Calorie Per Acre Improvements in Staple Crops Over Time

Posted on January 4, 2017 by mathscinotes

Quote of the Day

> We have invaded space with our rocket and for the first time. We have used space as a bridge between two points on the earth; we have proved rocket propulsion practicable for space travel. This third day of October, 1942, is the first of a new era of transportation, that of space travel.
>
> — General Walter Dornberger, project leader for the V2 rocket program during WW2. He made this statement after the first successful test launch of a A4 (aka V2) rocket.

Introduction

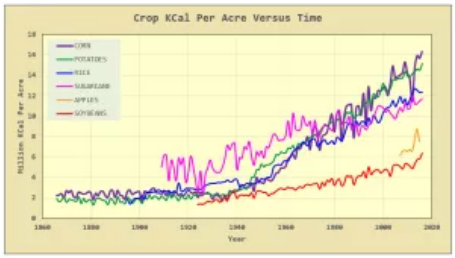

Figure 1: Calories Per Acre For Some Staple Crops. This is my plot of USDA data. Note that the apple data only goes back a few years.

My family has strong agricultural roots – mainly in dairy and potato farming – and our holiday conversations frequently turn to discussions of crop yields (bushels per acre or lbs per acre). As I listened to the discussion between my brothers on this year's crop yields, I realized that the yield numbers they were quoting were much higher today than we saw as children. This made me curious, and I decide to go out to the US Department of Agriculture's National Agricultural Statistics Service crop database and download CSV files on the yield of some key staple crops for processing by Power Query (i.e. recently renamed Get and Transform). I will be using this file to train my staff on defining Power Query functions. No macros were used in this analysis.

I am most interested in determining which staple crop produces the most food value per acre, with food value defined as calories per acre. When I was a boy, I was told that sugar cane produced the most calories per acre. Recently, I have had various farmers tell me that apples, corn, or potatoes produce the most calories per acre.

Figure 1 provides us the answer. I would make the following observations about Figure 1.

- Apples are not even close to winning the calories per acre contest.
  Rice, corn, sugarcane, or potatoes all outpace apples. Note that the USDA did not have apple yield data that went back in time very far.

- You can argue either corn or potatoes win the calorie per acre race.
  The corn crops show more yield variability than potato crops. I would guess that potatoes have more consistent yield because they are usually irrigated. I would also guess would be that corn would win over potatoes on a calories per acre per cost of production metric because irrigation is expensive.

- Sugarcane did produce the most calories per acre in my youth (1960s and 1970s).
  I find it interesting that while sugarcane has experienced yield improvement since the 1940s, it did not improve at the same rate as corn and potatoes.

- The rise in the yields of rice, corn, and potatoes since 1940 is remarkable.
  I have to believe that this yield increase is because of the application of technology to agriculture that occurred after WW2.

- Notice how there was almost no yield growth prior to 1940.
  I will do a bit more research to try and determine what happened after 1940 that was not happening for many decades prior.

The rest of this post covers how I generated Figure 1. For those interested in following my work, here is my source. You should be able to unzip my workbook and data files to any location and have it work. The data files are unmodified downloads from the USDA web page. The graph work is routine – Power Query is the interesting part.

Background

Definitions

yield
Crop yield refers to either volume of a crop per unit acre or the mass of a crop per unit area of land cultivated.

staple crop
A staple food, or simply a staple, is a food that is eaten routinely and in such quantities that it constitutes a dominant portion of a standard diet for a given people, supplying a large fraction of energy needs and generally forming a significant proportion of the intake of other nutrients as well.

food calorie
Food calories are measure in units of kilocalories (kcal).

Baseline

I decided to look at the calories per acre for the following crops:

- potatoes
- wheat
- rice
- apples
- corn
- sugarcane
- soybeans

All my data is based on US national averages – there is quite a bit of variability between the states. Note that some US crops yields are measured by volume, and I needed to convert these volumetric units to mass units for the energy calculation by using their densities. I obtain the densities from the table shown in Appendix B.

Horrific Units

This analysis involved some of the screwiest units I have ever used:

- bushels per acre
- hundredweight of crop per acre
- pounds per acre

I am afraid these units are still commonly used in US agriculture. I cover a calorie calculation example in Appendix A. I also include a video in Appendix C that shows how complex creating sugar from sugarcane is – I was impressed with the amount of work required.

Analysis

The analysis is straightforward and you can see how it is done by looking at my source. Here is my approach:

- download crop yield CSV files from the USDA National Agricultural Statistics Service.
- put together table of conversions from volumetric units to mass units.
- put together table of conversion for calories by mass unit of each crop.
- use Power Query joins to merge data and conversions.
- add column using formula to convert yields to calories.
- plot the data.

Conclusion

I wonder how far into the future these yield increases can continue. It would be interesting to know how much of this increase is attributable to improved techniques (e.g. fertilizer, irrigation) and how much is attributable to improved genetics. As the world's population increases, these yield increases will become more and more critical – our crop lands are limited and under much pressure.

If you want to see come other writings that confirm some of my calculations, see this blog and the newspaper article it references.

Appendix A: Unit Conversions for Sugarcane Calories/Acre.

Figure 2 shows an example of the sugarcane calories per acre calculation.

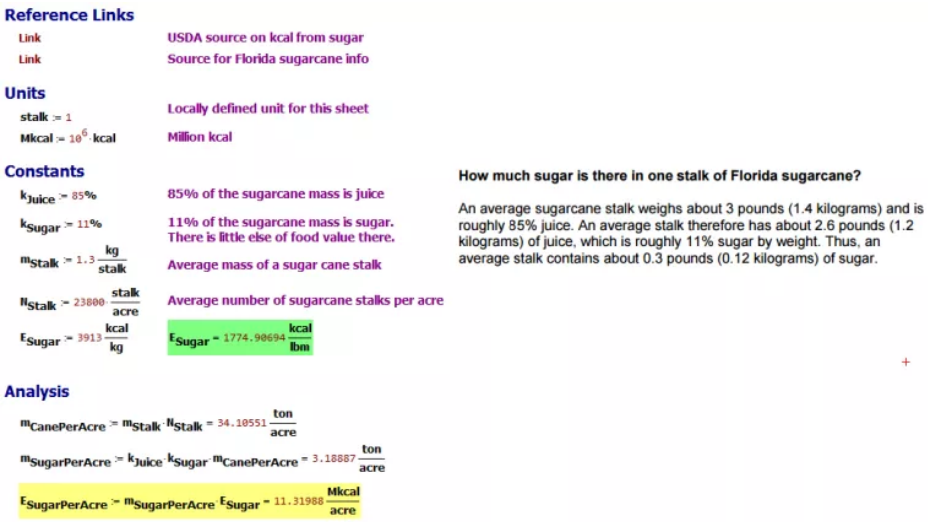

Figure 2: Sugarcane Calories Per Acre Calculation.

Appendix B: Crop Mass Densities.

I used the crop densities list in Figure 3 for a number of the calculations (Source).

WEIGHT PER BUSHEL AND BULK DENSITIES OF GRAIN AND SEEDS

Grain or Seed	Weight Per Bushel Pounds	Bulk Density Pounds Per Cubic Foot	Grain or Seed	Weight Per Bushel Pounds	Bulk Density Pounds Per Cubic Foot
Alfalfa	60	48.0	Oats	32	25.6
Barley	48	38.4	Orchard Grass	14	11.2
Beans:			Peanuts, Unshelled		
Lima, dry	56	44.8	Virginia type	22	17.6
Lima, unshelled	32	25.6	Runners, southeastern	28	22.4
Snap	30	24.0	Spanish	30	24.0
Other (dry)	60	48.0	Perilla	37-40	29.6-32.0
Bermuda Grass Seed	14	11.2	Popcorn:		
Bluegrass	14-30	11.2-24.0	On ear	70	28.0
Broomcorn	44-50	35.2-40.0	Shelled	56	44.8
Buckwheat	48-52	38.4-41.6	Poppy	46	36.8
Caster Beans	46	36.8	Rapeseed	50-60	40.0 & 48.0
Clover	60	48.0	Redtop	50-60	40.0 & 48.0
Corn:			Rice, Rough	45	36.0
Ear, husked	70	28.0	Rye	56	44.8
Shelled	56	44.8	Sesame	46	36.8
Green sweet	35	28.0	Sorgo	50	40.0
Cottonseed	32	25.6	Soybeans	60	48.0
Cowpeas	60	48.0	Spelt (p. wheat)	40	32.0
Flaxseed	56	44.8	Sudan Grass	40	32.0
Grain Sorghums	56 & 50	44.8 & 40.0	Sunflower	24 & 32	10.2 & 25.6
Hempseed	44	35.2	Timothy	45	36.0
Hickory Nuts	50	40.0	Velvet Beans (hulled)	60	48.0
Hugarian Millet	48 & 50	38.4 & 40.0	Vetch	60	48.0
Kafir	56 & 50	44.8 & 40.0	Walnuts	50	40.0
Kapok	35-40	28.0-32.0	Wheat	60	48.0
Lentils	60	48.0	Millet	48-50	38.4-40.0
Mustard	58-60	46.4-48.0			

Figure 3: Density of Staple Crops.

Appendix C: Video of Sugar Cane Processing.

Figure 4 shows how sugar cane is processed into granular sugar. The process is quite complex.

Figure 2: Good Video Briefing on Sugarcane Processing.

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One Response to *Calorie Per Acre Improvements in Staple Crops Over Time*

Ronan Mandra *says:*
February 3, 2017 at 12:36 pm

Mark, I've been playing with R and decided to see how your calorie data correlated per crop. If we only consider corn, potatoes and wheat production from 1866 to 2016, we have a 98% correlation between them. If we consider corn, potatoes, rice, soybeans, sugarcane, and wheat production from 1924 to 2016 when we have complete data on these crops, we have 0.87 to 0.98 correlation. All of this probably means that if one crop did well, the others also did well. I used this website to calculate the correlation values:
http://www.sthda.com/english/rsthda/correlation-matrix.php

Also, I tried to use html code for tables to post the correlations without success.

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