

Forage Intercropping for Resilience Experiment



CORNELL UNIVERSITY

Sustainable Cropping Systems Laboratory

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Purpose

Dairy farmers in the Northeast have reported challenges meeting their dry matter and forage nutrient needs. This is partially due to extreme weather including prolonged periods of wet soil and short-term droughts. Increasing diversity of the cropping system can increase yield stability and reduce the negative impact of variable weather.

Background

Resilience is the ability to manage risk and recover from disturbances, like extreme weather, pests, or market volatility.

The three capacities to enhance resilience are:

Absorptive. Increase tolerance to disturbances by diversifying crop production.

Adaptive. Increase management flexibility to better respond to disturbances in the future by double-cropping.

Restorative. Recover from disturbances with external support, like crop insurance.



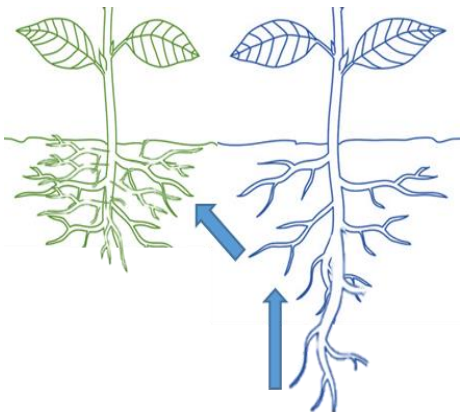
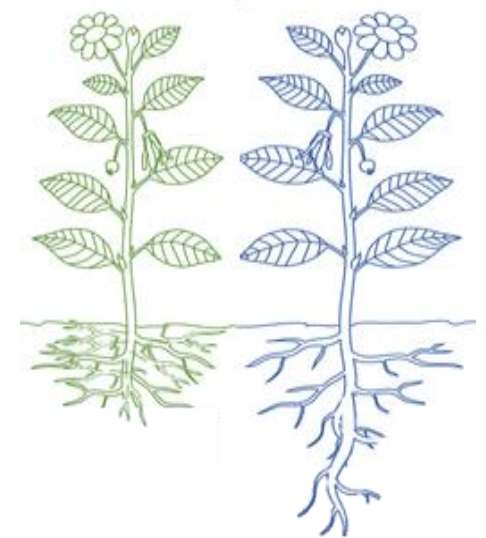
Why Crop Diversity?

Crop diversity can reduce the need for external inputs and better mimic natural systems. Here's how:

Resource-Partitioning

The more complete utilization of resources as a result of different nutrient acquisition traits, like rooting depth, vegetative architecture, phenology.

Example: The Three Sisters intercrop of corn-beans-squash. The beans fix nitrogen, the corn acts as a trellis, and the low-growing squash covers the soil and suppresses weeds.



Facilitation

One crop provides a limiting resource or improves the environmental condition to another crop. **This is more likely to happen in perennial systems.**

Examples: A legume can provide nitrogen to a grass. A plant with a deep taproot supplies water to other plants by hydraulic lift.

Experiment

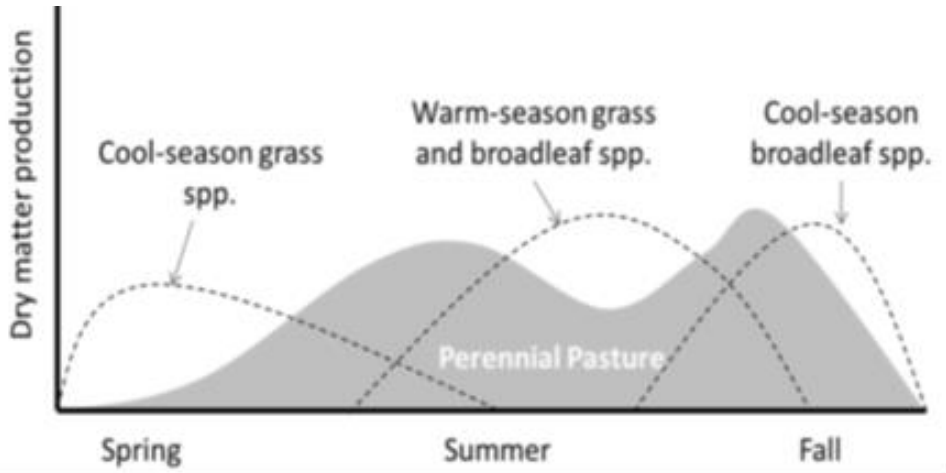
A four-year cropping systems experiment managed organically was established in 2016 in NY, VT, and NH.

- Compare two cropping systems: **alfalfa-based perennials**, and **double cropped annuals**
- Examine effects of intercropping

Both cropping systems have 4 different levels of crop diversity:

Very Low	Low	High	Very High
1 species	1 species	4 species	4 species
1 variety	4 varieties	1 variety	4 varieties

The dotted lines represent potential gains in forage production from double cropping that would help farmers overcome the summer slump.



Data Collection

To determine differences across systems and diversity treatments within a year and over time.

Crop performance

Crop biomass at species-level using quadrats

Yield at the plot-level (crops + weeds) using a forage harvester

Weed abundance

Weed identification and biomass at the quadrat-level

Forage quality

Crude protein, fiber analysis (ADF, NDF), and digestibility (NDFD) from forage harvester samples

Soil health

Cornell's soil health test taken at the beginning of the experiment and end of the experiment (4 years)

Organic matter, soil respiration, active carbon, wet aggregate stability, available water capacity, soil chemistry

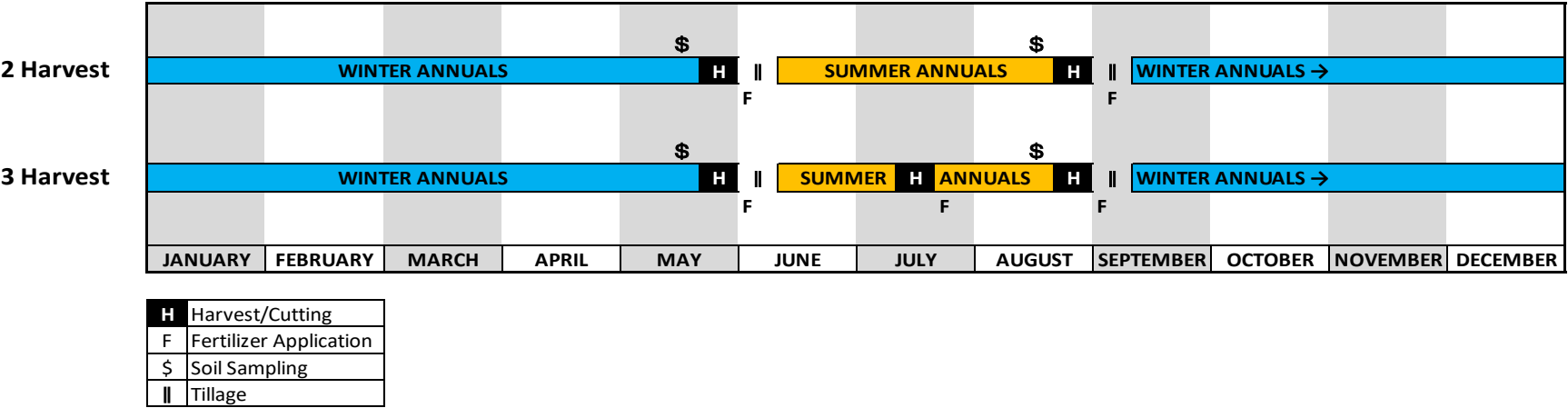
Economics

Partial budget analysis: seed costs, fuel, time, labor

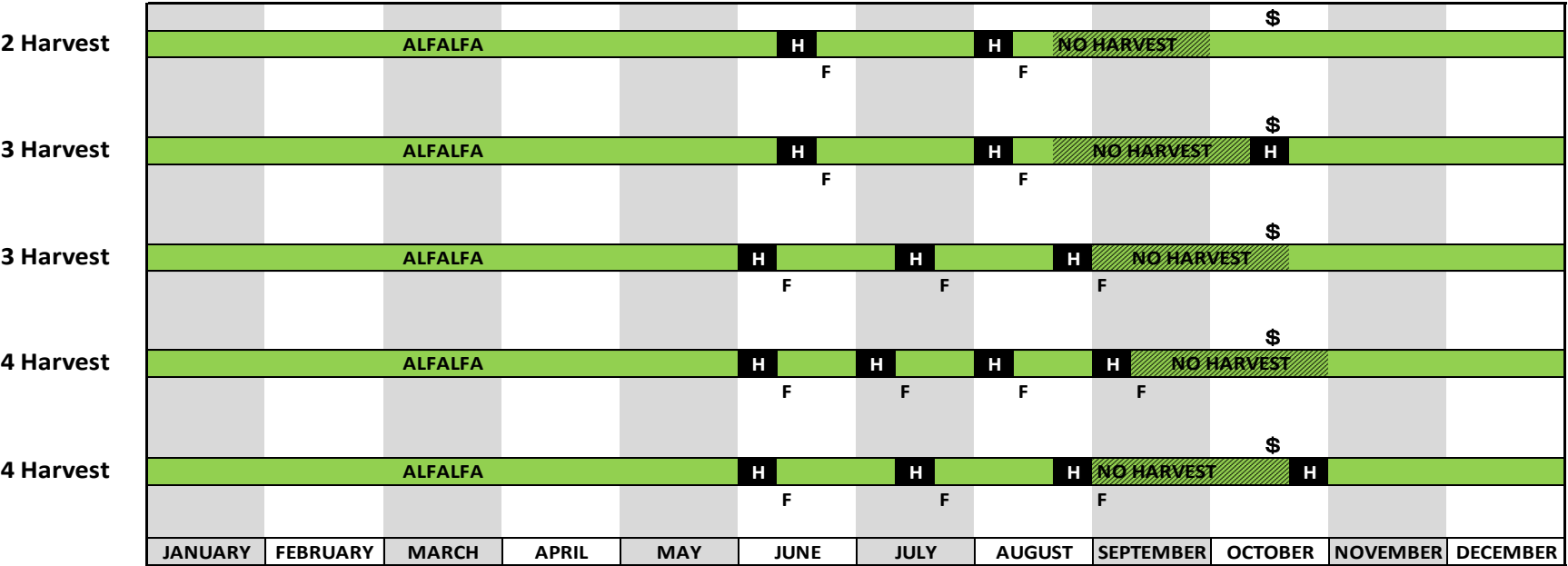
Milk estimates based on yield and forage quality

Harvest scenarios for a double-cropping system and a perennial cropping system.

Annals



Perennials



Perennial Seeding Rates

One quarter of the standard seeding rates of each species was used to make the four species mixtures.

Standard populations were used to make mixtures of multiple cultivars.

Diversity Treatments			
Very Low 24.6 lb/a	Low 17.4 lb/a	High 17.1 lb/a	Very High 14.9 lb/a
Alfalfa <i>Viking 370HD</i> Alfalfa was chosen as the 'head' species because it is a common forage for dairies.	Alfalfa <i>Viking 370HD</i> <i>FSG 420LH</i> <i>KF Secure BR</i> <i>Roadrunner</i>	Alfalfa <i>Viking 370HD</i> Orchardgrass <i>Extend</i> Timothy <i>Climax</i> White Clover <i>Alice</i>	Alfalfa <i>Viking 370HD, FSG 420LH, KF</i> <i>Secure, Roadrunner</i> Orchardgrass <i>Extend, Benchmark Plus, Niva,</i> <i>Intensiv</i> Timothy <i>Climax, Summit, Glacier,</i> <i>Promesse</i> White clover <i>Alice, Liflex, Ladino, Kopu II</i>

Winter Annual Seeding Rates

One quarter of the standard seeding rates for each species was used to make the four species mixtures.

Standard populations were used to make mixtures of multiple cultivars.

Diversity Treatments			
Very Low 211.8 lb/a	Low 208.8 lb/a	High 157.1 lb/a	Very High 163.1 lb/a
Triticale <i>Trical 815</i> Triticale was chosen as the ‘head’ species because of its high yield, forage quality, and later maturity.	Triticale <i>Trical 815</i> <i>Fridge</i> <i>NE426GT</i> <i>Hy octane</i>	Triticale <i>Trical 815</i> Cereal rye <i>Wheeler</i> Red clover <i>Mammoth</i> Winter pea <i>Austrian</i>	Triticale <i>Trical 815, Fridge, NE426GT</i> <i>Hy octane</i> Cereal rye <i>Wheeler, Guardian, Aroostook, Spooner</i> Red clover <i>Mammoth, Freedom, Starfire</i> <i>Duration</i> Winter pea <i>Austrian, Frostmaster, Whistler, Windham</i>

Summer Annual Seeding Rates

One quarter of the standard seeding rates for each species was used to make the four species mixtures.

Standard populations were used to make mixtures of multiple cultivars.

Diversity Treatments			
Very Low 59.3 lb/a	Low 51.1 lb/a	High 44.3 lb/a	Very High 47.4 lb/a
Sudangrass <i>Hayking</i> Sudangrass was chosen as the ‘head’ species because of its drought tolerance, fast growth and fine stems.	Sudangrass <i>Hayking</i> <i>Piper</i> <i>SSG886</i> <i>Promax</i>	Sudangrass <i>Hayking</i> Pearl millet <i>Wonderleaf</i> Sorghum sudangrass <i>Greengrazer</i> Ryegrass <i>Enhancer</i>	Sudangrass <i>Hayking, Piper, SSG886</i> <i>Promax</i> Pearl millet <i>Wonderleaf, FSG315, Exceed,</i> <i>Tifleaf</i> Sorghum sudangrass <i>Greengrazer, 400 x 38,</i> <i>AS6401, Sweet 6</i> Ryegrass <i>Enhancer, Tetraprime</i> <i>Marshall, Kodiak</i>

Field Management:

Location:	Musgrave Research Farm Aurora, NY
Soil type:	Lima silt loam
Previous crop:	Sorghum sudangrass & pearl millet in high density 50-50 mixture, no-till
Fertilizer applied:	7,000 gal/a liquid dairy manure sprayed 18-Aug 2016
Tillage operation:	Moldboard plow, cultipack 18-Aug 2016
Plot size:	30 x 50 ft
Replications:	4 per treatment



Perennials after the 2nd cut on July 25th, 2017.



Summer annuals after harvest on August 9th, 2017.

Field Management:

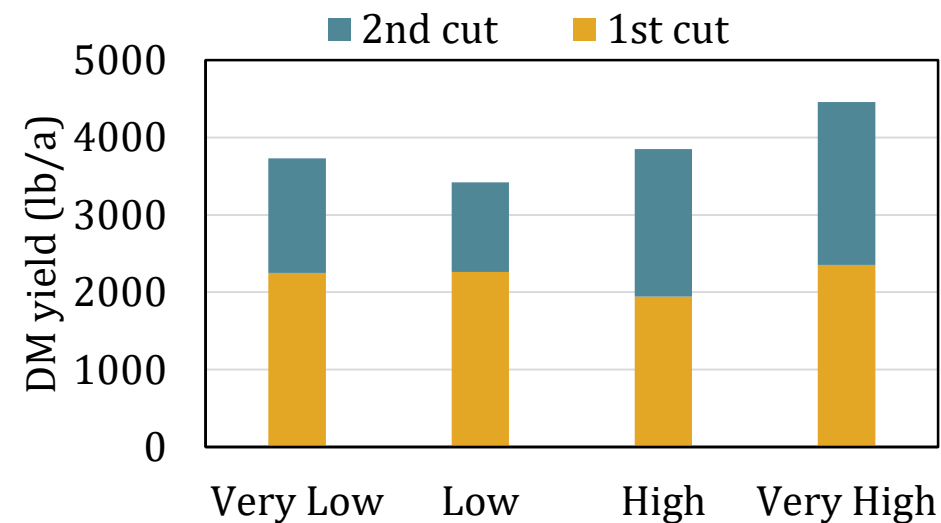
Perennial Operations	Date
Perennials planted (drilled 7.5" rows, 0.5" depth with no-till drill)	20-Aug 2016
Perennials replanted (broadcast same rates again)	4-May 2017
1st cut	8-Jun 2017
Fertilized using Willmar Spinner Spreader 800 lb/a poultry manure (5-4-3) 300 lb/a potassium sulfate (0-0-51-18)	15-Jun 2017
2nd cut	28-Jul 2017

Annual Operations	Date
Winter annuals planted (drilled 7.5" rows, 0.5" depth with no-till drill)	8 Sept 2016
Winter annuals harvested	16 May 2017
Fertilized using Willmar Spinner Spreader 1600 lb/a poultry manure (5-4-3)	15 Jun 2017
Chisel plowed 7-9", disked, and harrowed	15-Jun 2017
Summer annuals planted (drilled 7.5" rows, 1.5" depth with no-till drill)	18-Jun 2017
Summer annuals harvested	9-Aug 2017
Fertilized using Willmar Spinner Spreader 2000 lb/a poultry manure (5-4-3)	19-Sept 2017
Chisel plowed 7-9", disked, and harrowed	19-Sept 2017
Winter annual planted (drilled 7.5" rows, 0.5" depth with no-till drill)	20-Sep 2017

2017 Results: Perennials

The grasses in the **High** and **Very High** treatments did much better than the alfalfa in the wet spring.

Diversity treatment	Dry matter yield (lb/a)	Dry matter %	Crude protein	NDF -----% of DM -----	ADF	NDFD
1st cut						
Very Low	2248	35.3	11.8	56.9	42.4	39.3
Low	2261	31.3	14.2	55.1	42.0	34.5
High	1944	34.4	10.8	61.9	44.4	38.0
Very High	2353	33.1	10.3	62.0	44.2	41.5
Average	2202	33.6	11.8	58.9	43.2	38.0
2nd cut						
Very Low	1482	21.5	13.0	50.0	35.9	34.5
Low	1159	21.0	14.2	53.0	36.1	39.9
High	1905	20.6	11.8	56.5	39.8	45.9
Very High	2106	20.7	11.4	60.4	41.3	48.0
Average	1663	21.0	12.6	56.1	38.3	43.7



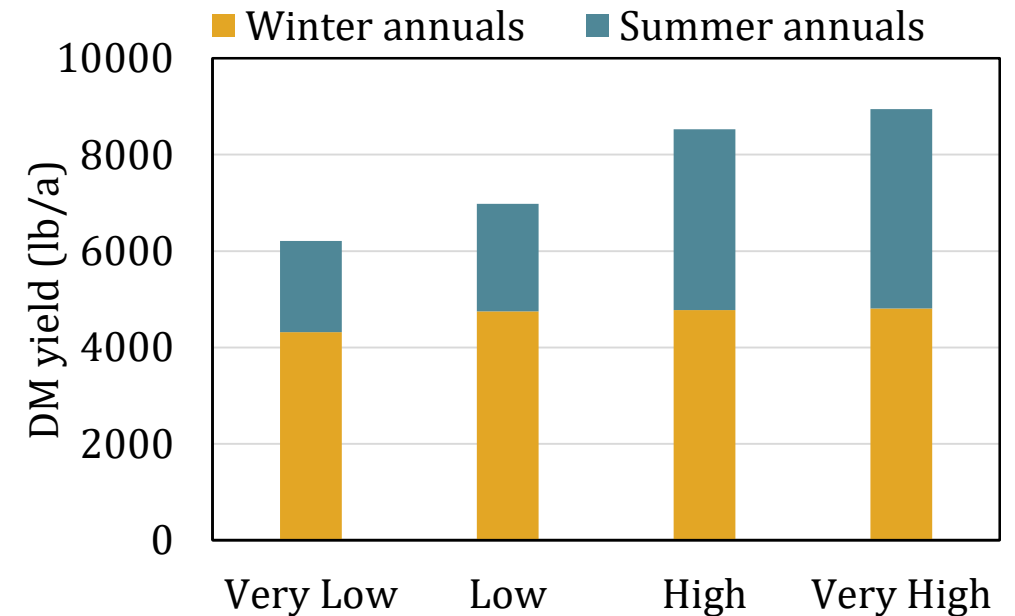
2017 Results: Annuals

Although winter peas and red clover were planted, most of the biomass was triticale and cereal rye in the winter annuals.

The **High** and **Very High** treatments produced more biomass in the summer than treatments with only sudangrass.

The forage quality from the 2017 **winter** annuals:

Diversity treatment	Dry matter yield (lb/a)	Dry matter %	Crude protein	NDF -----% of DM	ADF	NDFD
Very Low	4320	21.2	11.6	60.6	36.0	56.8
Low	4751	21.9	11.6	59.5	34.7	58.1
High	4774	21.1	11.4	63.0	38.5	55.8
Very High	4806	22.0	10.7	65.3	39.5	55.1
Average	4663	21.5	11.3	62.1	37.2	56.5



2017 Results: Annuals

The forage quality from the 2017 **summer** annuals:

Diversity treatment	Dry matter yield (lb/a)	Dry matter %	Crude protein	NDF -----% of DM -----	ADF	NDFD
Very Low	1889	18.4	9.6	61.2	40.8	51.8
Low	2228	17.8	9.7	63.5	41.3	54.8
High	3751	19.0	10.1	58.7	39.3	51.2
Very High	4140	18.5	9.2	62.7	41.3	54.2
Average	3002	18.4	9.7	61.6	40.7	53.1

Preliminary Results

- 2017 had some challenging weather: mild winter, very wet spring, and a dry spell in the summer
- Annual system was higher yielding than perennial system
- **Very High** diversity treatments had higher yields than **Very Low** treatments in both systems
- Winter annuals had higher digestibility (NDFD) than summer annuals and perennials
- Summer annuals had lower crude protein than winter annuals and perennials

Seed Costs

Seed costs depend on the system and seeding rates. Organically managed fields typically have higher seeding rates than conventional management.



Treatment	Perennials	
	\$/lb	\$/a
Very Low	5.80	127.47
Low	19.14	84.09
High	16.94	73.04
Very High	64.03	55.45

The alfalfa seed in the Perennial system was the most expensive treatment, meaning that the **Very Low** treatment had the highest cost per acre.

Treatment	Winter Annuals		Summer Annuals		Total	
	\$/lb	\$/a	\$/lb	\$/a	\$/lb	\$/a
Very Low	0.48	101.65	1.88	99.53	2.36	201.18
Low	1.64	83.81	6.66	86.81	8.30	170.61
High	4.11	86.42	5.26	54.28	9.37	140.70
Very High	21.15	103.94	21.28	65.43	42.43	169.37

The Annual system had less expensive seed per season, but double-cropping requires twice as much seed!

Tips for Mixtures

Greater crop diversity likely means greater management complexity.
Farmers will have to experiment and see what works for them.

1. Species should have a reasonable chance of survival after sowing.
2. If you don't see it growing, it probably is not providing benefits.
3. If mixing fast-growing annuals, plant species with similar growth rates so that suppression is reduced.
4. Seed more competitive species (grasses) at lower rates and less competitive species (legumes) at higher rates.

Project Team

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