


Predictive Yields for Small-scale Staple Crop Production in North Central States Using Common Homestead Equipment and Minimal Inputs

Great Lakes Staple Seeds
Eleanor & Scott Hucker

February 24, 2024
Marbleseed Organic Farming Conference

Agenda for Today's Presentation

- Our Project – what and why
- Who We Are
- The Plan (what we're doing)
- Methods (how we are doing it)
- Results to date
- Interpretations
- Next Steps & Collaboration Opportunities
- Summary

NORTH CENTRAL SARE
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Our Project in Brief

- **Small-scale (<12 acres)** production of staple crops using mostly manual labor with common equipment and minimal off-farm inputs
- **Crops** of interest: amaranth, barley, beans, buckwheat, maize, millet, milo, oats, potatoes, rye, sunflower, triticale, & wheat
- Agronomic analysis includes: yield per sq ft; energy inputs (calorie, diesel); growing degree days
- **Year 1** of a two year project – so not all topics covered today
- Southeast Michigan (~45 minutes **north of Detroit**)

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The Crops (Year 1)

Multiple varieties for many crops

Amaranth: source of summer greens; nutritional grain crop widely consumed in Africa and the Caribbean

Barley (**hull-less**): a medieval staple - easy to cook into portage (gruel)

Barley (**hulled**): animal feed or made into beer

Buckwheat: gluten-free flour for pancakes & soba noodles (needs de-hulling!)

Einkorn & Emmer: ancient, tasty but hulled grains - difficult to remove hull*

Maize: corn bread, polenta, nixtamalized to make masa for tortillas; Central American civilizations were powered by this staple crop

Millet: porridge as a major source of food in Africa

Milo (grain sorghum): major food source in Indonesia, Malaysia and Singapore

Oats: besides an animal food, Scottish porridge

Potatoes: major calorie food group for northern Europe

Rye: commonly used for porridge or baked as bread

Sunflowers: valuable source of cooking oil; important biodiesel food-stock

Triticale: hull-less grain combines cultivation advantages of rye with the utility of wheat

Wheat: commonly made into flour for bread, biscuits & cookies; enjoyed as whole berries

* Home scale hull removal needed!

What Motivated our Project?

- COVID and escalating social turmoil
- A shift away from "casual gardening" – more growers intentionally mindful of **caloric and nutritional benefits**
- Food security – personal / community
- Questions – from our customers and on various forums:
  - Our **"Sizing Your Plot to Meet Your Food Needs"** page is the second most accessed page on our site after our homepage
  - "How much [wheat] will I get if I plant [plot size]?"
  - "How much [triticale] do I need to plant to feed my chickens?"
- **Agronomic data** more aligned to the **cultivars and methods of pre-1950s** industrial cultivation that do not rely on modern chemicals and accounts for **modern shifts in weather patterns** is essential

Our Project Goals

Currently most agronomic data available focuses on **large-scale, industrialized cultivation**

- **not easily relevant for or applicable** to the manual labor, minimal input cultivation methods employed by an increasing number of North Central small-scale producers (2-12 acres)

Data generated based on **our actual small-scale experience** using common equipment, mostly manual labor, and minimal off-farm inputs

- **inform best-practice methods** to enable small-scale farmers to successfully incorporate staple crops into their sustainable, ecologically responsible production rotation

Our Project's Contribution to Sustainable Agriculture

Local, small-scale staple crop production by farmers/ranchers using common homestead equipment and minimal inputs is:

- **Ecologically sound** - sustains/improves environmental quality/natural resource base on which agriculture depends
  - reduces transportation carbon footprint
  - enhances/supports **biodiversity** in place of monoculture commercial ag
  - encourages responsible land stewardship - vested interest in **healthy soil/sustainable cultivation** practices
  - strengthens crop **resilience** to meet challenges growing in an increasingly unpredictable climate with each successive planting

Our Project's Contribution to Sustainable Agriculture

Local, small-scale staple crop production by farmers/ranchers using common homestead equipment and minimal inputs is:

- **Economically viable** – improves economic viability of growers and associate businesses
  - supports/encourages **secondary market** - artisan bakeries, millers, breweries, farms, specialty food markets
  - reduces need for expensive equipment/off-farm inputs
  - in high demand **artisan grains and heritage crops**

Our Project's Contribution to Sustainable Agriculture

Local, small-scale staple crop production by farmers/ranchers using common homestead equipment and minimal inputs is:

- **Socially responsible** – enhances quality of life for growers, communities, and society as a whole
  - improves community access to **nutritious, versatile crops**
  - lessens reliance on commercial monoculture agriculture heavily reliant on chemical fertilizers and herbicides
  - enhances and supports transition to localized biodiversity strengthening **personal and community food security**
  - encourages responsible **land stewardship**

About Eleanor and Great Lakes Staple Seeds

- Long time grower
- Love of seed stories and seed connections – Johnny Dewlen Blue Dent Corn
- Gained an appreciation of small-scale, manual labor agriculture while living in and traveling throughout Asia for nearly a decade
- Desire to enrich and enhance my family's homegrown food security
- Desire to preserve and expand available biodiversity for northern, short-season growers

"Any crop you would really want in your larder in the event of a national economic crisis like the Great Depression."

– John Sherck Nov. 2013

- high calorie
- nutrient rich
- utility / functional

Our seeds are

- **100% Michigan grown**
- **open-pollinated** and non-treated

Our seeds offer

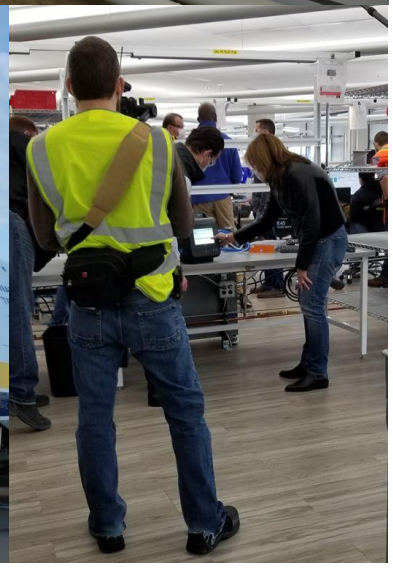
- food security
- self-sufficiency
- improved **biodiversity**

About Scott

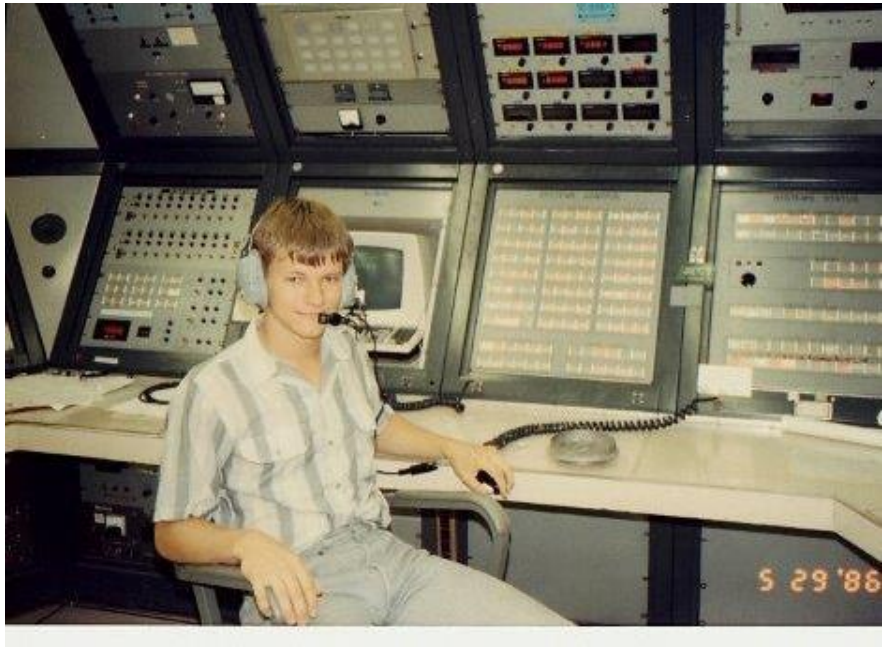
1984 (High School)

Aerospace Engineering vs Horticultural Plant Breeder

Hobbies & Making Things



4-H & Interests



Ended up at General Motors (1994-?)

- Manufacturing Engineering
- Lived in China for 8 years
- Built factories, machines & ventilators
- Support Great Lakes Staple Seeds
- Vacation days chosen by weather

14.1 kW of solar panels and a 2017 Bolt EV

Interest in This Topic

- Food security

We know people who grew up when food was rationed, and they were HUNGRY

Interest in This Topic:

"How much land does it take to feed one person?"

- Where: Biggest impact, sets up your challenges
  - Growing Degree Days (GDD)
  - Micro-climate: Rainfall, frost free season, critters
- What: One can not live on spinach alone
  - Staple Crops provide the calories to thrive, not just survive
  - Diversity to overcome seasonal variation
- Who: People, not corporations
  - Small groups of motivated people on 2~12 acres
- Methods: Homestead scale
  - Primarily hand tools, limited power equipment
- Timing
  - Various varieties will spread the work load (and weather risk) over weeks

Corn belt vs MI Varieties

Irish potato famine

Not commercial scale

Plot Size:

Our Current Scale

Square feet

- 10—test a few varieties, grow a bit for decorating
  - Everything with hand tools
- 100—taste one or two varieties, holiday treats
  - Hoe comes in handy
- 1000—eat something special weekly
  - Gas power tiller and the right hoe will be appreciated
- 10,000—serious homestead baking
  - Tools with a wheel or two will become useful for cultivation

- 100,000 (2+ acres)
  - Tradeoff between more equipment and time
- 1,000,000 (23+ acres)
  - Tractors with serious implements
- 10,000,000 (230+ acres)
  - Significant investments

Show of Hands:

- Who has any garden?
  - Could it be bigger than 25 ft by 25 ft?
- Who grows any portion of their dinner?
- Who grinds their own flour?
- Who cooks ‘grain berries’?

By your presence, you’ve some interest in the necessary skills….

The Problem Statement

"How much land does it take to feed one person?"

- What keeps you from growing your own food?
  - Percentage of the diet is not plant based
  - Livestock need their food grown too
  - Tools and equipment
  - Human labor
  - Fuel powered equipment saves time
  - Critters trying to eat your crops

The Plan

Reward of a successful harvest must exceed the inputs

- Each crop type has differences:
  - Will **require different amounts of effort** (human calories & diesel) to produce
  - Will require different amounts of space depending on how many calories are desired and type of crop
- Each crop has a **specific role** in meeting your needs:
  - Nutritional profile
  - Timing of harvest
- Plant spacing:
  - Row width (between rows) and in-row (between plants) result in **different "Area per Plant"** *Corn vs Wheat*
  - Plant spacing for our manual methods may be different that those used by modern equipment with chemicals or animal power

The Plan

For long term success, **harvest must exceed the inputs**

- Measuring the inputs for each phase of production
  - Fitbit to track steps and calories

    Victorian era laborers typically consumed > 5,000 calories
  - Timer to measure how much time was used per unit of plot size
  - Graduated cylinder to measure diesel usage (vegetable oil needed to make diesel is a proxy for space and human work required to make it)
- Outputs can be measured after harvest
  - Pounds (grams) of finished clean ‘food’ ready to be eaten by a person
  - Calorie equivalent using commonly accepted nutritional standards

40k steps or 5k calories

Nothing is free

The Plan

323 ‘samples’ from 13 crop types harvested in 2023

Count of ApP (sq in ea)	lumn L				
Row Labels	Fall	Spring	Winter	Summer	Grand Total
Barley	89	20			109
Wheat	18	9			27
Triticale	16				16
Emmer	4		6		10
Rye	43				43
Oats	3	25			28
Einkorn			24		24
Corn				20	20
Amaranth				17	17
Sunflower				7	7
Millet				11	11
Buckwheat				6	6
Potato				5	5
Grand Total	**173**	**54**	**30**	**66**	**323**

Some are still being processed, cleaned and weighed

The Plan

How to evaluate the yields on a homestead scale farm. Overall, we farm about 35k square feet (less than an acre). We haven't the space to grow large plots of multiple varieties of 13 crops, instead, **'test strips'** will be documented from within our typical plantings with vast measurements:

- Length of each strip, number of plants counted, average row spacing, position within the plot noted, soil type, weed pressure
- Ideally, 5 samples per type/variety to assess variation
- Manual labor and fuel used documented per plot and attributed to the test strip by proportion

Methods

- Labor tasks, manual and diesel powered:
  - **Soil Preparation:** Plowing, tilling, harrowing, raking, & planting
  - **Tending:** Seeding, thinning, weeding, & hilling
  - **Harvesting:** Measuring, cutting, drying, threshing, winnowing & measuring

Methods

Soil Preparation: **Mowing** to chop up the previous crop residue

No good manual method other than animal grazing

Methods

Soil Preparation: **Plowing** is the turning over of the soil (with less ‘chopping’ and beating)

Methods

Soil Preparation: **Tilling** to incorporate debris that needs to decompose

Manual method: broad fork
Powered is a massive time saver!

Rough Condition

Finish Condition

Methods

Soil preparation: **Tilling** more equipment friendly bottom plow/disc

Modern bottom plow drives heavier equipment than tilling

Methods

Soil Preparation: **Harrowing & Raking** (seed bed preparation)

Methods

Planting: **Seeding**

Single hand hoe works, but slow
Wheel hoe is very efficient

Methods

Planting: **Labeling**

Orange wooden labels get lost in grain fields and do fade
Pencil on plastic on snow poles!

Methods

Tending: **Thinning**

Amaranth thinning are great in stir fry (roots and all)

Methods

Tending: **Weeding**

scuttle knife blade

Scuttle wheel hoe is very efficient between rows

Hand tool for between plants within row

Don’t crowd the amaranth

Methods

Tending: **Hilling Potatoes**

Methods:

- Loosen soil by scuttle then handheld hoe
- Wheel hoe hiller tool

Methods

Harvesting: **Data Collection**

In-Row ‘plant spacing’

Count how many plants are within a fixed distance (not tillers, but actual ‘plants’)

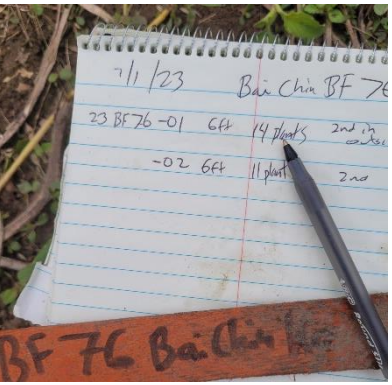
Between-Row

Measure between the row on either side, divide by 2
Measure start and end of strip, take average

Methods

Harvesting: **Cutting**

Label clearly & carefully both on the plants and in a notebook



Hand Sickle

Modern combining vs Cut/Bind/Stook/Thresh

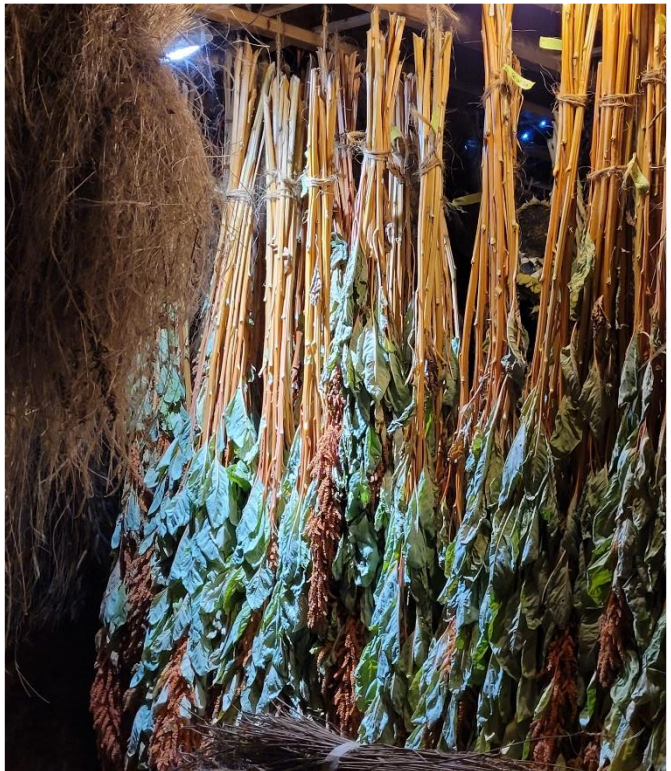
Stook

By Trish Steel, CC BY-SA 2.0, https://commons.wikimedia.org/w/index.php?curid=13576912

Methods

Harvesting: **Drying**

Seeds must be dried for safe storage!




FERRARI-
SONOMA

Methods

Harvesting: **Threshing**

- By “hand” by rubbing over a screen, beating a sack with a rubber hose, or flail on a threshing floor





- By “foot”


Pedal thresher works like a treadle sewing machine

Methods

Harvesting: **Threshing**

- Labor saving >50x
- Like a treadle sewing machine
- ~acre not sq ft

Methods

Harvesting: **Winnowing** separates the seeds from the chaff/debris

Windy day or window fan!

Some types also need a 'dehulling' step to remove the seed cover (emmer/einkorn)

Methods

Harvesting: **Drying**

In China, the threshed grain is dried on the side of the road. Swept up each afternoon, spread again until dry.

Methods

Harvesting: **Digging Potatoes**

	min/ft	cal/ft	ft/L	
Manual:	1.1	8.9	N/A	potato fork
Diesel:	0.2	0.7	1600	root digger

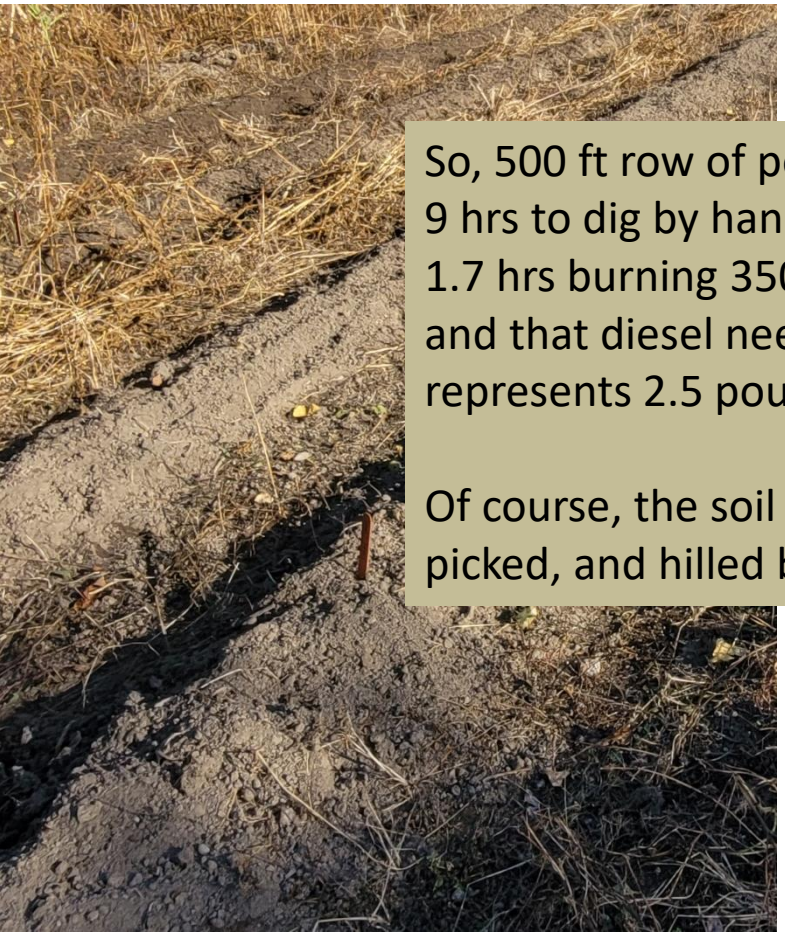
Remove plant material to make this go more smoothly

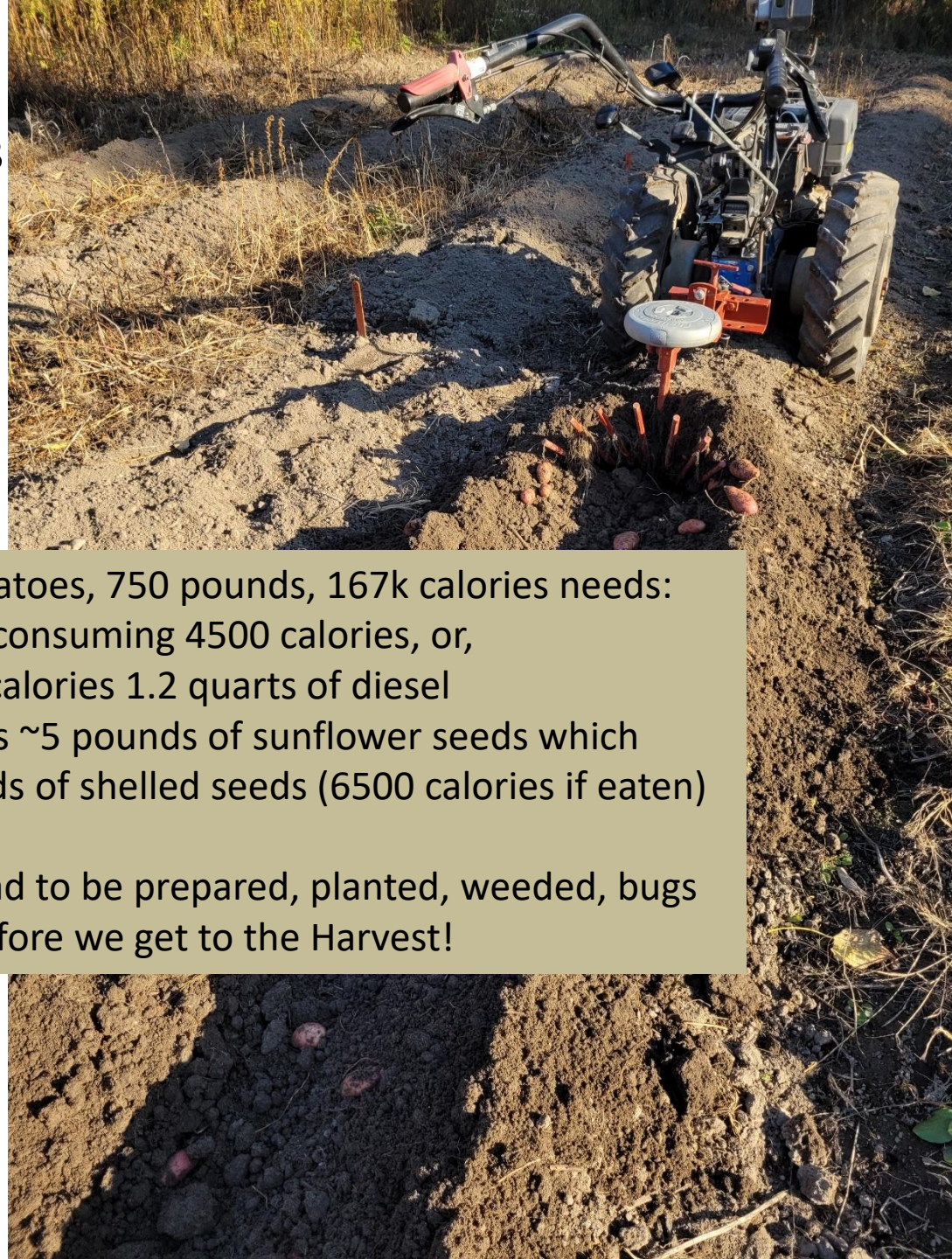
Methods

Harvesting: **Digging Potatoes**

	min/ft	cal/ft	ft/L	
Manual:	1.1	8.9	N/A	potato fork
Diesel:	0.2	0.7	1600	root digger

Yield of 1.5 lbs/ft giving 500 calories





So, 500 ft row of potatoes, 750 pounds, 167k calories needs:
9 hrs to dig by hand consuming 4500 calories, or,
1.7 hrs burning 350 calories 1.2 quarts of diesel
and that diesel needs ~5 pounds of sunflower seeds which represents 2.5 pounds of shelled seeds (6500 calories if eaten)

Of course, the soil had to be prepared, planted, weeded, bugs picked, and hilled before we get to the Harvest!

Methods

Harvesting: **Digging Potatoes**

Crops drive unique methods at different times in the season

"10 ft of strip" dug yielded 23 pounds of Santina Potatoes (best)

Methods

Harvesting: **Weighing**

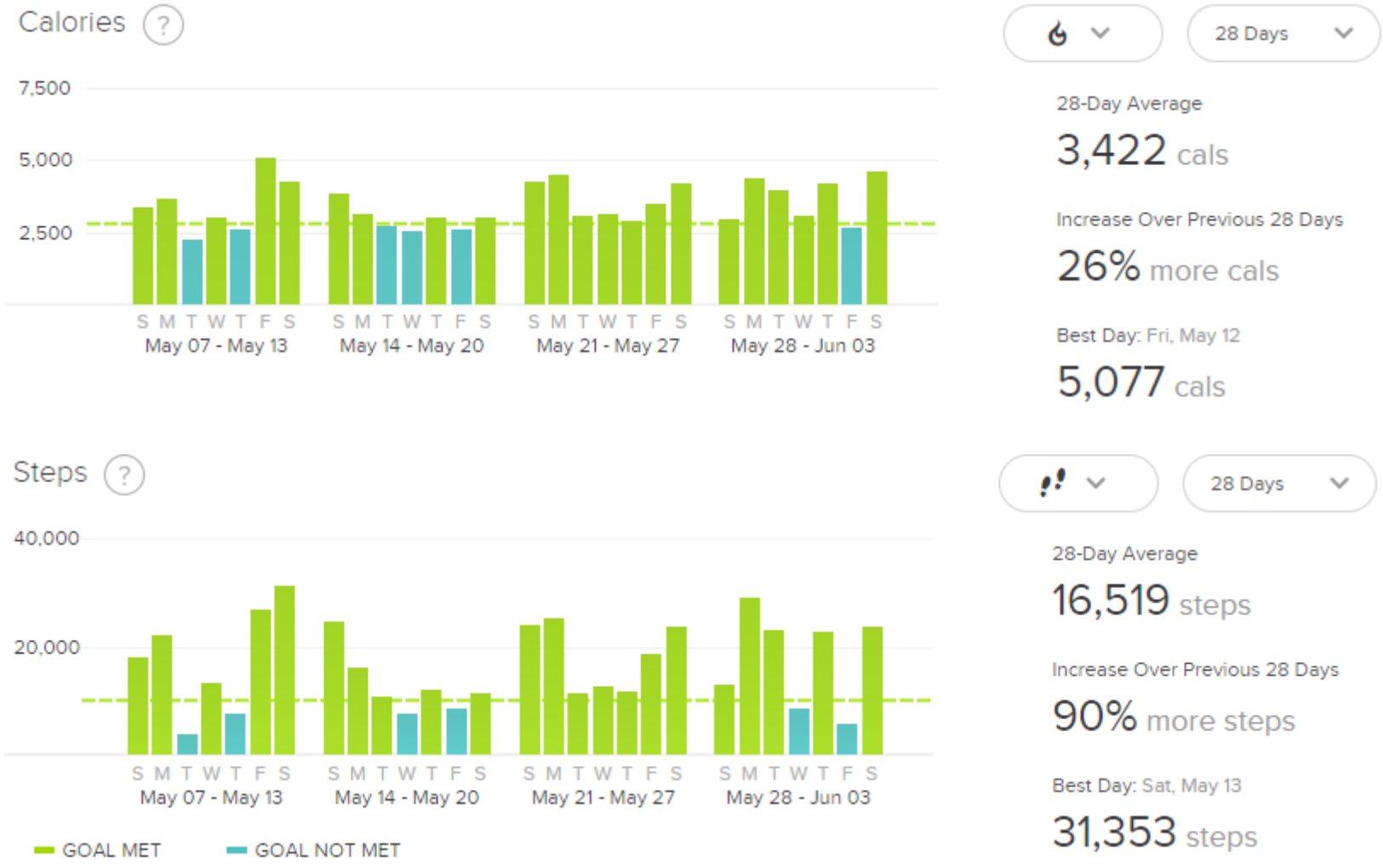
Each ‘sample’ is weighed on a digital scale

This step is specific to our ‘science project’

Results

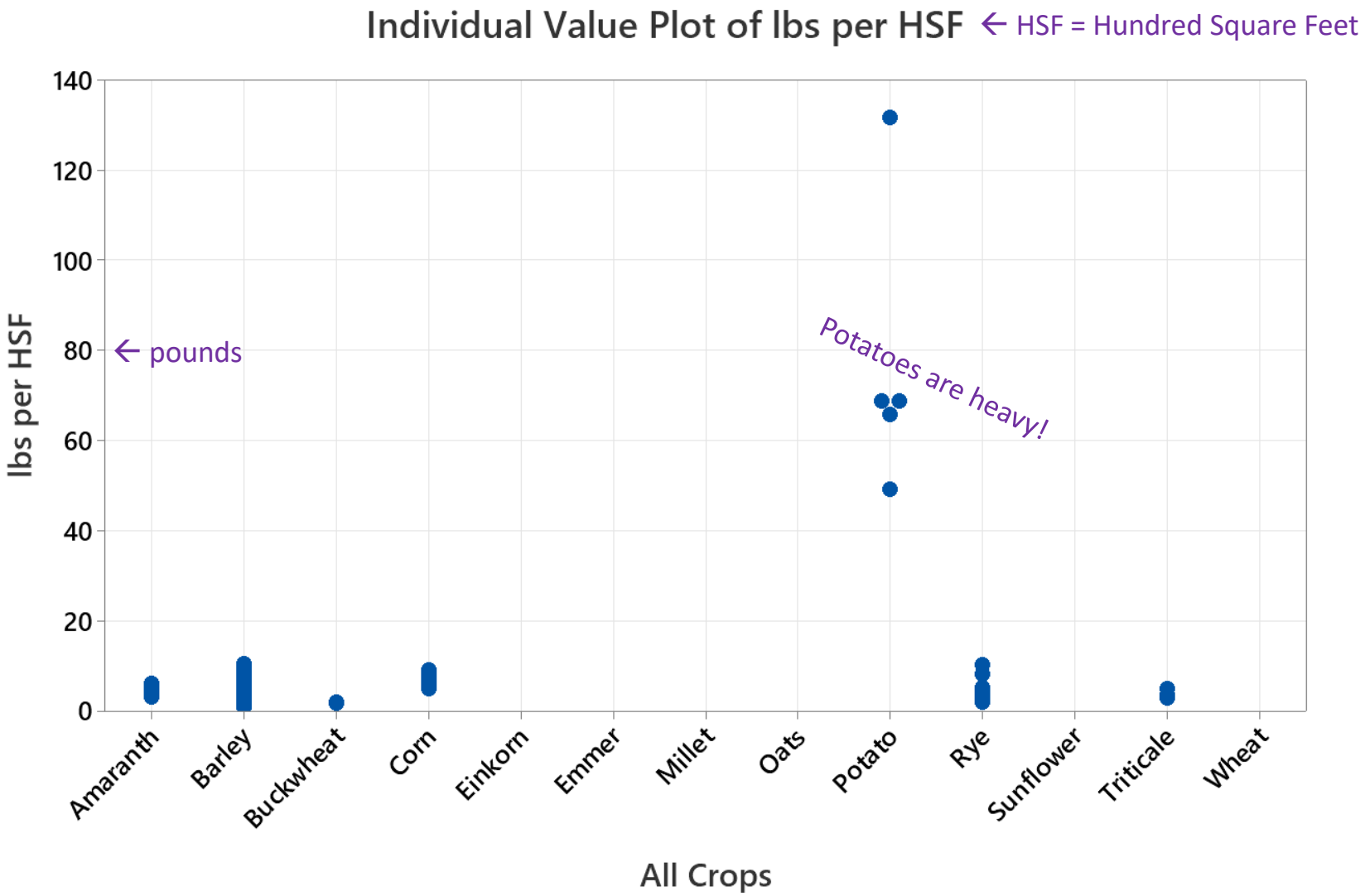
Measurement of the work performance to grow these crops

- Energy consumption (human & diesel) by task and soil type



Results

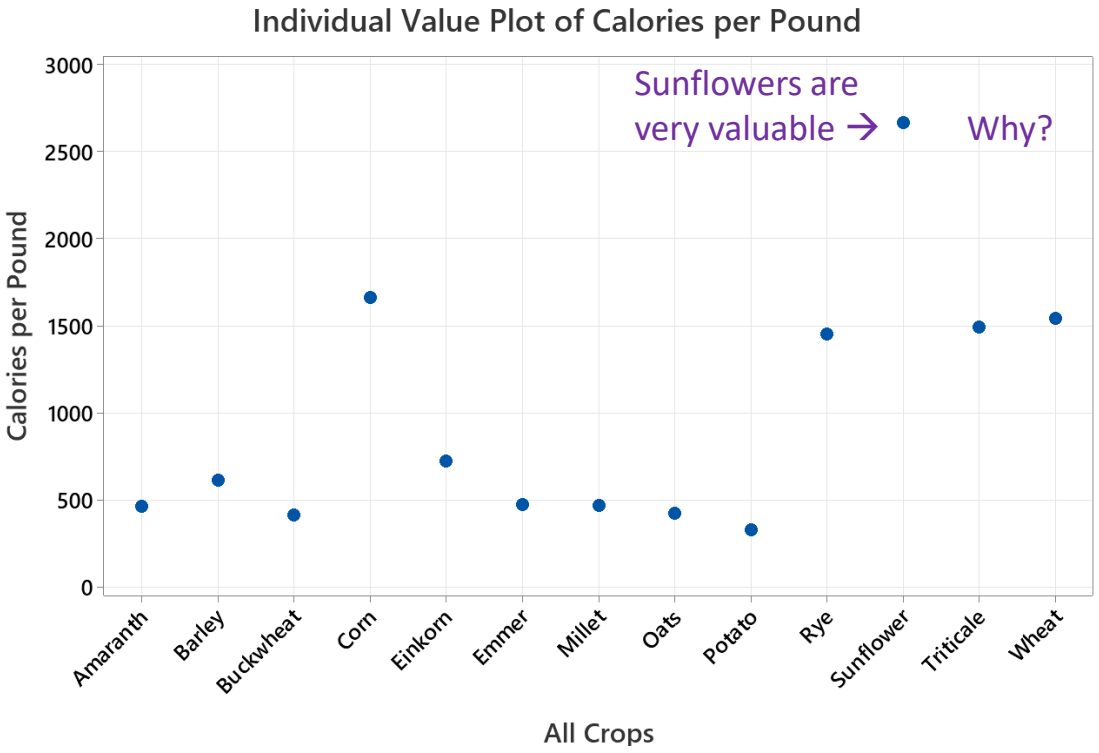
Pounds per 100 Square Feet: How many pounds of clean ‘crop’ after threshing (or shelling), winnowing (or digging) and weighing!



Results

However, all ‘pounds’ are not created equal in terms of their value of providing calories

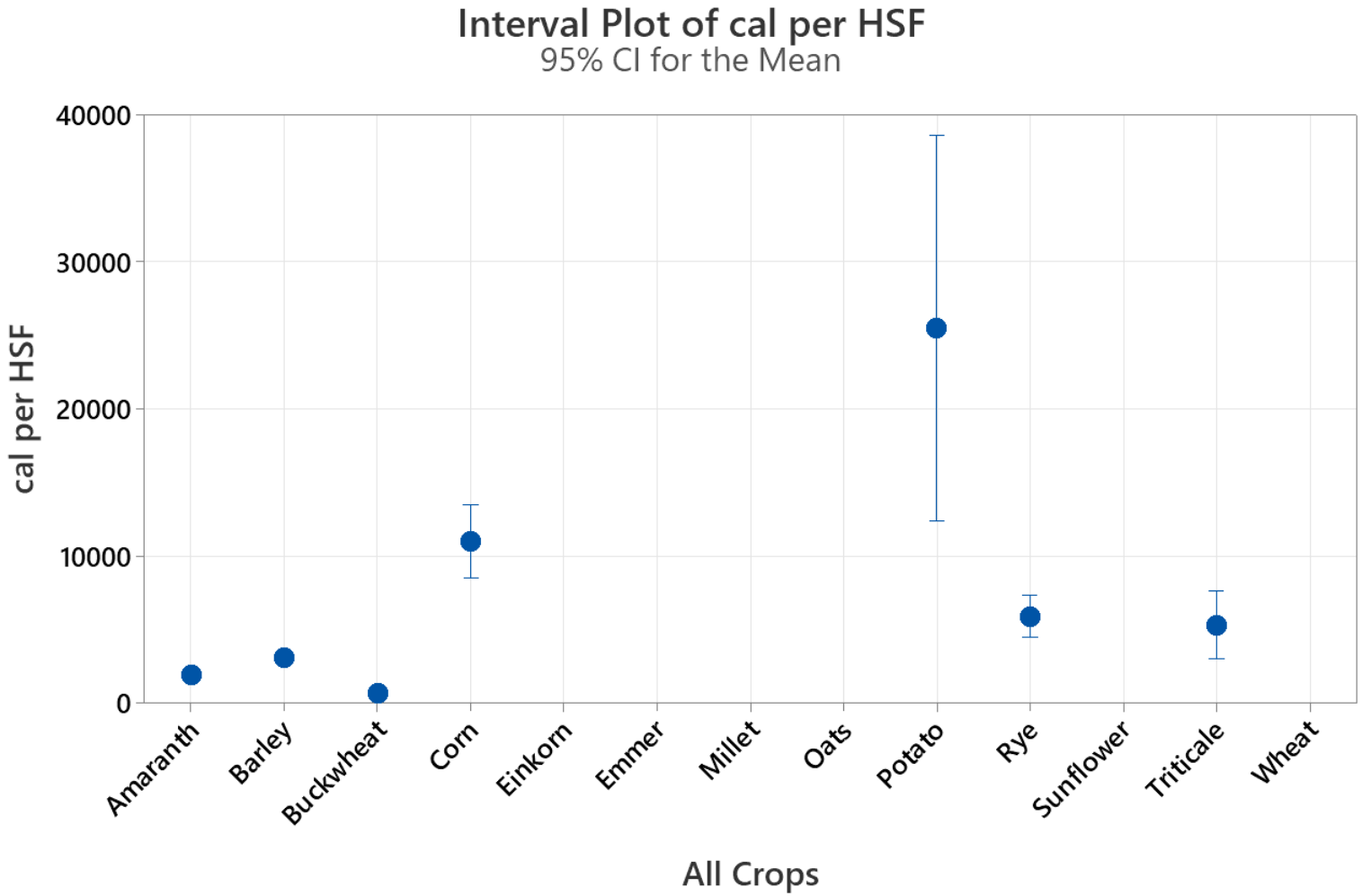
Type	Calories per Pound	Notes
Potato	332	as dug
Buckwheat	413	with hull
Oats	427	hull-less
Amaranth	463	
Millet	469	
Emmer	476	with hull
Barley	612	hull-less
Einkorn	726	with hull
Rye	1452	
Triticale	1492	
Wheat	1543	
Corn	1662	Flint
Sunflower	2665	unshelled



HSF = Hundred Square Feet
TSF = Thousand Square Feet

Results

Calories per 100 Square Feet: How much energy can these crops provide our person for the same amount of growing space?



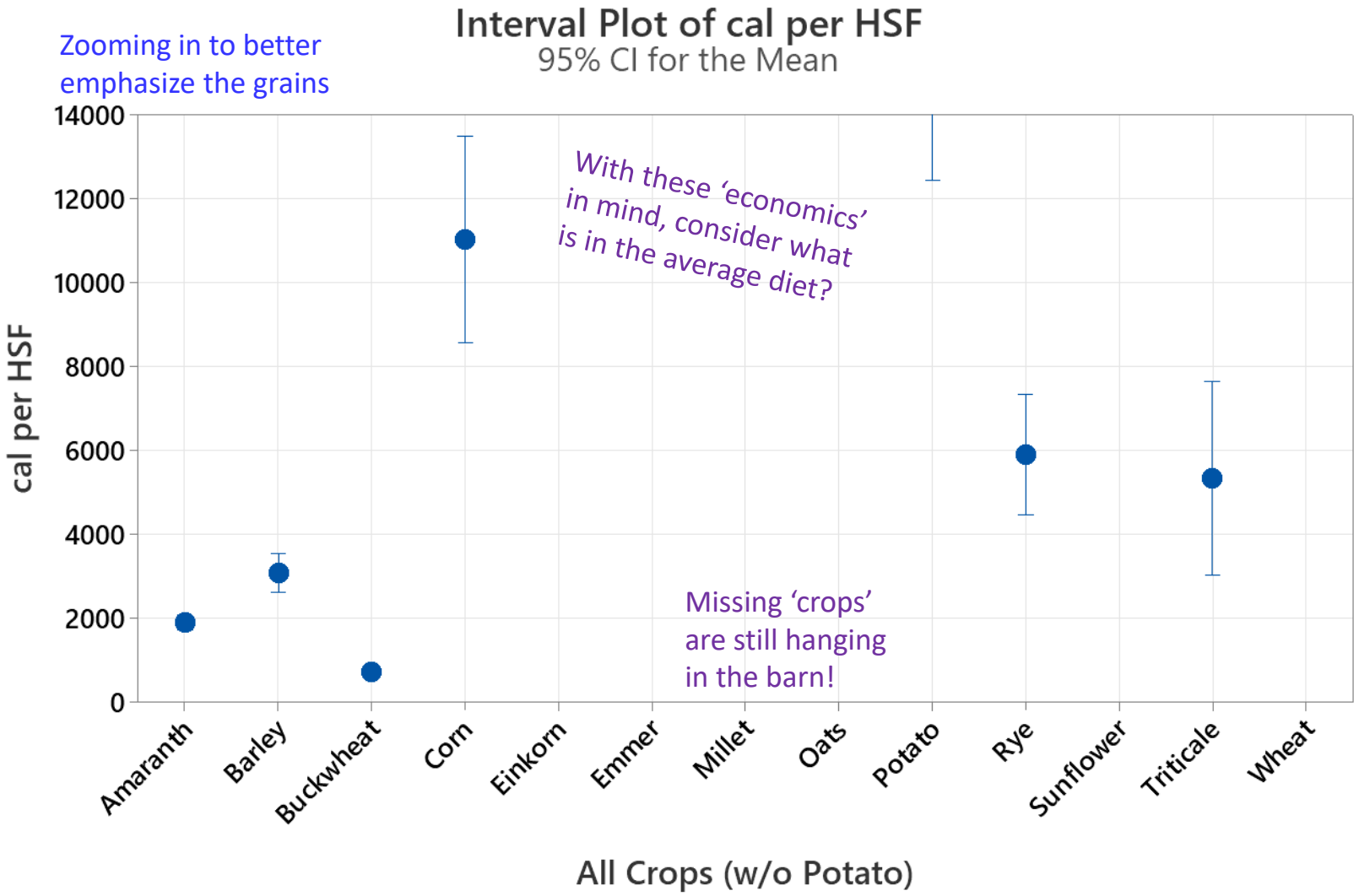
Individual standard deviations are used to calculate the intervals.

Results

HSF = Hundred Square Feet
TSF = Thousand Square Feet

Calories per 100 Square Feet: Focusing on the grain, corn is king!

Zooming in to better emphasize the grains



Individual standard deviations are used to calculate the intervals.

Results (Barley)


Wintermalt Barley


Black Russian Barley


Black Hull-less Barley


Curly Barley


Zou Xian Song Mang Da Mai Barley


Bai Chin Ke Barley


Dan Barley


Pike Barley


Schuyler Barley


Eve Barley


Fall Sardinian Barley


Gobal Barley

Results

Almost 30 pounds of fall planted barley spanning 13 varieties were planted in 2022 and harvested in 2023

Fall harvest of the barley ran from **6/25 thru 7/9** – to lessen the chance of crop loss to a single weather event!

Row Labels	Hulled	Hull-less
2-Row Early		
6-Row Early		
Bai Chin		1,716
Black Russian	2,234	
Catskill	536	
Dan		1,890
Dutchess	832	
Eve		449
Fimbul		
Pike	2,600	
Schyuler	800	
Wintermalt		
Zou X S		1,064
Grand Total	**7,003**	**5,119**
Weight in Pounds	15.4	11.3
	26.7	

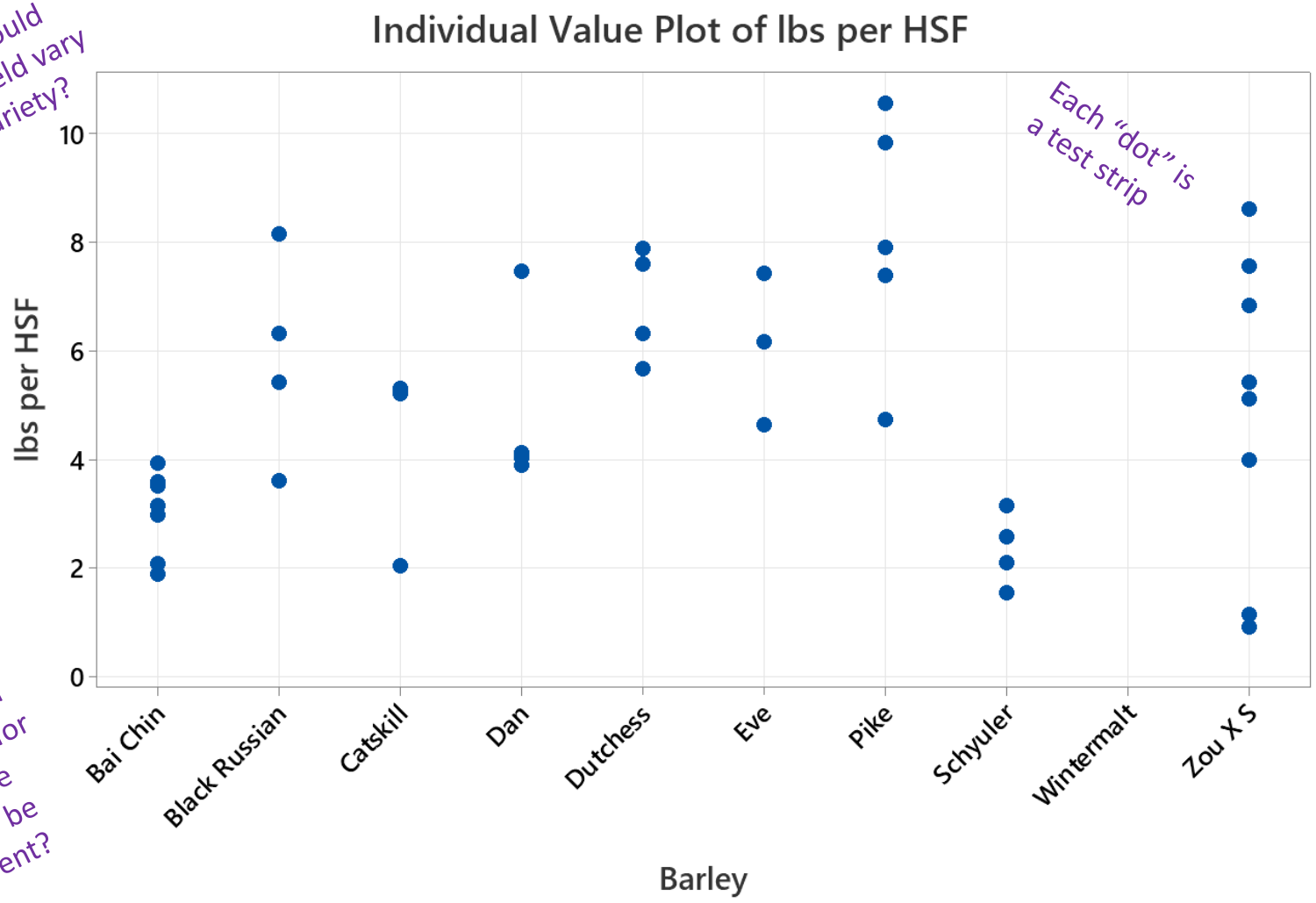
Don't put all eggs in the same basket

HSF = Hundred Square Feet
TSF = Thousand Square Feet

Results

Pounds per 100 Square Feet: How many pounds of clean grains after threshing, winnowing and weighing!

Why would the yield vary by variety?

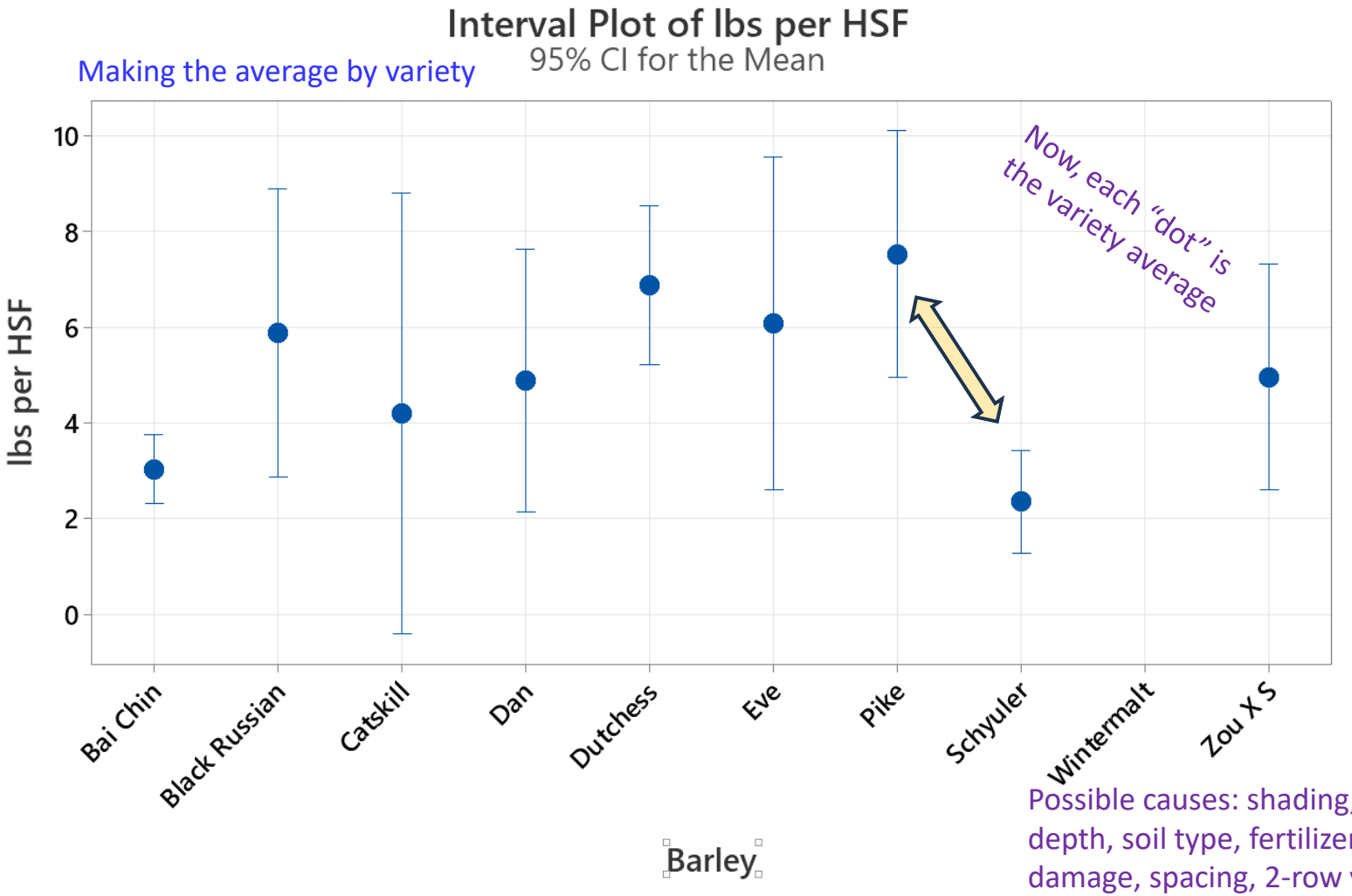


Why would the yield for the same variety be different?

Results

Black Russian thru Pike all ‘overlap’, hence, not really ‘different’

However, Pike vs Schyuler yields are ‘not the same’, why?



Individual standard deviations are used to calculate the intervals.

Possible causes: shading, planting depth, soil type, fertilizer, critter damage, spacing, 2-row vs 6-row, hulled or not, etc

Results

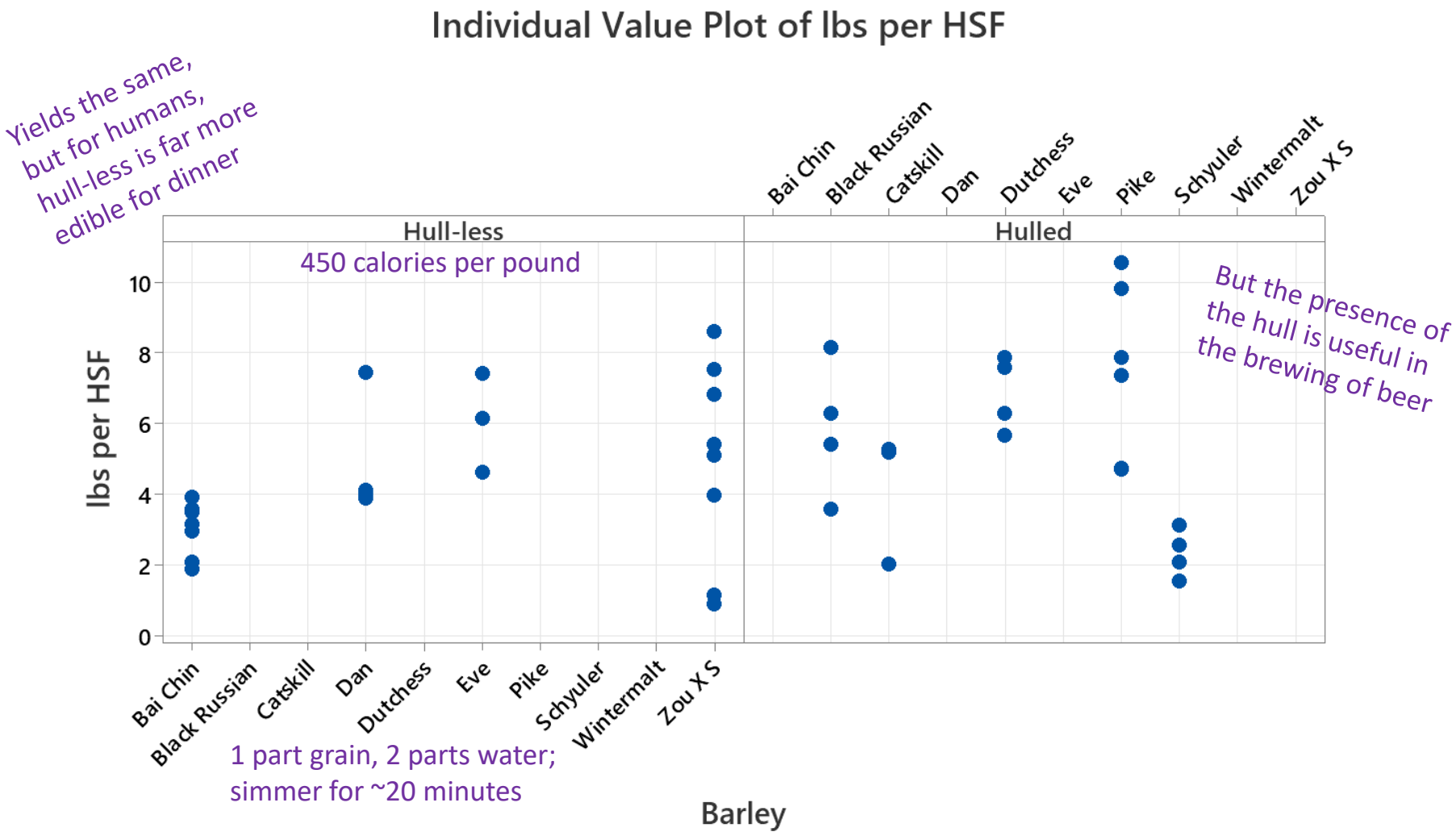
Bai Chin Ke Barley (Hull-less, that is, “no hull”)

Schuyler Barley (hulled, that is, “with hull”)

Both are ~3 pounds per HSF

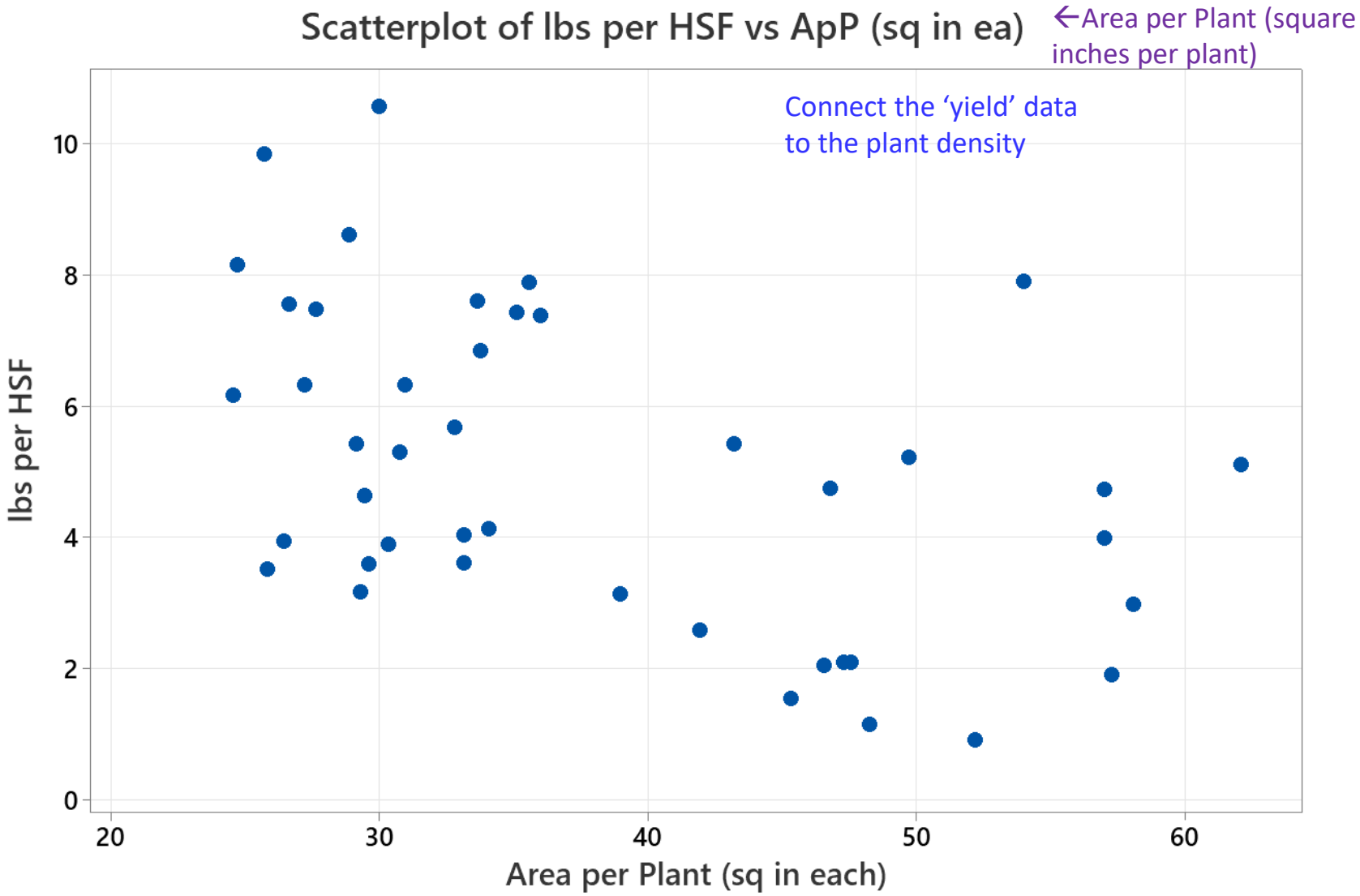
Results

Same data, now grouped by ‘hull-less’ and ‘hulled’



Results

Area per plant: How many square inches surrounding each "seed" that was planted!



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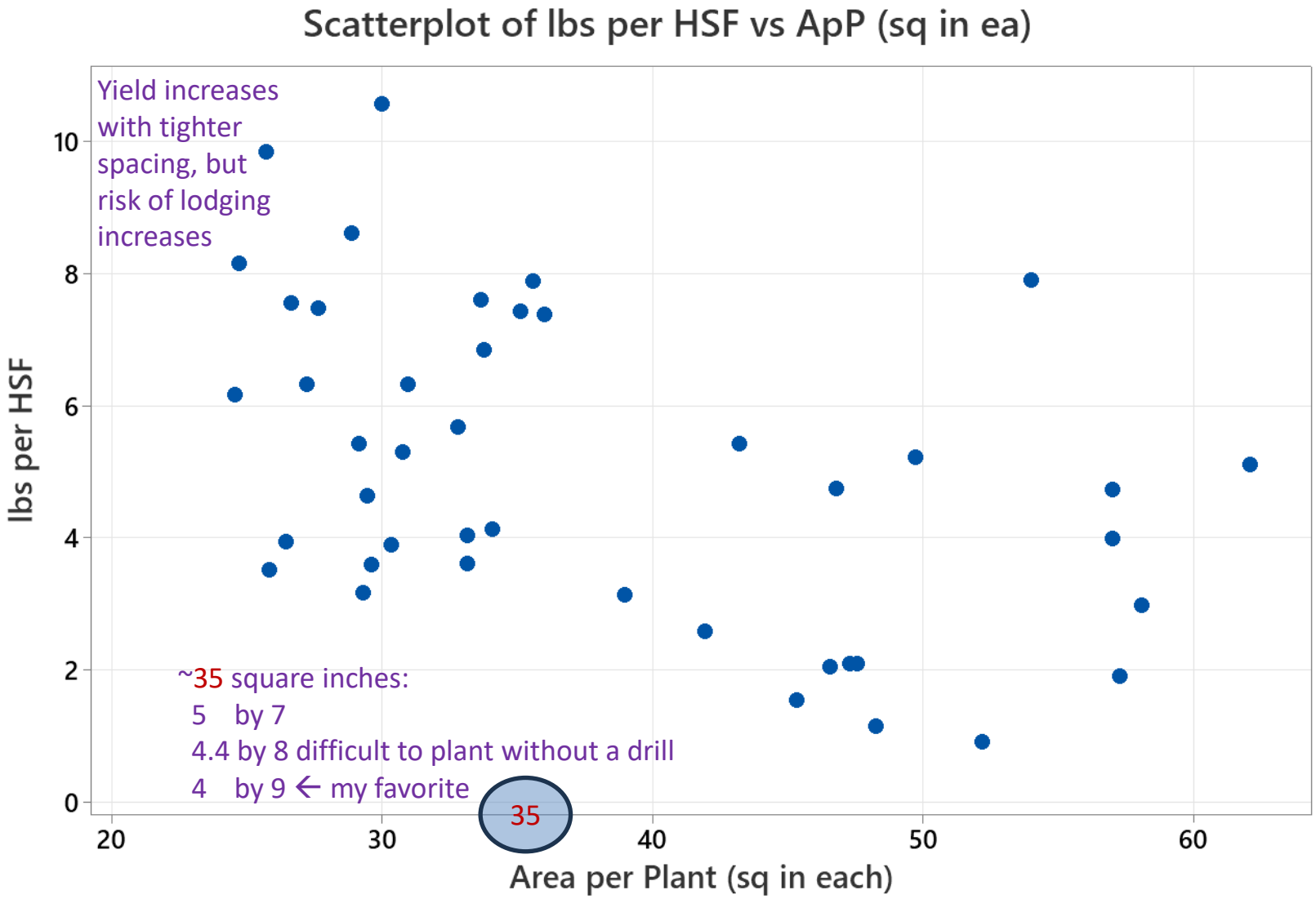
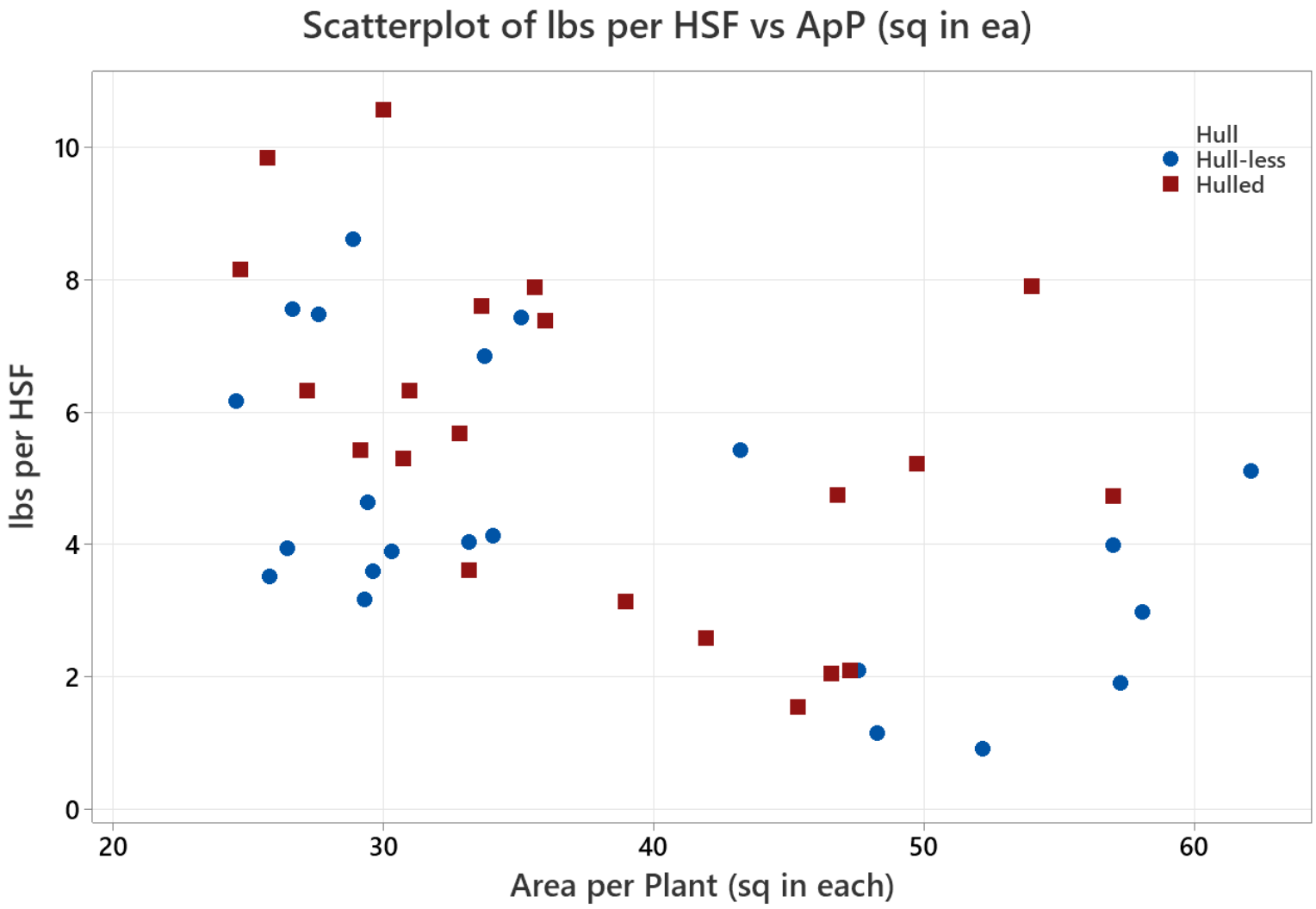


Results

Lodging→ Plants fall over

Results

Area per plant: How many square inches surrounding each "seed" that was planted!



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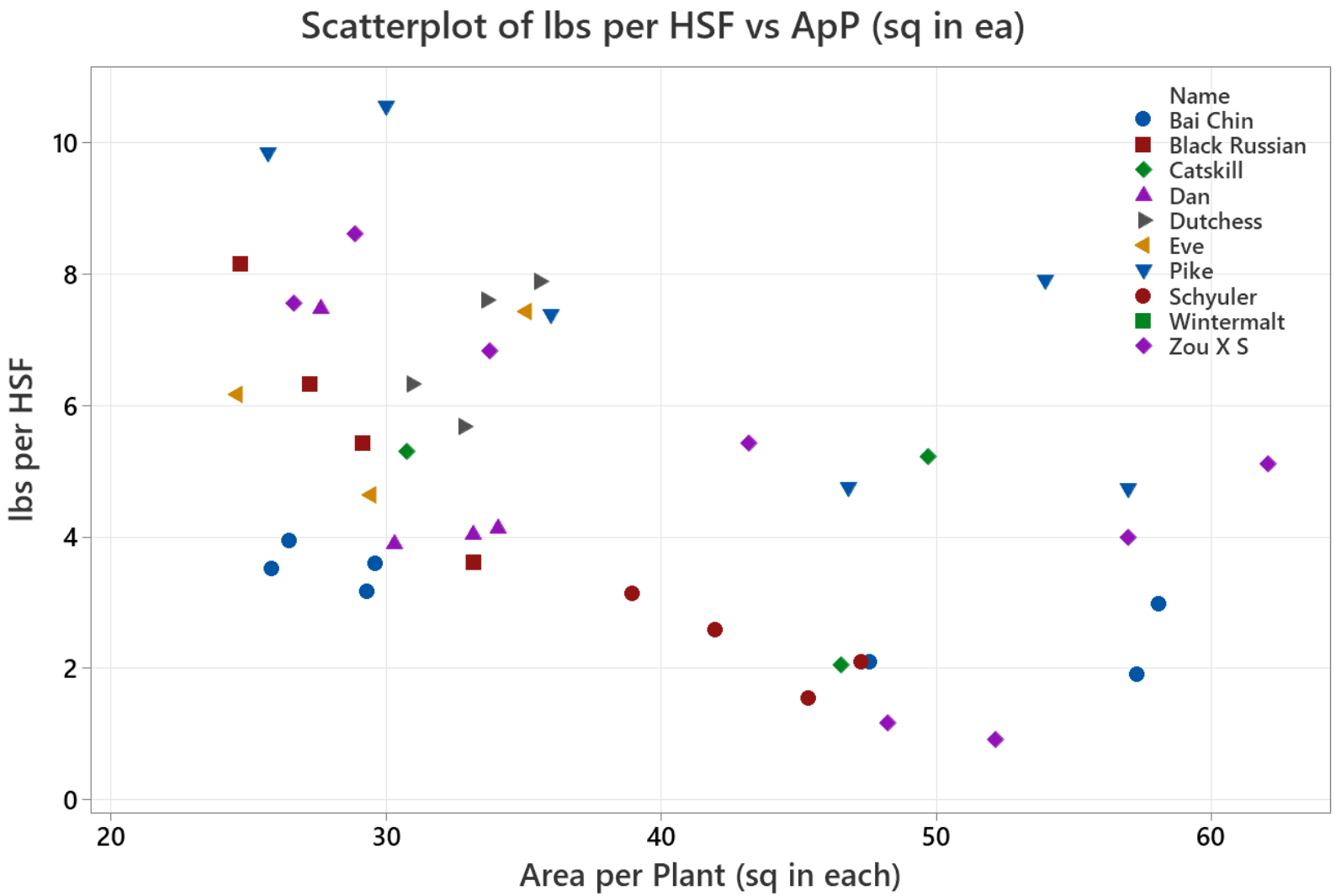

Results

Averaging across all varieties for “pounds per 100 square feet

Variable	Type	Mean	StDev	Minimum	Maximum
lbs per HSF	Amaranth	4.119	0.675	3.203	5.994
	Barley	5.040	2.395	0.918	10.562
	Buckwheat	1.768	0.205	1.551	2.044
	Corn	7.226	1.084	4.871	8.996
	Einkorn	*	*	*	*
	Emmer	*	*	*	*
	Millet	*	*	*	*
	Oats	*	*	*	*
	Potato	76.8	31.7	49.2	131.5
	Rye	4.060	2.098	2.012	10.188
	Sunflower	*	*	*	*
	Triticale	3.573	0.973	2.865	4.944
	Wheat	*	*	*	*

Could this have been a ‘poor’ buckwheat year?
Try again in 2024

Good reason to diversify!

Let’s see how much land is needed to feed our ‘1 person’

Results

Each crop type will use a sub-set of these 'energy tasks'

Task	Crop	Mode	Metric	Labor Time		Labor Energy			Diesel
				(sq ft/min)	(ft/min)	(calories/sq ft)	(sq ft/calories)	(calories/ft)	(mL/sq ft)
Mow	All	BCS	Area	133	-	0.053	19	-	0.05
Till, Rough	All	BCS	Area	199	-	0.050	20	-	0.08
Till, Finish	All	BCS	Area	109	-	0.071	14	-	0.10
Harrow	Grains	BCS	Area	136	-	0.048	21	-	0.04
Plant	All	Human	Linear	-	10.0	-	-	1.2	-
Weed	All	Human	Linear	-	tbd	-	-	tbd	-
Hill	Potatoes	Human	Linear	-	tbd	-	-	tbd	-
Harvest	Potatoes	BCS	Linear	-	tbd	-	-	0.7	0.06
Harvest	Grain	Human	Linear	-	0.9	-	-	tbd	-
					Totals -->	0.222	74	1.9	0.33
						(calories/sq ft)	(sq ft/calories)	(calories/ft)	(mL/sq ft)
								Work in Progress	
						4.5	0.0	0.5	3.0
						(sq ft/calorie)	(calorie/sq ft)	(ft/calorie)	(sq ft/mL)

0.1 mL is one drop from an eye dropper

1 teaspoon is 5 milliliter (mL)

BCS = 2-wheel tractor model BCS 853
Human = me

Interpretation

- Let's make the calculation with the data we have for 1 adult
- Dividing the year into seasons

One hard working adult		
Days	**Calories**	**Season**
73	3,000	Winter
73	4,500	Planting
73	3,500	Tending
73	4,500	Harvesting
73	4,500	Planting
365	4,000	<-- avg daily needs

- The harvest needs to return an average of **4,000 calories** which doesn't take into account any safety factors, taxes, critters, etc.

Interpretation

- Let's make <u>preliminary</u> calculation for 1 adult

	Potato	Buckwheat	Oats	Amaranth	Millet	Emmer	Barley	Einkorn	Rye	Triticale	Wheat	Corn	Sunflower
yield (lb/100 sq ft)	76.8	1.8	3.4	4.1	3.2	3.9	5	3.9	4.1	3.6	6.9	7.2	2.9
calores per pound	332	413	427	463	469	476	612	726	1,452	1,492	1,543	1,662	2,665
planted space	1,450	3,000	2,000	2,200	3,000	500	650	500	2,000	700	3,000	3,000	1,000
harvest, pounds	1,114	54	69	90	96	20	33	20	82	25	207	216	29
harvest, calories	369,715	22,302	29,408	41,763	45,220	9,288	19,890	14,167	119,064	37,598	318,802	358,992	76,475
calories per day	1,013	61	81	114	124	25	54	39	326	103	873	984	210
Sub-Totals	Food	Biodiesel		**Totals**								Diesel, L	37.7
calories per day	4,007											Diesel, gal	10.0
biodiesel, liters	37.7											sunflower oil, lbs	76.5
farmed land, sq ft	23,000	2667		25,667								sq ft needed	2667
farmed land, acres	0.5			0.6									

- Only grown calories are considered
- Calories & diesel to grow the crops not included (yet)
- Time & seasonal constraints not yet applied
  - You can't plant oats in June, or corn in April
- No consideration to protein (yet)
- No meat!

Indicates an 'estimate' until threshing is complete

Interpretation

- Adding a portion of chicken to your ‘staple crop’ diet, what happens to your field size?

Interpretation

- Adding a portion of chicken to your ‘staple crop’ diet, what happens to your field size?

- Our homestead raised meat chickens needed 4.5 pounds of mixed grains to become 1 pound of meat.

- So, the planting space will grow rapidly if you want a chicken dinner!

Our Next Steps

- Continue processing remaining samples from 2023
- Soil texture tests (jar test) & evaluate impact on yield
- Replicate the Santina Potato results
- Corn: Test compost application
- Make stooks in the field!
- Learn how to ‘edit’ and shorten videos
- Adjust spacing of spring planted crops (potatoes, corn, millet)
- Add a protein source: dried peas or beans? (row or pole)

Collaboration opportunities

- Dehuller – Ancient grains, buckwheat, upland rice
- Root crops for food & fodder
- Homestead scale production of
  - sugar beets into sugar, sunflower cooking oil, and biodiesel

In Summary

- Explained why this topic is relevant to self-sufficiency
- Identified the types of work required to grow & harvest staple crops
- Demonstrated how to collect agronomic data at the homestead scale
- Using barley as a focus crop, showed how planting density impact yield efficiency (lbs/HSF)
- Compared calorie yield relative to the crop weight
- Estimated 0.6 acres are needed to supply the plant-based calories for 1 adult per year (no meat or eggs)

Questions?

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SARE PROJECT NUMBER FNC23-1378

Predictive yields for small-scale staple crop production in North Central States using common homestead equipment and minimal inputs