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The implementation of carbon footprint modeling with supply chain

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***Abstract*---**This study focuses at discussing the effect of emissions of carbon owing to the different stages in an industry's supply chain. A short overview of different environmental concerns, emissions, carbon footprints and carbon estimation methods will be discussed. The most common method –LCA – is discussed in depth, including its stages and procedure for estimating emissions. A sample of the manufacturing of oatmeal is carried out. The data are gathered for outcomes and evaluated. In the formulation of a model, the Balan et al method also is utilised to get results. Based on the findings, suggestions were received for improving the oats sector supply chain system. The benefits to be environmentally friendly and to make the supply chain of an industry green and improvise its sustainability are shown.

***Keywords*---**implementation, carbon footprint, supply chain.

Introduction

Due to the increasing environmental consciousness of society, governments, regulators and companies are urged to prioritise environmental sustainability. One recent study revealed that 83% of people of the European Union choose to buy a product's environmental footprint (European Commission, 2009). In

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addition, environmental laws as introduced in 2005 and developing, including the Kyoto Protocol, and the EU emissions trading scheme (EU ETS), seek to guarantee environmental protection by reducing emissions of greenhouse gases. More and more businesses have thus progressively adopted sustainable methods, such as integrating CFM in their whole supply chain, in order to comply with environmental laws, while reducing waste and increasing their green image factor and competitiveness. Green business mindset has also become a business profitability centre for businesses and a competitive advantage. (Kumar et al., 2012).

There is a paradigm change in the way contemporary supply chain networks function and seek to improve organisational efficiency. The main focus traditionally been the control of the upstream functions of global supply chain management concepts. The efforts now go from compliance to the creation of value. There is a concern for keeping a carbon free supply chain in everyone engaged in the supply chain and logistics. From the beginning to the conclusion of the life cycle, the concept of a green supply chain includes all phases of manufacturing. Srivastara (2007) described Green Supply Chain Management (GrSCM) as an integrated environment in supply chain management, encompassing product design, material sourcing and seletion, manufacturing processes, consumer delivery of the finished product and end-of-life management. From green purchasing to an integrated green closed loop supply chain, the definitions of the green supply chain vary.

Many progressive businesses like Tesco, Walmart, Patagonia and Hewlett Packard have taken advantage of the possibilities for managing the green supply chain, which is why they are extremely worried about the environmental impact of their supply chain operations. Customers and companies across the supply chain are especially susceptible to reduced carbon emissions in the operation and design of supply networks (Hoffman, 2007). Operationally, the use of electricity efficient cars, the reduction in waste, process optimization and recycling may include carbon management of assets and infrastructure. Carbon control and carbon footprint measurement throughout a supply chain are becoming a problem for businesses. (Butner et al., 2008) In order to show carbon effect in operation in a typical supply chain, IBM tried to produce a carbon thermal map . Despite early attempts in business practise and even preliminary supply inquiries chains (Sundarakani et al., 2008), carbon footprint measurement needs to be investigated and the impact of carbon emissions on global supply chains better understood, quantified and rigorously analysed. The aim of this article is, therefore, to add to the understanding and practise of carbon footprint measurement and management throughout supply networks

Review of Literature

For the computation and evaluation of greenhouse gas emissions of individual activities or across the life-cycle products, CF developed as a valuable environmental concept. In practise, the carbon emissions of a business rely on its industry, value chain stance, and its particular features as to the nature of its goods or the technology employed across its supply chain (Lee, 2011). There are many scientific documents in literature, including case studies dealing with the estimate of CF. Below is a typical selection of these papers. The Hyundai Motor Company case study in the automotive sector shows CF integration in the supply chain of an automotive unit (Lee, 2011). In this instance, suppliers are seen as a major element affecting the CF of the supply chain, therefore integrating their emissions into the overall CF measurement. With regard to textiles, a recent research reveals that recycling pre-consumer waste procedure may help reduce the CF in the clothing supply chain; it is significantly more efficient than recycling post-consumer waste end-of-life (Muthu et al., 2012). At the same time, the CF assessment on the biofuel industries shows that the first supply Chain generates fewer emissions of greenhouse gases than the later, one for soy-to-biodiesel and one for maize-to-ethanol (Young et al, 2012). It also emerges that efforts have also been made in the assessment and reduction of carbon emissions in the chemical sector throughout the case study of AkzoNobel Plant in Saskatoon, Canada (Stein and Khare, 2009). Lastly, in the US dairy feed supply Chain, around 80% of the CF is responsible for feed production, while both energy and transport contribute about 10% towards total emissions of greenhouse gases (Adom et al., 2012). There are many case studies relating to CF in the context of supply chain management in particular in the food and beverage industry. The divergences of CO2 in the CF across the worldwide supply networks of different items of Norway's marine goods are compared by Ziegler et al, (2013) and by Rizet et al., (2012) with the two supply chains for apple and yughurt.

Röös et al. (2013) states that a CF may be regarded as an environmental effect indicator in production of various kind of meat, whereas an agriculture stage is responsible for the majority in animal-based food parts of greenhouse gas emissions, as per Virtanen et al. (2011). In addition, Kendall et al (2013) show that truck transports is the key component in carbon emissions in the life cycle of raw honey in the instance of a supply chain of honey in the United States. Furthermore, Craig et al. (2012) submits a CF estimate case study in the supply chain of the United States' largest banana importer. The findings show that transit generates more CF than banana production, while roughly 50% of the supply chain CF is due to indirect emissions outside the control of the business. In the final analysis the results of a CF estimation tool and an LCA methodology were compared, both applied in an actual scenario, with Patarra et al. (2012) using a tool for evaluating the changes of results among the different kinds of wine across the European Union. In this context, the wine supply chain was taken into account.

Objective

The purpose is to analyze the carbon footprint of the oat meal with SCM using LCA using the modified (Balan et al,2010) method. Secondly, the supply chain analysis is carried out. There is a clear discussion of the many components and phases. The material flow And the energy associated with it is recorded inside and outside of a specific component. Third, after the mass balance of the process is complete, the estimate of the carbon footprint will be made. This assessment aims to sum up, quantify, or identify the possible environmental impacts of the system being examined. This leads straight to the last stage in assessing and discussing the findings of the impact estimate. Other suggestions or choices about environmental effect or goal may be made, in addition to the projected numerical values. The collected findings may also be utilised for discussing subjective rudiments such as technological feasibility, social and economic problems, etc.

Research Methodology and Data Analysis

The environmental impact of LCA method for processes or goods is calculated. This method is mostly concerned with time consumption, and it is complicated by the absence of data in the early phases of the process or product development. A simpler version of this approach includes grouping the various phases in the product life cycle based on analogue processes. In view of their inter-dependence, LCA analyses every step of the product, i.e. one action leads to another. The LCA method therefore leads to the calculation of the overall environmental impact of the product resulting from each and every stage of the product's life being included in the study. LCA offers a complete picture of the environmental characteristics of a product or process by considering the effect throughout the entire life cycle. This product information will assist customers make the best choices during product selection. Therefore, Life-Cycle Assessment is used in present analysis if oatmeal manufacturing. (Balan et al,2010) has suggested a more complex version of the same method, although rather different from that (Balan Sundarakani, 2010). This study uses both the methods of modelling the process of oatmeal, the analysis of the carbon footprint and the comparison of the findings. This approach is used in this research theoretically. The current model was subject to several changes and additions. In the words of the authors, the carbon footprint is adequately measured but not published, yet the authors are credited to it since it provides a basis to formulate the model (oat meal supply chain).LCA is an instrument for measuring sustainable development and an effective technique for assessing environmental effects.

Steps of Life-Cycle Assessment

The first step was extensively covered in determining the objective. The following step consists of defining each of the components and variables of the system being investigated. The supply chain of the meal of oat is divided into segments before assessment. The many parts include the procurement, process of manufacturing, distribution, use and disposal of raw materials. In the purchase of raw material, we examine how oat grain, the raw matter, is produced. Agricultural activities and emissions are examined. In addition to oat grain, raw materials such as aluminium are also considered as plastic necessary for packaging. The manufacturing process is divided into the processing phase and the packaging stage. Oat beans are cleaned, steamed, rolled and roasted in a variety of methods. The by product - hull which is used for further processing is produced during this procedure. At the cost of the manufacturer, trash produced during the processing phase is recycled. Transfer to the packing area of prepared oat grain or the oats meal. They are delivered in lot once packing is done. The next phase is the distribution of the goods to storehouses or distribution centres and, in turn, to retail outlets. The consuming stage is afterwards. Because of the consumption and the ultimate disposal, a minimum quantity of waste is obtained. All these steps are examined, data are gathered and carbon footprints assessed.

It is also considered the passage of the whole supply chain. The conveyance to the production unit, to the waste conveyor area of the production unit and to the disposition area of the raw materials - oat grain and packaging - is assumed, to the storage factories and other retail outlets with finished product – oat meal and finally to the waste transferred to the recycling units by consumption is used. All aforementioned processes are investigated and processed individually and then the carbon emissions are evaluated. In order to measure where the product is, they are also compared to emission regulations. The following image shows all the above-mentioned components and phases of the supply chain of oatmeal. The steps are clearly illustrated under each category.

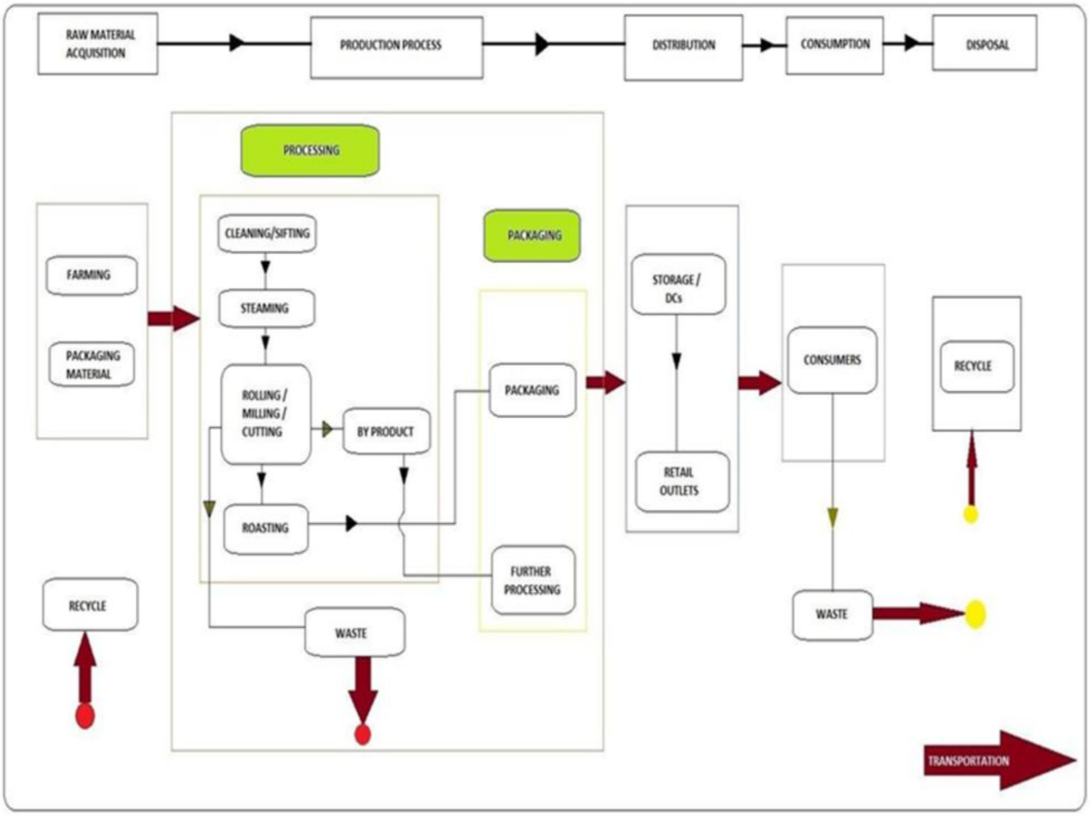

Figure 1: Oat meal supply chain process

After analysis and data collection, the required estimates are generated. The estimate is derived using the appropriate emission factors to multiply the activity data. The carbon footprint of the foodstuffs, the oatmeal here and overall carbon emissions from the oatmeal are thus equated to be the sum of the expected emission values. If Ex is the emission of the x-process,

$$Ex = (Activity\ data\ of\ x) * (Emission\ factor)$$

The whole carbon footprint expression will look like:

$$Etotal = \sum Ex,$$

Here Ex corresponds to each system activity's emissions. Method involves raw materials acquisition, waste production, recycling.

Once the estimations are made, it is important to verify that the variables – input and output – are taken into account. Here, the technique of mass balancing is useful. As mentioned above, the mass balance technique is only one metric, which guarantees a balanced input and output or that the total mass that flows into the process is equal to the amount of mass that flows out the process.. The variables that influence each step and the different components are well defined and thus it is simple to calculate.

The findings and analysis portion of the report include the calculations for each component in each phase. Some of the data utilised in this research are collected from authentication sources for which the references have been provided from the Internet. Data for some operations, such as by-products for whom data can not be obtained, are not supposed to be processed. Instead, a variable is utilised and estimated just as a big or little number in the estimate..

This technique utilises the long-range transport modelling method to forecast carbon emissions of any product throughout the whole supply chain. The logistics activities inbound and outbound are also subject to a mobile emission dispersion model. When this model was built, the end of the supply chain is considered as a closed loop. Since the feed chain is a loop, a similar model has been created also for the supply chain. Here emissions from different supply chain components or phases are categorised in two categories: stationary and non-stationary. The combined emissions from both stationary and non-stationary sources will thus be the overall carbon output or the carbon footprint. The categorization and assumptions used in this model are described below. The following are described.
The model uses emissions from the main level I provider to minimise the complexity of the issue. Like the LCA, stages with genuine data are presumed to be maximal or minimum variables, and likewise, compared to the emission of the manufacturing phase, emissions related to consumption of the end product should be deemed low. The concept is believed to be consistent in other variables, such as natural intervention.

Balan et al. , presented the generic Lagrangian model describing emissions in an open area (Balan Sundarakani, 2010) as :

$$\frac{dCi}{dt} = Ei + Ri(Ci) - \frac{\alpha i(Ci)}{h} - AiCi$$

$$\frac{dC_i}{dt} = E_i + R_i(C_i) - \frac{\alpha_i(C_i)}{h} - A_iC_i$$

Where

$Ei\ =\ source's\ emission\ rate,$
$Ri(Ci)\ =\ \ rate\ of\ change\ of\ chemical\ transformation$

The emission rate of the source is taken into account in this model in one direction. Balan et al believes that the emission is the main vector axes, namely x, y, and z, in all principal directions. In mathematical equation, carbon footprint emission may be interpreted as follows.

$$\frac{dC_i}{dt} supplychain = \left\{\left[\frac{dC_i}{dt}\right] stationary\ source\right\} + \left(\left[\frac{dC_i}{dt}\right] nonstationary\ source\right)$$

The above equation may be expressed as(oat grain supply chain):

$$\begin{aligned}\left[\frac{dC_i}{dt}\right] supply\ chain \\ = \left\{\left[\frac{dC_i}{dt}\right] farming + \left[\frac{dC_i}{dt}\right] cleaning + \left[\frac{dC_i}{dt}\right] steaming + \left[\frac{dC_i}{dt}\right] rolling \right. \\ + \left[\frac{dC_i}{dt}\right] roastng + \left[\frac{dC_i}{dt}\right] packaging + \left[\frac{dC_i}{dt}\right] waste\ dispoal\ 1 \\ \left. + \left[\frac{dC_i}{dt}\right] waste\ dispoal\ 2 + \left[\frac{dC_i}{dt}\right] by - product\right\} + \left(\left[\frac{dC_i}{dt}\right] transportation\right)\end{aligned}$$

In the case of stationary sources, it is assumed that the emission happens inside a closed volume of V, with velocity components in all three directions, namely, u, v, and w, and that the emission occurs within a closed volume of V. Therefore, agricultural emissions may be represented as

$$\begin{aligned}\left[\frac{dC_i}{dt}\right] farming = \iiint_V \frac{\partial C_i}{\partial t} dxdydz = \iiint_V \left(\frac{\partial\left(kx\frac{\partial C_i}{\partial x}\right)}{\partial x} + \frac{\partial\left(ky\frac{\partial C_i}{\partial y}\right)}{\partial y} + \frac{\partial\left(kz\frac{\partial C_i}{\partial z}\right)}{\partial z}\right) dxdydz \\ - \iiint_V \left(u\frac{\partial C_i}{\partial x} + v\frac{\partial C_i}{\partial y} + w\frac{\partial C_i}{\partial z}\right) dxdydz \\ + \iiint_V \{R_i(C_i)\} dxdydz - \iiint_V \left(\frac{\alpha_i C_i}{h} + A_i C_i\right) dxdydz\end{aligned}$$

The von Karman constant, k, is estimated to be about 0.40 in this case.

These equations are solved analytically by replacing the acquired data and taking into account the assumptions. This triple integral, commonly known as the volume integral, may be reduced to a surface integral. The Gauss Divergence theorem was used to get the integral across the volume, which was then solved using the different assumptions given. In the case of non-stationary sources, it is assumed that the carbon footprint follows a 3D trajectory derived from the trace model, which is referred to as the trace model. As a result, the non stationary source, which is the system's related transportation, is represented as:

$$\left[\frac{dC_i}{dt}\right] transportation = \frac{\partial C_i}{\partial t} = \frac{\partial}{\partial t}\left(Kx\frac{\partial C_i}{\partial x}\right) + \frac{\partial}{\partial t}\left(Ky\frac{\partial C_i}{\partial y}\right) + \frac{\partial}{\partial t}\left(Kz\frac{\partial C_i}{\partial z}\right) + R_i C_i - \frac{\alpha_i C_i}{h} - A_i C_i$$

The given equation may alternatively be analytically resolved by replacing the obtained data and applying the assumptions. The velocity of dry deposition (a) should be computed in the ratio of pollutant deposition to pollutant levels. The dry deposition is deemed insignificant for greater ease in estimating the carbon footprint. Similar to dry deposition, either physical or chemical deposition of gases or other particles, and even any changes in the surface composition, may be regarded very low. In case of non-stationary sources, the wind direction in the moving vehicle is considered to be along the direction and thus the term X is ignored. The carbon energy ratio may also be computed using the data collected and with the results, in addition to the calculation of the carbon foot prints.

Finding And Analysis

The footprints are estimated using the data that have been collected for each process or step in the process chart. Below are the calculations. The input materials purchase step comprises agriculture, the procurement of packaging material and the delivery to the processing section. As calculated from the Managed Emissions Table, emission per tonne of oat grain is 136 lb for agriculture. The tonne of oat meal is about 0,7 per tonne of oat grain.

$$Emission\ per\ ton\ of\ oat\ meal\ =\ 136\ *\ 0.7\ =\ 95.2\ lb.$$

The mean distance between farm and processing facility is calculated at 100 mile, and the emission per mile is estimated at 0,033 lb using emission sensitivity table and kind of vehicle.

$$Total\ Emission\ per\ trip\ =\ 0.033\ *\ 100\ =\ 3.3lb.$$

The average ton of oat grain that is being transported in every trip is 25 ton.

$Emission\ per\ ton\ of\ oat\ grain\ = \frac{3.3}{25} =\ 0.132lb.$ (The average tonne of oats carried each time is 25 tonnes.)

$$Emission\ per\ ton\ of\ oat\ meal\ due\ to\ this\ part\ of\ transportation\ =\ 0.7\ *\ 0.132\ =\ 0.0924lb.$$

The first stage is the cleaning or sealing procedure when processing the oat grains. The energy consumed by the tonne of oat grain is 60 kWh, and the emission is 1.1 lb per kWh, as achieved by the processing equipment.

$$Emission\ per\ ton\ of\ oat\ grain\ =\ 60kWh\ *\ 1.1lb/kWh\ =\ 66lb.$$

In the process, gas is also utilised as a component of electricity at a rate of 500kWh, which is 0.8lb per unit of gas consumed.

$$Emission\ per\ ton\ of\ oat\ grain\ =\ 500kWh\ *\ 0.8lb/kWh\ =\ 400lb.$$

The total energy and gas emissions are calculated as 466 pounds. The emission per tonne (constituent graph) of oat meal is estimated using 0.7:

$$Emission\ per\ ton\ of\ oat\ meal\ =\ 0.7\ *\ 466lb\ =\ 326.2lb.$$
$$Gas\ used\ per\ ton\ of\ oat\ grain\ =\ 2000kWh$$

$$\mathrm{E}mission\ per\ ton\ of\ oat\ grain\ =\ 2000kWh\ *\ 0.8lb/kWh\ =\ 1600lb.$$
$$Electricity\ used\ per\ ton\ of\ oat\ grain\ =\ 110kWh$$

$$Emission\ per\ ton\ of\ oat\ grain\ =\ 110kWh\ *\ 1.1lb/kWh\ =\ 121lb.$$
$$Emission\ per\ ton\ of\ oat\ meal\ =\ (1600+121)\ lb.*\ 0.7(The\ constituent\ factor)\ =\ 1204.7lb.$$

Rolling or grinding processes require power alone and a tonne of oat grain consumes about 200 kWh.

$$Emission\ per\ ton\ of\ oat\ grain\ =\ 200kWh\ *\ 1.1lb/kWh\ =\ 220lb. Emission\ per\ ton\ of\ oat\ meal\ =\ 220lb\ *\ 0.7\ =\ 154lb.$$

Like rolling, roasting uses just energy. electricity. It consumes around 140kWh according to sources.

$$Emission\ per\ ton\ of\ oat\ grain\ =\ 140kWh\ *\ 1.1lb/kWh\ =\ 154lb. Emission\ per\ ton\ of\ oat\ meal\ =\ 154lb\ *\ 0.7\ =\ 107.8lb.$$

As seen in the table of components, waste generated during oat grain processing is about 0.05% of the oat grain. This trash has a very low emission and the data derived from the treatment unit are calculated at 0,5 lb/ton of waste.

$$Emission\ per\ ton\ of\ oat\ grain\ =\ 0.05\ *\ 0.5lb\ =\ 0.025lb.$$

When compared with others, consumer waste from the use of oat meal is minimal. However, since there exist statistics on this front, they are calculated. The oatmeal emission of 0.25 lb per tonne and the oat-meal tonne of trash of around 0.002.

$$Emission\ per\ ton\ of\ oat\ meal\ =\ 0.25lb\ *\ 0.002\ =\ 0.0005lb.$$

The transit of trash produced by oat meal intake is extremely little. The final estimate of the carbon emissions is thus referred to as "M" and the number is presumed to be low. The transfer of trash from the treatment unit should, however, be taken into account. The average distance of the journey involving this trash is 50 miles.

$$Total\ emission\ per\ trip\ =\ 50\ mile\ *\ 0.033lb/mile\ =\ 1.65lb.$$

Here, waste is transported once every five days and vehicle emissions are derived in a vehicle emission database, computed at 35MPH on average and low environmental temperatures. The paper also includes the emission sensitivity table. In general, 6.25 tonne of trash is transported, so:

$$Emission\ per\ ton\ of\ waste\ =\ 1.65lb/6.25\ =\ 0.264lb.$$

Emissions from large trucks are considered for delivery of finished goods from manufacturing units to distribution sites or other retailers at an average pace of 55 MPH at ambient temperature and high altitude from the emission sensitivity table. Average distance from centres to processing plants is 250 miles, and on average one tonne of oatmeal is transported.

$$Total\ Emission\ per\ trip\ =\ 250\ miles\ *\ 0.016 lb/mile\ =\ 4lb.$$

The emission is not accomplished because of product processing, product usage, recycling etc. and therefore the total product-related emissions are regarded as "B." The content of B is not considered as little or small since it is used in further processing and represents an important component of products such as anti-freeze materials, medicines, synthetic rubber, lubricant oil, etc.

Aluminum and plastic are usually used for packaging. Emissions for aluminium manufacturing are acquired from reliable resources such as carbon trust and recycling. The same is true for plastics as well. Emissions are predicted to be 6 kg of carbon dioxide per kilogramme of plastic from purchase and recycling. The carbon trust estimates emissions in the case of aluminium vary greatly. The volume amounts to around 1 tonne CO2/ton, to be recycled and traded on the basis of the technology available for its production and to roughly 3 tonnes CO 2/tonne to 20 tonne CO2/ton. Therefore, emissions are expected to be ,"P" and disposal to , "P1" where both are extremely high values as a result of purchase of packaging material.

In order to get findings, the equations developed using the Balan et al model are also examined. In research by (Lee et al,2000), which was by (Balan et al 2010), developed a generic model for Lagrangian describing the emission into free space in order to analyse carbon footprints. To make the resolution of the three integrals more convenient, The conditions involving a person to be ignored will not be subject to any dry deposition in the surface of one of the parties in the supply chain. We further suppose that owing to emissions, no chemical or physical change occurs and thus R(C) is assumed to be zero. This allows us to go in different directions with the node emission levels and the carbon deposition coefficient. These equations are analytically resolved and the results are established along with the results obtained using the LCA method. The following table shows the estimates of the different actions involved in the supply chain of oat food:

Table 1: Emissions from each step in the oat meal supply chain

STAGES	STEPS INVOVLED	ESTIMATES	TOTAL ESTIMATES
		(lb per ton)	
Raw Material	Farming	95.2	95.2
Acquisition			
Production Process	Cleaning/ Sifting	326.2	1792.725 + P + B
	Steaming	1204.7	
	Rolling/ Milling	154	
	Roasting	107.8	
	Packaging	P	
	Processing Waste	0.025	
	By Product	B	
Consumption	Waste	0.0005	0.0005
Disposal	Packaging Material	P1	P1
Transportation	Raw Material	0.0924	4.3564 + M
	Waste from	0.264	
	production unit		
	Distribution Centers	4	
	Waste from consumer	M	

The overall estimate is thus (1892.2819 + X) lb. per tonne of oat meal where X is the cumulative emission amount owing to the use by consumer of materials for packaging, by products and trash. The aforementioned findings show that, as compared to other phases of the supply chain, the emissions from the manufacturing process are disproportionately high. The high use of gas and power in each of its four processes is usually attributable to this. The purchase and delivery of raw materials is also an important factor here. The emissions of the packing materials, both aluminium and plastic, have also been found to be exorbitantly high. Those issues and their effect on the environment have been increasingly worried by industries.

Emissions originate at every conceivable level of the oat grain supply chain, leading to the conclusion that almost every step requires attention. The issue goes beyond the different phases of the analysis, which has to be corrected. All the individuals engaged in the supply chain must make major adjustments and actions together to reduce emissions of carbon. The first approach should be to raise consumer knowledge of carbon emissions and their environmental effect. Carbon emissions should be taken into account when supply networks and other operations are developed. In fact, when combined with other criteria, they should be given higher weights. To become greener, manufacturers should maintain green purchasing practises; ensure that carbon emissions and the factor constitute an essential criteria for selecting their supplier.

The manufacturing procedures involved are another significant issue. The emissions from production operations are extremely considerable, as shown by the findings obtained. Investments in newer methods must be carried out in order to reduce these required measures to control emissions in the production facilities. The proper provision of sold devices and the use of novel sensing methods may be used to decrease inventories at retail shops and distribution centres, thus helping to cut emissions. Greener packaging and methods for distribution may be quite helpful. The disposal methods should be refurbished as well. Eliminating aluminium, plastic, and trash from production processes increases emission rates and thus appropriate recovery, re-use and disposal methods may also contribute to reducing carbon emissions. Finally, the manufacturers should also retain the logistics throughout the whole network. Emissions from vehicle use obviously play an important role in the whole estimate. The use of low-emission cars may contribute to the control of carbon emissions, the potential reduction of miles and other creative ideas.

Conclusion

This research examines the environmental effects of the several stages in the supply chain of oatmeal. It also discusses the available techniques, in particular LCA, in estimating the carbon emissions of the involved processes. The Balan et al method is also expressed and further solved for estimating emissions. Manufacturing processes, waste management, packaging, and construction are the four main areas most companies concentrate. Although many businesses or branches are unaware of their environmental effects, changes are required from the supply chain viewpoint. Although for many businesses, no specification or standards are set for each stage in the supply chain, several companies have found more effective methods of operations, which save operating costs and are eco-friendly if adopted. The company's innovative implementations and experiments have led to transformation of the conventional supply chain. Most firms hesitate to accept it as they are used to the original and traditional supply chain, because this concept is completely different. The time is necessary to make everyone understand the real need for greener systems in the supply chain. This can only be achieved by the proven results and the adequate transmission of carbon emissions and their impact. Everyone will surely adopt green techniques. The results. Modification is a must, as it is not only good for the environment, but also will give future generations the opportunity to use the resources available during their lives. The benefits of greener companies are that they are becoming a lesser environmental burden, enhance their profits and ultimately serve as an example for others. Given the present green scenario, it's not only profitable, but also correct.

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APPENDIX

A1. Emission Factor Table (http://www.arb.ca.gov/smp/techtool/waste-burn-emission-factors6.pdf)

Waste Burning Emission Factor Table

Crop Code	Crop Name	EIC Description	EIC Code	Emission Factors (lbs/ton) PM10	PM25	NOX	SO2	VOC	CO	Fuel Loading (tons/acre)	Source of Data
Agriculture - Field Crops											
241	Alfalfa	Agriculture - Field Crop	670-662-0262-0000	28.50	27.20	4.50	0.60	21.70	119.00	0.800	AP-42, Jenkins NOx & SO2
247	Asparagus	Agriculture - Field Crop	670-662-0262-0000	40.00	39.34	4.49	0.61	66.00	150.00	1.500	AP-42, Jenkins NOx & SO2
242	Barley	Agriculture - Field Crop	670-662-0262-0000	14.30	13.80	5.10	0.10	15.00	183.70	1.700	Jenkins (EF)
243	Bean/pea	Agriculture - Field Crop	670-662-0262-0000	13.70	13.00	5.20	0.10	14.20	148.00	2.500	AP-42, Jenkins NOx & SO2
244	Corn	Agriculture - Field Crop	670-662-0262-0000	11.40	10.90	3.30	0.40	6.60	70.90	4.200	Jenkins (EF)
245	Cotton	Agriculture - Field Crop	670-662-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
609	Dried flowers	Agriculture - Field Crop	670-662-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
246	Flax	Agriculture - Field Crop	670-662-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
609	Flower straw	Agriculture - Field Crop	670-662-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
612	Nursery prunings	Agriculture - Field Crop	670-662-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
248	Oats	Agriculture - Field Crop	670-662-0262-0000	20.70	19.70	4.50	0.60	10.30	136.00	1.600	AP-42, Jenkins NOx & SO2
255	Other field crops	Agriculture - Field Crop	670-662-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
260	Pea vines	Agriculture - Field Crop	670-662-0262-0000	13.70	13.00	5.20	0.10	14.20	148.00	2.500	AP-42, Jenkins NOx & SO2
249	Peanuts	Agriculture - Field Crop	670-662-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
250	Rice	Agriculture - Field Crop	670-662-0262-0000	6.30	5.90	5.20	1.10	4.70	57.40	3.000	Jenkins (EF)
251	Rye	Agriculture - Field Crop	670-662-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
252	Safflower	Agriculture - Field Crop	670-662-0262-0000	17.70	16.90	4.50	0.60	14.80	144.00	1.300	AP-42, Jenkins NOx & SO2
253	Sorghum	Agriculture - Field Crop	670-662-0262-0000	17.70	16.90	4.50	0.60	5.10	77.00	2.900	AP-42, Jenkins NOx & SO2
613	Sudan	Agriculture - Field Crop	670-662-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
610	Sugar cane	Agriculture - Field Crop	670-662-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
256	Vegetable crops	Agriculture - Field Crop	670-662-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
254	Wheat	Agriculture - Field Crop	670-662-0262-0000	10.60	10.10	4.30	0.90	7.60	123.60	1.900	Jenkins (EF)
259	Wild hay	Agriculture - Field Crop	670-662-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
Agriculture - Pruning											
101	Almond	Agriculture - Pruning	670-660-0262-0000	7.00	6.70	5.90	0.10	5.20	52.20	1.000	Jenkins (EF)
102	Apple	Agriculture - Pruning	670-660-0262-0000	3.90	3.70	5.20	0.10	2.30	42.00	2.300	AP-42, Jenkins NOx & SO2
103	Apricot	Agriculture - Pruning	670-660-0262-0000	5.90	5.60	5.20	0.10	4.60	49.00	1.800	AP-42, Jenkins NOx & SO2
104	Avocado	Agriculture - Pruning	670-660-0262-0000	20.60	19.40	5.20	0.10	18.50	116.00	1.500	AP-42, Jenkins NOx & SO2
720	Bamboo	Agriculture - Pruning	670-660-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
105	Bushberry	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)
106	Cherry	Agriculture - Pruning	670-660-0262-0000	7.90	7.40	5.20	0.10	6.00	44.00	1.000	AP-42, Jenkins NOx & SO2
602	Christmas trees	Agriculture - Pruning	670-660-0262-0000	8.67	7.76	4.27	0.14	4.35	64.69	1.000	Ponderosa Pine, Jenkins; use ARB's (Patrick Gaffney) fuel loading of 1 ton per acre
107	Citrus	Agriculture - Pruning	670-660-0262-0000	5.90	5.60	5.20	0.10	6.80	81.00	1.000	AP-42, Jenkins NOx & SO2
108	Date palm	Agriculture - Pruning	670-660-0262-0000	9.80	9.30	5.20	0.10	3.80	56.00	1.000	AP-42, Jenkins NOx & SO2
609	Dried flowers	Agriculture - Pruning	670-660-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
608	Eucalyptus	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)

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S://1-EIA section/Area Source Methods/Waste Burning Methodology/Emission Factors.xls

Crop Code	Crop Name	EIC Description	EIC Code	Emission Factors (lbs/ton) PM10	PM25	NOX	SO2	VOC	CO	Fuel Loading (tons/acre)	Source of Data
614	Vineyard removal	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	15.000	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter); Fuel Loading increased to 15 tons per acre based on consultations with compliance
125	Walnut	Agriculture - Pruning	670-660-0262-0000	4.20	4.00	4.50	0.20	4.80	67.00	1.200	Jenkins (EF)
Weed Abatement											
601	Berms	Weed Abatement	670-668-0200-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
361	Brush	Weed Abatement	670-668-0200-0000	18.00	16.25	4.00	0.35	12.55	133.85	13.100	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter) and Jenkins fir & pine; Hardy, 1996, NOx & SO2 avg.
581	Ditchbank & canal	Weed Abatement	670-668-0200-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
604	Dodder weed	Weed Abatement	670-668-0200-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
585	Fence rows	Weed Abatement	670-668-0200-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
584	Grass	Weed Abatement	670-668-0200-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
605	Lemon grass	Weed Abatement	670-668-0200-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
582	Noxious weeds	Weed Abatement	670-668-0200-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
606	Ponding/levee banks	Weed Abatement	670-668-0200-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
587	Star thistle	Weed Abatement	670-668-0200-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
586	Thistle	Weed Abatement	670-668-0200-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
580	Tules	Weed Abatement	670-668-0200-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
583	Tumbleweed	Weed Abatement	670-668-0200-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
Range Improvement											
362	Chaparral	Range Improvement	670-660-0200-0000	20.10	17.30	3.50	0.10	14.40	153.70	23.000	Jenkins fir & pine; Hardy, 1996, NOx & SO2 avg.
398	Grassland	Range Improvement	670-660-0200-0000	15.90	15.20	4.50	0.60	10.70	114.00	3.200	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
607	Pasture	Range Improvement	670-660-0200-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
Other											
703	Brooder paper	Other	670-995-0240-0000	0.78	0.74	4.27	0.14	4.35	64.69	0.030	PM & loading from UCD/Asbaugh, NOx, etc from Jenkins pine; using raisin tray
701	Diseased bee hives	Other	670-995-0240-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
258	Fert/pesticide sacks	Other	670-995-0240-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
800	Flood debris	Other	670-995-0240-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)
700	Other	Other	670-995-0240-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
805	Storm debris	Other	670-995-0240-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)

Crop Code	Crop Name	EIC Description	EIC Code	Emission Factors (lbs/ton) PM10	PM25	NOX	SO2	VOC	CO	Fuel Loading (tons/acre)	Source of Data
109	Fig	Agriculture - Pruning	670-660-0262-0000	6.90	6.50	5.20	0.10	6.00	57.00	2.200	AP-42, Jenkins NOx & SO2
609	Flower straw	Agriculture - Pruning	670-660-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)
110	Grape	Agriculture - Pruning	670-660-0262-0000	4.90	4.60	5.20	0.10	3.80	51.00	2.500	AP-42, Jenkins NOx & SO2
603	Grape stumps/stakes	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	10.000	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter); Fuel Loading increased to 10 tons per acre based on consultations with compliance
111	Kiwi	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)
112	Nectarine	Agriculture - Pruning	670-660-0262-0000	3.90	3.70	5.20	0.10	2.30	33.00	2.000	AP-42, Jenkins NOx & SO2
113	Olive	Agriculture - Pruning	670-660-0262-0000	11.80	11.10	5.20	0.10	10.30	114.00	1.200	AP-42, Jenkins NOx & SO2
114	Orchard removal	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	30.000	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter); Fuel Loading increased to 30 tons per acre based on consultations with compliance
126	Other prunings	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)
710	Pasture trees	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)
115	Peach	Agriculture - Pruning	670-660-0262-0000	5.90	5.60	5.20	0.10	3.00	42.00	2.500	AP-42, Jenkins NOx & SO2
116	Pear	Agriculture - Pruning	670-660-0262-0000	8.80	8.30	5.20	0.10	5.10	57.00	2.600	AP-42, Jenkins NOx & SO2
117	Pecan	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)
118	Persimmon	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)
119	Pistachio	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)
120	Plum	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)
129	Pluot (plum-apricot)	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)
121	Pomegranate	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)
122	Prune	Agriculture - Pruning	670-660-0262-0000	2.90	2.80	5.20	0.10	4.60	47.00	1.200	AP-42, Jenkins NOx & SO2
123	Quince	Agriculture - Pruning	670-660-0262-0000	7.80	7.30	5.20	0.10	6.30	66.00	1.700	Average of Almond, Apple, Apricot, Avocado, Bean/Pea, Date Palm, Fig, Grape, Nectarine, Olive, Peach, Pear, Prune, and Walnut (as of 9/12/00, Patrick Gaffney's letter)
124	Raisin trays	Agriculture - Pruning	670-660-0262-0000	0.78	0.74	4.27	0.14	4.35	64.69	0.030	PM & loading from UCD/Asbaugh, NOx, etc from Jenkins pine
611	Rose pruning	Agriculture - Pruning	670-660-0262-0000	15.90	15.18	4.49	0.61	10.73	113.95	2.175	Average of Alfalfa, Barley, Corn, Oats, Rice, Dafflower, Sorghum, and Wheat (as of 9/12/00, Patrick Gaffney's letter)