a short growing phase with cattle fattened on high grain diets in contained feedlots (Beauchemin, 2010). Significant amounts of inputs are required for transporting, feeding, and rearing livestock. Inputs include fossil fuel for housing regulation and animal transportation, medications and hormones for animal health and growth, materials for housing and infrastructure, feed requirements such as corn silage and soy beans, and water irrigation for feed crops and livestock needs.

Alternative farming techniques include free-range, organic, cage free, grass fed, or other combination of techniques. Generally these practices require more land and time for animals to grow but may require fewer chemical inputs and compartmentalized infrastructure. While free-range animals may be able to obtain a large portion of their dietary requirements through foraging, supplemental feed may be required. Although the supplementary feed for free-range animals is minimal the animals take longer to grow and thus may require a comparable amount of feed as compared to the shorter-lived intensive animals.

Cattle, chicken, sheep, and pigs have been domesticated for thousands of years and are capable of being raised in a wide range of biomes from dry scrubland to temperate grasslands. However, the extreme environments may require additional water, infrastructure, and energy inputs to protect animals from harsh cold, dry, or heat.

MARKET

The international protein market is heavily influenced by disease outbreak among livestock and climate events. Disease outbreak can cause death among livestock and severely reduce national and international supply. For example Indian poultry production declined in 2007 after a chicken cull was required due to rapid spread of the H5N1 avian flu virus (World Watch Institute). Pork production in China also declined in 2006 due to an outbreak of Porcine Reproductive and Respiratory Disease resulting in a massive culling of at least 1 million pigs (World Watch Institute). Countries inflicted by disease outbreaks, contamination threat, or questionable production practices may also experience a dramatic loss of demand through market shifts and global bans.

Extreme weather events such as droughts and floods can directly affect livestock in regions afflicted by the event, however weather can also indirectly influence protein production by impairing crop production required for feed. The 2012 drought in the Midwestern U.S damaged field corn and soy bean crops while price impacts for beef and pork sectors were smaller than anticipated poultry prices rose 5.5 percent from June 2012 to June 2013 (Crutchfield, USDA 2013).

Premium meat products are not interchangeable, however substitution may be possible when the protein commodity is an input for human processed foods, pet food, and animal feed.

ENVIRONMENTAL IMPACT

Meat production processes have significant environmental impacts however the level of impact depends largely on the livestock, management technique, and country of origin.

According to the FAO the global livestock sector is responsible for 18% of global emission of greenhouse gases. Emission contributions originate from the combustion of fossil fuels in the production process, carbon dioxide emission from deforestation in land use change, emission of methane from manure and enteric fermentation of ruminant livestock, and emission of nitrous oxide from application of fertilizers used in feed cultivation. (De Vries, 2010). A review of livestock LCA literature by De Vries reveals emissions from the production of beef generally has the highest global warming potential followed by the production of pork, and chickens. The differences in GHG impact are mainly due to differences in feed efficiency among livestock, differences in level of enteric CH4 emission between monogastric animals and ruminants, and differences in lifespan and reproductive rates. (De Vries, 2010)

The production of meat requires a lot of water, mainly to produce feed for livestock, but also to service animals and provide water for drinking. Globally, agriculture accounts for 92 per cent of the global freshwater footprint 29 per cent of the water in agriculture is used for animal production (Gerbens-Leenes, 2011). The water footprint of livestock is determined mainly by the feed conversion efficiency and the composition of feed consumed by the animals in the system. Feed conversion efficiency is a measure of the amount of feed it takes to produce a given amount of meat. A comparative study of the water footprint of poultry, pork, and beef in various countries and production systems reveals beef to have a larger total water footprint than pork and poultry. However the water use is very dependent on the type of production system. For example in a grazing system the blue and grey water footprints of poultry and pork are greater than those for beef because chicken and pigs in grazing systems still consume substantial amounts of additional feed. (Gerbens-Leenes, 2011).

Acidification potential in the meat production process is caused by the release of acidifying gases ammonia (NH3), sulfur dioxide (SO2), and nitrogen oxide (NOx).

Review of the LCA literature reveals the acidification and eutrophication potential from livestock production is mainly caused by the emission of NH3 from grazing, manure in housing and storage facilities, and the application of fertilizer in fields. Rates of emissions for all livestock are heavily influence by feed ration, type of housing, manure storage, fertilizer application technique, and even climatic conditions such as air temperature and air velocity. Considering emissions are heavily reliant on management technique and climactic conditions the researches shows great variation in emission rates within commodity categories. Without clear patterns within livestock categories impact trends across categories are weak making it difficult to determine a commodity type with the largest acidification and eutrophication impacts (De Vries, 2010).

STANDARDS OR CERTIFICATIONS

Multiple small scale and country specific efforts exist for the certification of healthy, safe, and sustainable meat production, however there are few international standards. The USDA is the primary entity in the United States assessing the safety and quality of meat products. The Global Roundtable for Sustainable Beef was created in 2010 and is currently the only global sustainability initiative in the meat sector. Additional research, academic, and industry association resources exist and provide support for producers, but producers voluntarily obtain the information.

ISO International Organization for Standardization: a voluntary International Standards the ISO 222000 family of standards covers food safety management including standards for meat processing and products.

USDA Food Safety and Inspection Service: a mandatory inspection for wholesome of meat and poultry production processes in the United States

USDA Agricultural Marketing Service: a voluntary grading of meat quality requested by producers and processors.

Global Roundtable for Sustainable Beef: The Global Roundtable for Sustainable Beef (GRSB) is an international multi-stakeholder initiative including retailers, producers, NGO’s and government entities collaborating to advance the sustainability of the global beef value chain. The organization is currently in the processing of drafting a set of principles and criteria for sustainable beef (GRSB, 2014).

AQUATIC PROTEIN

Commodity	Total Annual Production (tons)	Producing Regions	Consuming Regions	Primary Uses
Salmonids (salmon, trout, smelt)	3,896,627	Norway, Chile, Russia, US, UK	N/A	Human Consumption
Shrimps and Prawns	7,218,526	China, Indonesia, Vietnam, Thailand, India	N/A	Human Consumption
Tuna Species	3,771,460	Indonesia, Japan, Taiwan, Korea, Ecuador	N/A	Human Consumption
Marine Whitefish (cod, hake, haddock)	7,413,203	Russia, US, Norway, Argentina, Iceland	N/A	Human Consumption
Low Trophic Level Fish (herring, sardines anchovies)	21,160,431	Peru, Chile, US, China, Mexico	N/A	Industrial Inputs, Human Consumption

Data Source: FAO (2011)

PRODUCTION

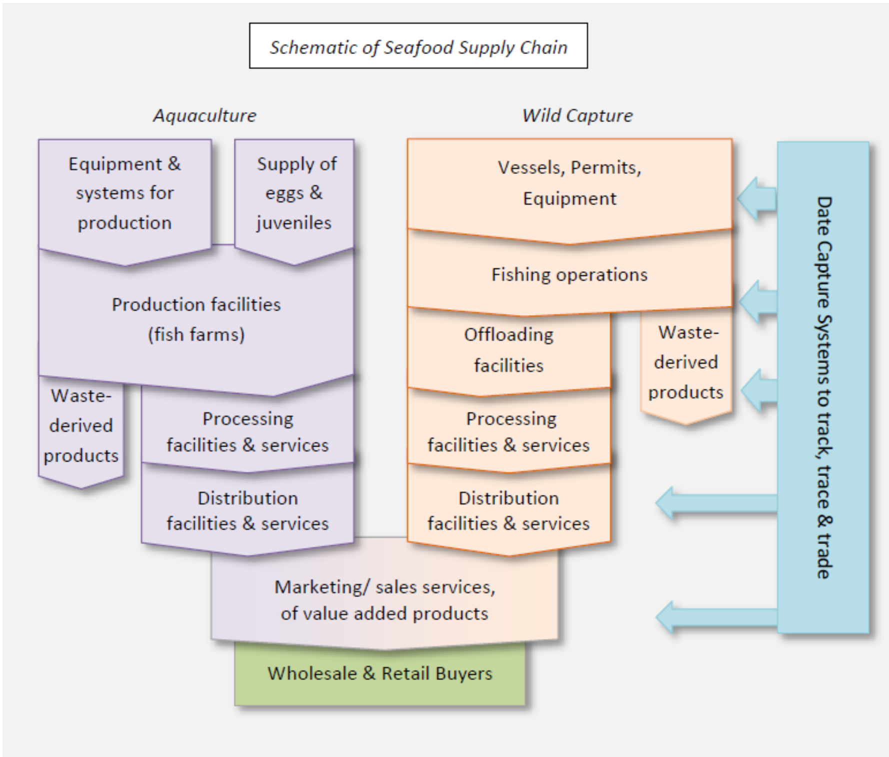
Aquatic protein production assumes two distinct production methods: aquaculture and wild caught.

AQUACULTURE

Aquaculture is practiced to produces a wide variety of aquatic protein for human consumption. Specific feed inputs and production methods vary widely, depending on the species of cultivation and the phase of cultivation. For example, production can take place in coastal farms and pens, inland farms, or in offshore pens. Costal farms and pens are used for species that are saltwater, brackish water or diadromous [3], inland farms are used for freshwater fish, and offshore pens are emerging in use for saltwater species or diadromous species. Each of these production sites pose unique environmental challenges, and thus choosing to source from a costal producer or an offshore producer will require a tradeoff on the type of environmental impact incurred. Furthermore, within each of these major production methods, a wide range of operational choices can be made by input providers and farmers that will affect the environmental impact and quality of aquaculture system outputs.

[3] Species that migrate between salt water and fresh water.

FIGURE 6: AQUATIC PROTEIN SUPPLY CHAINS



Source: *Manta (2013)*

WILD CAUGHT

Fisheries exist both in nationally regulated waters and international waters around the globe. Nutrient-rich upwelling zones in coastal areas near Northwest Africa, Southern Africa, Western North America, Western South America, and Northeast Africa give rise to especially productive fisheries. Depending on the desired catch and vessel type, fish are caught using different techniques. To highlight the variety of techniques available, tuna alone are caught in industrial and semi-industrial operations through using drifting gillnets, longlines, pair trawlers, purse seine nets, or trolling lines. As will be discussed in detail below, each of these methods has varying ability to minimize bycatch,[4] (Valdemarsen 2005) one of the primary environmental impacts associated with wild caught fish.

[4] Bycatch is the accidental capture of species that are not targeted for fishing. Bycatch may be discarded or landed for sale.

MARKET

Fish protein is divided into two primary products: fresh or processed fish for human consumption and fishmeal or fish oil used for indirect human consumption.

The aquaculture and wild caught fisheries serve the market for human consumption. End consumers are commonly provided with un-processed or processed product through one of the following outlets: fishmongers/fish markets, retail/grocery stores, food service providers, and restaurants (Boyle 2012). According to an industry study, farmed and wild fish are still largely interchangeable to consumers. The majority of consumers do not consider the environmental implication for both sources, but when they do, conflicting beliefs prevail on which source is more sustainable (Robinson 2010)

A distinguishing characteristic in the wild caught fish market for human consumption is the lack of transparency due to product mixing in the supply chain. Unlike terrestrial protein supply chains, strict chain-of-custody practices are not followed uniformly in the wild seafood supply chain. At certain points in the supply chain, such as wholesale auction markets, cold storage units, or at-sea-transshipments,[5] products are mixed and the chain of custody is lost (Boyle 2012). This supply chain confusion not only has implications for accurate species labeling in the market, but also clouds transparency in matching environmental impacts with sourcing channel. While this aspect of the wild caught supply chain remains a hurdle to better sourcing practices, buyers are increasingly sourcing direct from suppliers due with the advancement of e-commerce technology (Lem 2005). This direct relationship reduces the need for supply chain steps, which increase the risk for product mixing and lack of transparency.

Wild caught, low trophic level fisheries (such as sardines) largely supply the market for fishmeal and fish oil, which are primarily used as feed for the aquaculture sector. Fishmeal and fish oil producers use a variety of raw materials in the production of products including byproducts of processed fish for human consumption and low trophic level fish. In 2006, aquaculture sector consumed 68.2% of the total fishmeal production and 88.5% of the total fish oil production (Tacon 2008). Other uses for fishmeal and fish oil include feed for poultry and pigs (Shepherd 2007).

Consumption of fish has grown significantly over the past 4 decades as incomes in developing countries (such as China) have risen, however wild fisheries are already being exploited at maximum levels. Thus, it is it expected that the total supply of fish from fisheries will grow only at a slow rate and the growth of the aquaculture industry will increase (Delgado 2003). The aquaculture industry has shown significant growth since the 1970s, growing steadily at an average rate of 8.4 % since the 1970s and is now providing over 47% of the world's supply of

[5] At-sea-transshipments occur when one vessel transfers its fish as cargo to another vessel for carriage.

aquatic protein (Hall 2011). The aquaculture industry is expected to continue its growth trend as research and development allows more species of fish to be domesticated and farmed.

ENVIRONMENTAL IMPACT

Because from aquaculture and wild caught fish have such different production methods and implications, the environmental impacts of each type of fish are also vastly different. Thus, in the decision-making process to sourcing from one or the other, tradeoffs will be made.

These impacts will also vary in severity depending both on the type of species cultivated and the quality of the operating systems used. For example, *water usage* is not a risk for salmon raised in offshore pens, but it is for coastal shrimp production. Furthermore, *eutrophication* may have a low impact for farms that process wastewater before discharge but a high impact for farms with no effluent treatment systems in place.

The major environmental impacts from wild caught fish, as identified in *The 2050 Criteria* by WWF include:

- **Fishery Sustainability –** Damage to the fishery sustainability occurs in fisheries that lack adequate management to ensure sustainable harvests. Illegal, unregulated, or unreported fishing contributes to this impact and can occur where supply chains are not transparent.
- **Bycatch (Biotic Resource Use) –**The unintended catch of non-target fish can impact the population of the non-target fish and reduce biodiversity.
- **Seafloor Biodiversity –** Usage of bottom trawling equipment impacts the biodiversity and ecology of the seabed where it is used.

Impacts associated with wild caught fish can vary depending on the management scheme of the particular fishery and the type of equipment used.

STANDARDS OR CERTIFICATIONS

Best Aquaculture Practices Certification: provides best practice guidelines and certification for all links in the aquaculture supply chain including hatcheries, feed producers, farms, and traders.

Aquaculture Stewardship Council: founded by WWF and the Dutch Sustainable Trade Initiative to provide global standards and certification for all links in the aquaculture supply chain.

Marine Stewardship Council: provides certification, chain of custody tracking, assessment and consulting of fishery management practices, and raises consumer awareness of fishery sustainability issues.

FishChoice: an online database of sustainable wild caught seafood sources and a list of supplier certifications designed to assist procurement managers with sustainable seafood decisions.

Friends of the Sea: a sustainable seafood certification program for both wild caught and aquaculture seafood, founded by the creators of the *Dolphin-Safe* Certification Program.

Monterey Bay Aquarium Seafood Watch: the largely consumer-facing research group also releases a *Buyer's Guide* for chefs, suppliers, and other seafood professionals to highlight species, regional aquaculture systems, and fisheries in a simple red-yellow-green light system.

SECTION 3: BUSINESS APPLICATIONS

APPLYING COMMODITY RESEARCH TO BUSINESS SCENARIOS

"If sustainability meant always making the most ethical, environmental, or economic choice, it would be easy to achieve. However, all value and supply chain executives know that there are trade-offs that must be effectively managed to achieve enterprise competitiveness." (Closs, 2010)

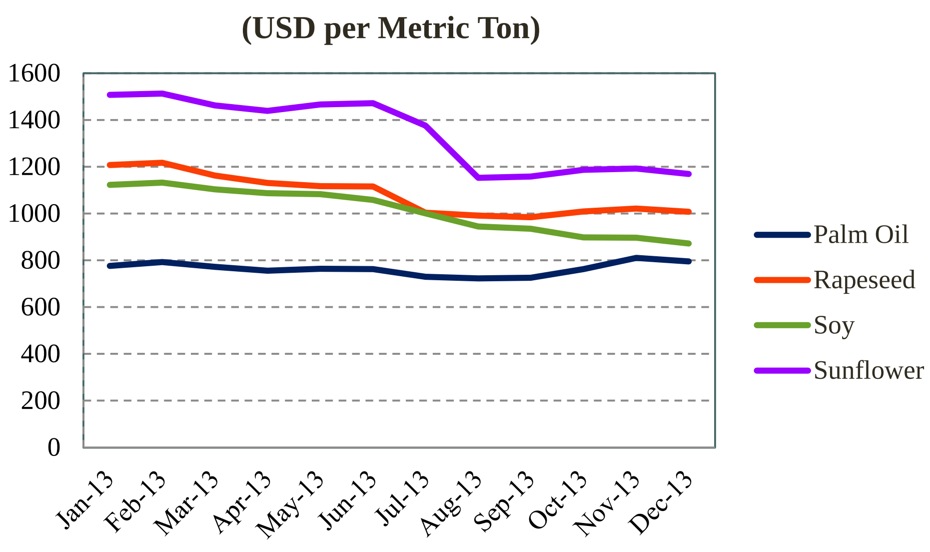
The challenge of sustainability in business is to find a place for it within the complicated matrix of strategic decision-making. The past decade has shown that there is indeed a place for sustainability in business. In many cases the business case and the sustainability case align and no tradeoffs or only minimal tradeoffs are necessary. It is within this context that the following chapter is presented in order to imagine how sustainable sourcing can be incorporated into the decision-making process.

Managing tradeoffs is something that firms address in all dimensions of decision-making within the business. As noted in a recent paper, adding sustainability to the decision-making matrix compounds the complexity of a decision-making process that many managers feel is already too complicated (Closs, 2010). The complexity and interconnectedness of sustainability issues makes evaluating outcomes and thus decisions seem even more complex. Sustainability strategy can take many shapes; focusing on goals within specific indicators (water use, greenhouse gas emissions, etc.), focusing on green consumer demands, focusing on resource use and replenishment, etc. The firm's sustainability strategy, sourcing requirements, future opportunity structures, and commodity industry will shape how sustainability decisions can be made. The following section provides a range of scenarios that may provide guidance on how complicated sustainability-oriented decisions faced by decision-makers in each of the commodity areas can be assessed and executed.

SCENARIO: COMMODITY TRADEOFFS IN OILSEED SOURCING

A product designer for a major food and beverage company's snack division is concerned about recent price fluctuations in vegetable oils used in a wide range of potato chip products (see Figure 7 below). In recent years the company had been switching between sunflower and canola oil, but given recent price trends is considering transitioning the entire product line to palm oil. With senior leadership paying closer attention to the environmental implications of the company's sourcing decisions, the product designer is interested in understanding how this change will affect the environmental footprint of the company's supply chain.

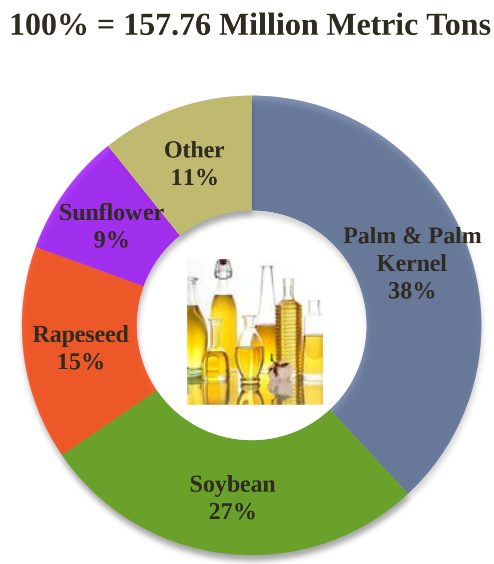
FIGURE 6: VEGETABLE OIL PRICES



Source: *IndexMundi (2014)*

Vegetable oils are used in a variety of food, industrial, and energy purposes. In addition to their use as frying oils or fats other common food applications for vegetable oils include margarine, shortening and salad oils (Schmidt and Weidema, 2008). Over the last several decades vegetable oil crop cultivation and per capita consumption have increased more quickly than for any other agricultural crop (Clay 2004). While 'vegetable oil' applies to any plant-derived triglyceride, palm (along with palm kernel), soybean, rapeseed, and sunflower seed oils represent the bulk of global production (USDA, 2012) and each of these oils are broadly substitutable for most major food applications (Schmidt and Weidema, 2008). Subsequently it is not uncommon for product packaging to reference a number of vegetable oils as possible ingredients. This gives the manufacturer the flexibility to switch between any of the listed oils should prices fluctuate without having to incur the cost of packaging alterations (Clay, 2004).

FIGURE 7: GLOBAL VEGETABLE OIL PRODUCTION (2012)



Source: *USDA, Foreign Agricultural Service, Oilseeds: World Markets and Trade*

ENVIRONMENTAL IMPACTS

Not every oilseed produces the same ratio of oil and meal and disparities among oil yield per hectare are considerable (see Table of Oil Productivity of Major Oil Crops). As with other soft commodities, agricultural inputs and land transformation are critical drivers of the overall environmental impacts of oilseed cultivation. Subsequently, oil yield per hectare is an important determinant of the overall environmental footprint. Dramatic differences in yield of a particular oilseed exist across regions, so it is important for the product designer to try getting insight into where the oilseed producers are located.

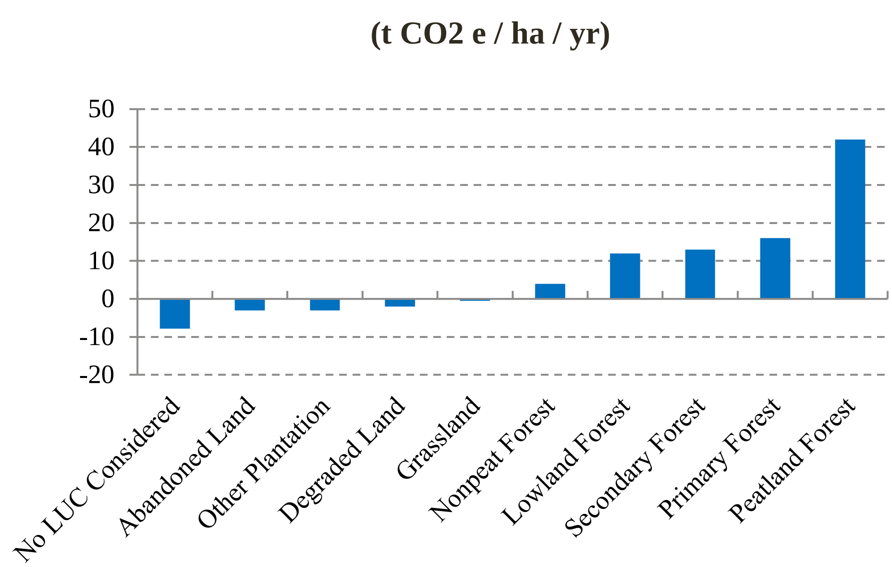
TABLE 5: OIL PRODUCTIVITY OF MAJOR OIL CROPS

Oil Crop	Average oil yield (tons/ha/year)	Average hectares per ton oil	Planted area (million ha)	Total area (%)
Palm oil	3.68	0.27	9.17	4.21
Rapeseed	0.59	1.69	27.30	12.52
Soybean	0.36	2.78	92.10	42.24
Sunflower	0.42	2.38	22.90	10.50
Other	_		66.55	30.52
Total			218.02	100

Source: *Adapted from Yee et al. (2009)*

Greenhouse Gas Emissions (GHG): With vegetable oil production, the associated land use change will most likely be the biggest determinant of greenhouse gas emissions. The conversion of the Brazilian Cerrado for soybean plantations is estimated to have a GHG impact similar to all of the UK's economy in 2009 (WWF, 2012). Subsequently it is rather difficult to compare the life cycle emissions of palm, rape, soy, and sunflower oils without a detailed understanding of the associated land use change and geographic location of the plantation. Even within a commodity group the greenhouse gas emissions associated with agricultural production can vary dramatically (see figure 9).

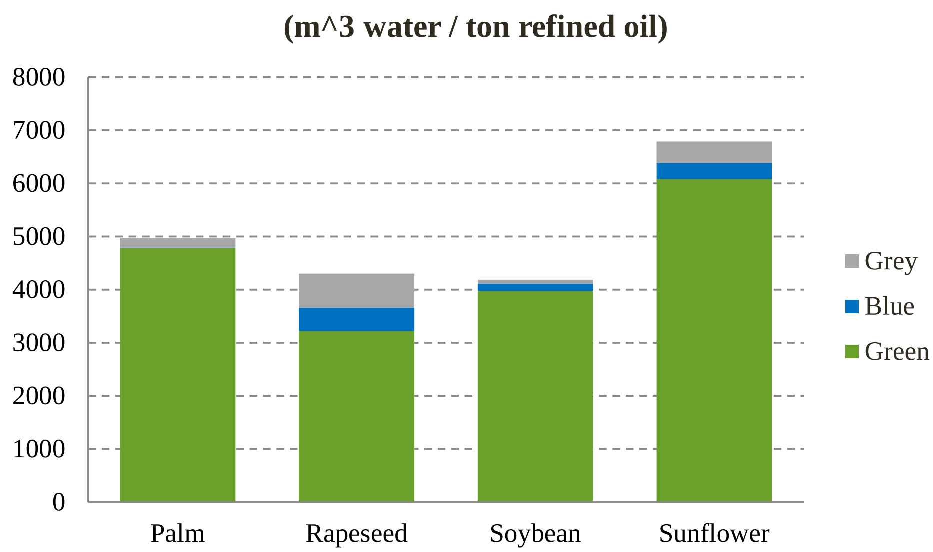
FIGURE 8: PALM OIL GHG EMISSIONS



Source: *Adapted from Manik and Halog (2013): (Table 4)*

Water Use: With growing industry attention on the efficient use of water resources, the product designer is also interested in understanding the water footprint of vegetable oil substitutes. The majority of water used to produce these oil crops is rain-fed ("green"). Of perhaps more importance to the product designer is the "blue" and "grey" water impacts of producing a ton of vegetable oil. "Blue" water refers to the surface and / or groundwater evaporated for crop irrigation purposes. And in this instance, "grey" water refers to the amount of water required to dilute the pollutants associated with oil crop production (Mekonnen and Hoekstra, 2011).

FIGURE 9: WATER FOOTPRINT OF MAJOR SEED OILS



Source: *Adapted from Mekonnen and Hoekstra (2011*)

As illustrated in the exhibit above, a switch from sunflower or rapeseed oil to palm oil may reduce both the blue and grey water impact of the snack product.

Land Use Change and Biodiversity Impacts: While palm oil requires the least land to generate a ton of vegetable oil (see Table of Oil Productivity of Major Oil Crops), satisfying growing global demand has contributed to considerable deforestation in regions where the commodity is produced. More than a third of the growth in oil palm production between 2005-2010 in Malaysia and Indonesia came from converted primary rainforest (WWF, 2012). This land transformation exerts enormous pressure on the region's biodiversity. Palm plantation development threatens a number of endangered megafauna including the Sumatran and Bornean orangutans, Sumatran and pygmy elephants, and the Sumatran tiger (Union of Concerned Scientists, 2014). The change in suitability of the transformed land can be significant. Where up to eighty species of mammal can be found in a hectare of Malaysian rainforest, less than a dozen may be present in a hectare planted with oil palm (Mattsson et al., 2000).

Sourcing soybean oil raises similar land use change and biodiversity concerns. Brazil has been responsible for most of the growth in soybean production over the last ten years. A significant amount of this expansion has come at the expense of a biodiverse savannah woodland known as the Cerrado which also helps regulate a sizeable proportion of the country's fresh water resources (WWF, 2012). Land transformation and biodiversity impacts associated with sunflower and rapeseed oil production should be less of a concern for the product designer as these crops are more likely to be produced on agricultural land that has been in continuous production for decades or centuries rather than having been recently converted (Mattson et al., 2000).

Eutrophication and Acidification: The cultivation and production of vegetable oils cause varying levels of eutrophication and acidification impacts primarily through the use of fertilizers and pesticides as well as fuel and equipment used in the field and for the milling and refining processes (Sanz Requena et al., 2011). Here again, yield is an important environmental driver as cultivating additional land requires a greater use of inputs (Sanz Requena et al,. 2011), (Arvidsson et al,. 2010). Sunflower and canola oil, which have roughly similar oil yields per hectare, are associated with roughly similar acidification and eutrophication impacts (Van der Werf, 2004). While no comparative LCA has looked at the eutrophication and acidification impacts of all four vegetable oils, a survey of several studies suggests palm oil cultivation may have the lowest acidification and eutrophication impact (Arvidsson et al., 2011), (Schmidt, 2010), and relatively speaking, soybean oil the highest (Sanz Requena et al., 2011).

CONCLUSIONS

While significant uncertainty remains regarding the environmental trade-offs associated with the product designer's decision to switch vegetable oils, efforts can be made to reduce the impact of sourcing the particular soft commodity. Given palm's relatively impressive oil yield many environmental indicators appear favorable. However the location and production practices of the palm plantations from which the company sources the oil will have a significant impact on the GHG, Land Use Change, and Biodiversity footprint of the finished product.

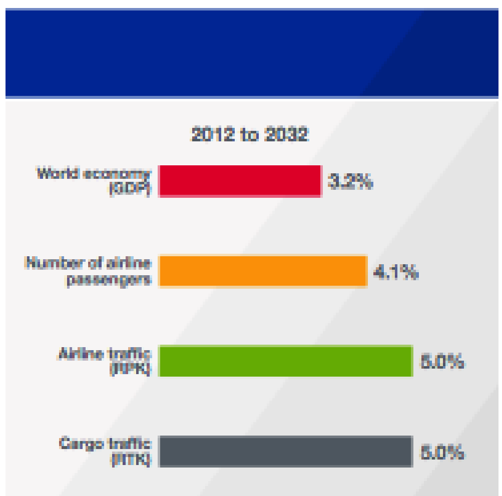
To alleviate these concerns the product designer can decide to purchase only Certified Sustainable Palm Oil (CSPO) which ensures standards established by The Roundtable on Sustainable Palm Oil (RSPO) are met. These include implementing best practices relating to agricultural production and oil processing as well as ensuring high value conservation areas are protected (WWF, 2012). RSPO members and purchases of CSPO include other established consumer packaged goods manufacturers including Mondelēz, Nestlé, P&G, and Unilever (RSPO, 2014). By sourcing certified sustainable palm oil, the product designer can take advantage of palm's favorable pricing, while pursuing a responsible management of the environmental trade-offs associated with switching from an alternate vegetable oil.

SCENARIO: COMMODITY TRADEOFFS IN CELLULOSIC BIOFUELS

Facing pressure from mounting government regulation of carbon emissions and increased interest from frequent corporate flyers looking to reduce their organization's carbon footprint, a global airline considers a significant investment to convert its fossil fuel based engines to biofuel.

Air travel is a significant contributor to greenhouse gases in the atmosphere and the demand for air travel is growing. A single flight from New York to London results in a global warming effect equal to 2 or 3 tons of carbon dioxide per person, which is significant given that the average American generates approximately 19 tons of carbon dioxide per year (Rosenthal, 2013).

FIGURE 10: BOEING'S CURRENT MARKET OUTLOOK (2013)



The above graphic from Boeing's Current Market Outlook report (2013) shows that passenger air travel is expected to increase by 4.1% over the next 20 years and cargo air travel is likely to increase by 5% over that same period; thus, the impact a global airline can have on carbon emissions from a transition to biofuels is likely to increase in the future.

To meet the market and government demands, the global airline seeks to reduce its overall CO_2 emissions by 50% over the next 50 years. Given recent technological developments in biofuel production pathways, the airline decides to invest exclusively in cellulosic biofuels (sometimes referred to as second generation biofuels). Cellulosic matter – biomass such as plant stalks, trunks, stems and leaves – is one of the most promising feedstock inputs for biofuel production as its environmental impact appears to be less per unit of energy output as compared with other feedstock, such as corn or sugarcane (Liang et al., 2012). However, the airline is especially concerned about the land use change effects of cellulosic-based biofuels and will base its procurement decision based on geographic and production sensitivities related to land use metrics.

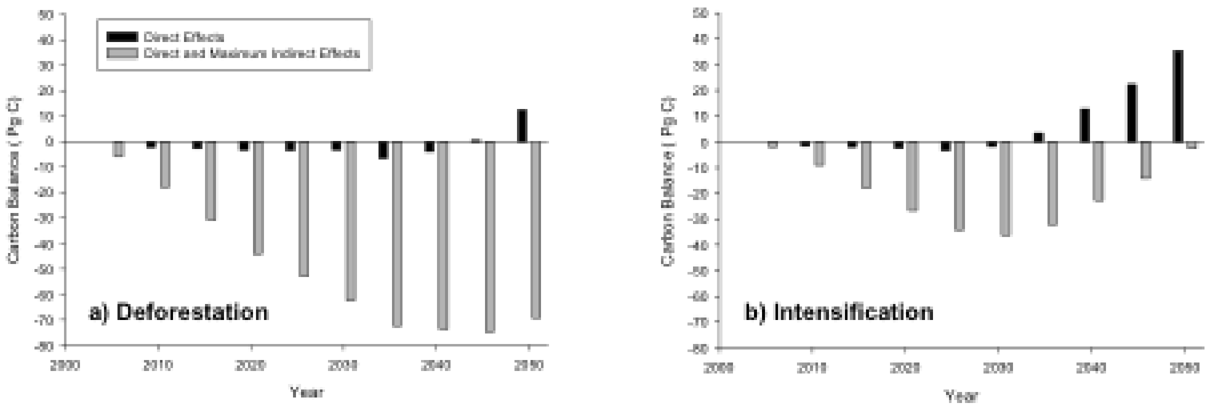
ENVIRONMENTAL IMPACTS

Greenhouse Gas Emissions: Biofuels, including cellulosic biofuels, release GHGs primarily in two stages: land use change in agricultural production and engine combustion. Across all biofuel feedstocks, there is a significant range describing the GHG benefit as compared to traditional fossil fuels. For some feedstocks, biofuels may actually have larger GHG emissions as compared to fossil fuels (Curran, 2008). Cellulosic feedstock is promising because the feedstock is often derived as the byproduct of another primary process, such as the harvesting of wheat straw from a wheat grain harvest. Depending on the production method and land used to produce the feedstock, cellulosic feedstock may have a lower net GHG impact as compared with fossil fuels.

Water Use: As with other biofuel feedstock, the production of cellulosic biomass requires water for irrigation and may lead to soil erosion, which in turn increases the water burden (Curran, 2008). However, as compared to other biofuel feedstock, cellulosic feedstock is likely the byproduct of other agricultural production and is not the primary driver of the water usage.

Land Use Change: A significant portion of the environmental impact from biofuel production hinges on the degree of land use change required to produce the feedstock. There are two types of land use change that result from biofuel product – direct and indirect. Direct land use change describes the deforestation of virgin land exclusively for the production of biofuels. Indirect land use change describes the production of biofuel feedstock on agricultural land, which displaces other agricultural production to virgin land (Melillo, et al., 2009). Depending on the geographic location, production method, and quantity of cellulosic biofuel demand, the land use impacts will vary significantly. For example, Melillo, et al. (2009) compare the net carbon impact of cellulosic biofuel production in two scenarios. The deforestation scenario represents a future where virgin land is cleared to meet the demand for additional biofuel. The intensification scenario represents a future where demand for biofuels is met on the same land area using more intense agricultural practices. The graphic below shows the net carbon balance – savings from using biofuels instead of fossil fuels less the carbon emitted from direct and indirect land use change – that result in each scenario.

FIGURE 11: NET CARBON IMPACT OF CELLULOSIC BIOFUEL PRODUCTION IN TWO SCENARIOS



Source: *Melillo, et al. (2013)*

Biodiversity: The biodiversity impact of cellulosic biofuels depends significantly on whether the feedstock is harvested from virgin land or as a byproduct of other agricultural production. If the land has already been converted for production, the biodiversity impact may only be indirect assuming that the feedstock production displaces other forms of agriculture to virgin lands. If the feedstock is derived from virgin land, the land conversion for production may have a direct impact on biodiversity (Melillo, 2009).

Eutrophication & Acidification: The biomass used for cellulosic feedstock production may typically be returned to the land as a fertilizer were it not for its use as a biofuel; therefore, the nutrient removal from soil may require additional use of fertilizer, thus increasing the risk of eutrophication and acidification (Curran, 2008).

CONCLUSION

By focusing on land use change, the global airline company is likely to observe the most important sensitivities in environmental impact in deciding to pursue a rigorous biofuels program. However, much uncertainty remains given variability of impact due to geographic location, production method, and quantity of feedstock demanded. The global airlines company should identify direct and indirect impacts of land use change depending on various feedstock supply sources. In particular, the airline company should identify if the cellulosic feedstock is derived from a byproduct of another agricultural process or if it requires its own unique production process. This will determine whether the impact of any land use change is attributably solely to the biofuel or attributable to multiple commodities, for example, wheat straw and wheat grain.

The global airline company may also look toward certification standards to help inform its decision. The EU International Sustainability and Carbon Certification System (ISCC) demonstrates whether a biomass or biofuel company meets European and German requirements across environmental, social, and traceability criteria. The Roundtable on Sustainable Biomaterials (RSB) measures social responsibility and environmental stewardship and grants certification to companies that exceed minimum levels established in the 2009 EU Directive for the promotion and use of renewable energy.

SCENARIO: MITIGATING FRESHWATER SCARCITY THROUGH COMMODITY TRADEOFS IN GRAIN SOURCING

A global pet food producer has growing concerns about global freshwater scarcity and worries that the grains it sources for its pet foods might increase the company's exposure to risk within their supply chain. Additionally, they worry that as freshwater becomes a more valuable resource, the prices of heavily irrigated crops will increase which may affect their margins. In order to get ahead of these trends, the company has decided to evaluate their options for grains within their products and look at rice, wheat and corn as potential feed ingredients. Although water use on grain crops is critically location dependent, the company has production facilities around the world and uses consistent product formulas.

In many products grains are not as easily substituted, however most grains in pet food fulfill the primary role of providing a source of carbohydrate and fiber in the feed as a source of cellular energy and contribute to gut health (Thompson, 2008). Pet foods also offer a unique place to evaluate tradeoffs since consumer preference, particularly in terms of the carbohydrate component of the feed is fairly minimal.

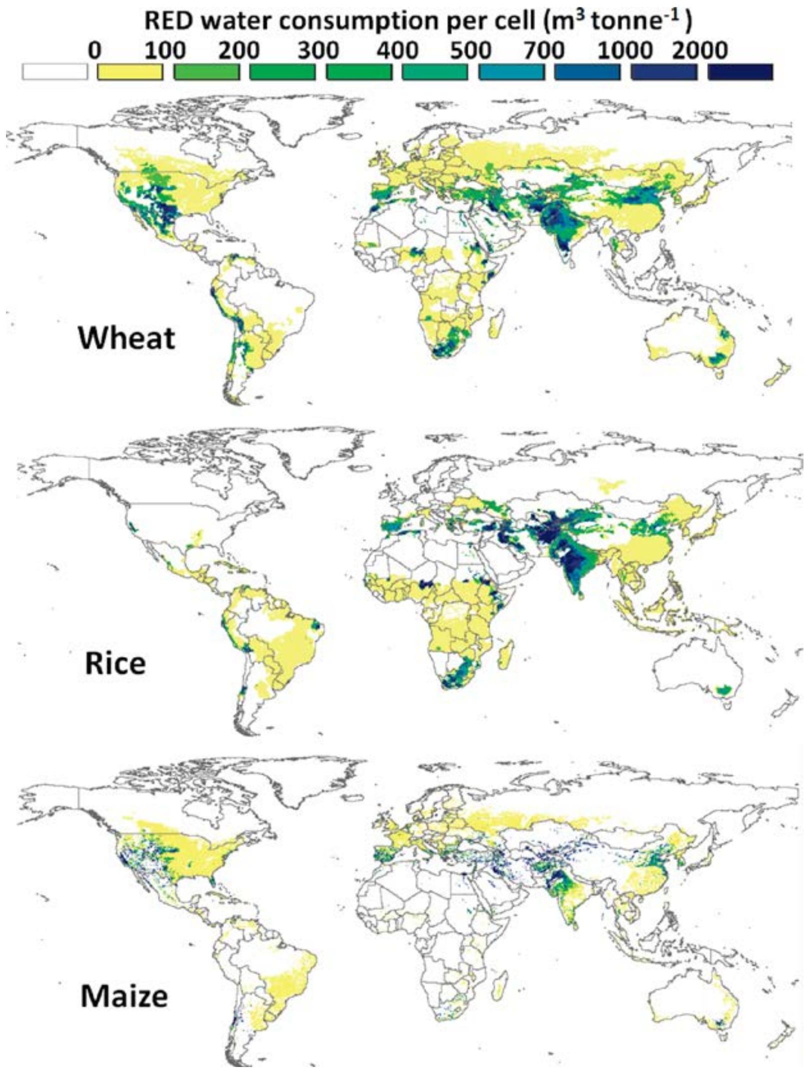
ENVIRONMENTAL IMPACTS

While the company is concerned primarily about the water use of their commodity options, they feel it is important to identify the various environmental impacts of the cereal grains to understand what tradeoffs they may be making in order to reduce their water risk.

GHG Emissions: The main sources of greenhouse gas emissions associated with grain production are from tillage practices, the production and application of agricultural inputs (fertilizer, pesticides, and herbicides). Nitrous oxide that is emitted from fertilizer on the field is the primary source of emissions for wheat and rice (West & Marland, 2002) and methane emissions is the largest source of emissions from the rice paddy for rice. The geography of production, intensity of fertilizer use, and production practices have dramatic impacts on the total greenhouse gas emissions by crop.

Water Use: Freshwater use for irrigation is a significant environmental impact for cereal grain crops since many of them are irrigated rather than rain fed and rice paddies are often artificially flooded. When evaluating the impacts of water use it is important to also consider the water stress in that area. For example, a liter of water consumed in the US West does not have the same impact as a liter of water consumed in the Midwest since water is must scarcer in the western regions. One recent study aggregated water use and water stress to create a metric of “RED water” or “Relevant Environmental Deficiency water” to assess the complex nature of water use impact. On a global scale, although rice consumes the most water, the impact of water use was greater for wheat and significantly less for corn (Pfister 2011).

FIGURE 12: RED WATER CONSUMPTION



Source: *Pfister 2011*

Land Use Change: The production of cereal grains uses huge quantities of land across the world. While in many areas the production is not causing new lands to be converted, this is changing particularly in developing countries where demand is growing quickly.

Biodiversity: Impacts on biodiversity from cereal grain production are incredibly difficult to measure and have not been widely studied. Biodiversity may be impacted as a result of destroying habitat to create new farmland as well as by herbicide and pesticide use on the fields which can have impacts on plants and animals living on the farmland as well as in the areas affected by chemical runoff. When using a measure of land productivity as a proxy for land quality wheat caused about 20% more land stress than rice and about 60% more land stress than corn when looking at globally aggregated data (Pfister, 2011).

Eutrophication & Acidification: Runoff of fertilizers contributes to the eutrophication of bodies of water which can permanently change their ecosystems. As with greenhouse gas emissions, these impacts are tied strongly to geography of production and production method.

CONCLUSION

If the pet food company is primarily focused on water risk and looking at sourcing on a global scale, the results of the study referenced above would promote moving away from wheat as an input and towards rice or corn. In this case, water risk tracks with land stress and you see wheat as the highest impact for both impact metrics. However, this may not be the case for other environmental impacts like greenhouse gas emissions or eutrophication. Further research into the lifecycle impacts of these crops along other impact areas would be useful for the company to be able to truly assess the implications of their decision.

As mentioned above, water use on grain crops depends significantly on where the grains are grown so while the company is currently using aggregated impact data, they should eventually move to evaluating the impact of their inputs based on the exact region they are coming from. For example, they may choose to use a different carbohydrate source for their feed produced in Asia than they do in North America.

SCENARIO: PRODUCTION METHODS IN BEEF SOURCING

A procurement officer for a global restaurant chain is revaluating the sourcing strategy of the company's beef products. Currently the company sources beef from conventional farming operations in multiple countries around the world. The company values long standing partnerships with its suppliers, however the company also holds their suppliers to strict environmental, health, and safety standards and conducts annual reviews of all supplier practices. Recent developments have led the company to reevaluate the standards they set for their beef suppliers especially the metrics that establish farm management practices. Consumers have grown increasingly interested in alternative grass fed beef as they have grown wary of animal welfare and public health issues with hormone use in traditional management. The company has also tracked corporate sustainability and climate regulation trends and has recently committed to a GHG emissions goal of 20% reduction by 2020. The procurement department is determining how their sourcing strategy and associated supplier management practices can influence the goal, while maintaining consumer interest.

Ideally the company would like to maintain a diverse portfolio to ensure consistent supply in a market with unstable climate and disease outbreaks among livestock, but they are open to changes in standards and supplier management practices at marginally similar cost. If an alternative management practice is preferred the company would rather work with suppliers to improve practices before terminating a contract.

The company aims to understand which beef production practice, conventional or grass fed, will help the company meet its emissions goals, while maintaining steady supply and assuaging consumer concerns? Are there additional environmental and social issues to consider? In either case do mitigation tactics exist that can help the company reach its goals?

ENVIRONMENTAL IMPACTS

The company primarily values greenhouse gas emissions and environmental issues associated with human health concern, however, beef production has multiple environmental impacts. Conventional (industrial, factory, of feedlot finished) and grass-fed (alternative, grazing, or pasture finished) management systems also vary in the extent of their impact.

Greenhouse Gas Emissions – Greenhouse gas emissions are a primary impact of the beef production process and are mainly caused by cattle enteric fermentation. GHG emissions are also released from cattle transportation, housing, and loss of carbon storage caused by land use change. Cattle release the greenhouse gas methane (CH_4) through the digestion process of enteric fermentation, contributing as much as 17 – 34% of all anthropogenic methane emissions (Beauchemin, 2010). Methane often does not get as much attention in the media as other greenhouse gases such as carbon dioxide CO_2, but methane's global warming potential is over 20 times greater than CO_2 (EPA, 2012).

Considering the cattle itself contributes the majority of the GHG emissions, the life span of the livestock greatly influences the overall impact. LCA research indicates that feedlot finished cattle generally emit fewer emissions relative to pastured beef due to the conventional cattle's shorter life span and lower overall methane emissions (Pelletier, 2010). However, studies such as the Pelletier study acknowledge the impact of pasture raised practices may be improved by enhancing the positive organic carbon sequestration of the soil. An optimally managed pasture system would likely perform better that the average systems modeled in studies (Pelletier, 2010).

Water Use – Raising cattle for beef production also requires significant water inputs. The total water footprint of the beef production system depends primarily on two main factors 1.) how much a cow needs to eat to produce a unit of meat and 2.) what the cow eats (Gerbens-Leenes, 2011). Management techniques directly influence both of these factors. In general, the feed conversion efficiency of conventional cattle is greater than grass-fed cattle as it takes less time and feed to produce 1 kg of beef. However, although conventional systems require less feed to produce the same amount of meat, the cattle in conventional and grass-fed systems are eating different types of feed with unique water footprints (Gerbens-Leenes, 2011). In conventional systems cattle primarily eat a concentrated feed mix of corn or soy usually grown off site, while grass-fed cattle glean the majority of their food through grazing on grass roughages. While the favorable feed conversion efficiency of the conventional system suppresses the overall water footprint, the conventional system still requires large amounts of feed concentrates that need significant irrigation, especially in dry regions. Alternatively, the roughage feed in grass-fed systems requires relatively little water inputs. Overall the global average water footprints of blue and grey water are found to be significantly greater in conventional systems than grass-fed systems (Gerbens-Leenes, 2011).

The relative impact of either system depends largely on the climate of the country and unique production technique required for those locations. For example "the water footprint of industrially produced beef in the Netherlands, the US and Brazil is smaller than the global average, while it is larger for industrially produced beef in China" (Von Witzke, 2011). Water use is especially relevant for the company if it sources beef from water stressed countries.

Land Use Change – The amount of land used for beef production depends largely on the farm management technique. The amount of land used is dependent on the area required for livestock and the area required for feed production. In conventional systems relatively minimal land is required to house cattle from the cow/ calf phase to the finishing phase as cattle per unit area is maximized, however additional land is needed to grow feed crops off site. In comparison grass-fed cattle require more land to graze than conventional cattle, but additional land is not required to grow feed because the grass-fed cattle rely mainly on roughages. In general, LCA assessments reveal greater land use in grass-finished beef (120m2/kg) versus feedlot-finished beef (84.3m2/kg) (Pelletier, 2010). However, although more land is required for grass-fed beef, the pasture may provide additional ecosystem services that conventional cropland and feedlots cannot provide.

The total amount of land used is not directly correlated with land conversion and is not necessarily associated with one farm management style or another. The company may need to conduct further studies to assess the specific land conversion impacts of their suppliers as the amount of land converted will depend largely on the specific location and land management.

Acidification – The release of acidifying gases ammonia (NH_3), sulfur dioxide (SO_2), and nitrogen oxides (NO_x) during the beef production phase depend largely on management practices and location. Acidification in the production phase is mainly caused by the emission of ammonia from grazing cattle, manure in housing and storage facilities, and the application of fertilizer in feed fields. Rates of emissions for all livestock are heavily influenced by feed ration, type of housing, manure storage, fertilizer application technique, and even climatic conditions such as air temperature and air velocity (De Vries, 2010). Considering emissions are heavily reliant on management technique and climatic conditions it is difficult to determine which production system unilaterally has a greater acidification potential.

Eutrophication – Similar to acidification, eutrophication impacts from cattle production are mainly caused by ammonia (NH_3) emissions and the leaching or run off of nitrates ($NO_3{}^-$) and phosphates ($PO_4{}^{-3}$) from grazing, manure, and fertilizer application for feed. Similar to the release of acidifying gases, the leaching of nitrates and phosphates from soils is influenced by local climatic and soil conditions. There is some evidence that grass fed beef contributes greater eutrophication impacts when compared to conventional, however multiple researchers acknowledge that impacts can differ largely among countries or even regions within the same country (Schils, 2007, Pelletier, 2010). There are also many different methods to quantify nutrient runoff, which makes it difficult to compare the impacts of different management styles (De Vries, 2010).

CONCLUSION

From a strictly economic perspective, conventionally produced beef provides three fold benefits for the restaurant company. Conventional cattle grow faster, are cheaper to produce, and produce a higher “grade” product in the U.S due to fat marbling (Cross, 2011). However there are complicated environmental and social tradeoffs associated with choosing conventional beef over grass-fed beef. While, conventional beef may produce fewer GHG emissions and help the company meet its 2020 reduction goal, GHG emissions are also influenced by land use change.

The total GHG emission of the company's suppliers will be influenced by land conversion rates in supplier's country and should be assessed at the supplier level. If the company's conventional suppliers are contributing greatly to deforestation rates, carbon emissions from land use change may be higher than normal. Simply choosing conventional beef over grass-fed beef will not necessarily result in the lowest GHG emissions. For example if the conventional beef is sourced from a deforested region, the total impact may be greater than grass-fed beef in an area with minimal land use change. Although the company is prioritizing GHG emissions, water use may be a relatively more significant issue for beef, especially if the company is sourcing beef from a water stressed region. Under water stressed circumstances, the company may consider sourcing grass fed beef as it has a lower total water footprint.

Since the company would like to continue sourcing beef from multiple regions it is difficult to catalog additional impacts of eutrophication, acidification, and biodiversity loss because these impacts are location dependent. However, if the company chooses to ensure their supplier's rates of GHG emissions by evaluating land use change on site, the company may also be able to measure the additional environmental impacts for a comprehensive environmental assessment.

The social tradeoffs of conventional versus grass-fed beef complicate the ultimate decision. While, one of the main drivers for revaluating conventional beef is public concern over negative human health and animal welfare issues, consumers may not be aware of the other environmental and social tradeoffs. Grass-fed beef may be perceived as better for human health and animal welfare, however customers may not realize the associated the greater greenhouse gas contribution of grass-fed beef. Consumers are also accustomed to the fine grade texture of conventional beef and may be surprised by the differences in taste and texture that grass-fed beef offers. Although there is scientific debate about which product is more nutritious, grass-feed beef may be perceived as the healthier, learner, and lower calorie cut (Cross, 2011).

Mitigation – Although, both conventional and grass fed beef production have negative impacts the company can chose either:

- The option with the lowest prioritization impacts; or
- The option with impacts that the company can most easily mitigate.

Whatever option the company chooses it may consider educating the consumer on the associated tradeoffs of the decision to avoid potential backlash.

GHG emissions from either production system may be mitigated by offsetting emissions through land restoration or by reducing emissions further down the supply chain. For example in sourcing meat, the company can try to reduce transportation emissions by choosing suppliers that are closer to processing plants and final restaurants. Suppliers can also capture methane from manure and convert it to biogas in anaerobic biodigesters. By converting the manure to biogas the supplier will reduce their total methane emissions, while producing an alternative form of energy. Regardless of agricultural practice land conversion should also be minimized to reduce GHG emissions and other potential indirect impacts such as biodiversity loss. Companies can work with suppliers to ensure suppliers are utilizing and enhancing existing agricultural land, instead of clear cutting new sites. Working with suppliers can also reduce the water footprint of cattle production by finding right balance between feed efficiency and feed crops with the lowest water footprint (Gerbens-Leenes, 2011).

More specific best management principles and criteria can be obtained from the Global Roundtable for Sustainable Beef (GRSB) http://grsbeef.org. The organization is an international multi-stakeholder initiative including retailers, producers, NGO's and government entities collaborating to advance the sustainability of the global beef value chain. Draft principles and criteria were published in April 2014 with plans for continued improvement. Roundtable membership and certification are voluntary for companies and suppliers, however GRSB is currently the only international sustainability body that corporations can consult if they are interested in improving the sustainability of their beef supply chain.

A table like the following may help companies understanding the overall tradeoffs. In the table below, the positive and negative values attributed to the different impacts of each management technique are loosely based on qualitative and quantitative research, but largely depend on the location, unique production process, and life cycle boundaries set for the specific production system studied. Some results also receive more comprehensive support from the field of LCA research, while others are debatable. The bolded issues are the company's priority values.

FIGURE 13: ILLUSTRATIVE COMPARISON OF BEEF PRODUCTION METHODS

Conventional Beef	**Grass-fed Beef**
Economic	
+ Cows grow faster	- Cows grow slower
+ Cheaper to produce	- High operating costs
+ Higher “grade” product in U.S	- Shortage of processors
Environment	
+ Less GHG Emissions	- More GHG Emissions
- More Water Use	+ Less Water Use
? Eutrophication	? Less Eutrophication
? Acidification	? Acidification
? Land Use Change	? Land Use Change
? Biodiversity Loss	? Biodiversity Loss
Social	
- Human health concerns related to hormones	**+ No negative human health concerns**
- Animal welfare concern	**+ Fewer animal welfare concerns**
+ Consumer acceptance of fine grade texture	- Consumer wariness about taste and texture
+ Long standing standards	- Loose standards for grass-fed
- More calories	+ Fewer calories
? Less nutritious (Debatable)	? More Nutritious (Debatable)

Meant For Illustrative Purposes Only

SCENARIO: PRODUCTION METHODS IN SHRIMP PRODUCTION

A buyer for a major food service provider is considering where and how to source shrimp for its cafeteria and catering services. The company made a commitment to source all of its fish products sustainably by 2025. The company defines sustainability as ensuring the long-term availability of wild stocks.

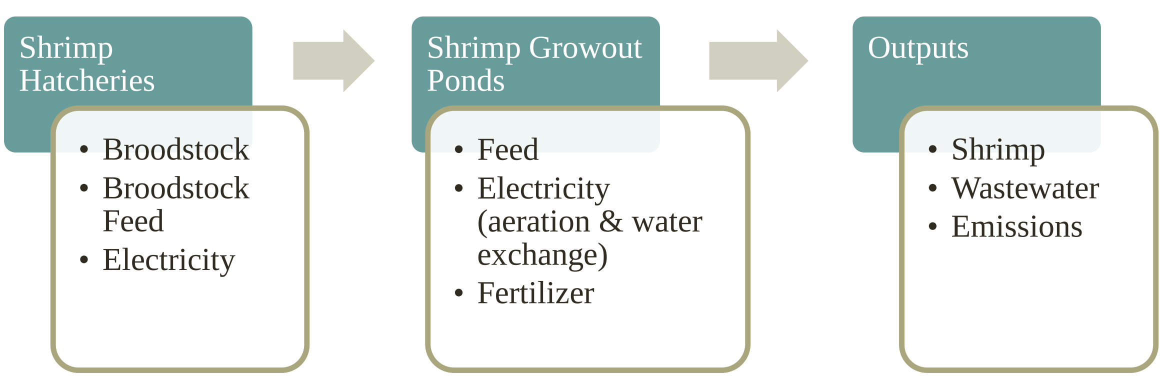
Shrimp has been named to the Natural Resources Defense Council's *Meals of Mass Destruction* list and Monterey Bay Aquarium's Seafood Watch List. Consumers, manufacturers, and retailers alike are responding. Unilever now sources over half of its seafood from sustainable and certified fisheries and mainstream outlets such as Target carry shrimp products with sustainability certifications. The message is clear across all seafood categories: consumers are increasingly aware of and care about the source of their seafood. The difficulty in deciding how to navigate this issue not only lies in the economic, marketing, and logistic tradeoffs that the buyer must make, but also within the different types of environmental impacts that aquaculture and fishing respectively produce. No matter which source the buyer chooses, there are serious concerns for meeting the company's expectations.

ENVIRONMENTAL IMPACTS

Farm Raised Shrimp

Farm raised marine shrimp are raised in both coastal and inland ponds. Shrimp larvae are provided form commercial brood stock or wild larvae is collected to be raised in the ponds. Once in the ponds, shrimp must be provided with adequate nutrients and water quality for shrimp and these needs are met through four primary operations: aeration, water exchange, fertilizing, and feeding.

FIGURE 14: SHRIMP FARMING PROCESSES AND INPUTS



These basic operations have implications for several types of environmental impacts. The list below provides a high-level overview of the major impacts that result from farming operations.

Greenhouse Gas Emissions –This is a hotspot issue for farmed shrimp. Electricity operated farming systems (including aeration and water treatment) and feed production cause the largest amount of energy use and greenhouse gas emissions in shrimp farming operations. For one kilogram of intensively farmed shrimp, an estimated 5.2 kg of CO_2 equivalents are released. (Cao 2011)

Water Use – Not a hotspot issue, however mismanagement of aquifers used to supply aquaculture systems can cause depletion or salinization. (Levin 2012)

Land Use Change – Many marine shrimp farms are located in coastal areas which can contribute to the destruction of costal habitats including mangrove forests, salt flats, mud flats, estuaries, tidal bases and coastal marshes. (Levin 2012)

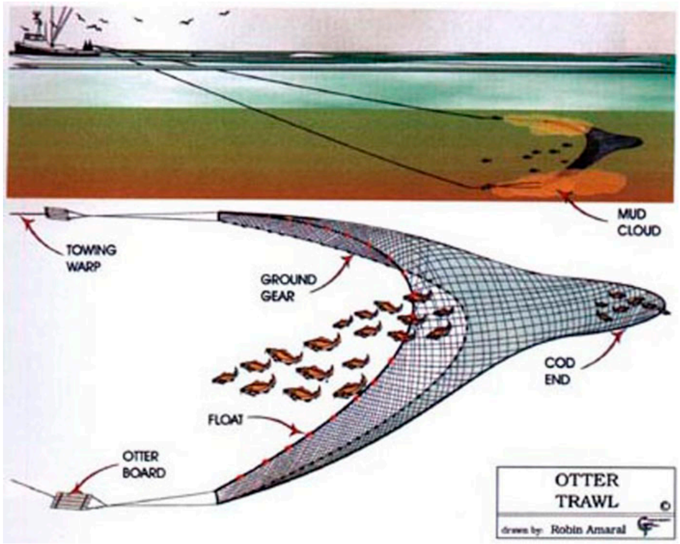
Biodiversity – Feed for shrimp currently contains wild caught fodder fish as a key ingredient. The use of fishmeal in aquaculture feed is a hotspot issue due to the biotic depletion of fodder fish and the energy required to harvest and process fodder fish. Through this supply chain, aquaculture shrimp are linked to the sustainability of wild fisheries. (Cao 2011, Levin 2012)

Eutrophication - This is another hotspot issue for farmed shrimp. The nutrient rich wastewater from shrimp ponds has a large eutrophication potential if simply released into nearby waters without treatment. Some farms fertilize the water to encourage the natural ecosystem of the pond to produce more microorganisms for shrimp to consume. This also increases the nutrient load and eutrophication potential of the water if not treated before it is discharged into waterways. Eutrophication can degrade coastal and inland ecosystems and fisheries. (Cao 2011) (Chislock 2013)

Acidification –Acidification occurs in farming systems as a result of fertilizer use, however this is not a major hotspot area. (Cao 2011)

Wild Caught Shrimp

FIGURE 15: OTTER TRAWL NET



Source: *Penobscot, 2014*

In the US, skimmer trawling and otter trawling are the prevailing methods to catch marine shrimp. In both methods a cone shaped net is dragged behind a boat at low speeds. Skimmer trawls are used in shallower waters where otter trawls can be used at a variety of depths. While the production method for trawling is relatively simple compared to farmed operations, it still has the potential to create negative impacts.

Greenhouse Gas Emissions – Emissions include diesel usage from vessel trawling as well as refrigerants used on-board the vessel. One study shows that for one kilogram of landed shrimp, 35 kg of CO_2E are emitted through diesel fuel use and refrigerants (Ziegler 2009).

Water Use – not applicable

Land Use Change – not applicable

Biodiversity – First and foremost, if shrimp fisheries are not well managed the risk of an ecological collapse of the fishery increases. Additionally, trawl nets catch many other species in the process of netting shrimp. According to one study, only 8% of the biotic resources caught in a shrimp trawler are landed shrimp, the rest is either discarded bycatch or bycatch that is landed and sold (Ziegler 2009). There is no understanding of how much of the bycatch is ultimately brought to market, released alive, or discarded as dead. Furthermore, bottom trawling equipment indiscriminately breaks up the seabed, disrupting the ecosystem. This unintended consequence contributes to biodiversity loss, loss of habitat, and loss of protected species.

Eutrophication – Not a major hotspot in trawling operations, but nitrous oxide emissions from fossil fuels contribute to eutrophication.

Acidification – Again, not a major hotspot in trawling operations, but sulphur emissions from fossil fuels contribute to acidification.

CONCLUSION

Lifecycle assessment studies were used to evaluate the environmental impacts of these operations. As mentioned in the *Existing Tradeoffs* chapter, lifecycle assessment is a common way to evaluate and weight differing impacts on a similar scale for a similar product. For example, how does 1 ton of frozen farmed shrimp compare to 1 ton of frozen wild shrimp in the relevant impact categories. In this tradeoff case, as with many cases, an LCA has not been conducted comparing these exact two production methods. In lieu of commissioning a study, examining existing LCAs for both wild caught and farmed shrimp can provide understanding the major impacts of each production method (as discussed above) and can provide a subjective comparison of the impacts.

In this scenario, the organization is concerned with the sustainability and health of wild stocks. A cursory examination of this issue may conclude that the best option is to procure only aquaculture shrimp and shrimp from strictly regulated fisheries. However, with a deeper understanding of the hotspot impacts of aquaculture, it is clear that more must be done. Aquaculture feed which uses fishmeal from low trophic level fish (anchovies, sardines, etc.) and thus needs to be considered even when sourcing from aquaculture systems. It is unlikely that the food service organization will be willing to audit suppliers of feed to the shrimp farms in its supply chain. However, certifications for responsibly produced feed are emerging through organizations such as the Best Aquaculture Practice group.

Furthermore, the eutrophication potential of aquaculture systems without adequate water treatment systems have been shown to damage coastal and inland ecosystems and fisheries (Chislock 2013). While specific conclusions of eutrophication's impact on the sustainability of local fisheries would need to be studied in a local context, this impact certainly runs counter to the organization's goal of encouraging sustainable fisheries. If the number of suppliers is not too many, the organization can audit suppliers or the organization could pledge to source from aquaculture operations certified as responsible by organizations such as the Best Aquaculture Practice group or through the Aquaculture Stewardship Council.

In terms of wild caught shrimp, the key indicator for this organization would be whether the procured shrimp came from fisheries that set catch limits based on scientific study and have the enforcement mechanisms to ensure limits are kept. Collaboration with non-profits such as the Natural Resources Defense Council, who regularly evaluate the effectiveness of fishery management, can help identify sustainable, effective fisheries around the world. Reduction of bycatch and seafloor damage is another important aspect to reaching the goal of sourcing sustainable seafood, since these unintended consequences can impact the sustainability of non-target species. This can be achieved through several techniques. Working directly with responsible suppliers or with certification schemes can ensure that the shrimp caught is taking all measures possible to decrease bycatch and conserve the seabed.

Both wild caught and aquaculture raised shrimp have implications for seafood sustainability, thus there is no either/or answer in this case. The organization can continue to source from both aquaculture and wild fisheries, however in both cases, controls need to be implemented to be sure that their suppliers are implementing best practices. These controls can be implemented in-house through an auditing system or can be outsourced to one of the many certification schemes.

SCENARIO: GEOGRAPHIC TRADEOFFS IN COTTON SOURCING

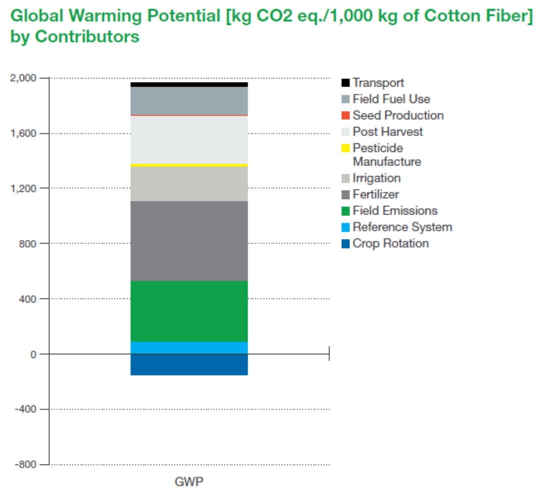
A global apparel retailer, seeing the trend in consumer demand for organic and environmentally friendly products, has decided to investigate its supply chain for ways to improve its environmental footprint. Recently, the company has made a number of public sustainability commitments, and has focused particularly on reducing water use in its operations and supply chain.

Knowing that cotton represents a significant portion of the raw materials used in the products it manufactures, the company has chosen to look specifically at water use related to cotton sourcing practices both because this provides an opportunity to improve product sustainability and because water scarcity imposes risks for the production of this important raw material. Although it does not directly source raw cotton, the company has put resources toward tracing its cotton supply chain back to the production phase of the cotton life-cycle and has determined that the majority of the raw cotton that ultimately becomes apparel comes from regions experiencing water stress.

Assuming that it has the ability to influence the geographic source of the raw cotton that goes into its products, the apparel retailer aims to determine: from what regions it should try to source cotton if the company is primarily focused on reducing water use, and what are the potential environmental tradeoffs in sourcing from one region or another?

ENVIRONMENTAL IMPACTS

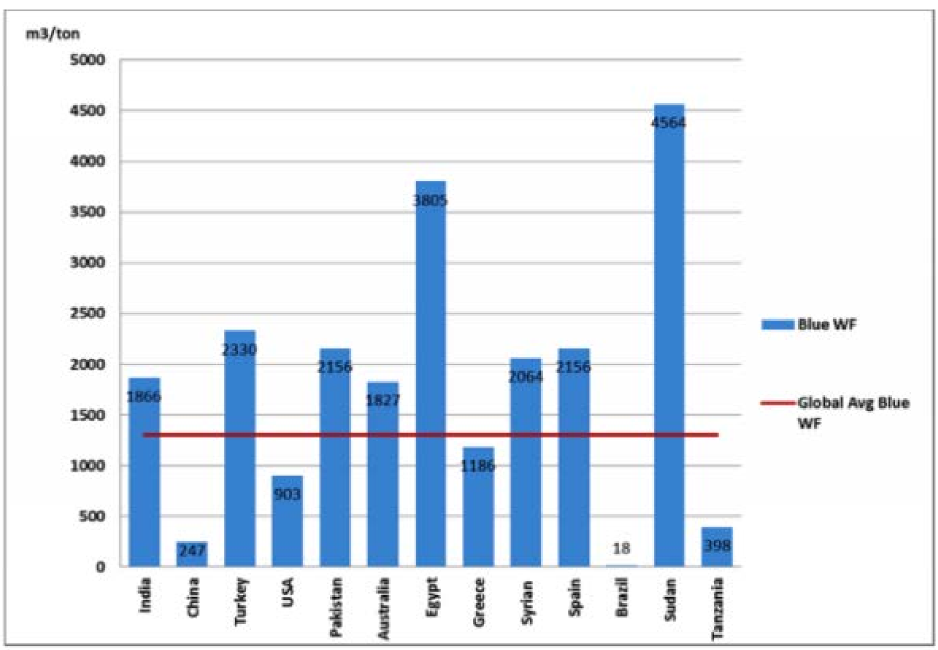
FIGURE 16: GLOBAL WARMING POTENTIAL OF COTTON FIBER



GHG Emissions: Cotton production accounts for an estimated 0.3-1% of global GHG emissions. At the same time, cradle-to-gate production accounts for only 5-10% of total emissions whereas the use phase (including garment washing and drying) accounts for 30-60% (International Trade Centre 2011). The application of petroleum-based fertilizers is the primary source of GHG emissions during cotton cultivation, and come from both fertilizer manufacture and decomposition of fertilizer in the field (Cotton Incorporated 2012). High pesticide use and greater levels of mechanization are also contributors (The Carbon Trust 2011).

Thus, the GHG footprint of cotton production can vary greatly with levels of agrochemical application, which in turn varies significantly by geography. For example, China and India were found to have the highest rates of fertilizer application in cotton cultivation and the highest overall GHG intensity of production, with the USA, Brazil, and Australia producing cotton with a lower GHG footprint despite higher levels of mechanization (The Carbon Trust 2011).

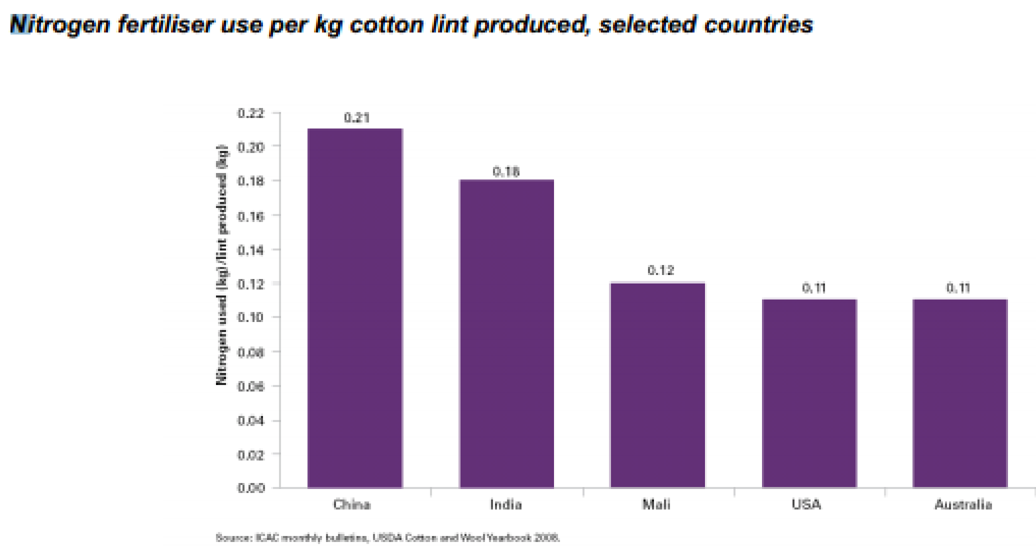
FIGURE 17 BLUEWATER USE BY COUNTRY OF COTTON PRODUCTION



Water use: Water use in cotton production varies widely by geography, both in terms of amount used and of type (irrigation versus rainfall). Drier regions such as Egypt, Uzbekistan, and Syria require heavy irrigation to ensure adequate yields, whereas wetter regions such as the US and China rely more on rainfall as a water source. Irrigation can deplete water tables and has a higher opportunity cost than rainfall in that a multitude of users compete for freshwater resources, whereas rainfall is less reliable but more renewable.

Examining the irrigated water (or "bluewater") footprint of cotton by geography reveals that top producers India and Pakistan exceed the global average, whereas the US, Brazil, and China are less bluewater intensive (Franke and Mathews 2006). The water content of cotton, which represents the total amount of water used per ton, provides a picture of the water efficiency of production in different regions. Among the biggest producers, the US, Brazil, and China show relatively low (approximately one quarter) water content per ton as compared with India, with Pakistan in between (Chapagain et al 2006).

Figure 18: nitrogen fertiliser use in cotton production by country



Eutrophication and Acidification: Cotton accounts for 24% of global insecticide (WWF 1999) and 11% of global pesticide use (Kooistra 2006) and a major user of petroleum-based fertilizers. The use of these agrochemicals may contribute to acidification and eutrophication due to over-use of agrochemicals and, in particular, runoff of these chemicals into nearby waterways (WWF n.d.). Increasing use of genetically modified cottonseed has contributed to an overall reduction in agrochemical application (Cotton Incorporated 2008; The Carbon Trust 2011), but large geographic differences remain in the rate of application of fertilizers and other chemicals, as illustrated in Figure 16 (The Carbon Trust 2011). Where management practices are employed that reduce the application of these chemicals, acidification and eutrophication potential will therefore be the lowest. Organic methods of cotton production, which eliminate use of agrochemicals, also decrease acidification and eutrophication potential (Murugesh and Selvadass 2013).

Land use change: Cotton production has an enormous land-use footprint, accounting for approximately 2.5% of global arable land use (International Trade Centre 2011). Although the total area under production has remained stagnant, degradation of land due to soil salination and other problems means that new land has been brought into production from another use (WWF n.d.).

An important factor in land-use change is yield per unit of land area, as lower per-unit yields means more land is needed to produce a given volume of the crop. A number of factors affect yields, including intensiveness of production (use of superior seed, mechanization, and so on), land fertility, application of agrochemicals, and irrigation (Cotton Incorporated 2014). Thus, cotton produced in a way that leads to lower yields may contribute to greater land-use change. For example, whereas producing cotton organically may provide other environmental benefits, it may also inadvertently contribute to land-use change if yields are lower. Increasing sourcing from regions where yields are low may have land-use implications unless efforts are made to improve yields.

Biodiversity: Cotton production has a number of consequences for biodiversity. The proportion of global pesticide use attributable to cotton production implies that it places a significant burden on global biodiversity, as pesticides create an inhospitable environment for both unwanted and beneficial organisms in the fields and where runoff occurs. Land-use change associated with cotton production also contributes to its negative biodiversity impacts of cotton, if lands are converted from more species-rich habitats to single-crop cotton plantations. Where water resources are scarce, cotton may compete with flora and fauna for water resources, with implications for biodiversity. Agrochemical use and soil salination also contribute to water pollution which may lead to a decline in the diversity of species in areas surrounding cotton fields.

CONCLUSION

The apparel retailer seeking to reduce the water footprint of its cotton sourcing may ultimately look to source from regions where the bluewater footprint of raw cotton is the lowest. Another perspective would be to look at the total water content per ton, which is an indicator of the amount of water needed to produce a ton of cotton. Taking into account other environmental impacts such as land-use change, acting on these perspectives may yield different decision-making outcomes. For example, a region with low irrigation may also have high yields, so sourcing more raw material from that region may lead inadvertently to greater land-use change than sourcing from a region with more irrigation and associated higher yields, but which may also have lower overall water content per ton of material. Similarly, regions where water impacts are lesser may also be regions where agrochemical use is higher, so there may be unintended consequences for other environmental indicators of a decision to source from those regions.

Given the complexity of these tradeoffs, the apparel company may seek guidance in emerging initiatives to identify best practices in cotton production, such as the Better Cotton Initiative. This program aims to reduce the environmental and social impacts of cotton production, and to connect businesses to more sustainable cotton supply chains (Better Cotton Initiative n.d.). Although this initiative is not a certification standard, it may help guide the company toward making cotton sourcing decisions that align with its priorities on reducing water consumption.

SECTION 4: BUSINESS CHALLENGES IN IMPLEMENTATION

ADDRESSING TRADEOFFS IN BUSINESS: CHALLENGES

Beyond the inherent complexity of evaluating tradeoffs between environmental impacts within soft commodity sourcing, businesses face a number of challenges in incorporating this research and understanding into their actual decision-making to achieve the intended environmental and business outcomes. Aside from the issues of price/cost, substitutability, consumer preference, and other possible roadblocks to decision-making on environmental impact parameters which are outside the scope of this project, two main challenges stand out: unintended consequences, and traceability.

First, there is strong potential for business decision-making to lead to unintended environmental consequences. The concept of tradeoffs means, fundamentally, that the selection of one option that performs better along one dimension will potentially lead to poorer performance along another dimension. Yet, the sheer complexity and interconnectedness of global supply chains implies that a decision will have both known and unknown consequences directly and indirectly resulting from that decision. As a result, a business decision to alter its supply chain may have far-reaching environmental impacts that it may not be able to predict, with great potential for unintended negative outcomes.

The other primary challenge discussed below is traceability, namely a company's ability to trace its own or its products' supply chain back to the raw material. Again, in light of how complicated and opaque the supply chains are of many products, traceability is a key stumbling block that must be overcome if businesses are to make decisions about sustainable commodity sourcing.

The following sections discuss these two challenges in depth.

UNINTENDED CONSEQUENCES

A key concept for decision-makers to understand when pursuing trade-off analysis is unintended consequences. The simplicity of the term ‘unintended consequences’ belies its complexity and rich application to an environmental context, and the surfeit of real-world examples of unintended consequences enforce their salience for corporations.

Decision-makers may be familiar with unintended consequences from popular economist like Steven Levvit and journalist Stephen Dubner who address the concept in their Freakonomics series. In particular, Levvit and Dubner look closely at the Cobra Effect, which describes the interplay between unintended consequences and bounty systems. The name Cobra Effect derives from a bounty placed on cobras by British colonialist in India to reduce the cobra population. Far from the desired result, local entrepreneurs began breeding cobras. Once the British discovered this practice and discontinued the bounty, the enterprising Indians set free the remaining stock of snakes. In consequence, the cobra problem worsened significantly.

Sociologist Robert Merton solidified the theory of unintended consequences in the first half of the 20th century, but Merton also describes that an intuitive sense of unintended consequences existed well before he expounded on the concept. He argues that few tried to dissect the concept before him because it was, “linked historically with transcendental and ethical considerations…ascribing uncontemplated consequences of action to the inscrutable will of God or Providence or Fate…(Merton, 1936)”

The theory that Merton advances describes how purposeful decisions designed to produce a particular outcome can result in unintended or unanticipated outcomes – neither specifically positive nor negative. Merton says this is especially true in situations where the, “interplay of forces and circumstances which are so complex and numerous that prediction of them is quite beyond our reach (Merton, 1936).” The reason humans are not able to manage this complexity is due to the economy of resource allocation. That is, the time and energy that would be required to analyze a complex interplay of forces would consume the time and energy needed to set a plan to action. Given this trade-off of resources, decision-makers often take actions without a full understanding of all the potential consequences.

Merton’s ideas may smack of academic theorization, but numerous real world examples of unintended consequences in modern contexts give Merton’s work credence. Not only do these examples support the idea that unintended consequences exist but given the fact that Merton’s theories are well-understood, the persistent surprise of decision-maker when confronted with unintended consequences speak to their insidious nature.

In 2008 Levvit and Dubner described the negative and unintended effect that the Americans

With Disabilities Act ["A.D.A."] has on disabled Americans (Levvit & Merton). The example they highlight involves the additional cost doctors must bear in interpreter fees in order to treat deaf patients. The A.D.A. requires doctors to provide an interpreter at the request of the patient and because insurance only covers a small percentage of the costs, doctors often lose money on a deaf patient. Clearly the A.D.A. intends to protect deaf patient rights but as a result of its regulations, doctors avoid treating deaf patients whenever possible. Deaf patients are therefore hurt by the A.D.A. provision, not helped.

Another example, described by Gunnar Eskeland and Tarhan Feyzioglu from the World Bank and International Monetary Fund, relates to an attempt by the government of Mexico City to limit the number of cars on the road. The law uses license plate numbers to determine what cars can drive on any given day (for example, cars with even numbered license plates). However, an unintended consequence of this law is that drivers in Mexico City often own multiple cars in order to drive throughout the week. On average the second car tends to be older and less fuel efficient than the first, which leads to increased pollution. Eskeland and Feyzioglu also found that drivers tended to drive more when they owned two cars instead of one; thus, the intended consequence of the license plate law resulted in countervailing unintended consequences (Eskeland & Feyzioglu, 1997).

Policy and action designed to improve environmental performance is an especially rich area for unintended consequence analysis. The Global Subsidies Initiative led by Director of Research Ronald Steenblik presented key findings from a survey of unintended consequences and environmental subsidy programs. A few examples from the survey appear in the table below:

TABLE 6: UNINTENDED CONSEQUENCES OF SUBSIDIES BY COUNTRY

Country	Subsidy	Desired Result	Unintended Consequence
Greece	To encourage adoption of catalytic converters Greece created subsidies for the disposal of older cars	Improved car emissions control	Low-income families were now able to purchase old, dirtier cars cheaply increasing the total emissions in Greece
U.S.A	Incentives tied to wind-generated electricity, irrespective of proximity to transmission lines	Increased production of clean energy	Turbines were erected in low cost areas away from transmission lines, resulting transmission line installation led to more construction and potentially greater environmental impact
U.S.A.	Subsidies for clean coal technologies	Reduction of GHG emissions	Many plants built in conjunction with high-sulfur, high-ash mines; thus, potentially offsetting environmental benefit
Irish & EU	Subsidies for peat-fired power plants	Reduction of GHG emissions	Bog destruction resulted in high net CO2 emissions

Decision-makers in the corporate context should be aware of unintended consequences because the environmental trade-offs described in this report are likely replete with complicated, interplaying forces that cannot be foreseen at the time of the decision. This does not mean that decision-makers should despair or take trade-off analysis lightly; instead, the added complexity suggests that decision-makers should seek out the most recent data and consistently reevaluate past decisions.

Of the commodity groups discussed in this report, biofuels provide an excellent case study for unintended consequences. Pursuit of biofuel technology has clear purpose or clear intended consequences – the reduction of greenhouse gas ["GHG"] emissions while continuing to meet the world energy requirement. Because the intention behind biofuel production is clear, unintended consequences are easily identified. Merton describes that one of the challenges with unintended consequences is that *post facto* decision-makers declare those consequences to be intended. Whether this is due to a rationalization effect or a misunderstanding of the originally intended consequences, the implementation of biofuel technology avoids this pitfall by being clear in intent. However, as with any decision that impacts ecosystems, understanding the scope and depth of unintended consequences is challenging.

Ecosystems are by definition complex interplays of forces. Under Merton's theory, ecosystems are therefore prime platforms for unintended consequences. This is one of the reasons that academics apply a systems thinking methodology to understanding the causes and consequences of environmental systems and interventions in that system. Donella Meadows, an environmental scientist from MIT, applied systems thinking to understand population growth. She deconstructed complex systems to understand the causal relationships that explain how a system, "to a large extent, causes its own behavior" (Meadows, 2008). A key tool of systems thinking is the causal loop diagram, which helps to illustrate the interplay between forces that are spatially and temporally separated from one another. For example, the below causal loop diagram (Maserang, 1976) illuminates the connection of increasing population density and population growth through cultural innovation, which can either lead to more population growth or reduced population growth. The "+" and "-" signs indicate whether the causal relationship along the directional arrow is reinforcing or opposing.

FIGURE 17: EXAMPLE OF CAUSAL LOOP DIAGRAM

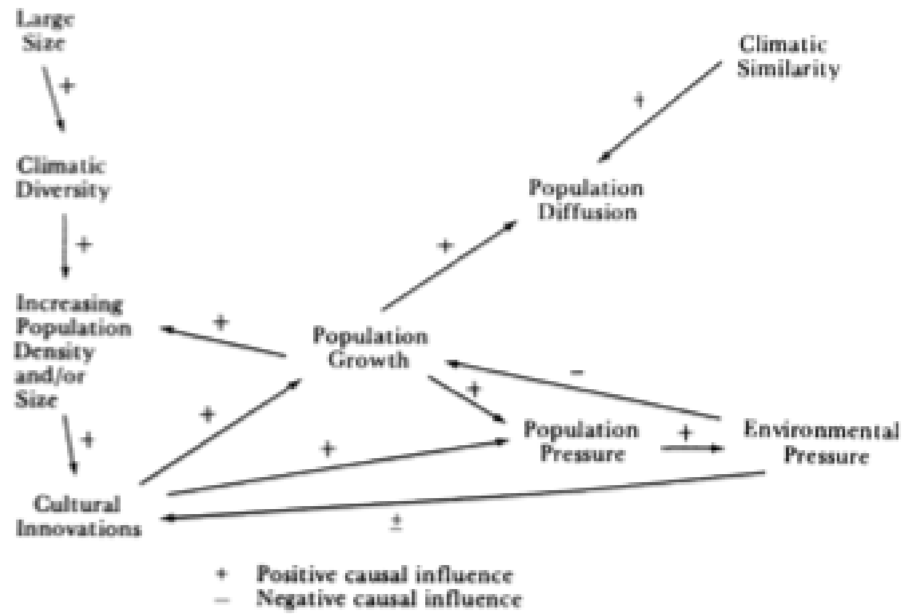


Fig. 9. Possible causal relationships between climate and other variables affecting population growth.

To create such a diagram requires anticipating what the potential consequences of a system could be. Scientist have begun to explore the consequences of biofuel production and have begun to raise concerns that the intended consequences (GHG emissions reductions) might not be as significant as originally imagined and that a number of unintended consequences related to environmental degradation are possible.

The U.S. Environmental Protection Agency ["EPA"] outlines the intended consequences of policy and regulations that support the production of biofuels. The Energy Policy Act of 2005 introduced a renewable fuel standards mandate that required an additive of renewable fuels to gasoline consumed in the U.S. Since then the EPA updated the program to reflect new scientific evidence and available market supply, but the general goal remained constant: "achieving significant reductions of greenhouse gas emissions from the use of renewable fuels, for reducing imported petroleum, and encouraging the development and expansion of our nation's renewable fuel sector" (Renewable Fuel Standards, Environmental Protection Agency). However, recent scientific studies suggest that there may be several unintended consequences to promoting biofuel production through mandates like the Renewable Fuel Standards.

It is not clear that biofuel substitution for traditional petroleum-based fuels is net positive from a GHG perspective and there are additional environmental burdens that arise as a result of biofuel production. As Mary Ann Curran from the Life Cycle Assessment Research Center argues, "there is no simple answer to the question 'are materials from bio-based feedstocks environmentally preferable?' Bioenergy, as an alternative energy source, might be effective in reducing fossil fuel use and dependence, slowing or reducing global warming effects…But its production may also contribute to environmental harm such as degraded soil and water quality" (2013). The complete list of unintended consequences Curran examines include net energy balance, global warming, air quality, land use, food-for-fuel, soil quality, water quality, water availability, loss of biodiversity, introduction of invasive species, and socio-economic concerns.

To understand the causal interplay that results in unintended consequences, Curran describes the relationships that drive each consequence.

Net Energy Balance describes the amount of energy that goes into the production of a fuel source compared with the amount of energy contained within the fuel. Understanding this relationship in a biofuel context depends on the heterogeneity of production methods and regions where biofuels are produced. For example, if a biofuel processing facility is close to where the feedstock is produced, the amount of energy required to transport the feedstock will be significantly less than if the feedstock is geographically distant. No single rule of thumb applies to all cases, but studies suggest that corn-based ethanol is actually negative in its net energy balance. Given that the renewable fuel standard in the U.S. restricts biofuel additives to corn-based ethanol, the intended consequence of GHG reductions may not be realized.

Global Warming describes the net emissions of GHGs as a result of biofuel production. The net energy balance described above in part drives global warming potential but it also is subject to indirect effects, such as the release of carbon into the atmosphere from land-use change associated with biofuel feedstock production. The global warming potential of biofuels varies significantly across studies but in general studies find that the global warming potential ranges from "being worse than gasoline to being about the same" (Curran, 2013).

Air Quality concerns result from the combustion of biofuels. While the air quality effect of petroleum combustion is well understood, the chemical and physical characteristics of biofuel combustion are distinct from petroleum, which means the impact of biofuel production on air quality does not directly correlate with petroleum. There have not been sufficient studies to appreciate the effect of biofuel combustion on air quality. As a result, few measurements into the unintended consequences on air quality are available.

Land Use Impacts capture both the direct and indirect effects of biofuel production. This issue will be explored in more detail later in this section, but the overarching being land-use change is that biofuel production results direct land-use change (through biofuel feedstock production) and indirect land-use change (through the displacement of other agricultural production). By increasing land-use, biofuels may contribute to soil and water quality degradation and may contribute to carbon emissions through land clearing. However, the degree of impact form land-use change depends on the quality of land converted to biofuel production. While it is clear that biofuel production results in land use impacts, whether the benefits outweigh the costs is not clear.

Food-for-Fuel describes the conflict between biomass production for food consumption and fuel production. Many critics of biofuel technology cite concerns over global food scarcity and the siphoning of limited land resources away from food production to biofuel production. This argument hinges on the type of biofuel being produced. Some biofuel feedstocks are more productive per acre of land than others, and some biofuel technologies, such as cellulosic (a biofuel technology that converts feedstock byproducts such as corn stover to ethanol), can grow symbiotically with food production. The interplay between food and fuel is essential to sound biofuel policy, but the manner in which food and fuel interact is incredibly difficult to predict.

Soil Quality concerns arise from the soil erosion, soil compaction, loss of soil structure, and soil acidity that result from biofuel feedstock production. In the case of cellulosic biofuel production, feedstocks such as corn stover were historically returned to the land after a corn harvest to replenish soil nutrients. By removing all the biomass from agricultural production to create cellulosic ethanol, the soil deteriorates more rapidly, potentially requiring increased use of fertilizer and other additives that adversely impact the environment.

Water Quality describes increased fertilizer usage and soil erosion that results in eutrophication in water systems. The effects of this impact are perhaps most notorious in the Chesapeake Bay where nutrient runoff from upstream farming results in massive algae blooms and “dead zones” – regions deprived of oxygen to the point of restricting biological production. Increased demand for biofuels may contribute to these water quality concerns, but as in the other cases, this depends on production method and location.

Water Availability relates to the water intensity of a biofuel production process. From water usage in the agricultural production to water usage in the biofuel processing plant, the biofuel supply chain is water intensive. Water scarcity is a significant environmental and human concern. Whether the benefits of biofuel production from a global warming perspective outweigh the cost of additional water usage is not immediately obvious.

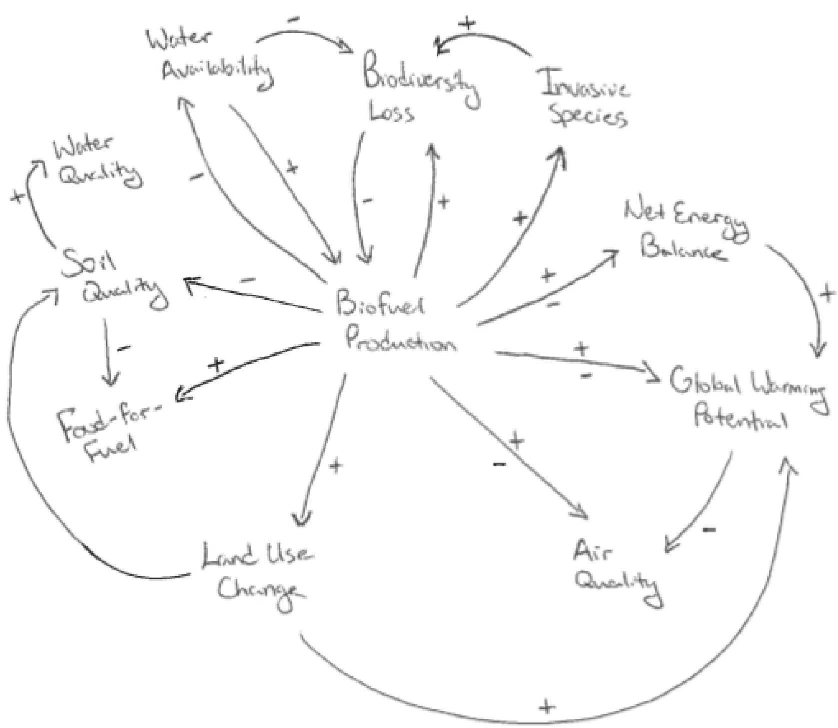
Loss of Biodiversity describes the impact biofuel production and accompanying land-use change and habitat conversion have on species diversity. It is possible, depending on the production method and location of production, that increased demand for biofuels could endanger biological diversity. Tracing biodiversity loss to a single driver, like biofuel production, is a significant challenge, which makes it an especially insidious unintended consequence.

Introduction of Invasive Species relates to the fact that the feedstocks that are most optimal for biofuel production are often invasive to many regions. Therefore, a production process seeking maximum biofuel yield at lowest cost may introduce an invasive species, which could threaten the local ecosystem, driving increased loss of biodiversity.

Socio-Economic Aspects relate to the net benefit (or loss) that results from increased biofuel production and the displacement of petroleum production on a social and economic level. The list of forces that fall into this category greatly complicates the potential unintended consequences of biofuel production, including food security, fuel independence, unemployment, international trade relations, and a host of health issues that result from the environmental impacts described above.

Based on these potential consequences, a causal loop diagram of biofuel production consequences may look like the below:

FIGURE 18: CAUSAL LOOP DIAGRAM IN BIOFUEL PRODUCTION



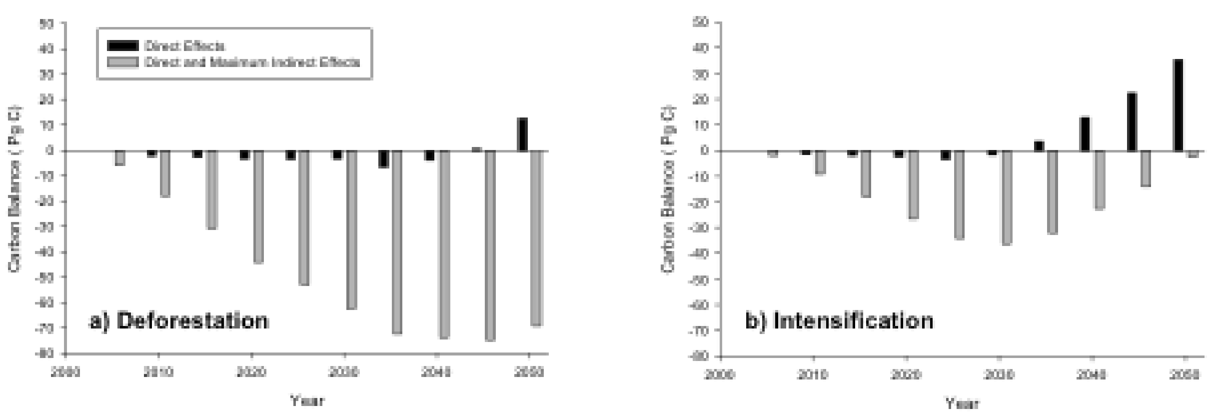
Several studies attempt to quantify the unintended consequences of biofuel production, considering all or at least some of the above forces.

Melillo, et al. (2009) use simulation modeling to assess unintended consequences associated with land-use change driven by cellulosic biofuel production. They secondarily consider how biodiversity loss and GHG emissions interact with land-use change given different scenarios. The study is in response to global renewable energy policies like the one instituted by the EPA, which drive increased biofuel production.

The two scenarios Melillo, et al. consider are a "deforestation scenario" and an "intensification scenario." Under the deforestation scenario they consider both the direct effects of land-use change from cellulosic production and the indirect land-use change that results from relocation of food agriculture. The intensification scenario assumes that limited access to new land will lead to intensification of existing managed lands.

In each case they calculate carbon balance, which is the savings associated with the substitution of biofuels for fossil fuels minus both direct and indirect effects. Negative numbers in the below graphs indicate a net release of carbon and positive numbers indicate carbon storage.

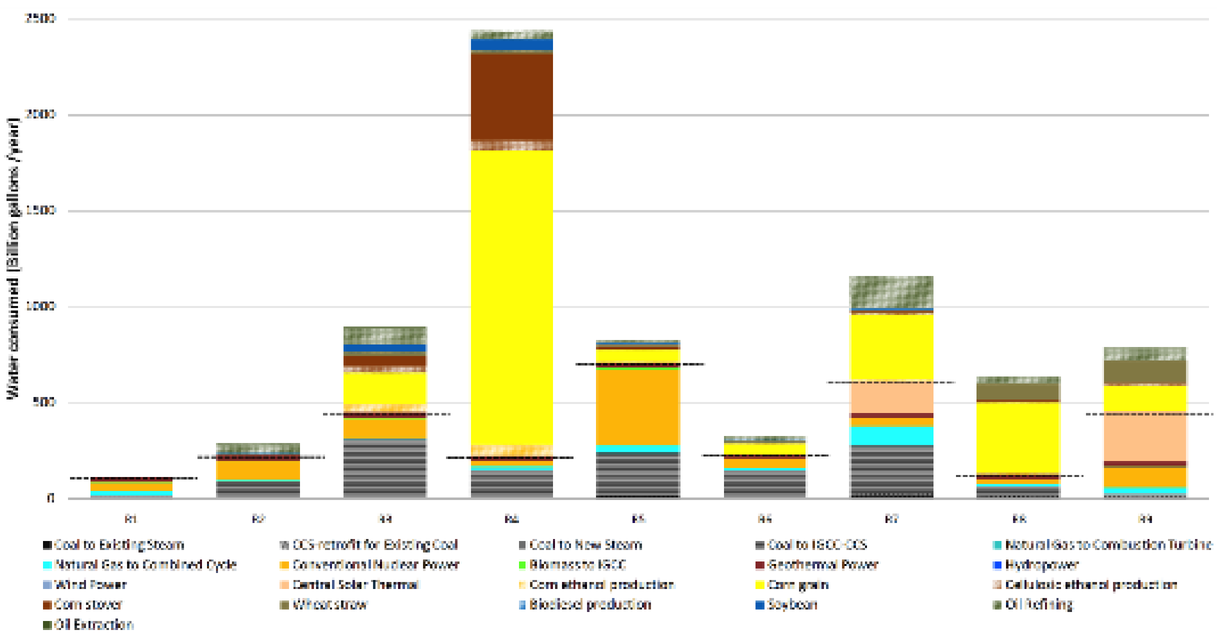
FIGURE 19: BIOFUELS SCENARIOS



In both the deforestation and intensification scenarios, more carbon is released as a result of biofuel usage as compared with fossil fuel usage. It is important to keep in mind that these scenarios rely on a number of assumptions about growth rates, bioenergy technology, and renewable fuel requirements. The results are therefore not guaranteed but possible based on the interplay of forces associated with biofuel production and land-use change.

Dodder, et al. (2011) study responds to the concern that water consumption for transportation needs in the U.S. may rise to 10% of total water consumption due to the EPA Renewable Fuel Standards. Dodder, et al. model four scenarios to understand regional differences in the U.S. related to increased biofuel production and water consumption. Their conclusion is that water consumption and fuel production demonstrates heterogeneous patterns throughout the U.S., which means that different regions will experience water availability threats differently. The below chart illustrates water consumption in billions of gallons per year in 2035 across regions and fuel types.

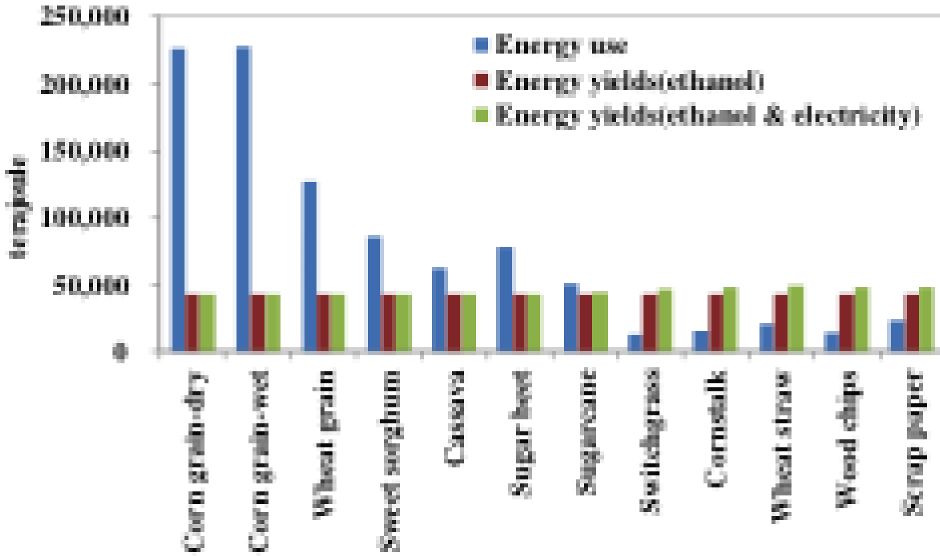
FIGURE 20: WATER CONSUMPTION IN BIOFUEL PRODUCTION



"R4," which corresponds to West North Central or the corn-belt, shows significant water usage in the corn grain sector as a result of renewable fuel standards. This area is therefore likely to experience a disproportionate amount of water stress due to increased biofuel production. The impact that may have on regulatory policy at the state and national scale is an important and not immediately obvious byproduct of the EPA regulation.

Liang, et al. (2012) consider the unintended consequences of bioethanol feedstock choice in China. Across eleven different feedstock they evaluate energy use, global warming potential, and economic benefits of each feedstock. The below graph decomposes the net energy balance across each fuel source, demonstrating that the impact of each feedstock differs dramatically from one another. For example, dry corn grain requires significantly more energy input for approximately the same amount of yield as scrap paper. The interplay between energy use and energy yield is a critical factor to determine the best biofuel feedstock. As with the Melillo, et al. study, this analysis rests on several assumptions regarding production technology and method, which determine the study results. Decision-makers should be aware of these assumptions and how sensitive the results are to changes in each assumption. This can help gauge how sensitive the unintended consequences are to changes in the system. Liang, et al. further elaborate on their study by considering technological advances in each feedstock production methods, which in turn changes the resulting impact across the three study categories. This kind of sensitivity is a particular robust analysis for understanding unintended consequences because it highlights the strength of causal connections in the system.

FIGURE 21: BIOFUELS ENERGY BALANCE



Doornbosch et al. (2007) also consider how renewable fuel mandates are insensitive to differences in biofuel technology, production method, and production location. Like Dodder, et al., this study considers differences in world regions, but Doonbosch, et al. look at the relative availability of land for biofuel production. The below table illustrates the gross land available by taking the total land surface and focusing down to land with potential for rain-fed cultivation. Land currently used for agriculture and land needed for additional growth are subtracted from that number, yielding gross land available. The world total is approximately 0.74 Gha (global hectare.)[6] The key takeaway from the table is that unintended consequences such as land-use change, food-for-fuel, and biodiversity loss will likely depend on the region of production. Effective policies regarding biofuel adoption need to consider the idiosyncrasies associated with different land areas and their current capacity to absorb increased agricultural production for biofuel feedstock.

[6] Global hectares measure the biocapacity of the earth. One global hectare is the average productivity of all biologically productive land (measured in hectares) in a given year.

TABLE 7: AVAILABLE LAND FOR BIOFUEL PRODUCTION IN 2050

Table 1. Potentially available land for energy biomass production in 2050 (in Gha)

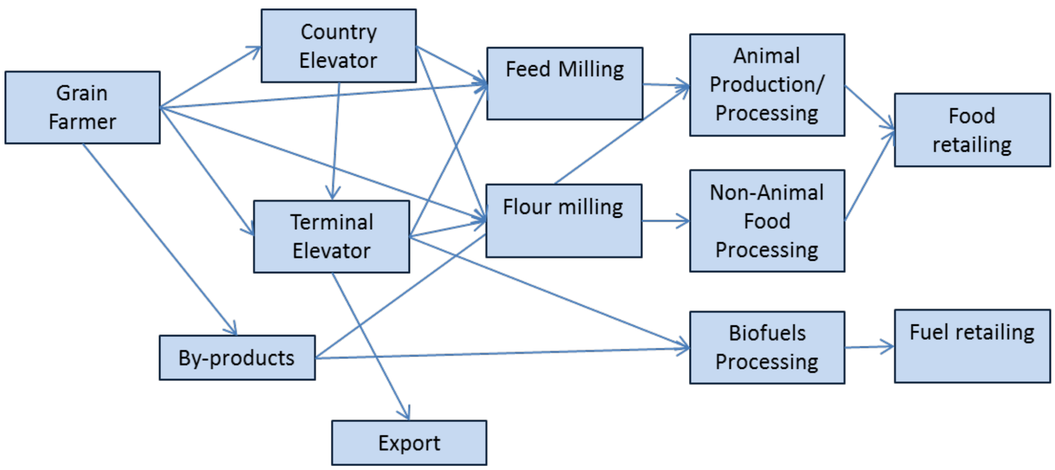
	Total land surface	Land with potential for Rain-fed cultivation	Potential land under forest	Land already in use for agriculture (arable land)	Additional land needed for food, housing and infrastructure until 2030/50[a]	**Gross Additional land available**	**Additional land potentially available**
	(-)	(1)	(2)	(3)	(4)	**(5) =(1)-(2)-(3)-(4)**	**(5) * (1 - % needed for grassland)**
North America	2.1	0.4	0.1	0.2	0.0	0.00	0.00 (0%)
South & Central America	2.0	0.9	0.3	0.1	0.1	0.25	0.25 (0%)
Europe and Russia	2.3	0.5	0.1	0.2	0.0	0.08	0.04 (50%)
Africa	3.0	0.9	0.1	0.2	0.1	0.44	0.18 (60%)
Asia	3.1	0.5	0.0	0.6	0.1	-0.07[b]	-0.07 (n/a)
Oceania	0.9	0.1	0.0	0.1	0.0	0.04	0.04 (0%)
World Total	**13.4**	**3.3**	**0.8**[c]	**1.5**[c]	**0.3**	**0.74**	**0.44**

The unintended consequences outlined in the studies above are by no means exhaustive, but the studies begin to define the causal relationships that exist in ecosystems and determine the consequences of a particular action. This report argues that decision-makers face trade-offs when adopting product procurement or design policies. Unintended consequences add an additional wrinkle by suggesting that the scope and the nature of trade-offs are often only partially understood. This does not mean that decision-makers should abandon efforts to maximize their goals through trade-off analysis; instead, it implies that decision-makers should frequently reevaluate their decisions and remain adaptive to new information. And decision-makers should be aspirational and hopeful as they attempt to navigate the decision process. Returning to Merton's statement that unintended consequences are the result of judicious allocation of limited resources – the prioritization of action over indefinite analysis of a potential action – recalls a quote from Dr. Martin Luther King, Jr. In his address "A Time to Break Silence" (1967) King argues that inaction is still worse than imperfect action. He says, "we are always on the verge of being mesmerized by uncertainty, but we must move on."

TRACEABILITY IN COMMODITY SUPPLY CHAINS

Soft commodity supply chains take a variety of forms and exhibit varying levels of complexity depending on the product, geography, and production method. In most, however, a number of different entities handle the product between the field and the consumer. An illustrative example of a corn supply chain is shown below and represents a simplified version of the many places the product could change hands after its production. In addition to the physical product, varying levels of information travel along with the good depending on the supply chain, such as geography of production and any quality characteristics.

FIGURE 22: EXAMPLE OF CORN SUPPLY CHAIN LINKAGES



WHAT IS TRACEABILITY?

Traceability refers to the ability to track food or feed through the stages of production, processing, and distribution giving the end user the ability to verify the source and history of the product in question. Traceability can be important for food safety since it gives business operators or authorities the ability to recall products that are identified as unsafe. This application, however, is less common in commodity supply chains where food safety is very rarely a concern. More often, commodity supply chains value traceability for its ability to shed light on the geography or production methods of the product, which can be important for evaluating both environmental and human impacts of the commodity production.

Given the number of businesses that can be involved in a supply chain between the farm and the end user, developing traceable supply chains is incredibly difficult. Traceability failure at any one point compromises the entire system since the chain is only as strong as the weakest link. Since food safety is less of a concern in most soft commodity supply chains, many companies have only minimal insights into the source of their inputs and often know only the county or general region their goods are sourced from and data resolution beyond that level becomes increasingly difficult and expensive to accomplish.

THE ROLE OF TRACEABILITY

Assessing tradeoffs in terms of geographic sourcing or production method both depend on a company's ability to have traceability in its supply chain. As Tim Wilson, CEO of Historic Futures so accurately states, "If you don't know where your stuff is coming from, how can you have a sustainability program?" (Gunther, 2009). Additionally, building off of WWF's 2050 Criteria report, recommending a range of key performance criteria to address environmental impact of commodities, traceability plays a key role in being able to assess and/or improve a supplier's performance on the identified areas (World Wildlife Fund, 2012). However, challenges with traceability represent a real problem to many decision makers. In a 2013 survey by CDP of 139 companies asking about deforestation in their commodity supply chains, "lack of traceability" ranked within the top three challenges for accurately assessing a company's deforestation impact, along with challenges with certification and regulatory uncertainty (CDP, 2013). Additionally, traceability of inputs often stands in contrast to the radical efficiency that characterizes commodity supply chains.

As the body of work evaluating the environmental impacts of commodities continues to grow, it is increasingly clear how important traceability is when navigating tradeoff decisions. Life cycle assessment (LCA) data is typically location and production method specific and comparing studies between even the same crop or protein illustrates the huge impact geography and production can have on the scale of emissions and other impacts. Because of these widely ranging differences, design or procurement decision makers can only accurately make tradeoff decisions if they are able to truly assess the impacts of their specific supply against the precise alternatives. Once a company knows where its inputs are coming from and how they are produced they can then evaluate the environmental impacts of their supply and determine both what the key impact areas for their supply chain are (i.e. water use vs land use) as well as what decision options they have (i.e. source from a new geography, source a interchangeable input commodity). Making those types of decision without knowing the source of the inputs requires relying on aggregated data and as such includes significantly more assumptions and creates room for error. Companies may also find that greater traceability provides closer relations with suppliers as the interaction moves beyond just a transactional basis and into a stronger partnership towards common goals allowing greater input into improving the sustainability of their supply.

Despite the benefits of traceability, it is not without its corresponding shortcomings. The most obvious is the costs added to the system that are reflected in commodity prices and eventually the final products. The commodity market has evolved over some time to be the model of efficiency in creating a good that is nearly identical the world over, negating the need for production or geographic data to travel with the physical good and allowing for unlimited mixing of batches between the grower and customer without much concern. Increasing traceability can increase costs by limited the ability to which those efficiency measures can be accomplished. As seen with organics, creating a secondary commodity market for value-added crops can increase prices rather drastically. However, unlike organics, there is often no discernable difference in the final commodity further reducing the need and demand for a segregated stream of traceable goods.

In addition, the push for traceable supply chains has caused some companies to limit their purchases from smallholder farmers. To some large companies unable to expend the resources to evaluate each smaller supplier, these smallholder farms represent a potential liability should they be found not to abide by the sustainable practices they promise, resulting instead on greater reliance on large plantations (Pearce, 2013). Additionally, some companies purchase only certified products, but certification costs are frequently prohibitively expensive for small farmers, further excluding them from the market. In these instances, environmental concerns appear to be winning out over social ones, hardly an unambiguous decision.

There are a few models of traceability emerging within soft commodities that aim to increase sustainability while mitigating some of the disadvantages addressed above. Palm oil is frequently lauded as an example for creating a market for sustainable produced commodities while maintaining the efficiency of a single commodity product. In this system, GreenPalm certificates for sustainably produced palm oil are provided to farmers abiding by certain production standards and can be sold on a secondary market independent of the oil itself to producers looking to support sustainable production of palm oil (RSPO, 2013). Similar to renewable energy credits that trade independently of the actual MWh of energy, the palm oil certifications bypass the physical supply chain entirely. While this still results in some increased cost for the goods, it allows sustainably produced oil to still capitalize on the efficiency of commodity pooling and transport by not requiring physical segregation throughout the processing and transport. Given the importance of an efficient commodity supply chain, users of other products should look for similarly creative ways to reward producers abiding by environmental standards while minimizing the increase in the cost of the products.

Companies are also are moving towards greater traceability within supply chains with the trend to closer vertical coordination and integration in supply chains. Vertical coordination is the process of managing or synchronizing successive stages in a supply chain, while vertical integration is a type of vertical coordination that refers to the common ownership and management of two or more stages of the chain, such as a farmer who produces corn and hay to feed his dairy operations. Within the agricultural industry, vertical coordination in the form of contract production, where buyers and sellers agree to things such as delivery schedule, pricing, product attributes, and ownership of production inputs, is the most common form of vertical coordination, particularly in animal protein supply chains. Companies and farmers pursue vertical coordination for a variety of reasons. From a farmer's prospective, contracting offers a guaranteed market, reduces the transaction cost of finding a buyer, can increase accessibility of capital, and offers some protection against highly variable commodity prices (MacDonald, 2004) (ERS/USDA, 1996). However, contracts also limit the profit potential from favorably changing commodity prices. Simultaneously, on the purchaser side, contracts give companies additional control over the quality of product, increased input into how the product is produced, some reduction of risk and a guaranteed supply (Stokstad, 2008). While these contracts are rarely, if ever, used to mitigate environmental impact, they allow companies greater insight into the source of their product which is the first step towards the ability to manage tradeoffs.

Trends towards vertical coordination can be evidenced by the number of companies that are acquiring the upstream farms or production methods or engaging in contracts with individual growers in order to ensure they have more complete knowledge of the source of their inputs (Hobbs and Young, 2000). Broiler chickens, for example are about 90% grown on contract between meat processing companies and the growers they work with (ERS/USDA, 2009), meaning the growers work closely with companies like Tyson with whom they have an agreement for purchase. While this practice is currently still low in some markets, particularly where there is little variability in the quality of product, (only about 9% of corn is currently grown on contract), it appears to be growing (Martinez, 2002).

SECTION 5: PROJECT CHALLENGES

While this report builds upon the success of WWF's *2050 Criteria* and provides additional guidance on soft commodity sourcing decisions, challenges faced in developing this report indicate opportunities for future research and development of knowledge in the fields of environmental tradeoffs, particularly with regards to using life cycle assessment data and input-output analysis to evaluate these tradeoffs.

Effectively assessing the tradeoffs associated with a business changing the geographic source or type of input in its supply chain requires a critical mass of life cycle impact data to inform the comparative assessment. Unfortunately, the scientific literature includes fewer life cycle assessments of our target commodities than initially expected. For several of the soft commodities identified as 'Priority' or 'Important' by WWF, LCA data was not available for one or more of the six environmental indicators. In rare circumstances there exist comparative LCA's that assess the environmental impact of related commodities along one or more indicators. While indicator data could be gathered from a number of life cycle assessments, discrepancies often existed among functional units, system boundaries, or midpoints and endpoints. These differences made reasonable comparisons challenging.

To address this dearth of information, the report attempted to provide at least directional guidance for business decision makers based on the best available LCA data. For example in some instances a meta-analysis study of LCA research on a given commodity was able to provide a reasonable range of potential impacts for one or more environmental indicators. A comparative LCA was preferred over the comparison of data from multiple studies with different assumptions. With great discretion and only in instances where multiple data points existed was this information applied towards any conclusion or recommendation.

This lack of LCA data is a critical shortcoming that requires additional attention from the scientific and business communities. Additional meta-analyses of existing LCA studies that apply rigorous normalization processes can help illuminate the environmental tradeoffs associated with commodity sourcing decisions. As companies begin employing personnel more experienced with conducting and understanding life cycle assessments more data should become available but further refinement in how this information is presented to decision makers will be essential. Additional research and discussion regarding how to utilize qualitative data particularly that related to biodiversity and land use change will also advance this field.

ANALYZING TRADEOFFS USING INPUT-OUTPUT ANALYSIS: SPECIFICATIONS, CHALLENGES, AND OPPORTUNITIES FOR ADVANCED ANALYSIS

To analyze potential trade-offs in environmental impacts between soft commodities, we turned to input-output analysis. Input-output analysis exists on the frontier of environmental research in a global context, especially in terms of the flow of commodities between national and international regions. Given that our report seeks to highlight trade-offs for decision-makers managing global supply chains, we believed input-output analysis would be the most effective tool for synthesizing massive global datasets into comprehensible and actionable strategies. Our project advisor, University of Michigan Professor Ming Xu, is also an expert in the subject and we planned to rely on him for guidance.

Due to unexpected obstacles and the complex scope of our project, we were unable to utilize input-output analysis to the extent that we planned. However, through our attempt to apply its theories, we gained greater insight into the complexity of core issues to environmental trade-offs in global supply chains. A description of input-output analysis, a brief view of its application, and our efforts to apply it to this project appear below.

WHAT IS IOA?

Input-Output Analysis ["IOA"] and input-output ["IO"] models enable researchers to evaluate economic and environmental dynamics on a regional and global scale.

IO models rely on linear algebra and matrices to quantify inter-industry relationships. Wassily Leontief (1905-1999) received a Noble Prize in 1973 for his work developing input-output theory. Although his models focused on the economic side of IOA, Leontief envisioned the environmental application of his theories (Murray and Woods, 2010). A highly simplified, single-region IO model appears below.

Sector	1	2	j	n	Final Demand	Total Output
1	z^{11}	z^{12}	…	z^{1n}	Y1	X1
2	z^{21}	z^{22}	…	z^{2n}	Y2	X2
i						
n	z^{n1}	z^{n2}	…	z^{nn}	Yn	Xn
Value Added	V1	V2	…	Vn	GDP	
Total Input	X1	X2	…	Xn		

Sectors ‘1’ through ‘n’ in both the rows and columns represent industries or sectors, for example, agriculture. The intersection of rows and columns (‘z’ cells) represents a relationship between sectors. For example, cell ‘z^{12}’ is the economic value of the products or services supplied by sector ‘1’ and consumed by sector ‘2.’ Final Demand (‘Y1’ through ‘Yn’) represents government and household consumption, change in stocks, fixed assets, and exports. Generally, this column reflects all final transactions that are not between sectors. Value Added (‘V1’ through ‘Vn’) represents salaries, taxes, depreciation, and profit. Value Added are the inputs required by a sector that do not directly interact with other sectors. Countries regularly produce input-output tables (the Bureau of Economic Analysis (BEA) manages IO tables for the USA), which is why the cumulative value of an IO table is GDP or the total market value of all the final goods and services produced within a country during a given period.

From this table the model generates “technical coefficients” (‘a’) and a technical coefficient matrix (‘A’). A technical coefficient, also referred to as production recipe, represents relative dependencies between sectors as compared with the total output of a sector (Murray and Woods, 2010).

Mathematically a technical coefficient is determined by:

$$a^{11} = z^{11} / X1$$

or

$$a^{1n} = z^{1n} / Xn$$

The matrix ‘A’ captures all the technical coefficients within the IO table.

a^{11}	a^{12}	…	a^{1n}
a^{21}	a^{22}	…	a^{2n}
. . .	. . .	. . .	. . .
a^{n1}	a^{n2}	…	a^{nn}

IOA uses linear algebra to solve the IO model based on estimated demand for each sector. Linear algebra solves a system of linear equations with unknown variables. In a highly simplified form, linear algebra solves the intersection of two lines:

$$2y + 2 = 6x$$

$$y + 4 = 2x$$

It is possible to manipulate an IO table to create alternative demand scenarios on various sectors, and because the model maintains constant technical coefficients it will generate the required input and output of each sector to meet the new demand. For example, if an insurance sector requires paper to produce insurance policies, then that sector depends not only on a paper sector but also wood harvesting sectors, steel production sectors, etc. The model allows us to answer the question: how much steel does it take to make $X amount of insurance policy. (Murray and Woods, 2010).

IO models can also be used to assess environmental impacts due to inter-industry dynamics and final demand. Across various models, greenhouse gas ("GHG") emissions, water footprint, land-use change, and emissions of toxins are the most common environmental outputs for this kind of analysis.

This process occurs through an augmentation of the technical coefficient matrix described above. Additional rows and columns are added to reflect relevant environmental impacts. Ronald Miller and Peter Blair (2009) describe this process in terms of pollution as the environmental indicator. The fundamental equation for the IO model is based on the *Leontief inverse* $(I-A)^{-1}$ or L where I is the identity matrix and A is the technical coefficient matrix. From this the expression x=Lf is used to describe economic relationships based on final demand of "f." To augment this equation to include pollution, which is captured by the variable D^p and where x^{p*} is equal to vector of pollution levels, the total pollution generated by the economy directly would equal $x^{p*} = D^pLf$. Variations of this equation can capture other environmental impacts as well. A critical assumption of this logic is that the relationship between economic output and environmental impact is linear.

MULTIREGIONAL MODELS

The model described thus far applies to a single economy or region. The IO framework may be used to compare economic and environmental impacts in multiple regions by replicating and expanding on the same logic applied to the single region. A schematic example of what a multi-region IO model would look like appears below for a *Region R* and a *Region S*.

		Purchasing Sector				
		Region R			Region S	
Selling Sector		1	2	3	1	2
Region R	1	z^{rr}_{11}	z^{rr}_{12}	z^{rr}_{13}	z^{rs}_{11}	z^{rs}_{12}
	2	z^{rr}_{21}	z^{rr}_{22}	z^{rr}_{23}	z^{rs}_{21}	z^{rs}_{22}
	3	z^{rr}_{31}	z^{rr}_{32}	z^{rr}_{33}	z^{rs}_{31}	z^{rs}_{32}
Region S	1	z^{sr}_{11}	z^{sr}_{12}	z^{sr}_{13}	z^{ss}_{11}	z^{ss}_{12}
	2	z^{sr}_{21}	z^{sr}_{22}	z^{sr}_{23}	z^{ss}_{21}	z^{ss}_{22}

LIMITATIONS TO IO MODELS

There are, however, important limitations to IO models. It is critical to understand these limitations in order to appropriately interpret results generated from IOA. First, in order to aggregate and manipulate enormous quantities of data, IO models make a number of assumptions regarding the relationships between sectors. These assumptions fail to account for important nuances and are not adaptable to ongoing developments within sectors. For example, new technology developments in a sector may dramatically change the fixed and variable costs associated with a unit of production within that sector. This could impact the technical coefficients related to that sector.

The transformation of economic output to environmental impact also requires several assumptions. Primary among them is that the models assume a linear relationship between economic output and environmental impact. However, this relationship is likely not linear because it fails to account for economies of scale and new technological developments.

Finally, the level of aggregation used by models to define sectors does not always mirror the target sector. For example, one IO database aggregates the entire seafood sector into a “fish” category. This level of aggregation not only means that individual species are not accounted for uniquely, but it also means that no distinction is made between wild and farmed seafood. This limitation may be overcome by using additional data and aggregation and disaggregation methods, which will be discussed later.

IOA CASE STUDIES

To understand how researchers apply IOA, we present several case studies involving distinct research questions, regions of interest, and environmental indicators. The studies are divided into five categories: *Multiregional Emissions*, *Single Region Emissions*, *Multiregional Multi-Indicator*, *Single Region Multi-Indicator,* and *Corporate Focused Multi-Indicator*.

Multiregional Emissions

1. Glen Peters and Edgar Hertwich (2008) use IOA to measure CO_2 emissions embodied in international trade of 87 countries with data from 2001. The study argues that recognizing embodied emissions in trade and observing countries that are net importers and net exporters of emissions is a critical step in sharing responsibility for emissions globally and could be used to improve regulation and discussion such as the Kyoto Protocol. Specifically the analysis showed that countries that signed the Kyoto Protocol were net importers of emissions, a concept known as carbon leakage. For example, Australia did not sign the Kyoto Protocol until 2007. This seems to be reflected in the graph below that shows that in 2001 Australia exported more emissions than it imported and a country like Germany, which signed the Kyoto Protocol prior to 2001 imports more emissions than it exports.

FIGURE 23: EEE AND EEI PERCENTAGES

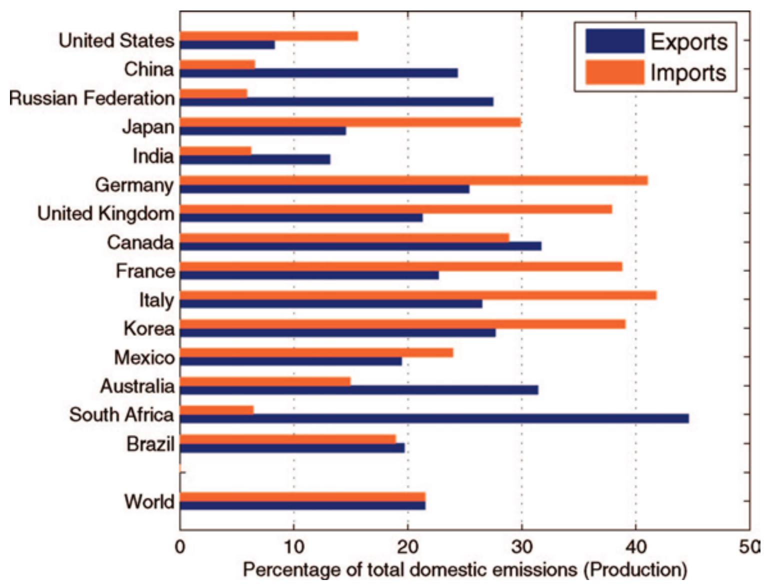


FIGURE 1. Percentage EEE and EEI compared to total production-based emissions for selected countries.

2. Thomas Wiedmann (2009) performs a literature review of single-region and multi-region IO studies in order to argue, like Peters and Hertwich, that fair allocation of environmental impact along the value chain is critical for climate change legislation. He argues (pg. 212), “if nations that import more embodied emissions than they export were to become partially responsible for emissions occurring elsewhere, the exporting nations

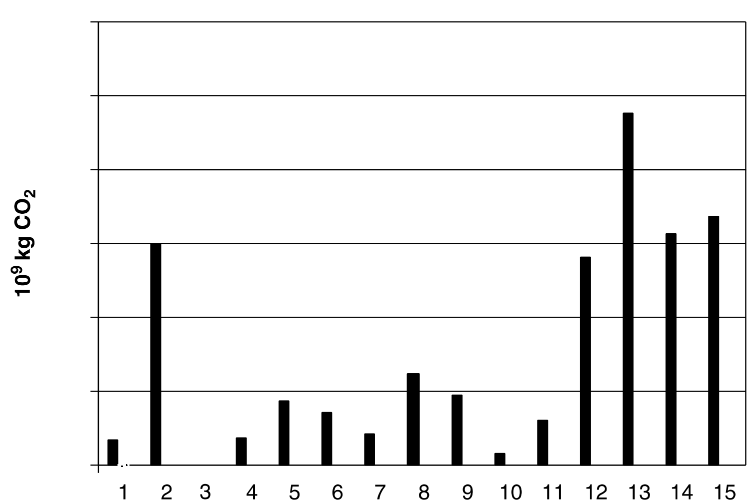
(mainly China and other developing countries) might be more willing to play an active role in post-Kyoto climate commitments."

The studies he reviews provide additional insight into the application of IOA to industry, environmental, and policy analysis. Bertini and Panicciá (2008) consider domestic and foreign demand as drivers for Global Warming Potential and Potential Acid Equivalents in Italy. Kanemoto and Tonooka (2009) demonstrate that embodied emissions of imports to Japan have increased overtime by analyzing 26 countries and the rest of the world to find CO_2 emissions embodied in trade during 1995, 2000, and 2005. McGregor, Swales, and Turner (2008) analyze the embodied emissions in trade between Scotland and the rest of the United Kingdom. And Weber and Matthews (2007) show the impact of US trade structure and volume from 1997 to 2004 on the environment by applying IOA to the US and its seven largest trade partners.

Single Region Emissions

3. Fulvio Ardent, Marco Beccali, and Maurizio Cellura (2009) apply IOA within the region of Sicily by observing trends in energy and environmental impacts of 15 sectors overtime (1989-1995). They are able to demonstrate how domestic demand drives total emissions for the 15 sectors over the time period. Through analysis of the graph below we can begin to understand how this kind of information could allow regulators to pinpoint the trends and sources of CO_2 emissions in an economy and assists in the formulation of effective policy.

FIGURE 24: CO2 EMISSIONS PER SECTOR



4. Qiao-Mei Liang, Wei Fan Ying, and Yi-Ming (2006) run scenario and sensitivity analyses for the years 2010 and 2020 in eight economic regions of China: Northeast, Beijing-Tianjin, Northern Coastal, Eastern Coastal, Southern Coastal, Central, Northwest, Southwest. The five scenarios they consider are: Business-As-Usual, Low Economic Growth, High Economic Growth, High Economic Growth + High Population, and High Economic Growth + High Technology. The study observes how an understanding of energy demand, supply, and intensity of each region and between regions is critical for energy strategy and policy. In particular, the unique energy requirements of each region have important tax and energy investment implications. Given different scenarios, the study is able to observe regional CO_2 emissions and energy demand. For example, the graph below depicts significantly different CO_2 emissions between different regions in the year 2020.

FIGURE 25: REGIONAL CO2 EMISSIONS IN 2020

Multiregional Multi-Indicator

5. G.Q. Chen and Z.M. Chen (2011) conduct a 34 country (representing 80% of the world economy), forty sector IOA to evaluate greenhouse gas emissions, energy sources, water resources, exergy resources, solar emergy resources, and comic emergy resources embedded in each sectors' activities. From this they are able to determine the relative environmental impact intensity of each sector on a global scale. For example, the graph below shows that the embodied GHG intensity in the energy mining sector (sector 2) is significantly greater than the embodied GHG intensity in the agricultural sector (sector 1).

FIGURE 26: EMBEDDED GHG INTENSITY

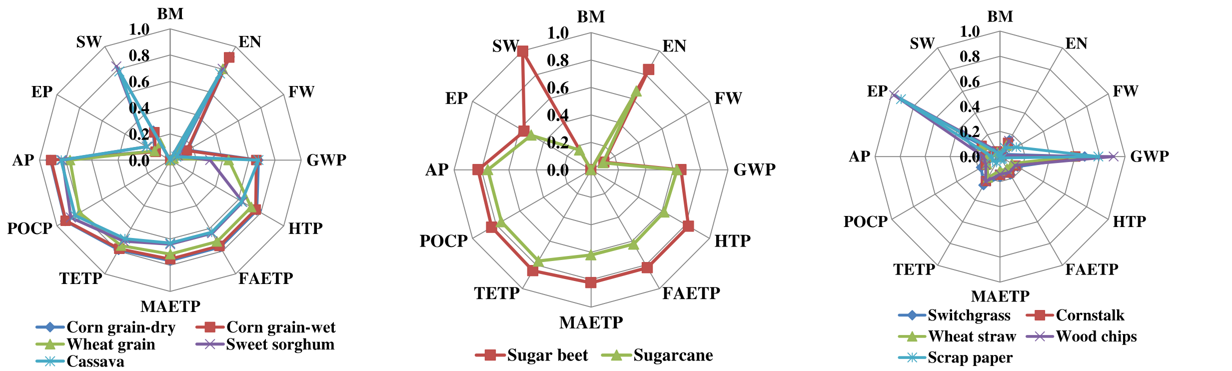
Sector

Single Region Multi-Indicator

6. Sai Liang, Ming Xu, Tianzhu Zhang. (2012) compare 11 biofuel feedstocks in China across energy, GHG, and economic metrics. The feedstock considered are: corn grain dry, corn grain wet, wheat grain, sweet sorghum, cassava, sugar beet, sugarcane, switch grass, cornstalk, wheat straw, wood chips, scrap paper. By using a mixed unit input output life cycle assessment method they are able to solve any potential boundary issues typical of LCA analysis (since IOA includes all upstream inputs) and are able to assess impacts throughout the production chain. The study performs an interesting sensitivity analysis based on changes in impact due to changes in technology or markets around biofuel cultivation and production.

   This study is furthermore significant because it demonstrates the ability of IOA to reveal the unintended consequences of product choice. While the obvious potential benefit of biofuel technology is to reduce GHG emissions, there are significant potential costs that may offset any gains.

FIGURE 27: BIOFUEL FEEDSTOCK COMPARISON



(d) Ethanol production technologies improve by 10%: Starch-based feedstocks

(e) Ethanol production technologies improve by 10%: Sugar-based feedstocks

(f) Ethanol production technologies improve by 10%: Cellulose-based feedstocks

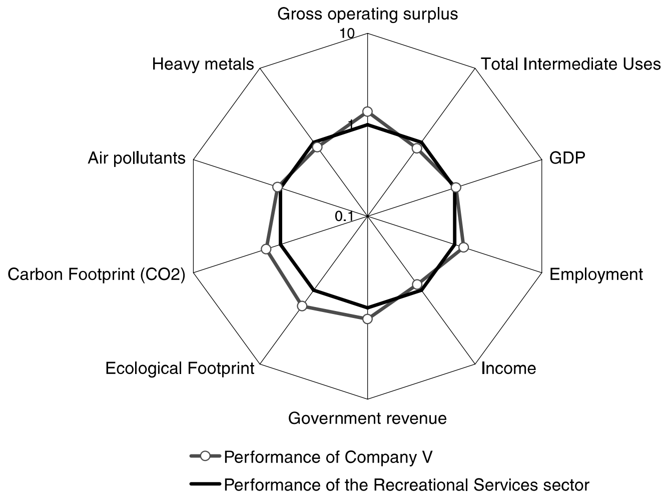
Corporate Focused Multi-Indicator

7. Thomas Wiedmann, Manfred Lenzen, and John Barrett (2009) discuss potential applications of IOA for triple bottom line accounting as applied to corporations. Adapting IOA to a company application requires important adjustments, such as allocating responsibility for impact appropriately along the value chain. Typically environmental IOA delays all responsibility to the final consumer; however, Wiedmann, Lenzen, and Barrett propose a 50/50 split of responsibility among suppliers and demanders. Furthermore, to adequately compare companies to industry averages or other companies, the authors recommend using a company's proportion of dollar of final demand as a denominator to the environmental metric (e.g. CO_2-equivalents per dollar of final demand). The study then uses various indicators for each line of the triple-bottom-line:

Economic	Gross Operating Surplus
	Total Intermediate Uses
Social	Employment
	Income
	Government Revenue (Taxes)
Environmental	Ecological Footprint
	Carbon Footprint
	Air Pollutants
	Heavy Metals

In order to perform this analysis, Wiedmann, Lenzen, and Barrett collected financial accounts of the company to determine its portion of the total sector impact as well as on-side data to derive the internal footprint of the company's operations. The result is a clear and compelling comparison between the company's performance as compared to the industry average as indicated in the spider graph below.

FIGURE 28: INDUSTRY / COMPANY COMPARISON



SOURCE DATA

The case studies presented above are also unique in that they relied on different sources of data to complete their analysis. There are several resources for IO data used by private and public institutions. For this project, we decided to use the Eora MRIO database to construct our models based on extensive research and advice from University of Michigan Professor Ming Xu. The table below compares potential sources of IO data.

TABLE 8: COMPARISON OF IO DATA SOURCES

Model	Countries	Industries	Commodities	Data Year	Model Output	Accessibility
CEDA	US, UK, EU			2002	Carbon & water footprint, embodied energy, nutrient emissions, land-use toxic chemicals	Free academic and research; license commercial use
EIO-LCA	US, China, Germany, Canada, and Spain	428		2002	GHG, Toxic Chemicals, Energy, Water	Free academic and research; license commercial use
Open IO	US		430	2002	Carbon and water footprint, embodies energy analysis, nutrient emissions, land-use toxic	Free

Model	Countries	Industries	Commodities	Data Year	Model Output	Accessibility
					chemicals	
GTAP	57 countries			2002	GHG, energy	Small fee
Eora	187 countries	15,909		2011	35 Environmental Indicators	Free academic and research; license commercial use

There are a number of advantages to using the Eora database. First, the Eora data uses the most current information from countries and third-party sources. The most current version of Eora data is from 2011, while all other models use data from over ten years ago. This means that recommendations made to businesses based on the Eora will be more salient and reliant. Furthermore, the data is the most comprehensive in terms of scale. Whereas other models focus on specific countries, Eora compiles data from 187 countries and 15,909 industries from those countries. Even models like the GTAP model, which integrates data from 57 countries, depend on highly aggregated sectors in order to meaningfully compare across multiple countries. Eora allows our team to explore commodity trade-offs throughout the supply chain and focus on global impacts based on the relationships between commodities.

Finally, Eora rigorously tests its compilation of disparate data sources and provides confidence reports based on those tests. This is essential because different data sources often report different input and output values. For example, one source may say that the USA exports $100 worth of goods to China and another source may say that China imports $109 of goods from the USA. Eora calculates a compromised value based on confidence standards in different data sources. For example, national accounts are considered more reliable than third-party calculators such as the UN. Eora will also show the standard deviation for each data point, which allows the interpreter of data to check its reliability (Foran, B, et al. 2011).

WHAT COULD IOA MODEELING CAN TELL US?

At the outset of this project our plan was to use IOA to evaluate commodity trade-offs on a global scale across environmental indicators. This analysis extends logically from the work WWF already accomplished with the Market Transformation's Initiative. WWF extensively evaluated individual commodities within food, fuel, and fiber categories. An IOA was intended to help our team to explore trade-offs between commodities within each commodity group and to observe the unintended consequences often hidden within those trade-offs. The team intended investigate the environmental impacts of shifting supply chain sourcing from one commodity to another, for example, palm to soybean oil. This analysis will be essential to develop best practice guidelines for the decision-makers of major soft commodity dependent businesses.

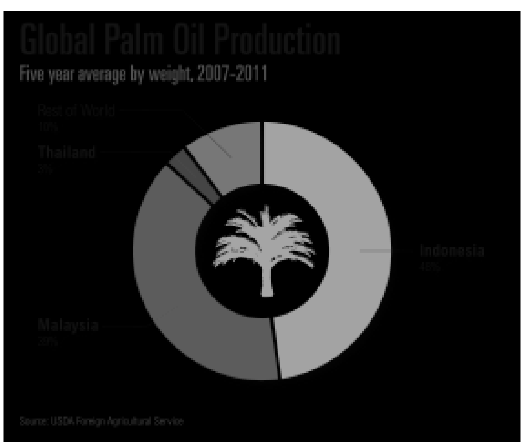
MODEL FINDINGS

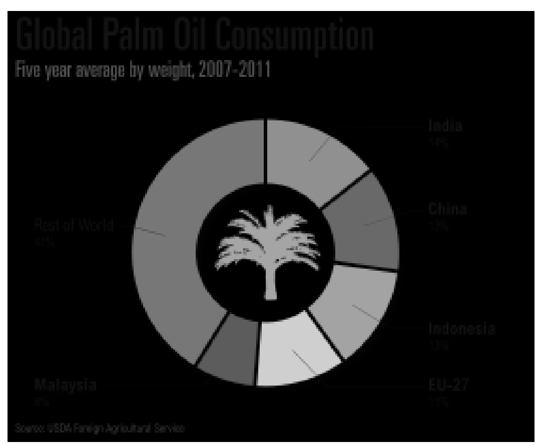
Objective

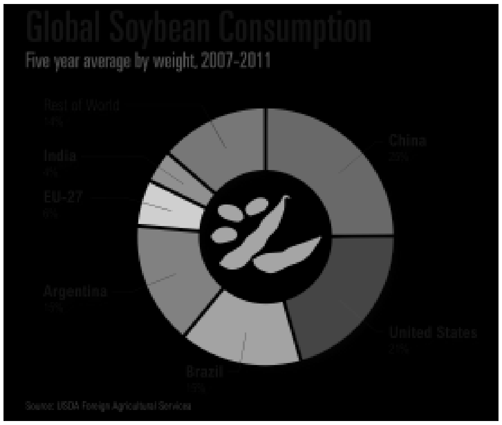
To inform our analysis of potential soft commodity trade-offs we decided to construct an IO model using the Eora database (http://worldmrio.com/). The goal was to generate a multi-regional, global model that could quantify the unintended consequences of shifts in supply chains from one commodity to another. Because there are a number of different commodity groups and potential commodity trade-offs in our project, we needed to prioritize certain trade-offs to pursue first in case we were limited by the project timeframe. To develop our first case we looked to potential trade-offs with soybean and palm oils. This was a logical place to start because we had a significant amount of data in this commodity group from LCA research, the negative environmental impact of palm oil cultivation are salient, and the two commodities can often be substituted for one another in the product formulation stage – in other words, the trade-off is actionable.

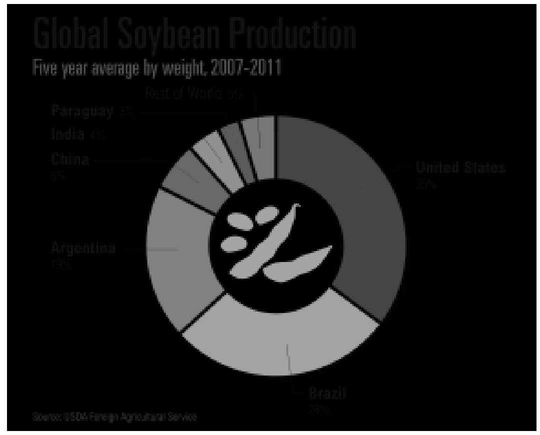
There are six countries that produce and consume the majority of palm and soybean oil globally: Indonesia, Malaysia, China, India, USA, and Brazil (charts below from WWF *The 2050 Criteria).*

FIGURE 29: PALM AND SOY PRODUCTION AND CONSUMPTION









In addition to the six regions, we decided to capture the remaining global production by including a seventh rest of the world (ROW) region, which is standard practice in IOA (Miller & Blair, 2006; Wiedmann, 2009). With this basic framework, we began collecting index data for each country from the Eora database showing the sector classifications of every country included in the database. Sai Lian, a postdoctoral fellow at University of Michigan, and Yu Feng, a doctoral track student at University of Michigan, were critical at lending guidance and technical support at this stage of the project.

Why The Model Did Not Achieve Desired Outcomes

On analyzing the classification systems of each of the seven regions for our potential model, we recognized that significant resolution alignment would be required in order to compare across regions. Because countries maintain their own IO tables based on different sector classification systems, there are often divergent approaches for the degree of sector resolution. For example, one country may maintain over 270 sectors (as is the case for the USA), while a country like Argentina maintains 125 sectors.

To resolve differences in sector resolution, IO researches recommend processes of aggregation or disaggregation. In aggregation, multiple sectors are combined into a single sector whereas disaggregation is the division of unique sectors from a single sector. Because our goal was to observe the impact of changes in specific commodities, we planned to mostly perform disaggregation unless a country IO table specifically identified the commodities of interest.

S. Lindner, J. Legault, and D. Guan (2013) recommend the following data in order to perform a sufficient disaggregation: the total output of the new sector(s), the proportion of output of the new sector(s) into other sectors in the economy, and the total portion of input from other sectors in to the new sector(s). If this data is not available, estimations of output and input related to the new sector can be estimated based on proportions from the original sector. However, Lindner also argues (2011) that the downside of this method is that it lacks nuance as the proportions reflect the existing sector and not the unique qualities of the new sector.

In the case of our proposed study (soybean and palm) the six regions we intended to focus on had different classification resolutions. For example, Malaysia maintains 98 sectors according to the Eora database, while Indonesia maintains 77. An excerpt from the Eora database showing the sectors that possibly contain soybean and palm oil are compared in the below table. Aside from the obvious case of palm oil in Malaysia it is unclear under which sectors palm and soybean reside. Furthermore, it is possible that palm and soybean occupy multiple sectors as the cultivation may be distinct from the production of the oil. In Malaysia soybean could reside in any of the four sectors except for *Oil Palm Primary Products*.

Malaysia	**Indonesia**
Agricultural Products Other	Food Crops
Oil Palm Primary Products	Non-Food Crops
Oils and Fats	Other Food Products
Other Foods	

To extract the desired sectors from the six countries would require reviewing their classification coding system. For example, the USA applies the North American Industry Classification System (NAICS), which clearly outlines the components of each sector. However, this document alone is several hundred pages and the equivalent for each country are often just as lengthy and can only found in their original language. This made the viability of multiple or even a single IOA potentially outside the scope of this project.

A further concern with IOA based on our growing understanding of the literature and the Eora database was that IOA is most often applied to inform national or global policy and regulation. Given that the IO framework is region or country-specific, this application is sound; however, our project sought to provide insight for corporations. MRIO may not be suitable for this type of analysis as the corporations that WWF works with often operate in multiple countries and are therefore both within the supplying and demanding country. In other words, the application to corporations is less sound because the relationships are not seamlessly rooted in country boundaries. As discussed earlier in the IO case studies, Wiedmann, Lenzen, and Barrett (2009) are successful in their application of IO to company triple bottom line accounting but this is only after collecting a significant amount of financial information from a specific company. Without this information the application of IOA to a general corporate audience is potentially less meaningful.

Given these challenges, we decided to not pursue IOA as part of this project. The process of learning about IOA and its application was nonetheless useful because it allowed us to define the trade-off scenarios of our project more clearly and provided a sense of what information would be most helpful to companies looking at potential trade-offs given an IOA framework.

CONCLUSIONS

This report provides guidance to business decision-makers for assessing environmental impacts related to sourcing practices, product formulation, and product design. The analysis evolves organically from WWF's Market Transformation initiative and *The 2050 Criteria* report in particular, and it builds on that work by recognizing the complex choices businesses face in supply chain management. Often these decisions involve tradeoffs that carry economic, social, and environmental weight. While the report recognizes the primacy of economic concerns for most businesses and it briefly identifies that importance of social factors, the focus rests with environmental concerns. Where there is flexibility in decision-making beyond economic concerns, businesses have significant opportunity to reduce their environmental impact. This report provides a framework for navigating business decisions to optimize for environmental goals by examining environmental tradeoffs through 6 environmental indicators and 4 decision dimensions. Through the framework of these indicators and decision dimensions, the report identifies several key findings and recommendations for businesses.

The key findings identified in this report relate to measurement and communication. In terms of measurement, businesses often face a dearth of information related to their supply chains. The report describes traceability and LCA data resolution as two primary barriers for in depth analysis of potential tradeoff decisions. In addition, the complexity of environmental systems means that many of the consequences of a particular action are difficult if not impossible to predict. This notion of unintended consequences suggests that even with sufficient information, the future and how a particular action will impact the future is difficult to predict.

In terms of communication, business struggle to communicate the complexity of tradeoffs to stakeholders. While companies need to make improvements in their ability to communicate, they should be wary of becoming myopic in their approach to environmental issues. Simplification is unfortunately not an appropriate response to the complexity of environmental tradeoffs.

Key recommendations emerged from the analysis of current industry practices and a review of scientific literature related to the commodity groups. First, this report identifies the importance of normalization and value weighting when LCA data is available. Companies need robust, cross-functional unit frameworks for assessing tradeoffs. LCAs are a valuable tool so long as decision-makers can compare across different LCAs. Second, companies need to clearly articulate the problem they are seeking to address and match that problem to their internal value systems. The report explores how this may look through a variety of scenarios, ranging from oilseeds for a major food and beverage company to cotton sourcing for the global apparel industry. Third, corporate decision-makers should not become discouraged by the complexity associated with environmental tradeoffs and should not allow uncertainty to result in inaction.

This last recommendation is simple to state but challenging to enact. Decision-making is rarely, perhaps never, a perfect process. The goal of this report is to provide guidance to corporate decision-makers to make better decisions and, importantly, to encourage the continual improvement of the decision-making process. The importance of environmental concerns in supply chain management will increase in the future. Corporate decision-makers should react to this growing importance by continually defining their problem, assessing potential choices, acting, and measuring the consequences of those actions. Through this process, decision-makers may expect fewer environmental impacts and consequently more stable and productive supply chains.

Finally, LCA normalization and weighting, input-output analysis, traceability, and unintended consequences represent the next horizon for commodity supply chain research. Academic institutions, NGOs, and governments can provide support to businesses by investigating these topics in greater depth. Through collaboration between organizations like WWF and the corporate community, companies will be better equipped to confront future decisions related to environmental concerns.

APPENDIX A: COMPANY INTERVIEW GUIDE

Project Background:

University of Michigan graduate students at the School of Natural Resources, in collaboration with World Wildlife Fund's Market Transformation Initiative, are pursuing a research project to better understand the environmental impacts and trade-offs of WWF's 15 priority commodities within the categories of food, fuel and fiber. Interviews with product formulators and procurement staff will both inform the research and data gathering part of the project and steer final deliverable development to make sure that the information is relevant to our key audiences.

The end deliverable will be a visual report aimed at corporate decision makers including a series of case studies or examples applying the information developed in the research portion of the project to demonstrate how this information can be applied in a typical business context. Considerable effort will be invested to provide data in a way that will most effectively communicate to our target audience.

If possible, we would also like to conduct a second follow up interview at the start of the writing process in late 2013 in order to address any outstanding questions that arise during the research and modeling process.

Interview Questions:

1. General – Corporate Level Goals and Trade-offs
   a. From our initial research, we understand your company's sustainability goals to be : A B C – are there any we are missing?
      i. At the corporate level, are there any of these goals that get more resources allocated to them or more attention given to their success?
      ii. If yes, how were these weightings determined – is there a decision making framework used internally?

2. Product Design/Formulation
   a. For these business units, please explain the product design process at your company.
   b. How are high level sustainability goals (e.g., GHG, water) implemented in the product design phase if at all?
   c. Are there specific business unit level sustainability goals that are embedded into this process? Please describe. (e.g., any tools used, weighting, review process?)
      i. If you use a software to help evaluate environmental impact of commodities used, can you tell us how that factors into your decision making?
      ii. Are employees encouraged or incentivized to consider these things when designing products?
   d. What stages in the product life cycle are evaluated during product development? Pre-processing, processing, end of life?
   e. Given the portfolio of products you sell, how much flexibility do you have in changing the ingredients used in your products?
      i. How difficult would the process be to do so?
      ii. When this happens, could you explain how it occurs?
      iii. What types of external factors play into this decision? (e.g., price, availability?)
   f. Would the associated environmental impact of a product ever drive an ingredient/material change decision?

   g. When designing new products, how often and to what level are new materials/ingredients evaluated as potential substitutes?
   h. What information would be helpful for your company at the product design phase in analyzing trade-offs?
   i. Are there specific examples of information that has been helpful in the past?

3. Procurement/Sourcing
   a. For these business units, please explain the procurement process at your company?
   b. How are high level sustainability goals (e.g., GHG, water) implemented in procurement, if at all?
   c. Are there specific business unit level sustainability goals that are embedded into this process? Please describe. (e.g., any tools used, weighting, review process?)
      i. If you use a software to help evaluate environmental impact of commodities used, can you tell me how that factors into your decision making?
      ii. Are employees encouraged or incentivized to consider these things when designing products?
   d. When sourcing commodities, what units are used?
   e. Do you look at any other measure of the commodity? e.g. protein per gram?
   f. What sort of information about environmental impact do you require from your suppliers? How do you collect this information?
   g. How much flexibility do you have to change suppliers or sourcing regions?
   h. Could you please describe the process of changing a supplier – how long it takes – what steps are taken?
   i. Do you rely on certifications as an indication of supplier performance on environmental or social factors? Which ones?
   j. For this product category – approximately how many suppliers do you source from? Could you please describe this supply chain and where you fit?
   k. Besides environmental impact, do you have any specific requirements that suppliers must meet? (e.g., social sustainability?)
   l. What information would be helpful for your company at the product design phase in analyzing trade-offs?
   m. Are there specific examples of information that has been helpful in the past?

4. R&D Decision Support
   a. How do you support other departments in decision making in product design or procurement?
   b. What types of tools do you use for this decision support? Software, guidelines, certifications, reviews, etc.
   c. What are the best examples of trade-off analysis that you have seen this area?
   d. What information would be helpful to you in supporting your business units?

5. Communicating to Decision Makers
   a. How do you gather your information about the environmental impacts of your product components/ingredients/materials?
   b. What do you consider as the most effective ways to present trade-offs information?
   c. Have you received any information about environmental trade-offs that was particularly helpful? Particularly unhelpful/confusing?

Process ideas:

- How many interviews are sufficient?
  - 5-6 interviews for R&D decision support
  - 10 interviews on procurement
  - 5-6 interviews on product design
- Who should be on the interview calls?
  - A note taker from our team
  - Mallory
  - Martha
  - Relationship Manager
- What kind of personnel do we want to talk to? Sustainability Directors vs Procurement Directors?
  - Start with Procurement Staff
  - Talk with Sustainability Directors if they end up being involved in procurement decisions
  - Maybe add CSR person to call anyway if they are interested
  - Less relationships with product design folks – maybe use CSR department to make the connections to talk to those people
  - R&D departments related to environmentally related decision making
    - GE, Alcan, BASF, P&G (don't have a software, but do have an LCA and toxicity staff)
    - EcoAssesment Team, R&D?
    - Dealing directly with decision support for the software
- Conference call software?
  - Martha will set that up

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