DONALD BREN SCHOOL OF ENVIRONMENTAL SCIENCE & MANAGEMENT
UNIVERSITY OF CALIFORNIA, SANTA BARBARA

# Sustainability and Tracking Strategies for Gills Onions Farming Operations

## A 2011 Group Project

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As authors of this Group Project report, we are proud to archive this report on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Bren School of Environmental Science & Management.


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The mission of the Bren School of Environmental Science & Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention, and remedy of the environmental problems of today and the future. A guiding principal of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political, and economic consequences that arise from scientific or technological decisions.

The Group Project is required of all students in the Master's of Environmental Science and Management (MESM) Program. It is a three-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

James Frew

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# 1. Abstract

Agriculture has a significant impact on the environment. The systematic tracking and reporting of resources used in farming allows the industry to communicate sustainable practices and measure progress over time. For this project, we worked with Gills Onions, the largest onion processing company in the United States, to assess the resources used and waste generated at a bulb propagation farm in Indiana and three growing regions in California. We first assessed the value of resource tracking, including the economic value of reducing the use of costly inputs, helping growers prepare for upcoming water and air quality regulations and the potential market value of sustainability tracking. We collected data for five resource categories: water, energy, fertilizers, pesticides and waste, and documented current record keeping practices on the farms. We then calculated baseline resource use in these categories for the four growing regions. In addition to informing Gills Onions about their supply chain, our analysis served as a pilot project for the Stewardship Index for Specialty Crops (SISC), a national effort to standardize reporting metrics for non-grain, conventionally grown agriculture. In order to simplify Gills Onions' tracking efforts in the future, we developed a comprehensive data tracking framework for the four regions and a database in Microsoft Access to house the information.

# 2. Executive Summary

Farming in California has a significant effect on the environment including impacts such as water pollution from irrigation runoff that may contain pesticides and fertilizers, air pollution from farm machinery and field applications, energy consumption, and the generation of waste.

Industries are increasingly looking for ways to put a value on sustainability and transparency. Voluntary reporting systems allow vendors to communicate information about the sustainability of their products. Some of these sustainability systems operate to provide a specific certification, such as the organic label, while others provide a sustainability ranking structure that does not have absolute cut-off criteria but rather demonstrates relative sustainability. Still others operate on the idea that increased disclosure alone will result in more ethical corporate behavior.

Since its inception 25 years ago, Gills Onions, the largest onion processor in the country, has been firmly committed to environmental stewardship and leadership. The company has been recognized for innovation and excellence in sustainability by the Energy Solutions Center, the California Environmental and Economic Leadership Award bestowed by Governor Schwarzenegger through the California Environmental Protection Agency, and the Golden State Award for Engineering Excellence from the American Council of Engineering Companies. In accordance with these values, Gills Onions completed a zero waste analysis of its processing facilities with the Bren School in 2010.

After implementing multiple energy and waste reductions strategies at their processing plant, Gills Onions enlisted the Bren School to expand their sustainability accounting to their four growing regions. The first critical step for the company was to understand the amount of resources used and waste generated in farming operations. To meet this need, our group calculated a baseline for the 2008-2009 growing season in all four growing regions: Monterey County, Fresno County, Imperial County, and the onion bulb propagation facility in Indiana. We surveyed all of the inputs at the farm level including water use, fertilizer use, pesticide application, and energy consumption. We also determined how each input was measured, and documented the total waste generated on the farm.

We determined that Gills Onions would benefit from having a simplified data recording system that would allow the company to track resources and standardize the data being reported across each of the growing regions. We worked closely with Gills Onions' growers and staff to create a database that could be used to record farming inputs, data that could ultimately be used to determine the environmental impact of Gills' onion production. The system is tailored to the growers' current data collection processes to reduce the burden of additional data collection, and should assist with evolving government and sustainability reporting mandates. We also recommended methods to reduce data gaps, improve data quality, and prioritize data recording efforts.

The agricultural industry, like so many others, is exploring different ways to measure sustainability. One such initiative is the Stewardship Index for Specialty Crops (SISC), a consortium of stakeholders, including growers, suppliers, trade associations, environmental and public interest groups and university researchers. SISC is developing metrics that aim to communicate and track sustainability for smaller scale specialty crops. As part of our work with Gills Onions, we participated in a pilot study for SISC. The pilot study involved completing the SISC trial metrics with the data we had collected and providing feedback on the feasibility of different kinds of data collection and the metrics themselves. Participating in the pilot project gave us an insider's view of the direction the sustainable agricultural tracking industry may be headed. Since Gills Onions expects to continue their relationship with SISC, we tailored our database so that it would be able to generate the data requested by SISC.

This project will provide Gills Onions with a greater understanding of the environmental impacts of their farming operations. In combination with the Bren School 2010 Zero Waste project, this analysis will ultimately provide Gills Onions with a comprehensive understanding of the environmental impact of their business from the seed to the finished product and allow Gills Onions to prepare for increased demand for sustainability in the marketplace.

# 3. Acknowledgements

We could not have done this project without the participation of the growers contracted with Gills Onions. We hope the work we have done to streamline data tracking for the company will make future tracking more efficient and effective for their own operations.

We would like to thank the following individuals from Gills Onions and Rio Farms for their partnership with the Bren School and dedicated assistance with data collection: Steve Gill, Founder and Owner; Nikki Rodoni, Director of Sustainability; Don Arevalos, Director of Procurement; and Cesar Flores, Director of Operations and a special thanks to Bob Martin, General Manager of Rio Farms for sharing his time and knowledge to help us complete the project..

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# 4. Introduction

Gills Onions is one of the largest onion producers in the United States. It is a privately owned company and was founded in 1983 by brothers Steve and David Gill. Gills Onions sells chopped and sliced onions to retail, food service, industry, and for direct consumer purchase in grocery stores. Their processing plant is located in Oxnard, California and their onions are grown in three different growing regions throughout California and then transported to Oxnard for processing. Gills Onions has a strong record of being environmentally progressive. In 2009, Gills implemented a "Zero Waste" initiative in their processing facility in collaboration with students from the Bren School of Environmental Science and Management. In that same year, they installed an innovative biodigester fuel cell to turn the onion waste from their processing facility into methane fuel that they now use to help run the plant. The fuel cell investment will ultimately save the company money and is already reducing its environmental impact. Gills was subsequently recognized for innovation and excellence in sustainability by the Energy Solutions Center, the California Environmental and Economic Leadership Award bestowed by Governor Schwarzenegger through the California Environmental Protection Agency, and the Golden State Award for Engineering Excellence from the American Council of Engineering Companies.

In 2010, Gills Onions again turned to the Bren school, this time with the goal of reducing the environmental impacts of their onion growing operations. These impacts include water pollution from irrigation runoff, air pollution from farm machinery and other farming practices, energy consumption, and waste generation. Irrigation runoff is polluted with pesticides and nutrients from fertilizers, and can flow into ground and surface water sources, degrading water quality. There are also indirect environmental impacts as a result of water consumption: approximately 80% of California's water is used to irrigate farmland (CEC 2010). Agriculture's high water demand results in reduced instream flows, and impaired aquatic and riparian habitats for fish and other species, as well as requiring large amounts of energy to be moved around the state (CDWR 2009a). These environmental impacts have grown in recent years. From 2003 to 2009, vegetable production (in tons) in California has increased by over 42% while cropland area has increased by only 7.5% (NAAS 2010). This increased production has been accompanied by large intensifications in water, fertilizer, pesticide and fossil fuel energy use, creating a significant impact on our natural resources.

Our project addressed the environmental impacts of Gills Onions' farming operations through sustainability tracking; specifically, the cataloging of on-farm resource use. Tracking the environmental impacts on the farm would allow Gills Onions to complete their sustainability accounting, from onion seed to final product. These agricultural sustainability measurement and reporting systems are being developed across all sectors of the food and beverage industry, from manufacturers and distributors to retail grocery outlets and restaurants. These systems allow sellers to market the sustainability of their products, and buyers to ensure that the sustainability claims are accurate. Individual growers also stand to benefit from tracking resource use more closely, as inputs such as diesel, pesticides and water are expected to rise in cost. If these resources are carefully tracked, growers may identify potential cost savings. Agriculture is also subject to increasing government regulations that relate to environmental concerns such as water quality, erosion, biodiversity, and climate change. Resource tracking may prepare the company and its growers for these new regulations.

The industry, government, and economic drivers that we have identified led us to our ***Objective 1: Assess the value of sustainability tracking.*** We identified how resource tracking would benefit Gills Onions and its growers, focusing our analysis on relevant California resource costs and projections, regional regulations and movements within the agricultural industry to prepare our client for the changes ahead.

Once we established the benefits of sustainability tracking for Gills Onions, we began collecting and aggregating data to establish a baseline. This became our ***Objective 2: Establish a baseline of resource use and waste generation.*** We focused on the 2008-2009 growing season since it was already fully completed at the start of the study. We collected data on the five major inputs to the growing operations: water, electricity, fuel, pesticides and fertilizers, and the two major outputs: waste and onions. We aggregated the data and determined baseline values for farming inputs on a per-acre and per-ton (of onions) basis.

In light of the increased demand across the board for sustainability reporting and the company's own commitment to greening their product line, Gills Onions has become involved with an agricultural data collection and sustainability program, The Stewardship Index for Specialty Crops (SISC). SISC is a consortium of stakeholders, including growers, suppliers, trade associations, environmental and public interest groups, and university researchers that is developing metrics to help the industry measure, communicate and track sustainability. We collaborated with SISC by submitting some of our baseline data as part of a pilot project to test their metrics and provide feedback. This process gave us the opportunity to provide suggestions to Gills Onions on data collection methods that would help them participate in future SISC sustainability tracking. By participating in the pilot project we were able to see what direction the agricultural tracking industry was headed.

One of the challenges we faced in collecting baseline data was that Gills' onions are grown in four separate areas. Three of the growing regions- Monterey County, Fresno County, and Imperial County- are in California, and Gills buys onion sets (partially grown onion bulbs) from a bulb propagation facility in Indiana. Each region has different climatic conditions, cultural practices, management systems, and record keeping methods. The difference in climatic conditions means that regions cannot be easily compared, and the difference in record keeping practices means that a uniform reporting system requires a significant time investment by growers and their staffs.

The growers also have different business relationships with Gills Onions. In Monterey County, the head grower is employed by Gills' subsidiary Rio Farms, whereas in the other three regions, the growers are contracted with Rio Farms but also do business with other processors and buyers. This creates a difference in incentives between the objectives of Gills Onions/Rio Farms, who have a vested interest in assessing the sustainability of their supply chain, and the contracted growers, who often have other more pressing concerns.

These regional differences meant that aggregating the baseline data was not a simple task and comparing future data and potential environmental improvements would probably also be very challenging for the company. We decided that Gills Onions would benefit from having a better and more unified method of tracking resource information from all of the growing regions. This became our ***Objective 3: Establish a data tracking framework.*** We built a Microsoft Access database to house the data and tailored it specifically to match the growing region practices and the types of information we expect will be demanded of the industry in coming years.

In conclusion, our objectives were:

**1. Assess the value of sustainability tracking for Gills Onions and their growers.**
**2. Establish a baseline of resource use and waste generation.**
**3. Establish a data tracking framework.**

We met the above objectives by working with growers from each of the growing regions and fulfilling a thorough data collection process. In areas with data gaps, we provided suggestions for future data collection needs and methods, and ensured that the recommended processes were feasible and sustainable by consulting the growers.

By providing Gills Onions with an overview of current sustainability trends, a baseline from the 2008-2009 growing season, a framework to continue their data collection process, and a strong working relationship with the SISC consortium, our project should have significant and lasting impacts. The steps that Gills takes to foster a culture of data tracking within their grower community will set an example for growers and buyers both inside and outside of the onion market. As Gills leads the way in sustainability tracking, other California growers and producers will join in, ultimately leading to resource savings and environmental benefits throughout the industry.

# 5. Objective 1: Assessing the Value of Sustainability Tracking

Sustainability tracking is a valuable tool that can help businesses prepare for upcoming environmental regulations, respond to industry demand for sustainability, and manage the economics of rising resource costs. In this section we will explore the value of sustainability tracking from the perspectives of policy drivers, industry drivers, and economic drivers.

## 5.1 Policy Drivers for Sustainability Tracking

Gills Onions and its growers will have to consider how their operations are affected by new air and water quality regulations. Some of these regulations may mandate operational changes, but major changes will come in the form of monitoring and reporting mandates. Implementing a resource tracking system will help Gills Onions to quickly comply with new regulations and to serve as a sustainability leader in the agricultural industry.

### 5.1.1 New Regulations from the Regional Water Quality Boards

Farming operations represent a significant source of nonpoint pollution in each of the watersheds where Gills Onions are grown. In California, the Regional Water Quality Control Boards (RWQCBs) manage non point source pollution under the Porter-Cologne Water Quality Control Act. The RWQCBs mandate that all polluters must file a report of waste discharge with their RWQCB to obtain mandatory waste discharge requirements (WDRs). However, the California Water Code allows the RWQCBs to grant conditional waivers for WDRs if the waiver is not against public interest (Gerstein, 2005). Irrigation return water from agricultural practices currently falls under a conditional waiver from WDRs. These conditional waivers were established as a preliminary program for agricultural dischargers, in which individual dischargers or coalition groups would evaluate and implement Best Management Practices (BMPs) that address the water quality objectives of the watershed. These waivers were implemented with the plan that once a greater understanding of BMPs' effects on water quality was established, the conditional waiver program would likely lead to the adoption of individual or general WDRs (CCRCD, 2005). Under California law, waivers must be reviewed, renewed, revised, or replaced every five years (CCRCD, 2005).

Several of the RWQCBs are reviewing their conditional agricultural waivers, which may affect Gills Onions' growers. The three growing regions in California are under the jurisdiction of three disparate RWQCBs. Two of these regions are in the review process: Monterey County's Central Coast RWQCB and Fresno County's Central Valley

RWQCB (CVRWQCB, 2010). Imperial County's Colorado River Basin RWQCB has not begun the review process, but will do so after the conditional waiver is expires (CVRWQCB, 2010).

The Central Coast's review process may provide an outline of what Gills' growers in each of the regions can expect in terms of additional regulation. Although none of the proposed changes have been adopted yet, the final draft proposal of a new Agricultural Order has been open for public comment, and a final version is expected by March 31, 2011 (CCRWQCB, 2010). The current Central Coast RWQCB's draft agricultural order specifies additional monitoring and reporting mandates for groundwater and receiving water bodies of agricultural runoff. Agricultural dischargers must monitor for temperature, turbidity, nutrients, toxicity, and other details outlined by the water board (CCRWQCB, 2010). The draft order also outlines mandates for monitoring plans and reporting schedules. The order arranges agricultural polluters into tiers, based on proximity to impaired water bodies, ranch acreage, and use of specified pesticides. Based on this draft order, it is likely that growers in Monterey County will be subject to tier 2 requirements, (out of a proposed 3 tiers) which in addition to ground and surface water monitoring, will potentially require Gills Onions' growers in Monterey County to report the total nitrogen applied to their fields on an annual basis (CCRWQCB, 2010).

The Central Coast's proposed draft Agricultural Order has been opposed by the agricultural community; growers are concerned about the additional monitoring and reporting mandates that may be enforced by the RWQCB. There are also concerns over the process of assigning tiers, the economic stress that the order may create for growers, and the presence of legacy pollutants in the ground water, which will show up in water tests, but are not indicative of current farming practices (Public comment, 2010). The additional monitoring requests will likely be expensive and time consuming, and growers overwhelmingly favor voluntary pollution prevention measures to the prescribed measures in the agricultural order (Scott, May 14, 2010).

Our project has gathered fertilizer application data from many sources and provided a database to store the application information. These records of farming practices may assist Gills' growers in informing regulation in the future. Solid record keeping will allow growers to demonstrate their environmental responsibility, which may deter future policies that propose onerous or redundant monitoring demands.

### 5.1.2 New Regulations from the Air Quality Control Board

Gills Onions' growers must also comply with air quality restrictions imposed by the California Air Resources Board (CARB). The CARB has long-term plans to reduce emissions from in-use agricultural equipment, as outlined in the 2007 State Implementation Plan (CARB, 2010). The board plans to implement regulation that will result in an agricultural fleet with lower nitrogen oxide (NOx) and particulate matter (PM) emissions. Although the board does not currently have a policy proposal to meet these goals, policy will likely be directed at exhaust control technology and setting maximum horse power standards (CARB, 2010).

Although there are no draft policy proposals available from the CARB, the agency is collecting information to inform future policy. For example a survey, available on the CARB website, asks growers to list the farm equipment, mileage, and tractor hours that they use. The data that we collected in this project may help Gills growers participate in the agency's information gathering process.

## 5.2 Industry Drivers for Sustainability Tracking

Many in the business community have already taken first steps to evaluate sustainability. The Dow Jones Sustainability Index (DJSI) was created in 1999 in association with the sustainability investing firm Sustainable Asset Management (SAM). The assets included in the DJSI have gone from a total value of less than USD 500 million to more than USD 8 billion as of 2009, representing both an increase in the number of participants and an increase in the value of their assets. The DJSI (World) list is determined when SAM invites the 2500 largest companies in the world to participate in a sustainability assessment each year. The responders are assessed based on criteria that give equal weight to economic, environmental, and social criteria, and then all responders are assigned an overall corporate sustainability score. The environmental criteria, which count for exactly 1/3 of the sustainability score, assess both environmental reporting practices and industry specific standards. Only the 10% with the highest overall scores are included in the DJSI. This list can change from year to year, meaning that companies that maintain the same level of sustainability instead of improving may be dropped from the list if they are surpassed by others, creating an incentive for continuous improvement (SAM, 2010).

There is some evidence that more sustainable companies may tend to outperform sustainability laggards in the stock market. A study by SAM comparing the 20% of assessment responders with the highest sustainability scores against the 20% with the lowest sustainability between the years of 2001 and 2008 found that sustainability leaders annually outperformed the average by 1.48% while sustainability laggards underperformed by 1.46%. Outperformance held true in spite of market swings (de Groot, 2010). Academic studies have confirmed the significant correlation between corporate sustainability and financial performance, and show that the difference between cumulative returns on best-in-class and worst-in-class portfolios is increasing in size (Derwall, 2005; Lo, 2007).

In February of 2010, the U.S. Securities and Exchange Commission (SEC), which requires that companies disclose all meaningful risk and financial information to potential investors, released a statement indicating that companies must now include considerations of climate change in this information. Potential climate change related issues include: impact of legislation and regulation, international accords, indirect consequences of regulation or business trends, such as decreased demand for goods that produce significant greenhouse gasses, and physical impacts of climate change, such as the arability of farmland or the availability of fresh water. The SEC's position on this matter is both an indicator of the seriousness with which climate change risks are being considered in terms of corporate value, and the impetus for an increase in transparency about carbon emissions and associated financial risks (Murphy, 2010).

Many environmental protection initiatives presume that disclosure alone will result in improved environmental performance. Such reporting initiatives include: the Toxic Release Inventory (TRI), the Carbon Disclosure Project (CDP), and the Global Reporting Index (GRI). Mandatory or even voluntary disclosure is believed to function as a quasi-regulatory measure by virtue of the company's desire for positive public perception (Konar & Cohen, 1997). Studies looking at the TRI, a mandatory measure, and the GRI, a voluntary one, confirm that both types of reporting are associated with improved environmental performance (Konar & Cohen, 1997; Clarkson, Li, Richardson, & Vasvari, 2008). These studies underscore the importance of tracking and reporting as an effective method of improving corporate sustainability.

In 2010 several large manufacturers and food service corporations announced agricultural sustainability initiatives. In April of that year, Unilever announced the Unilever Sustainable Agriculture Code, which sets sustainability expectations for its suppliers. Under the code all suppliers are required to demonstrate that they meet a set of minimum standards based on eleven indicators including water, biodiversity, agrochemicals, fuel and energy (Unilever, 2010). Unilever has committed to obtaining all of its agricultural raw materials from "sustainable sources" by 2020 (Porritt, 2010). In July 2010, Del Monte Foods released its set of formalized environmental sustainability goals, which commit to making improvements in the areas of waste, greenhouse gas emissions and water consumption across the supply chain (Li and Stengel, 2010). Sysco Corporation (Sysco) also has several Agricultural Sustainability programs. Their Integrated Pest Management (IPM) program requires suppliers to comply with set IPM standards and to measure and report on items such as pesticide use and waste disposal. Sysco also participates in the Business Coalition for More Sustainable Food, which is working to identify best practices and improve environmental performance of specific supply chains in the areas of land use, water use, packaging, pesticides, and energy consumption (Sysco, 2010).

Agricultural sustainability programs are also becoming popular in the retail and restaurant industries. In October 2010, Wal-Mart Stores, Inc. released its Global Sustainable Agriculture Goals, which aim to support farmers, increase resource efficiency and sustainably source agricultural products. As part of this program, Wal-Mart plans to ask suppliers about water, energy, fertilizer and pesticide use per unit of production and to add a Sustainable Produce Assessment to its Sustainability Index (Clifford, 2010). McDonald's Corporation currently uses an Environmental Scorecard for its suppliers. The Environmental Scorecard was developed in 2005 in collaboration with Conservation International and is used to drive improvements related to impacts in energy, water, air and waste categories for key suppliers (Conservation International, 2010).

In order to demonstrate compliance with initiatives such as Unilever's Sustainable Agriculture Code, or Wal-Mart's Sustainability Index, growers and produce suppliers such as Gills Onions must be able to accurately track and report their resource use. Therefore, as more large corporations adopt sustainability standards, resource tracking programs will be critically important for businesses that wish to stay competitive in the produce marketplace.

The California winegrowing industry has demonstrated the environmental and business benefits of implementing sustainability measurement and reporting programs. In 2001, the Sustainable Winegrowing Program (SWP) was created as a partnership between the Wine Institute and the California Association of Winegrape Growers (CAWG) and is now implemented through the California Sustainable Winegrowing Alliance (CSWA), an independent nonprofit organization. The purpose of the SWP is to establish standards for sustainable practices within the industry and to facilitate education and knowledge sharing between growers and vintners regarding sustainability (California Sustainable Winegrowing Alliance, 2009).

The foundation of the SWP is the *Code of Sustainable Winegrowing Practices Self-Assessment Workbook*. The workbook was created in collaboration with diverse external stakeholders ranging from industry to academia to government. The workbook addresses ecological, economic and social sustainability and includes 227 criteria across 14 different categories including soil management, energy efficiency, water quality and waste reduction. A measurement system is included in the workbook with which the growers and vintners assess their practices according to a four-category system based on increasing levels of sustainability (California Sustainable Winegrowing Alliance, 2004). Participants then voluntarily submit the results of their self-assessments to SWP. The results are compiled by SWP and returned to the growers so that individuals can compare their results against regional and statewide data. In 2004 and 2006, the results of these self-assessments were compiled into public reports that identified strengths of the program and opportunities for improvement (California Sustainable Winegrowing Alliance, 2006).

The SWP has been effective in advancing sustainable practices throughout the wine industry as well as providing cost savings to participants who implemented sustainable practices. A study by the University of California found that participants and experts in the field regard SWP and similar programs as being successful in increasing adoption of sustainable practices, increasing communication among growers and reducing environmental risk in the industry (Hillis et al., 2010). Over the last eight years, SWP has demonstrated improvement by participants in 170 of workbook criteria and educated more than 9,000 attendees on sustainable practices at its educational workshops (California Sustainable Winegrowing Alliance, 2009). A second study by the University of California at Davis found that economic benefits exceeded economic costs for a majority of sustainability practices implemented through sustainable winegrowing programs. Cost savings fell into three main categories: reduced input cost, improvements in grape and vineyard health and increased ease of compliance with environmental regulations (Lubell et al., 2010). The CSWA and the SWP have demonstrated the value of organized efforts in successfully and cost-effectively improving sustainability within the agricultural industry.

## 5.3 Economic Drivers for Sustainability Tracking

All growers contracted with Gills Onions are sensitive to the rising costs of resource inputs such as water, fertilizer, pesticides and diesel fuel. This analysis gives an overview of the past and projected costs of these resource inputs. Many resources are forecasted to rise in price in the coming years, which highlights the growing importance of using each input efficiently. Tracking resource use and cost will benefit individual growers by allowing them to compare their resource use from year to year and identify areas for cost savings.

In 2008, oil prices skyrocketed to $147/barrel and food prices followed, primarily due to the increased costs of fertilizer, pesticides and direct fuel used in agriculture. Figure 1 shows the close correlation between oil prices and farm inputs with the Department of Agriculture projections for the future of these inputs. According to USDA future projections, "energy-related production expenses for fertilizer and for fuel and oil rise faster than the general inflation rate over the projection period, largely reflecting increases in crude oil prices." (USDA 2010). Fertilizer and fuel price increases will raise the cost of producing onions in the future; meaning that careful tracking of resources and targeted changes in growing practices could result in huge cost savings.

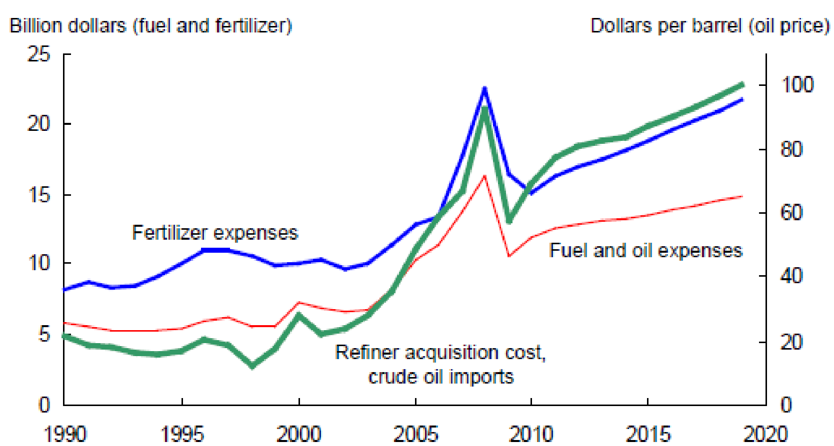


**Figure 1 Current trends in oil prices and fertilizer and fuel inputs (USDA 2010)**

Recent trends in diesel and electricity may also give insight to what future prices for these farm inputs may be. Figure 2 shows the average electricity prices for industrial users and the cost of diesel number two for the state of California, based on data from the U.S. Department of Energy (US EIA 2010b, US EIA 2011). In the past 15 years, diesel prices have risen from $1.277/gallon to $3.562/gallon, a 179% increase (US EIA 2011). In the future, the EIA predicts that the cost of a barrel of oil "rises from $79 per barrel in 2010 to $108 per barrel in 2020 and $133 per barrel in 2035" a 68% increase over this time period (EIA 2010a).

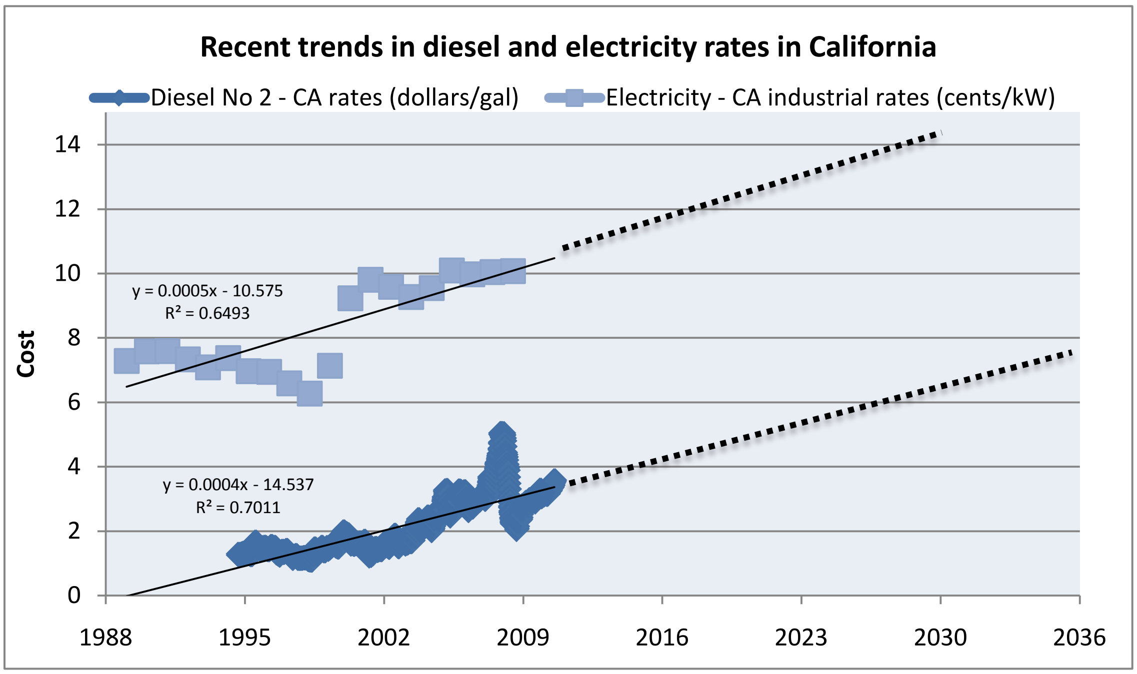


**Figure 2 Recent trends in Diesel and Electricity Prices**[1]

The graph also shows that industrial electricity prices in California increased by 38% between 1990 and 2009, from 7.28 cents to 10.07 cents per kilowatt hour. The California Energy Commission states that when adjusted for inflation, electricity rates may actually decrease by 0.3% by 2016. However, this change may not be seen in all parts of the state: the agency estimates that Imperial Irrigation District's rates may increase 43.7% in

[1] Electricity prices based on "Total Electric Industry" sector category from the U.S. Energy Information Administration State Historical Tables for 2009 (EIA 2010b). Diesel number 2 prices are from the U.S. Energy Information Administration Spreadsheet of Complete Diesel Historical data (EIA 2011). Note that off-highway diesel prices used in farm equipment are not available online, however federal taxes were $0.18 through 1996 and $0.244 since 1997, and California charges an additional 8.25% sales tax on diesel.

nominal terms and 8.7% in real terms, which could impact growers in this region (California Energy Commission 2007).
Perhaps the most difficult resource to predict is the future cost and availability of water in California. Current contracts in the state's largest distribution system, The Central Valley Project (CVP) over-allocates water resources almost every year, a system that makes water supply an annual source of controversy for growers. "The CVP, for example, has only been able to provide 100% of the allocated water to contractors south of the Delta three times since 1990. Likewise, the State Water Project has only provided 100% of the allocated contract water to its customers five times since 1996." (Cooley et al. 2009). Growers in the Fresno County region have experienced this in past years including 2009 and had to supplement Westlands Water District water with groundwater resources.

In addition to current issues with water distribution, climate change models predict California mean temperatures will increase 1.5-4.5°C by 2100. In the same timeframe, spring snow pack in the Sierra Nevada, a main source of water for the San Joaquin Valley, is expected to decline by 30%-40% (Hayhoe et al., 2004, Mote et al., 2005). Scientists predict that this will change the type of crops grown in the state, decrease crop yields, spread pests and invasive weeds, increase soil erosion and diminish productivity of agricultural lands. A study conducted by the California Climate Change Center applied the Statewide Agricultural Production Model and predicted that by 2050, the effects of climate change will reduce irrigated land by 20%, water availability by 20%, and overall farm revenues by 11% (Hewitt et al., 2009).

With an expected diminishing supply, it can be argued that water prices will at least keep up with recent rate increases, if not surpass them. Based on estimates from the California Department of Water Resources, agricultural water prices could rise 10 percent to 39 percent by 2030 (Groves et al. 2005). On the higher end of estimates, The Pacific Institute has estimated an average 68% price increase by 2030, and as high as a 196% increase for water from the Central Valley Project which serves the Fresno County growing region (Gleick 2005).

Thus, the costs of all major agricultural resource inputs are expected to rise in the near future. Fuel and associated products like fertilizer and pesticides are expected to outpace inflation, electricity costs may grow in parts of the state, and water supply in perhaps as much question as water prices. As resource inputs for farming become more expensive, food prices would be expected to follow, as they did in 2008. If growers track resources carefully and make incremental changes that reduce their overall resource use, they will have a competitive advantage over less efficient farms and will save on costly inputs.

In summary, from our evaluation, we find that the tracking of resource use has clearly defined economic and political benefits. Reducing resource use could yield huge competitive advantage for growers who are using resources more efficiently. By systematically tracking resource use, growers will be able to meet the challenges of upcoming regulations and address the needs of tracking for the many buyers within the industry.

# 6. Objective 2: Establish a baseline of resource use and waste generation

## 6.1 Growing Regions

Gills Onions has three growing regions in California, located in Imperial, Fresno, and Monterey Counties. It also contracts with a bulb propagation facility in Indiana. The map in **Figure 3** shows the location of the California growing regions. The regions have different business relationships with Gills Onions, as well as different climates and soils, making management and growing strategies diverse. See Table 1 for more detail.


**Figure 3 Gills Onions' Growing Regions (Gills Onions, 2011)**

| | Imperial County Region | Fresno County Region | Monterey County Region | Indiana |
|---|---|---|---|---|
| Business Relationship to Gills Onions | Growers are contracted to grow onions for Gills Onions | Growers are contracted to grow onions for Gills Onions | Operations are owned by Gills Onions' sister company, Rio Farms | Growers are contracted to produce onion bulbs for Gills Onions |
| Temperature Range (ºF) | 38.9 - 107.6[1] | 35.2 – 100.4[1] | 34.6 – 86.9[1] | 25 - 80[2] |
| Annual Average Precipitation (Inches) | 2.65[1] | 6.62[1] | 11.24[1] | 40[2] |
| Soil Type | Holtville Silty Clay Wet[3] | Westhaven Clay Loam[4] | Greenfield Fine Sandy Loam[5] and Oceano Loamy Sand[6] | Bourbon and Hanna |
| Size of Operation in 2009 (Acres of onions) | 420 | 860 | 1500 | 19 million bulbs were grown on 13 acres in Indiana, then shipped to the growers in Imperial County and planted on approximately 225-250 acres. |
| Onion Varieties Grown | Red, Yellow and Sweet | Red, Yellow and Sweet | Red and Yellow | Red, yellow and sweet onion bulbs are raised to a size of 3/8th – 7/8ths of an inch |

**Table 1 Site Characteristics for Gills Onions' Growing Regions**

References:
1. Western Regional Climate Center, 2011
2. Indiana State Climate Office, 2011
3. NRCS web soil survey (NRCS, 2010), Midwest Laboratories Inc. soil test.
4. Fresno County Region grower records
5. Irrigated Crop Mgmt, Inc. Work Order, Pesticide Use Report
6. Monterey County Region grower records

## 6.2 Growing Season

Figure 4 provides a summary of the planting and harvesting timeline for each growing region. The staggered growing seasons provide Gills Onions with a continual supply of onions. As described above, Gills starts bulb propagation in Indiana in the spring and these sets are shipped to Imperial County for planting in the fall. Fresno and Monterey Counties follow with planting in the winter and early spring. Harvesting follows the planting cycle, with harvesting beginning in April in Imperial Valley, July through October in Fresno and August through December in Monterey County region. We gathered baseline data for the onion crop that was harvested in 2009. Because planting and harvesting is staggered, actual growing season and harvest dates for the crop varied by region.

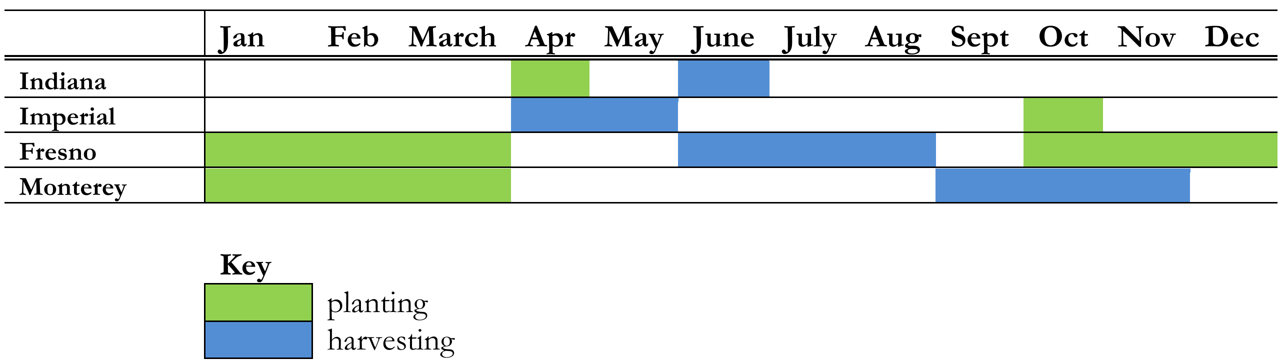


**Figure 4 Planting and Harvesting Schedule for Gills Onions' Growing Regions**

## 6.3 Growing Processes

Figure 5 shows the processes involved in growing onions for Gills Onions as well as the inputs and outputs that we considered in our project. Our system boundaries included all on farm onion growing processes, from planting to sorting. Specifically, we included soil preparation, planting, irrigation, fertilizer and pesticide application throughout the season, harvesting, and sorting out the onions that are too small or damaged to be of use to Gills Onions for processing. We did not include the transport of equipment between regions, since this data was unavailable, or the transport of harvested onions to Oxnard, since this information was included in the Zero Waste initiative. Onion refrigeration was also included in the previous project, and so was excluded from our scope.

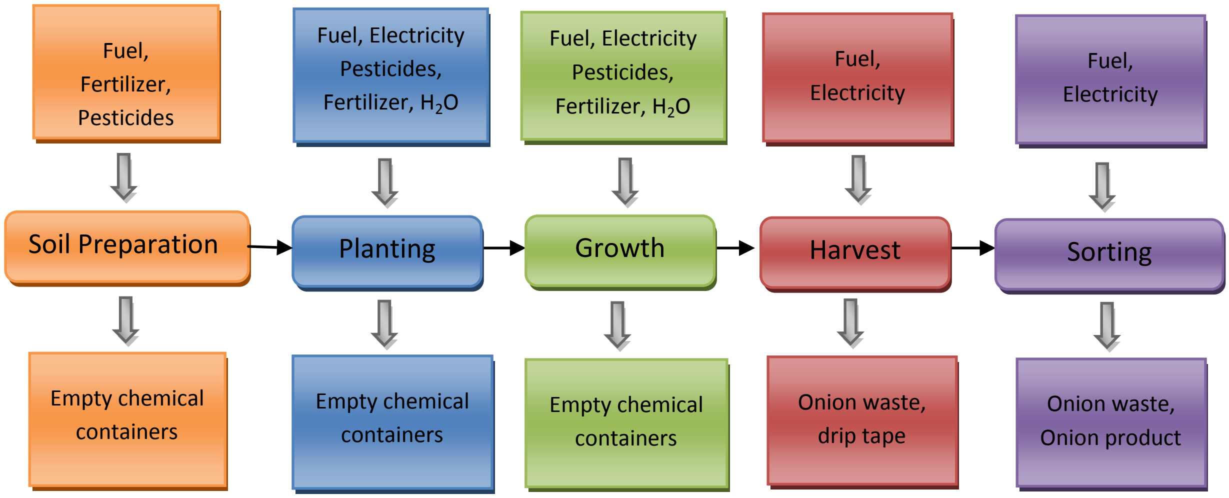


**Figure 5 Onion Growing Processes**

## 6.4 Lot Selection

At the smallest level in each growing region, the onion crop is divided into field lots. A lot is a portion of a ranch, usually from 10 to 35 acres, where one onion varietal is grown. Gills Onions tracks its incoming onion crops by the lot. Each lot is given a unique code that corresponds to the region, year, grower and variety of onion. We collected data on a sample of lots from each region instead of gathering data for the entire crop. The study lots are listed in Table 2 below.

| Region | Number of study lots | Total acres in region | Total acres of study lots | % sampled (study/total acreage) |
|---|---|---|---|---|
| **Indiana** | 1 | 13 | 13 | 100% |
| **Imperial County** | 8 | 423 | 132.5 | 31% |
| **Monterey County** | 4 | 1504 | 49.3 | 3% |
| **Fresno County** | 9 | 805 | 164.5 | 20% |

**Table 2 Summary of 2008-2009 Study Lots**

Lots were chosen based on grower recommendations, to be representative of the crop in each region in terms of variety, performance and yield. We chose four lots in the Monterey County Region, nine lots in the Fresno County Region and eight lots in the Imperial County Region. To test whether our method of selecting sample lots was biased, we performed a pseudo Monte Carlo statistical test using the algorithm documented below in Table 3. The test results validate that our lot selection was unbiased: proportional values varied, between regions and onion types, for relative comparisons of all possible lot combinations of mean yield and mean waste values, less than or equal to the mean yield and mean waste values of the chosen sample lots.

| Region | Onion Type | # Lots Total | # Lots sampled | Mean of Yield Sample Lots (tons/acre) | Mean of Waste Sample Lots (tons/acre | Proportion of All Lots Yield Mean <= Sample Lots Yield Mean | Proportion of All Lots Waste Mean <= Sample Lots Waste Mean |
|---|---|---|---|---|---|---|---|
| **Imperial** | Red | 10 | 4 | 38.1 | 4.7 | 0.31 | 0.39 |
| **Imperial** | Yellow-sets | 13 | 2 | 22.0 | 3.1 | 0.27 | 0.23 |
| **Fresno** | Red | 11 | 2 | 47.3 | 3.6 | 0.73 | 0.58 |
| **Monterey** | Red | 11 | 2 | 47.3 | 2.6 | 0.73 | 0.58 |
| **Monterey** | Yellow-sets | 28 | 2 | 65.9 | 6.2 | 0.89 | 0.80 |

**Table 3 Statistical Test and Results for determining lot selection sampling is unbiased**

## 6.5 Site Visits

Data collection began with visits to each of the growing regions. We visited Imperial county in April, and Monterey and Fresno counties in July. The site visits included tours of the fields and facilities as well as meetings with the growers and their staffs. The field tours provided an overview of the growing operations and the equipment used in each region. We conducted initial interviews with the growers and staff to find out how information was tracked, what data was available and where to obtain it.

## 6.6 Remote Data Collection

After the site visits, data was gathered remotely via phone interviews and email correspondence with the growers and their staffs. Phone interviews were conducted both by individual team members to gather information in certain data areas, and by the team as a whole in teleconferences with the growers. In some cases, we also contacted external experts for additional information. The data collection methodologies in each resource area are described in more detail below.

## 6.7 Resource Areas

The following sections address each of our objectives within the five resource areas: water, fertilizer, pesticides, energy and waste. Within each section we will set the environmental context for each resource area, provide the specific data collection methodologies used in each at the four growing regions. We will also present the results from the calculated baseline of resource use for the 2008-09 growing season including results reported to SISC and our suggestions for future data tracking procedures.

***Note: This version of our document does not include Appendicies that give specific baseline results, due to confidentiality issues. Appendix A has been provided to our client at Gills Onions.**

# 7. Water

## 7.1 Water: Background

### 7.1.1 Environmental impact of water use in agriculture

Excessive irrigation wastes water, leaches out important nutrients such as nitrogen, reduces root growth, and causes water logging and salt buildup in the root zone. Insufficient irrigation reduces the productivity of the soil and lowers evapotranspiration in plants, resulting in overall lower crop yields and farmer income (CDWR, 2010b). Postel (1997) estimates that technology like precision sprinklers and drip irrigation systems can increase water uptake efficiency by 60-70%. The California Water Plan 2009 Update estimates that efficiency could save up to 0.1-0.8 million acre feet of water per year (a total savings of $0.3-4 billion through 2030), and that 3.8 million acres in California could be converted to micro-irrigation (CDWR 2009a).

Irrigation technologies used in the state include sprinkler, furrow, and surface/subsurface drip (also known as microirrigation). Decades of research indicate that drip irrigation is the most efficient way to irrigate onion crops (Ayars 1999, Patel et al. 2009, Al-Jamal et al. 2001). Onion roots are typically unbranched and shallow (less than 30 cm deep), and subsurface drip irrigation applies water directly to the root zone. This can reduce water and nutrient runoff and evaporation, improve yield and crop quality, reduce fungal diseases, and allow for greater control of the applied water (Ayars et al. 1999).

After planting seeds, the ground must be kept moist until germination occurs, taking anywhere from 10-21 days (Voss and Mayberry 1999). After the initial pre-emergent phase, irrigation proceeds as needed (usually 1-3 times/week) until maturity, when the tops of the onions fall over. Near the time of harvest, growers must carefully adjust irrigation schedules: yields will be reduced if the plants are under-watered, but if over-watered, onions can split, decay, or have delayed maturity (Voss and Mayberry 1999). According to the University of California at Davis Vegetable Research and Information Center, with 70-80% water use efficiency, records show that onions need about 30-36 inches of irrigation or about 2.5-3 acre-feet of water per acre of onions (Voss and Mayberry 1999).

## 7.2 Water: Methods

### 7.2.1 Overview

Gills Onions has not historically collected any type of water use data from its growers. In all regions, we interviewed the head growers to understand their management and record keeping practices for the 2009 year onion crop.

### 7.2.2 Monterey County Region

There are no water meters installed at the field level at the Monterey farms. Since many different crops are grown in this region and they are often watered at the same time, it was difficult to determine the percentage of total water extraction being used on the onion crop. The growers in charge of this region did know the approximate amount of water that the onions received per acre in a season. Growers advised us that all onions received approximately the same amount of water, so we used this average number to calculate the total estimated amount of water used for onions in this region.

### 7.2.3 Fresno County Region

The Fresno County farm has water meters on its fields that it uses to measure the amount of water being applied at the field level. Unfortunately, the growers do not keep records of past water use and no longer had documentation for 2009. Failing exact measurements, we would have liked to get an estimate, but because growers customarily water many fields at once, the growers in this region said it would be impossible to determine exactly how much water any given field was receiving without having the actual field level water meter records and declined to give an off-the-cuff estimate. We were ultimately unable to obtain any measurement of water use for this region.

### 7.2.4 Imperial County Region

Growers in the Imperial County Region were able to provide the exact number acre-feet of water applied per acre to each of the fields during the 2009 season based on bills from the Imperial Irrigation District. We calculated an average irrigation rate for the eight lots we concentrated on, and extrapolated to the total acreage for all the 2009 onions planted in Imperial County.

### 7.2.5 Indiana Region

The growers in the Indiana Region used electricity bills to calculate the amount of water used for half of the onion acres. We assumed that the rest of the onions were receiving approximately the same amount of water, and so we doubled this amount to get the total water used in this region. We cross checked this number with the amount of water the growers said the onion bulbs require per acre in this region and found that growers were actually overestimating the amount of water applied by about double. We ultimately used the estimates based on water bills because we assume they are more accurate.

### 7.2.6 SISC Pilot Study

The SISC Water Use metric sought to collect two things. First, it sought data about the total volume of water applied to the field. The metric described several ways in which SISC thought growers would be collecting water use data, including irrigation district reporting, closed conduit measuring devices, and open channel measuring devices. Alternatively, SISC suggested using power records to extrapolate water use. This technique required knowledge about the kilowatt-hours needed to pump an acre-foot of water.

Second, the metric required data regarding crop evapotranspiration (ETc). This data could be obtained either by field monitoring or by theoretical calculations. Since our growers did not have ETc monitors in their fields, we used the second approach. We looked up the Grass Reference ET on the CIMIS website and the crop adjustment factor for onions in a dry year and multiplied these together to get the calculated ETc per month of the growing season.

In each region, we chose a single lot and reported water use and crop evapotranspiration data for that lot to SISC.

## 7.3 Water: Results

### 7.3.1 Monterey County Region

In the Monterey County Region, growers use well water to irrigate their fields. Water is applied via sprinklers for germination and initial growth, followed by surface drip irrigation after about the $6^{th}$ to $8^{th}$ true leaf stage. There are no water meters at the field level. However, the head grower was able to estimate the average amount of water used for onions here on a per acre basis over the entirety of the season. Multiplying this average by the number of acres planted with onions gave us the total amount of water for the Monterey County Region.

### 7.3.2 Fresno County Region

In the Fresno County Region, growers primarily rely on irrigation water from the Westlands Water District, although they had to supplement their allotment with well water for the 2009 onion crop due to reductions in water allotments during this dry year. Initial watering is applied via overhead sprinklers, and subsequent water is applied via drip irrigation. As mentioned above, the growers have water meters and are currently tracking water use, but did not have the records from the 2009 onion crop and did not give us an estimate.

### 7.3.3 Imperial County Region

In this region, farmers use Colorado River water provided by the Imperial Irrigation District. The water is delivered via surface canals throughout the valley. Farmers order irrigation water a day in advance and are charged by the volume of water that is delivered to each field via gated canals. The farm has seven on-site filtration and pump devices that filter water with silica sand and rock and then push the cleaned water through the drip lines. Generally one irrigation delivery unit can feed 35-50 acres. Any excess water that drains through the field is captured by a tile layer buried beneath the field. This layer drains the water into the drainage ditch near the road, sending it directly to the Salton Sea. Each field gate has a unique address, and the billing scheme allows the farmers to easily keep track of their water use on a field level. Unlike allocations through the Central Valley Project, the IID has not limited allocations to farmers (IC grower, personal communication 4.30.10).

### 7.3.4 Indiana Region

Indiana Dutch Valley growers use well water and center pivot sprinklers to irrigate onion sets.  Growers say that water is abundant in this region - the farms are just south of Lake Michigan in an area that gets occasional summer rains.

## 7.4 Water: Discussion

The findings for all regions were within the normal range of expected irrigation for onions.

The relatively low water needs of the Indiana bulbs are likely due to the short growing season and potentially local weather. Applications for Monterey and Imperial Counties ranged from 3.3 to 4.5 acre-feet, which is slightly above the suggested average application rate of 2.75 acre-feet (Voss et al. 2009).  However, 2008-2009 was a dry water year, which means more irrigation was required for the crops to compensate for the lack of rain (California Department of Water Resources, 2010a).  Therefore our database includes a wet/dry year classification, as it is an important consideration for Gills staff when doing any inter-annual comparisons. The typical growing season in California does not involve significant rainfall, which allows for a more controlled irrigation program and a higher, more predictable quality of product during dry years.

Climate differences between the different areas make inter-regional comparisons difficult.  As discussed in section X.x, the Monterey County Region has the most temperate climate of the 3 California regions due to its proximity to the Pacific Ocean with an average maximum summer temperature of 86.9°F and annual precipitation of 11.24 inches (WRCC). The Fresno County Region has an average maximum temperature of 100.4°F with annual precipitation of 6.62 inches, and the Imperial County Region has an average maximum temperature of 107.6°F and annual precipitation of 2.65 inches (WRCC). Higher temperatures accelerate evapotranspiration of water from the ground, making precise water application even more important. By contrast, the Indiana Region has annual maximum temperatures of 80°F and annual precipitation of 40 inches.

Salinity is a significant problem in California's soils. High levels of soil salinity can decrease the amount of water and nutrients a crop is able to take up. The Natural Resource Conservation Service advises Fresno County growers to apply "more water than is need to grow crops," since the extra water will be used to leach salts downward and away from crop roots (NRCS, 2006). Surface waters in California are generally relatively low in salinity, but wells that draw from groundwater can vary significantly in salinity levels, and irrigation water from the Colorado River, which feeds the Imperial Irrigation District, is the most saline in the state (Letey, 2000). Even if irrigation water salinity is not high, it can build up over time in highly irrigated areas, which has happened in the San Joaquin Valley, where the Fresno County Region is located. These varying levels of soil salinity between regions contribute to differing irrigation needs.

The type of soil that is in a particular field can also affect irrigation needs. Some soils, such as clay-loam soils, retain water much better than others, whereas a sandier soil will more quickly let the water drain beyond the reach of an onion's roots. As described in section X.x, soils in the Fresno County Region are predominantly clay loam, soils in the Monterey County Region are predominantly sandy clay loam, and soils in Imperial County Region are predominantly silty clay wet.

One important finding of our project was that within the last decade almost all the growers contracted with Gills Onions made the switch from furrow to drip irrigation, which is known to be the most efficient means to irrigate onions in terms of percentage of delivered water that is retained and taken up by roots. Imperial County growers estimate that a recent switch from flood irrigation to drip irrigation has halved their average water application from 6 acre-feet to 3.5 acre-feet per acre of onions (IC grower, personal communication 4.30.10). One important note for future analysis is that, unless there are significant advances in alternative forms of irrigation, additional water efficiency gains may be difficult to realize.

Most farmers interviewed indicated that they did not rely on soil water sensors or online tools, but visually inspect the health of the crop to determine watering needs. It is difficult to determine whether the growers could improve their water use with other practices, however there are many such tools available to California farmers. Growers in California are aided by 120 weather stations managed by the California Irrigation Management Information System (CIMIS). CIMIS is an online database that collects and stores measurements of solar radiation, air temperature, relative humidity and wind speed, taken every minute. The system also estimates parameters such as evapotranspiration, which growers can use to calculate their plant watering needs (CDWR 2010). Growers can also take soil cores with a hand-push probe and calculate the total moisture using the Gravimetric Weight Method (Molina-Martinez et al. 2009). Software for smart phones is being developed to help growers determine the diameter of emitters that will help them use water more efficiently (Molina-Martinez et al. 2009). Electrical resistance blocks, granular matix sensors, tensiometers, and data loggers are more advanced technologies available to farmers, with costs ranging from $25 to $500. High value crops and large farms employ more expensive means of monitoring irrigation and fertilizer needs, including using remote sensing, time domain reflectometers, and infrared thermometry (Morris, 2006).

## 7.5 Water: Recommendations for future data collection

1. Imperial County – Continue tracking water at field level based on Water Bills and report field level seasonal water to Gills Onions.

2. Monterey County- Growers in this region have agreed to install water meters on select onion fields. This will enable them to have more exact measurements with which to compare their own understanding of how much water onion fields receive. The grower can compare his estimates for the current season to the actual water used, which may give insight to estimates for the 2009-09 season. Depending on the type of water meter selected, the growers can calculate the total volume of water applied.

3. Indiana- Irrigation is less of a concern in this region due to plentiful rainfall, so water meters may not be worth investing in.

4. Fresno County- Continue tracking water application at field level based on water meters. Begin reporting this information to Gills Onions.

# 8. Fertilizer

## 8.1 Fertilizer: Background

### *8.1.1* Environmental impact of fertilizer use in agriculture

According to the National Agricultural Statistics Service, in 2006 approximately 9.7 million pounds of nitrogen, 4.5 million pounds of phosphorous, 798,000 pounds of potash, and 715,000 pounds of sulfur fertilizers were applied to onion fields in California (NASS, 2008). Fertilizers are an important resource input in conventional agriculture, however the over-application of nutrients can cause a host of environmental problems including polluting water resources and emitting nitrous oxide (a potent greenhouse gas) into the atmosphere.

The Environmental Protection Agency states, "agricultural nonpoint source pollution was the leading source of water quality impacts on surveyed rivers and lakes, the second largest source of impairments to wetlands, and a major contributor to contamination of surveyed estuaries and ground water." (US EPA, 2005) Excessive fertilizer application can cause water quality issues such as eutrophication, which depletes the dissolved oxygen levels in surface waters and impairs aquatic habitat. California has designated specific "nitrate sensitive areas" including Salinas Valley and the eastern San Joaquin valley, where nitrate pollution in groundwater and surface water resources has been identified as especially detrimental. These areas are deemed sensitive for two reasons: either they have very high levels of nitrate contamination or they have a high number of people who rely on local groundwater resources for drinking water (CDFA, 2010).

In addition to the water quality impacts of fertilizer use, there are also the resulting emissions of nitrous oxide ($N_2O$). Nitrous oxide is a greenhouse gas and has a global warming potential that is 296 times that of carbon dioxide (IPCC 2006). This potency is derived from its persistence in the atmosphere (120 days), its heat trapping effects, and its contribution to ozone destruction (US EPA, 2007).

### 8.1.2 Soil fertility management for onion production

Practicing site-specific fertilizer management maximizes crop yields while minimizing the amount of residual fertilizers in soils. This involves determining an appropriate amount of fertilizer based on crop type, climatic variables, and soil chemistry. According to the literature, onions grow best in medium textured, sandy loam soils that retain water in the shallow root zone, similar to those found in Monterey County. They may be grown in sandy soils if watering methods maintain soil moisture (Mayberry 2000).

The timing of fertilizer application is critical. Generally, fertilizer ratios for the California onion planting season are as follows: occasional pre-plant fertilizer, 1/3 at planting, 1/3 when the plants have 3-4 leaves, 1/3 at mid season (Voss & Mayberry, 1999). Applying excess nitrogen late in the season can cause problems such as delayed maturity (re-greening of leaves) or decreased storability and splitting, creating products that may not be sellable. In addition, late application of sulfur can increase pungency so it is advised to add this micronutrient after the harvest, well before the next growing season (Oregon State University, 2004). Since onions are highly sensitive to ammonia, fertilizers with high ammonia content should be avoided. Direct observation of the crop is the most common way California onion growers determine a crop's nutrient demands. A tissue sample of the leaves or petiole can also be used midseason to determine nutrient requirements. (Voss & Mayberry, 1999).

Suggested fertilizer application rates can be found in UC Extension Agent bulletins and by looking at past reported application rates. In 2002, actual applications for dry onions in California were an average of 213 pounds Nitrogen (N)/acre, 221 pounds phosphorus oxide ($P_2O_5$)/acre and 81 pounds potassium oxide ($K_2O$)/acre (ERS-USDA, 2002).

**Table 4** provides a summary of fertilizer application rates suggested in this and other studies in the literature on a per acre basis, including actual rates reported for 2002.

| Site of study and author | N lbs/acre | $P_2O_5$ lbs/acre | $K_2O$ lbs/acre | Details |
|---|---|---|---|---|
| California | 213.16 | 221.94 | 81.23 | 2002 Actual fertilizer use for dry onion bulb production |
| Georgia | 121.29 | 143.20 | 161.56 | |
| New York | 107.48 | 105.67 | 158.27 | |
| Oregon | 275.17 | 140.60 | 83.58 | |
| Texas | 155.78 | 108.39 | 38.41 | |
| Washington | 204.53 | 147.99 | 192.90 | |
| (Economic Research Service, USDA 2002). | | | | |
| California<br>Voss & Mayberry (1999), Voss et al. (1999) | 100-400 | 200 | - | Suggested rates |
| Imperial County, CA<br>Mayberry (2000) | 205-255 | 260 | - | Suggested rates |
| Eastern Oregon<br>Western Oregon<br>Oregon State University (2004) | 150-280<br>120-160 | 50-200<br>100-200 | 0-200<br>0-200 | Suggested rates, depending on soil tests |

**Table 4 Summary of suggested and reported fertilizer application rates for dry bulb onions**

All California growers contracted with Gills use their drip irrigation systems to deliver fertilizers directly to the rooting zone, known as fertigation. This has many benefits including reducing total fertilizers used (a cost savings and environmental benefit) and increased yields. In addition to applying the product directly to the root zone, drip systems reduce the volume of water applied, which in turn reduces runoff and leaching of products. Scientific studies such as Halvorson et al (2006) have shown that in addition to significant water savings, drip fertigation results in significantly higher yields in comparison to the furrow irrigation-tractor applicated fertilizers, and also required lower levels of nitrogen.

Gills Onions currently does not require growers to report to the company any fertilizer applications, or the results of soil tests. Overall the company has few fertilizer use guidelines for their growers; however, their Good Agricultural Practices (GAP) Grower Manual states that: "All growers shall maintain specifications, Material Safety Data Sheets, and application records for all chemical fertilizers used to grow Gills Onions products" (Gills Onions 2010). The GAP also requires that Monterey County growers use compost that is registered and certified.

## 8.2 Fertilizer: Site-specific Methods and Results

### 8.2.1 Monterey County Region

#### *Current data collection methods*

Fertilizers were applied between 15 November 2008 and 15 August 2009 and the scale of applications ranged from 11-30 acres. Prior to planting, fertilizers and compost is applied via tractor applications. During the growing season they are applied by third party applicators and by field staff through the drip irrigation system. Because of these various parties that apply fertilizers, the data is recorded in a number of formats, including invoices from third party applicators and handwritten records from the field staff and an excel spreadsheet. The sources of data are summarized in Appendix B-2.

Invoice information from Irrigated Crop Management, Inc. Work Orders and SoilServ Inc. included information on acres applied, pesticide and fertilizer name and brand, quantity of product applied and cost. The State Pesticide Use Report confirmed the application of these products and the amount applied by Irrigated Crop Mgmt Inc.

In addition to these documents, Monterey County growers track additional fertilizer and soil amendments on handwritten records. The handwritten "Planting Sheet" lists applications of acid and pesticide applied at time of planting. The Irrigation Information Card lists the date, hours of drip or sprinkler irrigation and any fertilizer applied through drip fertigation. The irrigation cards also list the ranch lot, crop and foreman. There are additional fertilizer accounting sheets that confirm the fertigation applications listed on the irrigation cards. These handwritten records are then input into an excel spreadsheet and also included the cost of fertilizers.

### *Data Collection Challenges and Assumptions Made*

- Some products (such as 15-10-20 and 20-0-0-5) are mixed at local stores such as Oxnard Farm Supply and Wilbur Ellis. We were unable to find the density of product. Following the advice from Monterey County grower and Bren professor Dr. Arturo Keller, we decided to use 10 pounds/gallon as an appropriate figure for these calculations. Most fertilizers have densities that range from 10 to 12 pounds per gallon therefore, if anything our results under-estimate the nutrients applied.
- There were some inconsistencies and errors with the multiple handwritten field data sheets. Details are found in Appendix B-4 Report for Monterey County Growers.

### *Results*

Growers in this region stress the importance of healthy soil. To determine a fertilization plan, one soil test per ranch is taken in the fall before planting. Each year the growers conduct a petiole test and soil sample tests while the onions are growing to look for any minor additions. (MCgrower, personal communication 2011-07-15 ). The Irrigated Crop Management Work orders also have soil information on them. While the growers consider that there are nitrates in the irrigation water that may add to the overall nutrient budget, they mostly rely on soil tests that measure nitrates in the soil directly (MC grower, personal communication 2010-11-15).

Growers in this region apply compost before the growing season to increase the fertility of their soil. Small amounts of crop residue are tilled into the soil to prevent pests, however because of pink root (a soil-borne fungus), onion waste cannot be directly applied to the fields (MC grower, personal communication, 2010-07-15). Label information for compost used in 2009 was not obtainable. In 2010, Monterey County growers used compost made out of Monterey mushroom waste combined with spinach and nursery waste, culled onions, grape pumice, calcium and peat moss (MC grower, personal communication 2010-11-15). This mushroom mulch is produced by Salinas-based Keith Day Company.   The nutrient composition of this compost is 1.7% N, 1.3% $P_2O_5$, 1.9% $K_2O$, 5.5% Ca with a small amount of other micronutrients (Michelle Williamson, Keith Day Company Inc, personal communication 2011-01-31).

Detailed results on the average pounds of nutrients applied per acre and per ton of onion are found in the Appendix (omitted from this draft due to proprietary information). Growers in Monterey County apply approximately 10-15 gallons per week per acre of Calcium Ammonium Nitrate (CAN-17) through drip fertigation when onions are bulbing (MC grower, personal communication 2010-07-15). In addition to drip fertigation, growers in Monterey County contract out the aerial spraying of fertilizers from third party applicators Irrigated Crop Management Inc. and SoilServ Inc. For the lot selected for the SISC study (Tognetti 363N) in addition to compost, Monterey County growers used eight different types of soil fertilizer in the growing season spread over nine applications. The applications averaged out to 177 pounds of nitrogen per acre, 0 pounds of phosphorous and potassium and 89 pounds of calcium per acre, with an average cost of $235/acre (although cost information for six applications was missing).

#### *Recommendations for future data collection for Monterey County Region*

**Grower processes:**

1. Choose a study ranch
2. Combine and simplify handwritten records and field data sheets (planting, irrigation and fertilizer) into one sheet where possible. We have suggested a data collection sheet in Appendix B-32.
3. Record information in excel as you normally do and email spreadsheet and field data sheets to Gills Onions
4. If using a new fertilizer product or a locally-sourced product, record product label information including: pounds per gallon and % content of nutrients.
5. Provide any application invoices from ICMC or SoilServ for study ranches.

**Gills staff processes:**

1. Discuss with growers the issues involved with multiple field data sheets and determine most efficient way to collect application data.
2. Double-check the amount applied in the spreadsheets with handwritten field notes. Enter into "fertilizer applied" table in database.
3. Add all other soil amendments from Irrigated Crop Management, SoilServ Inc. invoices to Fertilizer applied table in database.
4. The database includes all label information for fertilizers used in 2009 and also includes links to the product labels were available. If growers use new fertilizers try to get the label information from them or online. Enter the following information into fertilizer products tab in the database:
    a. Pounds/gallon, % N, $P_2O_5$ and $K_2O$ and any other nutrients you want to track through the years
    b. If you are interested in total N loading you may want to add compost label information.

### 8.2.2 Fresno County Region

#### *Current data collection methods*

Current applications for fertilizer and pesticides are tracked using computer program Tiger Jill (FC grower, personal communication 2010-07-08). For the purposes of this project, the growers provided a summary of application methods on an excel spreadsheet for two ranches Dresick 5-4 (155 acres) and Dresick 7-4 (173 acres). Information provided included, total acres treated, gallons per acre applied, product name, total gallons applied and total cost.

### *Results*

To determine fertilizer plans for the following year, soils are tested annually after harvest by Pacific Agronomics. The lead grower then bases all applications on these reports (FC grower, personal communication 2010-07-08). The growers also take petiole and soil samples throughout the season to test nutrients. Firebaugh has salty, boron soils but Huron does not have any issues with salinity.

The data provided did not include information on the number or specific date of applications throughout the season, the Tiger Jill export only listed the total application and cost. Detailed results on the average pounds of nutrients applied per acre and per ton of onion are found in the appendix. Fresno County growers used exclusively CAN-17 and the growers in this region claim that they use this product exclusively because the calcium helps build the cell walls of the plant (FC grower, personal communication 2010-07-08). Final results are listed in the Appendix (omitted from this draft due to proprietary information). This region used an average of 140 pounds N/acre applied and 72 pounds Ca/acre with a total cost of $116 per acre. Because all applications were the same per acre, the same numbers above were reported for the SISC pilot project study.

### *Recommendations for future data collection for Fresno County Region*

**Grower processes:**

1. Choose a study ranch
2. Gills Onions owns Tiger Jill database that might make it easy to export data directly without much additional work.
3. Ensure that applications by third party applicators are also in Tiger Jill database records and/or fax invoices to Gills personnel.

**Gills staff processes:**

1. If all applications are tracked in Tiger Jill, then the growers could potentially export their information on applications to an excel file and email to Gills Onions and then import the data into the database we have created. If Gills chooses to use Tiger Jill as a tracking system, there would likely be a way to import data from other Tiger Jill applications.
2. Because we were unable to get raw data sheets such as handwritten notes from the field or a detailed explanation of how they track individual applications, we suggest Gills Onions continue to work with growers to understand their processes to insure no applications are overlooked.

### 8.2.3 Imperial County Region

#### *Current data collection methods*

Text data was supplied to the group on anexcel file by the growers. Although this was on an excel file, the submission was in text format and was the same for all ranches: *"11-52-0 fert was applied at 600 lbs. per acre as a pre-plant application. CAN-17 was applied during the growing season approx. 20 units per application for a total of 150 units."* (IC grower, personal communication 2010-07-15). Applications were given for the following ranches and lots: Tamarack 199 all lot numbers (140.24 acres), West Side Main 66-2 lot # 19RBA1 & 19RBB1 (22.69 acres), and New Spruce 9 lot #s 19YAB1, 19YAE1, 19RAA1, 19RAB1 (64.32 acres). Exact dates of fertilizer application were not provided however we know they were applied between October 2008 – April 2009 with approximately nine applications total.

#### *Additional methods*

We clarified with the growers that "units" of application for CAN-17, refers to 150 pounds of nitrogen per acre applied for all acres for the selected lots in Imperial Valley. Using the total pounds N we were able to then calculate the gallons of product used, and with the label information of pounds/gallon calculated the % calcium also applied with CAN-17 with the following equation:

*Total pounds N applied / 17%*12.64 lbs/gallon = total gallons or product applied to field*
*# gallons of product applied *12.64 lbs/gallon * 8.8% Ca = total lbs Ca applied*

We also confirmed that 600 pounds of 11-52-0 was 600 pounds of the product (not pounds N) applied per acre.

*600lbs * 11% = total lbs N applied per acre*
*600lbs/acre*52% = total lbs $P_2O_5$ applied per acre*

#### *Data Collection Challenges and Assumptions Made*

- Data provided was text based, however in a phone conversation, growers explained that they do track applications on excel and word based documents. Therefore more streamlined data sharing with the company may be available.
- No information on cost was available. One of the growers owns an agricultural chemical application business. He purchases fertilizer in bulk and does not separate costs out for onion production from other crops, which may make it difficult for Gills Onions to understand grower costs for this region.

#### *Results*

The growers indicated that they have been testing using less fertilizer each year and haven't seen a loss in production. They indicated this is a slow process because it is done throughout the season, and ultimately they do not want to reduce overall harvest. As with our other sites, the growers in Imperial County are acutely aware that reducing fertilizer use also reduces their costs. "The cost of fertilizer goes up with the price of gasoline, so when gas was high we were sensitive to that. In the past it could cost up to $300 per acre for fertilizer." (IC grower, personal communication 2010-04-30).

Growers in the region base applications by a visual inspection of the crop in the field. They have done petiole tests in the past but have found that they often incorrectly indicated their plants were deficient in nutrients. The growers knew the plants were healthy and they attribute the faulty results to the fact that the tests aren't made to be used on drip-irrigated systems (IC grower, personal communication, 2010-04-30).

Detailed results on the average pounds of nutrients applied per acre and per ton of onion are found in the Appendix (omitted from this draft due to proprietary information).-2. Growers in this region use two types of fertilizer: 11-52-0 applied at 600 pounds/acre as a pre-plant does and CAN-17 spread out over about 8 applications through the growing season. This is similar to rates suggested by Mayberry (2000) for the Imperial County. Because the data provided was the same application rate per acre, all lots in Imperial County Region have an average application of 216 pounds N/acre, 312 pounds $P_2O_5$/acre and 77 pounds Ca/acre; these values were reported to the SISC pilot project study. The growers did not provide an estimate for the cost of fertilizer, due to the fact that they purchase fertilizers in bulk for their multiple fields.

#### *Recommendations for future data collection for Imperial County Region*

**Grower processes:**

1. Choose a study ranch
2. Email Gills any electronic data that you already are keeping, this will aid in uploading to database.
3. If third party applicators also apply fertilizers, fax invoices to Gills personnel and consider adding to your own files to track nutrients applied.

**Gills staff processes:**

1. Because we were unable to get raw data sheets such as handwritten notes from the field or a detailed explanation of how they track individual applications, we suggest Gills Onions continue to work with growers to understand their processes to insure no applications are overlooked.

### 8.2.4 Indiana Region

#### *Current data collection methods*

Data on fertilizer applications between April-May 2009 was provided by Dutch Valley Growers (DVG) and included invoices from application company CoAlliance LLP - Valparaiso Agronomy. A handwritten note from DVG personnel identified applications specific to the 5.33 acre study lot. Data provided included pounds fertilizer applied, cost per pound, total cost and date applied. Where cost data was not provided, we calculated costs based on invoice information.

### *Results*

All growers in the Indiana Region follow the same fertilizer practices and practice minimum tillage where possible. The DVG representative said that generally the growers are as frugal as possible when it comes to not wasting fertilizer; this translates into more sustainable growing practices. Between seasons cover crops such as rye grass or corn residue are used to minimize wind and water erosion and maintain soil fertility. There were no soil tests available for the region, but one grower claimed to have total organic carbon content of 4% (J. Rietveld, personal communication 2010-09-08).

Three types of fertilizers plus a host of micronutrients are used by DVG. In early spring, approximately 150 pounds/acre of 0-0-60 is applied to the fields and before planting 1000 pounds/acre of 8-15-06 of liquid fertilizer is applied along with micronutrients such as boron, manganese, zinc, copper. Later in the season urea and pelleted lime are also applied.

### *Recommendations for future data collection for Indiana region*

**Grower processes:**

1. The data provided was excellent, especially the handwritten summation of what was applied on a field with invoices detailing the information to back it up. It was helpful to circle Gills Onions applications on the invoices as there were other products listed not used on onion fields. Continue this process as requested by Gills.
2. This year total acreage was 13 acres and the selected farm was 5.33 acres. If applications are truly the same for all fields you don't have to take the extra steps to scale down to one grower – Gills could just take the total applied for all acres grown for their company.

**Gills staff processes:**

1. Data was good quality and seemed pretty straightforward for DVG to share. If visiting the region, observe any field data collection processes or other tracking methods such as excel or other database to determine if there is an easier way to collect data.

## 8.3 Fertilizer: Discussion

### 8.3.1 Baseline results and data processes

In 2002 the average reported fertilizers applied to onion fields in California was 213 pounds of N per acre, 221 pounds $P_2O_5$ per acre and 81 pounds of $K_2O$ per acre (USDA 2002). According to publications by UC Cooperative extension agents applications can range between 100-400 pounds of N per acre, 0-200 pounds per acre for both $P_2O_5$ and $K_2O$ (Voss et al. 1999, Voss & Mayberry 1999, Mayberry 2000). The results from our study conclude that all growers have applications near the suggested ranges.

Data availability varies dramatically for 2009. Data for the Monterey County growing region and Dutch Valley growers in Indiana were more detailed with handwritten field notes, invoices and other raw data provided. Indiana was the only site able to provide full cost information for fertilizers. Fresno County growers used a Tiger Jill export with cost and amount applied and Imperial gave estimates on a per acre basis. Neither site provided a schedule of applications. Gills Onions is considering purchasing a database technology to help monitor pesticide applications and potentially fertilizer application (D. Arevalos, personal communication, 2010-11-12). Challenges to data collection include having multiple application methods, third party applicators and researching detailed product information online.

### 8.3.2 Future fertilizer strategies

In addition to average applications, all regions apply fertilizer at least in part through their drip irrigation lines. This method of application can save on application costs such as tractor and fertilizer spreader diesel and effectively applies nutrients directly to the rooting zone. By reducing overall water applied, it can also reduce the leaching and runoff of valuable soil amendments and decrease water quality issues associated with fertilizers. Gills could highlight this practice on their website along with the benefits of reduced water use.

Calcium ammonium nitrate (CAN-17) was used in all three growing regions and was the only fertilizer used in Fresno County Region. This fertilizer is high in nitrate nitrogen and low in ammonium nitrogen and also supplies soluble calcium. Growers in more than one region and Gills personnel claim that calcium is important for onion cell wall thickness and strength and can also improve water penetration in saline soils. Interestingly, we could find no information on the calcium needs of onion plants in USDA publications, UC Extension bulletins or the Oregon State University website. While we have found that Gill's growers are applying the average amount of nitrogen for optimum growth rates, researchers such as Dr. Charles M. Burt claims that "CAN 17, however should not be used as a major source of calcium since the crop will be fertilized with excessive amounts of nitrogen." (Burt, 1998). In the future, Gills' growers could look for other sources of calcium that would help meet crop nutrient needs if they are concerned about over-applying nitrogen.

Growers in all regions are sensitive to costs of the inputs and are interested in saving money, which in turn usually means reducing total nutrients applied. Wang and Keller (2007) have created a model, AgInput that allows for a more detailed quantitative understanding of fertilizer needs and appropriate application rates. This model may be utilized as a tool to identify growing regions where fertilizer savings are possible and can be tailored for Gills Onions' growers based on the soil types, crop variety, etc. in each region.

Details on the timing of fertilizer application in the irrigation sets was not requested for this project, however growers could potentially improve their environmental performance examining their fertigation practices. In general, if a fertilizer is injected early on in a long irrigation set, the nutrients may leach out, especially if it is mobile fertilizers such as urea or nitrate fertilizers (such as CAN 17). If added later in the schedule, the fertilizer could remain stagnant in the drip tape (and if corrosive could damage the drip tape). Therefore it is best when using a highly mobile urea or nitrate fertilizer to inject the fertilizer in the middle 50% of the application, also known as the quarter-half-quarter rule (Burt 1995, Niederholzer 2010). Growers should time applications to ensure it reaches the farthest point in the drip system and flush it with the same amount of water for the same amount of time. An electrical conductivity meter can be installed near the last emitter to calculate the travel time (Niederholzer, 2010).

If interested in saving applied nutrients, growers could experiment with different emitters on their irrigation lines. Khalil (2007) examined nitrate leaching with onion fertigation and found that well-drained sandy loam soils (like those found in the Monterey County Region) to have the highest nitrate leaching rates of up to 5% of the fertilizer applied. Sandy clay loam soils (like those in Fresno growing region) had lower rates of about 1.5% and silty clay loam soils like those in Imperial region have negligible leaching rates. The study found that a lower emitter rate (1 liter water/hour versus 4 liters/hour) resulted in less nitrates leached (Khalil 2007). This could be one strategy for growers to reduce nitrate leaching and help achieve Total Maximum Daily Load goals.

Soil salinity is a problem that growerss in both Imperial County and Monterey County growing regions face. Salts in the soil and irrigation water increase the negative osmotic potential in the soil, making it difficult for plants to extract water. Drip irrigation can advance this problem; as less water is applied the soil is drier overall, leading to a more negative matric potential and higher evaporation rates, leaving salts behind (Bali 2010). Conventional practices sometimes include flooding fields with irrigation water before planting begins to flush away the salts (IC grower, personal communication 4.30.10). In MC, growers use sulfuric acid to treat water. Applying sulfuric acid to treat water and soils could potentially leach out calcium in soils. To fix the problem, growers may apply CAN-17, which has 8.8% calcium by weight. This may solve one problem but cause another deficiency (Julie Airosa-Locke, personal communication 2011-01-20).

Another way to combat saline soils is to address fertilizer management plans. In 2010, growers in all regions started experimenting with BTN+ on a portion of their fields to see if the product can reduce overall nutrients applied and increase nutrient uptake. On select fields growers are halving the amount of CAN-17 they are using in conjunction with BTN+. This fertilizer is a carbon based 5-4-4 plus sulfur, and has a low pH of 1.32. In contrast, CAN-17 fertilizer used in all of the regions has a solution pH of 6.0-6.5 (J. Airosa-Locke, personal communication 2010-09-08, U.S. Department of Labor, 2006). The fertilizer's acidity allows for better leaching of salts from the soil and is designed to break down and prevent aggregate building that occurs when sodium content rises in the soil. This results in better plant growth and higher uptake of nutrients by the plants – reducing overall nutrient applications (J. Airosa-Locke, personal communication 2010-09-08**)**. Its acidity can also remove calcium carbonates that build up in drip irrigation lines acting as both a water treatment and as a fertilizer ((J. Airosa-Locke, personal communication 2011-01-20). Using BTN+ may cut the amount of CAN 17 input by as much as half, rendering the smaller amount more efficient and creating less waste and detrimental environmental conditions. Results from these extensive trials in 2011 will give growers the information necessary to move forward with this program or look into other methods of fertilizer management.

Because BTN+ has about a third of the nitrogen of CAN-17 and may improve nutrient uptake, the company may see increased growing performance in conjunction with lower nitrogen applications. One important consideration however, is that BTN+ costs approximately $16/gallon, significantly more expensive than the costs of CAN-17, which is about $1.70/gallon. The database tracking solution we are proposing will allow growers and Gills to assess the financial costs of this BTN+ test lots, compared to its total pounds N, $P_2O$ and $K_2O$ and Ca applied on a yield and acre basis.

# 9. Pesticides

## 9.1 Pesticides: Background

### 9.1.1 Environmental impact of pesticide use in agriculture

Some of the major environmental impacts of agriculture derive from the use of pesticides, a broad category including agrochemicals such as insecticides, fungicides, and herbicides. In 2006, onion farms in California used a total of 65 tons of herbicides, 26.5 tons of insecticides and 72 tons of fungicides (NASS, 2007). While pesticides have played an important role in increasing the productivity of agriculture, they have also introduced the risk of a variety of significant effects on humans and other organisms in the environment.

In humans, exposure to different pesticides may raise the risk for a range of both short and long-term detrimental health effects, including sensory symptom disruption, ocular irritation, dermatologic reactions, liver damage, respiratory problems, increased cancer risk, risk to the fetus, endocrine disruption, immunological impacts, and many others (Calvert, 2008; Gilden, 2009). Farmers and farm workers are at a particularly high risk given their high levels of exposure during mixing, application, or coming into contact with pesticides during other duties.

Other organisms also bear a large share of the unintended consequences of pesticide use. The California condor is a classic example of a species that is on the brink of extinction primarily due to its consumption of a pesticide, DDT, which thins the eggshell and prevents birds from hatching successfully (Kiff et al., 1979). DDT has since been outlawed and is no longer used in this country. However, there is evidence that even legal and cutting-edge pesticides can cause significant harm. One study of the relationship between biodiversity loss and pesticide use found that the hot spots of species loss in Canada contained 90% of their herbicide treated croplands. The statistical effect of herbicides was significant above and beyond the effect of agriculture, population density, and habitat loss (Gibbs, 2009).

Due to the serious impacts associated with the use of agricultural pesticide several organizations such as the Pesticide Action Network (PAN) and the World Health Organization (WHO) have created rankings to communicate the danger of many of the most hazardous products on the market. These rankings can be useful as a guide for growers and buyers to ensure environmental and human safety. For example, the Unilever Corporation has mandated the reduction of WHO class 1a and 1b pesticides, the top two WHO hazardous rankings, in the production of their raw materials (King, 2010).

### 9.1.2 Pest management strategies for onion production

Given the potential for such serious health and environmental effects, there is a movement towards decreasing pesticide use and integrating it with non-toxic approaches to pest control. This is generally referred to as Integrated Pest Management (IPM). IPM involves using a combination of techniques to reduce pesticide application. Prevention, employing methods like crop rotation and planting pest-free stock, is also important. Once the decision is made to use pesticides, IPM tries to use less toxic ones that are specifically targeted to the pest in question, thereby decreasing the potential for unintended effects (EPA, 2011).

Gills Onions' growers, like most farmers, depend on pesticides to prevent and treat pest infestations. Onions are particularly susceptible to certain pests in California such as onion thrip, leaf miners, the diseases downy mildew, pink root, and other bacterial rots (Voss & Mayberry, 1999). Onion thrip and leaf miner, insects that damage the leafy portion of developing onions and impact yield, are of particular concern for Gills' growers. Gills' growers also reported that a well managed fertilization program played an important role in reducing pest outbreaks.

Onions are also uniquely vulnerable to weed infestation since they have a very long growing season, inviting both summer and winter weeds, and because it takes them a long time to establish complete ground cover (Voss & Mayberry, 1999). It is customary to treat for weeds preemptively with an herbicide, and to treat for other pests with a combination of preemptive and responsive pesticide applications (Voss & Mayberry, 1999).

Currently, Gills Onions Good Agricultural Practices Grower Manual requires that growers submit pesticide treatment and crop history information after harvest and that random-sample pesticide residue analyses be completed. Additionally, Gills recommends that growers consult with a Pest Control Advisor (PCA) and that IPM be followed when possible.

## 9.2 Pesticides: Methods for all regions

Growers in all regions are required by Gills Onions to report pesticide use and crop history information. A hard copy of this information is submitted to the company with details about the application date, area treated, area planted, product applied, and application rate. In some instances growers also report the mass of pesticide active ingredient applied per acre. Thus, tracking pesticide use in each growing region was a straightforward process of requesting copies of the submitted materials. Specific information such as pesticide product label information and World Health Organization ranking was found online. Where pounds of active ingredient (AI) were not reported the following equations were used for conversion:

If gallons of pesticide product applied was provided:

*gallons of product applied * density of water at 70º F (lbs/gal)* % active ingredient = total pounds of AI applied*

If pounds of pesticide product applied was provided:

*pounds of product applied * % active ingredient = total pounds of AI applied*

Given the calculated pounds applied and the planted area we were able to calculate average pounds of active ingredient applied per planted acre for each region and using the harvesting information, pounds of active ingredient applied per ton of onion harvested.

## 9.3 Pesticides: Results for all regions

Detailed information concerning pesticide use in each region can be found in appendices A-2 through A-4.

All pesticide applications for one lot in each region were reported to SISC as part of the pilot program.

## 9.4 Pesticides: Recommendations for future data collection

**Farmer processes:**

Continue tracking pesticide use and submitting post-harvest reports to Gills under the current protocols.

**Gills staff processes:**

The current method of submitting pesticide and crop history information after harvest is adequate. These faxed documents are easily entered into Excel and summarized or imported into the database.

## 9.5 Pesticides: Discussion

Since 1990, pesticide regulation in California has mandated detailed reporting of agricultural pesticide use (CADPR, 2010b). Because of these strict regulatory requirements, tracking of pesticide use for sustainability reporting is largely a straightforward process. In all regions hard-copy records of pesticide use are filed with Gills Onions and easily converted to electronic format.

Based on results from the baseline data collection effort, all regions fall within the expected range of pesticide use for onions in California. In 2008, the average reported pesticide use on dry-bulb onions in California was approximately 11 pounds of active ingredient per planted acre (CADPR, 2010b).

Although all growers currently engage in Integrated Pest Management (IPM) and also consult with local agricultural advisors, more detailed tracking of IPM strategies and best management practices could assist Gills to better understand the impacts of pesticide use in each region. The Pesticide Risk Mitigation Engine tool (PRiME) developed by the IPM Institute of North America is one example of a program that could be used to better track pesticide impacts in each region. The PRiME tool incorporates the expected environmental fate and hazard information for each pesticide application and develops a risk characterization based on local sensitive receptors such as nearby streams. The tool also contains information on comparable pesticide products that could be applied at lower risk (IPM, 2011).

# 10. Energy

## 10.1 Energy: Background

### 10.1.1 Environmental impact of energy use in agriculture

Estimates of agricultural consumption of fossil energy range from about 1% to 7% of the total fossil energy consumption of the United States (Schnepf 2004; Heykoop, 2001; Pimentel 2008). According to the EPA, agriculture also contributes about 15% of the total U.S. greenhouse gas emissions; including 30% of all $CH_4$ emissions and 76% of $N_20$ emissions (EPA 2009).

Energy use in agriculture can be divided into two categories: direct uses and indirect uses. Direct use refers to the consumption of energy at the farm level through machinery operation. Indirect energy use refers to fossil energy consumed beyond the farm for manufacture of production inputs, including fertilizers, pesticides, equipment and seed stock (Hulsbergen et al. 2001). In 2002, about 65% of the energy used in agriculture was consumed as direct energy, mainly in the form of diesel, gasoline or electricity (Schnepf, 2004). This energy was consumed by onsite growing operations including field preparation, chemical application, harvesting, storage and cooling (Hulsbergen et al., 2001). Diesel fuel is the dominant direct energy source, and made up about 27% of farm energy use in 2002 (Schnepf, 2004). Diesel is used to power farm machinery including tractors, combines, mowers and large trucks (Pimentel, 2002). The second largest direct energy source is electricity, used to power onsite facilities as well as small operating equipment such as irrigation pumps. In California, irrigation can consume a significant amount of energy, in some cases accounting for 70% to 90% of electricity use in crop farming (Brown, 2005; De Gryze et al., 2009). Gasoline, natural gas and liquefied petroleum gas comprise the remaining 17% of energy consumed (Schnepf, 2004).

The most significant indirect use of energy is synthetic fertilizers, particularly nitrogen fertilizer, which is the primary fertilizer used in the United States (Pimentel, 2002). Natural gas is a major feedstock for nitrogen fertilizer, making fertilizer production extremely energy-intensive (Schnepf, 2004). Fertilizers accounted for about 29% of agricultural energy use in the United States in 2002, but can vary from 33% to 85% of indirect energy use depending on the crop and production practices (Pervanchon, 2002). Pesticides generally make up a much smaller proportion- about 2%- of total energy use, (Helsel, 2002) but this figure can vary depending on the type of pesticide, the crop and the cultural practices of the grower (Pervanchon, 2002).

The energy consumption of equipment production, maintenance and repair accounts for about 2.4% of total energy consumed in agricultural operations (Bowers, 2002). Equipment is often considered in lifecycle-assessment-based energy analysis of food production. However, because growers have already invested in certain equipment, it takes time to update equipment inventory with more efficient machines (Pervanchon, 2002). The energy used in seed production is also highly variable, ranging from 1% to 13% of indirect energy use (Pervanchon, 2002; Tzilivakis et al., 2005).

Several economic and environmental benefits to growers and society as a whole can be realized by reducing energy use and improving energy efficiency in agriculture. First, energy efficiency is an important cost saving strategy for growers. Energy costs are about 15% of total agricultural operating costs in the United States, but can vary by product and production method (Schnepf, 2004). Because agricultural operations and inputs are dependent on fossil fuels, rising fossil fuel prices will increase production costs for agricultural operations across the country (Heykoop, 2001). Reducing dependence on external energy can protect growers from variability in energy and fuel markets.

Second, reducing fossil energy use in agriculture is essential to reducing greenhouse gas emissions and improving air quality both locally and regionally (Tzilivakis et al., 2005). Growing concerns regarding global climate change have encouraged development of energy efficiency technologies and renewable energy sources for use in agriculture (University of California Davis, 2009).

## *10.2* Energy: Site-specific Methods and Results

Head growers were interviewed to identify farm processes that required electrical or fuel-based energy, including tractor operations (soil preparation and crop applications), electric and diesel-powered water pumps and electricity used at grading and sorting facilities. Utility bills documented the amount of gas and electricity used. We also collected data from the growers regarding how much fuel different machines consumed. Some of this information was not tracked previously, either at all or at a sufficient (per-crop) level of detail.

### 10.2.1 Monterey County Region

In the Monterey County Region, the grower had not historically tracked the amount of fuel used by his machinery for any particular crop, but agreed to do it for the 2010 harvesting season. The employee in charge of machinery in this region took meter readings for the onion machinery every day and kept track of the amount of diesel being consumed by each individual machine. Since management practices had not changed from the 2009 onion crop in terms of field machinery usage, we used this 2010 estimate as a good approximation of fuel consumption in 2008-2009.

Well irrigation pumps in this region are powered by electricity. The grower estimated that it took 250 Kilowatt hours to pump one acre-foot of water, and that the onions required on average 4.5 acre-feet of water per acre of onions. The rate of electricity to water pumping volume was determined by independent contracted pump testing. Therefore:

*4.5 acre-feet/acre onion * 250 kwh/acre-feet water * total acreage * = total kwh 2009 electricity usage*

The packing and sorting facility shares an electricity meter with the cooling facility, so we had no way of knowing how much power was consumed by the packing facility alone. However, we did account for the diesel and propane used to run the sorting and grading facility machinery.

#### *Data Collection Challenges and Assumptions Made*

- In cases where there was no data for 2009, we tracked harvest fuel use and applied to 2010 year.
- Since we could not differentiate between electricity used for the packing and sorting facility and cooling, we did not include this in our estimates.
- Electricity use for water pumping was based on an estimate for the amount of water applied.

#### *Results*

In the Monterey County region, irrigation and farm machinery were the largest consumers of energy. Irrigation pumping is powered by electricity, most farm machines are powered by diesel fuel, and the sorting and grading facility runs primarily on propane. These resources were not easy for growers to monitor, but tried to track fuel use and are willing to do so for one or two fields in the future. Electricity is harder to measure directly since there are no electric meters that correspond to specific fields, but can be calculated from better water application measurements and the amount of energy needed to pump an acre foot of water.

#### *Recommendations for future data collection for Monterey County Region:*

1. Improve measurements of water and electricity to improve total electricity estimate. Soil sensors and water meters on sprinkler and drip systems in 3 or 4 test fields of Gill's growers in 2011 accomplish this, and will allow for a more exacting application of irrigation water.

2. Monitor all machinery used on as many fields as possible to get an estimate of average fuel use per acre of onions for all processes throughout the season.

3. Continue tracking propane and electricity used by the sorting and grading facility.

### 10.2.2 Fresno County Region

The Fresno County Region did not historically track fuel usage by crop. We received information about the total amount of diesel or propane used by each machine for the harvesting of onions during the 2010 season and worked under the assumption that fuel consumption and crop management practices had not changed since 2009. We were unable to obtain an estimate of planting fuel use for this region. We collected PG&E invoices for the sorting and grading facility's electricity meter.

### *Data Collection Challenges and Assumptions Made*

- We did not have field machinery fuel use data for 2009. Planting fuel use was estimated based on Monterey planting averages. Harvest fuel use was tracked in 2010 and applied to 2009 year.
- No data was obtained regarding irrigation energy requirements.

### *Results*

The main energy consumers were the sorting and grading facility, which relies heavily on propane, and field machinery, which uses diesel. Growers in this region also tracked fuel use by harvesting machinery for the 2010 crop. This may involve a certain amount of additional work for staff, but is necessary to obtain accurate fuel measurements.

### *Recommendations for future data collection for Fresno County Region*

1. Continue tracking propane and electricity used by sorting and grading facility.

2. Monitor all machinery used on as many fields as is feasible to get an estimate of average fuel use per acre of onions for all processes throughout the season.

## 10.2.3 Imperial County Region

Imperial County Region growers were already tracking a lot of information about their machinery fuel use. The growers provided a list of the machines used for planting, the estimated number of times each machine ran over each onion field and the average fuel usage of each vehicle in gallons of diesel per acre. We were therefore able to calculate total gallons of diesel used:

*Gallons/acre * times the machine ran over a field * acreage = gallons of diesel*

The growers also provided an estimate of the total amount of diesel fuel used for harvesting the 2009 onions, was based on their invoices to Gills Onions, who reimburses the growers for the fuel.

The electricity consumer in this region is the sorting and grading facility. The meter for this facility is shared with another building, and the growers did not think they could accurately distinguish the amount of electricity used for onion-related functions, so we did not include this data.

### *Data Collection Challenges and Assumptions Made*

- No electricity data were available.
- Fuel use calculations are based on an estimate of gallons per acre for each machine, which may not be exact.

- We used sorting and grading energy consumption averages per ton onions from Fresno since same machine is used in Imperial County.

#### *Results*

In this region, we found that the field machinery fuel calculations were particularly high. We believe this is because we used estimates instead of direct measurements. Field machinery and the sorting and grading facility were the main consumers of energy in this region.

#### *Recommendations for future data collection for Imperial County Region*

**Farmer processes:**

1. Consider recording fuel use on a daily basis for all machinery on a few fields to get accurate reading on machinery fuel consumption.

2. Install a separate meter to measure electricity use at the sorting and grading facility.

### 10.2.4 Indiana Region

Indiana Region growers sent us handwritten records describing each type of machine, the gallons of fuel it used per acre, and the number of times it was passed over the fields. We used this information to calculate total gallons of diesel used:

*Gallons/acre * times the machine ran over a field * acreage = gallons of diesel*

Electricity in this region is mainly used to dry the onion bulbs and prepare them for shipping. Since onions were only one of several crops being dried in the facility, the growers estimated the amount of electricity used based on the percent onions of the total volume of crops dried in the facility each month.

#### *Data Collection Challenges and Assumptions Made*

- Fuel use was estimated based on gallons per acre— it may or may not have been directly measured.

- Electricity had to be allocated to onions based on mass because multiple crops are dried in this shop.

#### *Results*

Fuel use by field machinery per acre was surprisingly high in this region give the shortness of the growing season. However, many onions are planted in a small area and may require more intensive care and preparation for shipping. The onion bulb drying shed contributed a large amount to electricity consumption.

#### *Recommendations for future data collection for Indiana Region*

1. Continue monitoring fuel used by farm machinery, on a daily or weekly basis if possible.

2. Since this data was collected, the company has invested in much more efficient bulb drying equipment. In coming years, it will be interesting to monitor the change in electricity use as compared to the 2009 baseline.

### 10.2.5 SISC

SISC requested information on annual electricity use, stationary combustions sources of energy use and the type and amount of fuel they consumed, and mobile combustion sources and the type and amount of fuel they consumed.

We submitted this information for one lot in each region.

## 10.3 Energy: Discussion

We found collecting data on energy use to be particularly challenging. Energy is consumed in many different forms, including propane, electricity, and diesel fuel. It is difficult to compare these without further analyzing their environmental impacts, since the greenhouse gas emissions associated with each fuel type are different. A second challenge is that these energy sources are consumed by many different farm processes, including irrigation, farm machinery, sorting and grading, and onion drying. This makes it particularly challenging for growers to locate and report complete information on energy consumption. In addition, many energy consuming machines are used on multiple fields and crops in the same day, so even if growers track fuel used by machine, they will also have to track or allocate it by field or crop in order to have crop specific energy consumption information.

# 11. Waste

## 11.1 Waste: Background

### 11.1.1 On-farm waste generation in agriculture

Agricultural systems generate three main categories of waste: organic waste, solid waste (including plastics, paper and cardboard) and hazardous waste (generated from the liners of some agrochemical packaging) (United States Environmental Protection Agency, 2010). The type, amount and disposal methods of waste generated can vary widely depending on the type of crop and the cultural practices of the growers.

Organic waste is created when portions of the crop are left on the field during harvest or culled during sorting and grading operations. For economic, food quality and safety reasons, growers often harvest selectively, leaving behind small, misshapen or blemished produce. These crop losses can constitute a large part of the waste stream on many farms, however there are few studies that examine on-farm losses: most assess post-harvest waste at the restaurant and consumer levels. (Kantor et al., 1997). In the agriculture industry as a whole, food loss rates on the farm can range from 15% to 35% depending on the crop (Williams, 2004). In the fresh vegetable industry, the average food loss rate on the farm ranges from 20% to 25% of the total crop (Lundqvist et al., 2008).

Because organic waste is rich in nutrients, it can be a valuable resource for many sectors of the agriculture industry, and therefore several options exist for its disposal and recycling. Organic waste can be applied directly back onto the field and worked into the soil (Grower, personal communication, 2010). A second option for disposal is composting, which is the controlled decomposition of organic wastes. Composting creates a valuable amendment that improves the physical, chemical and biological quality of the soils (United States Composting Council, 2008). Depending on the space and resources available to the growers, composting can take place on site, or the organic waste can be sent to a commercial composting facility to be processed. Finally, some growers send the waste to be used for animal feed (Grower, personal communication, 2010). Growers will choose different disposal methods depending on the type of crop, local climate and soil conditions and the logistics of disposal (Grower, personal communication, 2010).

In general, plastic is one of the largest contributors to agricultural solid waste. Use of plastic in agriculture began in the 1940s when it was used as a cover for greenhouses. Since then, plastics have spread throughout the agricultural supply chain. Common forms of plastic used in agriculture include drip tape, plastic films, silage bags, bale wraps, nursery pots and pesticide containers. It is estimated that California agriculture disposes of approximately 55,000 tons of agricultural plastics per year (California Integrated Waste Management Board 2008).

Agricultural non-hazardous plastic waste can be disposed of by re-use, recycling, sending it to a landfill, or burning it (California Integrated Waste Management Board, 2008). Because plastics are a valuable resource, the preferable method of disposal is either re-use or recycling. In a survey of California growers conducted by the California Integrated Waste Management Board, approximately 36% of respondents indicated that they are recycling at least some of their agricultural plastics (California Integrated Waste Management Board, 2008). Growers cited two main difficulties in increasing their plastics recycling: distance to recycling facilities and restrictions on recycling agricultural plastics (including type, amount, color and cleanliness) (California Integrated Waste Management Board, 2008). Waste officials in California are studying incentive structures to increase recycling of agricultural plastics (California Integrated Waste Management Board, 2008).

Paper and cardboard are generated in smaller quantities from discarded pesticide and fertilizer packaging (Grower contractor, personal communication, 2010). These wastes are either burned or picked up by the local waste hauler for disposal or recycling (Grower, personal communication, 2010).

Hazardous waste is generated from certain agrochemical packaging and packaging liners (Donna Abraziru, personal communication, 2010). In California, pesticide packaging is considered hazardous waste unless it is managed according to applicable regulations (California Department of Resources Recycling and Recovery, 1995). According to California Department of Toxic Substances Control regulations, if properly cleaned, plastic pesticide containers can be recycled or disposed of in a landfill. Empty pesticide bags are not considered hazardous waste and may also be disposed of in a landfill or burned if they are emptied according to California Department of Pesticide Regulation guidelines (California Department of Resources Recycling and Recovery, 1995). Recycling programs for pesticide containers are regulated under the Food and Agriculture Code section 12841.4 (California Department of Pesticide Regulation, 2009). All recycling programs are required to comply with ANSI/ASABE Standard S596 and S596 in the handling and processing of pesticide containers.

## 11.2 Waste: Methods and Results for all regions

In all regions, data collection began by interviewing the grower to understand the major sources of waste associated with the growing operations. Qualitative data regarding the processes that generate waste and the practices for dealing with waste were gathered from these initial interviews. Quantitative data on waste generated was gathered through subsequent phone conversations and emails to the growers and relevant contracting companies. We used metrics from the SISC framework as a guide to collect quantitative data for waste associated with the onion growing operations. In general, waste from the growing operations falls into two categories: culled onion waste and solid waste (drip tape, pesticide and fertilizer packaging etc).

### 11.2.1 Culled Onion Waste

The SISC framework included two metrics that we used to evaluate culled onion waste: total material sent to compost and total material sent to animal feed. We added a third metric, total material applied back to the fields, since some growers use this disposal method. These metrics were calculated using Gills Onions Production Completion Records. A Production Completion Record is a data sheet generated for each lot at the time of harvest that contains information such as the grower, onion variety and total amount (in pounds and tons) harvested for each size class of onion. To determine the amount of culled onion waste generated we subtracted the "Total Packout (lbs.)" column from the "Harvest Summary Lbs. Received" column in the Production Completion Record for each lot. We then interviewed growers to determine the region specific practices for disposing of culled onion waste.

### 11.2.2 Solid Waste

We collected data on the amount generated and the disposal methods of four types of solid waste: drip tape, plastics, paper/cardboard and hazardous waste. Because cultural practices, business operations and record keeping pertaining to solid waste differ across the three growing regions, the data gathering process was slightly different in each region. Unique aspects of the data collection, challenges in data collection, and calculation methodologies for each region are described below.

### 11.2.3 Indiana Region

#### *Methods*

Qualitative information regarding waste was gathered via grower interviews; however, quantitative data on the amount of waste produced was not available.

#### *Results*

A qualitative description on waste practices for the Indiana Region indicates that culled onion waste is reused as compost and spread on soybean fields. No information was available regarding solid waste.

### 11.2.4 Imperial County Region

#### *Methods*

The growers in Imperial County Region do not keep records on solid waste. Pesticide and fertilizer container waste handling and drip tape recycling is outsourced to a private third party (IC grower, personal communication, 2010-10-14). This company did not have data available for the amount of solid waste corresponding to onion production for Gills Onions in the 2009 season (Jack Klein, personal communication, 2010-10-25). Thus, total amounts of waste distributed to landfill or incineration, hazardous waste, and recycling are unknown.

The amount of drip tape recycled is based on a calculated estimate. All drip tape used for the 2009 onion crop was used once and recycled. Lay flat hoses, which connect to the drip tape, are reused but no quantitative data is available for the amount. The beds were 80-inches wide (IC grower, personal communication, 2010-04-30). The drip tape used in 2009 was manufactured by Queengil company. The dimensions of the Queengil tape are ⅞-inch diameter by 6 mm thick (IC grower, personal communication, 2010-10-20). It was not possible to obtain the weight of the Queengil tape from the company directly so the weight of a T-Tape, a similar drip tape manufactured by John Deere, was used as a proxy. Weight of drip tape per foot was obtained from the T-Tape product data sheet on the John Deere website (John Deere, 2011). The total weight of drip tape was calculated with the following equation:

*Weight of the tape (lbs/ft) * amount of drip tape used/acre * #acres/lot = total weight drip tape.*

### *Results*

#### Culled Onion Waste

Three categories of short-day onion types, which bulb when daylight is between twelve to 14 hours, are grown in the region: yellow from Indiana onion sets, yellow from seed, and red. As illustrated in the Appendix (omitted from this draft due to proprietary information), the yellow from seed category had the most waste in mass per unit acre while yellow from sets had the highest waste in percentage of yield. On a per lot basis, yellows from seed had the highest mean value of waste mass per unit acre. Culled onion waste is all reused as compost on the local farm fields (IC grower, personal communication, 2010-10-14).

#### Solid Waste

The total estimated amount of drip tape recycled for the 2009 season was 73,243 pounds, or approximately 172.8 pounds per acre.

## 11.2.5 Fresno County Region

### *Methods*

Qualitative information regarding solid waste was obtained via phone interviews and email correspondence with the staff of the Fresno County Region growing operations. However, because no quantitative data regarding solid waste was available, we did not make any calculations for this category.

### *Results*

#### Culled Onion Waste

Four categories of intermediate onion types are grown in the region: yellow, red, white, and trials. As shown in the Appendix (omitted from this draft due to proprietary information), the red category had both the highest waste measured in mass per unit acre and percentage of yield. On a per lot basis, the trials category had the highest mean value of waste mass per unit acre. All waste onions are sent to a dairy to be used as cattle feed (Chito Coronado, personal communication, 2010-10-28).

#### Solid Waste

The growers in the Fresno County Region produce a variety of crops for different clients and they do not separate waste generated by the different crops. Furthermore, waste is disposed of in different ways depending on the type of material. Paper and cardboard products are burned. Plastic packages are triple rinsed and then put in the growers dumpsters for pickup by Mid-Valley Disposal (FC grower, personal communication, 2010-10-18). Mid-Valley Disposal does not weigh the dumpsters at pickup, so it was not possible to get any waste data for this region.

Drip tape for the 2009 crop was used once and then recycled. In 80-inch wide beds, the growers use 19,620 feet of drip tape per acre. All beds for the 2009 crop were 80-inch wide beds (FC grower, personal communication, 2010-07-07). The drip tape used was John Deere T-Tape; however, the grower did not provided details on the thickness of tape used for the 2009 crop, so it was not possible to calculate the total weight of drip tape recycled.

### 11.2.6 Monterey County Region

#### *Methods*

The growers in the Monterey County Region do not keep records regarding materials waste. Therefore, estimates of solid waste generation were obtained through interviews with the grower and contracted chemical application companies.

An estimate of the amount of waste generated from pesticide and fertilizer packaging for the 2009 crop was made by the Pest Control Advisor at the chemical application company contracted to apply agrochemicals to the onion crops. This estimate took into account the number of acres of onions, the types of chemicals applied, the number of applications and the weight of each bottle or package (Donna Abraziru, personal communication, 2010-10-22). To calculate lot level data, these estimates were divided by the total acres of onions planted in 2009, then multiplied by the acre size of our chosen study lot. Total weight of drip tape per lot was calculated using the following equation:

*Weight of the tape (lbs/ft) * 19,620 ft of tape/acre * #acres/lot = total weight drip tape.*

Weight of drip tape per foot was obtained from the T-Tape product data sheet on the John Deere website (John Deere, 2011).

### *Results*

#### Culled Onion Waste

Four categories of intermediate and long-day onion types are grown in the region: intermediate reds, storage reds, sweet Spanish, and storage yellows. As shown in in the Appendix (omitted from this draft due to proprietary information), the sweet Spanish category had both the highest waste measured in mass per unit acre and percentage of yield. On a per lot basis, the sweet Spanish category also had the highest mean value for waste mass per unit acre.

After harvest, the onions are sorted and graded at Rio Farm's facilities. All onions culled during the sorting and grading process become waste onions and are composted locally through Keith Day Composting in Salinas, CA.

#### Solid Waste

There were two main sources of waste in this region – packaging from agrochemicals and drip tape. The growers in the Monterey County Region contract with Integrated Crop Management Consultants, Inc. (ICMC) in Greenfield, CA to apply pesticides to the onions. Waste generated from pesticide packaging is either cardboard or plastic depending on the product. In addition, a small amount of hazardous waste is generated from the package liners of some chemicals. ICMC handles the disposal of waste from the pesticide applications. Plastic containers are triple rinsed and then recycled, cardboard is also recycled, and hazardous waste is disposed of at a hazardous waste facility in Kettleman City, CA. ICMC does not keep records of the amount of waste generated by specific crops and growers. The PCA was able to provide an estimate of the amount of plastic, paper and hazardous waste produced for the 2009 crop. These estimates are presented in the Appendix (omitted from this draft due to proprietary information).

The other source of solid waste is drip tape. Approximately 342,087.76 pounds of drip tape was used for the 2009 crop, or about 229 pounds per acre, comprising over 90% of the waste stream in this region. During the 2009 season, all drip tape was re-used.

### 11.2.7 SISC

SISC requested data on the total amount of waste sent to landfill/incineration, composting, animal feed, recycling facilities or re-use on the farm. In order to calculate food utilization, SISC also requested information on the total acres harvested compared to total acres planted. We used the results of our data collection to submit this information for one lot in each region.

## 11.3 Waste Discussion

### 11.3.1 Onion Waste

Each region disposes of its culled onions differently: in the Monterey County Region culled onions are composted, in the Fresno County Region culled onions are sent to animal feed and in the Imperial County Region, culled onions are spread back onto the field and worked into the soil. Operational and climatic differences contribute to different disposal methods. In the Monterey County Region and the Fresno County Region, the growers are not able to spread the onions back onto the field due to concerns about pink root, a soil-borne fungus that infects the roots, killing the plant (Voss, 1999). However, in Imperial County Region, the hot dry climate and sandy soils make it possible to spread the onion waste back on the field (IC grower, personal communication, 2010-12-01).

The three California regions also differed in the amount of culled onions per acre and the average amount of onions produced per acre. All three California regions had less than the average on- farm food loss rate of 20% to 25%. Variation in the culled onion waste values between regions is due to the different onion types grown and the different resulting harvesting practices. In the Imperial County Region, the onions are short day onions and have larger rings allowing for a greater loss of moisture. Short day onions can only be stored for 30 days. In the Monterey County Region, primarily long day storage onions are grown. These onions have more stems and longer necks which inhibit the entry of pathogens. During the harvest process, the machine that removes the onion tops (the chopper ) is set at a higher level so less of the onion top is removed. As a result of the longer necks and lowered chopper, there is relatively more waste. In the Fresno County Region, intermediate onions are grown and these are trimmed more by the chopper and thus have less waste in comparison to the Monterey County Region (Don Arevalos, personal communication, 2011-02-04).

There are various contributors to uncertainty in our quantitative results for culled onion waste. The waste left on the field during the mechanical harvest process is not accounted for in the production record spreadsheets (IC grower, personal communication, 2010-10-14). If interested in determining these values, Gills Corporation could initiate a sampling study in future years to weigh onions left on select lots after harvest. In addition, some lots in the Imperial County Region and the Monterey County Region are used for experimental purposes and the associated waste tonnage is not recorded for these lots (Don Arevalos, personal communication, 2011-02-04). A third uncertainty factor is the measurement error of the scales at the harvest facilities, which is assumed to be negligible. Finally, there are also potential for incorrect data on the productions spreadsheets due to human error.

### 11.3.2 Solid Waste

Information regarding generation and disposal of solid waste was very limited. Drip tape appears to be the most significant type of solid waste generated by the growing operations. Because the amount of drip tape used per acre is constant, the main possibility for reducing the amount of drip tape used is to re-use drip tape to the maximum extent possible. There are several factors that determine whether or not the drip tape can be re-used and therefore disposal of the drip tape varies by crop and season. The first factor affecting drip tape re-use is the thickness of the tape – 4 mm tape is usually recycled after one season, 6 mm tape can be re-used for one to two seasons, 8 to 12 mm tape can be re-used for up to three to five seasons. The second factor is the configuration of the field. Drip tape must be spliced back together in order to be re-used. If the field has many short rows, re-splicing the tape is time and labor intensive, therefore a thinner tape is often used once and then recycled. If a field has long rows, splicing the tape is easier, so the growers are more likely to invest in thicker tape and re-use it for several seasons. The final factor is cost of the tape at the time of purchase. Growers must balance investing upfront in higher cost thicker tape for re-use, or choosing a lower upfront cost for thinner tape that will be recycled. The growers are currently investigating the possibility of switching to thicker tape, which could be used for more growing seasons (FC grower, personal communication, 2010-07-07).

## 11.4 Waste: Recommendations for Future Data Collection

### 11.4.1 Culled Onion Waste

**Farmer processes**

1. Start providing estimates for onion waste that is not currently accounted for where possible such as on lots used for experimental purposes or where crops are not harvested

**Gills staff processes**

1. Request onion waste data from Dutch Valley Growers in Indiana.
2. While the data needed to calculate the amount of culled onion waste is already available at the lot level in Gills Onions' Production Completion Records, these records should be verified for accuracy using a quality control procedure prior to data entry in the sustainability tracking database.

### 11.4.2 Solid Waste

**Farmer processes:**

1. Record the following items regarding drip tape used for each lot or crop send this information to Gills staff:
    a. Type of drip tape (manufacturer and thickness)
    b. Number of feet of tape used per acre
    c. Disposal method (re-use, recycling, landfill etc.)
2. Record the following items regarding the package/container for each type of agrochemical used and forward to Gill staff:

    a. Weight of a single package/container
    b. Material of package (plastic, paper, cardboard etc.)
    c. Volume of product held in each container/package
3. Record the disposal method for all agrochemical packaging and forward to Gills staff.

**Gills staff processes:**

1. Contact drip tape manufacturer to obtain the weight of the tape per foot.
2. Calculate the weight of the tape for each lot or crop with the following equation:

*Weight of the tape (lbs/ft) * feet of drip tape used/acre * #acres/lot = total weight drip tape.*

3. Where growers are responsible for generation and disposal of agrochemical packaging:
    a. Use information regarding agrochemical packaging forwarded by the growers in combination with pesticide and fertilizer application data to calculate the amount of waste generated:
        i. Divide total amount of each type of agrochemical applied (obtained from fertilizer and pesticide data) by the volume of a single container for each product to obtain the number of containers used.
        ii. Multiply the number of containers used by the weight of each container to obtain total weight of packaging waste generated for each chemical.
        iii. Aggregate waste generated based on material (paper, plastic, cardboard etc).
        iv. Record disposal method for each type of packaging.
4. Where a contracted third party is responsible for the generation and disposal of agrochemical packaging:
    a. Investigate the possibility of negotiating contracts with chemical application companies to record the amount of waste generated from agrochemical applications.

# 12. Objective 3: Establish a data tracking framework

Given the difficulty presented by tracking resource use in the four disparate growing regions, we investigated a tracking strategy that would help streamline data collection and aggregation. This led us to develop a database model of the data collection processes in each region. See Figure 6. We anticipate that this schema will be portable and therefore could be implemented in various database or tracking software packages.

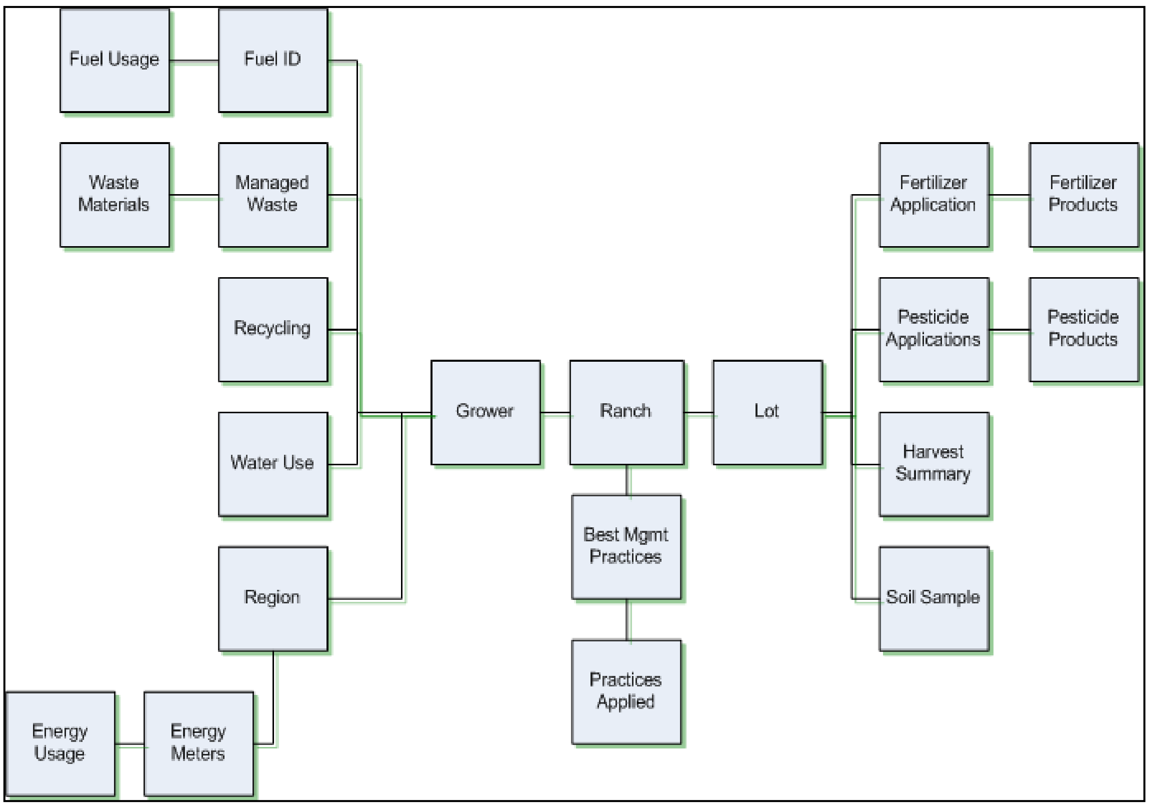


**Figure 6 Database Model**

We implemented the database model in Microsoft Access, which we chose for its usability and so that Gills Onions and their growers would not have to purchase additional software. The database is being used to manage the information gathered during the initial baseline data collection and Gills intends to use of the database in the Monterey County growing region next season.

The Microsoft Access database is based on a relational database architecture. Information is organized in data structures called tables and tables are indexed by primary keys allowing information to be referenced easily. In addition, information between tables may be joined or linked by the definition of relationships and key fields. The associations between tables is one of the benefits of a relational database model as it prevents duplicate information from being stored and also facilitates queries and report generation.

## 12.1 Conceptual Design

The database tables designed for Gills Onions may be conceptually divided into four categories. As summarized in Table 5, these logical data categories include the following: 1) spatial representation, 2) resource description, 3) resource usage, and 4) grower outputs. The spatial category provides context for the location of where onions are grown. The resource description category contains descriptive information about all resources used in onion production. This includes fertilizer, pesticide, drip tape, and farm machinery product specifications as well as energy meter identifiers. The resource usage category relates to the quantitative data about the resource materials utilized during the growing season. The output category also includes quantitative data about onion harvest and resulting waste material.

| Logical Data Category | Database Tables |
| --- | --- |
| Spatial | Grower, Ranch, Lot |
| Resource Description | Fertilizer_Products, Pesticide_Products, Equipment_ID, Energy_Meters, Waste_Materials |
| Resource Usage | Fertilizer_Application, Pesticide_Application, Soil, Water_Use, Fuel_Usage, Energy_Usage |

**Table 5 Logical Categories of Database Tables**

## 12.2 Table Relationships

As mentioned above, associations between tables are formed using relationships and key fields. A summary of the database table relationships is listed in Table 6. Relationships between the Region, Grower, Ranch, and Lot tables are used to track information about growing onions on a specific area of land. These spatial relationships may be considered representative of a nested spatial hierarchy. Growers are located in a specific geographic region; ranches are managed by growers, and lots are the smallest land unit within a ranch for tracking onion production. The table relationships for associating between resource usage and location vary with respect to spatial scale depending on the resource category. Some resources like energy, water, and solid waste are tracked at the grower level while other resource categories like fertilizer, pesticides, and soil samples are being tracked at the ranch and lot level. Harvest production is tracked at the lot level; solid waste is tracked at the grower level.

| Table Relationship | Relationship Type | Data Category | Key Field for Linking Tables |
|---|---|---|---|
| Region:Grower | 1:Many | Spatial | Region |
| Grower:Ranch | 1:Many | Spatial | Grower_name |
| Grower:Water_Use | 1:Many | Resource Usage | Grower_name |
| Grower:Equipment | 1:Many | Resource Usage | Grower_name |
| Grower:Energy_Meter | 1:Many | Resource Usage | Grower_name |
| Grower:Waste_Managed | 1:Many | Output | Grower_name |
| Equipment:Fuel Usage | 1:Many | Resource Usage | equipment_id |
| Energy_Meter:Energy_Usage | 1:Many | Resource Usage | meter_id |
| Ranch:Lot | 1:Many | Spatial | ranch_id |
| Lot:Harvest_Summary | 1:1 | Output | gills_lot_id |
| Lot:Fertilizers_Applied | 1:Many | Resource Usage | ranch_id,lot_id |
| Lot:Pesticides_Applied | 1:Many | Resource Usage | ranch_id,lot_id |
| Lot:Soil | 1:Many | Resource Usage | ranch_id,lot_id |
| Fertilizer_Products:Fertilizer_Applied | 1:Many | Resource Usage | product_name |
| Pesticide_Products:Pesticides_Applied | 1:Many | Resource Usage | pesticide_name |
| Waste_Materials:Waste_Managed | 1:Many | Resource Usage | material_name |

**Table 6 Table Relationships**

## 12.3 Database Workflows

The database facilitates sustainability tracking by offering a centralized information repository and a logical data management architecture; however, these benefits will not be realized without adhering to operational procedures for capturing information in the database. For every growing season, it is required to perform four workflows so that all resource categories are tracked and stored in the database. These four workflows include the following:

**1) Specify the selected lots for the growing season**

**2) Document descriptions and specifications of any new fertilizer, pesticide, machinery, drip tape materials not used in previous onion growing seasons**

**3) Calculate and determine the total quantities of resources used for onion growing**

**4) Tally the harvest tonnage and waste materials**

A high-level outline of the workflow steps is provided below.  Detailed procedures are documented in a database user-guide.

### 12.3.1 Workflow 1

Purpose:  Specify the selected lots for the growing season

Steps:

1) Launch Microsoft Access and open Gills Onions database
2) If a small number of lots are being tracked for the season, use the Lot form to input ranch and lot information. Otherwise, create lot and ranch spreadsheets and use External Data/Import/Excel function to transfer data from spreadsheets to the database.
3) Perform Lot query to confirm ranch and lots for the growing season are now added to database.

### 12.3.2 Workflow 2

Purpose: Document descriptions and specifications of any new fertilizer, pesticide, machinery or drip tape materials not used in previous onion growing seasons

Steps:

1) Launch Microsoft Access and open Gills Onions database
2) Enter new product information using the applicable forms.  (e.g. Fertilizer_Products, Pesticides_Products, Equipment, Waste_Materials).
3) Perform applicable query to determine new product information is now added to database.

### 12.3.3 Workflow 3

Purpose: Calculate and determining the total quantities of resources used for onion growing

Steps:

1) Launch Microsoft Access and open Gills Onions database
2) Enter all resource usage information for the growing season using the applicable forms (e.g. Water Use, Fuel Usage, Energy_Usage, Fertilizers_Applied, Pesticides_Applied),  If a large number of applications or utilizations are being tracked, create spreadsheets and use External Data/Import/Excel function to transfer data from spreadsheets to database.

3) Perform applicable query to determine resource information is now added to database.

### 12.3.4 Workflow 4

Purpose: Tally the total harvest tonnage and waste materials

Steps:

1) Launch Microsoft Access and open Gills Onions database
2) Enter all onion harvest and waste management for the growing season using the applicable forms (e.g. Harvest_Totals, Waste_Managed), If a large number of lots are being tracked, create spreadsheets and use External Data/Import/Excel function to transfer data from spreadsheets to database.
3) Perform applicable query to determine harvest and waste management information is now added to database.

# 13. Case Study: Carbon Footprint for Monterey County Region

In order to show one of the ways in which this type of data can be used to reflect environmental impacts, we performed a carbon footprint analysis. Because the data for the Monterey County Region was the most complete of the four regions, we chose to focus on the carbon footprint for this region only.

## 13.1 Methodology

The carbon footprint temporal boundaries started with the soil bed preparation and included all activities up to and including sorting and grading of the onions after harvest. The spatial boundaries of the carbon footprint were the four lots for which we had collected data. We also included the sorting and grading facility and allocated energy usage based on the studied acres/total onion acres. The total growth cycle and its resource requirements are as follows:

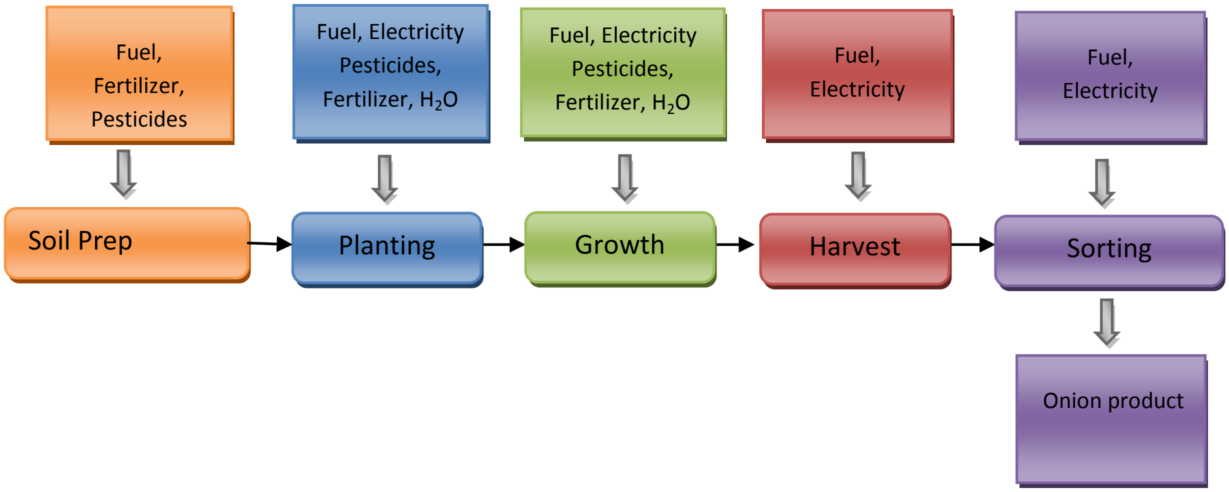


**Figure 7 Onion Production Flow Diagram**

| Emission Sources | | |
|---|---|---|
| **Scope 1** | **Scope 2** | **Scope 3** |
| Direct emissions from fuel used in farm machinery | Emissions released at power plant to create electricity to pump irrigation water. | Embedded energy in agrochemicals including: pesticide, herbicide and fertilizer production. |
| Direct nitrous oxide emissions from the field | | Embedded energy in farm machinery production |
| | | Embedded energy in onion seed production |
| | | Embedded energy in diesel and fossil fuel production |

**Table 7 Carbon Footprint Emission Sources Summary**

## Fuel: Diesel, Propane, Gasoline

Fuel, in the forms of diesel, propane, and gasoline, is directly consumed by the farm machinery that are used for tilling, planting, pesticide application, harvesting, and machines at the sorting and grading facility. We used greenhouse gas emission estimates from the Energy Information Administration to calculate the amounts of $CO_2$, $CH_4$, and $N_2O$ directly emitted through the combustion of each fuel type and converted all emissions into kg of $CO_2$ equivalents ($CO_2e$). (Energy Information Administration, Documentation for Emissions of Greenhouse Gases in the U.S. 2005, DOE/EIA-0638 (2005), October 2007, Tables 6-1, 6-4, and 6-5 (Non-biogenic carbon content and gross

heat of combustion for motor gasoline and diesel (distillate fuel)). We assumed a Global Warming Potential$_{100}$ ($GWP_{100}$) conversion of 298 for $N_2O$ to $CO_2e$, and 25 for $CH_4$ to $CO_2e$ (Forster, 2006). We used the educational version of the Comprehensive Environmental Data
Archive (CEDA) 3.0 database for Greenhouse Gas Emissions to calculate the cradle to gate GHG emissions indirectly embedded in the production of these fuels. CEDA 3.0 is a database that quantifies the emissions associated with a product based on an input-output model of the U.S. economy, and provides the total emissions from product creation to retail based on cost.

## Electricity

The only source of electricity consumption was the wells on the farm that are used for irrigation. We used the grower's estimate for irrigation needs and the amount of electricity needed to pump an acre-foot of water from the well to determine the total amount of electricity consumed. We then used the EPA's e-grid data to calculate the amount of $CO_2$, $CH_4$, and $N_2O$ emitted through the production of electricity in the California region to estimate the kg of $CO_2e$ resulting from electricity use.

## Pesticides and Herbicides

We used the CEDA 3.0 database to calculate the Kg $CO_2e$ embedded in the production of pesticides and herbicides. We entered the amount of money spent on purchasing pesticides and herbicides throughout the season for our four lots.

## Fertilizer

We also used the CEDA 3.0 database to calculate the kg $CO_2e$ embedded in the production of fertilizers. In addition, part of the nitrogen in fertilizers results in direct volatilization of $N_2O$. We relied on prior research that found a volatilization rate of 0.0125, meaning that on average, 1.25% of the N applied to fields in the form of fertilizer becomes direct emissions of $N_2O$ to the atmosphere (Mosier et al., 1998).

## Machinery

We used our inventory of farm machinery to estimate the cost of buying the machines new. This cost was entered into CEDA 3.0 to calculate the GHG emissions associated with producing the machinery. We assumed a 20 year lifespan for farm machinery, and allocated the production emissions based on the machinery being owned by Gills Onions for 20 years and used in all three California growing regions.

## Seeds

CEDA 3.0 was used to calculate the GHG emissions associated with the production of onion seeds. This estimate was based on the cost of seeds for each of our four lots.

## 13.2 Results

The following pie chart (Figure 8) shows the percentage of emissions coming from each category of emission source and Table 8 shows the emissions as Kg $CO_2$e per ton of onions harvested for each category of emissions source.

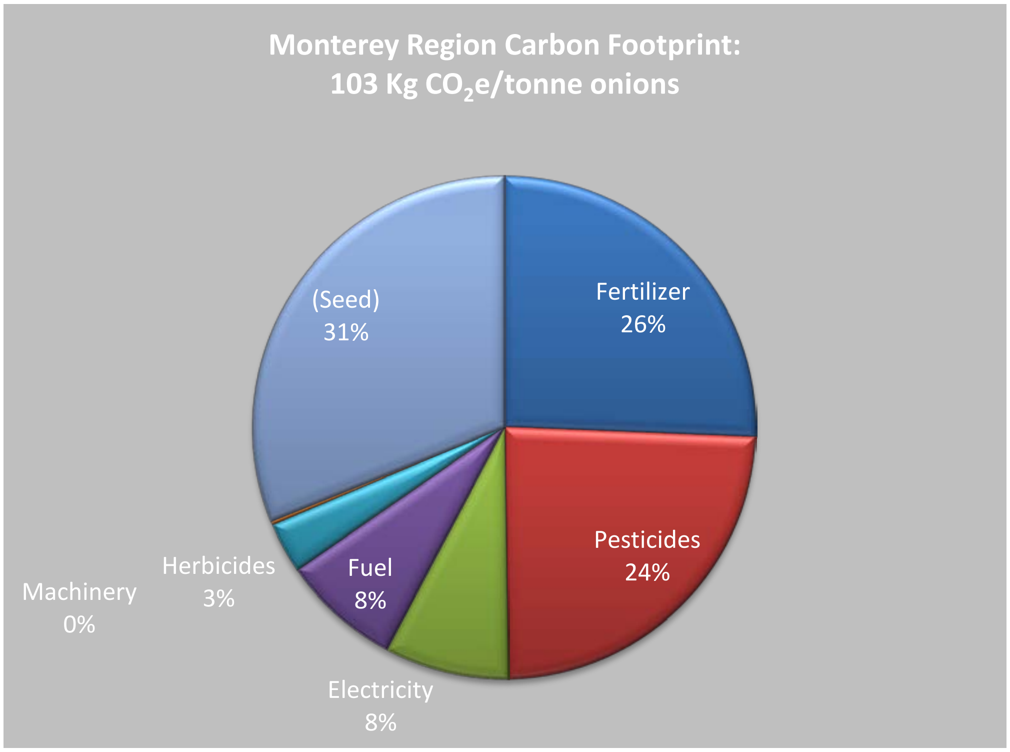


**Figure 8 Gills Onions' Monterey County Carbon Footprint**

| Emissions Source | Kg $CO_2$e/tonne onion |
| --- | --- |
| Fuel | 26.50 |
| Electricity | 24.95 |
| Fertilizer | 8.23 |
| Pesticides | 7.92 |
| Herbicides | 3.37 |
| Machinery | 0.26 |
| Seed | 32.13 |
| **Total** | **103.37** |

**Table 8 Kg CO2e/tonne onion per Emission Source for Onion Production**

## 13.3 Discussion

A carbon footprint is most useful when viewed as a tool for highlighting the areas of highest GHG emission and prioritizing interventions. The most significant source of emissions in this footprint was estimated to be the purchase of onion seeds. This was initially surprising, but makes sense given that the production of onion seeds is itself a whole onion growing operation which requires many of the same inputs as the Gills onion operation. However, given the relative importance of this emission source, it would be worth looking further into the seed growing operations to get a more accurate estimate of their emissions. CEDA 3.0 did not have a listing for onion seed, and so grass seed was used instead. The estimate for grass seed was cross checked by calculating emissions based on all other agricultural processes not listed in CEDA, which yielded approximately the same number. Nonetheless, further research on the GHG emissions embedded in onion seed purchasing is needed.

The second most significant emissions sources were fertilizer and pesticides. This reflects mainly the emissions released in the production of these chemicals, an energy intensive process (Pervanchon, 2002). Fertilizers can also release nitrous oxide ($N_2O$) into the atmosphere, a potent greenhouse gas with a global warming potential 298 times that of $CO_2$. In this carbon footprint, $N_2O$ emissions were estimated based on a flat volatilization rate from (Mosier et al., 1998). However, $N_2O$ emissions actually vary based on soil type, fertilizer type, application method and scheduling, and crop. A more accurate carbon footprint would incorporate site-specific information on these variables. It is interesting to note the relatively small contribution of fuel to the total carbon footprint. In our study, there is much uncertainty in the data on fuel usage, since it is based on grower estimates of machinery efficiency and extent of use. These numbers can be improved with better tracking of fuel usage.

Overall, we found that the Carbon Footprint for this region was about 103 Kg $CO_2$e/ton of onions. We compared this number to 2 different studies and found it to be well within the range reported by others, especially those that accounted for nitrous oxide emissions (Saunders et al, 2008; Wiltshire et al., 2009).

| Region | Kg $CO_2$e/ton (production) | Kg $CO_2$e/ton ($N_2O$ from fertilizer) | Kg $CO_2$e/ton (seed production) | Total Kg $CO_2$e/ton reported |
|---|---|---|---|---|
| Monterey | **60** | **11** | **32** | **103** |
| **United Kingdom[1]** | 45 | NA | NA | 45 |
| **New Zealand[1]** | 60 | NA | NA | 60 |
| **United Kingdom[2]** | 133 | 24 | NA | 157 |

1. Saunders et al, 2008
2. Wiltshire et al, 2009

**Table 9 Carbon Footprint Study Comparison**

# 14. Conclusion

It is difficult to compare on-farm resource use between different growing regions, as there are many interrelated differences between them including:

- Growing processes are staggered throughout the year to provide Gills Onions with a steady stream of inventory to supply their buyers. While one region is planting another may be harvesting, making changes in weather, cost of supplies and other factors difficult to compare.
- The three regions have very different climates (even if they were growing at the same time). Imperial Valley is a desert, and with higher evapotranspiration rates it requires more irrigation to grow a typical crop than in moister climates such as Fresno County.
- Geography can drive other factors such as soil fertility and pests. Crops in Monterey or Fresno County Region may be more susceptible to fungal infestation due to fog. Highly saline soils are more of an issue in Imperial and Monterey County Regions than in Fresno County, necessitating different management strategies, such as a pre-plant flooding of the fields to flush salts away. Loam soils found in Fresno and Monterey County Regions may are more fertile and provide better drainage than the silty-clay soils found in Imperial Valley.
- The short and long day varieties and red vs. white onions may make inter-regional comparisons difficult.

Although these differences exist, sharing best management practices between the sites is valuable for Gills Onions and their growers and may be interesting to the scientific community as a whole. Because the sites are not in direct competition with each other, knowledge sharing on particular soil amendments, irrigation technologies or harvesting techniques could provide additional cost savings, may increase yields and/or reduce environmental impact. Gills Onions staff can promote knowledge sharing as they have already though activities such as testing new onion varieties and testing BTN+ fertilizer.

Our study highlighted several potential challenges to agricultural resource tracking. Data tracking and reporting may require significant time investments or procedural modifications by farm staff. In cases where data is not currently being tracked, growers will need to organize new systems for measurement. For example, tracking fuel consumption will require a new data tracking method, and will likely require machinery operators to record fuel measurements regularly. Operational changes may be challenging for growers and their staff and may not have time to devote to additional monitoring activities. Increasing sustainability may also require capital investments in measuring equipment (for example, water meters) or more resource efficient technologies. An additional challenge is that growers may not immediately recognize the benefits of recording and reporting resource use information. Growers and processors have different priorities. Sustainability tracking may benefit Gills Onions by making their products more marketable. However, the growers may not see the value added.

Because of these challenges, we suggest that Gills Onions prioritize data collection and tracking of resources in the following order: fertilizer, water, energy, waste, and pesticide (Table 10). 1.) Upcoming regulations may require growers to report fertilizer use, which makes tracking this resource our first priority. Product information provided in the database regarding fertilizer density will help the company and growers make quick calculations and meet local and state regulations. 2.) Water is our second priority. For Imperial and Fresno regions the growers simply need to share their invoices from the local irrigation district, making this relatively simple. Where well water is used, study ranches can be selected and water meters should be installed. 3.) We list energy tracking as our third priority because good data collection would require a relatively large time investment by staff, and our project finds that this is less of a priority since the carbon footprint we conducted showed that the embedded energy in pesticides and fertilizers had a greater impact than that of fuel use. Therefore tracking these two categories before tackling energy may make more of an impact on overall greenhouse gas emissions. 4.) Our fourth priority is waste. Gills Onions is already tracking onion waste at the lot level as part of their harvest weighing process. In future seasons, the company could conduct a study of the onion waste left on their fields to fill this data gap. Gills could potentially reduce their drip tape waste as new products hit the market, but for things like agrochemical packaging, the company may have little say in how much waste they generate. 5.) Lastly, pesticides are fifth on our priorities list. Pesticides are already being tracked due to state regulations and Gills Onions' Good Agricultural Practices handbook; additional tracking for this input is not needed. Also, given the complexity of pesticide choice and application, the substitution of less impactful pesticides would require additional analysis by an expert.

| Tracking Priority | Suggested level of tracking | Reason for prioritization level |
|---|---|---|
| **1. Fertilizer** | Determine the acreage based on what drip lines cover – usually at the ranch level | Upcoming regulations may require tracking. Fertilizers are major contributor to both carbon footprint and hazardous waste generation. |
| **2. Water** | Determine the acreage based on what drip lines cover – usually at the ranch level | Relatively easy for Imperial and Fresno to track given current systems.<br>Monterey growers will have to select study lots and install water meters. |
| **3. Energy** | Determine this based on the tractor route – usually at the ranch level. | Complex resource area due to multiple fuel types, machinery sharing between different fields, and staff time requirements. |
| **4. Waste** | All acres | Gills already knows pre- and post- grading onion waste, making it easy to track.<br>Gills may have little influence on how agrochemicals are packaged. |
| **5. Pesticide** | All acres | Already tracking due to state regulations and requirements outlined in Gill's Good Agricultural Practices protocols.<br>Pesticides are major contributor to both carbon footprint and hazardous waste generation. |

**Table 10 Prioritized List of Resources to Track**

The economic investments that onion growers may be willing to make to increase sustainability are constrained by the financial uncertainty of the onion market. The onion market is extremely volatile. For example, between October of 2006 and April of 2007, onion prices soared 400%. Then, in March of 2008, the onion market price crashed by 96%. This market volatility is due to many factors, including rates of production, and weather variability, but may also in some part be due to the ban on onions futures trading (Birger, 2008).

The fluctuation in conventional yellow and yellow marketed sweet onions between 2009 and 2011 is shown in Figure 9. The price of a three pound bag of onions prices rose from about $1.50/lb in January 2010 to $2.98/3lb bag, a 235% price change in just three months. Yellow marked onions rose from a low of $0.89 in June 2009 to $1.42 for a lb in April 2010, a 60% change in 10 months (USDA Agricultural Marketing Service, 2011). Based on these market fluctuations, it's clear that onion growers face substantial uncertainty in their business. This uncertainty may come into play when growers consider the capital investments that they are willing to make to improve sustainability, or the additional tasks that they are willing to take on to improve sustainability reporting that will likely add to their workload.

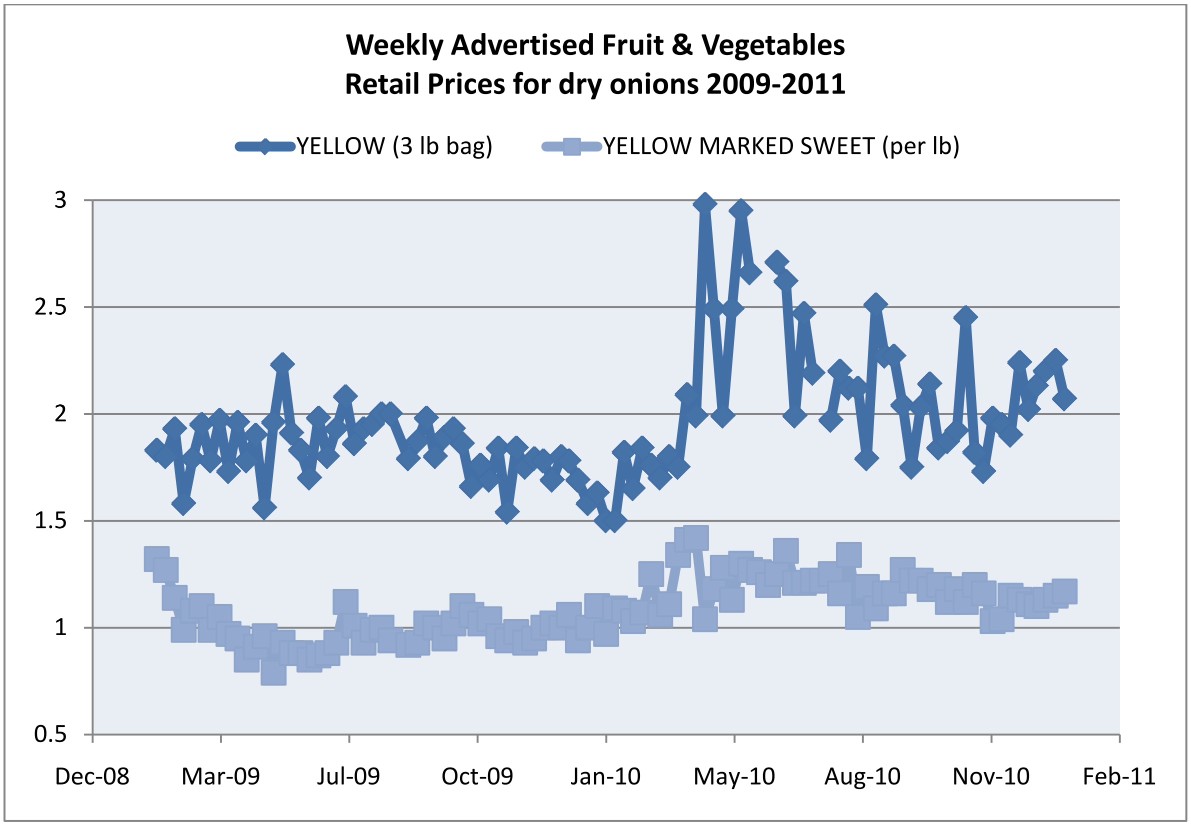


**Figure 9 Retail Prices for Dry Onions 2009-2011 (USDA Agricultural Marketing Service, 2011)**

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Another consideration that we encountered in this project is that the Gills Onions' growers feel that they are already farming sustainably. Through their improvements in best management practices and resource reductions over the years, they believe they understand how best to farm sustainably in their regions and individual ranches. Many growers see the monitoring and reporting as just more work. This highlights the different incentives that exist for growers and Gills Onions as a company. Gills Onions stands to improve their profitability through increased sustainability reporting as the agricultural industry requires increasing transparency. However, for the growers, sustainability reporting has upfront costs and appears as a burden to daily operations.

Despite these considerations, we believe that growers will benefit from tracking their resource use more closely. By systematically recording their resource consumption, growers will be better able to identify opportunities for increased efficiency and reduced costs. Also, given the changing market and industry trends, growers will be able to expand sales by being more transparent and sustainable. Growers may also apply their improved data collection processes complying with developing environmental regulations that will likely call for additional monitoring and reporting by growers. For example, the draft agricultural order from the Central Coast Regional Water Board will likely mandate the Monterey County growing region to report their nitrogen applications each year. This information can be easily calculated using our database. Growers may also use the information they collect to inform future regulation – if an onerous regulation in proposed, Gills Onions' growers will have data available to demonstrate their sustainability and best management practices.

In conclusion, farm level data tracking will allow Gills Onions to better understand its environmental impacts and market itself as a transparent and sustainable company. Careful data tracking will allow Gills and its growers to identify areas for continuous environmental improvement and cost savings. This will provide Gills Onions with the tools it needs to continue to be a leader in the world of sustainable agriculture.

# 15. Appendix B-1 Specific Fertilizer Calculations for the Stewardship Index for Specialty Crops

Fertilizer labels report percentages of nitrogen, phosphorous oxide ($P_2O_5$), and potassium oxide ($K_20$). Most environmental studies find it more useful to report total phosphorous used (not $P_2O_5$) as phosphorous has the direct environmental effects such as eutrophication. To do so one must calculate the atomic weight by the number of atoms present in P2O5 with the following formula:

P = 30.973 g/mol * 2 atoms = 61.946
O = 15.999 g/mol * 5 atoms = 79.995
Total molecular weight of P2O5 = 141.941
% P in P2O5 = 61.946/141.941 = 0.44

The same manner can be used to calculate % K in $K_20$:
K = 39.09831 g/mol * 2 atoms = 78.197
O = 15.999 g/mol * 1 atoms = 15.999
Total molecular weight of K2O = 94.1960 g/mol
% K in K2O = 78.197/94.1960 = 0.83

Therefore, 0.44 is a multiplier that can be used to calculate the mass of phosphorous available in the reported phosphorous oxide and 0.83 is a multiplier used to calculate potassium content in potassium oxide. This is the process required in reporting to the Stewardship Index for Specialty Crops.

If product application was given in gallons the following calculation was made for all applications:
# gallons of product applied * lbs/gal* % N = total lbs N applied
# gallons of product applied * lbs/gal * % $P_2O_5$ * 0.44 = total lbs P applied
# gallons of product applied * lbs/gal * % $K_2O$ * 0.83 = total lbs K applied
Other micronutrients – follow process of N above.

However, because our clients are farmers and the values presented in the literature state values for applied P2O5 and K2O, we will not be utilizing these methods but reporting total P2o5 and K2O applied without factoring out the P and K portions of the fertilizer.

# 16. Appendix B-2 Fertilizer Data Collection Methods

| Fertilizer and other data collection methods for Monterey County growers | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Date** | **Ranch** | **Lot** | **Gallons product used** | **Acres applied** | **Gallons/acre** | **Lbs N, P or K/acre** | **cost** | **Manufacturer** | **Product name** | **Notes** |
| **Irrigated Crop Mgmt, Inc. Work Orders** | X | X | X handwritten | X | X | X | | | | X | Pesticides and fertilizer applications |
| **SoilServ Inc. Job Confirmation** | X | X | X | X | X | X | | | X | X | Pesticides and fertilizer applications |
| **State Pesticide Use Report** | X | X | X | | X | | | | | | Pesticides and fertilizer applications |
| **Planting sheet (handwritten)** | X | X | X | | X | | | | | X | Lists mostly pesticides and acid applications, no fertilizers |
| **Irrigation Information Card (handwritten)** | X | X | X | X | | | | | | X (usually 17-0-0) | Irrigation and fertilizer information |
| **Fertilizer accounting sheets (handwritten)** | X | X | X | X | X | Requires field worker to calculate. | | | | X Choice of 20-0-05, 32%, Urea, 17% and N-Phuric | Does not have choice to select how many gallons of specific products, if more than one is used. |
| **2009 applications Excel spreadsheet** | X | X | X | X | X | | | X | | X | Most but not all of the drip irrigation applications were recorded on this. |

# 17. Appendix B-3 Recommended Irrigation and Fertilizer Tracking Sheet for Monterey Region

| Grower | Ranch | Lot # | Acres | Plant Date | Variety |
|---|---|---|---|---|---|
| Gill Ranch Co. | Lesnini | 306 | 15 | 3/26 | **Red Wing** |

| **Irrigation** | | | **Fertilizer** | | | **Staff** | |
|---|---|---|---|---|---|---|---|
| Date<br>Fecha | Water meter reading<br>contador de agua | hours<br>horas | Fertilizer<br>Fertilizante | total gallons fertilizer app<br>total de galones | method<br>metodo | responsible<br>resonsible | notes<br>notas |
| | | | CAN 17<br>20-0-05<br>Urea<br>N-Phuric | 5gal*15= 75<br>7gal*15= 105<br>12gal*15= 180<br>15gal*15= 225 | drip<br>ground<br>air | | |
| *7/5/09* | *3290* | *8* | *20-0-05* | *180* | *drip* | *BM* | |
| *7/13/09* | *3350* | *12* | *CAN 17* | *150* | *drip* | *BM* | |

The above is an example field data sheet for Monterey County that may reduce the errors we found and meet goals for tracking fertilizer and water applications (see below). Gills Corporation will have to work with growers in the region to address whether a new system will work for the day-to-day operations of the farm. The small changes to this form include:

1. Lot information copy-pasted from planting sheet (lot numbers, acreage and variety)
2. Space to record water meter reading
3. Example calculations to minimize mathematical errors made in field. Create these based on the acreage of the study ranch and the volumes commonly applied
4. Separate lines for different fertilizers applied: use if there are multiple fertilizers applied at one time.

**We identified the following data collection challenges from the multiple field datasheets**

1. The "2009 fertilizer application by Rio Farms" had most but not all of the fertilizer applications from the field data sheets. In addition, we added applications from Irrigated Crop Mgmt, Inc. Work Orders, SoilServ Inc. Job Confirmation orders and Pesticide Use Reports.

2. The handwritten fertilizer accounting sheets allow the worker to circle application of 20-0-05, 32%, Urea, 17% and N-Phuric, however it does not have a space for indicating *how much of each* product was used. For example, the fertilizer sheet listed that on 5/13/09 Ranch KCS 131, lot 31, 150 gallons of 20-0-0-5 and 17% were applied but did not specify how much of each. We double-checked these numbers with the 2009 fertilizer application by Rio Farms spreadsheet. This only listed 133 gallons of 17% were applied on that date to the ranch. For the purposes of this project, we deduced that 150-133 = 17 gallons of 20-0-0-5 were applied on that date. Note that the 20-0-0-5 was not listed on the original 2009 fertilizer application by Rio Farms spreadsheet.

3. The fertilizer accounting sheets also gave a space for calculating acres, gal/acre and total gallons applied. One application (11/15/2008 on Pettit lot 1136) estimated 20 gallons/acre was applied to 21 acres but listed a total of 380 gallons applied (although 20* 21 = 420). For that date we assumed that it was 380 gallons applied.

4. Misnaming of lots due to human error on the handwritten field sheets (for example, Pettit Ranch had records for lots 136, 10136, 1136). We confirmed with growers that these were the same lot numbers.

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