Compost Bedded Loose Housing (CBP) Dairy Barn for Sustainable Dairy Production

Joseph L Taraba and Jeffery M Bewley

Department of Biosystems & Agricultural Engineering
joseph.taraba@uky.edu

Animal & Food Sciences
jbewley@uky.edu

University of Kentucky

Compost Barn Research Team

Animal Science	Biosystems & Agricultural Engineering	Agronomy & Plant Sciences
Jeff Bewley	Mike Sama	Mark Coyne
Randi Black	George Day	Leslie Hammond
Elizabeth Eckelkamp	Flavio Damasceno	
Bettie Mawonga	John Evans	
Matthew Borchers	Katie Wolf	

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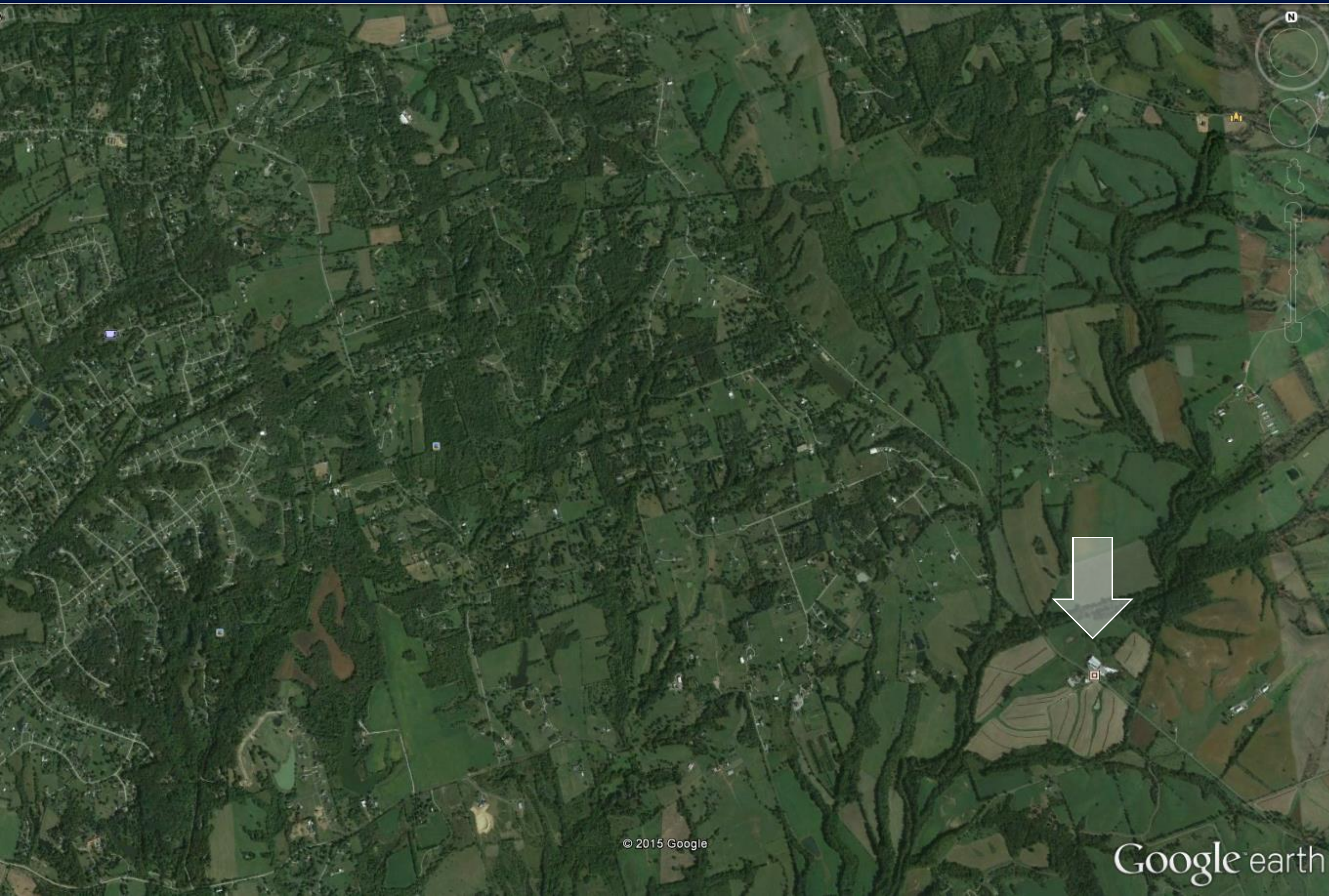
CBP barns fit within goals of sustainable agriculture

- Benefits to the cow
  - Space,
  - health,
  - rest,
  - exercise,
  - social interaction
- Benefits to the farmer
  - low investment,
  - labor-extensive,
  - reduced manure storage costs,
  - milk production (milk quality, milk yield, conception rate),
- Benefits to the environment
  - reduced ammonia and greenhouse gas emissions, odor and dust emissions,
  - reduced energy consumption,
  - improved manure fertility flexibility to meet nutrient management plans).

Goals

- Reduced air and water pollution
- Composting process - Compost bed
- Greenhouse gasses
- Barn Structural impacts - ventilation
- Bed management - bedding and tillage
- Fertility of compost

Environmental Impacts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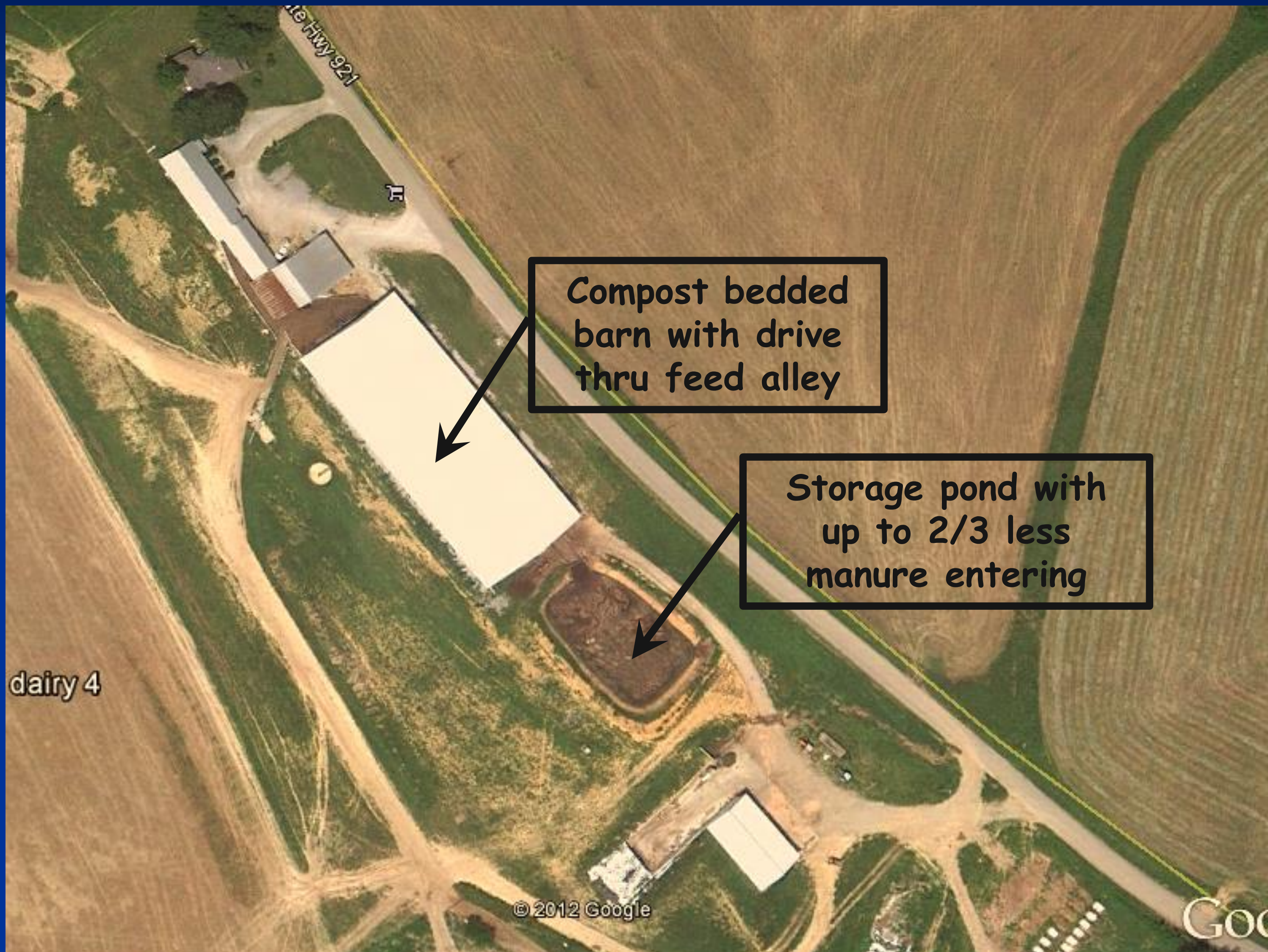
Google earth


Klingenfus Dairy
1315
Hannah Rd

Bedding Impact On Waste System

Compared to freestall barn using sand bedding – "the gold standard":

- Less capital spent for recovery and recycling sand
- Less time and $$ for storage desludging
- Less equipment wear from sand abrasion


Hwy 921
Compost bedded barn with drive thru feed alley
Storage pond with up to 2/3 less manure entering
dairy 4
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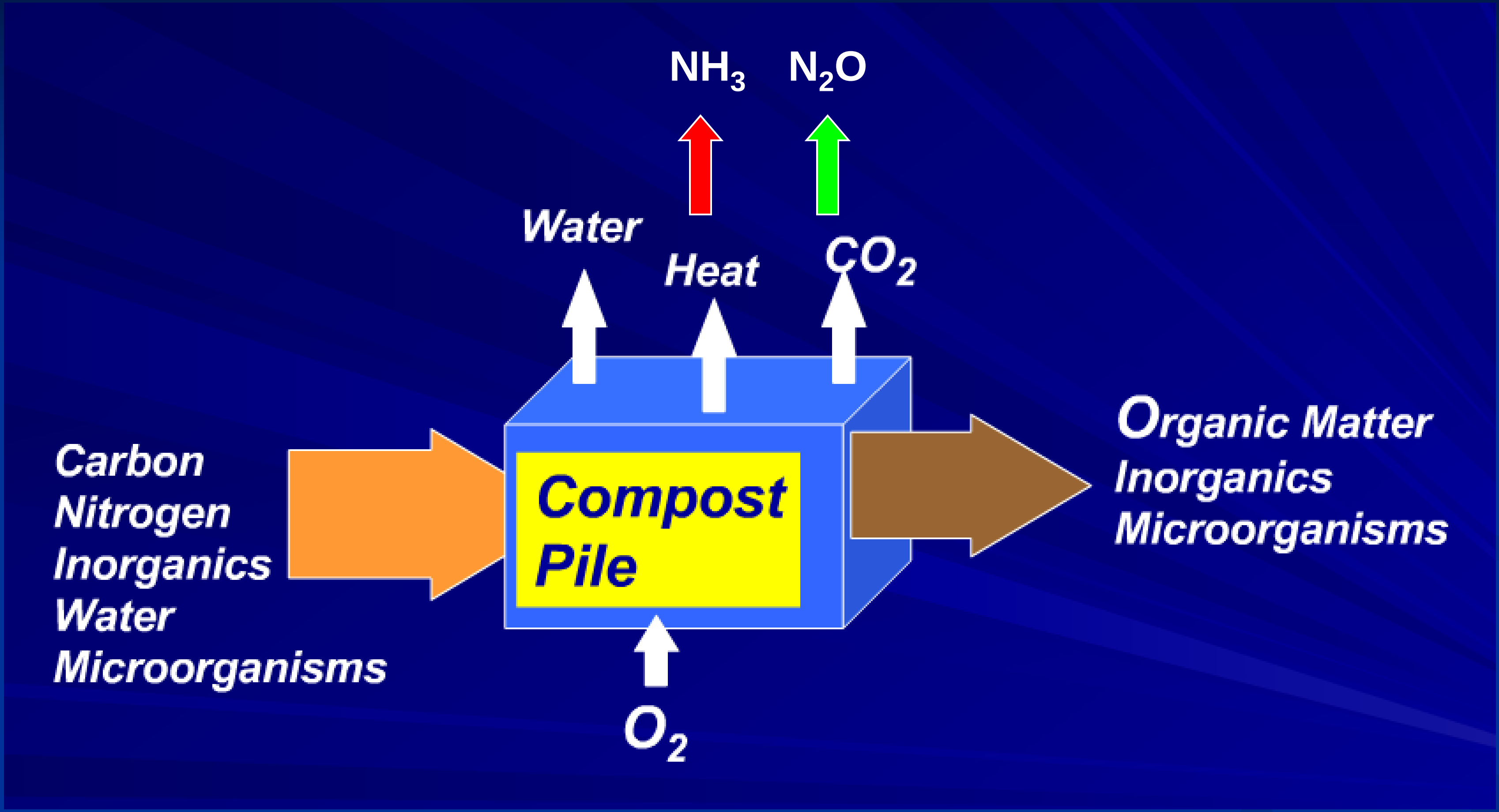
COMPOST BEDDED LOOSE HOUSING BARN

Important alternative manure management practice to allow flexibility in utilization of plant nutrients and organic matter for soil fertility.

Composting Process

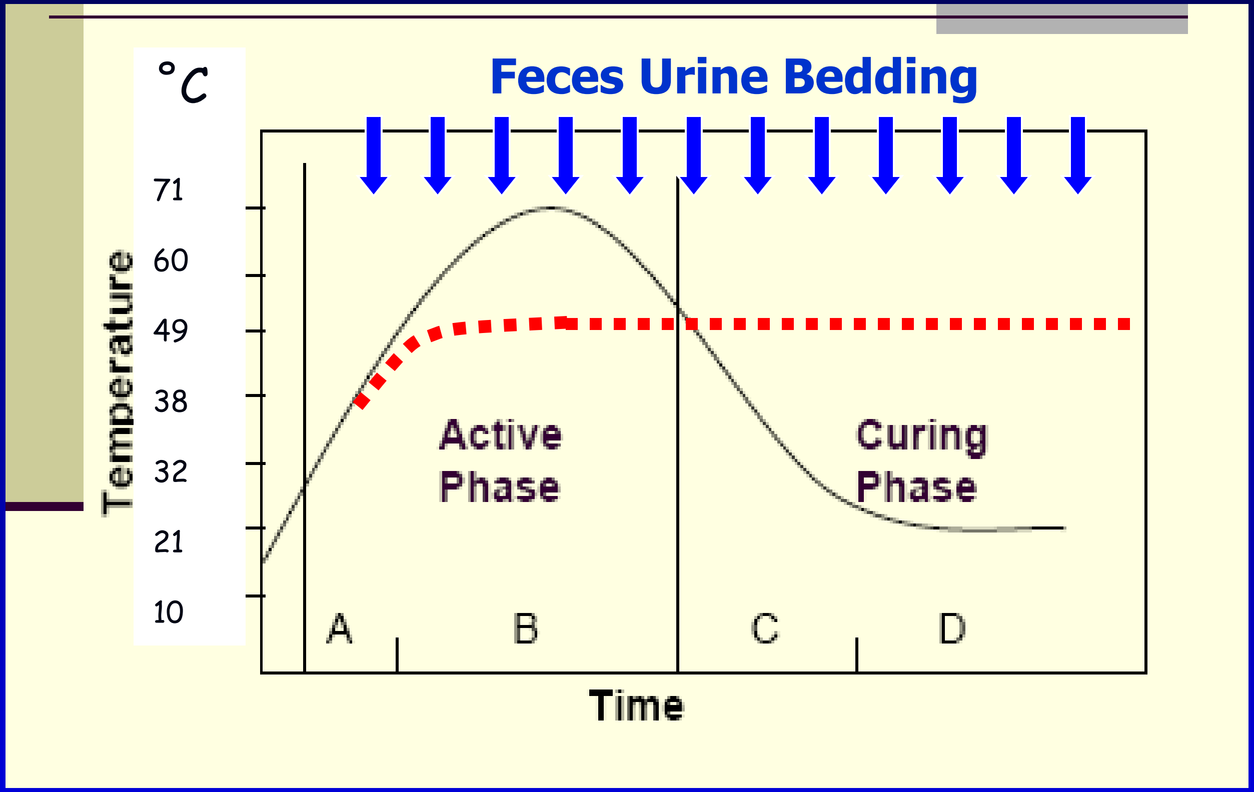
Compost Dairy Barn

The "Ideal" Composting Process



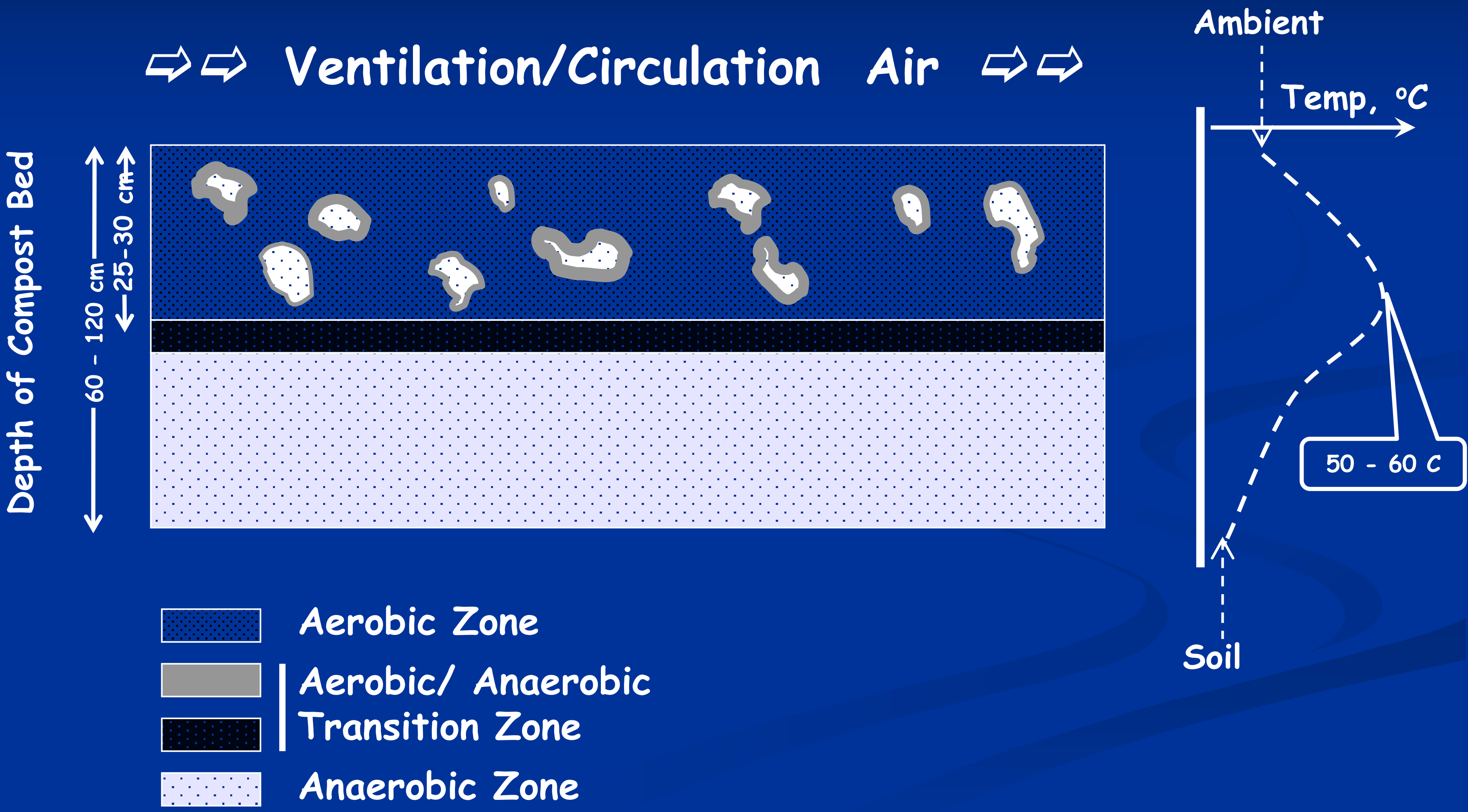
Temperature Dynamics

Adding feces, urine and bedding continuously changes static bed composting process



A=mesophilic
B=thermophilic
C=mesophilic
D-maturation

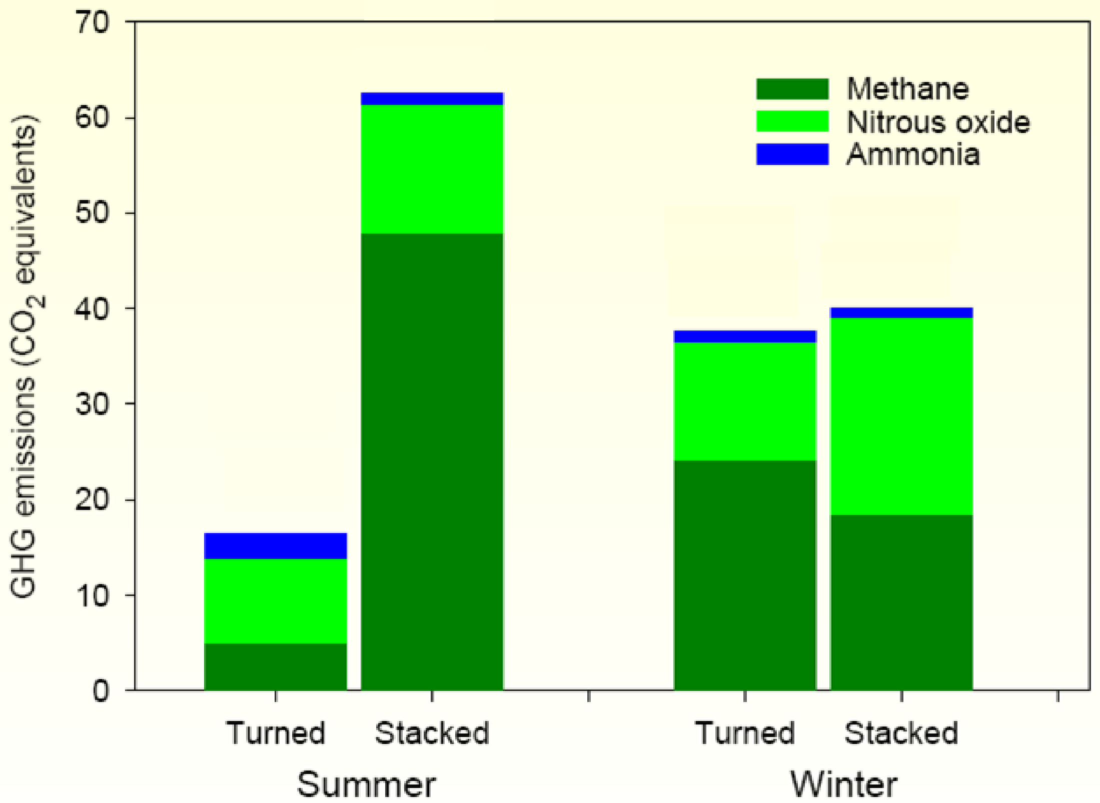
Compost Bedded Pack



Aerobic Zone
Anaerobic Zone

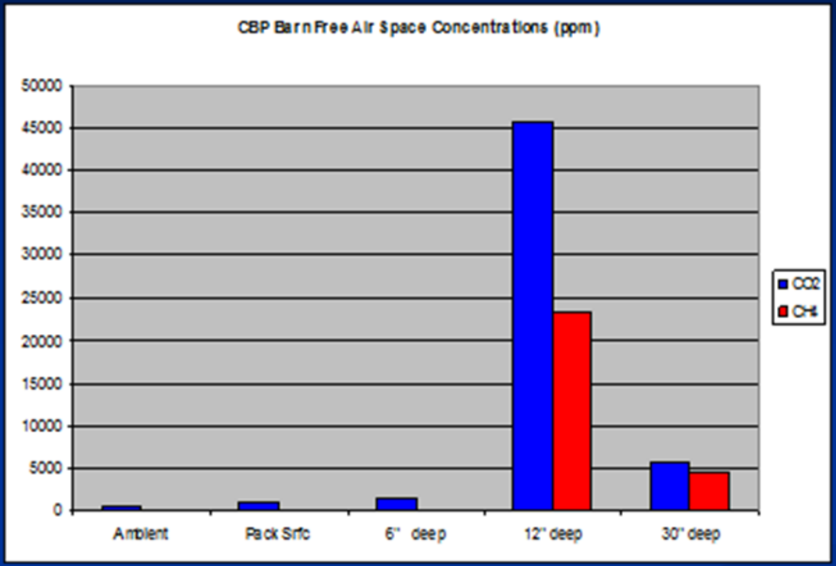
For Equal Heat Loss Surface Areas:	Heat Loss to Air Surface Area (sq. m) / Heat Generation Volume (cu m)
Compost Windrow Aerobic Zone	1.6
Compost Bed Aerobic Zone (20 cm depth)	6.1
Compost Bed Aerobic Zone (30 cm depth)	4.1

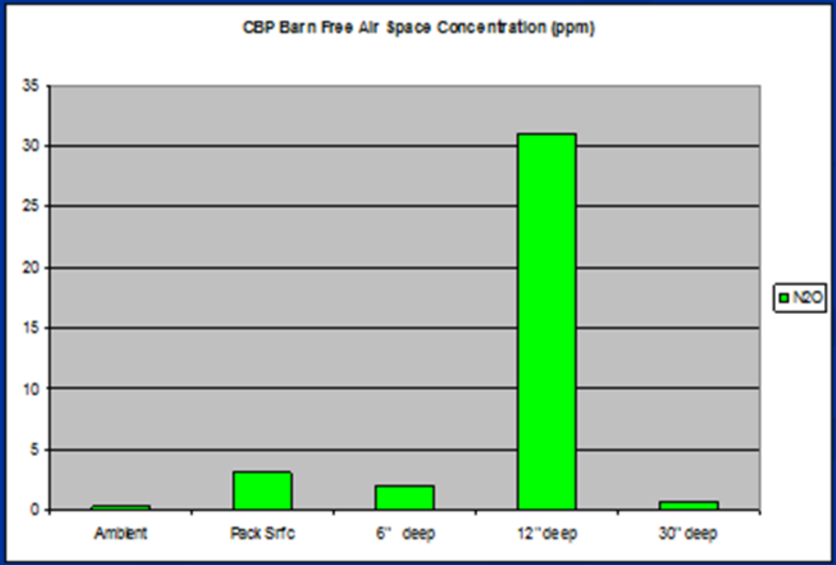
GHGs and Dairy Manure



(Amon et al., 2001)

Limited GHG Measurements





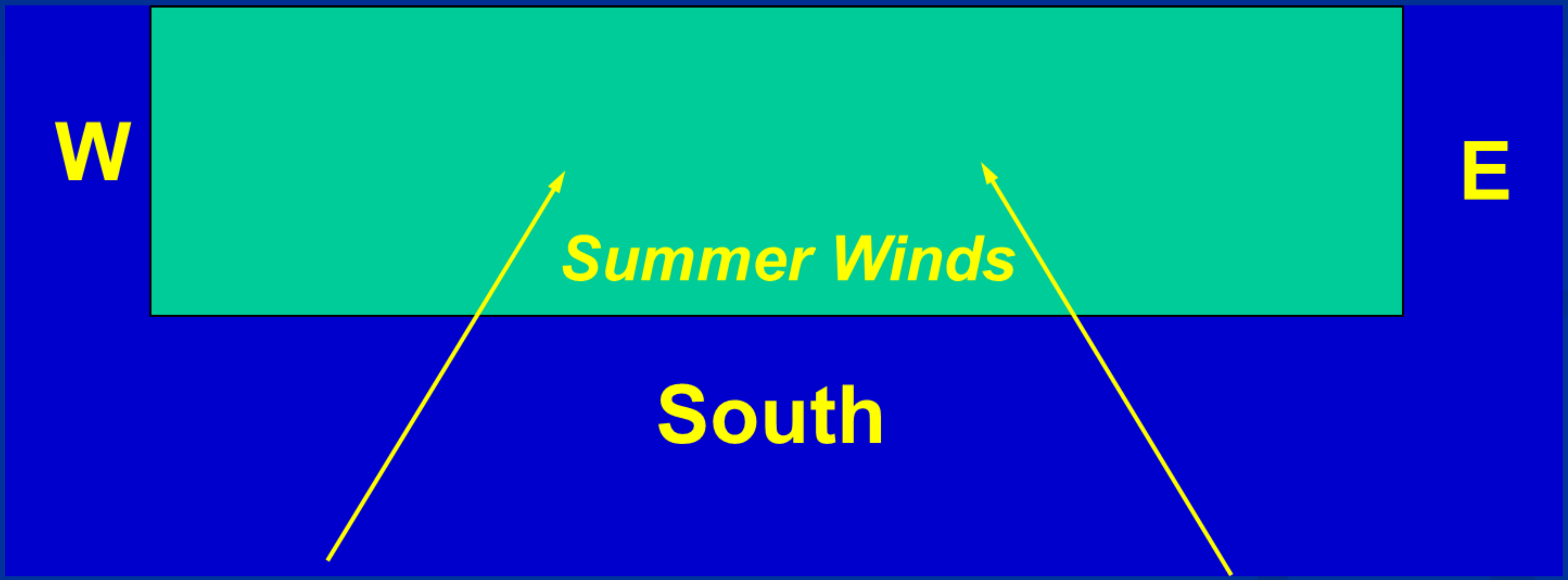
What Was Learned of Constructed Compost Barns

Heat and Moisture Concerns in Compost Barn

Structural Components Affecting Ventilation Rate

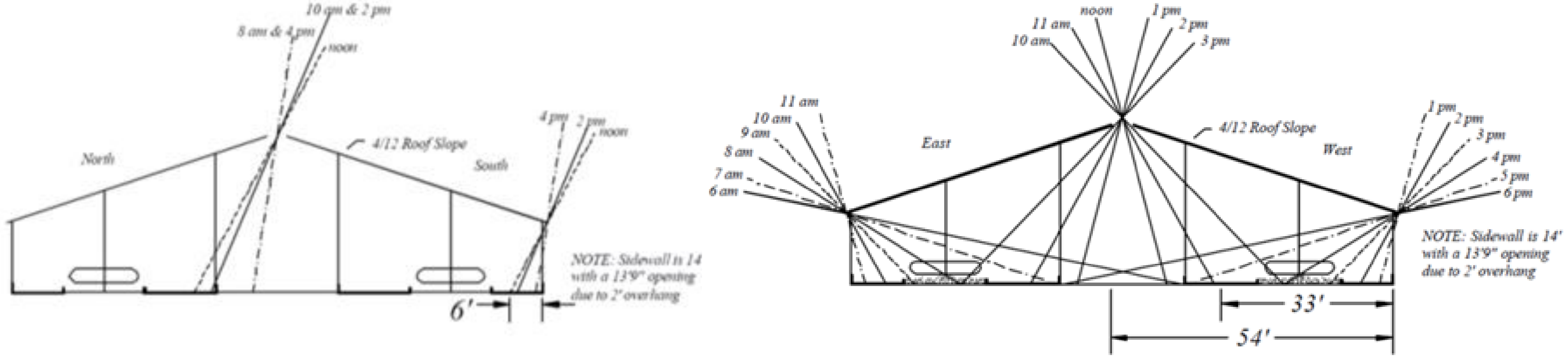
- Orientation
- Position within landscape
- Nearby obstructions upwind and downwind
- Side wall opening height
- Side wall opening area
- Roof elevation
- Roof slope
- Ridge opening width
- Ridge opening design

Orientation - Wind



Orientation - Sunlight

- East-west orientation has least sunlight penetration over north –south



Sun Angles for E-W Freestall - August 21st

40 Degrees North Latitude (Omaha - Springfield)

Sun Angles for N-S Freestall - August 21st

40 Degrees North Latitude (Omaha - Springfield)

Roof Pitch and Style

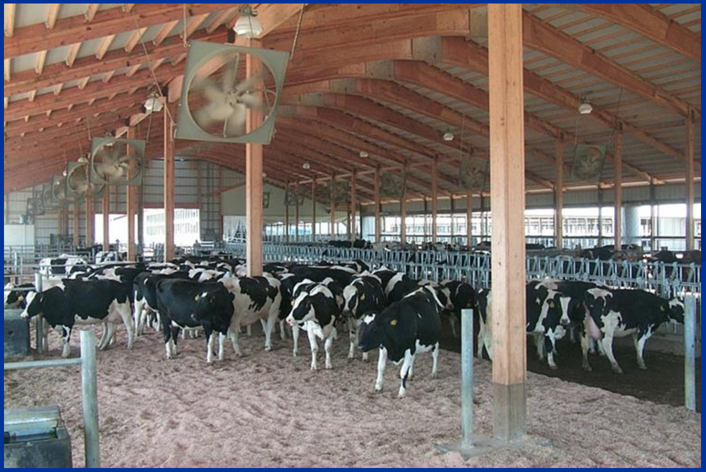
- Under calm winds, a gable roof has 3.5 times higher ventilation rate then a monoslope roof (shed roof)
- Under calm winds, the 5/12 pitch gable roof had a 35% higher ventilation rate than the 3/12 pitch gable roof
  - For the same structure width, a higher pitch roof ridge vent has higher elevation over inlet that increases buoyancy

Side Wall Opening

- Under calm winds, higher side wall opening gave higher ventilation rate
- In winds, if opening increased from 1.8 m to 3 m ventilation rate increased by 60%

Circulation/Cooling Fans

- Two types fans:
  - HVLS ceiling fans for air speeds at cow level of 2 m/s
  - Box/Panel fans for air speeds of 4 m/s
- Fan spacing
  - 2.5 times HLVS fan diameter
  - 8-10 times box/panel fan diameter



Potential Warm Weather Compost Bed Drying Rate

- Rototilled bed (~ 55% wb) - Cows Producing 23 kg/day

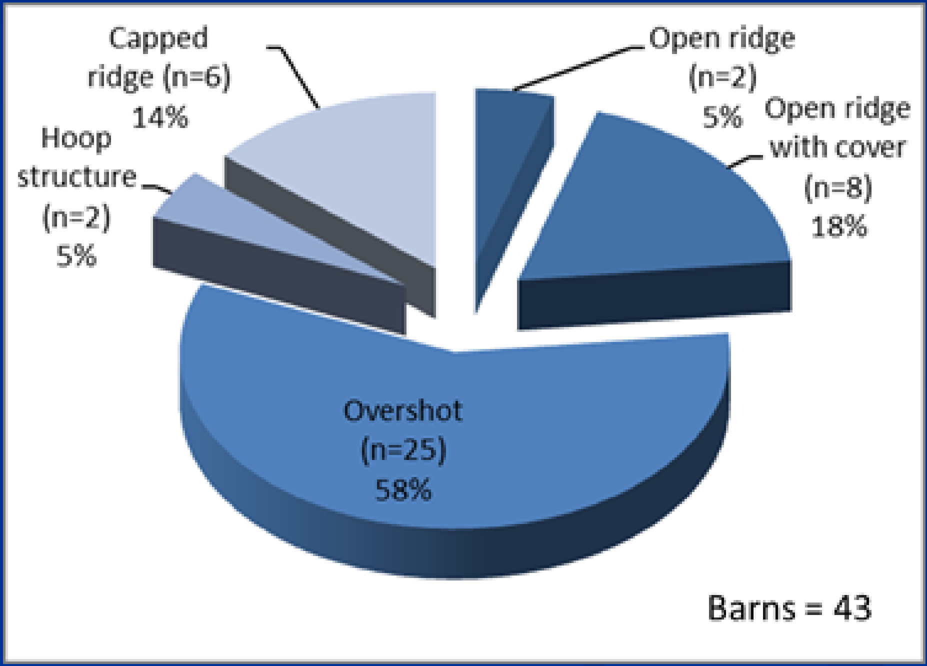
Air Velocity 2" Above Bed Surface		Net Water Drying Rate	Cow water output
mph	ft/min	#/ft2/day	#/day/ft2
4	360	0.9	0.93
2	180	0.6	0.93
0	0	0.2	0.93

Ridge Vent - Opening

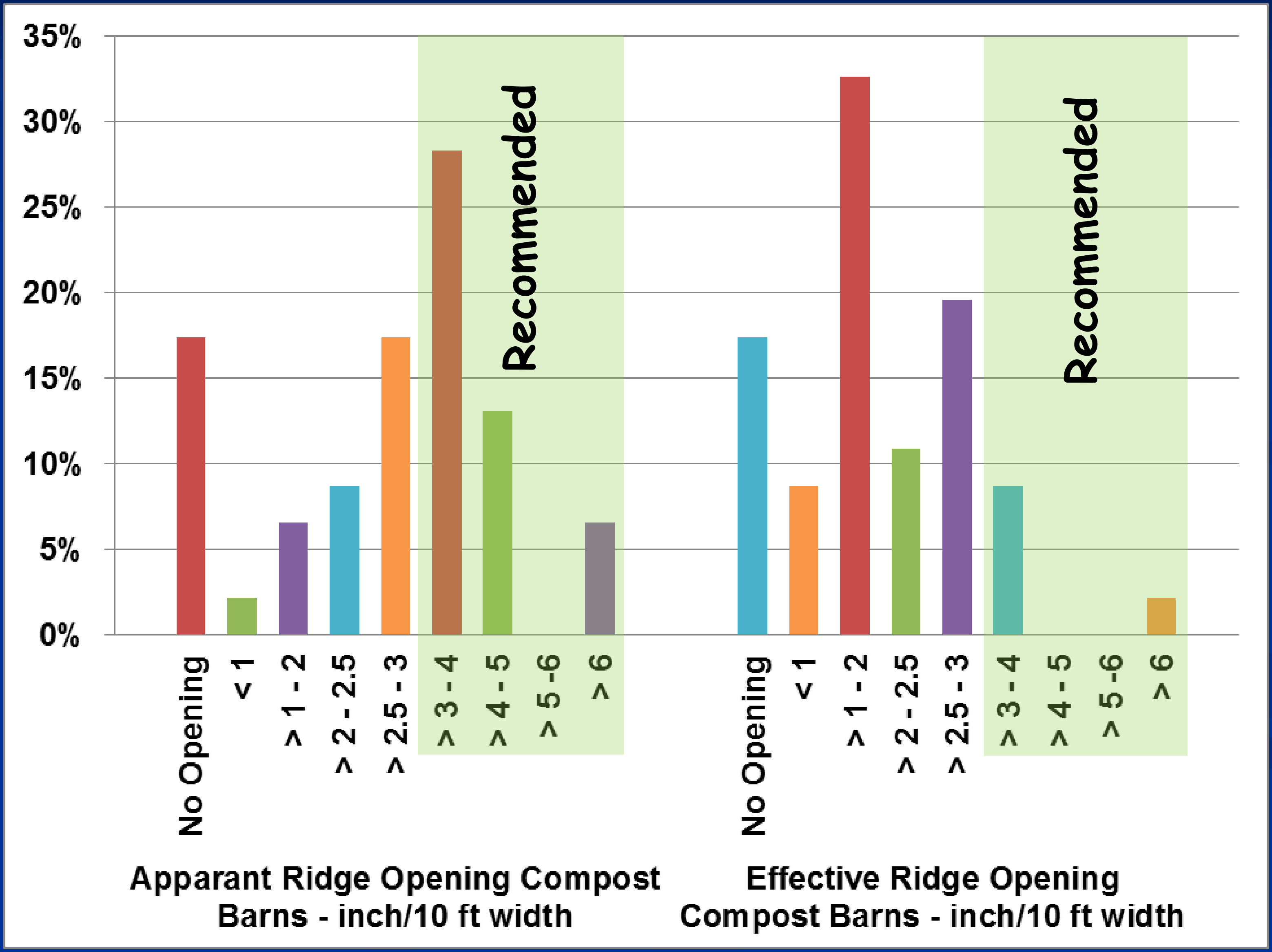
- In calm winds, barn ventilation rate increases 2.5 times if ridge opening is increased from 1.7 cm/m building width to 4.2 cm/m
- Under windy conditions, an open ridge of 2.5 cm/m of barn width will increase the barn ventilation rate by 33% over 1.7 cm/m

Ridge Design

Type		Name	
		Open Ridge	Recommended
		Open ridge with cover	
		Overshot	
		Hoop structure	
		Capped ridge	



Ridge Opening to Barn Width Ratio



Potential Design Flaws

- Not enough space per cow
- Inadequate ventilation
  - Sidewall opening above retaining wall too low (<3.5 m)
  - Too close to other buildings (, 25 m)
  - Too small ridge opening (<4.2 cm/m of width)
  - Poor ridge opening design
  - Fan availability/placement
- Lack of eave overhangs (1/3 side wall height or curtains to block rain and cold wind
- Building orientation
- Alleyways <4.25 m
- Walls along pack
- Proximity to feed
- Not enough feed bunk space (60 to 75 cm per cow)
- Not enough water space (60 cm of tank perimeter per 15 to 20 cows
- Cow flow/traffic bottlenecks
- Waterers access from pack
- Concrete base?
- Access to alleyway from pack limited (access spacing <3.5 m)
- No fence on top of knee walls

Potential Design Flaws Cause

Grouping/Crowding of Cows
in Heat Stress

Managing the Compost Bed

Stirring the Bed

2 x per day **religiously**

Rototiller tillage depth 15-20 cm


25-30 cm stirring depth with deep tillage

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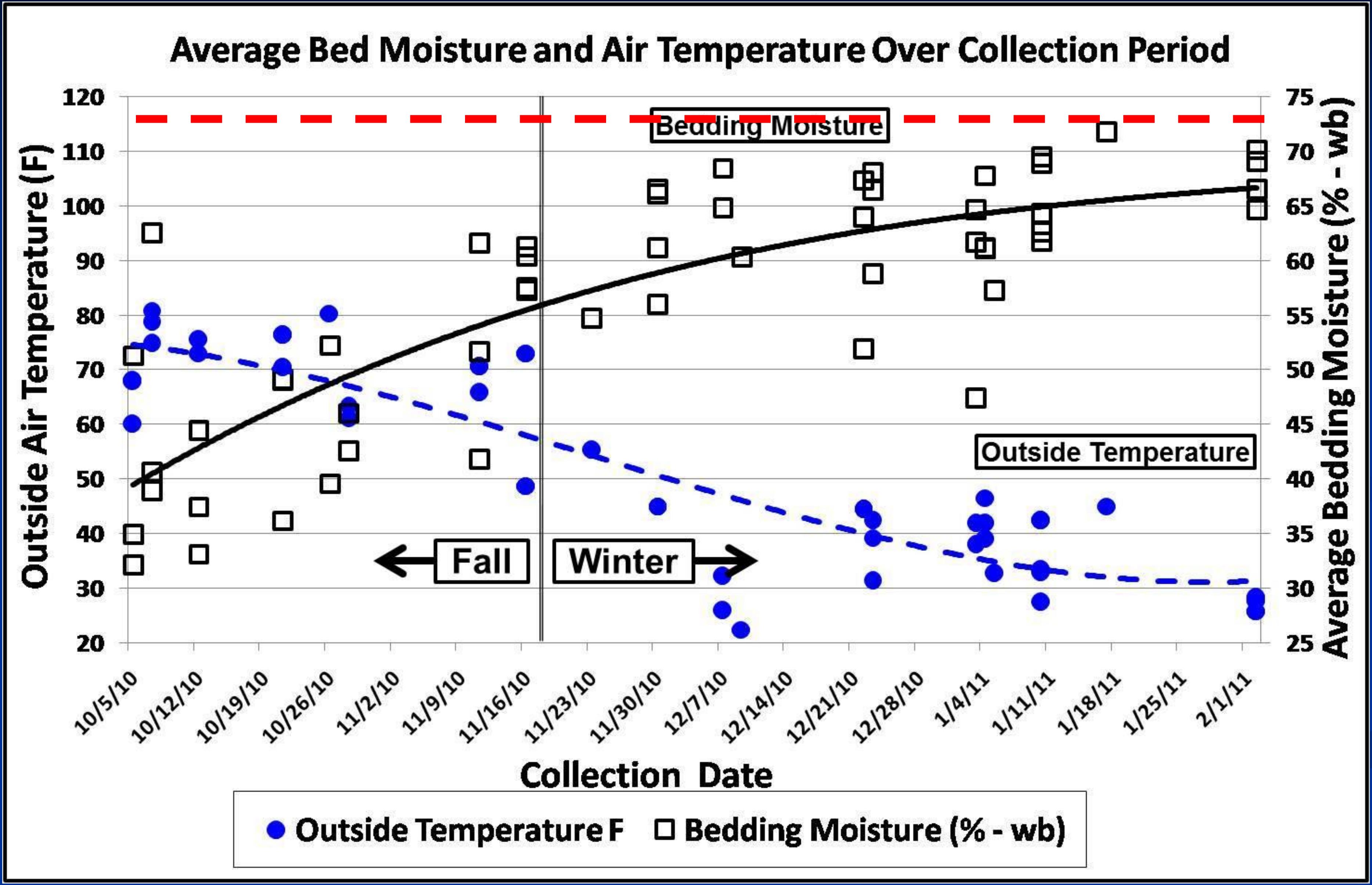
Hybrid Tillage/Aeration Tool

Average Water Holding Capacity = 72.7%



Pack Moisture Control

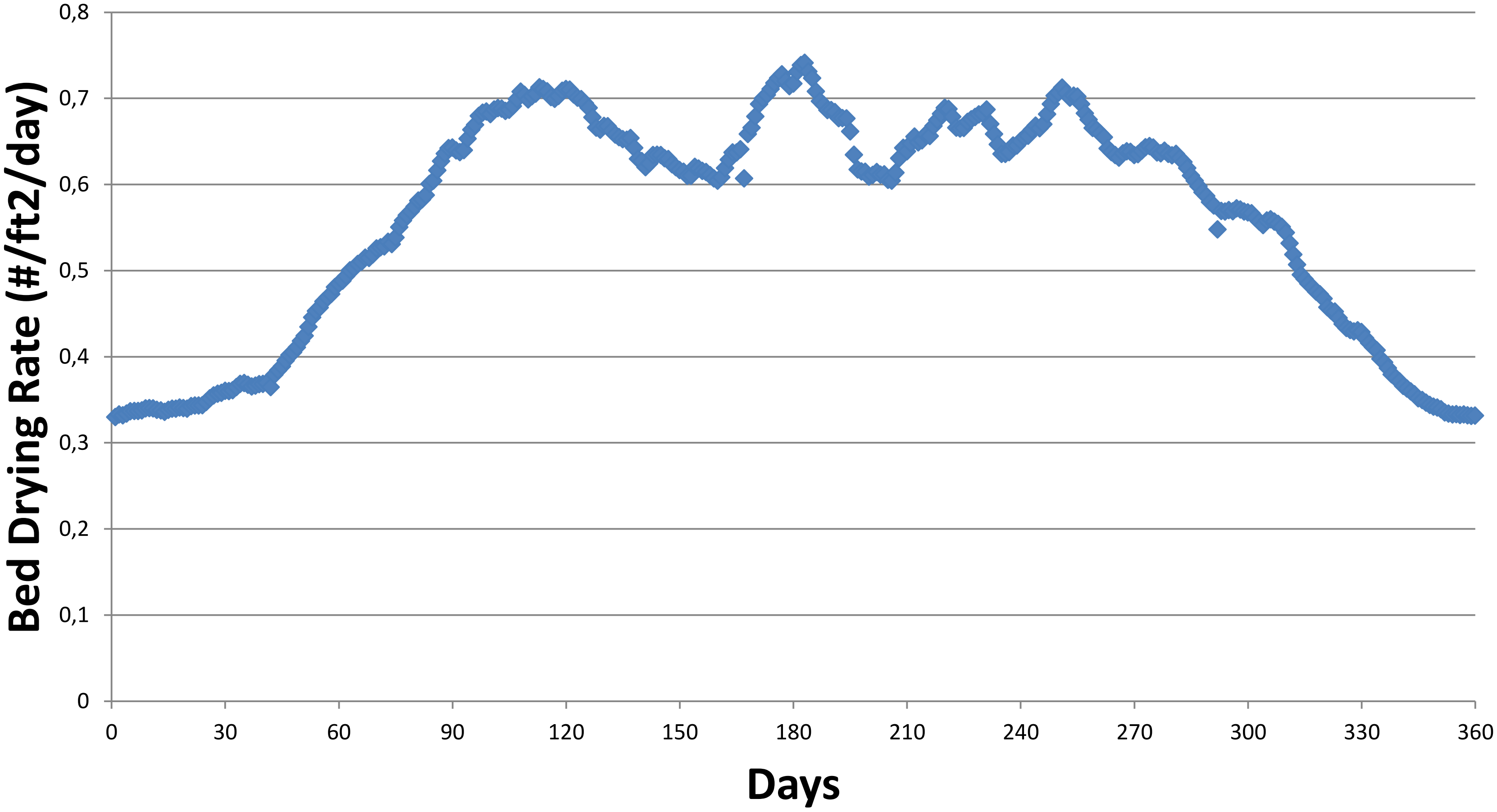
MOST IMPORTANT MANAGEMENT FACTOR

- Biological activity generates heat which helps to dry the bedding material
- Bedding cannot absorb all the water from urine and manure without evaporation of water

Unless area per cow more than doubles in winter/wet season

- Too wet of a bedded pack reduces aeration, slows biological activity, slow heat generation and water evaporation

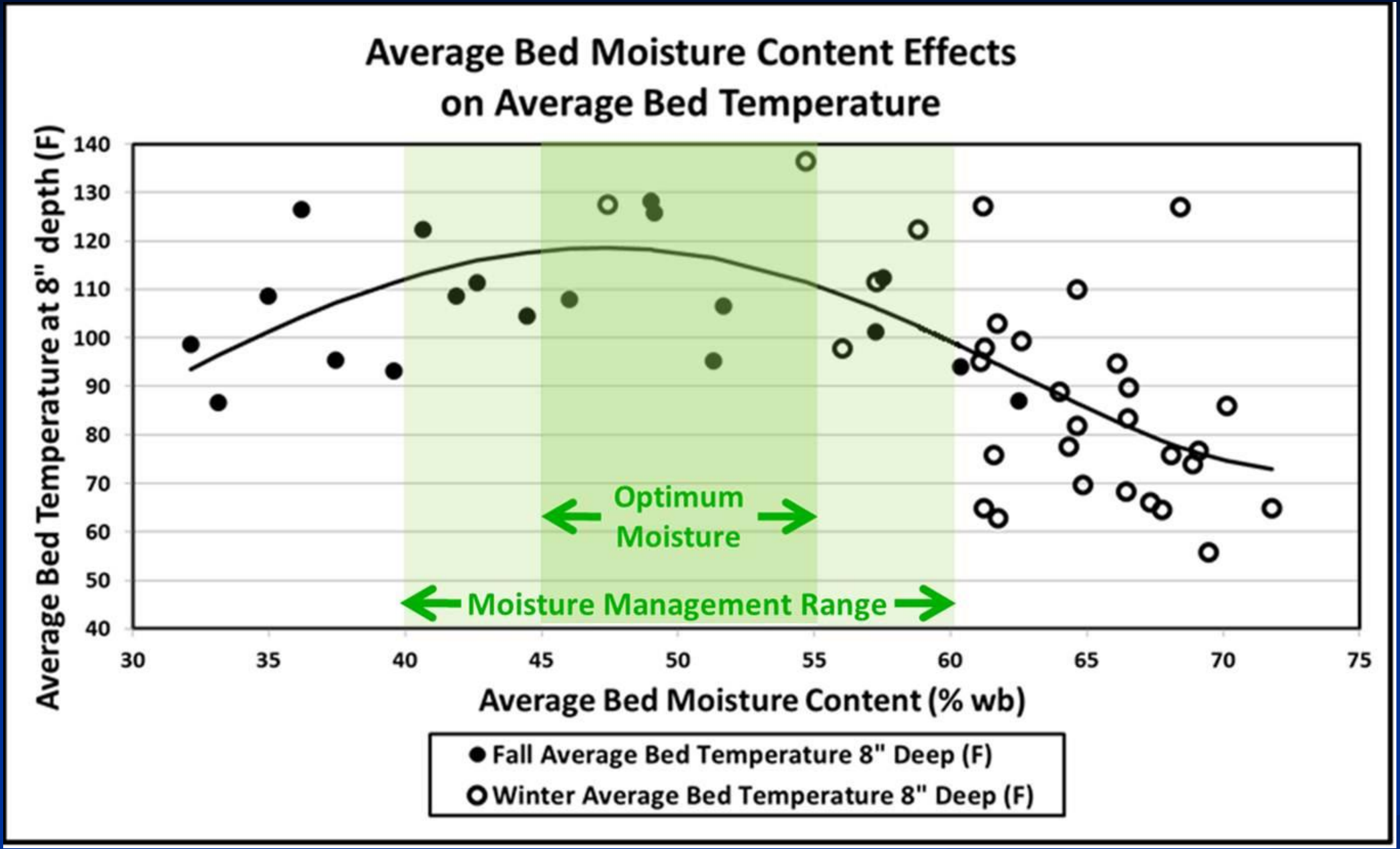
Bed Drying Rate during a Year
- Using 30 year weather means -

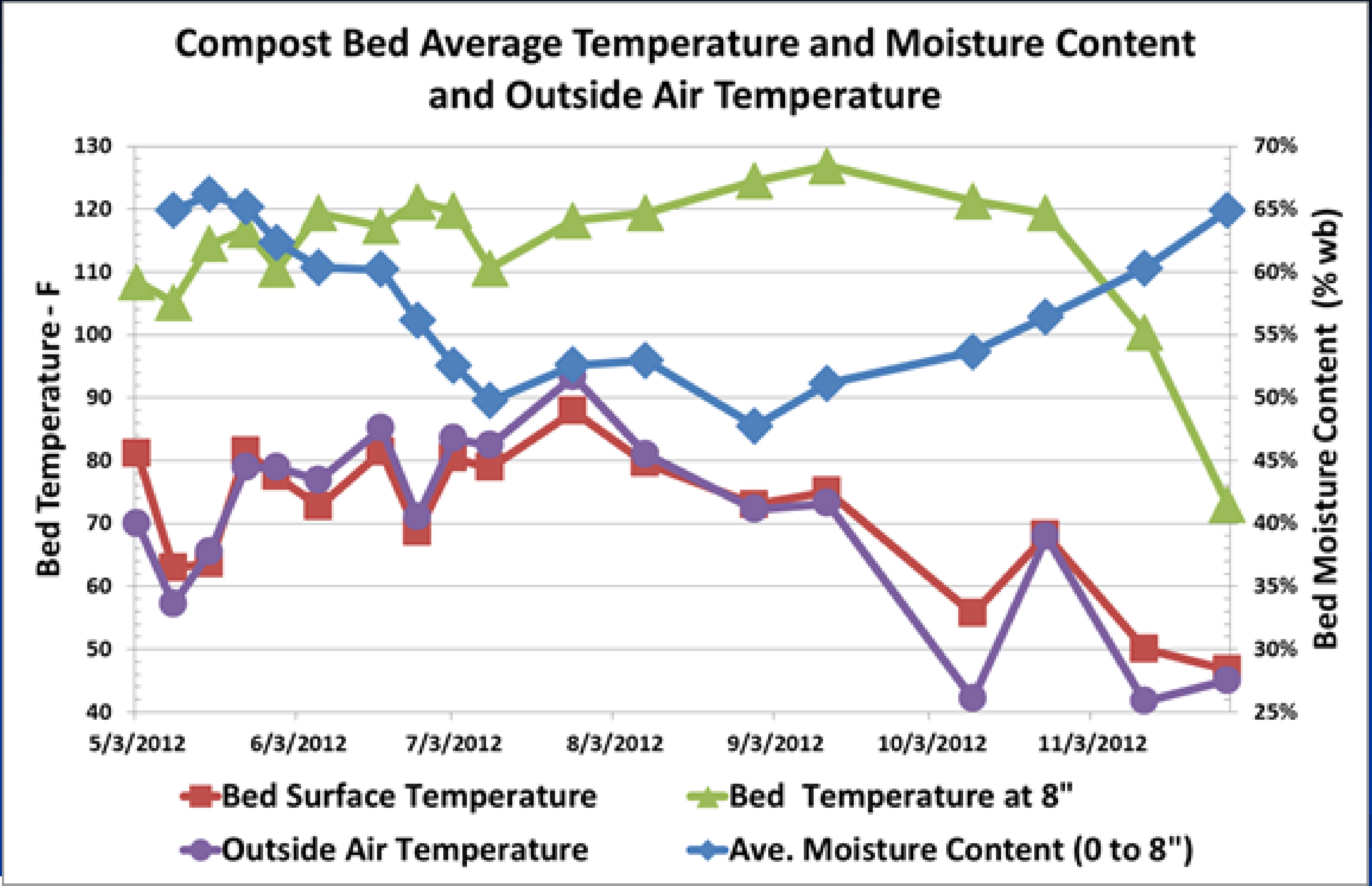


Potential Bed Failure

Dense Beds

Poor Hygiene


Average Bed Moisture Content Effects
on Average Bed Temperature
Average Bed Temperature at 8" depth (F)
140
130
120
110
100
90
80
70
60
50
40
Optimum
Moisture
Moisture Management Range
30
35
40
45
50
55
60
65
70
75
Average Bed Moisture Content (% wb)
Fall Average Bed Temperature 8" Deep (F)
Winter Average Bed Temperature 8" Deep (F)



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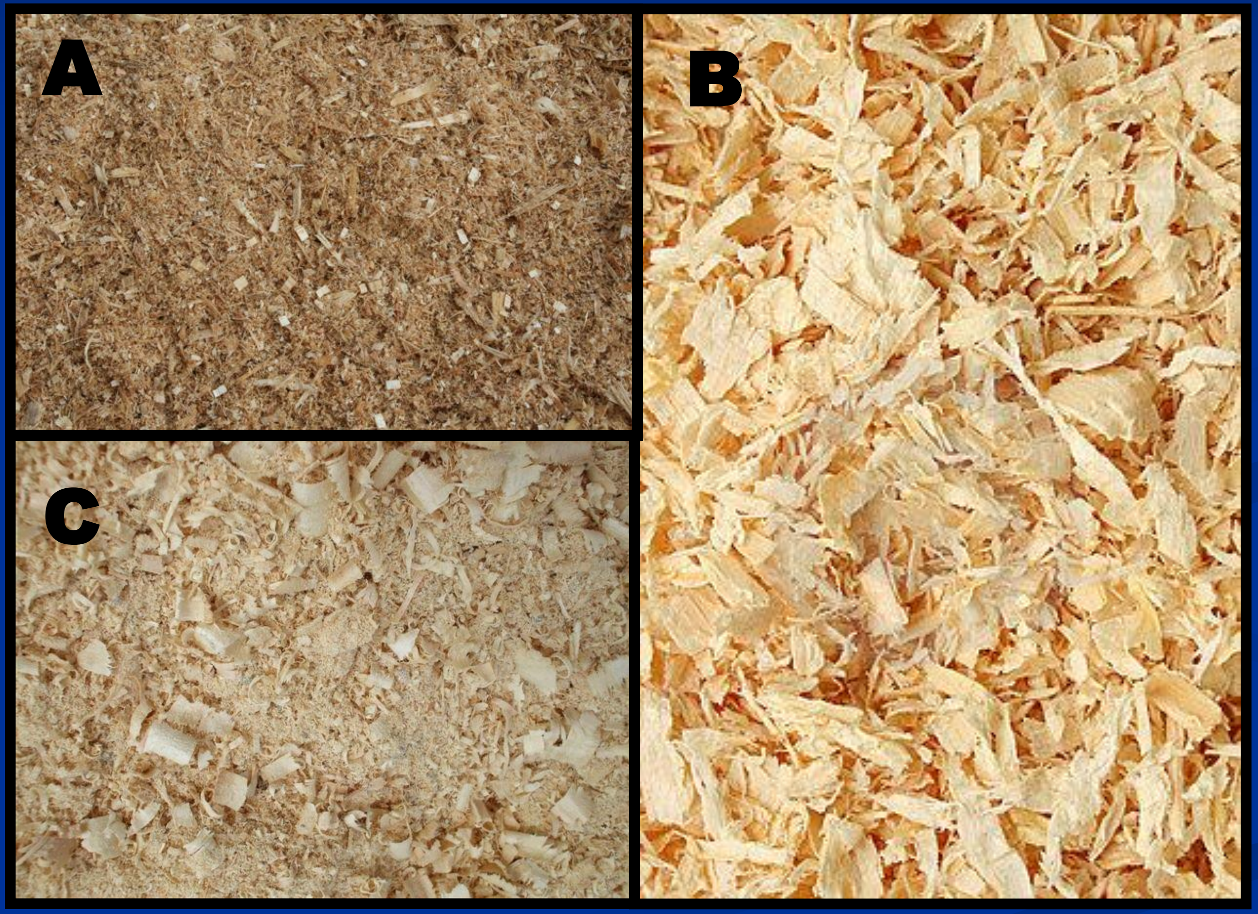
Type Bedding Materials

Sawdust



Shavings

Sawdust/
Shavings

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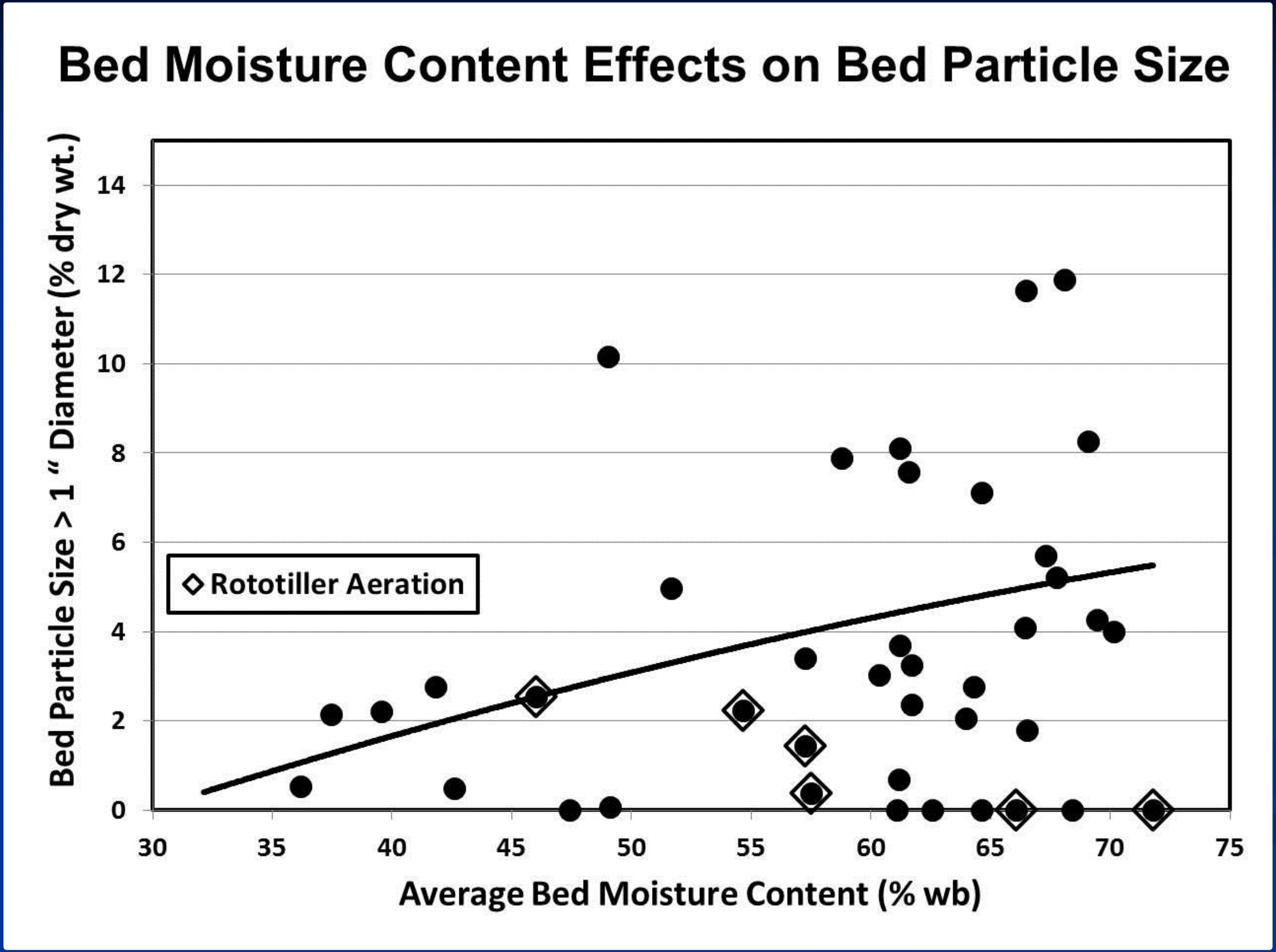
1:1 Ground Straw:sawdust

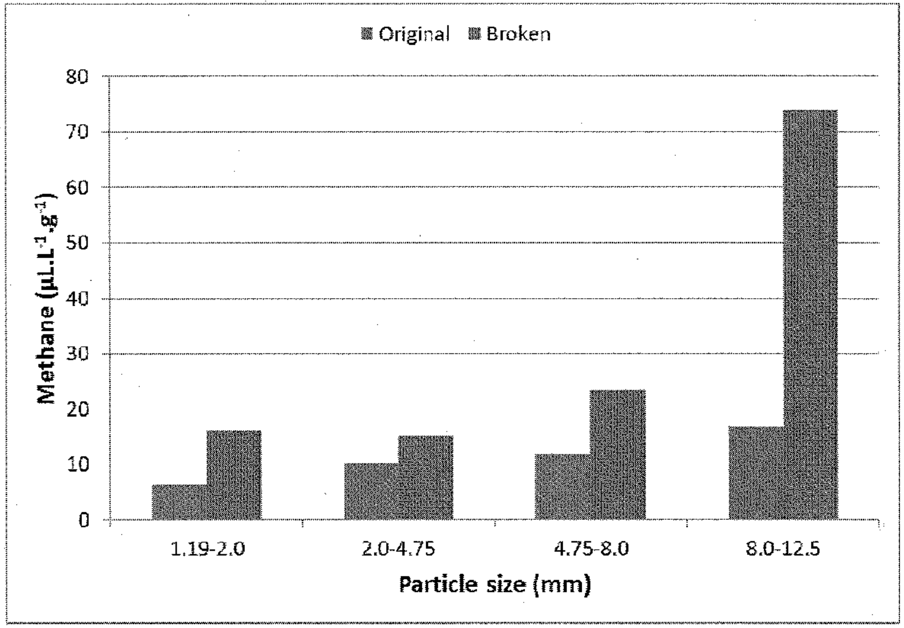

Ground Straw

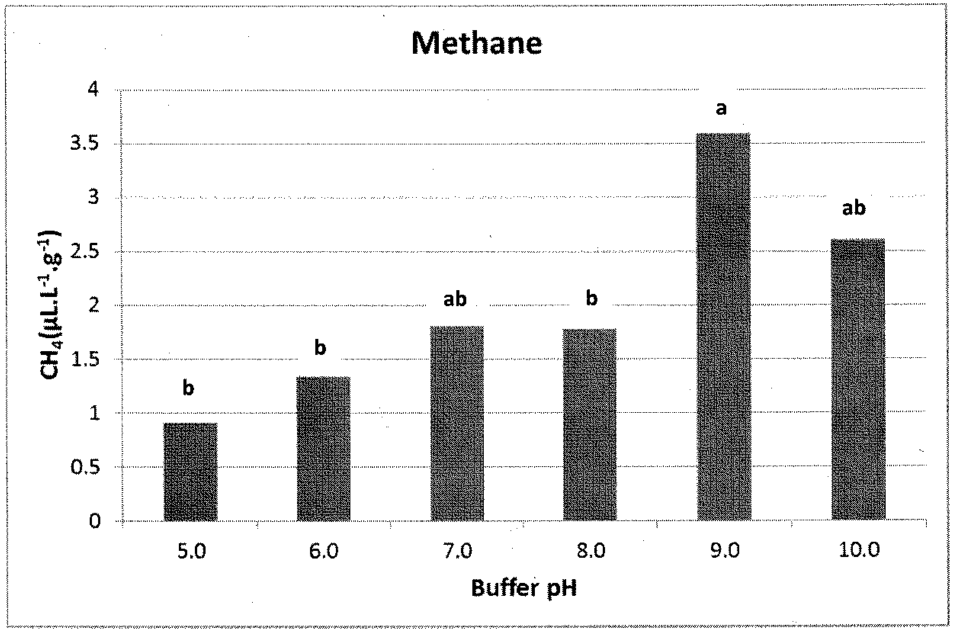

Ground Straw
thru 2 cm Screen
Chopped
Straw


Sweep tillage tool
Rototiller tillage

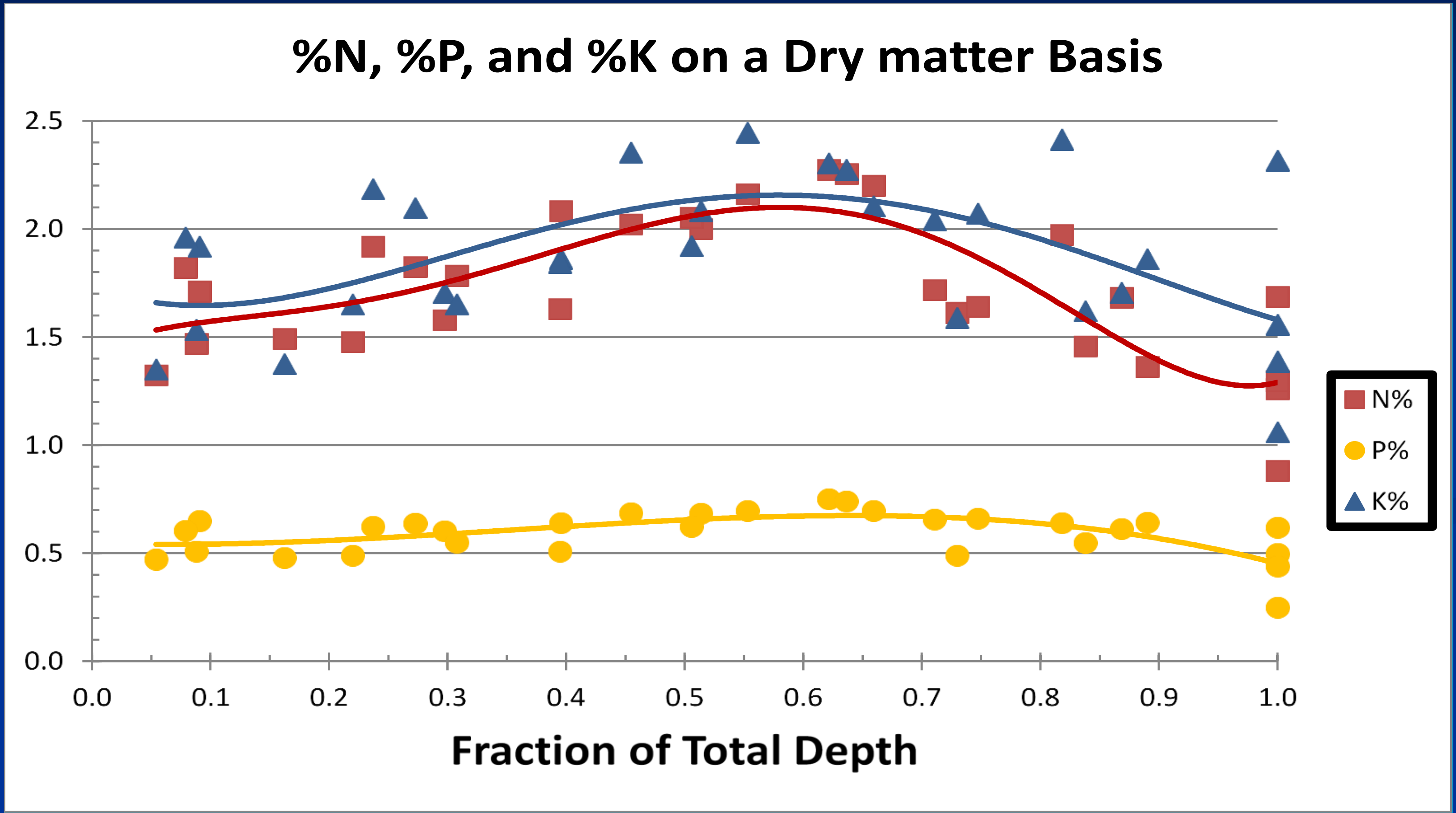

Bed Moisture Content Effects on Bed Particle Size
Bed Particle Size > 1 " Diameter (% dry wt.)
0
2
4
6
8
10
12
14
30
35
40
45
50
55
60
65
70
75
Average Bed Moisture Content (% wb)
◇ Rototiller Aeration

Particle Size and pH Affect GHG Production

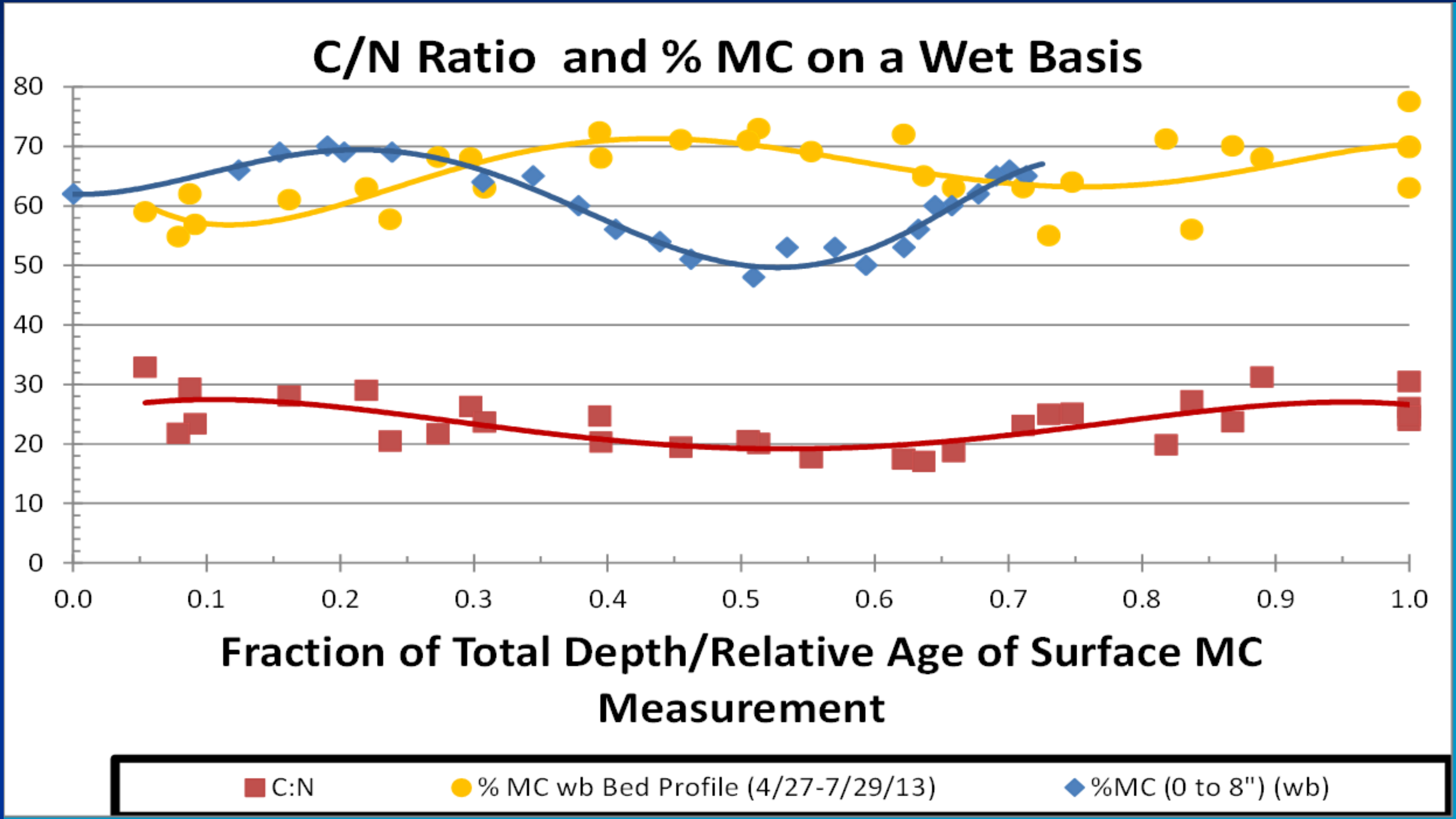




Compost Fertility



The highest fertility values are reflected around 50-60% fraction of the profile.



Lower moisture contents tend to experience lower C:N ratios.

Change in Soil Test Phosphorus

Faywood silt loam soil

Low STP

Time (Days)	Control STP (mg kg^{-1})	25 CBP	25 Fresh Manure	50 CBP	50 Fresh Manure	100 CBP	100 Fresh Manure
		Application Rate (mgkg^{-1})					
0	18^{a}	38^{b}	NS^{a}	66^{c}	27^{d}	116^{e}	41^{b}
30	18^{a}	34^{bc}	32^{b}	50^{d}	38^{c}	98^{e}	50^{d}
60	16^{a}	23^{b}	25^{b}	34^{c}	31^{c}	62^{d}	45^{e}
90	16^{a}	21^{b}	24^{b}	40^{c}	30^{d}	72^{e}	42^{c}
120	16^{a}	19^{ab}	24^{b}	30^{c}	30^{c}	54^{d}	43^{e}

NS =; not a significant change from the control; α=.05.

High STP

Time (Days)	Control STP (mg kg^{-1})	25 CBP	25 Fresh Manure	50 CBP	50 Fresh Manure	100 CBP	100 Fresh Manure
		Application Rate (mgkg^{-1})					
0	189^{a}	209^{b}	201^{c}	220^{d}	210^{b}	273^{d}	237^{e}
30	184^{a}	200^{bc}	198^{b}	216^{d}	204^{c}	264^{e}	216^{d}
60	172^{a}	197^{b}	196^{b}	209^{c}	197^{b}	237^{d}	230^{e}
90	188^{a}	212^{b}	199^{c}	223^{d}	219^{d}	257^{e}	242^{f}
120	191^{a}	209^{b}	205^{b}	219^{c}	223^{c}	249^{d}	246^{d}

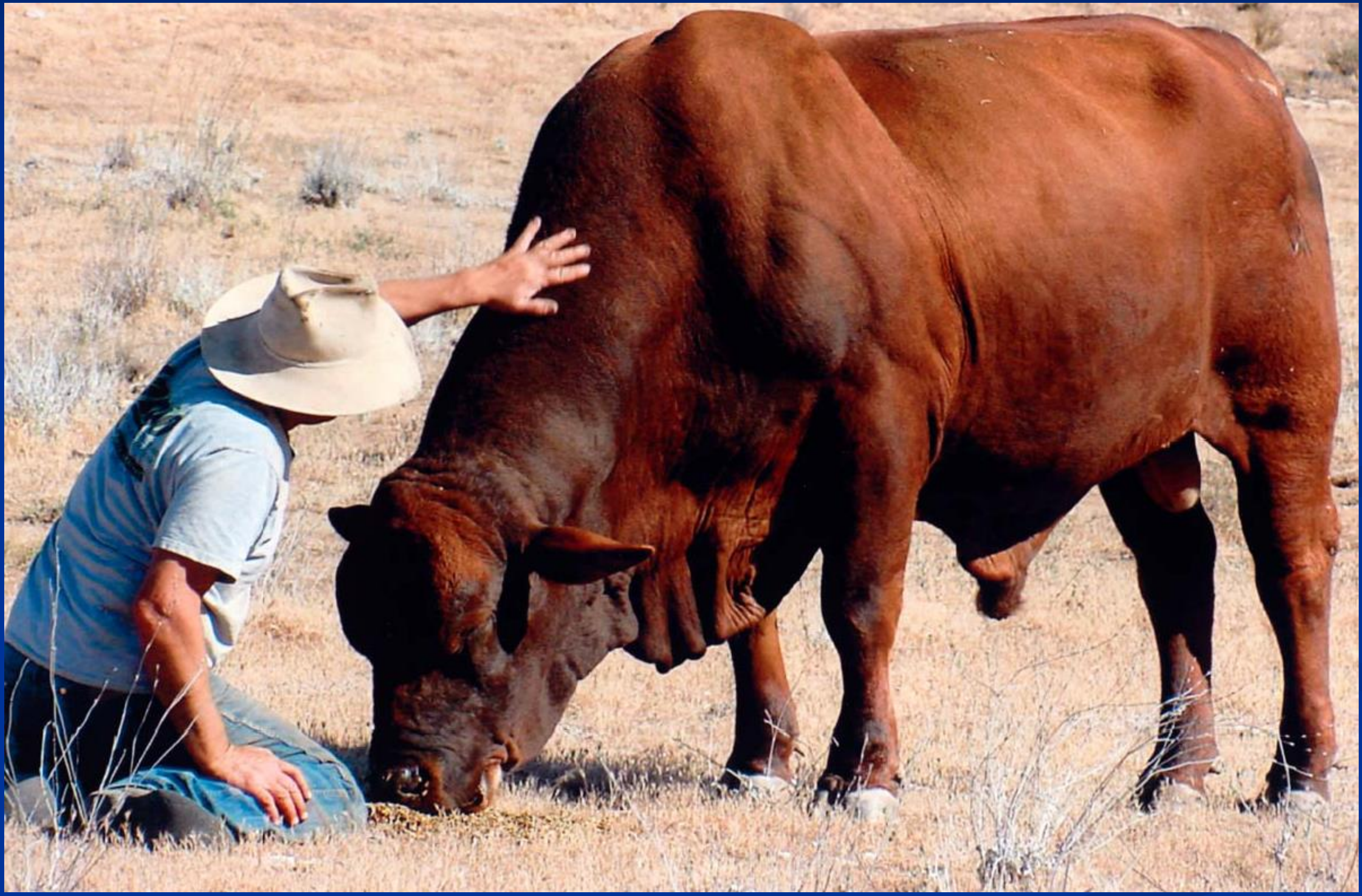
Study Implications

- In general, CBP yields more plant available P than fresh manure
- STP measurements likely change within a growing season
- Long Term Fertility
- Contradicts results of limited current literature

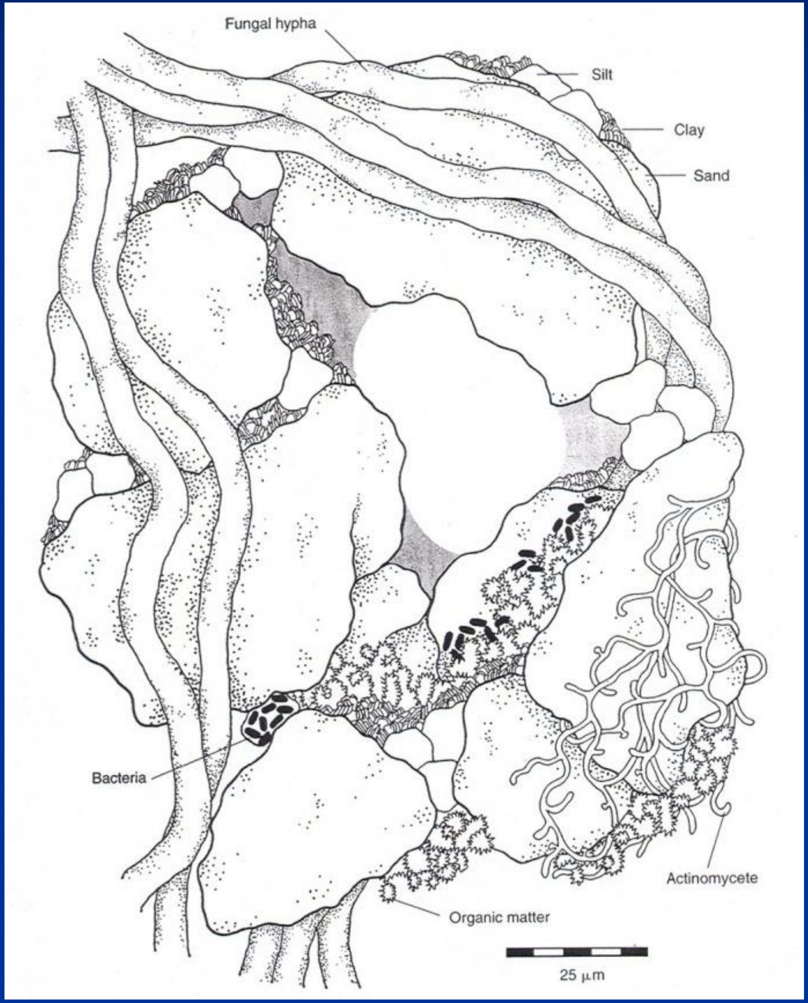
Limitations:

- - Ideal conditions in the laboratory
- - One soil type used
- - No competition for available P
- - Incorporated material only
- - Highly processed samples

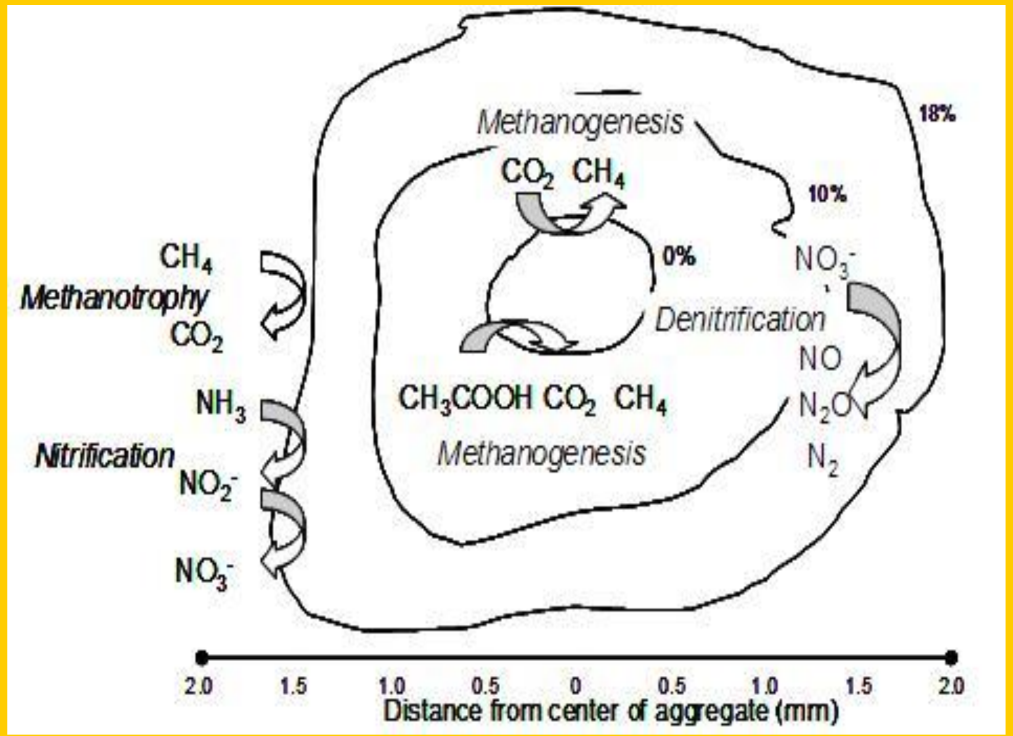
Questions?



Soil Aggregate Microenvironment Model



Typical Soil Aggregate
Sylvia, et al. 2005. Prin. & Appl. Of Soil Micro. Pearson. Upper Saddle, NJ.



Distribution of physiological properties within an aggregate/particle. Lines represent isobars of O_2 concentration (%). Coyne, 2010.