1. **Find enterprise budget**

Choose an enterprise budget from the UC Davis cost studies website. In this example we will walk through using the 2016 San Joaquin South Large Bales (file 01, screenshot below).

A stack of hay bales

Description automatically generated

1. **Translate enterprise budget**

The first thing I did was try to translate the text from the PDF into something in the format I needed. This is file 02. However, I found this didn’t help much.

1. **Visualize enterprise budget**

I instead decided to translate it into a visual representation (file 03, screenshot below). This allowed me to more easily discuss the assumptions with folks like Dan.

A diagram of a train

Description automatically generated with medium confidence

1. **Create input files**

From this visual, I created three files that serve as the templates for data going into my R code. The three files are Tulare\_fieldops, Tulare\_other, and Tulare\_pests. I will explain each below. I used three separate files because I had a hard time keeping things straight when they were all in one file. So the separation is merely for my own convenience. The file 04\_baseline-scenarios attempts to summarize the assumptions made based on each county’s enterprise budget.

* 1. ***Tulare\_fieldops***

A screenshot of a computer

Description automatically generated

This contains information about every field operation that occurs in the field EXCEPT harvest operations. Harvest operations are in the Tulare\_other file because they are a function of the number of harvests, which is variable. The values in Tulare\_fieldops are used to estimate fuel consumption. The ‘desc’ column is standardized – the word has to appear in the file ‘ref\_ops-fuel-usage’ (alfalfa>R>data\_refs>ref\_ops-fuel-usage). This reference file was created using NRCS estimates, the code used to process the NRCS data can be found in alfalfa>R>code>00\_refs>03\_create-tractor-fuel-use-ref. In the above example, during the life of the alfalfa stand insect control is applied 6 times.

The amount of fuel used during the alfalfa stand life has two components to the energy/GHG calculations: firstly, burning fuel uses energy and releases GHG emissions. Additionally, energy is used (and GHGs are emitted) in the manufacturing of the fuel. Both have to be accounted for.

* 1. ***Tulare\_pests***

This contains information about the amount of pesticides applied over the stand life of the alfalfa. This is used because it takes energy to manufacture the pesticides, so we must know how much pesticide is applied to estimate the embedded energy/emissions from applying these products.

A screenshot of a computer

Description automatically generated

In this table, you put the product name and the amount of product applied. This is not the same as the active ingredient. I found the product’s active ingredient concentrations from company product sheets and included them in the document ref\_pest-ais (screenshot below, found in alfalfa>R>data\_refs>ref\_pest-ais). The only publicly available information on pesticide manufacturing is on an active ingredient basis, which is why you need to know how much active ingredient is applied, not how much product.

A screenshot of a computer

Description automatically generated

* 1. ***Tulare\_other***

This is where the bulk of the information AND assumptions are made for a given scenario. It includes yields; irrigation types, amounts, and sources; type of seed; the harvest operations involved in a making hay or haylage; n20 calculation assumptions; carbon credits based on Healthy Soils Program; the subsequent crop and fertilizer credit that crop receives from alfalfa; the energy used in manufacturing a given active ingredient; the seed yield from an alfalfa crop; the energy source used for operations (diesel, electricity, gas); which data source to use for fuel energy content and GHG emitted from using fuel; and the timespan assumption for the greenhouse warming potential.

A screenshot of a computer

Description automatically generated

1. **Run R code**

The above three data sheets are fed directly into R code. Each code file does something specific, which I describe briefly below. To understand what the code is actually doing you will have to walk through the code…

* 1. ***01-make-scenario***

This code just simplifies and combines each of the three datasheets above into one file. The file produced from this code is called ‘tulare-scenario-notouch.csv’.

* 1. ***02-process-production-data***

This code uses the file created in 01-make-scenario, and is mainly unit conversions. It produces the file called ‘tulare-scenario-notouch-production-data.csv’.

* 1. ***03-calculate-energy-use***

This is the heart of the analysis. It reads in references, the scenario information, and calculates the energy used (in MJ/ha) or energy avoided (in the case of fertilizer). It is composed of 7 sections:

1. Energy ‘saved’ by avoiding the use of fertilizer in subsequent crop
2. Energy used to manufacture the fertilizer applied
3. Energy consumed through using tractor fuel
4. Energy used to irrigate
5. Energy used to manufacture the fuel used in the tractor
6. Energy used to manufacture the pesticides applied
7. Energy used to grow the seed planted to grow the alfalfa crop
   1. ***04-calculate-ghg***

Here the net GHG emissions are calculated. Alfalfa can reduce GHG emissions by sequestering carbon (estimated using the California Health Soils estimates) and by reducing the need for fertilizer in the subsequent crop, and therefore avoiding N2O emissions. It releases GHG emissions through the energy it consumes and N2O emissions from the soil and fertilizer application.

1. **Run other scenarios**

The document 04\_baseline-scenarios summarizes the baseline scenarios extracted from the enterprise budgets and all of the assumptions I had to make if the enterprise budget didn’t include necessary information. It also shows the different scenarios I explored. I built functions to do this because as you can see, the number of runs needed was quite high. You may just want to use OpenLCA rather than using R. If I had continued as a post-doc with Cameron I probably would have tried to run the base scenarios in OpenLCA to compare the values/rankings.