Making the Most Out of Manure
最大化利用粪污

Wendy Powers
Professor 教授
Michigan State University
密歇根州立大学

Manure is a valuable product from the dairy
对于牧场来说，粪污是一个有价值的产品

- Important source of nutrients for the farm
- 是牧场重要的营养来源
- Challenge 挑战
  - Added layer of management to prevent manure from becoming a waste
  - 更多的管理以防止粪污变成一种废弃物
  - Can become an enterprise separate from milk production (herd management) 可变成一个与牛奶生产（牛群管理）分开的一个企业。

On-farm uses of manure 粪污在牧场的使用

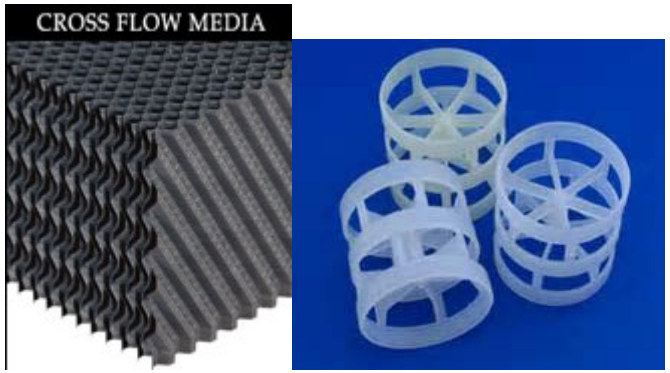
- Crop nutrient and soil amendment 作物的营养成分和土壤改良
- On-farm energy use 牧场的能源使用
- Bedding material 卧床垫料

Off-farm manure uses 牧场外的粪污利用

- Fertilizer and soil amendment 化肥和土壤改良
  - Forests, fields, horticultural products 森林，农田和园艺产品
- Off-farm energy 牧场外的能源
  - Generated on-farm and sold to grid 牧场自己发电，并销售至电网
  - Manure relocated off-farm for energy production
  - 粪污运输至牧场外，并用于发电

Anaerobic digestion 厌氧发酵

- Diluted manure (1 part water: 2 parts manure) 稀释粪污（水：粪污=1：2）
  - Plug flow digester design
  - 塞流式沼气池的设计
- Dilute manure 稀释粪污
  - With solids removal – 1:1 dilution
  - 移走固体- 1:1 稀释
    - Fixed film digester, CSTR 固定膜沼气池
  - Without solids removal – requires greater dilution water (flush lane, milk house water if allowed by law) 无需移走固体-需要大量的水来稀释（冲洗管道，如果法律允许的话， 奶厅的水）
    - Earthen storage with floating cover, fixed film, CSTR
    - 有浮顶的地面贮存池，使用固膜

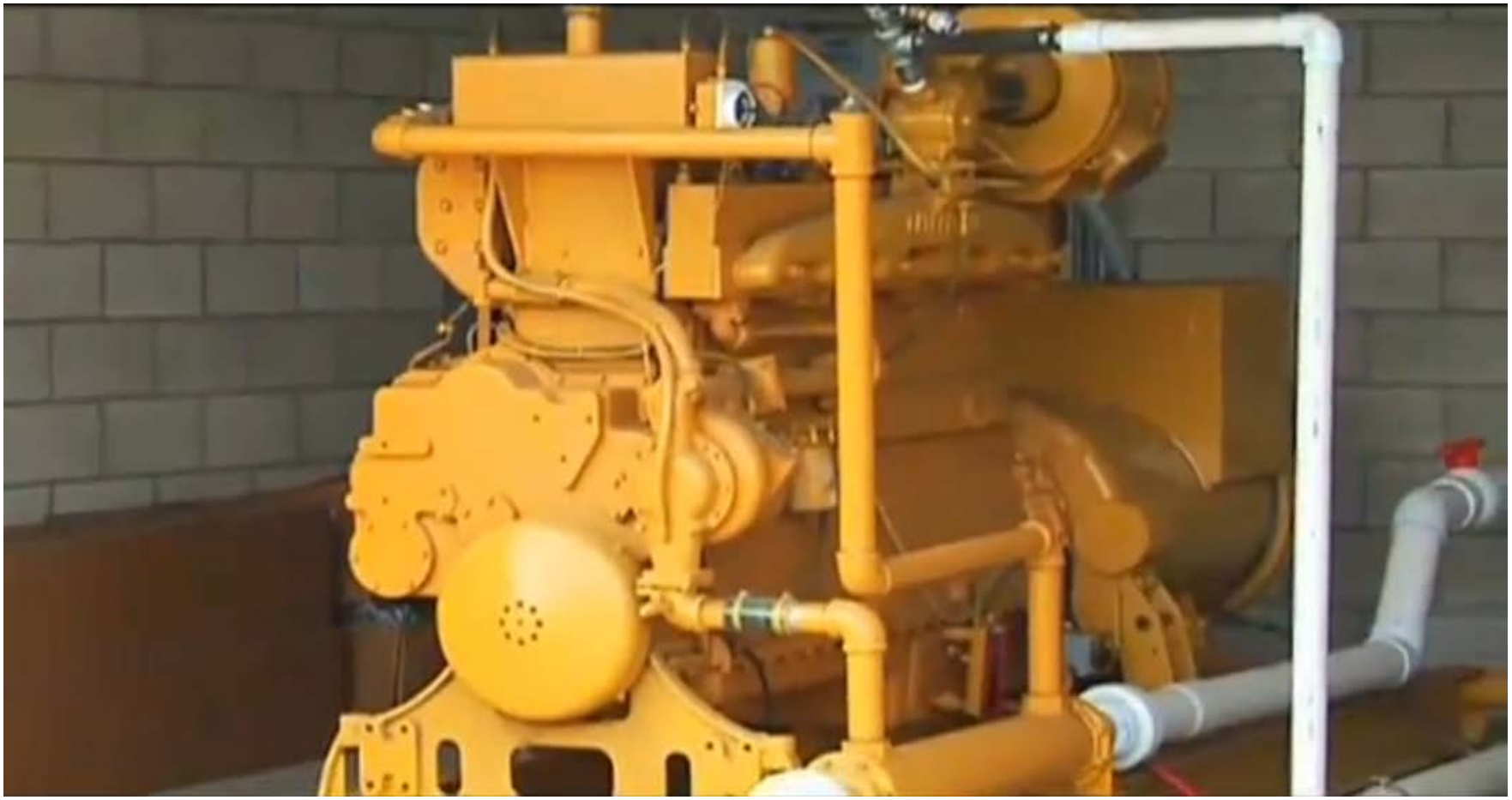


Challenges with anaerobic digestion
厌氧发酵的挑战

- Level of management needed for success
- 成功所需的管理水平
- Fixed costs - $$$$
- 大量的固定成本投入
- Maintenance costs - $
- 维持成本

Anaerobic digestion opportunities
厌氧发酵的机会

- Recovery of costs through offset of utility bills
- 通过对公用事业费用抵消成本回收
  - Most promising for dairy farms running a parlor 24 hr/d
  - 许多有前景的牧场奶厅都是每天24小时运转
- Potential for grants or other investment assistance
- 潜在的补助金或其他投资援助
- Community digesters offer promise
- 沼气池群提供承诺
  - Transfer expertise requirement to a third party
  - 传递专业知识需求给第三方
  - Greater potential to incorporate food wastes 更大的消纳粮食废弃物的潜力
    - Increased digester efficiency 增加沼所池的效率



Hilarides Dairy, California

Michigan State University dairy farm digester
密歇根州立大学奶牛场的沼气池

- Dairy manure plus cafeteria waste
- 牛粪加上自助餐厅的废弃物
- 20 to 30 day retention time
- 20-30天的保留时间
- 450,000 gallons　45万加仑
- 17,000 tons waste =
  2.8 million kwh with
  20% used to heat digester
  1.7万吨废弃物=280万千瓦时，20%用于加热沼气池
- $5 million investment 500万美元的投资

Wet gasification 湿法气化

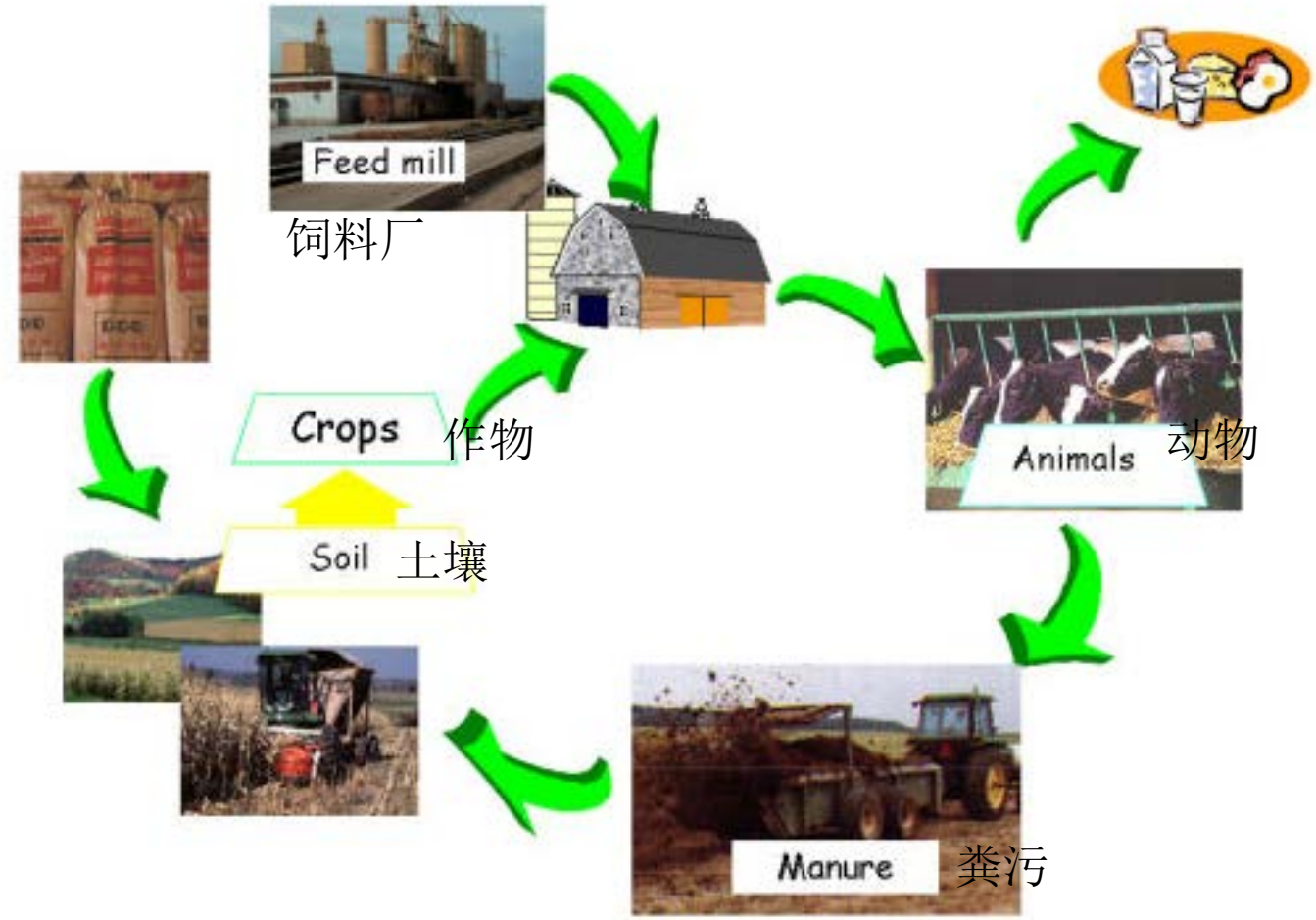
- Drying not necessary 干燥不是必需的
  - <40% moisture needed for traditional gasification
  - 水分小于40%，需要传统的气化
- Products: syngas, bio-oil, biochar
- 产品：气，生物油，生物炭
- Syngas – for use on-farm as energy source (converted vehicles, heating)
- 合成气–作为能源在牧场使用（转换为车辆的燃料，暖气）
- Bio-oil – as off-farm value-added product 生物油–作为牧场外的增值产品
- Biochar – nutrients (heat-stable minerals) 生物炭–营养成分（热稳定矿物质）
  - On-farm use or off-farm value-added product 牧场自己使用或牧场外的增值产品

Wet gasification 湿法气化

- Management and investment challenges that apply to anaerobic digestion apply here, too
- 湿法气化与厌氧发酵面临同样的管理和投资挑战
- $375 per animal unit, compared to $95/animal unit for anaerobic digestion
- 与厌氧发酵的每头动物95美元的投资成本相比，采用湿法气化每头动物需要375美元
- Still in research phase 仍在研究的阶段
- Traditional gasification cheaper if manure is dry
- 如果粪污是干燥的，传统的气化较便宜

Integrated crop and dairy farming
作物和牧场一体化

- Manure nutrients used for crop production
- 粪污的营养成分用于作物生产
  - Manure is an important source of fertilizer
  - 粪污是一种重要的肥料来源
  - Manure is stored for extended periods of time or applied daily 粪便可长时间贮存或日常应用
    - Both present challenges 两种方式的挑战
      - Storage: odor issues, nutrient losses during storage
      - 长时间贮存：气味问题、在贮存的过程中的营养成分损失
      - Daily haul: Nutrients available when crops don’ t need them; potential runoff and pollution concerns 每天运送： 在作物不需要养分时，养分已具备；并存在潜在的径流和污染



Source: Doug Beegle, Pennsylvania State University.

Manure use criteria 粪污使用标准

- Manage manure to prevent 管理粪污以防止
  - Excessive build up in soils 在土壤上过多施用
  - Wasteful losses to the atmosphere 营养损失在空气中
  - Runoff to surface waters or surface water conduits 地表水径流或地表水的管道
  - Leaching to ground waters 渗透到地底水
  - Nuisance to neighbors 损害邻居
- Bottom line: aim for high nutrient use efficiency
- 概要：目标是高养分的利用效率
  - Fraction of applied nutrients actually used by crops 部分施用的养分实际上被作物使用
  - kg nutrient taken up by crops÷kg nutrient applied 被作物使用的养分的公斤数÷施用的养分公斤数

Ways to increase nutrient use efficiency
提高养分使用效率的方式

- 4 R’s of nutrient management
- 养分管理的4R原则
  - Right source of nutrients applied
  - 养分施用的正确来源
  - Right timing of nutrient application
  - 养分施用的正确时机
  - Right placement of nutrients 养分施用的正确位置
  - Right rate of application of nutrients
  - 养分施用的数量
- Method of application 施用的方法

Source of nutrients applied
养分施用的来源

- Supply nutrients in plant-available forms
- 以植物可利用的方式提供养分
- Suit soil physical and chemical properties
- 适合土壤的物理和化学性质
  - Flooded soils, soil pH 淹水土壤，土壤pH值
- Recognize synergism between nutrients
- 认识到养分的协同作用
  - N increases P availability 氮增加可用磷

Timing of nutrient application
养分施用的时间

- Assess timing of plant uptake　植物吸收时间的评估
  - Side-dress applications 侧施肥
- Assess dynamics of soil nutrient supply
- 评估土壤养分的供应动态
  - Mineralization of soil nutrients – timing
  - 土壤养分的矿化--时机
- Recognize when soil nutrient loss occurs
- 确认什么时候土壤养分流失
  - When does leaching occur? 什么时候发生渗透？
- Evaluate logistics of field application 评估施用田地的物流
  - Timing of other events (planting, harvest)
  - 其他事件的时机（播种，收获）

Placement of nutrient application
养分施用的位置

- Consider where plant roots are growing
- 考虑作物根系生长的地方
- Suit the goals of the tillage system
- 合适的翻耕目标
- Manage spatial variability within a field
- 管理田地的空间差异性
  - Nutrient loss vulnerability (slope) 养分流失（坡度）
  - Differences in soil types 土壤类型的差异
    - Crop productivity 作物生产力
    - Nutrient supply capacity 养分的供应能力

Rate of nutrient application 粪污的施用量

- Plant nutrient demand 作物的养分需求
  - Target yield 目标产量
- Soil nutrient supply 土壤养分提供
  - When soils and tissues are assessed
  - 评估土壤和组织
- Predict nutrient use efficiency 预测养分的使用效率
  - Long-term deficiencies not good for soil
  - 长期缺某种养分不利于土壤
- Best return on investment when all available nutrients are used by the plants 当所有的养分被都被植物利用时，是最好的投资回报

Method of nutrient application
养分施用的方法

- Extension of “Right placement”
- “正确施用位置”的扩展
- Influences nutrient losses post application
- 施用后营养成分流失的影响
  - Surface application 表土施肥
  - Surface application with incorporation 表土施肥和追肥
    - Immediately 即刻
    - 24 hour after application 在施用后的24小时内
    - 24 to 72 hour after application在施用后的24-72小时
    - > 72 hour after incorporation 在追肥后的72小时以后

Balancing nitrogen (N) and phosphorus (P) 平衡氮和磷

- Typical plant needs (Midwestern US)
- 典型的作物需求（美国中西部）

	N氮	P磷	P_2O_5	N:P_2O_5 氮：五氧化二磷	*Source 来源*
As-excreted dairy manure	0.99	0.17	0.39	2.54	*ASABE D384.2*
Crop needs 作物需求					
Corn 玉米 (12.55 metric tons/ha 12.55吨/公顷)	0.75		0.33	2.27	*Ward Laboratories; Kearney, NE*
Soybeans 大豆 (3.77 metric tons/ha 3.77吨/公顷)	3.6		0.77	4.68	*Ward Laboratories; Kearney, NE*

Balancing nitrogen (N) and phosphorus (P) 氮和磷的平衡

- Typical losses during storage 在贮存过程中的养分流失

System	Nitrogen lost	Nitrogen retained
	Percent	
Solid		
Daily scrape and haul	20–35	65–80
Manure pack	20–40	60–80
Open lot	40–55	45–60
Deep pit (poultry)	25–50	50–75
Litter	25–50	50–75
Liquid		
Under floor pit*	15–30	70–85
Above-ground tank*	10–30	70–90
Holding pond	20–40	60–80
Anaerobic lagoon	70–85	15–30

From Midwest Plan Service 18, 2005.

Balancing nitrogen (N) and phosphorus (P) 氮和磷的平衡

- Typical losses 4 days following application 施用4天后的养分流失

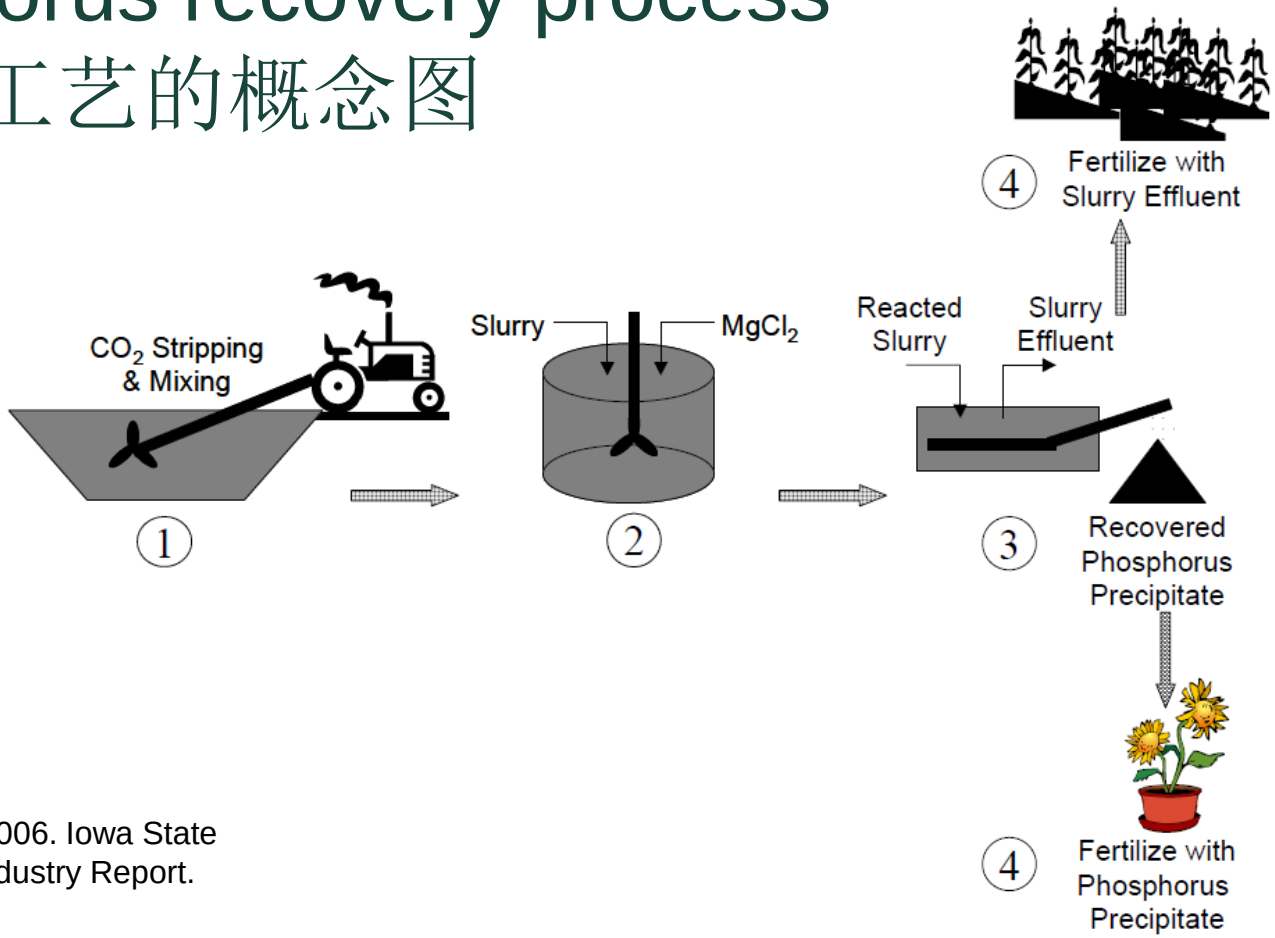
Application Method	Type of Manure	Nitrogen Lost, %
Broadcast	Solid	15-30
	Liquid	10-25
Broadcast with immediate incorporation	Solid	1-5
	Liquid	1-5
Knifing	Liquid	0-1
Sprinkler irrigation	Liquid	0-1

From Midwest Plan Service 18, 2005.

Nutrient balance without solid/liquid separation 未固液分离的养分平衡

- Conserve N (minimize losses during storage and application) 氮的保存（在贮存和施用的过程中，把养分的流失降至最低）
  - Permeable covers 可渗透的覆盖物
  - Impermeable covers 不可渗透的覆盖物
  - Under building storage 地下的贮存
  - Acidification??? 酸化？

Conceptual schematic of the proposed phosphorus recovery process
磷回收工艺的概念图



From Burns et al., 2006. Iowa State University Animal Industry Report. AS Leaflet R2120.

Manure as a nutrient source
粪污作为一种养分来源

- Emphasis on N and P content 强调氮和磷的含量
- Organic matter improves soil quality, ability of soil to hold moisture 有机物改善土壤质量，土壤保持水分的能力
  - Especially important where nutrient applications are followed by rainfall or irrigation 尤其重要的是，养分在降雨或灌溉后施用
- Micronutrients further improve soil health
- 微量元素进一步提高土壤健康
  - Microbial communities 微生物群落

Conclusions 结论

- Avoid losing valuable nutrients from manure during storage and land application 在粪污贮存和还田过程中，避免损失有价值的养分
- Opportunities are out there to make manure a value-added product from the dairy farm
  - 有机会使牧场的粪污变成增值的产品
  - Additional management necessary 需要额外的管理
  - Capital investment also needed 也需要资本的投资