National Mango Board Sustainability Assessment

Baseline Assessment Findings & Recommendations

October 14 2010

www.common-fields.com

Contents

Introduction

The National Mango Board (NMB), as documented in its March 2010 Board of Director Resolution, has authorized the completion of a research report that accomplishes the following objectives:

- Develop a set of sustainability indicators that may impact the mango industry
- Determine what information is available on the carbon footprint of mangos and the vulnerabilities of the mango industry
- Perform a baseline assessment to
    - Identify current Board Member sustainability activities
    - Quantify actual performance against the sustainability indicators
    - Verify NMB perceptions of sustainability performance of mango production and distribution to the US market

It is anticipated that the results of this research effort will enable the NMB to develop performance targets for a sustainability program and identify the positive stories that can be shared both internally and externally as prioritized by the NMB. Further, this study is the first step in enabling the NMB to achieve the aspirations contained in the draft sustainability statement developed by staff:

> ***The Mango Industry demonstrates a commitment to sustainability by being good stewards of its human and environmental resources, which supports its ability to continue to provide the highest quality tropical fruit to its customers.***

This assessment builds upon previous work conducted with the NMB to provide an overview of sustainability, climate change and sustainable agriculture and baseline Board of Director, staff and customer perceptions, needs and interests. Findings from these efforts are highlighted in this report in the section "Review of Sustainability History and Current Market Trends".

This report is presented in the following sections:

- Purpose of Study
- Review of Sustainability History and Current Market Trends
- Data Collection Methodology
- US Mango Industry Carbon Footprint: boundary setting, estimated greenhouse gas (GHG) emission inventory, estimated sequestration
- Baseline Performance: social, environmental, biodiversity, product integrity
- Best Practices: social, environmental, biodiversity, product integrity
- Opportunities to Enhance Performance: social, environmental, biodiversity, product integrity
- Study Limitations and Scope for Future Study

Sustainability History & Market Trends

Sustainability is broadly defined as, "The ability to meet the needs of the present without compromising the ability of future generations to meet their own needs." "Sustainable" is often used synonymously with terms such as "green" and "natural," amongst others. In recent years, frameworks such as Full Cost Accounting and The Natural Step have been introduced to better define sustainability and provide a platform for businesses to understand the environmental and social impacts of their operations and products. The NMB Board of Director Sustainability Sub-Committee members offered[1] the following definitions of sustainability:

- Sustainable Agriculture should be considered across the value chain from producer to the retailer.
- Sustainable Agriculture includes, at a minimum, the environmental and social impacts of production. Also to be considered is product integrity (e.g., quality, safety and traceability) and the potential positive economic impacts of Sustainable Agriculture on farm production and retail sales.
- Sustainability is about "doing the right thing".

While a legally binding definition and national standard does not presently exist for the term "sustainability," the market is responding to consumer demand for products with low environmental impact and positive social benefits. Efforts such as Global Reporting Initiative, Carbon Disclosure Project and Wal-Mart's Supplier Sustainability Assessment

[1] These definitions were offered during telephone interviews conducted by Common Fields in August 2009.

Initiative are serving to incorporate greater transparency in reporting of company efforts to assess and reduce their impacts.

Market leaders are also quickly viewing sustainability as a strategic business imperative for companies that want to remain relevant in their market sector. A global 2008 McKinsey study[2] found that 60% of CEOs consider climate change to be a strategically important issue for their company to consider, with leading drivers including Corporate Reputation (54%), Consumer Preferences (35%), and Media Attention (34%). Further, a recent Harvard Business Review article outlined approaches being taken at global companies to integrate sustainability throughout their companies and approaches to decision-making.

The conversation is no longer about whether sustainability is a fad to be watched; rather it has turned to how to ensure companies are considering their environmental and social impact, working to decrease their negative impacts and improve upon their positive contributions, and communicating with their customers and consumers before they are asked or blogged[3] about their performance.

Fresh Produce Trends

In the world of fresh produce, the sustainability discussion is ramping up among distributors, retailers and producers. Events such as Produce Marketing Association (PMA) 2009-2010 regional discussions and national convention where sustainability was a key topic of discussion among participants, United Fresh's 2010 Sustainability Workshop, and the

---

[2]http://www.mckinseyquarterly.com/Energy_Resources_Materials/Environment/How_companies_think_about_climate_change_A_McKinsey_Global_Survey_2099

[3] An excellent case in point is the Discovery.com article placing Mangos at the top of the worst carbon footprint offender list, which is explained in more detail in a later section.

2010 Sustainable Agriculture Partnerships Conference. Each of these venues focus on sharing documented case studies of sustainability initiatives and their results in reducing operating costs, enhancing brand image, supporting farm workers and their communities and attracting and retaining consumers[4]. Following are a few such case studies:

- The California Association of Wine Grape Growers forming the Sustainable Winegrowing Program to promote and report on its industry's sustainability achievements.
- The National Dairy Innovation Board advocating for dairymen sustainability initiatives including promoting the 20x20 initiative to supply America with farm derived renewable energy that has on-farm and community benefits.
- Washington State Cherry Growers Association who successfully demonstrated to their Japanese buyers that use of non-chemical based pesticides and traps was as effective at eliminating presence of the cherry fruit fly as was traditional agrochemicals and fumigation. The result was extended product shelf life and lower operating costs.
- McGill's Onions turning their "waste" product (i.e., onion tops and skins) into a source of renewable energy for their facilities.
- Starbucks Corporation's support of REDD projects that provide economic benefit back to the communities that supply their coffee beans resulting in increased funding for schools and healthcare facilities.

These case studies are examples of opportunities taken by industry leaders to reduce their negative environmental and social impacts and help to avoid negative press such as the following examples:

---

[4] http://thepacker.com/ArticleLandingPage.aspx?oid=840057&urltitle=PMA-Fresh-Connections-event-focuses-on-sustainability&&src=email_a_friend_visitor

- The boycott of tomato growers by a student led coalition resulted in an influential buyer, Bon Appetit, calling for comprehensive changes to US farm labor practices. This effort resulted in Florida tomato farmers seeing an increase in wages for the first time in 30+ years.
- The Stern Review, a seminal study released in 2006 by the government of the U.K. on the economic indicators and risks of climate change, placed the kiwi fruit onto the biggest climate offender list because of what it called "the largest carbon footprints of produce items". The Kiwi industry[5] found itself in a reactive position, unprepared to respond to the charges, and embarked on an extensive carbon foot printing analysis that demonstrated lower greenhouse gas emissions than reported by the Stern Report.
- The *E. coli* outbreak in the spinach industry created a downward spiral of sales for many growers, extending for months even after the point of origination was identified. The poor handling practices of a single distributor resulted in a significant loss of revenue for many growers, and the consumer was left with concerns about food safety in general. The 2009 peanut recall served to reinforce those concerns.
- Fresh Express, a subsidiary of Chiquita, issued three different product recalls between May and August of 2010.
- The United States experienced the single largest recall of eggs due to presence of E. Coli on farm and resulting consumer illnesses.

Through a well focused sustainability assessment the above instances may have been avoided. While the instances lasted for only a few months or weeks the impact of the

[5] This information was gathered through a telephone interview with the lead researcher for the Kiwi industry.

negative press will remain for quite some time in the minds of consumers and consumer advocate groups.

With great foresight, the NMB commissioned this study to begin to document the US Mango Import Industry's carbon footprint. Within days after the study was approved, an article was found on Discovery.com highlighting the mango on the list of worst carbon footprint offenders. The article was based on miscalculations and use of an inappropriate calculator and the research team and NMB leadership worked quickly to communicate with Discovery.com about the errors and to ask that the article be removed. Discovery.com responded by removing the article from the website.

Consumer Knowledge, Attitudes & Behaviors

There is evidence in the US market of an increasing consumer interest for purchasing "green" products[6]. A study by the Food Marketing Institute found a 60% increase in sustainable product sales between the years 2006 and 2008[7]. In the United States, 2009 sales of organic food and beverage saw a 5.1% increase over 2008 with a total of $24.8 billion in sales in 2009. Sales in 2009 of organic fruits and vegetables were up 11.4% over 2008[8]. Fair Trade has reported a similar pattern of increased sales.

The Grocery Marketing Association (GMA) partnered with Deloitte in 2009 to identify the profile of the consumers that were driving the increase in sustainable sales. They identified the "green shopper" as having a higher household income and more education than other consumers. These "green shoppers" are a highly desirable group due to the increased

---

[6] Boston Consulting Group (January 2009). Capturing the Green Advantage for Consumer Companies.

[7] Source: Janet Greenlee, Fleishman-Hillard from presentation by Jeanne Von Zastrow, Food Marketing Institute.

[8] Organic Trade Association's 2010 Organic Industry Survey

frequency with which they shopped, the greater quantity they purchased per visit and their loyalty to green products-

> *"…sustainability characteristics drive a relatively large amount of product switching. Once a more sustainable product has captured the shopper's commitment it tends to create brand stickiness by retaining the shopper's loyalty through repurchase."* [9]

A 2008 study by the Boston Consulting Group found that 75% of respondents indicated companies should provide information on the environmental impact of their products, 54% felt companies should be involved in a social project and 81% believe companies should be clear about product risks and safety. This is consistent with Deloitte's findings that "nearly all shoppers surveyed would buy green; [and] nearly two thirds actively seek it on each shopping trip." [10]

However, green shoppers report that they experience difficulty in obtaining sustainability information at the point of sale. The Deloitte study found that "fifty-four percent (54%) of shoppers interviewed consider sustainability to be one of their decision making factors…" [11] In order to identify sustainable products they are looking for information pertaining to the following:

1. Low water usage
2. Reduced packaging
3. Organic
4. Locally grown

---

[9] GMA/Deloitte (2009) Green Shopper Study

[10] GMA/Deloitte (2009) Green Shopper Study, p.22

[11] GMB/Deloitte (2009) Green Shopper Study, p.7

5. Fair trade
6. Energy efficient
7. Biodegradable
8. Non-toxic and low volatility organic compounds
9. Recyclable materials or content

Once given the ability to identify green products data shows that consumers often increase both their purchased volume and price. Research commissioned by the Produce Marketing Association found consumers are willing to pay a premium for products that demonstrate the following sustainable practices:

1. Pay workers a fair living wage
2. Worker safety programs
3. Water conservation programs
4. Pollution reduction in transportation
5. Energy conservation programs
6. Water reuse programs
7. Products in recyclable packaging
8. Trash reduction programs[12]

When looking at the exotic fruits and vegetable market and mango buyers specifically, a study commissioned by the National Mango Board found that:

- 52% of mango buyers would pay more for exotic tropical fruit that have positive social benefit
    - Mango and non-mango buyers would pay between 5% and 10% more for exotic tropical fruits with social benefit

[12] Produce Marketing Association (May 2008) Sustainable practices consumers are willing to fund

- 55% of mango buyers would pay more for exotic tropical fruit grown using environmentally responsible methods
    - Mango and non-mango buyers would pay between 5% and 10% more for environmentally produced tropical fruits
- The labels most likely to influence buying decisions are: Natural, Organic and Environmentally Responsible

Labeling, Rating, Certification

Greater emphasis is being placed on standardization efforts such as the Stewardship Index for Specialty Crops and Leonardo Academy's Sustainable Agriculture Standard with sub-committees working diligently to come to agreement on standards, metrics, definitions and measurement approaches. Further, Wal-Mart recently introduced its Supplier Sustainability Product Index to over 100,000 suppliers, which requires suppliers to demonstrate their commitment to sustainability by conducting baseline assessments and disclosing the results and corresponding plans for improvement. While it is unclear when a standard set of metrics or framework for assessing sustainability will be agreed upon, what is clear is there is continued interest across the industry to actively discuss the possibilities for standards. Companies and industries that are able to articulate their baseline performance will be well positioned to respond to both voluntary and compliance-based standards.

National Mango Board Perspective

BOD Self-Assessment:

During the September, 2009 Board of Directors meeting, Common Fields facilitated a self-assessment process for board members to identify existing perceptions on the levels of understanding and ability of the board around sustainability issues. Detailed results of this self-assessment were provided in the report "Perspectives on Sustainability for the National

Mango Board”, delivered in September, 2009. Summary information from that report is provided in this section.

Current Performance (from September, 2009):

- Overall, Board members identified several areas of opportunity for improvement across each quadrant of sustainability. This holds true for environmental, product integrity and economic sustainability for which all three categories received ratings below the acceptable category.
- Although the social indicators were rated as being in need of improvement, they received slightly higher ratings, especially among producers. Two indicators approached the rating of “acceptable”: worker access to potable water and compliance with local and international labor laws.
- When looking both at the performance rating and open-ended responses to identify best practices, there were very few indicators for which a best practice could be identified by more than one person. In total, only a handful of items were identified as a best practice with little consistency between each. Of particular note was identification as a best practice the creation of the National Mango Board.

Risk to the Industry:

- Board members perceived at least a medium amount of risk across all four categories.
- Among the four quadrants, product integrity is considered to have a greater level of risk with it approaching high risk on specific indicators. Specifically, zero food safety issues, standard traceability process, screening for communicable disease and consistent application of food safety practices that prevent food borne illnesses are all perceived as medium to high risk indicators.
- Nearly all social indicators were rated as low to medium-low level of risk.
- On the economic quadrant, the profitable operations indicator was rated as the highest risk, especially among producers.

Self-Assessment Key Findings

To gain broader input from the full board, a self-assessment worksheet was provided in both English and Spanish that follows the Common Fields framework on Sustainable Agriculture. In total, 26 indicators were presented in the self-assessment to which 83% of the full Board (17 respondents – 9 producers and 8 importers) responded.

Current Performance

As seen in the following chart, Board members identified several areas of opportunity for improvement across each quadrant of sustainability. In fact, only a handful of indicators in the social and product integrity categories began to approach the "Acceptable" rating. This also holds true when looking at producers and distributors independently of each other.

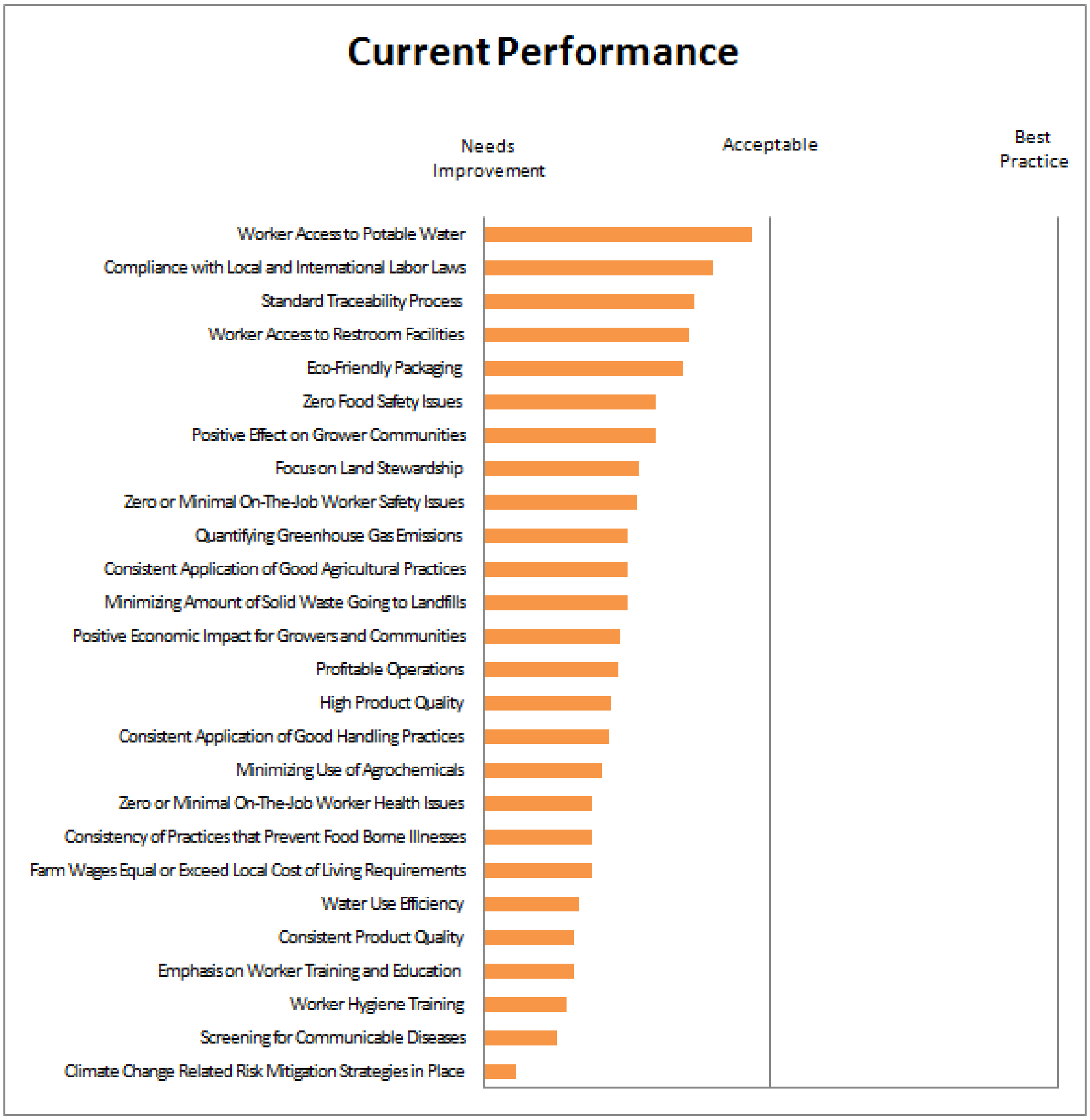

Chart 0.1.1 Current Performance of the Mango Industry

Regarding performance, four indicators stood out as candidates for greater education for Board members. As shown in Graph 0.1.2, a significant percentage of National Mango Board of Directors indicated they don't know the current performance of the Mango Industry with respect to "Climate Change Risk Mitigation" (44%), "Quantifying Greenhouse Gas Emissions" (38%), "Screening for Communicable Diseases" (29%) and "Minimizing Amount of Solid Waste Going to Landfills" (29%). Given the recent emergence of climate change mitigation and greenhouse gas emission issues in the agricultural sector, the findings suggest the Board is in need of additional information about how the Mango Industry is performing relative to these indicators, and how it will be affected by retail channel and/or governmental reporting requirements going forward.

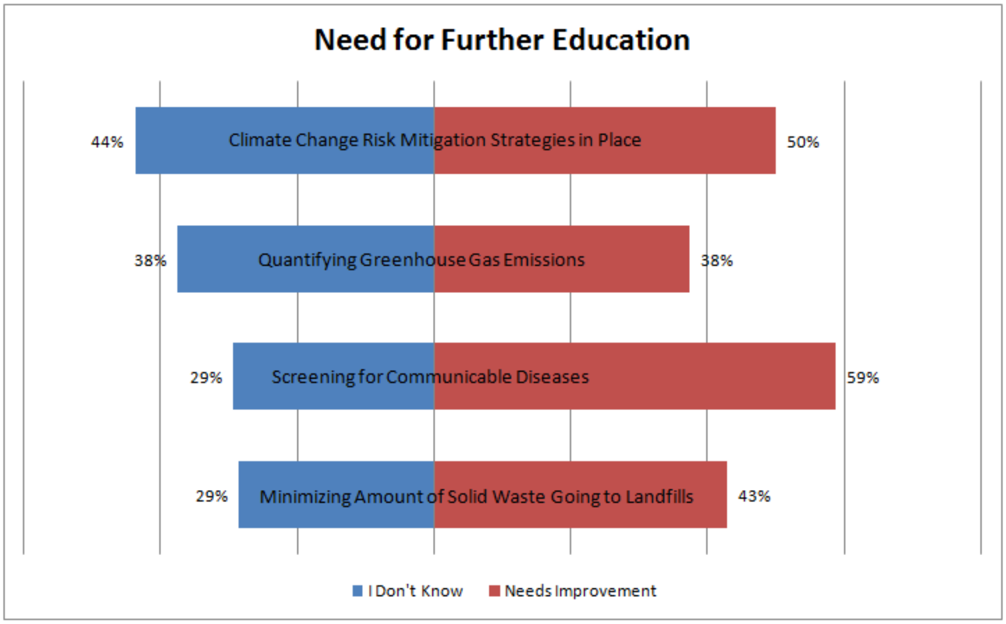

Chart 0.1.2 Response Discrepancy and the Need for Further Education

<u>Potential Risks</u>

Board members were asked to rate the level of risk each indicator presented to the Mango Industry. As illustrated in the following graph, each area of sustainability presents some risk but in comparison to perceptions of current performance there are two areas of divergence that are particularly noteworthy.

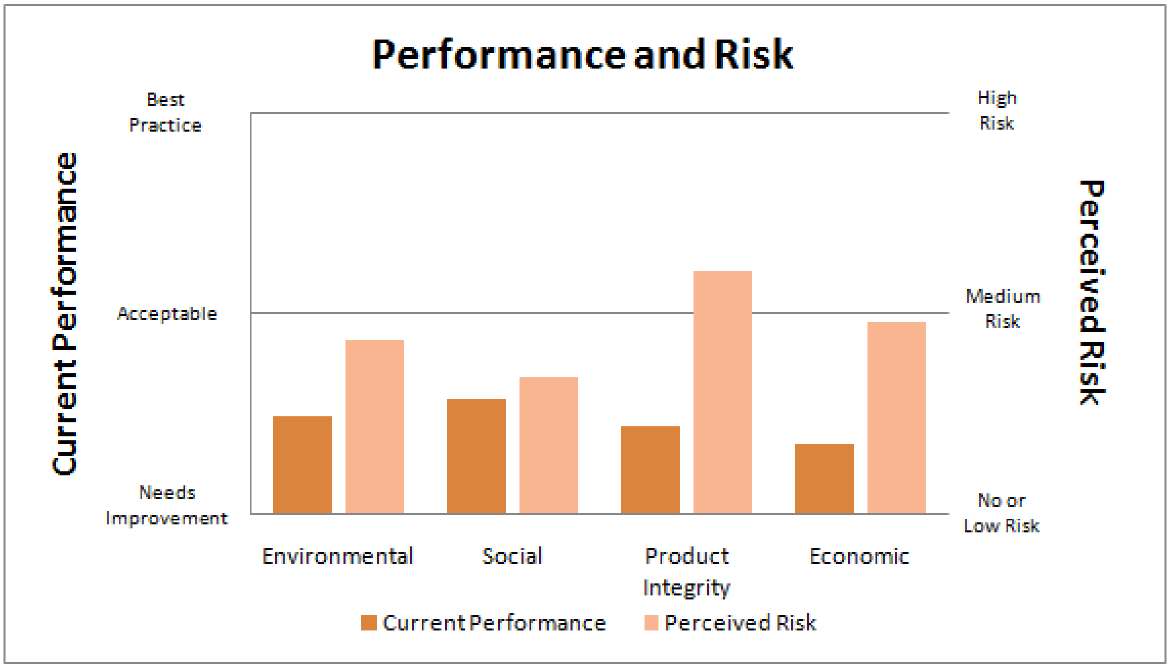

Chart 0.1.3 Average Risk and Performance across each Quadrant

As shown in Graph 0.1.3 National Mango Board of Directors indicate the Mango Industry has both a low level of performance and a medium to high level of perceived risk in the product integrity quadrant. Respondents also indicated a very low level of performance and medium level of risk for economic indicators. Lastly, although the current performance of social indicators was rated as below acceptable, respondents indicated it only poses a low to moderate level of risk.

<u>Response to Media Requests</u>

Board members were asked to rate the National Mango Board's current ability to respond to media requests concerning the industry's sustainability practices. Here, as seen in Chart 1, slightly less than one quarter of the respondents (22%) indicated the National Mango Board could effectively respond to media requests with a relatively equal number (23%) suggesting the response would not be effective. The remainder indicated the response would be somewhat effective.

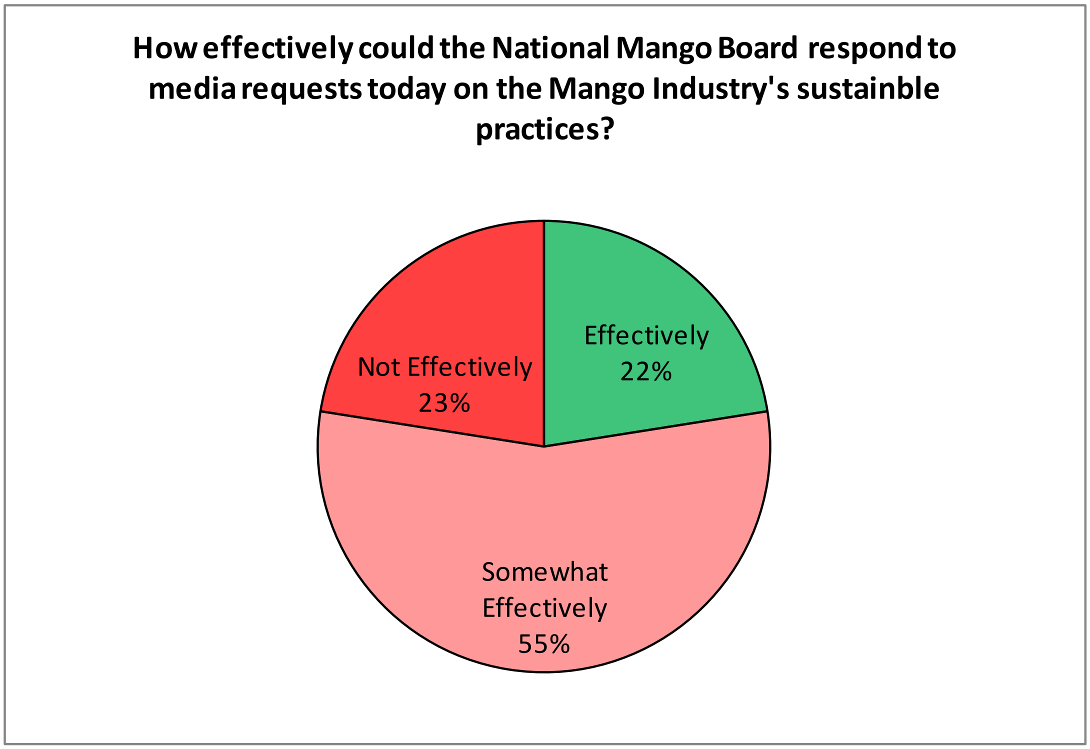

Chart 0.1.4 National Mango Board's Ability to Effectively Respond to Media Requests

Summary

The National Mango Board of Directors identified several areas for improvement with a specific need to focus more effort on minimizing risk on product integrity. Further, the low risk and priority ratings on the social indicators suggest the Mango Industry may be performing well with respect to some of these issues. There may be great stories at the country level that demonstrate the positive social and economic impact the Mango Industry provides to grower communities, and the Board should seek to promote these practices. The clustering of responses towards the lower performance, moderate risk and lack of best practices suggests opportunities exist for the National Mango Board to "get the word out" among its members about industry best practices as well as the gap between current and desired performance.

Assessment Methodology

Common Fields, in collaboration with NMB staff, implemented a six-step approach to this sustainability assessment:

Step 1: Conduct Literature Review, Prioritize Sustainability Indicators & Develop Carbon Footprint Assessment Plan

NMB staff, with advice from Common Fields, conducted a review of available literature to identify mango carbon footprint and vulnerability data[13]. This information was used to customize the Common Fields Sustainability Indicator Bank[14]. The Common Fields team presented proposed sustainability indicators to the NMB staff for consideration and prioritization. A US Mango Industry Carbon Footprint Assessment Plan was developed (as presented in the next chapter).

Step 2: Survey Development

Using the set of indicators developed in Step 1, Common Fields, with the support of the NMB, developed a survey that was comprehensive of environmental, social and product integrity related indicators (these surveys are presented as attachments to this report). The survey was split into three sections, producer, packing-house operator and importer which all had a vast subset of identical questions, but with a few customized questions to fit the respective value chain target (e.g. farm related questions were only put in the producer

[13] It was during this review that the aforementioned Discovery.com article was identified.

[14] This indicator bank is based on the Stewardship Index for Specialty Crops draft metrics, Sustainable Food Lab definitions and approaches, Wal-Mart's Supplier Sustainability Assessment and Leonardo Academy's Sustainable Agriculture Standard. NMB staff provided product integrity indicators.

section of the survey). Following is the data collection approach with each segment of the value chain:

- Producers – online survey, in-person interviews, onsite assessments
- Packing Houses - online survey, in-person interviews, onsite assessments
- Importers – online survey
- Retailers – self-report assessment/telephone interview (described further below)

Surveys were developed in both English and Spanish versions and implemented using Survey Monkey (www.surveymonkey.com). In addition to the online survey an excel spreadsheet was developed that included only questions pertaining to GHG emissions from agrochemicals and third party mango transportation (included as an attachment to this report). A toolkit of instructions, metric conversions, list of documents needed to fill out the survey, help contacts and who to email completed excel spreadsheets to, were also prepared as a component of survey development (included as attachments to this report).

The online survey, the excel spreadsheet and the toolkit were pilot tested with four mango industry "volunteers". This action provided feedback on the detail, process and platforms of the surveys, which was used to finalize the surveys, spreadsheet and instruction toolkit.

Step 3: Finalize & Implement Survey, Develop Field Assessment Plan

The NMB and Common Fields contacted potential survey respondents prior to the distribution of the survey in order to encourage participation. NMB Board members received the survey on June 22, 2010 and all others received the survey 48 hours later. The survey was closed on August 31, 2010 and two e-mail reminders and one follow-up phone call was used to encourage participation and completion.

The survey was distributed to 20 farms and 23 packing-houses in Mexico and to 4 importers in the US. The following disposition table illustrates completion rates within each category of the value chain:

Table 0.2.1 Survey Disposition Table

Category	Distributed to	Attempted	Completed	% Completed
NMB BOD	19	9	6	32%
Non-BOD Importer	3	1	0*	0%
Non-BOD Packing House	22	10	8**	36%
Non-BOD Producer	20	13	7**	35%
Retailer	4	0	0	0%
Totals	68	33	21	31%

*The report includes analysis for one completed importer survey, which was completed by a NBM BOD member.

**These surveys were completed with assistance from the research team while conducting on-site assessments.

As shown in the above table, completion rates of the surveys (including board members) were low and it seemed apparent that the coincidental timing of the Mexican harvest had affected the prioritization of this task for facility managers. However completion rates remained low even once harvest had finished in the southern part of Mexico.

A field assessment plan was developed by Common Fields in conjunction with NMB and finalized to include the following: 1) Common Fields team members and responsibilities, 2) farm and packing-house visit schedule, 3) key on-site indicators to verify and evaluate, 4) case study template, and 5) emergency contacts and other important travel items. To/From country travel arrangements and in country coordination with farms and packing-houses were made by Common Fields.

Step 4: Conduct Field Assessment & Develop Retailer Interview Guide

The onsite assessment was conducted to validate self-reported data from the surveys and to obtain more data where gaps existed. Further, the onsite assessment enabled the research team to obtain data on tree dimensions and productivity data for the carbon sequestration data collection.

A final database of producers and packing-houses to be visited was produced and the visit to them finalized. The Common Fields team spent 12 complete days assessing farms and packing-houses in the States of Chiapas, Sinaloa and Nayarit during August 2010. Four members of the research team conducted onsite assessments during August 2010 with seven farms and eight packing-houses in the states of Chiapas, Sinaloa and Nayarit, as presented in the following map.

Graphic 0.2.1 Map of Mexico and Regions Visited

The Common Fields onsite team used the Survey Monkey survey and GHG spreadsheet as a guide to interview facility managers/operators. In a few cases where the survey had already been filled in beforehand by the facility manager or owner, Common Fields verified the data. During this time Common Fields visited farms and documented additional data on 1) sequestration of CO_2 by mango trees, 2) biodiversity not included in the surveys, and 3) sustainability best practices. A field report was completed and sent to NMB upon the return of the Common Fields onsite assessment team.

A retailer telephone interview was developed (included as attachment to this report) in an attempt to gather GHG emissions related to mango sales. Unfortunately no retailer agreed to participate in the data collection effort.

Step 5: Conduct Analysis of Survey and On-Site Assessment Data

A excel based database was created of responses to the survey and other data captured during the onsite assessment. Survey and GHG emissions and sequestration data were analyzed, including the GHG analysis. Board member survey data were separately analyzed and presented in this report to allow for a separate discussion and comparison overtime.

Step 6: Reporting

The final deliverable is this report that focuses on providing NMB staff and Board of Directors the following:

1. Estimated Carbon Footprint of the mangos imported to the United States (using imports from Mexico as the proxy for this estimate)
2. Baseline performance of social, environmental, biodiversity and product integrity indicators
3. Documented best practices that can be shared broadly with the Mango Industry to inspire change and to inspire contributions to a "best practice database"
4. Opportunities to enhance the industry performance across all indicators
5. Study limitations that affected the quality of the results.

1. US Mango Industry Carbon Footprint

A key objective of this effort was to establish the carbon footprint of the US Mango Import industry. The resources afforded to this project did not allow for a comprehensive review of the mango industry greenhouse gas emissions inventory or carbon sequestration potential of mango plantations. As such, the research team, in collaboration with the NMB made the following assumptions and decisions:

1. Because Mexican mango imports represent approximately 63% of all mangos imported into the US, Mexico would be used as a proxy for the carbon footprint of the US Mango Import industry.
2. A diversity of farms and packing-houses would be selected for on-site data collection. The following criteria were used to select each:
    a. Geographic dispersion across the four growing regions to account for climatic and fruit fly prevention differences: North Sinaloa, Sinaloa, Central and South
    b. Size of farm: small, medium, large
    c. Type of operations: farm only and vertically integrated (with packing-houses)
3. The carbon footprint of one typical mango would be too difficult to ascertain and not meaningful to the industry given the diversity of mango varieties grown and imported and diversity of growing conditions across multiple countries. As such, a key objective was to collect emissions data from as many facilities as possible within each category of the value chain from which a category average could be derived.
4. Emissions are reported in terms of intensity rather than absolute figures and use a 1 kg of mangos as the unit, since this allows a direct comparison to be made across

boundaries. Furthermore, it allows a direct comparison with other agricultural produce where GHG emission intensities are known.

Following are the details of the greenhouse gas emissions inventory and carbon sequestration methodology and findings of the analysis.

1.1 Boundary Settings and Carbon Accounting Methodologies

Process Map and Boundary Setting

Mango production in Mexico is highly diverse being undertaken by small-scale farmers growing mangos on one hectare to large commercial scale farms of several hundred hectares. This heterogeneity is also apparent, although less extreme in the packing-house category where processing facilities may be small, catering to a single farm's production, to large packing-houses catering to several farms of the region. Such diversity within the industry offers particular challenges to sample design and data handling as discussed below. To account for this diversity, the business to consumer (B2C) value chain model (Fig. 1.1.1) was developed in conjunction with the NMB.

Consolidation Approach

This investigation used operational control as the primary parameter for assigning GHG emissions. To ensure that mango transport was accounted for only once in each segment of the value chain this project assigned transportation to the facility that paid for the fuel (Scope 1) or service (Scope 3). Typically, a third party transports mangos between farm to packing-house and packing-house to the border. Transportation between farm and packing-house is sometimes paid for by the farm and sometimes by the packing-house (discussed below). Since the objective of this investigation is to calculate the GHG footprint of the entire mango value chain rather than any individual company or facility this methodology has no bearing on the final result.

Operational Boundary

Indirect and direct GHG emissions were investigated throughout the mango value chain (Fig 1.1.1). Direct or Scope 1 emissions included fossil fuel consumption, fertilizer and other agrochemical use and refrigerant use. Refrigerants used within packing-house cooling machinery were not refilled annually, rather once every two or three years. Only refrigerants refilled in year 2009 (which corresponds to the scope of the analysis) were reported, with the assumption that this would represent an average fill rate over facilities, each year.

Indirect or Scope 2 emissions, as is the convention under the GHG protocol, were confined to electricity consumed from third party suppliers. Indirect or Scope 3 emissions were limited to the embedded energy of agrochemicals (i.e. the energy used to manufacture the agrochemicals, including fertilizers), company business travel by employees on commercial airlines (i.e. calculation of GHG emissions from the jet fuel used to operate the aircraft) and emissions associated with the transportation of mangos by contracted trucking companies (Fig. 1.1.1).

Transport of mangos through the value chain is recognized as an activity with potentially significant GHG related emissions. Most transportation of mangos from farm to packing-house and all transportation from packing-house to the US border was found to be undertaken by third party contractors and hence easily obtained from scope 3 reporting from producers and packers. Importer and retail mango transport was obtained from their scope 1 reporting on fossil fuel use.

An unknown amount of mango transportation however is hidden within scope 1 fossil fuel reporting from producers and packers, since some of the time these entities transported mangos themselves. Scope 1 fossil fuel use is an aggregate of all fossil fuel use, including that used for pumps, generators, farm vehicles and passenger vehicles owned and operated by the company.

Omissions

This inventory did <u>not</u> include embodied carbon of infrastructure, equipment, or input materials other than fertilizers and agrochemicals, used during the production and processing of mangos, including packing materials at the packing-houses. In addition this inventory does not include GHG emissions from solid and liquid waste products produced during the production and processing of mangos. Transportation of material inputs or disposal of wastes was not specifically captured in this analysis unless reported within Scope 1 fuel emissions (see above). This "incomplete" picture will affect the ability to directly compare mango data to GHG emissions associated with other produce. However, since there is no standard for setting boundaries, comparison of data across sectors is inherently difficult to achieve even when a full life cycle analysis is undertaken.

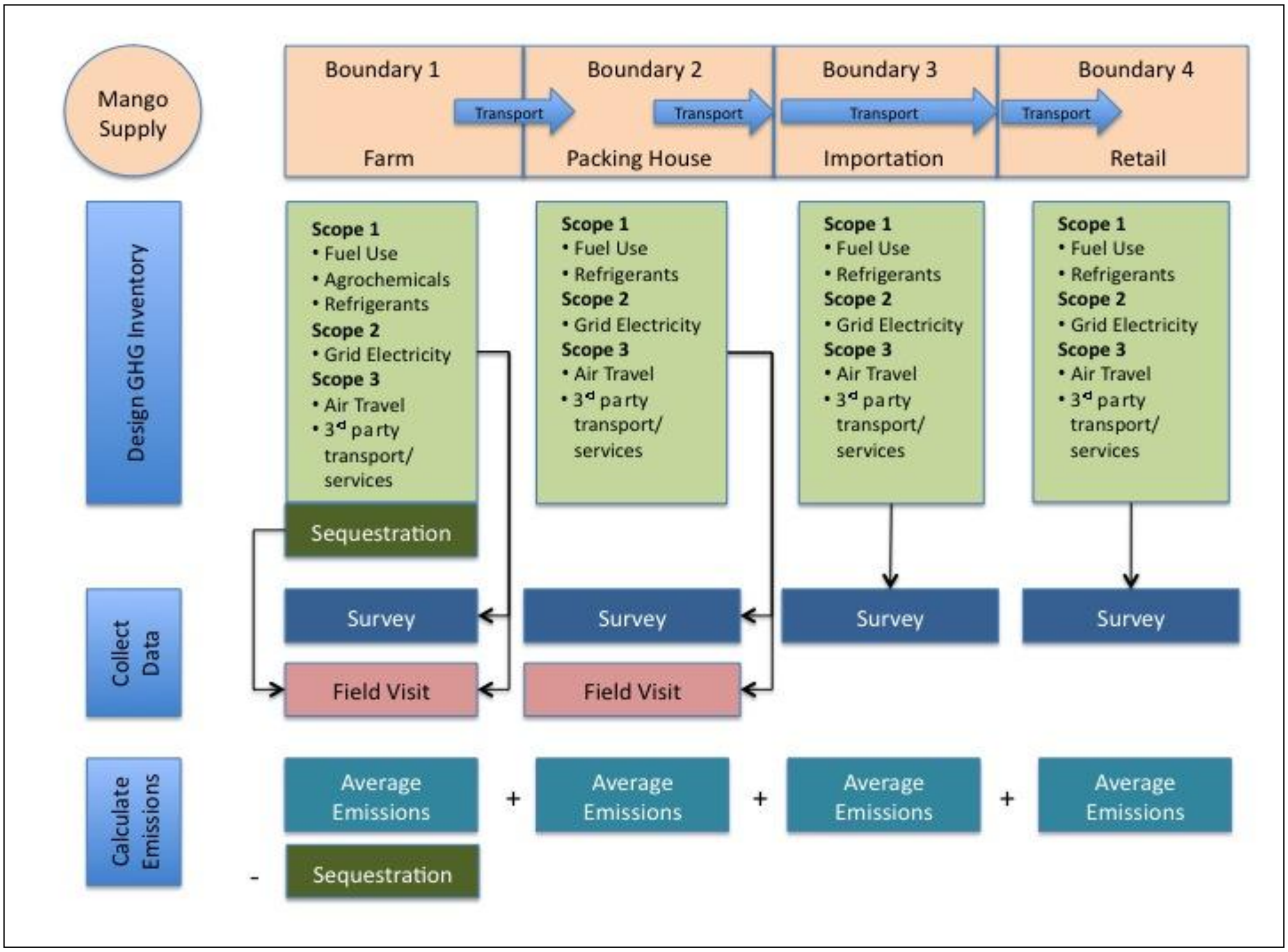

Figure 1.1.1 Data collection process map and boundary setting within the Mexican mango supply chain. [Note: transportation to packing-house can be undertaken by third party, farm or packing-house.]

Sample Design

Four sub boundaries were established for each of the four primary categories that make up the mango value chain. Further, transport was assigned according to operational control as described above in Figure 1.1.1

Functional Unit

The PAS 2050 and ISO 14040 series of LCA standards specify that a functional unit should be defined that describes the unit of analysis for any study. Even though mangos are traded in boxes of 4 kilograms, the analyses in this document are standardized to a one (1) kilogram unit. This allowed for easy comparison both among boundaries of the mango value chain as well as comparisons to other industries where GHG emissions have been reported.

Data Collection

Multiple data collection tools (described in the Assessment Methodology chapter) were leveraged to capture greenhouse gas emission and sequestration potential data: 1) online self-assessment survey (with accompanying greenhouse gas emission data spreadsheet), 2) onsite assessment surveys and 3) telephone interviews.

Data were collected from each value chain category (see Fig. 1 above) as follows:

- Producers – online survey, in-person interviews, onsite assessments
- Packing Houses - online survey, in-person interviews, onsite assessments
- Importers – online survey
- Retailers – online survey, phone interviews (attempted only – no retailer participated)

The following specific greenhouse gas emissions indicators were included in the online survey:

- Scope 1:
    - Fossil fuel (diesel, gasoline and LPG) consumption
- Scope 2:
    - Grid electricity consumption data
- Scope 3:
    - Non-transport related third party services that use fossil fuels such as tree pruning utilizing chainsaws

An accompanying excel spreadsheet captured the following data:

- Scope 1:
    - Fertilizer and other agrochemical use (for farms only)
    - Refrigerant use
- Scope 3:
    - Third party transportation

Surveys were distributed on June 22, 2010 and were closed on August 31, 2010. The survey was distributed (in either English or Spanish) to 20 farms and 23 packing-houses in Mexico and to 4 importers in the US. Four members of the research team conducted onsite assessments during August 2010 on 7 farms and 8 packing-houses in the states of Chiapas, Sinaloa and Nayarit.

Data Analysis

Types of chemicals and their associated release of gases that had global warming potential (GWP) were noted for the calendar year 2009 within each boundary of the supply chain for Mexican mangos. Data were obtained from both surveys and first hand reports.

Exact GWP 100 figures are based upon complex models. It is therefore important to recognize that in any GHG footprint calculation there are basic assumptions about the quality of the models used. In this case we have used calculations and conversions based upon commonly accepted models and supported by major research institutes and international centers for GHG research.

Following is the data analysis approach used to calculate greenhouse gas emissions and carbon sequestration potential:

- Types of chemicals and their associated release of gases that had global warming potential (GWP) were noted for the calendar year 2009 within each boundary of the supply chain for Mexican mangos.
- Agrochemicals and electricity use were converted to CO_2e kg by using conversions found within the "Cool Farm" calculator tool (v. 1.044[15]). The Cool Farm tool uses a country specific conversion factor for national electricity generation based upon the ratio of nonrenewable and renewable resources used in the generation.
- Diesel, petroleum, LPG and jet fuel usage was converted using the EPA's Pollution Prevention Calculator[16] (2008) and associated conversion factors.
- Refrigerants were converted to CO2e by referencing Defra's conversion factor annexes[17] (2007).

15 The Cool Farm Tool. Unilever. http://www.growingforthefuture.com/content/Cool+Farm+Tool

16 EPA Pollution Prevention_P2 Calculator 2008: http://www.docstoc.com/docs/15266613/Greenhouse-Gas-Conversion-Tool---Pollution-Prevention-_P2

17 http://www.defra.gov.uk/environment/busi

1.2 GHG Emissions

Greenhouse gas emissions were calculated from producers, packing-houses and importers and each of their related activities separately (see boundary setting diagram). Emissions are reported in terms of intensity rather than absolute figures and use 1 kg of mangos as the functional unit, since this allows a direct comparison to be made across boundaries. Furthermore, it allows a direct comparison with other agricultural produce where GHG emission intensities are known. For an explanation of the principle GHG emission sources included in these results please see section 1.1 above.

Mexican Orchard GHG Emissions

Seven farm operations were assessed in the field; however one producer provided insufficient information with regards to GHG emissions so it was removed from the analysis. On average 0.229 kg of CO_2 equivalents are produced for each kg of mango fruit produced by the farms visited (Table 1.2.1). The majority (57%) of this comes from the production and use of agrochemicals, notably fertilizers. Scope 1 fossil fuel was used principally for farm vehicles, including tractors and pickup trucks as well as for water pumps, no distinction however was made in this analysis between the various fuel uses when purchased directly by the company being assessed (see section 1.1 above for details).

Table 1.2.1 Emissions from farm operations in Mexico

Emissions in kg CO_2e/ kg product	Scope 1		Scope 2	Scope 3			Total
	Purchased Fossil Fuel	Agro-Chemicals	Purchased Electricity	Agro-chemicals	Truck Transport	Air Travel	
N. Sinaloa	0.03	0.06	0.0002	0.03	0.002	0	**0.11**
Sinaloa	0.02	0.05	0.05	0.03	0.014	0	**0.17**
Sinaloa	0.13	0.11	0.0002	0.04	0.012	0	**0.30**
Sinaloa*	0.10	0.05	0.02	0.05	0.015	0	**0.19**
Nayarit	0.05	0.13	0.00	0.04	0.000	0	**0.21**
Chiapas	0.10	0.14	0.05	0.06	0.014	0	**0.36**
Average	**0.07**	**0.09**	**0.02**	**0.04**	**0.009**	**0**	**0.229**
Confidence (95%)	**0.068**	**0.04**	**0.019**	**0.01**	**0.007**	**0**	**0.072**

[**Note**: Asterisk represents a board member owned farm. Scope 1 agrochemicals indicate the CO_2 and N_2O emissions related to the use of the chemicals while Scope 3 emissions are related to the manufacture of the chemicals.]

Electricity was primarily used for pumps and sometimes for farm buildings, although many farms did not have buildings on the property. Electricity use was therefore found to be highly variable since some farms used water from irrigation canals where the use of electricity was unnecessary.

The use of fertilizers (number and amount per hectare) was found be highly variable contributing to the large range of values and confidence interval for Scope 1 emissions. The use of agrochemicals is discussed further below.

The large variation in the data and the few data points available to this study means that we have to throw some caution to these results. The confidence interval, calculated at a probability threshold of 95%, is high (0.072), suggesting that these results are liable to change as more data are added. However this assessment has allowed us to understand the variability in the mango production process and the variability that occurs over a large portion of the country, including those areas most important to mango production in the country. It is the belief of the researchers that the magnitude of these results is correct and can be used as a guide for the interim until more data is obtained.

In addition to the Mexican board member included in the above Mexico analysis, analysis was conducted with data provided by an additional board member associated with production enterprises in the US and Brazil. However, it should be noted that they only partially completed the online survey and accompanying spreadsheet (Table 1.2.2).

Table 1.2.2 Emissions from farm operations for Board members in countries other than Mexico

Emissions kg CO_2e / kg product	Scope 1		Scope 2	Scope 3			**Total**
	Purchased Fossil Fuel	Agro-Chemicals	Purchased Electricity	Agro-chemicals	3rd party service Fuel	Air	
USA	0.002	?	0.003	?	?	?	**0.005**
Brazil	0.002	?	?	?	?	0	**0.002**
Average	**0.002**		**0.003**			**0**	**0.005**
Confidence (95%)	**0.000**						

[**Note**: A question mark indicates missing or non-entered data.]

The results of the board member surveys were not complete and hence we could not undertake an entire analysis.

Packing House Emissions

On average 0.192 kg of CO_2 equivalents are produced for each kg of mango fruit processed by the packing-houses visited (Table 1.2.3). This result includes transportation to the US-Mexican border. Scope 1 fuel is divided between vehicle use, which sometimes included transportation of mangos from orchards to packing-houses, and heating of hot water tanks (LPG) for the treatment against fruit fly larvae, where relevant. In some packing-houses, water was heated using electricity rather than LPG. Due to the variation in energy source and the use of disaggregated data for fossil fuels it is unclear from our data whether the use of the hot water treatment had a significant effect on total emissions. Although each packing-house had an emergency electricity generator powered by diesel in no instance was it used on a regular basis and was largely irrelevant to the overall fuel usage. We speculate that the principal electricity use for packing-houses is for the cooling machines that must keep the cool rooms at a stable temperature of 55°F.

Table 1.2.3 Emissions from packing-house operations up to US-Mexican border

Emissions in kg CO_2e / kg product	Scope 1	Scope 2	Scope 3		**Total**
	Fuel	**Electricity**	**Truck Transport**	**Air**	
N. Sinaloa‡	0.0204	0.0211	0.2554	0	**0.2969**
N. Sinaloa‡	0.00005	0.0083	0.0898	0.0009	**0.0991**
Sinaloa	0.0193	0.0251	0.0742	0	**0.1185**
Sinaloa	0.0214	0.0433	0.1042	0	**0.1689**
Sinaloa*	0.0133	0.0579	0.1664	0	**0.2376**
Nayarit	0.0697	0.0238	0.0587	0	**0.1521**
Nayarit	0.0306	0.0049	0.1186	0.00004	**0.1541**
Chiapas	0.1194	0.0279	0.149	0.0032	**0.2995**
Average	**0.037**	**0.027**	**0.127**	**0.001**	**0.192**
Confidence (95%)	**0.04**	**0.01**	**0.06**	**0.001**	**0.08**

[**Note**: that although refrigerants were used extensively none were used with GWP.]

* Represents a board member owned packing-house; ‡ Packing-houses that do NOT incorporate fruit fly control during processing.

However, the majority (66%) of the total emissions for the packing-house were through the transportation of mangos from the packing-houses to the distribution centers at the national border. Some facilities reported that trucks transporting mangos returned empty from the border DC to the packing-house, while others reported that all or a fraction returned carrying another cargo. Fuel used during an empty return trip would be associated with mango transportation even though the truck is not transporting mangos during this leg of the journey. The GHG emissions associated with a return journey transporting another commodity would belong to the commodity being transported. Few facilities appeared to send staff on business trips by air.

As before, non-Mexico board member responses were separately analyzed and information was obtained for one enterprise in Brazil (Table 1.2.4).

Table 1.2.4 Emissions from packing-house operations for Board Members in countries other than Mexico

Emissions in kg CO_2e / kg product	Scope 1	Scope 2	Scope 3		**Total**
	Purchased Fuel	**Electricity**	**Truck Transport**	**Air**	
Brazil	0.0792	0. 015	?	?	**0.094**

[**Note:** A question mark indicates missing or non-entered data.]

The information was incomplete for GHG emissions and could not be used to undertake a full analysis.

Importer Emissions

Importer emissions data were derived from only one respondent who was also a board member from Mexico (Table 1.2.5). The use of just one data point for this part of the value chain has inherent problems in terms of industry wide representation. However, it is included here to provide a more complete GHG emission assessment up to the point of the US distribution center before retail.

Table 1.2.5 Emissions associated with import of mangos from Mexico to US

Emissions in kg CO_2e / kg product	Scope 1	Scope 2	Scope 3		**Total**
	Purchased Fossil Fuel for Transport	**Purchased Electricity**	**Transport**	**Air**	
	0.0017	0.0216	0.00	0.0025	**0.0258**

Retailer Emissions

Retailer associated emissions, or boundary 4 emissions (Fig. 1.1.1), is the final part of the total emission scenario accounted for in this analysis.

Unfortunately no retailers were able to provide information to us on transport related fuel consumption, other fuel uses, electricity or air transport. Since we had no direct data we used indirect data to provide a working emissions figure, until direct data could be obtained at a later stage. For the sake of ease we only calculated emissions related to transportation of mangos from the importer DC to the retail DC, assuming that local transport to retail outlets and energy use while at the retail outlet were relatively insignificant.

We know from our onsite data that each pallet contains 204 boxes of mangos and each box weighs on average 4.2kg (NMB, pers. comm.), or that each fully laden pallet contains 856.8 kg of mangos.

Likewise we know that each 53 x 9 ft trailer contains 26 pallets[18] for a total of 22,2768 kg of mangos when fully laden.

We then took an average destination within the continental lower 48 states of the US to calculate an average road distance that a truck would have to travel to reach a retail DC. We chose St Louis MO as that average point and calculated the road distance to be 2049.45 km[19] .

We took the average fuel efficiency to be 6.6 mpg[20] for heavy trucks. Assuming that trucks do not make empty return journeys we calculated that an average journey from importer DC to retail DC would emit 1949.5 kg of CO_2e or 0.008751 kg CO_2e/kg mango.

Total Emissions of Mangos from Mexico

Total GHG emissions from mango production to the US retail distribution centers, therefore average 0.4556 kg of CO_2e per kg of mango. The majority of emissions, 32.13% and 28.53%, are from transport from packing-houses in Mexico to US distribution centers within the US and agrochemicals respectively (see Table 1.2.6). Some transport of mangos is likely to be included within the scope 1 fossil fuel category since production and packing operations reported fuel usage as a global amount which was not disaggregated into transport and other mechanical operations requiring fossil fuels such as heating of water tanks. We do not

---

[18] From http://en.wikipedia.org/wiki/Cargo#Truckload_freight

[19] From http://distancecalculator.globefeed.com/

[20] From Huai et al 2006, Atmospheric Environment 40, 2333-2344

believe that the transport component within the scope 1 fuel category is significant however.

Table 1.2.6 Total emissions by type during the production of mangos from field to retail distribution center

	EMISSIONS FROM:				
TOTAL EMISSIONS kg CO_2e / kg product	**FOSSIL FUEL USE**	**TRANSPORT OF MANGOS THROUGH VALUE CHAIN**	**AGROCHEMICAL USE IN MANGO PRODUCTION**	**GRID ELECTRICITY**	**BUSINESS AIR TRAVEL**
0.4556	0.107	0.1464	0.130	0.0686	0.0035
100%	23.48%	32.13%	28.53%	15.06%	0.77%

Over half of all emissions (50.26%), not unexpectedly, come from the production of mangos, while 42.14% (Table 1.2.7) come from packing emissions, together contributing over 92% of total emissions to the mango value chain.

Table 1.2.7 Total emissions partitioned to boundary divisions

kg CO_2e / kg product	**Sub-Boundary 1 Producers**	**Sub-Boundary 2 Packers**	**Sub-Boundary 3 Importers**	**Sub-Boundary 4 Retailers**
Total Emissions (% of total)	0.229 (50.26%)	0.192 (42.14%)	0.0258 (5.66%)	0.008751 (1.92%)

1.3 GHG Emissions – Summary and Mitigation Strategies

The data presented here provide a preliminary estimate of the greenhouse gas emissions associated with US Mango Imports Industry.

It should be noted that greenhouse gas emissions analysis is a fundamentally complex process with many data points being consolidated into single figures. Errors in the data can easily become compounded and hence it is necessary that primary data is correct. These data, although giving an indication of greenhouse gas emissions associated with the growing and commercialization of mangos from Mexico for the US consumer, do not provide the entire story of the carbon footprint of the mango for several reasons.

1. Firstly there are several gaps in the data. Most obviously it was not possible during the course of this study to acquire direct information from retailers. This analysis did not include embedded emissions of material inputs and infrastructure.
2. Secondly, a much larger data set is needed to provide confidence in the numbers. A single importer cannot provide representative information for this value chain category and hence we must use caution when using this particular data point or the estimate of retailer emissions in making any assumptions or decisions.
3. Thirdly, through the onsite data collection process and analysis data quality issues were identified, which is nearly always the case with self reported data and the reason for on-site verification. The majority of data quality issues related to a lack of response to survey questions both in their entirity and also in part. Many surveys that had been started were not finished. Other data quality issues related to a misunderstanding of the question, while others showed inconsistency with the majority of other data points reported by other facilities.

These limitations withstanding, the use of agrochemicals and transport of mangos together, account for approximately 60% of the industry's GHG emissions. The use of agrochemicals makes production the boundary's most significant GHG contributor. The use of agrochemicals makes production (boundary 1) the most GHG intensive phase of the mango value chain. If agrochemicals (including fertilizers) were not used in production, the total emissions of the value chain could be reduced by approximately 30%, while the production phase would only contribute 30.41% to the industry’s total GHG emissions. In this scenario packing would contribute almost 60% of the GHG emissions, two thirds of this coming from its trucking activity to the US border.

Agrochemicals, especially fertilizers, are major GHG emitters. A major source of GHGs is from the production of synthetic fertilizers, which are commonly manufactured by using natural gas. The production of synthetic ammonia, a common precursor of fertilizers, currently consumes about 5% of global natural gas supplies, which is equivalent to just under 2% of world energy production.

Fertilizer use also contributes to GHG emissions in the form of nitrous oxide and methane. Through the increased use of nitrogen fertilizer, which is currently used at a global rate of approximately 1 billion tons per year, nitrous oxide (N_2O) has become the third most important GHG emitted after carbon dioxide and methane. It has a global warming potential 296 times larger than an equal mass of carbon dioxide and it also contributes to stratospheric ozone depletion. In the data presented here GHG emissions associated with the use of agrochemicals (0.09 kg CO_2e/kg product) was more than double the amount emitted during their production (0.04 kg CO_2e/kg product) mostly through the emission of N_2O during application.

A large variation in fertilizer use was observed between farms, both in number of products and intensities used. A future study might examine the best practice of agrochemical use (see the biodiversity section on toxicity of agrochemicals used), since not only could a more scientific approach to agrochemical use cut toxicity and harmful environmental effects but it could also significantly cut GHG emissions.

The transport of mangos across the value chain is a substantial contributor to the total GHG footprint of mangos. In order to reduce emissions from this process the following might be considered: 1) Optimizing haulage so that full loads are always used, 2) Reduce or eliminate empty return trips, 3) Seek third party trucking companies with fleets that have the best fuel efficiency, 4) Regularly maintain vehicles and acquire fuel-efficient fleets.

Fossil fuel use was the third largest contributor to GHG emissions within the carbon footprint of mangos, followed by electricity.

Fossil fuel use data was obtained as a global amount from each facility and included the fuel used to operate all company vehicles, generators, pumps and appliances that ran on either gasoline, diesel, LPG or natural gas. It is more difficult to recommend mitigation actions for this category since exact proportions of fossil fuels used for particular operations are unknown. We speculate however that changing irrigation methods to drip and dispersion from flood or higher water intensity methods would reduce GHG emissions from pumping machinery that is likely to reduce mango production related emissions significantly. Increasing the fuel efficiency of vehicle fleets, and switching motors and engines to LPG or natural gas would also reduce emissions.

All electricity was sourced from the grid, and apart from onsite emergency generators, no onsite generation occurred. The regions of Sinaloa, Nayarit and Chiapas are noted for the number of sun filled days that occur during the year, yet not one facility used photovoltaic panels. Renewable energy systems, especially the use of photovoltaic cells is an obvious way in which GHG emissions could be reduced. A further reduction in electricity might be achieved through more efficient use of the cool rooms. One way in which this could occur is to partition the rooms so that only sections that contain produce need to be cooled, rather than the entire room at any one moment. This would have to be investigated and suggestions made on a case by case basis. Increasing the energy efficiency of the packing-houses and other farm buildings, as discussed further in the environmental chapter of this report, will also serve to decrease electricity consumption and subsequently the greenhouse gas emissions of mango production.

Studies of other agricultural produce were examined to provide a comparison with this preliminary estimate. Unlike many of the other studies, due to resource constraints and access to necessary data, this study did not include a full life cycle analysis and did not include emissions from material inputs such as packaging. However, the preliminary estimate suggests (Table 1.3.1) that mangos fare well in comparison to other fruit and vegetable commodities such as tomatoes, much of which are grown in greenhouses that require heating and thus have elevated emissions related to fuel use. A more in depth study of mango production and processing will yield greater insight into its impact in comparison to other commodities.

Table 1.3.1 Comparison of life cycle GHG emissions from agricultural produce per kg of product

Food Item	GHG Emissions (kg CO2e/kg	Country	Source
Beef (from dairy farm)	14	Sweden	LCA Food 2001[21]
Cheese	8.8	Sweden	Berlin 2002[22]
Semi-skimmed milk	1.0	Sweden	LCA Food 2001
Frozen flatfish fillet	20.9	Denmark	Thrane 2006[23]
Carrot[1]	0.3-0.6	Sweden, Denmark, Netherlands, UK, Italy	Carlsson-Kanyama 1998[24]
Carrot puree	1.5	Sweden	Mattsson 1999[25]
Tomatoes[1]	0.8-5.6	Denmark, Netherlands, Spain, Sweden	Carlsson-Kanyama 1998
Rice[1]	6.4	USA	Carlsson-Kanyama 1998
Bread	0.19-0.4	Sweden	Sundkvist et al.2001[26]
Cereal-based baby food	2.0	Sweden	Mattsson and Stadig 1999[27]

---

[21] LCA Food 2001. The environmental impact of food from origin to waste: interim report from LCA food project. Stockholm, LRF The Federation of Swedish Farmers.

[22] Berlin J 2002. Environmental Life-Cycle Assessment (LCA) of Swedish semi-hard cheese. International Dairy Journal 12: 939–953.

[23] Thrane, M 2006. LCA of Danish fish products. International Journal of LCA 11(1): 66–74.

[24] Carlsson-Kanyama A 1998. Food consumption patterns and their influence on climate change. Ambio 27(7): 528–534.

[25] Mattsson B 1999. Environmental life cycle assessment of organic and integrated production of carrot puree. Paper 1 in B Mattsson 1999 „Environmental Life Cycle Assessment (LCA) of Agricultural food production, PhD thesis. Alnarp, Swedish University of Agricultural Science.

[26] Sundkvist A, Jansson AM, Larsson P 2001. Strengths and limitations of localizing food production as a sustainability building strategy: an analysis of bread production on the island of Gotland, Sweden. Ecological Economics 37: 217–227.

Potatoes – King Edwards[1]	0.6	UK	Tesco 2008[28]
Kiwi	1.74	New Zeaand	Mithraratne et al. 2008[29]
Mango[2]	**0.4556**	**Mexico**	**This report**

[1] Transport from retailer to consumer not included.

[2] Transport downstream of retail DC not included. Not a full LCA.

Source Mithraratne et al 2008[25]

1.4 Carbon Sequestration Potential

Photosynthesis is the process that describes the conversion, by plants, of carbon dioxide from the atmosphere into carbohydrates (sugars) using solar energy. The sugars in their various forms become part of the living plant biomass (trunk, branches, roots and leaves) as it grows and are also used for internal energy needs. The photosynthetic process of plants is vital for climate cooling since they regulate the concentration of atmospheric carbon dioxide (CO_2), an important greenhouse gas, which may otherwise increase to concentrations that cause global warming. Agricultural expansion has been culpable of destroying much of the world' s forests thereby reducing the planet' s potential to sequester carbon from the atmosphere. However perennial crops such as orchards can also sequester carbon. It is essential therefore to know what this potential is and how to maximize it.

---

[27] Mattsson B, Stadig M 1999. Screening life cycle assessment of organic and conventional production of a cereal based baby food product. Paper 2 in B Mattsson 1999 „Environmental Life Cycle Assessment (LCA) of Agricultural food production, PhD thesis. Alnarp, Swedish University of Agricultural Science.

[28] Tesco 2008. Carbon labelling and Tesco. Available at: http://www.tesco.com/assets/greenerliving/content/pdf/Carbon_Labelling_and_Tesco.pdf

[29] Mithraratne et al. 2008. Carbon Footprinting for the Kiwifruit Supply Chain. Landcare Research Contract Report: LC0708/156 MAF Contract No. GHG0708-A

The International Panel on Climate Change (IPCC[30]), a U.N. body which received the 2007 Nobel Peace Prize, in 2006 recognized that perennial woody vegetation in orchards, vineyards, and agroforestry systems can store significant carbon in what they term long-lived biomass. The amount stored depends on species type and cultivar, density, growth rates, and harvesting and pruning practices. The benefits of maximizing sequestration potential are large and include achieving carbon neutrality within farm operations as well as local climate stabilization among others. A stable local climate, in terms of rainfall and temperature is very important for agriculture to thrive as well as for natural ecosystems.

Why report on Sequestered Carbon?

It is generally recognized that changes in stocks of sequestered carbon and the associated exchanges of carbon within the atmosphere are important to national level GHG emissions inventories, and consequently, these impacts on sequestered carbon are commonly addressed in national inventories. Similarly, industries such as the mango products industry can have a potentially high overall impact on atmospheric CO_2 levels through carbon sequestration as a result of their growing operations. Some tree based product companies have begun to address this aspect of their GHG footprint within their corporate GHG inventories.

Moreover, the World Business Council for Sustainable Development, Sustainable Forest Products Industry Working Group, which represents a significant cluster of integrated forestry companies operating internationally, is developing a project that will further investigate carbon measurement, accounting, reporting, and ownership issues associated with the forest products value chain. Information on a company’s impacts on sequestered atmospheric carbon can be used for strategic planning, for educating stakeholders, and for identifying opportunities for improving the company’s GHG profile. Opportunities may also

---

[30] IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

exist to create value from reductions created along the value chain by companies acting alone or in partnership with raw material providers or customers. Accounting for sequestered carbon in the context of the GHG Protocol Corporate Standard Consensus methods have yet to be developed under the GHG Protocol Corporate Standard for accounting of sequestered atmospheric carbon as it moves through the value chain of biomass-based industries.

Assumptions Boundaries and Calculations

This preliminary analysis of mango orchards in Mexico has the principal objective to derive above ground carbon stocks and sequestration rates among mango trees of the farms visited by the research team. Baseline carbon data was not incorporated (previous use or natural state), turnover data such as thinning or timber harvesting, soil enrichment (from pruning) or non-mango carbon data into our calculations, since these were out of scope for this phase of the project. It was assumed that all woody waste was stored long term and none was burnt. Although this assumption was not universally true since some wood was sold and used for cooking stoves, all farms incorporated prunings and woody debris into the soil as a normal management practice.

In order to provide additional data to those that currently exist the research team measured the above ground standing carbon stock within mango trees among 7 farms in Mexico, that currently export to the US market. From the standing carbon stock data the sequestration rate of carbon by mango trees within the Mexican production context was calculated. These data are seen as a first phase attempt to understand carbon dynamics within the mango forestry system of Mexico. Future research efforts could consider carbon dynamics in terms of mango tree classes (e.g. stem, branches, and foliage), their growth, mortality, management and end use. Further studies may also investigate associated carbon pools such as intercrop and ground cover as well as soil carbon dynamics. In future phases it will be important to consider undertaking these analyses along geographic and environmental clines in order to gain an understanding of how carbon sequestration changes in response to external variables.

To estimate above ground biomass (AGB) in Mexican mangoes the allometric equations were used according to the following formula.

(1) $AGB = ri \exp(-0.667 + 1.784 \ln(DBH) + 0.207(\ln(DBH))^2 - 0.0281(\ln(DBH))^3)$

Where DBH = diameter at breast height (cm); ri = species specific wood density value (g cm^{-3}) of tree[31].

Equation 1 was specifically constructed for dry forests. However the assumption was made that since one species of tree (*Mangifera indica*) was being analyzed it would serve as a better comparison to use the same equation across climatic zones. Climatic data was confirmed by the Mexican National System of Meteorology website (http://smn.cna.gob.mx/climatologia/climaMex.html), which suggested that although Chiapas attracts a very different climate than Northern Sinaloa (Fig. 1.4.1), they are both prone to extended dry periods during the year. The use of this equation for Chiapas grown mangos will only underestimate carbon content, compared to using another equation that is intended for use for tree growing in humid environments. These assumptions and use of this equation or others should be reviewed as better estimates of biomass from tree diameters are formulated.

AGB was multiplied by 47% to derive carbon content which is an intermediate carbon content for tropical trees and conservative compared to the 50% used in the investigation by ECCM (2005) and generally recommended by the IPCC (2006). Trees from different age classes were grouped and mean carbon content / tree from each age class calculated. An annual increment of carbon sequestered was calculated from the gathered data. Note that the weight of CO_2 is 3.67 times the weight of carbon.

---

[31] Chave J., Andalo C. et al. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145, 87-99.

Figure 1.4.1. Precipitation data of Mexico showing the difference between the extreme south western region of Chiapas with the north western region of Sinaloa and Nayarit. Source, ATLAS GEOGRÁFICO Del MEDIO AMBIENTE Y RECURSOS NATURALES 2006.

These data are presented as a first phase to understanding more about carbon sequestration dynamics within mango trees in Mexico and assume many things about production, tree densities, age class proportions and turnover of wood debris among others and do not take into account natural vegetation conversion. However, this preliminary analysis lays the foundation for a more detailed study of GHG emissions and sequestration in the future.

1.5 Sequestration Results

Tree measurements at breast height (1.3m) were entered into a table and a scatter plot drawn (Fig. 1.5.1). It was evident that even with the use of the single equation (1) to estimate tree biomass that Chiapas trees grew significantly faster and sequestered more carbon than those in the north of the country. We therefore decided to treat the two tree types separately in subsequent calculations.

Chiapas Trees

A best fit polynomial regression curve was adapted to the Chiapas sequestration data. The function $y = -0.0016x^4 + 0.0269x^3 + 1.9204x^2 + 8.8945x - 10.246$ was found to best explain the sequestration curve of Chiapas trees up to age 30 at which age a tree could harbor an estimated 1415.25 kg of carbon (Fig. 1.5.1). The average carbon content of trees, assuming equal proportions of all ages between 1 to 30 years is 645 kg of carbon. This equation also suggested that trees of age 18-19 years sequester the most carbon at 67 kg per year (Fig. 1.5.2). This amount of carbon is equal to 246 kg of atmospheric carbon dioxide. Assuming that there are equal proportions of age classes of mango trees from 1 to 30 yrs old and that there are 33 trees per hectare (average observed in Chiapas), each ha of mango trees would contain on average 21.3 tonnes of carbon and sequester 1.5 tonnes of carbon or 5.7 tonnes of atmospheric carbon dioxide per year.

Sinaloa and Nayarit Trees

The best fit polynomial regression function $y = -0.0004x^4 - 0.0035x^3 + 1.2655x^2 - 7.28x$ was found to best explain the sequestration curve of Sinaloa and Nayarit mango trees up to age 35 at which age a tree could harbor an estimated 545 kg of carbon (Fig. 1.5.1). The average carbon content of trees, assuming equal proportions of all ages between between 1 to 35 years is 242 kg (Figure 1.5.2). This equation suggested that the maximum sequestering potential of these trees occurred at age 21 when approximately 26 kg of carbon or 95 kg of atmospheric carbon dioxide is sequestered annually per tree (Fig. 1.5.2). Again, assuming an equal distribution of age classes from years 1 to 35 among orchards and that there are 162 trees per hectare (averaged over farms from these regions), each hectare would contain approximately 39 tonnes of carbon and on average sequester 2.5 tonnes of carbon or 9.2 tonnes of atmospheric carbon dioxide per year.

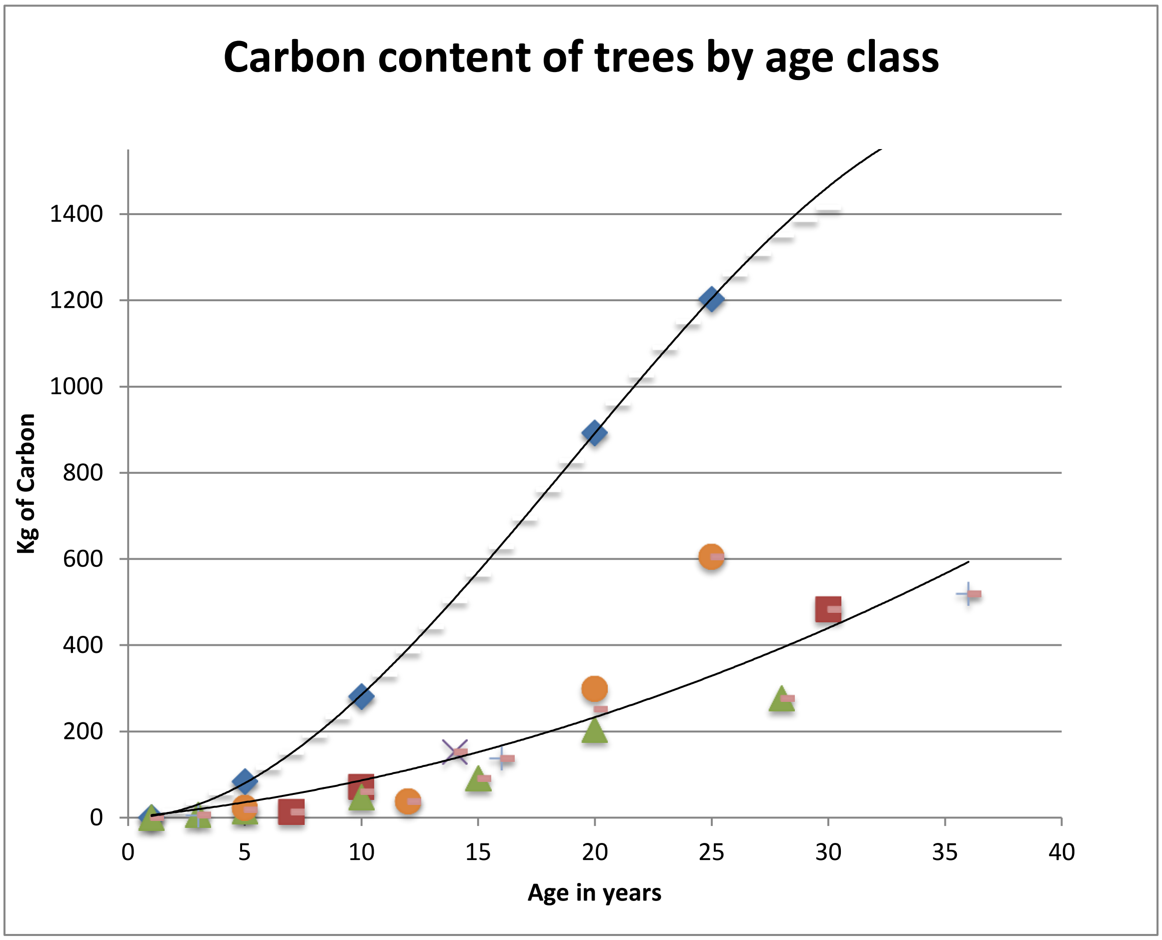

Figure 1.5.1 Carbon content per tree by age class from orchards in Mexico

[Note: Diamonds represent trees from the southern state of Chiapas, crosses (+) are from Nayarit and the remainder are from Sinaloa. **–** represents the average of Sinaloa and Nayarit data. Polynomial trend lines were calculated for Chiapas and an average of all others trees, separately.]

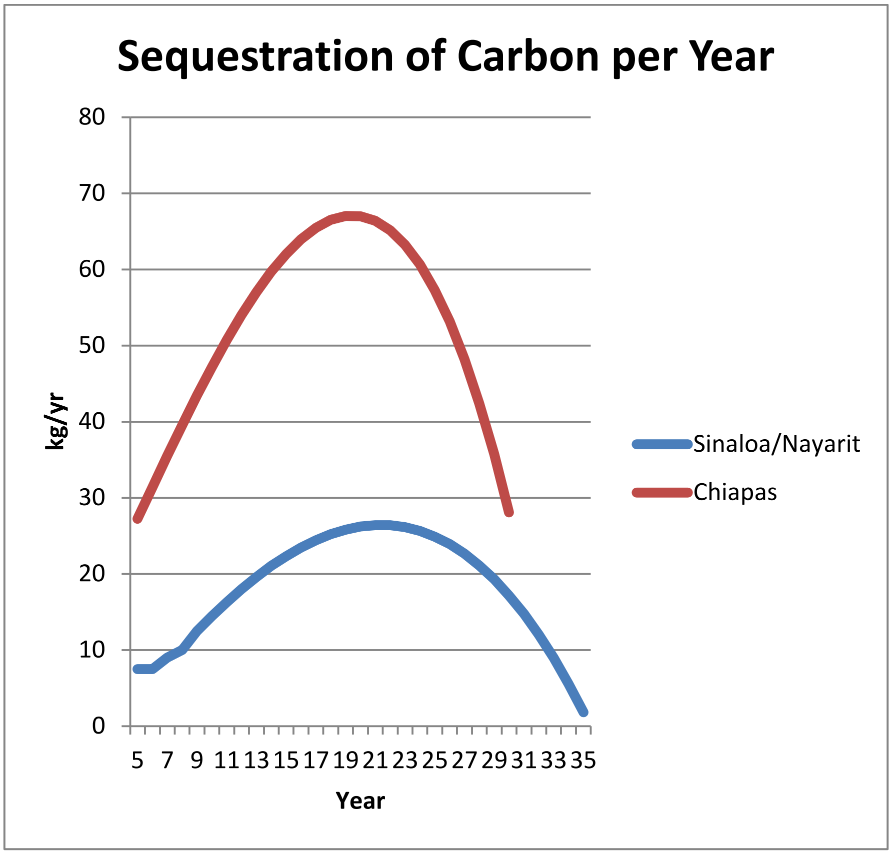

Figure 1.5.2. Carbon sequestration by mango trees.

[**Note**: that CO_2 weighs 3.67 times as much as carbon]

1.6 Productivity

One goal of this effort was to elucidate how much CO_2e is produced by the production and processing of mangos that are sold in US retail stores and relatively how much is offset by the growth of trees. Although, from the above calculations, the approximate rate of capture of CO_2 per mango tree was identified, what was not known is how many kg of mangos, and hence how much CO_2 was emitted by that production, could be produced per mango tree. The research team hence set out to investigate the productivity of an ideal tree over its lifetime.

Although mango production in Mexico occurs at many scales and geographic locations, the team attempted to calculate an approximate production figure for one tree over its assumed lifetime of 50 years. This was accomplished by collecting production data from single age stands from as many orchards as possible. This information helped to fill the gaps in knowledge by extrapolating across ages. It was also assumed that a mango tree maintains a steady production level after age 16 years, an age confirmed by several of the producers interviewed. This calculation is only as good as the data for the years in which data was available and it is assumed that these years are representative of the 50 year productive life of a mango tree.

Data were used from two farms separated by approximately 100km in Sinaloa. One farm provided production data from 16 different age class stands from 2006 to 2009 and included trees aged 5 to 24 years. A second farm provided production data from 7 orchards during the years 2007 to 2010 of trees aged 11 through to 14 years. In total 80 data points were obtained over 20 production years. Outlying data points were removed based on the assumption that these were caused by prior year prunings, weather anomalies or disease and hence were not representative of normal production for that age class.

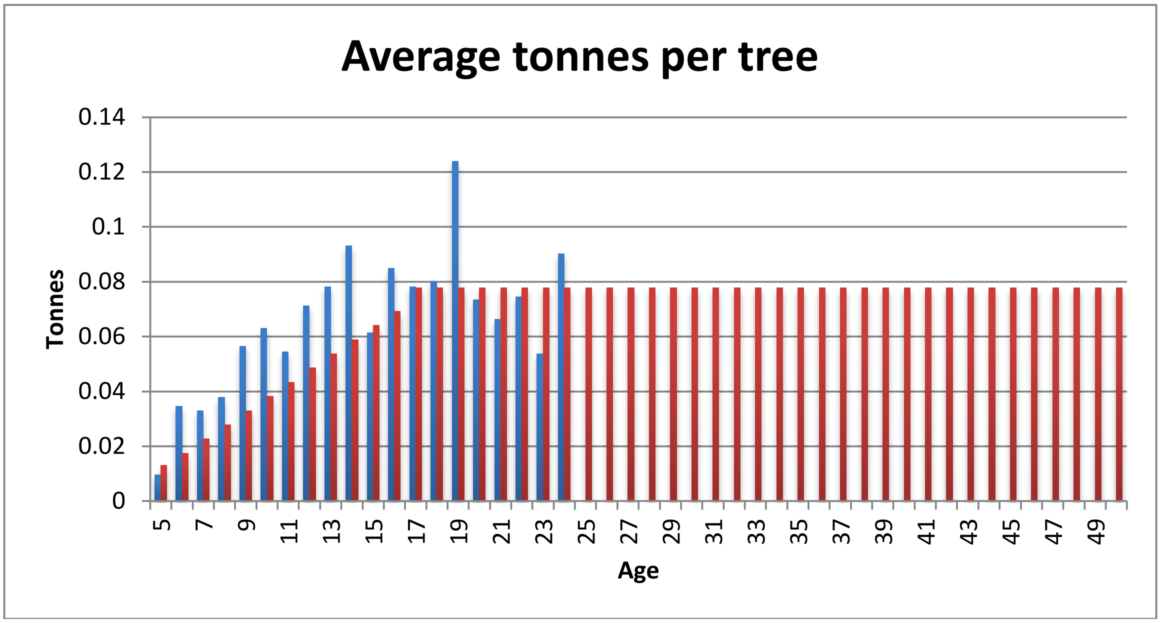

Figure 1.6.1. Average tonnes of mangos produced per tree by age.

[**Note:** Blue bars represents actual data averaged over orchard per year class. Red bars show the model produced by calculating average yearly increments from years 5 to 16. It was assumed that production remains the same from years 16 to 50.]

Production data was obtained in tonnes per hectare (ha), which was then transformed to tonnes per tree by dividing by the density of trees planted per ha on the farms from where data was derived. Production by age class was averaged to produce the following bar chart (Fig. 1.6.1, blue bars). In order to extrapolate the data to year 50, a simple model was used in which production was assumed to increase linearly from years 5 to 16 and that production does not increase from year 16 onwards. First, production was averaged from years 16 to 24 years from the data to find that average production per tree was equal to 0.075 tonnes/yr during this period. Increments were then divided equally from minimum production in year 5 to the maximum obtained in year 16 over the 11 intervening years to create the bar chart in Fig. 1.6.1 (red bars). This model is conservative, as can be seen by the shorter red bars compared to blue, for the production years 5 to 16 but is less so from 16 onwards.

From these data it was calculated that the average tree during its production life of 50 years could produce approximately 3.13 tonnes of mangos that are sent to the packing-house.

This data and analysis findings were anecdotally confirmed with farm managers and growers and there was general consensus over timing of production onset and age at which mangos reach maximum annual production. Since no farm visited had trees over 35, it is difficult to say if mangos do indeed continue producing at the maximum rate up to 50 years of age in Mexico.

1.7 CO_2 Emissions and Sequestration of Mangos

It was found that trees growing in Chiapas could sequester carbon at approximately three times the rate than trees growing in other regions of Mexico analyzed in this study. One explanation could be that the moist warm climate in Chiapas permits growth all year round. Large differences were not found in management techniques, the only one being that the managers of orchards in Chiapas allowed cattle to graze, whereas none in the orchards of the north allowed this practice. This however is not viewed by the research team as a significant factor for the growth of trees.

Table 1.7.1 Modeled productivity and sequestration of mango trees, by age

Tree age	***Yr 30***	***Yr 35***	***Yr 50***
Mango Production kg (total to year)	1580	1970	3130
CO_2e kg Emitted (total to year)	719.69	897.34	1425.71
CO_2 kg sequestered (Sinaloa/Nayarit)	1840	2000	
CO_2 kg sequestered (Chiapas)	5193		

From our caculations above, it was found that a tree could produce approximately 3.13 tonnes of mangos during its 46 years of production, from years 5 to 50 which would have associated CO2e emissions of 3130 x 0.4556 kg CO_2e or 1.426 tonnes of CO_2e (Table 1.7.1) due to production, processing and transportation of fruit.

At age 30, Sinaloa and Nayarit trees would have sequestered 1840 kg of CO_2, yet through the production and processing of mangos would have emitted only 719.69kg (a ratio of 2.55:1). At age 35 that relationship would be 2000 kg sequestered and 897.34 kg emitted (ratio of 2.20:1)

On the other hand a tree of age 30 in Chiapas would have sequestered 5193 kg of CO_2 and produced 719.69 kg of mango fruit related emissions (a ratio of 7.22:1). One should note that production figures are modelled from Sinaloa orchards and production figures may differ in Chiapas. If it is assumed that there exists equal proportion of tree ages in all the orchards then one can expect that on average these figures hold true as an annual ratio of sequestration to emissions no matter what geographical scale or unit is being measured.

Although we have found that sequestration of carbon by mango trees compensates for the GHG emissions measured by this analysis, these data must be interpreted with caution. The GHG inventory did not incorporate a full LCA of GHG emissions and it is based upon few data points (see above for discussion). Furthermore the carbon footprint has not taken into account the GHG release from land conversion from natural vegetation to mango plantation, nor undertaken a full LCA of the woody debris post mortem of trees or tree parts nor incorporated soil carbon dynamics into the model.

Agriculture is a significant global polluter and globally contributes 31% of CO_2 equivalent gases (CO_2e) in the form of CO_2, CH_4 and N_2O, to the atmosphere[32]. Historically land-use change from native vegetation to intensive agriculture would have contributed greatly to human induced CO_2 emissions. However, agriculture is important not only because of the potential to reduce its own emissions, but because of its potential to reduce net emissions from other sectors. Agriculture can remove carbon dioxide out of the atmosphere and store it as carbon in plants and soils. Hence, through careful management of soils and organic waste products, agricultural lands can act as net CO_2 sinks[33]. Indeed, in the US it is estimated that if farmers widely adopted best management techniques to store carbon, and undertook cost-effective reductions in nitrous oxide and methane, total U.S. greenhouse gas emissions could be reduced by 5 to 14 percent[34].

The data presented here do provide a good understanding of emissions and regional variation of sequestration, however additional data would provide a more robust model that increases the boundaries of the GHG emission inventory and the dynamics of tree growth and productivity from different areas. It is evident however, that mango trees can sequester significant quantities of carbon from the atmosphere for their growth, a factor that should be remembered when developing sustainability indicators within this industry.

---

[32] Flach, K.W., Barnwell, T.O.J., Crossen, P., 1997. CRC Press, Boca Raton, pp. 3-13.

[33] EPA. 2010. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2008, U.S. EPA # 430-R-10-006

[34] Paustian et al 2006. Agriculture’ s Role in Greenhouse Gas Mitigation. Pew Center on Global Climate Change.

Photo 1.7.1 Measuring diameter of trees to calculate biomass

2. Baseline Performance

2.1 Social

Social sustainability considers the broadest aspects of business operations and the effect that they have on employees, employee families, communities, suppliers, investors, and consumers. Social sustainability is also related to fundamental human needs such as happiness, safety, freedom, and dignity. Social sustainability strives to take future generations into consideration, and to live with the awareness that business decisions and actions make an impact on others and the world at large.

Workforce

The majority of the workforce that is allocated to mango production and mango packing is seasonal, typically employed between 90 - 120 days (contiguous) a year. In cases where production and packing facilities include products other than mangos, the workforce is retained for these other crops typically for a period of 10 months of the year. It should be noted that this practice of retaining the workforce for other crops represents only a minority of the facilities that were visited.

Figures 2.1.1 and 2.1.2 below show the average amount of labor (average number of workers / total kg mangos processed) required for processing a kilogram of mangos across the value chain. The data in table 2.1.1 indicate that production uses two and a half times more labor per unit than packing, and packing uses 23 times more labor per unit than importation. Board of Directors (BoD) only data indicates that production uses only 15% more labor per unit than packing and in general shows a lower per unit labor requirement than non-BoD data. As the industry considers where to invest in workforce related programs, focusing on producers first will have the greatest impact since this is where the majority of the labor in the value chain is concentrated.

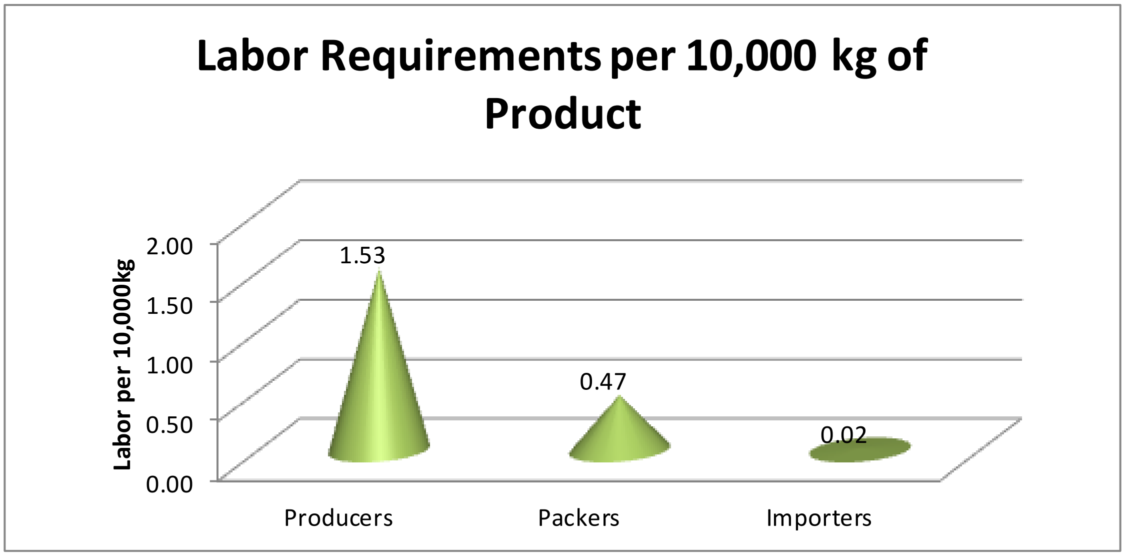

Figure 2.1.1 Labor requirements per kg of product.

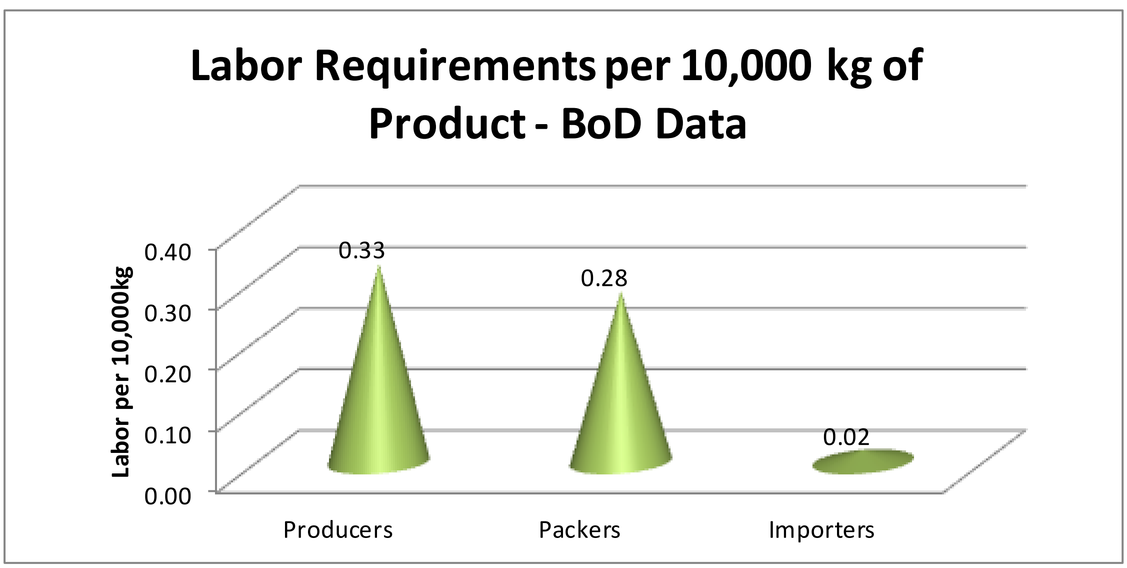

Figure 2.1.2 Labor requirements per kg of product, BoD data

Worker productivity is an important indicator at the facility level for comparison against other indicators such as product integrity, compensation, company safety practices, employee training, etc. Figures 2.1.3 and 2.1.4 reflect a high degree of variance in terms of worker productivity, both in production and in packing. While out of scope for this phase of the project, the data indicates that there could be best practices at farms and facilities with higher rates of productivity that could be identified and shared with the rest of the industry to make the entire supply chain more efficient. Additional investigation would be necessary to determine the specific reasons for higher productivity rates, including an evaluation of best practices.

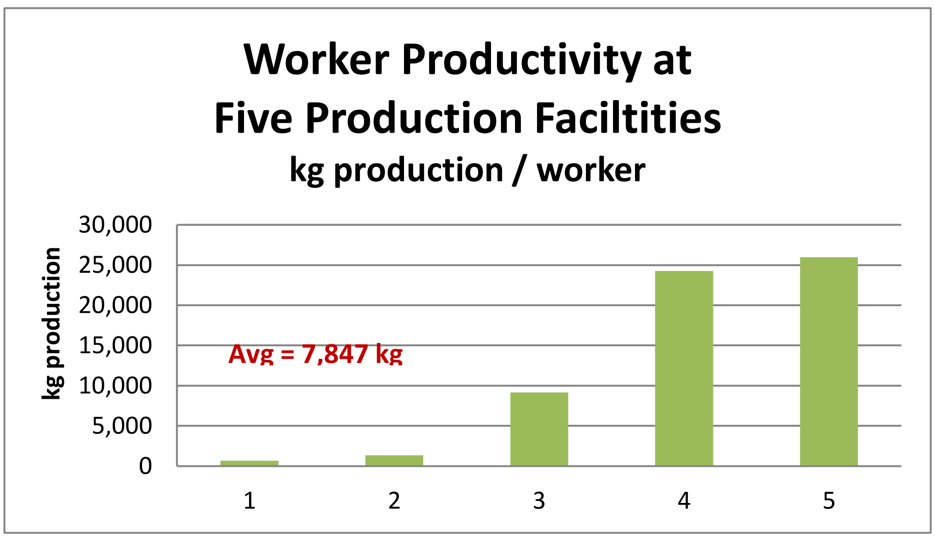

Figure 2.1.3 Producer productivity

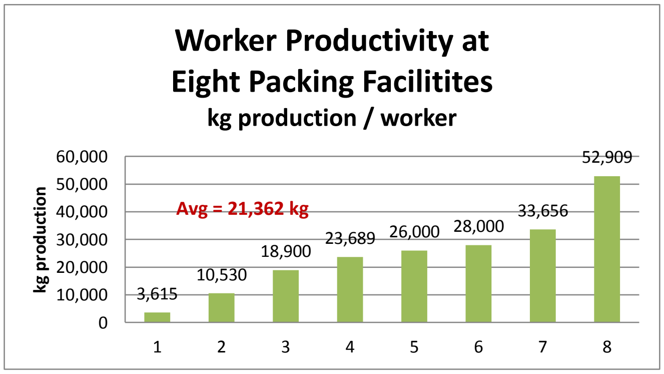

Figure 2.1.4 Packer productivity

Turnover rate reflects the rate of gain or loss of employees during a reporting period. It is calculated by dividing the number of employees that leave the company by the average number of employees during the reporting period. It can be further refined by measuring voluntary vs. involuntary terminations, supervisory vs. non-supervisory turnover, etc. Since employee acquisition and training typically represent significant costs to a company, programs designed to decrease turnover can often result in net cost savings for the company. In order to establish a turnover rate benchmark for the mango industry, much more data will need to be collected and analyzed. Table 2.1.1 shows that those producers who reported data for this project have zero turnover. It is important to note that in an industry that employs tens of thousands of workers that this sample is not likely to be representative of the industry for this particular indicator. In Table 2.1.2, the BoD data does however support the indication of a low turnover rate in production. Further data collection and analysis is required to understand the reasons behind the low rate of turnover in production.

Table. 2.1.1 Turnover Rate

	Total Turnover Rate	Voluntary Turnover	Involuntary Turnover	Non-Supervisor Turnover
Producers	0.00%	0.00%	0.00%	0.00%
Packers	15.71%	12.17%	3.54%	16.08%
Importers	25.00%	8.33%	16.67%	14.29%

Table 2.1.2 Turnover Rate – BoD Data

BoD Data	Total Turnover Rate	Voluntary Turnover	Involuntary Turnover	Non-Supervisor Turnover
Producers	3.91%	3.45%	0.46%	4.02%
Packers	69.95%	35.92%	34.04%	72.44%
Importers	25.00%	8.33%	16.67%	14.29%

Wages paid in comparison to a local living wage is one of the most important social indicators for a company and/or industry to measure and monitor. Living wage differs from minimum wage in several ways. Living wage is calculated based on the actual costs of acquiring the basic necessities for life: food, housing, medical care, and transportation. Other categories such as child care and education can be included in the analysis depending on local norms and customs. A living wage analysis also includes these costs for an individual (adult), two adults, one adult + one child, two adults + one child, and two adults + two children. In Tables 2.1.3 and 2.1.4, the living wage comparison was done using the living wage amount for an individual[35]. Table 2.1.5 provides the daily living wage requirements for

[35] The living wage was calculated using a calculator developed by Dr. Amy K. Glasmeier and implemented by West Arete Computing, and is part of the Poverty in America project. http://www.livingwage.geog.psu.edu/counties/04023. We used data specific for Mexico garnered from http://www.cfomaquiladoras.org/listaacuna_sep06.es.html, /www.sedesol.gob.mx/index/index.php?sec=25 and http://news.bbc.co.uk/hi/spanish/specials/2006/salud/newsid_5212000/5212836.stm

the various family units included in the analysis. A minimum sustainability target would be to have all full-time wages paid be equal to or greater than the local living wage.

Table 2.1.3 Wages

	Average Daily Wage	High Daily Wage	Low Daily Wage	Regional Living Wage per day	Avg Wage / Living Wage
Producers (MP)	138.6	160	120	125	110.9%
Packers (MP)	125.1	170	101	125	100.1%
Importers (USD)	115	115	115	59.84	192.2%

Table 2.1.4 Wages – BoD Data

BoD Data	Average Daily Wage	High Daily Wage	Low Daily Wage	Regional Living Wage per day	Avg Wage / Living Wage
Producers (MP)	123.0	150	96	125	98.4%
Packers (MP)	101.0	101	101	125	80.8%
Importers (USD)	115	115	115	59.84	192.2%

Table 2.1.5 Living Wage Table, calculated estimates for Mexico, in Mexican Pesos

One Adult	One Adult, One Child	Two Adults	Two Adults, One Child	Two Adults, Two Children
125	206	167	248	357

In Mexico, workers are provided access to health insurance through the Federal Social Security program. Employers register employees with Social Security upon employment and pay 29% percent of the premiums. This coverage extends to employee families. Providing access to affordable healthcare for employees and their families is an important social practice in which the mango industry is participating. With a state sponsored program in place in Mexico, further investigation is recommended to determine why access and participation are not 100% for employees and their families (tables 2.1.6 and 2.1.7).

Table 2.1.6 Health Benefits

	Health Insurance	Family Coverage	% of Cost Covered
Producers	85.7%	85.7%	88.6%
Packers	93.8%	87.5%	30.4%
Importers	100.0%	0.0%	60.0%

Table 2.1.7 Health Benefits – BoD Data

BoD Data	Access to Health Insurance	Family Coverage	% of Cost Covered
Producers	33.3%	33.3%	42.0%
Packers	75.0%	100.0%	50.0%
Importers	100.0%	0.0%	60.0%

Unionization and collective bargaining is an important component of the agricultural labor force in Mexico. There are a number of different unions that represent employees, and a variety of issues are negotiated on employees' behalf including wages, hours, benefits, etc. Tables 2.1.8 and 2.1.9 show the average union representation in the workforce and the amount of variance (high and low) from the average. Based on the data, workers in the packing facilities appear to have a higher level of union representation than those in production.

Table 2.1.8 Unionization

	Union Representation	Maximum Representation	Minimum Representation
Producers	1.62%	2.58%	0.00%
Packers	35.90%	100.00%	0.00%
Importers	0.00%	N/A	N/A

Table 2.1.9 Unionization – BoD Data

BoD Data	Union Representation	Maximum Representation	Minimum Representation
Producers	16.55%	43.75%	0.00%
Packers	61.95%	71.43%	41.54%
Importers	0.00%	N/A	N/A

Data indicate that injuries associated with jobs in production are two and half times more likely to occur than with jobs in packing (tables 2.10 and 2.1.11). There is also a great deal of variance in terms of number of on-the-job injuries between facilities (figures 2.1.5 and 2.1.6).

Safety training and standardized operating procedures are key components of organizational safety programs. Well designed and managed safety programs can have a positive impact on productivity and result in cost savings associated with industrial insurance rates and avoidance of regulatory fines or customer penalties for non-compliance.

Table 2.1.10 Safety statistics across facility type

	Injuries per hour worked	Hours worked per injury	Max. hours/ injury	Min. hours/ injury
Producers	0.000050	19,902	77,500	480
Packers	0.000020	50,737	95,040	2,500
Importers	0.000000	N/A	N/A	N/A

Table 2.1.11 Safety statistics across facility type – BoD Data

BoD Data	Injuries per hour worked	Hours worked per injury	Max. hours/ injury	Min. hours/ injury
Producers	0.000033	30,462	366,080	6,800
Packers	0.000009	115,460	186,000	68,960
Importers	0.000000	N/A	N/A	N/A

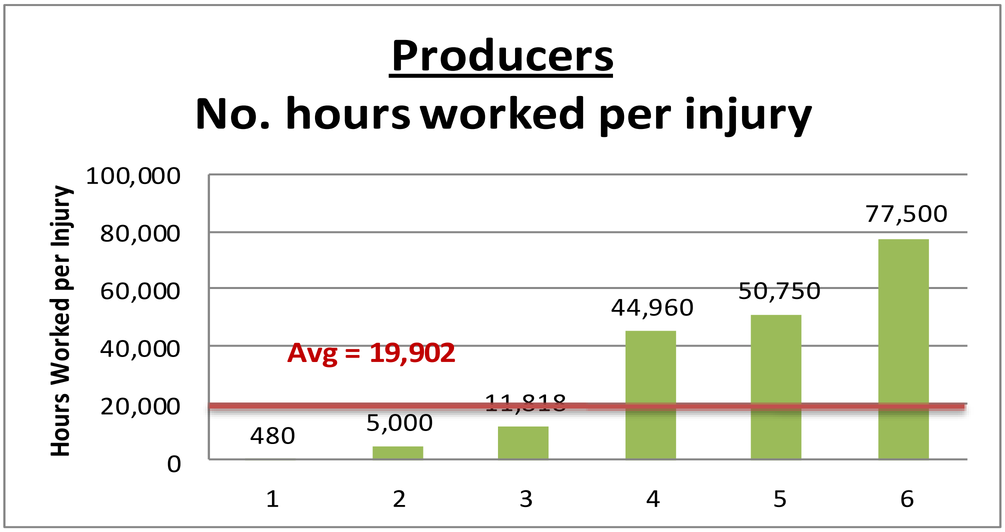

Figure 2.1.5 Number of hours worked per injury at production facilities.

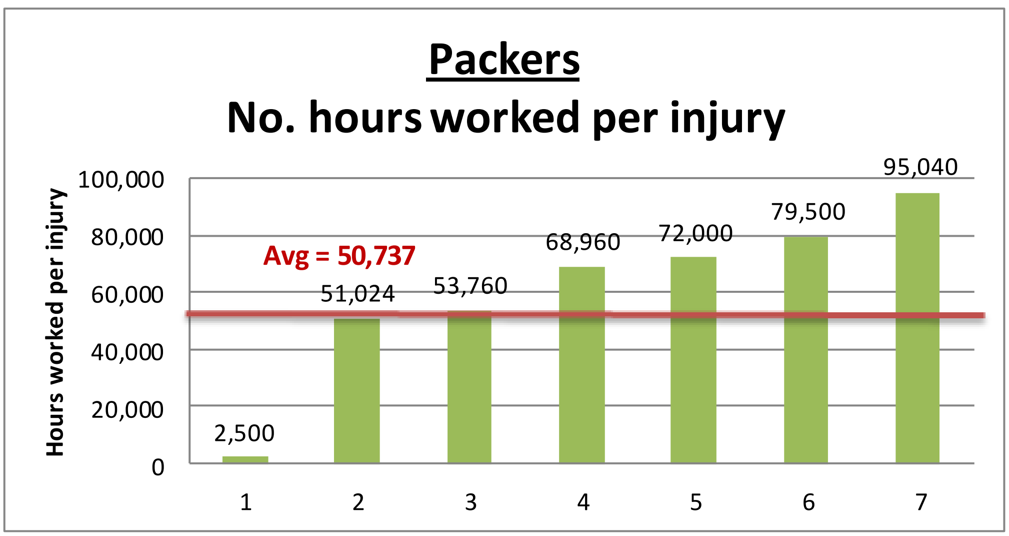

Figure 2.1.6 Number of hours work per injury at packing-houses.

2.2 Environmental

Environmental performance includes the criteria and indicators most commonly associated with sustainability. Measurement focuses on production inputs such as water, materials and fuels, and on production outputs such as solid waste, effluents, and emissions. Resource use efficiency is a key concept, and a practice that generally results in improved environmental performance and reduced operating costs. Investments made in material use efficiency and waste reduction can have significant financial returns, so good business and good environmental performance go hand in hand.

Water

The most significant use of water in the mango value chain is as a production input. Even with water being a critical component of packing operations, the amount of water used in production is nearly 1,000 times greater than anywhere else in the value chain. It is expected that water use for mangos in the retail component of the value chain will be similar to that of the importer component since the activities are similar. Therefore, based on the data gathered in this project, it can be estimated that it takes one cubic meters (1,000 liters) of water to produce one kilogram of mangos.

Table 2.2.1 Water consumption by facility type

	Producer	Packer	Importer
m^3 water/kg mango	0.98718	0.00111	0.00002
m^3 water/ha	9,090	N/A	N/A

Table 2.2.2 Water consumption by facility type – BoD Data

BoD Data	Producer	Packer	Importer
m^3 water/kg mango	0.33	0.00100	0.00002
m^3 water/ha	5,101	N/A	N/A

Several different irrigation practices used for mango trees were observed. Flood irrigation and micro spray irrigation were the two methods used most often. For flood irrigation verbal information was provided that water was allowed to pour onto the land and soak in until water remained above ground to the depth of 10cm. It was agreed that about 3 times this amount was used to soak into the ground, suggesting approximately 40cm of water is used at any point. To convert this to m^3 per ha 40cm was multiplied by 10,000 m^2 to obtain 4,000m^3 of water per hectare per flood irrigation event. Typically mangos, where flood irrigation occurred, were flood irrigated 3 to 5 times annually or in total 12,000 to 20,000 m^3/ ha/yr. In comparison one online source (http://articulos.infojardin.com/Frutales/fichas/papayas-cultivo-papaya.htm) suggested that papaya needs 2,000m^3/ha/yr of irrigation, while oranges need 6,000 to 7,000 m3/ha/yr (http://www.infoagro.com/citricos/naranja.htm).

The production facilities visited that use flood irrigation techniques are doing so because that is the method by which agricultural water was made available in the region. Governmental authorities manage the irrigation process and farms coordinate water frequency and locations with the authorities and pay for water based on number of applications and number of hectares receiving water.

It is evident based on Figure 2.2.1 that flood irrigation techniques use significantly more water per unit of output than do micro spray irrigation techniques - nearly 100 times more water. Figure 2.2.2 reflects that micro drip irrigation is potentially 10 times more efficient than micro spray irrigation.

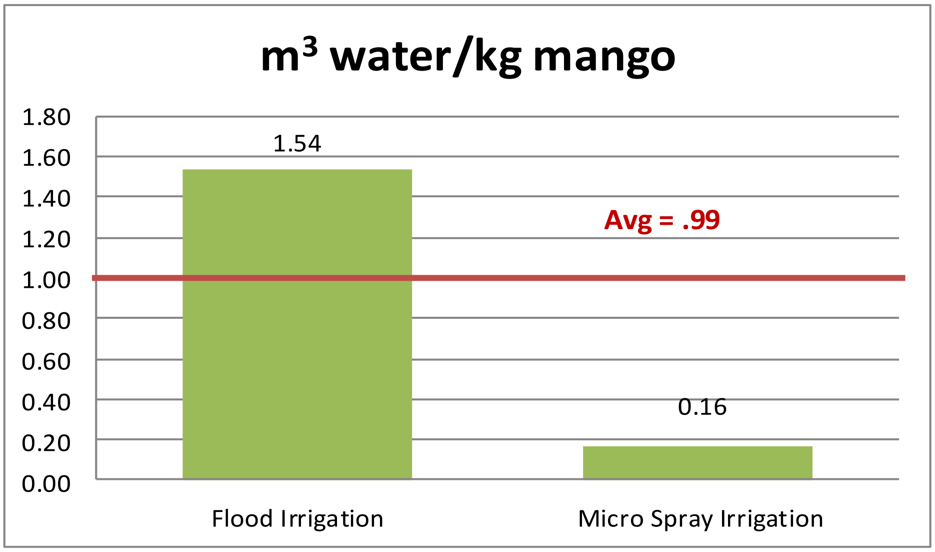

Figure 2.2.1 Water consumption by irrigation practice

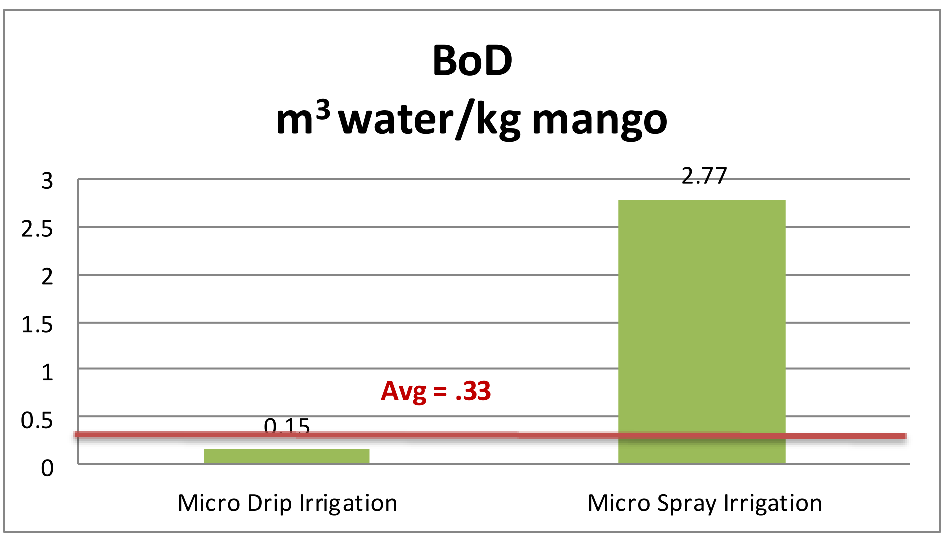

Figure 2.2.2 Water consumption by irritation practice – BoD Data

Average water use for the production of mangos appears to be at the high end when compared to other produce (Table 2.2.3). As noted above, flood irrigation practices significantly increase the average. Micro spray irrigation reflects a water consumption rate of

650 liters/ kg of mangos, and micro drip data reflect a consumption rate of 150 liters/ kg of mangos.

Table 2.2.3 Amount of water needed to produce each product

Product (per serving or otherwise stated)	**Water** (liters)
Almonds 1 kg	1,596
Orange 1 kg	330
Lettuce	22.68
Rice	132.3
Tomatoes 1 kg	64
Watermelon	378
Mangos 1 kg	**1,000**

Source: USGS website

Photos of flood irrigation system

Rio Fuerte in Northern Sinaloa used as a source for irrigation to neighboring farms

A pump used to extract water from the Rio Fuerte to irrigation canals

Irrigation ditch to control water within canals

A flooded irrigation canal. N. Sinaloa

Solid Waste

Packing operations produce more solid waste per unit of output as compared to production and importer operations (Tables 2.2.4 and 2.2.5). The scope of this project did not include an analysis of the types of waste generated in each component of the value chain, but based on observation the key sources of waste are summarized in Table 2.2.6 below.

Table 2.2.4 Solid waste by facility type

	Producer	Packer	Importer	Total
kg waste/kg mango	0.0047	0.0099	0.0006	0.0151
recycled/ttl waste	47.2%	45.7%	0.0%	31.0%

Table 2.2.5 Solid waste by facility type – BoD Data

BoD Data	Producer	Packer	Importer	Total
kg waste/kg mango	0.0003	0.0172	0.0006	0.0181
recycled/ttl waste	25.0%	40.2%	0.0%	21.7%

Table 2.2.6 Waste types by facility type

	Waste Sources
Production	agrochemical containers
Packing	packing materials and packaging
Importing	(not observed)

Organic waste is comprised of tree prunings and harvested mangos that don' t meet quality standards. In general, tree prunings are left in the field to eventually get incorporated into the soil, or are piled and burned. Waste mangos are typically piled and composted onsite, although the composting observed was not managed and essentially the pile was left to rot above ground.

Electricity Use

Table 2.2.7 Electricity use by facility type

	Producer	Packer	Importer	Total
kWh/kg mango	0.016	0.046	0.004	0.066
kWh/ha	147	N/A	N/A	

Table 2.2.8 Electricity use by facility type – BoD Data

BoD Data	Producer	Packer	Importer	Total
kWh/kg mango	0.018	0.076	0.015	0.004
kWh/ha	191	N/A	N/A	N/A

There does not appear to be a measureable increase in the amount of electricity used per unit of output by facilities that are required to perform the hot water treatment and use electricity as the source for heating the water (Figure 2.2.3 below). In fact, these facilities had the lowest kWh/kg mango measure when compared to all other facility types. This result is counter-intuitive in that if all other sources of electricity use were the same, facilities required to perform hot water treatments using electricity to heat the water would have a higher kWh/kg mango measure than other facilities. This result suggests that there is a great deal of variance across facilities around how electricity is used for specific tasks.

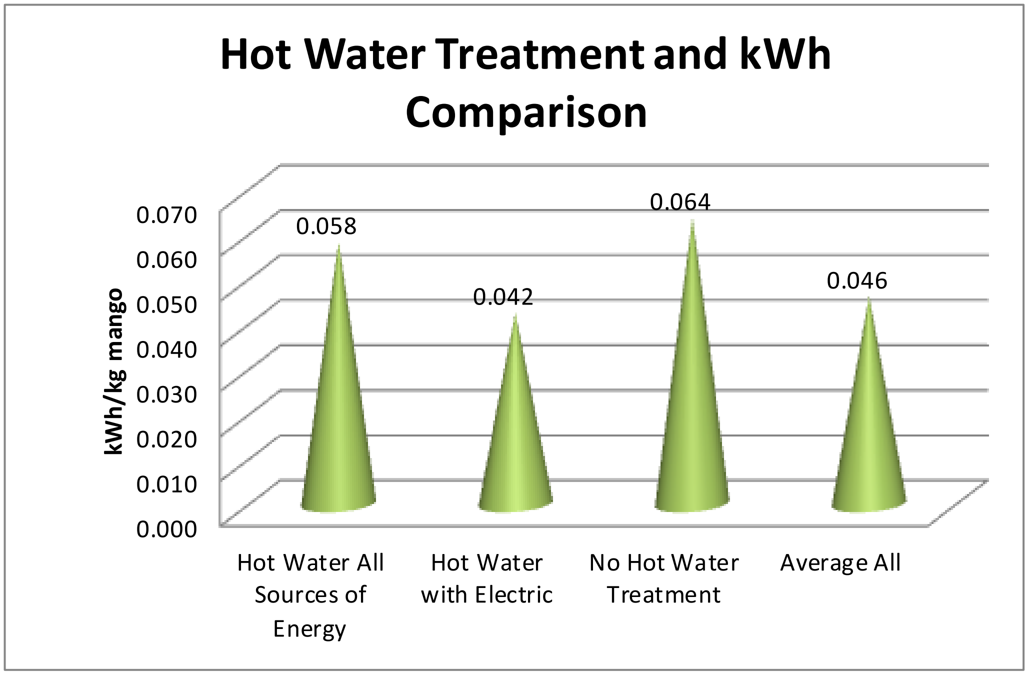

Figure 2.2.3 kWh usage by hot water treatment energy source

Fuel Use

Table 2.2.9 Fuel consumption by facility type

	Producer	Packer	Importer	Total
fuel/kg mango	0.0154	0.0126	0.0007	0.0287
fuel/ha	154	N/A	N/A	

Table 2.2.10 Fuel consumption by facility type – BoD Data

BoD Data	Producer	Packer	Importer	Total
fuel/kg mango	0.010	0.0376	0.0007	0.0484
fuel/ha	276	N/A	N/A	

The data indicate that facilities required to perform hot water treatment and use natural gas or propane as the fuel type for heating water have a higher than average consumption of fuel per kilogram of mangos processed (Figure 2.2.4). This is consistent with what would be expected in a scenario where all other uses of fuel are the same, those facilities that use fuel to heat water will have a higher consumption ratio per unit of output than those facilities that don' t heat water with fuel. It should be noted however that there are many different uses of fuel in the packing facilities, and a more detailed study would need to be completed to identify specific opportunities for reducing consumption or switching to alternative energy sources.

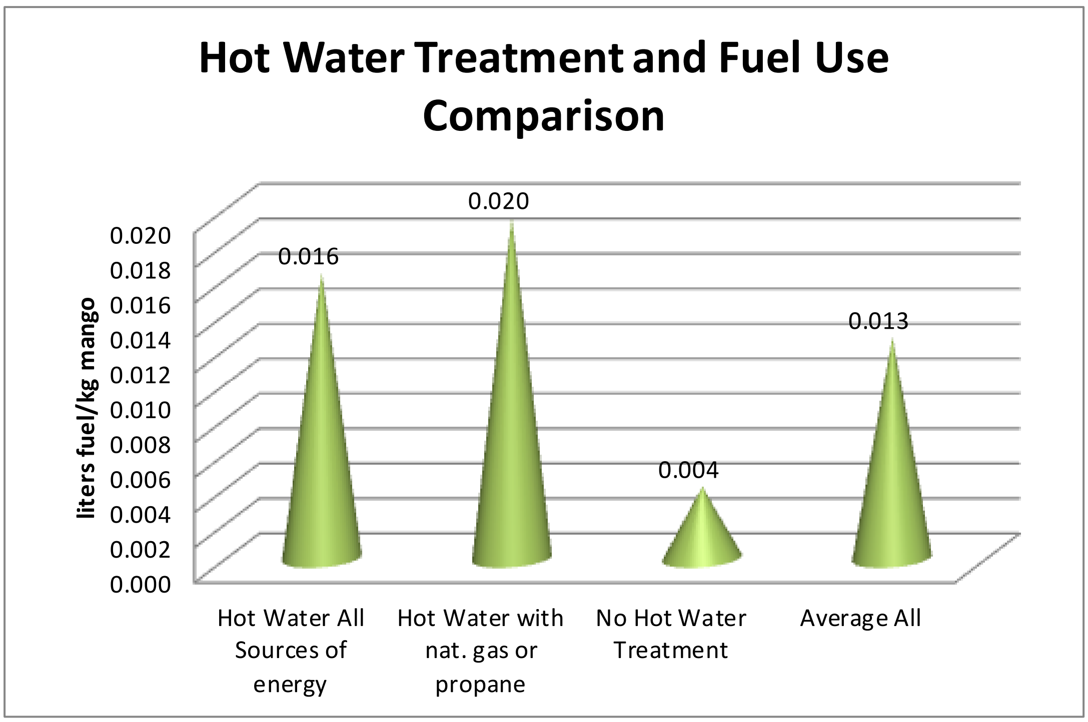

Figure 2.2.4 Fuel consumption by hot water treatment energy source

2.3 Biodiversity and Ecology

Why Biodiversity is Important as an Indicator of Sustainability

Biodiversity provides us with a host of raw materials, foods and medicines and is the basis for the life support system of our planet by, for example, underpinning the continued availability of clean air and fresh water. Interwoven with these functional aspects are spiritual, cultural and recreational elements. These elements are more difficult to value, but in many countries and cultures they are considered to be at least as important as the more functional aspects of biodiversity.

Biodiversity provides and is also dependent on a host of services and hence the status of each service can be indicated by the well being of the biodiversity present. Biodiversity and habitat protection is becoming ever more important on a planet whose resources are shrinking quickly. Industrial activities in or around sensitive areas in particular need monitoring and hence in these cases it is the biodiversity itself that is the sustainability goal. By confirming the continued existence of biodiversity as measured from some baseline, one can demonstrate low impact industry.

Biodiversity and Competitive Advantage

Most importantly, the work done by companies themselves over the past five years has revealed a great deal about the nature of biodiversity risk. Extractive companies, in particular, have repeatedly cited biodiversity in risk assessments to investors, such as 401K declarations and Operating & Financial Reviews (OFR) in annual reports. To date, there has been no clear evidence that good biodiversity management has given a competitive advantage, or that poor biodiversity management has led to revenue loss. However, extractive companies, unlike the majority of their shareholders, are used to planning for 30-50 year scenarios, and their move towards better biodiversity risk management indicates a long-term view of where the materiality of the biodiversity debate is heading — particularly the ability of companies to access and exploit land and marine areas. Three other sectors that have begun to make progress — often in response to consumer, regulatory and media pressure, rather than that of investors — are the Equator Principles banks, utilities companies and importantly, sections of the agro-industry. For example since 1995, Unilever has employed four sustainability initiatives within which biodiversity appears as an indicator. Unilever recognizes that biodiversity offers:

1. Genetic variation for plant breeding
2. On-farm biodiversity for integrated crop management, and
3. General ecosystem services, e.g. pollination, nutrient cycling, water purification, flood prevention, weather etc.

Among the research that has been emerging recently from brokerage houses that provide investment analysis to fund managers have been some clear references to biodiversity and ecosystem services, for the first time. Again, this has often sprung from research looking primarily at the impacts of climate change. Some research notes have shown a very full understanding of the complex links between, for example, climate change, the cost of water, the provision of other ecosystem services and the potential impact on company valuations. The most specific research has focused on Australia, where investment analysts are beginning to understand the enormous potential effect of environmental change on agricultural and related industries.

Biodiversity and Agriculture

Striking a balance between production and conservation goals in agricultural landscapes is a global problem and there is much debate over the relative merits of land sparing or wildlife friendly farming. Conservationists rightly argue that agriculture contributes significantly to the erosion of biodiversity (and possibly ecological function), through the clearance of natural vegetation for and the intensification of farming practices on land already highly modified. Simultaneously, farmers face demands for increased production to meet global food, fuel and fiber needs, and the rate at which these demands are increasing is unlikely to diminish in the near future—indeed, global food demand is set to double by 2050.

When large, continuous areas of natural habitat are broken up into disconnected fragments, many ecological processes are disrupted. The seeds of many native plants cannot be dispersed into new habitats, making it difficult for them to respond to changing environments or local climates. Animals struggle to survive in small areas where food, nesting and refuge supplies are limited. These plants and animal species can become locally extinct and cause knock-on effects for other species interacting with them.

The following three concepts are important to consider when managing an agricultural landscape:

1. Corridors: These are linear patches of natural habitat that link or connect fragmented areas, allowing species movement and ecological processes to continue. Corridors may also pro- vide shelter, reduce water and wind erosion and enhance the aesthetic appeal of a landscape. Examples include the vegetation along river and stream banks, or natural habitat left on roadside verges. Old agricultural fields can also act as animal movement corridors, providing shelter for movement between natural vegetation pockets.
2. Connectivity: This refers to the degree to which patches of a given natural habitat are joined by corridors into a network of linkages. This affects the ease with which species can move among vegetation patches in the landscape.
3. Edge Effects: These exist where transformed areas are adjacent to natural areas. Natural habitats are sensitive to influences from surrounding cultivated areas, such as fertilizer run- off and invasion of agricultural weeds. This is especially an issue for small fragments, where much of the fragment is exposed to edge effects.

Maintaining biodiversity on farmland

The following is a list of widely accepted guidelines for enhancing biodiversity and landscape function of farmland:

1. Conserve large and continuous areas of threatened habitat
2. Conserve a full variety of habitat types, focusing on sites close to, or well-connected to, other natural areas
3. Look out for special habitats deserving conservation attention, such as rare geological patches and wetlands.

4. Consider actively restoring or allowing the natural recovery of disturbed areas that could function as corridors between natural habitats.
5. Where a property forms part a larger natural area, consider how to protect landscape level processes on the property.
6. Minimize edge effects through careful land management. Create buffer zones adjacent to natural areas, where the land is free of pesticides and invasive agricultural weeds.
7. Avoid runoff of fertilizers and pesticide drift into natural habitats.
8. Starting at the source of the invasion, clear alien plants.
9. Maintain optimal fire regimes, if relevant.

Performance of Biodiversity Protection and Function in Mango Orchards of Mexico

The field component to this study was undertaken in Los Mochis, Mazatlan and Escuinapa in Sinaloa, Arivania in Nayarit and Tapachula in Chiapas. In total six separate mango production company operations were visited with a total of approximately 20 orchards of different ages and mango varieties. Biodiversity monitoring was undertaken using a customized field sheet that asked questions of size, borders, biodiversity (including native vegetation) and management techniques used on the farm.

All operations were in close proximity to the Pacific coast with Finca Arivania in Nayarit being the most inland (approximately 25 km from the coast). The Farms were of varying sizes, ranging from 10 ha to over 600 ha blocks.

Climate variation was high, being dry arid in the north (Los Mochis) to humid tropical in the south (Tapachula). The Landscapes were equally varied from volcanic hilly to coastal low lying plains.

Physical Characteristics of the States Visited

Sinaloa: Sinaloa lies along the coast of the Gulfo de California. It covers an area of 58,091 square kilometers (22,429 square miles), which is a little smaller than the US state of West Virginia. In the summer months of June, July, and August, the daytime temperature averages

32°c (90°f); in the winter months of December, January, and February, the daytime temperature averages 27°c (80°f). Most of the rainfall occurs during July, August, and September. In the capital city of Culiacán, the average year-round temperature is 24°c (76°f) and the average rainfall is 54 centimeters (21.3 inches) per year, however Los Mochis can reach temperatures of 45ºC (113ºF) with only 30 cm (12 inches) of rain per year. Los Mochis' agriculture depends almost entirely on irrigation from the Rio Fuerte.

In Sinaloa, there are principally three landscape types: a coastal plain to the west, mountains (Sierra Madre Occidental) to the east, and valleys between them. Valleys lie between the ranges of mountains and the coastal plain, where the land is flat with few hills. The vegetation type is classified as dry thorn forest throughout most of the state, to sub humid forest in the far south.

The rivers rise in the Sierra Madre Occidental and cross the state to flow into the Gulfo de California and the Pacific Ocean. Major rivers are the Fuerte and Sinaloa.

Through the North American Commission for Environmental Cooperation (CEC), the state of Sinaloa has formed a strategic partnership with the US state of Alaska in a project called the Western Hemisphere Shorebird Reserve Network. The Sinaloan wetlands serve as the winter home for over 30% of the Pacific Flyway shorebirds that breed in Alaska, Canada, and other West Coast regions of the United States. The Bahia Santa Maria (Santa Maria Bay) is one of several protected areas in the state.

Agriculture is the dominant economic activity. Most crops are dependent on irrigation. Agricultural products from Sinaloa include tomatoes, beans, corn, wheat, sorghum, potatoes, soybeans, sugarcane, and squash. Crops are grown near sea level under irrigation in large fields using mechanized methods. The beekeeping industry that contributes to the pollination of these crops was devastated by the arrival of the Africanized honeybee in Sinaloa around 1990.

Nayarit: Nayarit is located on the western coast of Mexico. It covers an area of 27,620 square kilometers (10,664 square miles). The average year-round temperature in Tepic is

20°C (68°F). However, it is much cooler at higher elevations of the state. The statewide average high temperature is 27°C (80°F). The average low temperature statewide is 21°C (69°F). Annual rainfall ranges from a minimum of 77 centimeters (30 inches) in some regions to a maximum of 264 centimeters (104 inches) in other parts of the state.

The main rivers are the Santiago, San Pedro, and Acaponeta. The Ameca River forms the border with Jalisco to the south and Las Cañas forms the border with Sinaloa to the north. There are a number of lakes along the coast, including the Santa María del Oro, San Pedro Lagunillas, and Agua Brava.

Native vegetation varies from mangroves along the coast to lowland sub humid forest and pine and oak in montane regions. Common animals include white-tailed deer, wildcats, pumas, and wild boars. Smaller mammals include skunks, badgers, rabbits, and armadillos. Mountain doves, cojólite (a kind of pheasant), and the bobo bird can be found here.

Both tobacco and sugarcane are the primary export crops of the state. Fruit growing is a major part of agriculture and includes production of avocados, mango, papaya, bananas, and tamarind. Other major crops include corn, beans, peanuts, and squash. The southern region of the state is known for its honey production.

Chiapas: Chiapas is situated in southern Mexico. It has an area of 73,724 square kilometers (28,465 square miles). The average temperature is 20°C (68°F), however temperatures may reach as high as 40°C (104°F) and as low as 0°C (32°F) depending on elevation.

Chiapas has a coastal plain along the Pacific Ocean to the south. In the north, the coastal plain that begins in Tabasco extends into Chiapas. The Sierra Madre is a chain of high mountains that run from the northwest to the southeast. The highest peak is the Tacaná volcano (4,093 meters/13,428 feet in elevation), which lies on the border with Guatemala. The Grijalva River flows northwest through the center of the state until it empties into the Bahía de Campeche.

Orchids and bromeliads (plants of the pineapple family) are native to the tropical areas of the state. Mangrove trees are also native. The tropical humid forest resembles that of tropical South America and includes species such as jaguars, flying squirrels, monkeys, white-tailed deer, tapirs, toucans, and parrots. At higher elevations there are hardwood trees such as mahogany and cedar. Crocodiles and many species of birds live along the Pacific coast.

In the 1990s, Chiapas began to protect and preserve its cloud forests (forest at high elevations) and coastal areas. The El Triunfo Biosphere Reserve is located in the south in the Sierra Madres. It ranks as one of the most biologically diverse places on the planet and encompasses approximately 300,000 acres. La Encrucijada Biosphere Reserve is located in the Pacific coastal area of Chiapas and covers 357,824 acres. This reserve offers the tallest mangroves on the Pacific coast and healthy numbers of crocodiles, jaguars, raccoons, and iguanas.

Coffee is the most valuable agricultural product; about 60% of Mexico's total coffee output comes from Chiapas. Chiapas ranks second among the Mexican states in the production of cacao, the product used to make chocolate. Other crops grown in Chiapas include sugarcane, cotton, bananas, and other fruits. These are grown especially in the lowland regions near the Pacific coast.

Protected Areas of the Regions Visited

In order to provide more context as to the landscapes and conservation requirements of the areas under production we searched for state and nationally protected land in the vicinity of the orchards we visited.

Table 2.3.1. Protected areas in the regions visited.

State	Protected Area	Name
Chiapas	Reserva de la Biósfera	Volcán Tacana
Chiapas	Reserva de la Biósfera	El Triunfo
Chiapas	Reserva de la Biósfera/RAMSAR	La Encrucijada
Chiapas	Reserva de la Biósfera	La Sepultura
Chiapas	Área de Protección de Recursos Naturales	Terrenos que se encuentran en los Municipios de la Concordia, Ángel Albino Corzo, Villaflores y Jiquipilas
Chiapas	Santuarios/RAMSAR	Playa de Puerto Arista
Chiapas	RAMSAR	El Gancho Murillo
Chiapas	RAMSAR	Zona sujeta a la conservación ecológica Cabildo Amatal
Chiapas	RAMSAR	Sistema estuario Boca del Cielo
Nayarit	Áreas de Protección de los Recursos Naturales	Cuencas Alimentadoras del distrito de riego 043 Estado de Nayarit
Nayarit	RAMSAR	La Tovara
Nayarit	Avisos de Decreto/RAMSAR	Marismas Nacionales
Nayarit	Avisos de Decreto	Sierra de Vallejo
Sinaloa-Sonora	Área de Protección de Flora y Fauna	Sierra de Alamos-Río Chuchujaqui
Sinaloa	Área de Protección de Flora y Fauna	Meseta de Cacaxtla
Sinaloa	Santuarios/RAMSAR	Playa El Verde Camacho
Sinaloa	Santuarios/RAMSAR	Playa Ceuta
Sinaloa	RAMSAR	Laguna Huizache-Caimanero

Sinaloa	RAMSAR	Ensenada Pabellones
Sinaloa	RAMSAR	Laguna Playa Colorada Santa María Reforma

Many of the protected areas close to the farms visited are RAMSAR sites, or wetlands of special international concern. Wetlands are highly fragile, specialized ecosystems that play an integral part in coastal formation, hydrological (including flood) control, and coastal (marine) productivity among others. They are home to numerous species of birds, many of which are migratory and are important constituents of both North and South American avian communities (Figure 2.3.1 below). Many of these regions are internationally recognized as harboring bird species of special concern.

Given this information, in order to be wildlife friendly, agriculture from these regions must be highly sensitive to the natural ecosystems on which they rely and the social value placed on the native species and habitats in which they are found. Wetlands, for example, are sensitive to upstream drainage and freshwater chemical changes (especially pesticides and fertilizers) and hence farms should aim to minimize these specific impacts when close to such areas.

In subsequent research, landscape impacts of mango farming should be investigated so that improvements can be made to increase sustainability and demonstrate biodiversity and ecosystem friendly practices. We provide some foundation to this approach in the following sections.

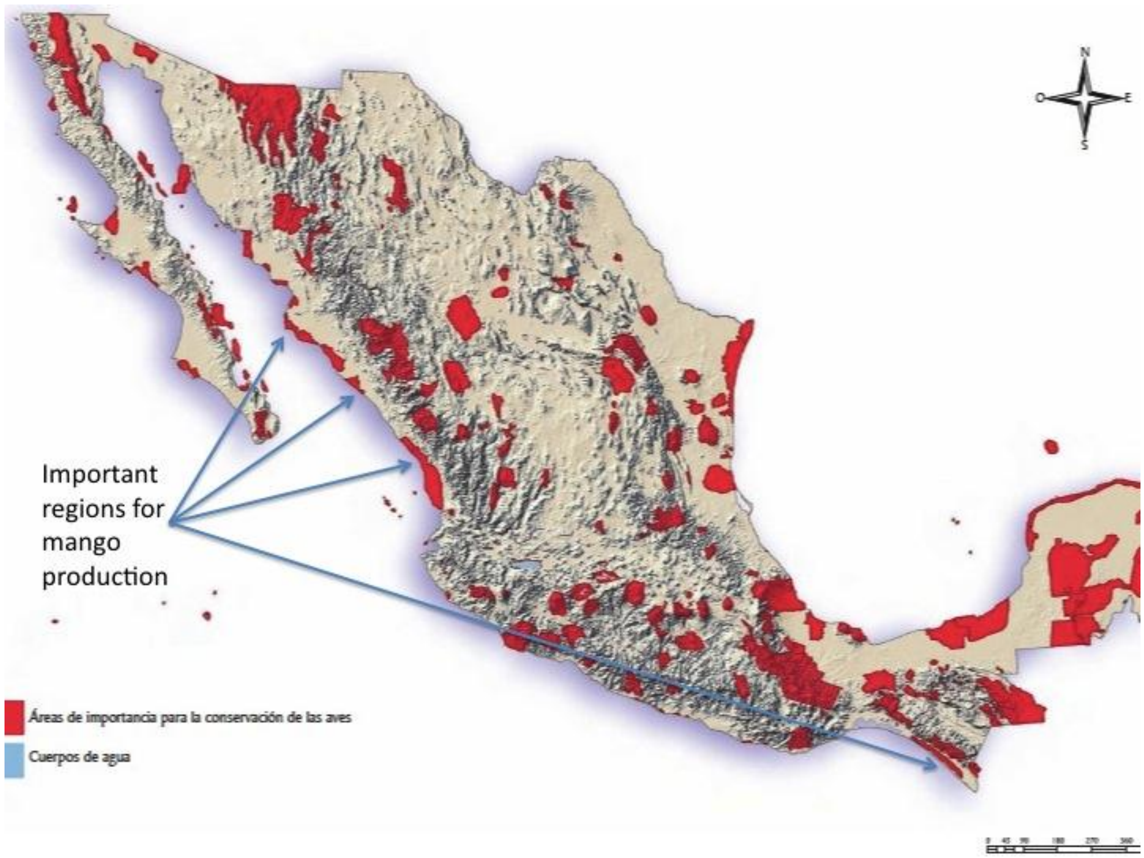

Figure 2.3.1. Internationally recognized important areas for bird habitat and conservation in red. Important regions of mango production, visited by Common Fields, on the western coasts of Sinaloa, Nayarit and Chiapas show a potential conflict with biodiversity. Source, ATLAS GEOGRÁFICO Del MEDIO AMBIENTE Y RECURSOS NATURALES 2006.

Biodiversity and Conservation Management Plans

No farm had a conservation management plan that was written or even a verbal plan that was adhered to. All farm managers responded to the question about nuisance species. The principal species that orchard managers did not want on their farm was the fruit fly, followed by thrips, ants, white scale, cows, horses, dogs and field rats. Various reasons were given for not wanting these species present, from fruit destruction in the case of fruit flies, thrips, ants and rats to against regulations of the orchard or fruit fly control procedures. The principal means of eradicating these species was by agrochemicals followed by fences (cows and horses) and human disturbance.

Only five of seven farms responded to the question about beneficial species on their farms. Species that were welcomed into the orchards were bees, other flies, wasps, lacewing (*Chrysopa* sp), and sterile fruit flies and in one case in Chiapas, cows. In most cases, pollination was cited as the driving factor for wanting these species, although the lacewing is used as a biological control agent for thrips and sterile fruit flies for fruit flies. In two cases bee hives were brought onto the orchard property to aid in pollination. Cows were seen as beneficial in terms of weed control, providing fertilizer and attracting flies, which pollinate the mango flowers.

In general there was a lack of understanding and information with regards to beneficial insects and animals. In the case where a beneficial service was understood little was done to promote this activity.

In order to increase sustainability, farm managers, in conjunction with professionals, should seek to design a management plan that aims to promote native biodiversity, integrate farm design and practices into the local ecology and landscape while promoting good orchard management and production. Ideally a third party would verify this plan.

Corridors and Native Vegetation Protection

Native vegetation habitat corridors are important for the dispersal and movement of species. Corridors can be found alongside flowing waterways or along fence lines or borders. We specifically investigated the width and length of borders and their adequacy as habitat for native wildlife.

A variety of different borders were found within mango orchards however in no farm did we find a particular management procedure directed towards the creation or protection of habitat corridors. Indeed most inter and intra property borders were filled with non-native weeds and grasses that were actively cut each year. Along the perimeter each orchard had a well maintained wire fence line. The fences in all cases were primarily for demarcating ownership boundaries and to keep out unwanted domestic animals such as cows and horses (see below). In only one case were live borders grown together with fencing wire, although it was not highly complex and consisted of one dominant species (“coquillo”, *Jadropha* *curcas*). These live borders were trimmed regularly to less than 2m in height and undergrowth removed. Unfortunately these borders were not particularly useful corridors for most species.

Irrigation canals were present in many farms; however none were protected by a buffer of natural vegetation.

In one case semi-mature (approximately 20-30 yrs old) native vegetation was found alongside a natural waterway running through an orchard. This stand of vegetation was rich in tree species and was habitat for both birds and bats, which are usually understood to indicate ecological functionality (although a more in depth study would be needed to confirm this). This stand was however isolated from other native vegetation in the region and hence was not an ideal corridor. This particular stand had been reduced in size recently to make way for an extension to the mango and rambutan fruit tree orchard so that the river that was once fully protected by this natural vegetation buffer was now exposed on both of its banks for part of its course through the orchard.

In two cases recent (within 2 years) removal of native vegetation to make way for mango orchard expansion was observed. In most cases mango orchards had been grown on existing agricultural land.

For farms to become more sustainable and demonstrate wildlife friendly practices live borders of native vegetation must be planted along fence lines and alongside all water courses and boundaries. Significant waterways should have at least 5m of native vegetation either side of the high water mark. Ecologists working in agricultural landscapes accept this as best practice. The practice of permanent vegetation boundaries would reduce the cost of weed management substantially.

Soil Biodiversity

Soil biodiversity was not directly measured however soil management was investigated as part of the field study. Soil management techniques were similar across all the farms visited. Soil management for the most part included the permitted growth of weeds and grasses during the rainy season with cutting and soil incorporation using machinery during the dry season. On all but one farm the herbicide "Roundup" (glyphosate) was used around the base of the mango tree to halt weed growth. Although this is considered a "least toxic" chemical there is still debate over its impact on earthworms and beneficial insects. It is known to have a toxic effect on amphibians and aquatic invertebrates.

The management technique of incorporating organic material into soil through tilling the ground has both positive and negative effects, although arguably the negative effects far outweigh the positive. Positive effects include the building of organic materials into the soils, which ultimately reduce the amount of fertilizer applications needed. Negatively it leaves soil bare and hence the top soil is prone to wind erosion, it reduces soil biodiversity and activity and increases carbon dioxide emissions from the soil. It also reduces available habitat for beneficial ground species such as amphibians and carnivorous insects.

It is commonly understood that no till practices have least impact on soil organisms and can also increase the carbon sequestration potential of the soil. In their most sustainable state, orchards would have a permanent ground cover, perhaps utilizing nitrogen fixing legumes, which could be managed but not tilled into the soil. A permanent ground cover would aid the creation of a balanced soil and ground community that would perhaps aid production and reduce the costs of management.

Pollinators

Flies, bees, ants and beetles have all been found to pollinate mangos, however there is some debate in the literature as to the proportion and effectiveness of bee pollination in mangos. Most farm managers visited, cited domestic flies as being important and the literature does provide evidence of this. No active management or concern about pollinators at the farms visited was witnessed, apart from two farms where domestic bees had been incorporated into the management of the orchards. At one farm, very little knowledge was had about pollination needs for mangos and pollination itself was not considered being a risk to production. In fruit fly control areas the broad spectrum insecticide malathion is used widely. Anecdotal evidence confirmed that this control agent kills beneficial insects including those that pollinate mangos. Indeed in those farms where domestic bees are utilized, dead bees are often found in fruit fly traps utilizing malathion.

A sustainable orchard would enhance the habitat for pollinator species. Leaving areas of natural vegetation (as described above) would provide cover for such species. The planting of native flowers would attract native pollinators to the orchards. We suggest further research on mango pollinators in Mexico and their ecological requirements.

Regulatory Compliance

The entry of domestic animals into orchards was reported by various farmers as being contrary to the norms of fruit fly control and hence was not a practice commonly seen. On reviewing the regulation 023 of SAGARPA (Secretaria de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación) used as a guideline to combat the fruit fly pest in high-risk areas, it was not apparent where the specific control of domestic animals within orchards was stated. However in only one case within the fruit fly high-risk area were cows actively encouraged to enter in order to keep weeds and grasses low and to provide fertilizer to the trees. It was also noted by the farm manager of this farm that the flies attracted by the cows, provided beneficial pollination services. All relevant farms appeared to be in compliance with fruit fly control measures according to regulation 023.

The number and amount of agrochemicals used at each of the farms also varied tremendously. One farm stated itself to be organic although it did not have third party certification. This farm used only organic fertilizers and incorporated a system of integrated pest management that utilized biological control agents. Other farms used up to 7 different agrochemicals on their trees to rid them of insects, fungus and weeds. Of particular concern was the use of the herbicide Paraquat on one farm. This chemical agent has been given the notorious distinction of being included in the list of most toxic agrochemicals that are dangerous to humans and it has been withdrawn by the European Union and has restricted use in the US and Mexico. It is not recommended (but not restricted) for use on mangos under regulation 023. Another compound of concern used by one farm is Methyl Parathion. This compound is highly toxic to humans and has been cancelled or restricted for use by the EPA in the US especially in fruit and vegetables eaten by children. It is banned in the European Union and listed under Annex III of the Rotterdam Convention of the UN as a severely hazardous pesticide.

A sustainable farm would use integrated pest management in order to control pests, utilizing biological agents, native species and chemical solutions to specifically target pests. Systems that use wide spectrum pesticides cause disruption to finely balanced farm ecosystems and can often cause more harm than good (e.g. extermination of pollinators through use of insecticides).

Native vegetation patch within orchard

A waterway without a natural vegetation buffer

No ground cover

A dead fence line with only grasses and weeds

Glyphosate to control vegetation around trees

An orchard with ground cover after harvest

2.4 Product Integrity

Food Safety

There was zero food safety issues reported for 2009 by all components of the supply chain.

Consistent Product Quality

Producers reported an average rejection rate of 27% by the packing-houses, but the packing-houses reported only a 10% rejection rate on product received from production (Table 2.4.1). This discrepancy is likely due to small sample sizes. It does make sense that packing has the highest rejection rate since this appears to be where the first detailed quality inspection takes place. Packers and Importers both reported a 2% rejection rate on product received from packing. Only one Importer reported rejection data by retailers, so the 6% should be interpreted in that context – it may or may not be representative of the industry as a whole.

Table 2.4.1 Product quality at each facility type

	#2 in Color when Harvested	% Mangos Rejected by Packer	% Mangos Rejected by Importer	% Mangos Rejected by Retailer
Producers	97%	27%		
Packers	N/A	10%	2%	
Importers	N/A		2%	6%

Table 2.4.2 Product quality at each facility type – BoD Data

BoD Data	#2 in Color when Harvested	% Mangos Rejected by Packer	% Mangos Rejected by Importer	% Mangos Rejected by Retailer
Producers	97%	14%		
Packers	N/A	21%	7%	
Importers	N/A		2%	6%

At least 90% of the mangos tested at the retail receiving point in the United State should expect to fall in stage 2 or higher of internal flesh color according to the Mango Maturity & Ripeness Guide (Tables 2.4.1 and 2.4.2).

Reasons for rejection, listed in order of frequency:

1. Maturity
2. Damage/cracking
3. Ripeness
4. Mislabeled

Good Agricultural Practices

The use of standard operating procedures (SOPs) is a key component of good agricultural practices (GAP). Data reported indicate that a little over half of producers use SOPs as a component of managing good agricultural practices, while nearly 100% of the reporting packing-houses use SOPs to manage GAP.

Table 2.4.3 Good Agricultural Practice indicators for 2009

	Use of GAP SOPs	3rd Party GAP Audit	Water Testing Frequency/yr
Producers	57%	43%	2.7
Packers	100%	87%	3
Importers	60%	100%	0

Table 2.4.4 Good Agricultural Practice indicators for 2009 – BoD Data

BoD Data	Use of GAP SOPs	3rd Party GAP Audit	Water Testing Frequency/yr
Producers	93%	100%	7
Packers	93%	100%	5
Importers	60%	100%	0

Worker Hygiene

Reported data indicate a significant variance in the number of times per year that hygiene training is provided to workers. On average, the number of trainings provided annually is five times higher in packing than it is in production. Insufficient data was received from importers to include in the analysis. Providing hygiene training frequently enough to ensure all employees are knowledgeable of good hygiene practices for food handlers is accepted and audited as a good agricultural practice.

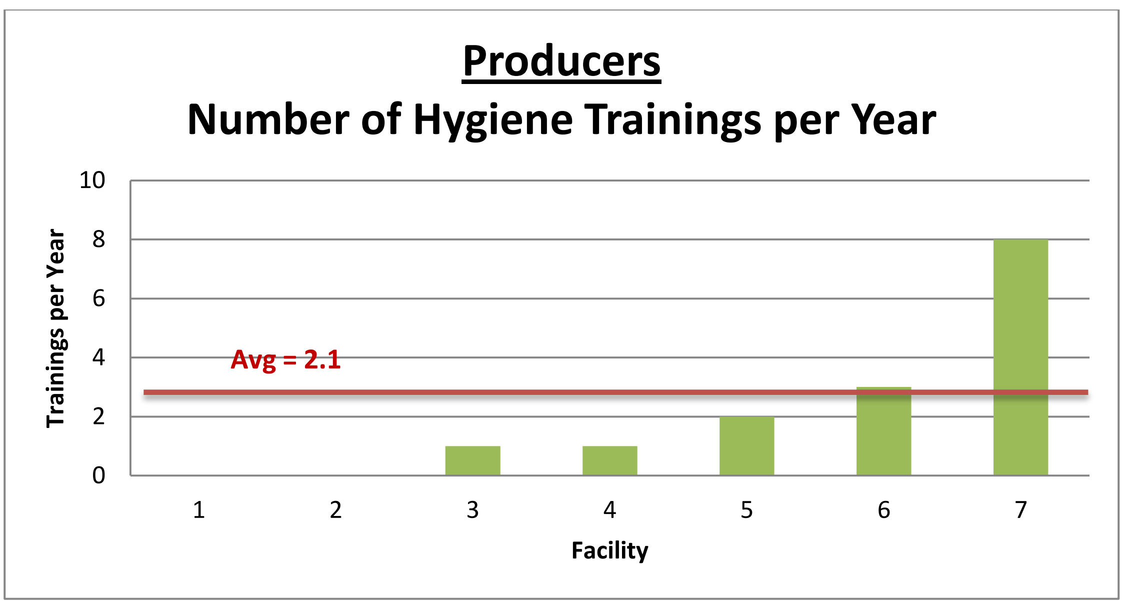

Figure 2.4.1 Number of hygiene trainings per year at production facilities

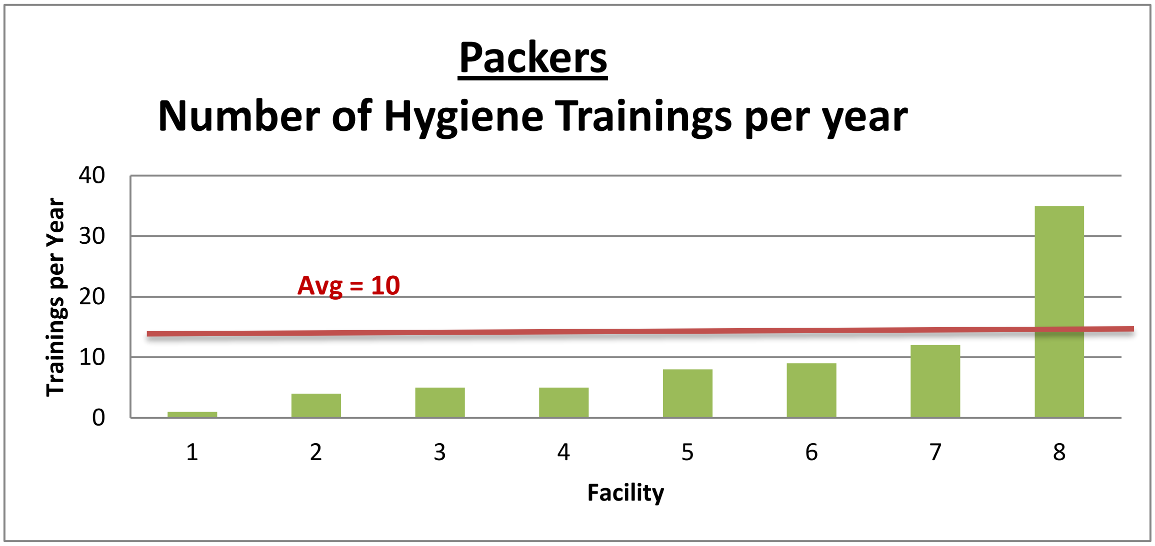

Figure 2.4.2 Number of hygiene trainings per year at packing-houses

3. Best Practices

3.1 Social

Workforce

While 0% turnover in production jobs is unlikely to hold true across all mango production facilities in Mexico, it is indicative of a low turnover rate. Understanding the practices in place that contribute to low turnover could provide best practices to be shared with the rest of the mango value chain. Employee recruitment and training are both contributors to overhead costs, and minimizing these costs will have financial benefits in addition to the social benefits associated with jobs that have low turnover.

Wages

Paying wages that exceed the local living wage contributes additional social value to worker families and the communities in which they live. After the necessities have been paid, surplus income can be used to further enhance security through savings, or spent on items such as education, additional medical care or improved nutrition, all of which contribute positively to the quality of life and an individual's ability to lead a dignified life.

Health Benefits

In Mexico, registering employees for Social Security and paying premiums on employees' behalf is a legal requirement. Ensuring that all eligible employees are registered with Social Security upon employment so that they and their families have access to medical care is an important practice, and one that appears to be happening consistently in the mango industry.

Unionization

Union membership is an important social norm for agricultural workers in Mexico. A company that encourages union membership and works collaboratively with the unions to ensure an equitable balance is achieved between employer and employee needs is fulfilling an important social contract. Several mango facilities visited had negotiated items with the union in addition to wages, such as the provision of educational scholarships.

3.2 Environmental

Water

Micro spray irrigation was the technique observed that had the lowest water use rate per unit of output. Once the system is installed, application timing and rates can be controlled electronically, and systems can be further refined with the installation of heat and moisture sensors. Micro spray emitters require only 10 – 15 psi to operate efficiently, so "powering" the system via gravity or solar pumps is practical.

Solid Waste

The use of reusable, plastic field crates for transporting mangos from field to packing facility has several benefits related to waste management including the ongoing reuse of the crates (versus disposable crates), and the protection provided to the mangos to prevent damage to the fruit. In every packing facility visited it was observed that the field crates are washed and stacked in an orderly fashion, contributing to the usable life of the crates.

Identifying alternative uses for organic waste is a sound sustainability principle. One practice observed was the diversion of larger diameter tree prunings to a local firewood business that collects the prunings and resells as firewood. This practice generates a small amount of income for a community member and provides fuel wood for cooking using a waste material from the farm to replace the practice of collecting wood from native forests.

Electricity Use

Several packing facilities visited make use of translucent panels in the roof to provide natural lighting in the plants during daytime hours. This practice greatly reduces the number of overhead lights required to provide sufficient light.

Cooling rooms used for staging and storing mangos prior to shipping are generally curtained-off from the non-cooled portion of the facility. The use of curtains provides some reduction in loss of conditioned air in the cooling rooms while still allowing personnel and equipment to easily pass between different areas of the facility.

Many facilities have seals installed between loading bay doors and trailer openings. This practice further reduces the amount of conditioned air that is lost due to leakage when loading bay doors are open.

Fuel Use

None observed or reported.

3.3 Biodiversity and Ecology

Natural Vegetation Protection

In only one instance (Chiapas) were areas of native vegetation being protected within an orchard. This area had been spared from orchard development for at least 20 or more years, given the apparent age of some of the large trees in the stand. This area of native vegetation contained a small river running through it and was an excellent example of how by protecting native vegetation, one can provide natural habitat for native species as well as protect water resources on the farm. Of concern however is that it was uncertain how protected this patch of forest was, since it was evident that some of it had been cut down recently to make way for an extension to the mango orchard. Given the high biological sensitivity of the regions that were visited a best practice would be to conserve between 20-30% of native vegetation within the orchard.

Natural Buffers and Corridors

A best practice in this category would be natural buffers lining all borders, including fence lines and waterways at approximately 5m in width that connect native vegetation patches inside and outside the orchard. Buffers are important factors in farm sustainability for biodiversity. The closest thing to a best practice was the use of live fence lines in one orchard (Chiapas) using a single species of a fast growing bush. This provided some habitat for a few species, however did not fulfill the scope for a working live border that was of general utility for native biodiversity. In N. Sinaloa one small line of neem trees was identified. Although non native they did provide some shade and habitat for local wildlife.

Biodiversity Protection

A best practice would be biodiversity and habitat conservation plan, adhered to and verified. In no farm was there a conservation plan, either written or adhered to verbally. Biodiversity protection was not considered a management priority nor necessarily a public relations priority to those managers or owners that we spoke with. Biodiversity protection is a vital part of agricultural sustainability and hence should be addressed in future sustainability actions.

Organic Composting and Soil Health

A best practice would be the reutilization of organic materials to build organic matter into the soil, thereby promoting soil biodiversity and increasing carbon content and sequestration potential of the soil. The use of natural organic fertilizers can be an effective means to restore a natural nutrient cycle while allowing soil biodiversity to flourish and equilibrate. This has both short and long term benefits and results. In two separate orchards we heard of efforts to use organic fertilizer but witnessed the production of fertilizer in only one of them (Chiapas). In this case the orchard was using cow dung as the principal organic ingredient using a vermicultural (worm composting) process utilizing the species commonly known as "Californian Reds". It is understood that not only does the use of organic compost have beneficial effects on soil health when used correctly, but can also reduce costs. In this instance organic waste material from the farm was not being used. A recommendation would be to reduce organic waste by recycling it back into the system as compost.

Combining Agricultural Activities for Greater Ecological Complexity

Not often considered a biodiversity benefit, cattle can promote natural cycling of nutrients, reduce the invasive grass/weed base and hence reduce the need for mowing, and quickly biodegrade plant material to useful fertilizer through their dung. The single farm manager that allowed this practice on his orchard recognized these benefits. In addition cattle attract flies that pollinate mango flowers, another service recognized by this particular farm manager. Additional benefits are that cattle by attracting a host of flies also attract birds and carnivorous flying insects that prey upon insect pests including the fruit fly. Hence by allowing large herbivores within an orchard environment one starts to build a semi natural ecology. Unfortunately all other orchard managers did not allow this practice citing it as being contrary to the fruit fly control program, although on a cursory look at the regulation we could not find this particular management statement. It would be interesting to study the effects of cattle within orchards, since this practice could have overall benefits as yet unrealized by the majority of the mango farming community.

Pollination Activities

A best practice would be to conserve native pollinators by conserving their habitat within and outside of orchards. Although this was not observed, non native domestic bees were utilized in two orchards although we witnessed their use in only one (Chiapas). Several orchard managers when asked why they were not used cited bee Africanization and subsequent aggression as a problem. The use of domestic bees, especially Africanized ones is a double-edged sword. On the one hand it promotes pollination, not only of mangos but of native flowering plants also. However these bees are non-native and can replace native American bees. Furthermore, it is currently unclear how effective domestic bees are in the pollination of mango flowers. More research would be necessary along these lines to understand the effects and efficiencies of keeping domestic bee hives within mango orchards.

Bee hives used in one farm to increase pollinator numbers

Use of worm compost from local organic ingredients instead of synthetic fertilizers

A live fence of neem provides a wind break and area of habitat for local wildlife.

Area of native vegetation within a farm provides habitat for native wildlife and migratory species

3.4 Product Integrity

Consistent Product Quality

Maintaining a low rejection rate from packing through retail represents good sustainability practice by eliminating waste in the value chain. By the time product gets to retail, almost all of the material inputs like water, fertilizer, pesticides and fuel have already been consumed, and their associated externalities such as pollution, toxicity and emissions are already "placed" in the environment. Good quality control processes by the packing facilities significantly reduce product waste further down the supply chain, and this contributes significantly to lowering environmental impact per unit of consumed product.

4. Opportunities to Enhance Performance

4.1 Social

Workforce

Data reflect a high degree of variance between farms and facilities in terms of labor efficiency. Further study could reveal a collection of best practices related to workforce efficiency across the industry that could be summarized and shared. Improving the efficiency of labor is an important component of reducing operational costs. It is also consistent with the tenants of sustainability that look to optimize efficiency and eliminate waste in all processes. An efficient workforce is much more likely to use resources efficiently and focus on waste reduction.

Wages

Conducting more detailed living wage assessments in mango growing regions will provide more accurate data for the industry to use when designing compensation programs for workers. It is important to use comparative data that is truly representative of the basic living expenses of the target workforce. Paying wages that equal the local living wage requirement should be the minimum objective. Wages paid in excess of the living wage contribute additionally to social benefit that can be attributed to the industry.

Health Benefits

All eligible workers should be registered for Social Security upon commencement of employment. Implementing internal controls and procedures to ensure this happens is considered a minimum performance requirement.

Unionization

Based on conversations with business owners and senior managers, the data reported on union representation is much lower than anticipated. This inconsistency merits further study to better understand the role of unions in the mango industry in Mexico.

Safety

Reported data indicate a large variance between companies in terms of rates of injury. This implies that a variety of practices are in place with varying degrees of hazard. It is recommended that a more detailed Occupational Health and Safety study be completed in order to identify best practices in the industry and establish standardized operating procedures that are aimed at improving employee safety for core activities.

4.2 Environmental

Water

When there is opportunity to select micro spray irrigation over other irrigation techniques, the deployment of micro spray techniques has the potential to significantly reduce water consumption as an input to mango production. When compared to flood irrigation, micro spray can reduce water use by greater than 90%. Depending on the cost of water in a given region, investment in micro spray could have a short break even period and provide a solid return on investment to the grower.

In addition to cost savings, water conservation is a foundational activity to sustainable agriculture, and implementing irrigation techniques that use less water per unit of output will contribute to improving the environmental performance of mango producers.

Solid Waste

The pressing challenge for managing all categories of solid waste is to replace "linear throughput" processes with "closed loop" processes. Linear throughput processes are characterized by post-use materials moving out of production cycles and into waste streams (landfills). Closed loop processes are characterized by one or more of the following processes:

- Post-use materials being cycled back into the same use production cycle (e.g. water capture, treatment and reuse)
- Alternative use internal production cycle (e.g. tree prunings collected and used as fuel wood for heating water)
- Alternative use external production cycle (e.g. tree prunings collected and sold as firewood in local community)
- Use as feedstock for different industry (e.g. organic waste combined with sludge at local water treatment facilities)

- Reuse (e.g. reusing field crates and maintaining to extend useful life)
- Recycle (e.g. used office paper recycled by paper manufacturer into new office paper)
- Down-cycle (e.g. recycled plastic containers used as material input for plastic pallets)
- Managed composting (e.g. shredded, piled, turned, moisture and air flow maintained at optimal levels)

Identifying the most cost-effective closed loop solution needs to consider several variables such as:

- Type of material
- Volume of material
- Potential downstream uses for material
- Feedstock potential of material for onsite use
- Feedstock potential of material for off-site use
- Available infrastructure for recycling material off-site
- Distance between waste material and potential off-site users of the material.

After the most cost-effective, potential solutions are identified they can be evaluated for environmental and social co-benefits (additional value for which to account). For example, the ROI of converting organic waste to energy through bio-digestion and the ROI of managing the composting process onsite may be similar, but the environmental co-benefit of replacing fossil fuel derived energy with biofuel derived energy may have a higher environmental return than the environmental benefit realized through producing compost.

Electricity Use – Energy Efficiency

Energy efficiency is an important activity as part of any energy reduction initiative. Equipment that draws electricity should have its use minimized through controls and scheduling in order to realize energy savings. After minimizing activities that use electricity the next step is to focus on improving efficiencies in the equipment and fixtures that use electricity and tightening the building envelope. The oft cited example that demonstrates reduction versus efficiency is in light bulbs – have as few as needed, turn them off or use occupancy controls and/or timers (conservation) and light spaces with CFLs or LEDs when turned on (efficiency).

The efficiency of the pumps, the ratio between the energy used to run the pump versus the amount of energy imparted on the water, should be established and monitored at each facility that pumps water. An energy consumption threshold for pumping a cubic meter of water should be established for each pump which, as it become less efficient, triggers either maintenance or replacement of the unit.

Ongoing, scheduled maintenance of equipment that uses electricity will keep equipment operating as efficiently as possible, keeping necessary electricity requirements for operation at a minimum. As with water pumps, motors and other electrical components should be replaced when an established energy consumption threshold can no longer be achieved.

Efficient Cooling

The basic elements of efficient cold room design include –

- Calculating an appropriate R-value for insulation for a raised concrete slab, walls and ceiling
- Allowing for the dynamic curtaining of the space
- Separation of cooling units, each with independent controls, to allow for different levels of cooling to be applied as the space is sub-divided according to inventory
- Loading bays that create air seals with trailers and don't have to be opened until the trailer is in place
- Building orientation that minimizes exposure to sun
- Use of landscaping such as large trees to maintain shade on the structure
- Appropriate choice of cladding and roofing materials to reflect heat
- Energy Star, or similar efficiency certification, for all cooling equipment
- Minimal doors and no windows

Fuel Use

Many opportunities exist for reducing fuel consumption. Similar to the objectives for reducing electricity consumption, minimizing activities that require fuel is the first step, and then improving the efficiency of activities that can’t be avoided is the second step. Ongoing, scheduled maintenance of equipment that uses fuel will keep equipment operating as efficiently as possible, keeping necessary fuel requirements for operation at a minimum.

Transportation is the most significant activity that consumes fuel across the value chain. While most of the transportation is provided by third party companies, procurement policies that mandate certain fuel efficiency standards by transportation providers can create awareness, establish efficiency policies, and ultimately reduce costs of shipping for producers, packers, importers and retailers.

4.3 Biodiversity and Ecology

The majority of orchard growers were unaware or ambivalent towards the need for greater protection of habitat within their orchards. One orchard owner, in response to the question, "what native wildlife commonly utilize the orchard?" mentioned that he wanted no animals in his orchards. There however exists an opportunity through education to change the minds of these growers so that mango farming becomes commonly known as a wildlife friendly practice. The majority that recognized the benefits that could arise from greater protection of habitat were undertaking some interesting practices but these were neither systematic nor well thought out or monitored. This made it challenging to appreciate the benefits that were being derived from these activities, and to modify the practices so that they could be improved or better integrated into normal farm management. There exists ample room for improvement within all the factors pertaining to biodiversity considered in this report.

4.4 Product Integrity

Good Agricultural Practices

The use of standard operating procedures in the management of good agricultural practices is an agriculture industry standard. It is recommended that all facilities across the mango value chain create or obtain and use SOPs that align operations to generally accepted good agricultural practices.

5. Study Limitations And Scope For Future Work

5.1 Study Limitations

Mangos are an important export commodity for Mexico. Mexico is the fourth largest mango producer and the largest mango exporter in the world. The US imported 297,449 tonnes of mangos in 2008 with a value of US $210 million[36]. Sixty one percent (61%) of these were from Mexico.

With such large volumes and region of production spread throughout the country a meaningful analysis of the entire industry and its variations is a gargantuan task. For this reason the assessment was broken into phases. In this, Phase 1, the primary area of investigation was specific aspects of the industry relating to GHG, environmental and social performance and targeted a specific subset of producers and packers from which to obtain data. Common Fields designed a comprehensive, yet manageable set of survey questions that would adequately afford information for a high level assessment of the industry, from a Phase 1 perspective, and provide guidance on a phase 2 investigation. In order to provide both breadth and relevance to the National Mango Board, all board members, no matter where their business interests lay, were also surveyed.

Although several weeks were allowed for participants to respond to the survey, a limited number of BOD and non-BOD members completed the survey. Of those that did only two surveys were complete enough to be able to undertake a full analysis.

---

[36] (US Department of Commerce, GATS database)

An onsite assessment was organized initially to validate information that would be obtained from the surveys. However due to the low response rate, the onsite assessment became the principal data collection activity for the project. Fortunately while onsite; the team was able to validate the two facilities that had completed the online survey.

There are two primary reasons why survey response rates may have been low. Firstly, harvests were occurring at the same time as the survey went out and facility owners/managers may not have had time to fill it out. Secondly, a limited understanding of both sustainability and the motivation of NMB for undertaking this assessment may have made owners/managers less enthusiastic to place the survey as a high priority. It is likely that a combination of the two of these reasons led to a lower than desired response rate.

The large variation in mango production and processing systems in Mexico means that large sample sizes of over 30[37] data points per boundary are required to capture this variation and obtain statistical confidence in the data. Despite these limitations, this study did obtain interesting and useful data as discussed above. The data collection process and the results obtained have provided us with a solid foundation from which to devise and prepare for future research on all the areas covered within this investigation.

5.2 Scope for Future Study

---

[37] A sample size of 30 gives approximately an 18% confidence interval at 95% confidence. Given the great geographic variation in mango production across Mexico it should be noted that sample sizes greater than 30 would be needed to capture that variation, but this will very much depend on the question being asked.

This section has been left blank so that it can be filled in after this report has been discussed with the NMB

- More farms and packing-houses
- Retailers
- Importer facilities
    - GHG Emissions and Sequestration
    - Environmental
    - Social
    - Biodiversity
    - Product Integrity
- Geographical Breadth (# regions analyzed)
- Geographical Intensity (# farms per region analyzed)

ANNEXES

(The following files will be included along with the final report)

- .pdf of all four survey monkeys
- Excel spreadsheet that includes "raw" survey data
- Excel spreadsheet that includes survey data analysis tables and summaries
- Survey Instruction "package"
- E-mail communications in English and Spanish when survey was implemented and reminder/thank you e-mails
- Farm assessment plan
- Retailer emissions data gathering tool and project overview document