NESARE Sustainable Dairy Cropping Systems Research

Heather Karsten, Dept. Plant Science, PSU and ARS collaborators

Evaluating innovative conservation cropping systems at field scale:

- to produce all forage & feed, some fuel for average PA dairy farm
- minimize off-farm inputs & environmental impacts
- adapt to & mitigate climate change

Penn State NESARE Dairy Cropping Systems Team

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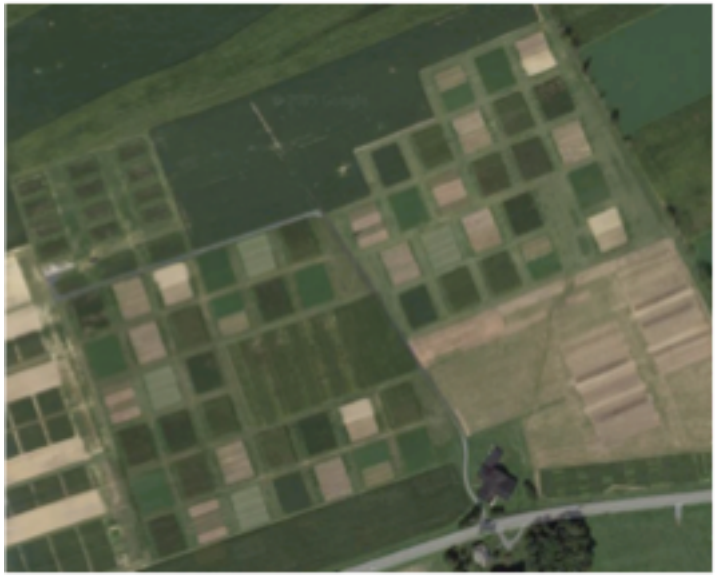

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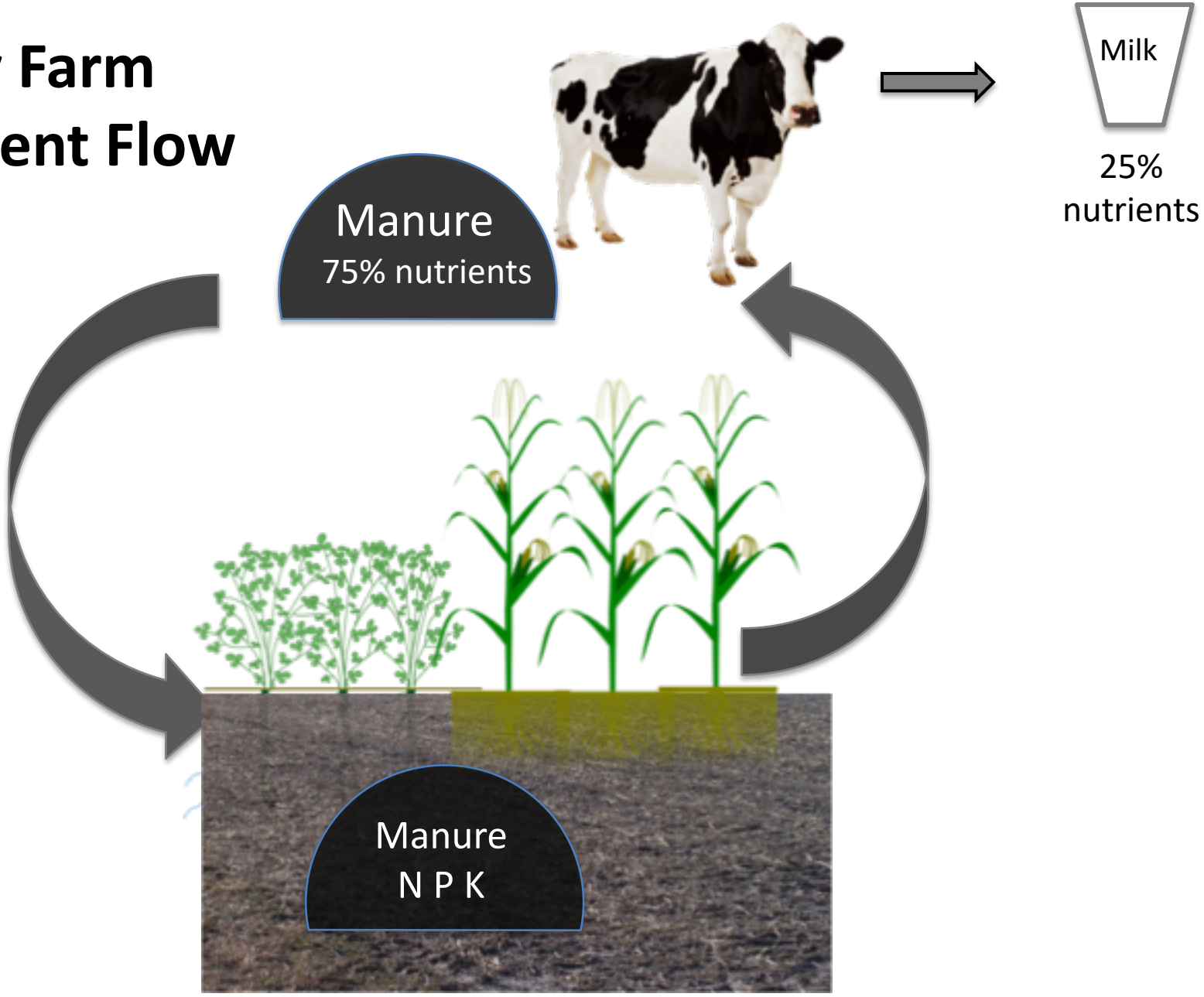
Typical Northeast Dairy Farm

Import Feed and Fertilizers

Grow forages on-farm: corn silage and alfalfa

Dairy Farm Nutrient Flow

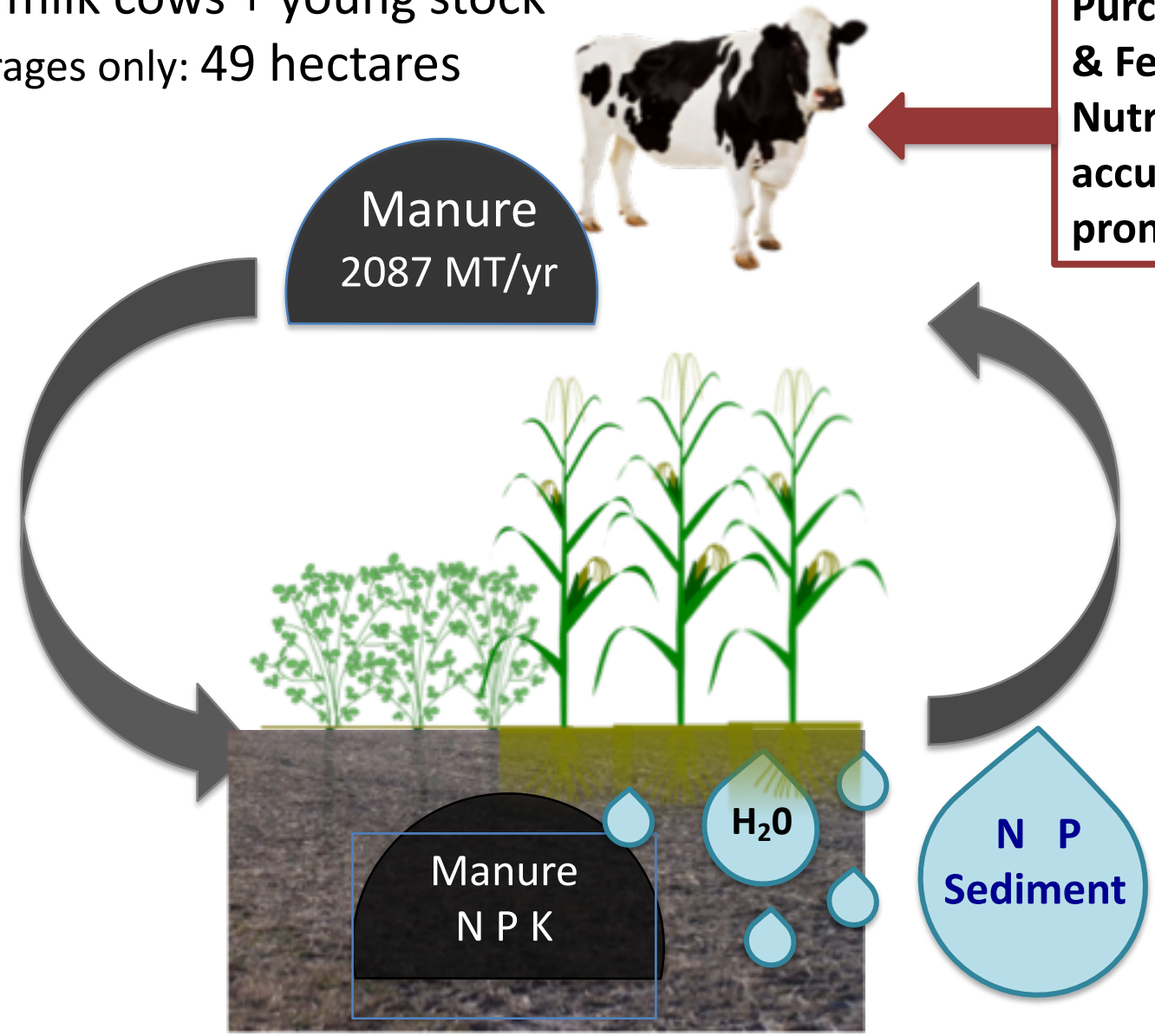


Alfalfa drawing: Kristen Haider

Typical Pennsylvania Dairy Farm

65 milk cows + young stock

Forages only: 49 hectares



Dairy Farm

Milk

Manure
2300 T

Plant no-till, inject manure, reduce N, P losses

N P
Sediment

Manure
N P K

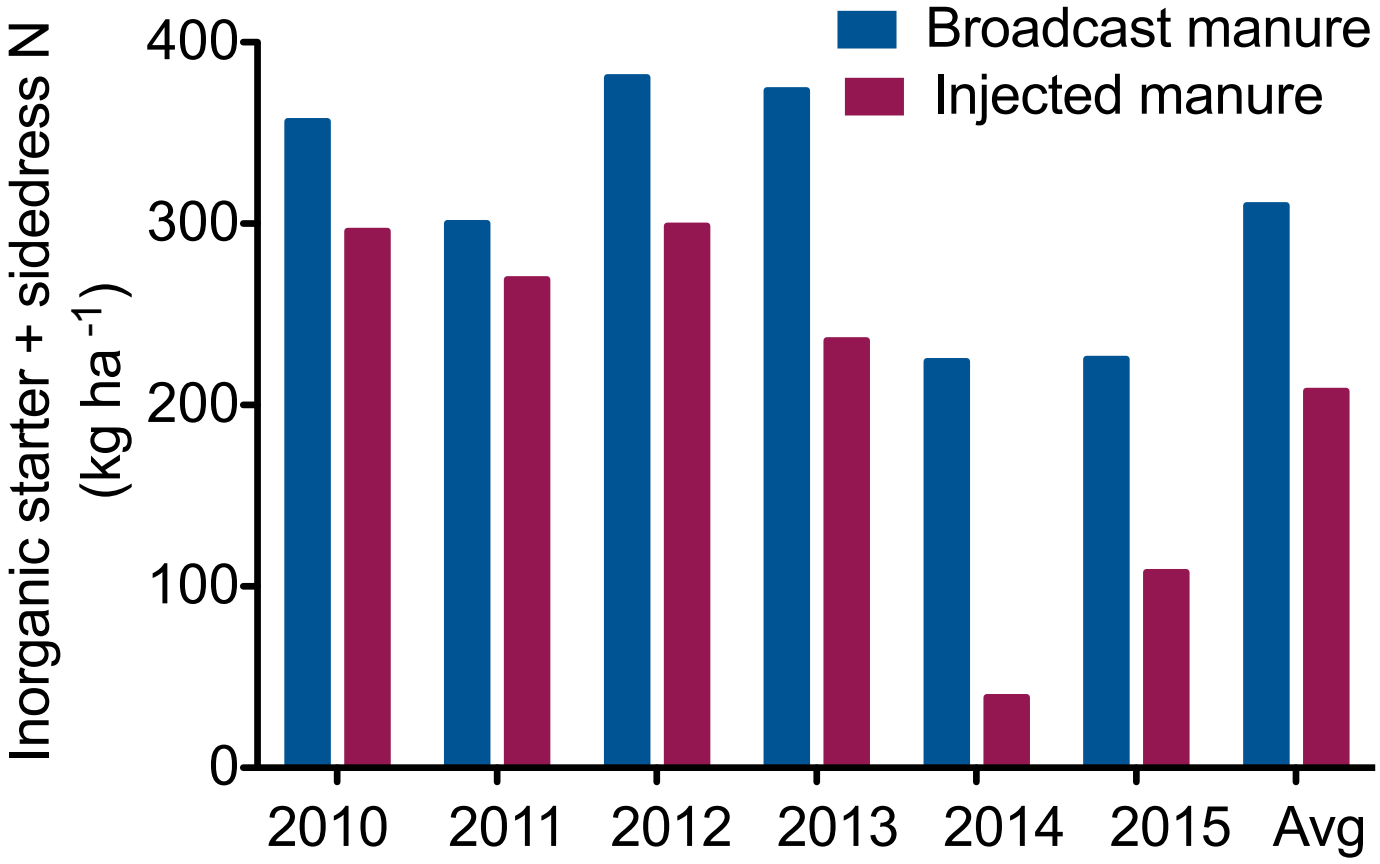
Purchase $:
- **Herbicide**

Purchase LESS:
- **Less Fertilizer**
- **Less fuel**

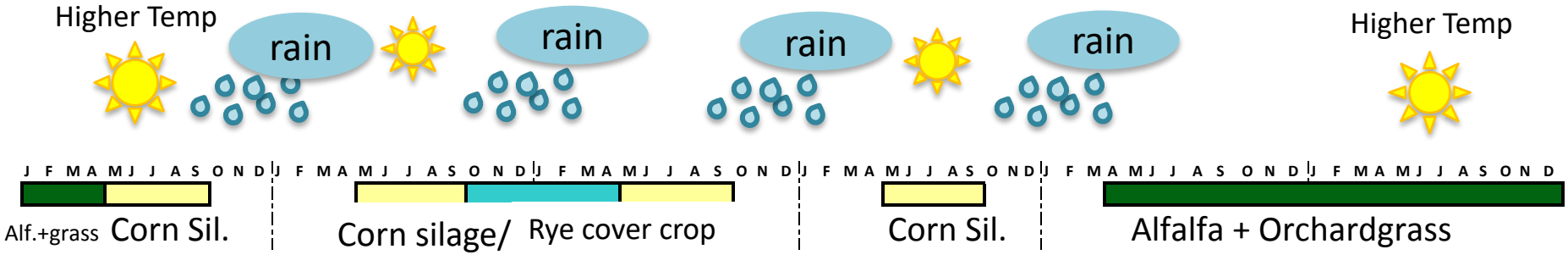
Photos: Margaret Douglas, Robert Meinen

Compared surface **broadcast** to **injected manure** across 6 yr rotation:
- same rate of manure applied, PSNT to determine side-dress N

With injected manure used 33% less inorganic fertilizer N (100 kg/ha), maintained similar yields



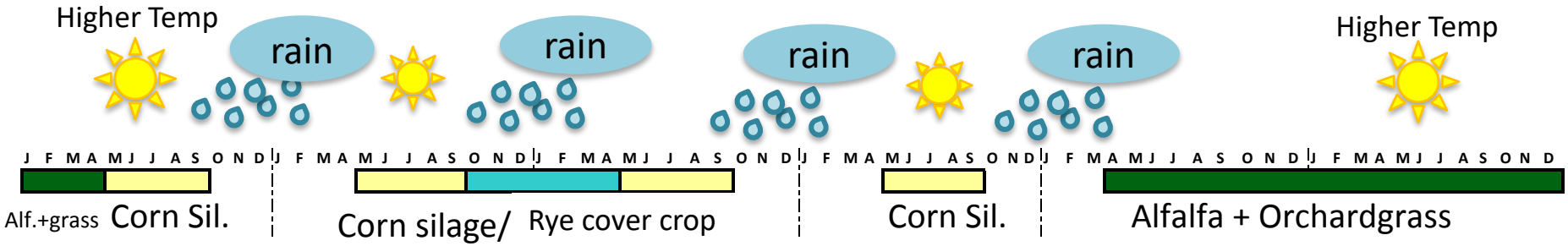
Potential Climate Change Risks for Northeast Dairy Farms



- more soil erosion & nutrient loss in fall, winter, & spring

due to rain & warmer temperatures promoting nutrient mineralization

Climate Change Potential Risks for Northeast Dairy Farms



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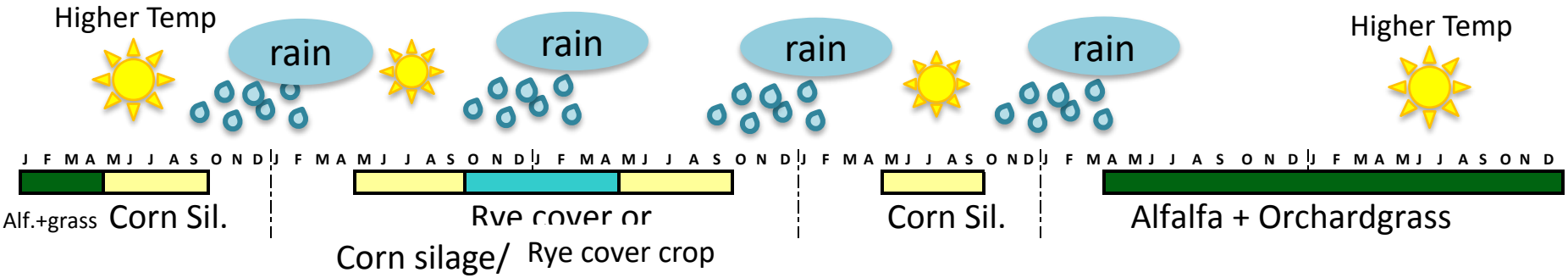
due to rain, warmer temperatures promoting nutrient mineralization

- difficulty timely planting of crops in wet soil, particularly in spring

Climate Change Potential Risks for Northeast Dairy Farms

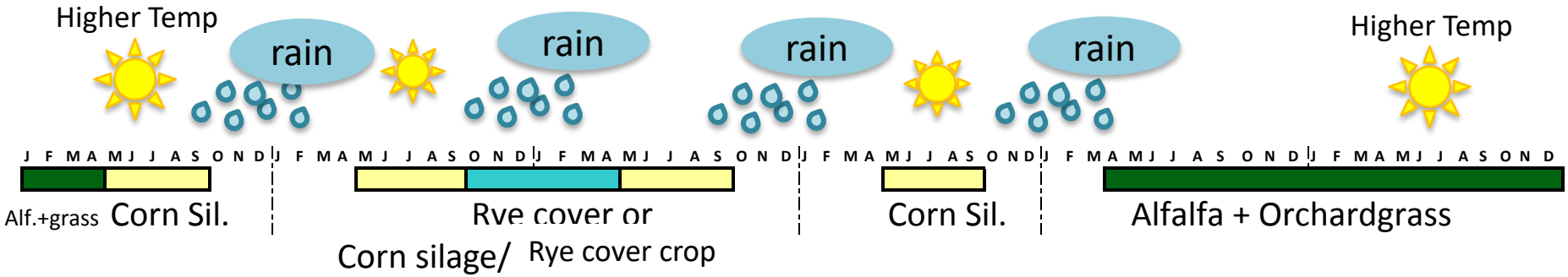


- more soil erosion & nutrient loss in fall, winter, spring due to rain, warmer temperatures

- difficulty timely planting of crops in wet soil, particularly in spring

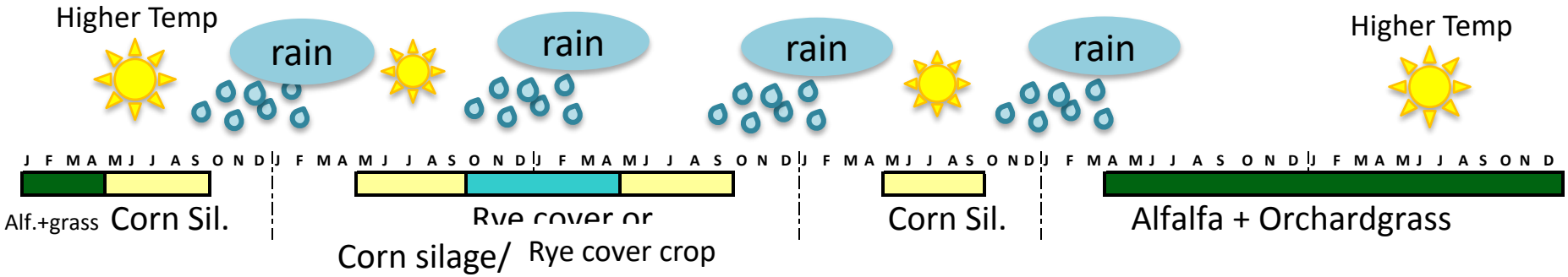
- summer yield declines with increased temperature, risk of drought

Climate Change Potential Risks for Northeast Dairy Farms



- more pests, particularly diseases with moist and warm conditions, more insects, slugs, weeds

Climate Change Potential Gains for Northeast Dairy Farms

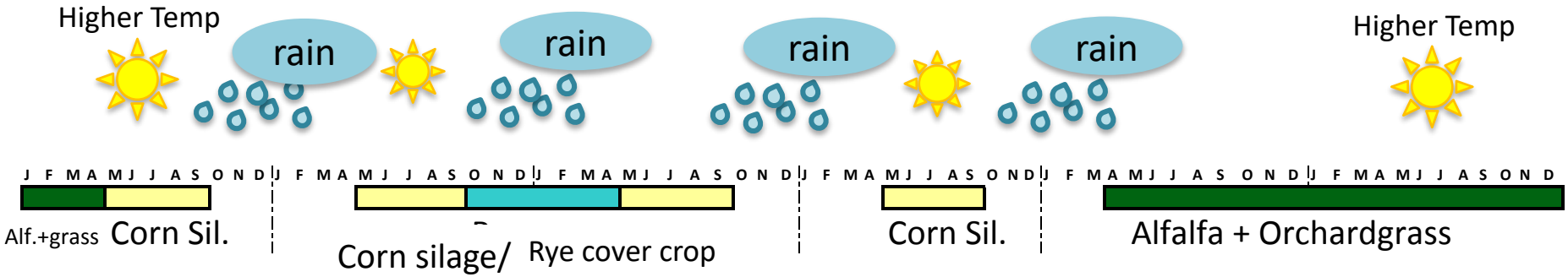


a. Longer growing season, esp. in fall and spring

b. Warmer temps all season may benefit northern regions

c. Possible increased demand ($) for NE milk due to lower production in drier and warmer western climate

Enhance the Resiliency of Northeast Dairy Farms



More year-round crop production, utilize fall and early spring growing seasons

Keep soil covered more continuously, to prevent erosion, improve soil health and Utilize manure applications (not just cover crops)

Conservation Agriculture:
Reduce tillage, Produce and retain Crop Residue on Soil, Rotate Crops

Improve soil structure, prevent compaction and enhance water infiltration

Distribute planting, growth and harvesting operations over more seasons

Two Diverse 6 yr No-till Crop Rotations

Manure Rotation

Pest Rotation

- IPM for insect pests
- No Bt traits
- No seed insecticides
- Double & cover crops, perennials

Corn-soybean No-till rotation

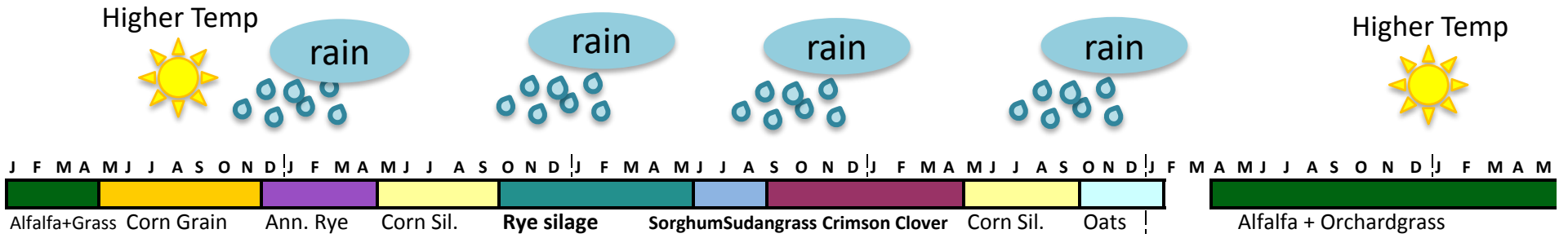
- Triple-stacked Bt
- Seed insecticide
- Insecticide at planting (Warrior)
- No cover crop

Enhancing Resiliency of Northeast Dairy Farms

Continuous cover

Crops that utilize manure

Crop diversity



Double crop forages: corn silage/rye, rye silage/sorghum sudangrass

In Corn grain, interseed annual ryegrass and clover cover crops

Double-crop winter annual silage with fall manure after corn silage:

Rye silage dry matter yield after corn silage

Year	Injected manure	Surface broadcast manure	SE	P-value
	(MT DM ha^{-1})			
2014	6.29	6.89	0.24	0.02
2015	6.85	6.74	0.48	0.16
2016	8.47	7.8	0.11	0.19
2017	9.76	8.8	0.30	> 0.01
Average	7.74	7.56		

Winter annual silage benefits:

- produces more forage utilizing fall manure nutrients

- good forage quality for dry cows and heifers

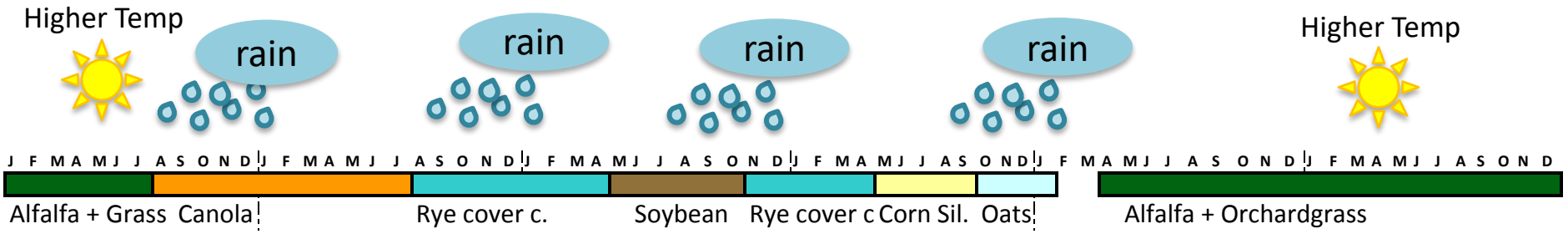
- protects soil longer in spring

Rye silage yield or rye cover crop biomass, corn silage yield, 2017

	Rye Biomass	Corn Silage	SE
		(MT DM ha^{-1})	
Rye **Silage**/Corn Silage	**5.69 a**	15.61	0.83
Rye **Cover**/Corn Silage	4.16 b	17.12	0.83

Enhancing Resiliency of Northeast Dairy Farms

Continuous crops retain soil, manure, promote soil health
Spread production risk over more seasons
Produce more feed and fuel, enhance profitability



Fall planted winter canola

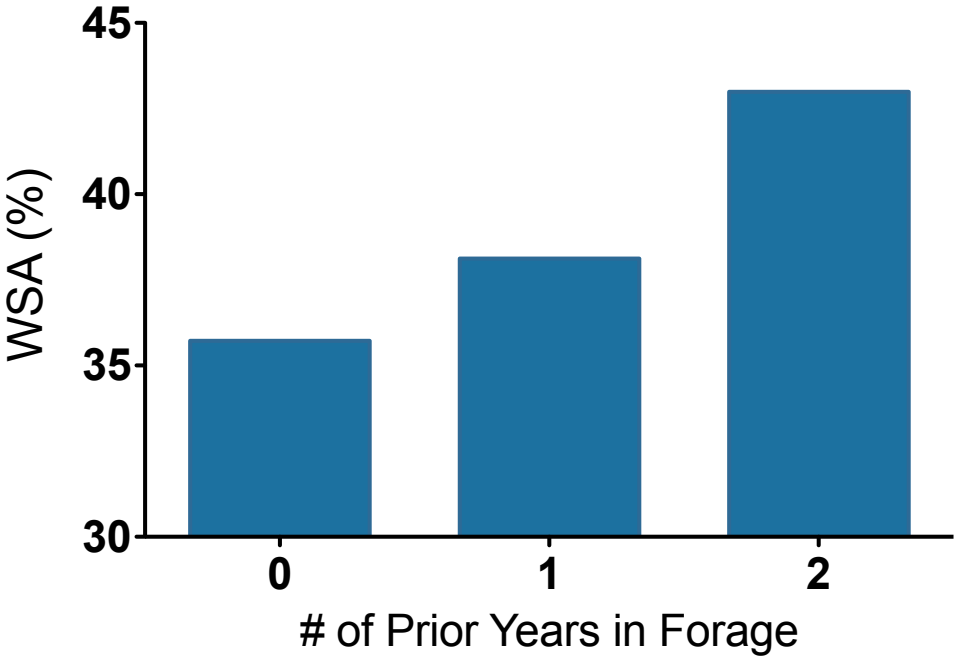
Soybean

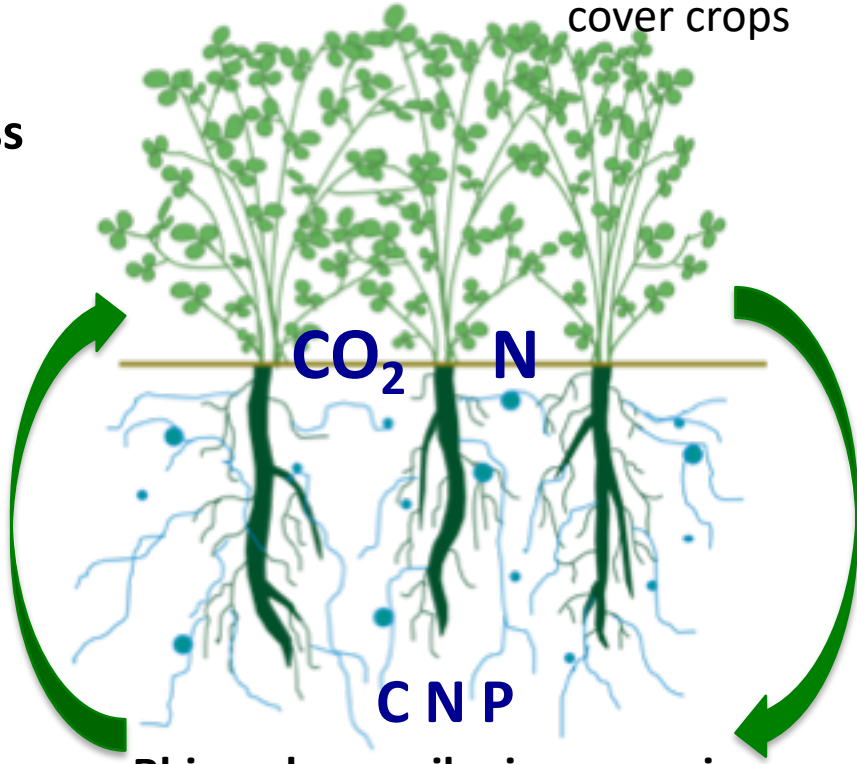
Continuous cropping (perennials, double-crops, cover crops, interseeded cover crops):

- retain soil and nutrients
- add organic matter, sustain micro-organisms
- improve soil structure, water infiltration
- suppress weeds

Interseeded cover crops

Water stable aggregates increase with years in perennial alfalfa and alfalfa and orchardgrass





Rhizosphere soil micro organisms

Photo: Ian Grettenberger; Alfalfa drawing: Kristen Haider

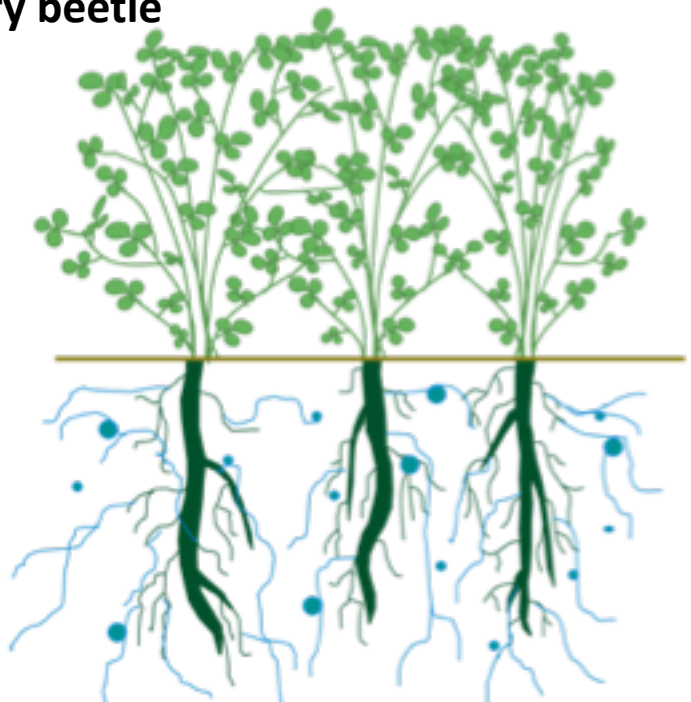
Continuous crops

- provide habitat for beneficial organisms

- compete with and suppress weeds

Predatory beetle

Insect, slug, weed seed predators



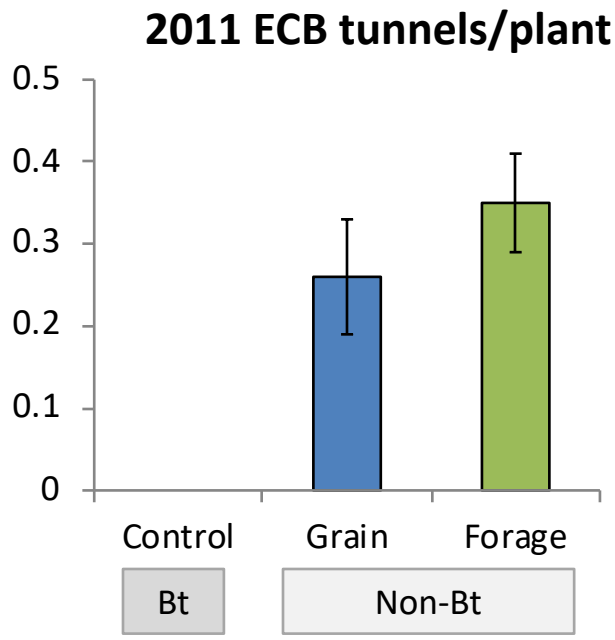
Photos: Margaret Douglas ; Alfalfa drawing: Kristen Haider

Diverse crop rotation interrupt pest lifecycles

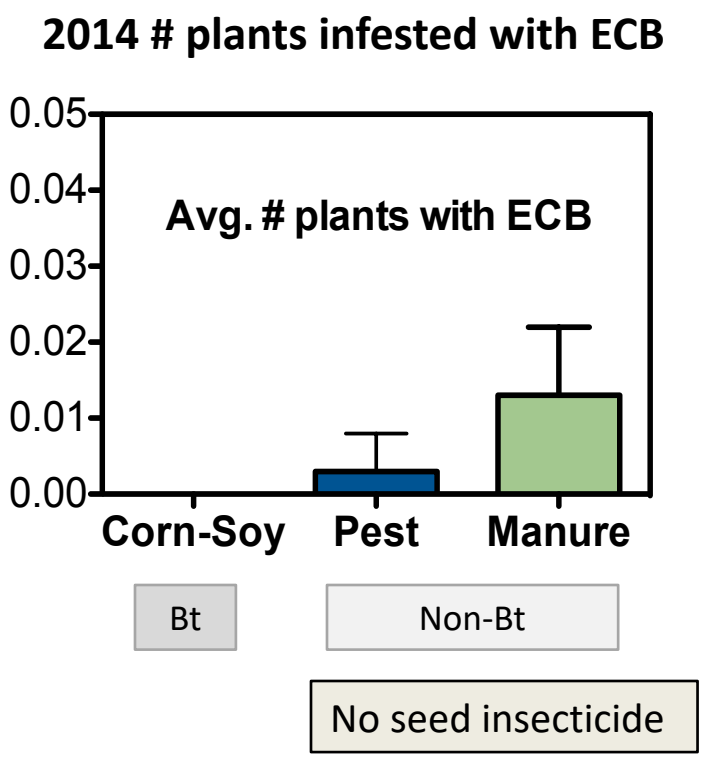
Use IPM

Protect natural enemies, prevent pest resistance

Corn European Corn Borer damage has been low and below economic threshold



Expected yield loss about 2.5% per tunnel



No seed insecticide

Integrated Weed and Pest Management

- Diversify weed control tactics
- Shift crop planting dates to avoid peak slug activity periods
- Minimize/select insecticides to conserve natural enemies

Slug predator

Cover crop

Band herbicides over crop row

Cultivate between crop rows

Plant annual forage crop with PLH resistant alfalfa

Till to terminate alfalfa, tillage interrupts slugs

Herbicide
Insecticide

Reduce pesticide use, selection for pesticide resistance

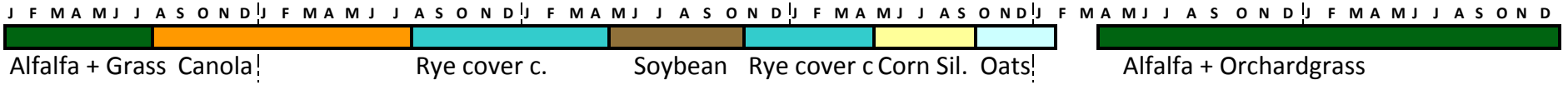
Purchase LESS:
- **Herbicide**
- **Insecticide**

Photos: Margaret Douglas, William Curran, Robert Meinen

Enhancing Resiliency of Northeast Dairy Farms

In Corn grain, interseed cover crops

Double crop forages: corn silage/rye, rye silage/sorghum sudangrass



More feed and fuel

Continuous cover

Crop diversity

IPM for insects

Dairy Farm

65 milk cows and young stock

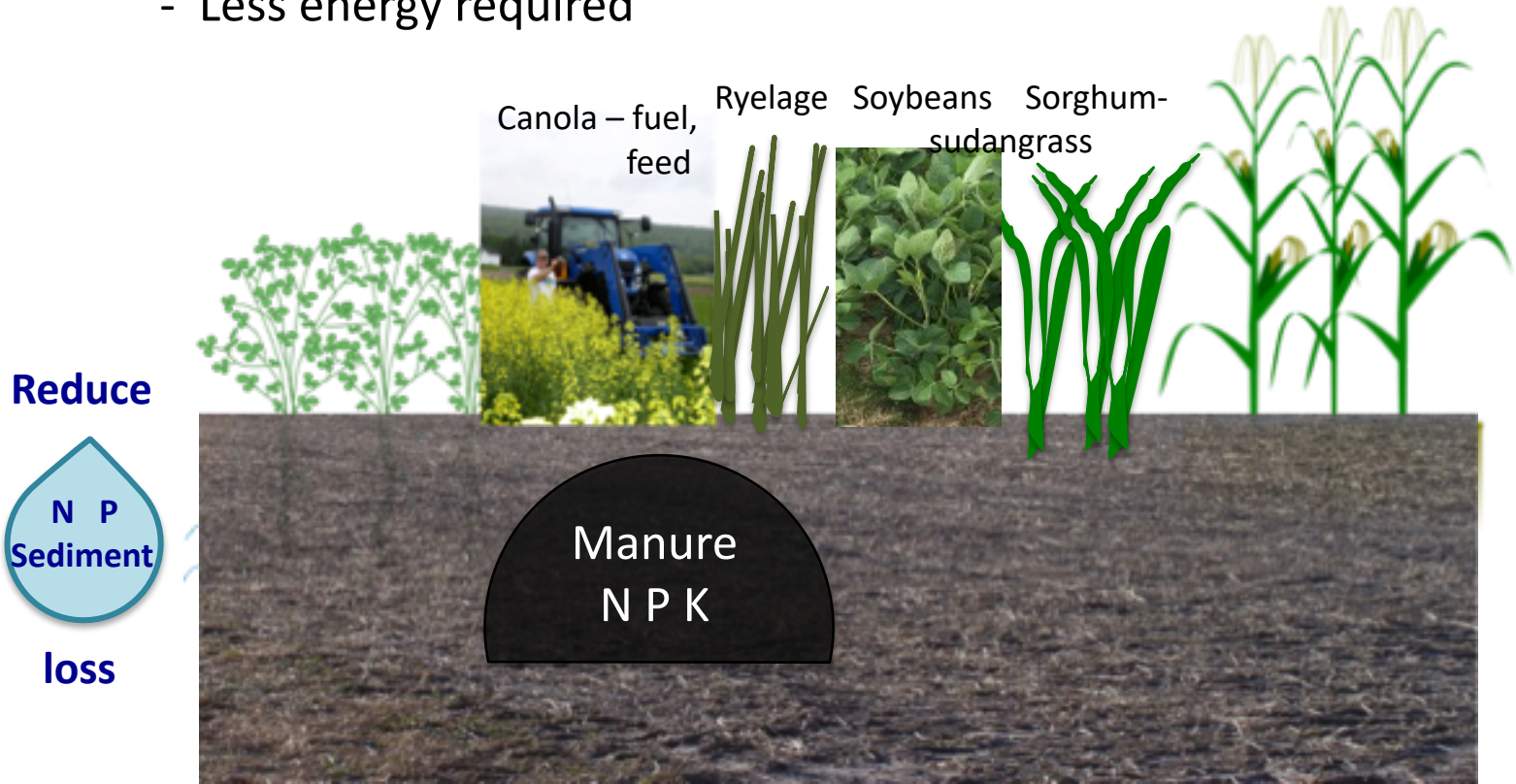
97 hectares

$ profitable

Purchase little feed – poor weather years

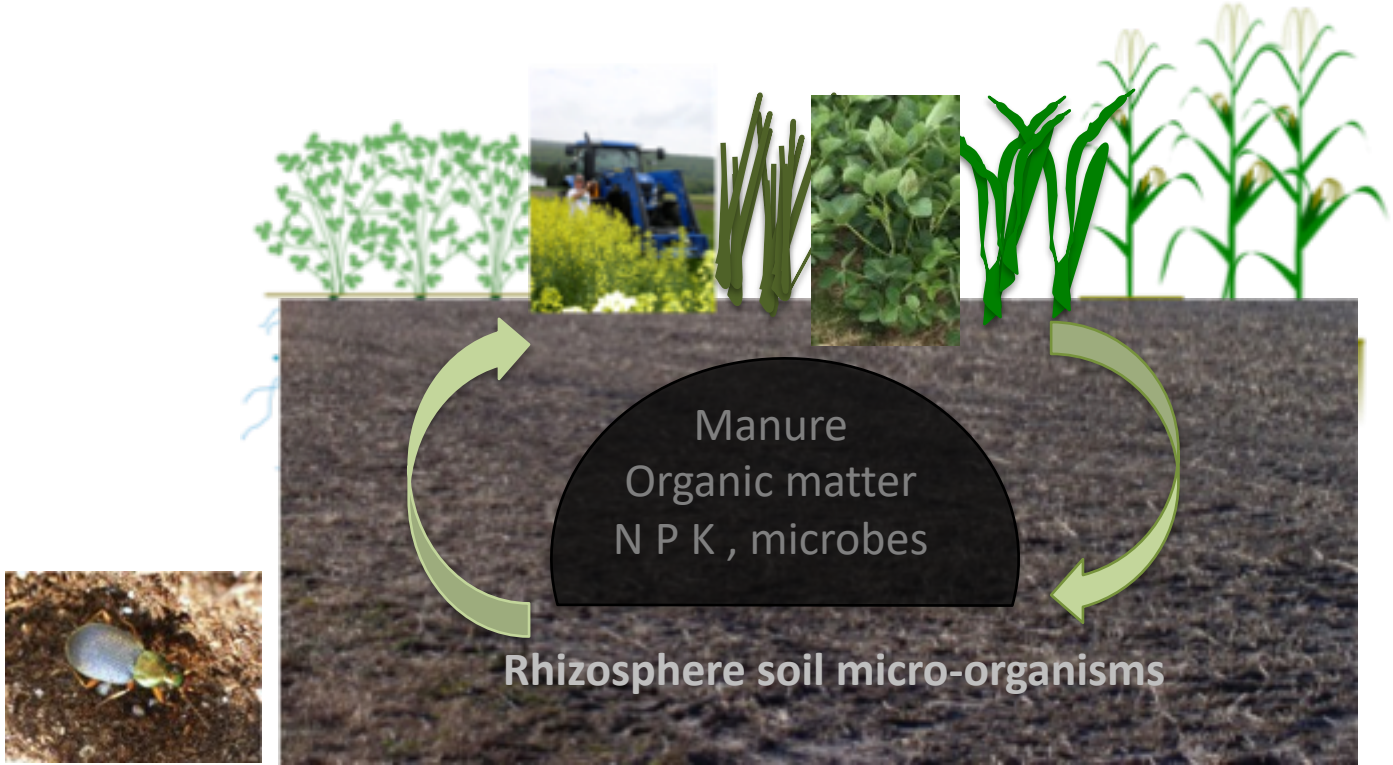
Grow all dairy feed and forages on more acres

- Manure utilized for more crops, fewer nutrients lost
- Diverse crop rotation interrupts pest lifecycles
- Lower feed costs, profitable Dairy farm over multiple years
- Less energy required



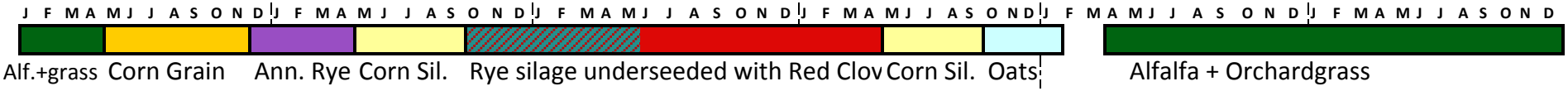
System Synergies

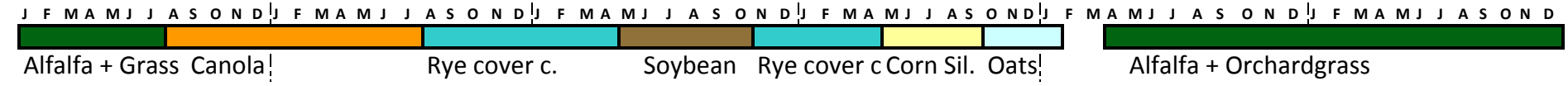
- Enhance resilience to climate change
- Reduce soil and nutrient loss, pesticide use, feed costs
- Protect water quality
- Enhance farm profitability
- Promote soil quality
- Reduce selection for pest resistance



Enhancing Resiliency of Northeast Dairy Farms

- More year-round crop production, utilize fall and early spring growing seasons
- Keep soil covered more continuously, to prevent erosion, improve soil health,
  Utilize manure applications (not just cover crops)
- Conservation Agriculture:
  Reduce tillage, Produce and retain Crop Residue on Soil, Rotate Crops
- Distribute planting, growth and harvesting operations over more seasons
- Diversify crops for heat tolerance, to interrupt pest lifecycles,
- provide habitat for beneficial species
- Use IPM
- Work with: dairy nutritionists to integrate diverse crops
- farmer networks to promote above strategies

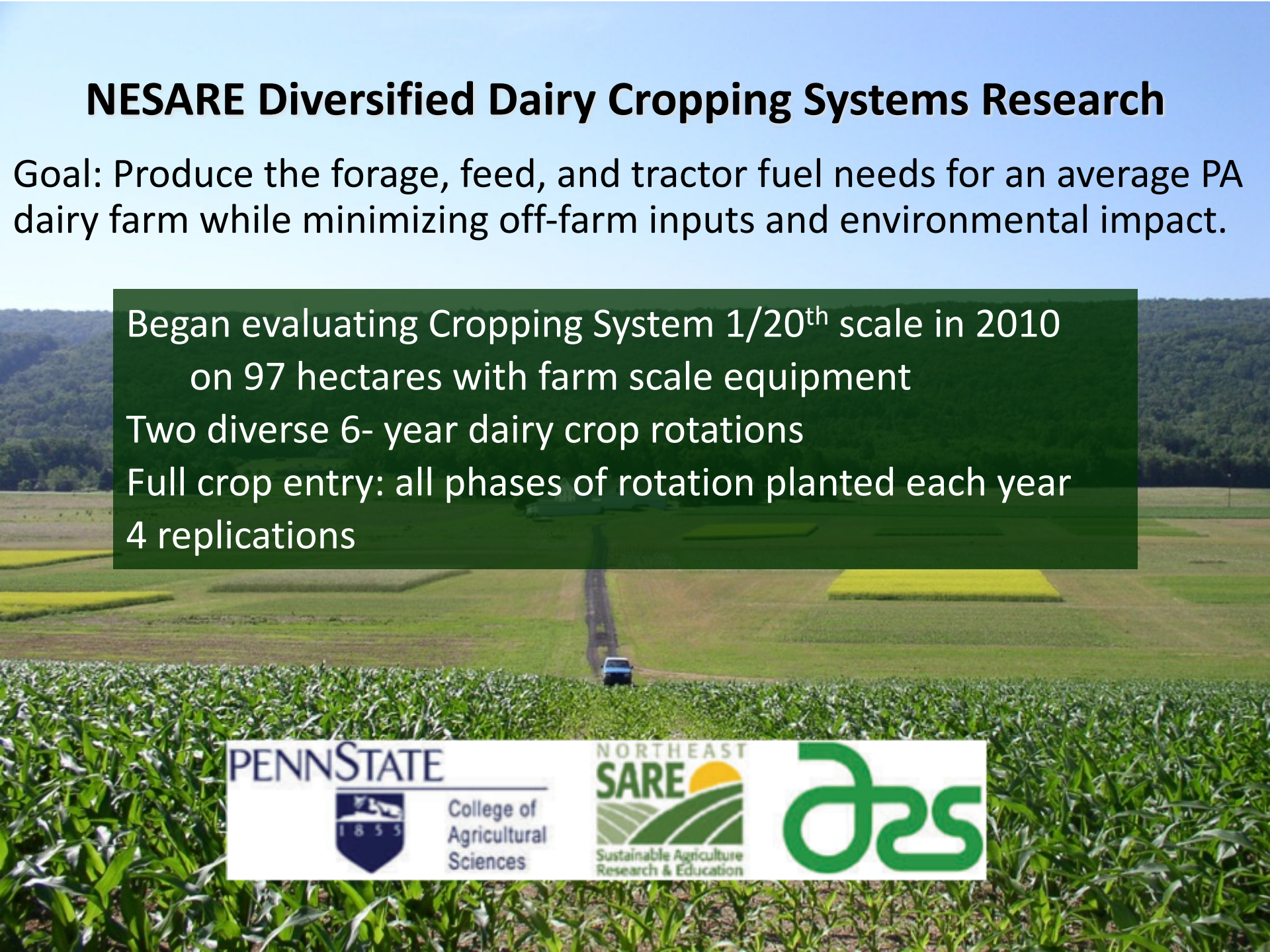




NESARE Diversified Dairy Cropping Systems Research

Goal: Produce the forage, feed, and tractor fuel needs for an average PA dairy farm while minimizing off-farm inputs and environmental impact.

Began evaluating Cropping System 1/20th scale in 2010
on 97 hectares with farm scale equipment
Two diverse 6- year dairy crop rotations
Full crop entry: all phases of rotation planted each year
4 replications



Two Diverse 6 yr No-till Crop Rotations

MANURE ROTATION

PEST ROTATION

- IPM for insect pests
- No Bt traits
- No seed insecticides
- Cover covers & Perennials

Corn-soybean No-till rotation

- Triple-stacked Bt
- Seed insecticide
- Insecticide at planting (Warrior)
- No cover crop

Simulate Dairy Herd: Dairy Production & Nutrition Models

The Virtual Dairy Herd: 65 milking cow herd, dry cows, young stock

Forage Crops:
- alfalfa mixtures
- corn silage
- rye silage

or sorghum sudangrass

Grain Crops:
- corn
- soybeans
- canola

Crop Yields
Crop Quality

Virginia Ishler

Dairy & Nutrition Models

Milk Production
Manure Production

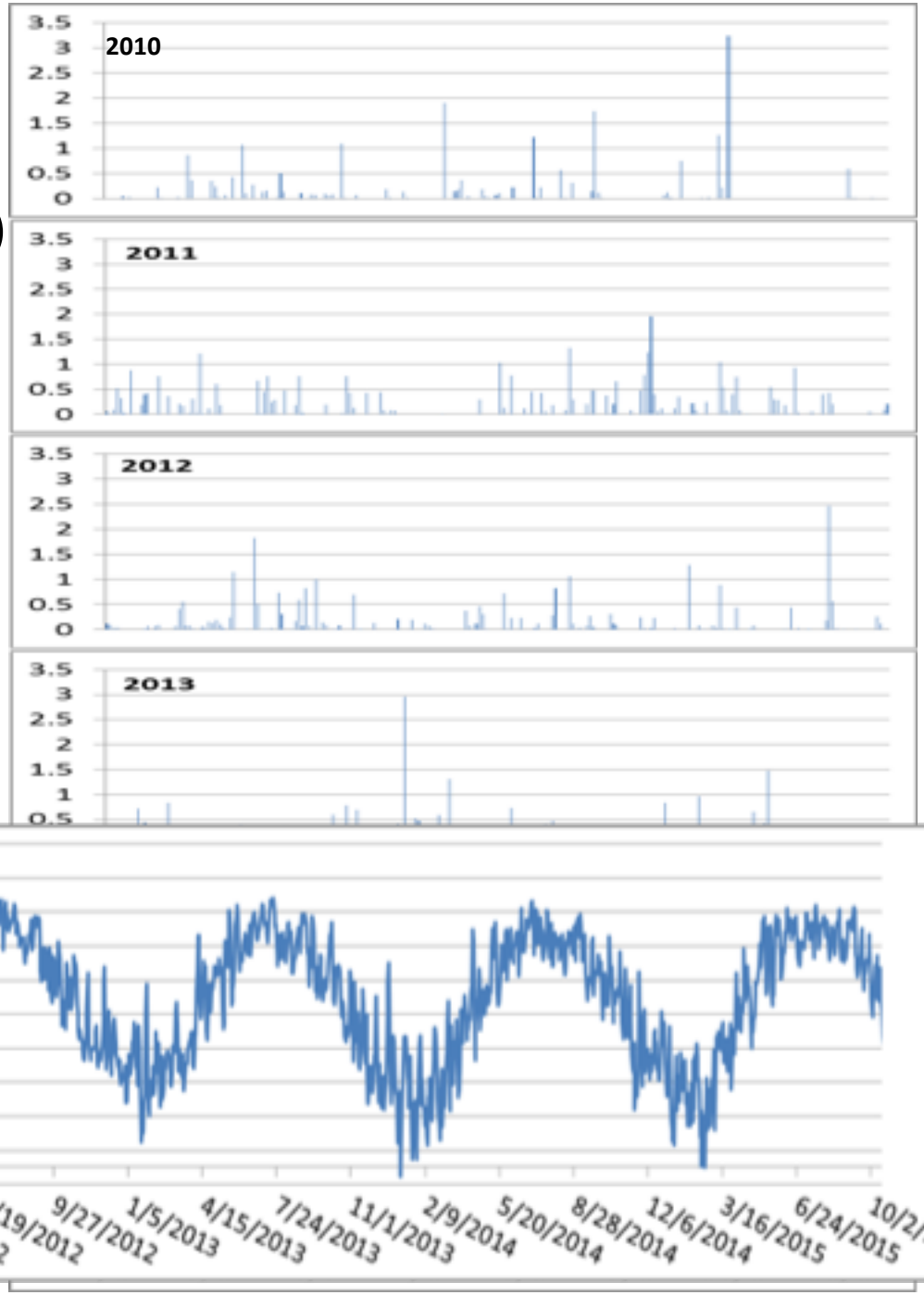
Evaluate Whole Farm Profitability Over Time

- Whole Farm Enterprise Budget, FINPAC
- Compare to Benchmark PA Dairy Farms

Experienced range of weather

- wet fall (2010, 2011)
- wet springs (2011, 2012)
- dry mid summer year (2011, 2012)

Daily Growing Season Precipitation (in) 2010-2015

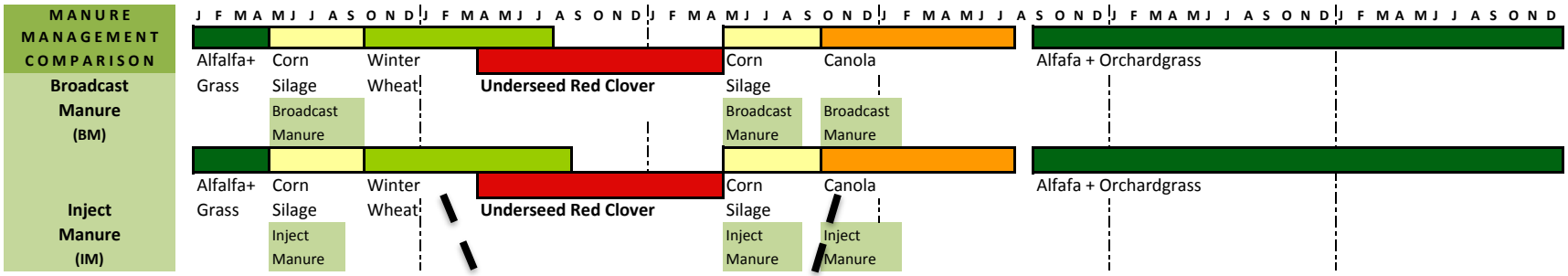


Daily average air temperature (°F) 2010-2015

- low winter temps. (2014, 2015)
- warm spring temps. (2012, 2015)

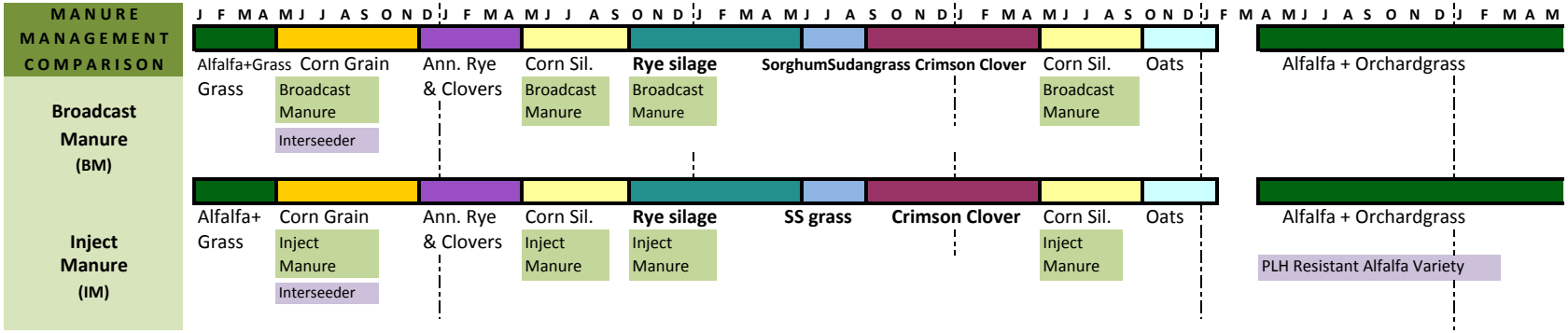
Manure rotation: to produce enough in poor weather years replaced winter wheat and canola

2010 - 2012



with 3rd year of corn silage/rye silage, sorghum sudangrass

Manure Management Rotation: injection vs. broadcast manure, standard herbicides, IPM for insect pests, and non-Bt corn



2013 - 2015

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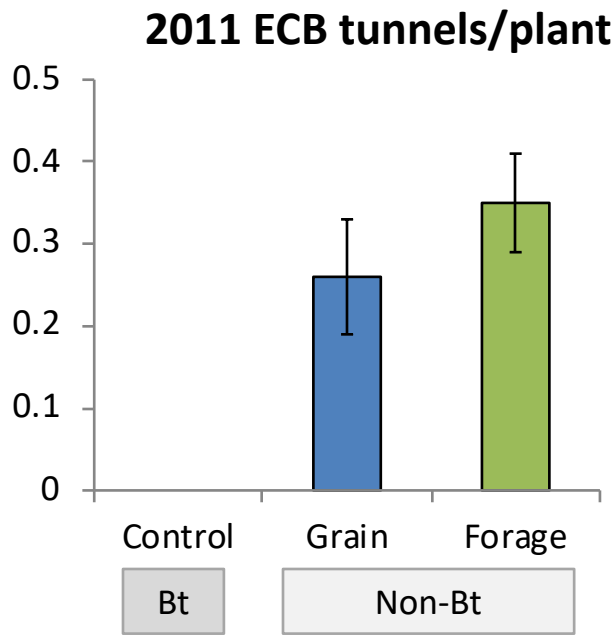

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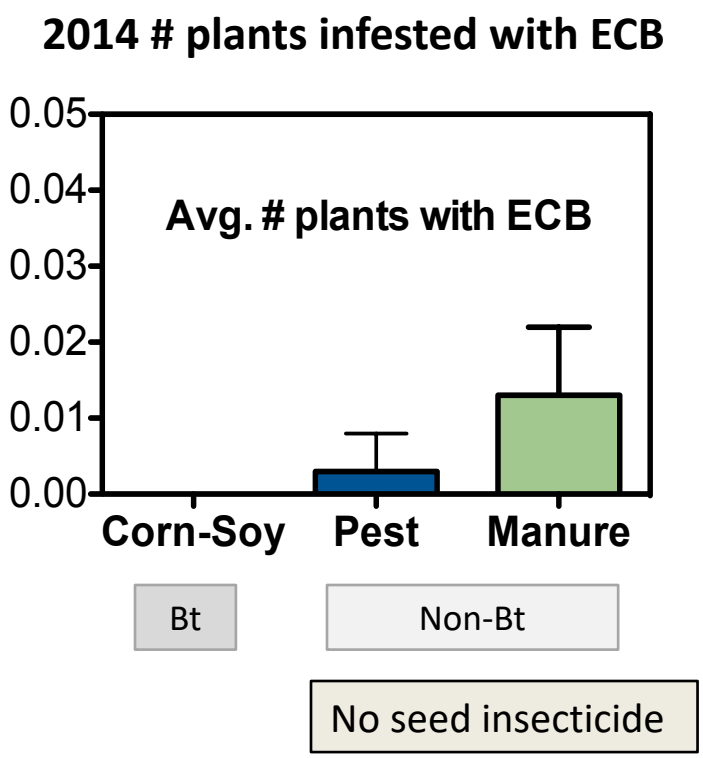
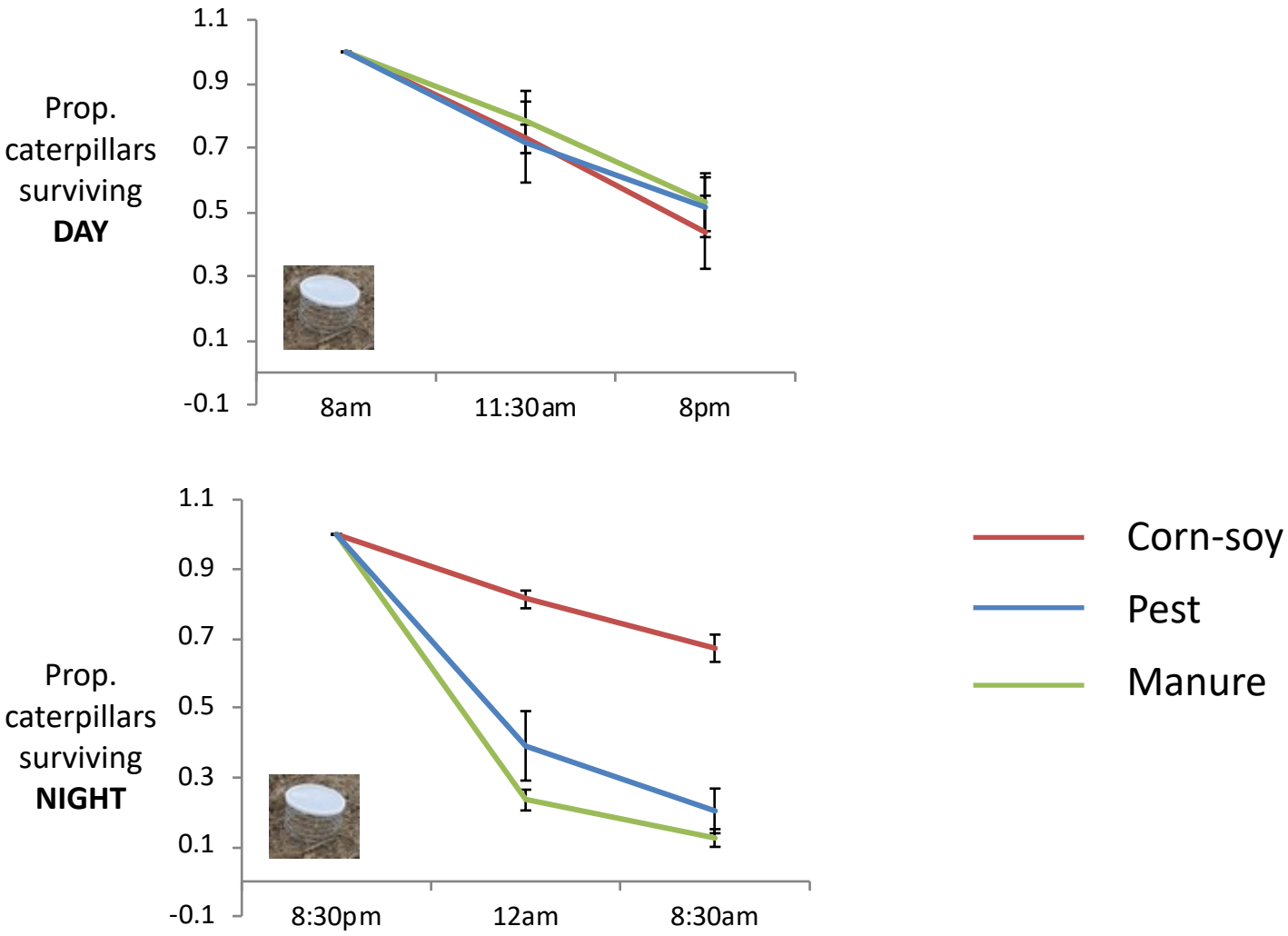


No seed insecticide

Insect predation in corn was higher at night in the diverse rotations each year in June and July

July, 2014, observed the same trend each year



Corn grain yields: 3 of 5 years were higher in diverse rotations vs. the corn-soy rotation.

Corn Yields (Bu A^{-1})
15.5% Moisture

	Diverse Rot. (P)	CORN-SOY (C-S)	P vs. C-S	Centre Co. or PA State Average
Year	SE = 6.86		(p-value)	
2010	202.40	216.68	0.17	132.5
2011	163.60 a	129.08 b	**0.01**	92.7
2012	159.76	170.04	0.31	132.0
2013*	193.64	150.18	**0.03**	147.0
2014*	192.02	154.43	**0.009**	-

Different letters (a,b) indicate statistical significance at the p=0.05 level for yield within year & nested in rotation.

*In the diverse rotation corn followed alfalfa & orchardgrass in 2013 and 2014

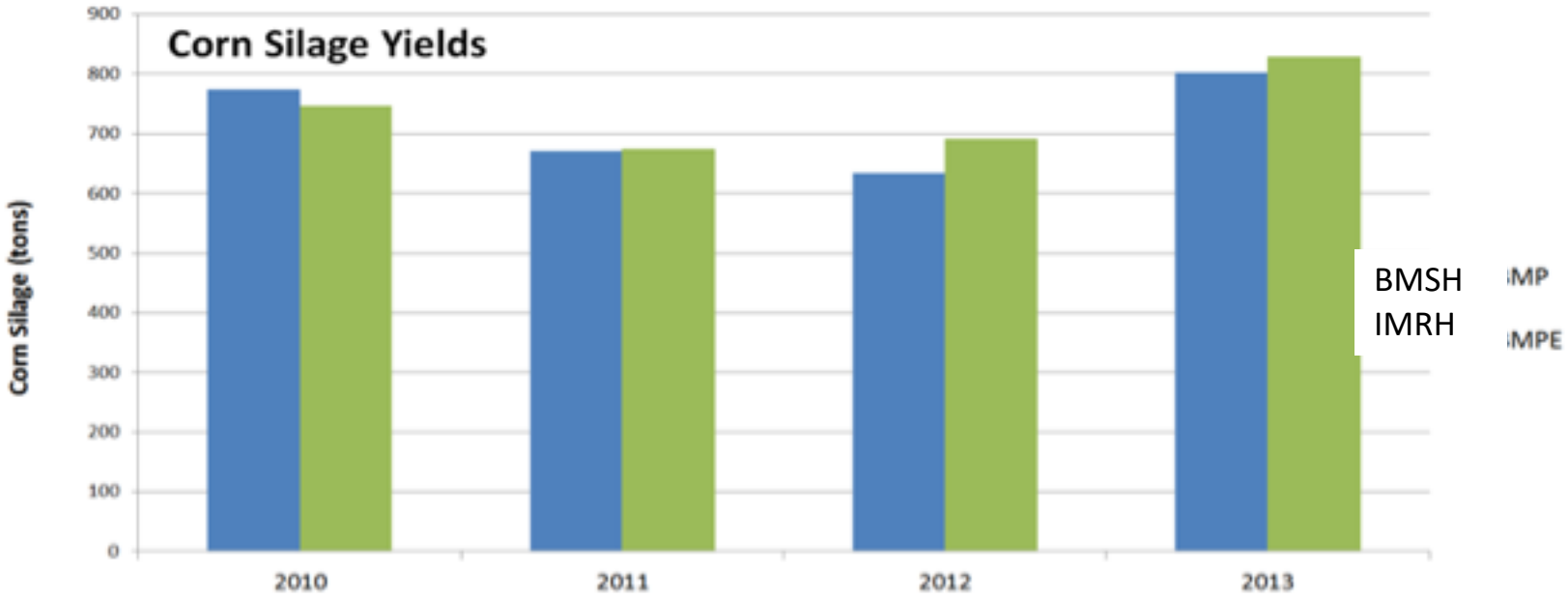
Best Management Farm	Enhanced Best Management Farm
Cover & green manure crops	Small grains for silage
Alfalfa and alfalfa & orchard grass mix	Only alfalfa & orchard grass mix
Integrated pest management	**Reduced herbicide**
Canola for feed and fuel	**Manure Injection** (vs. surface application) Canola for feed and fuel

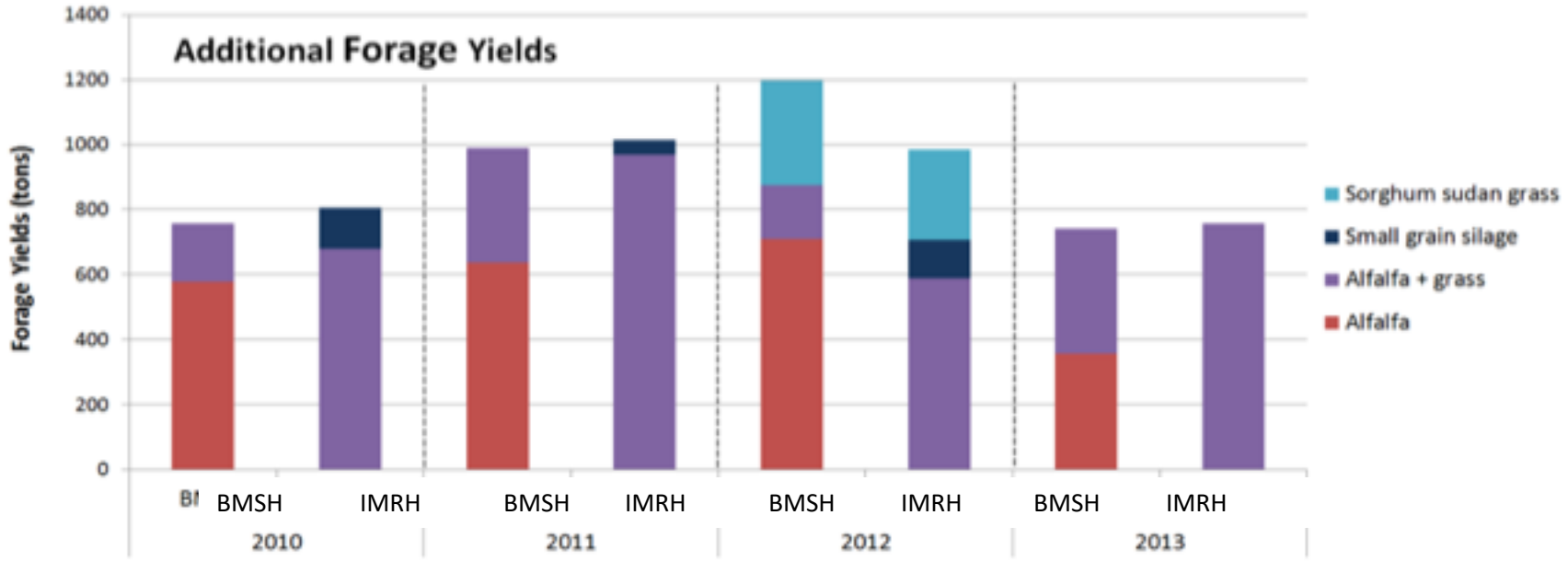
Cultivating weeds between row crops

Small grains (triticale & peas) with alfalfa + orchardgrass vs. pure alfalfa

Injecting manure

Flexible Cropping Strategies





Crop Cost Summary (2011—2014)

Crop	BMSH Average	IMRH Average
Corn Silage $/T Yield T/A	$35.93 18.4	$34.79 19.1
All Hay Crops $/T Yield T/A	$59.77 4.15	$70.78 3.72
Corn grain $/bu. Yield bu/A	$1.85 193.7	$1.85 190.2
Soybeans $/bu. Yield bu/A	$5.27 56.5	$5.68 46.3

Summary

Breakeven Milk Price/cwt

	2011	2012	2013	2014	Avg.	
BMSH Cost per cwt w lbr & mgt	$19.03	$18.21	$19.98	$17.77	$18.75	
IMRH Cost per cwt w lbr & mgt	$19.47	$18.00	$20.22	$16.72	$18.60	
BMSH Dairy Net return over lbr & mgt/cow	$396	$216	$254	$1,911	$695	$800-$1000
IMRH Dairy Net return over lbr & mgt/cow	$290	$274	$211	$2,255	$758	$800-$1000