ADAPTING TO A CHANGING WORLD: THRIVING IN THE FACE OF CLIMATE CHANGE, A GROWING POPULATION, & SHRINKING RESOURCES

Mark Dempsey, Carolina Farm Stewardship Association
Peter Brezny, Psycho Chicken Eco Farm
CFSA Sustainable Ag Conference | Nov 2022
$6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$
We're up against a lot...
WE’RE UP AGAINST A LOT
Pt. 1: CHALLENGES
Climate Change

- Hotter summers & warmer winters

woods.stanford.edu/news/effects-climate-change-hunger
Climate Change

- Bigger storms

(weather.com)

(DTMprogressive Farmer)

(The Packer)
Increased water stress & scarcity
Climate Change

Sea level rise

Business as Usual Development and Sea-Level Rise Threaten Agricultural Land
Soil Erosion
Soil Erosion

[Image: A photograph depicting the effects of soil erosion on farms, with a description of how soil erosion threatens food and farms.]
Soil Erosion
Soil Erosion
Soil Erosion

- Nationally, we’ve lost 12”+ top soil since we began plowing (post-colonization)
- Ag soil erosion rates are not sustainable:
  - 2x-3x USDA’s “sustainable” loss (0.25mm-1mm/yr)
- Truly sustainable soil rates difficult to determine, but current erosion rates threaten human longevity

D. Montgomery 2007 PNAS 104 (33) 13268-13272
Reusser, Beirman & Rood 2015 Geology 43(2) 171-174 (Southeastern US)
Thaler et al 2022 Earth’s Future 10 (Midwestern US)
Soil Organic Matter Loss

- Soil organic matter also threatened by the plow
- Organic matter critical soil resource
  - Nutrient source upon decomposition
  - Holds cation nutrients, buffers against acidity
  - Increases water retention
  - Product of good soil structure = better infiltration
- Long-term organic matter gains set back by a single tillage event
- OM losses threaten farm resilience
Growing Population & Food Demand

- Population expected to hit 9-10 billion by 2050
Disproportionate Food Demand Increase

- Population expected to hit 9-10 billion by 2050

Food demand expected to increase disproportionately (to 2050): meat consumption in developing countries

Foley et al 2011 "Solutions for a Cultivated Planet" Nature 478 337-478
J. Foley nationalgeographic.com/foodfeatures/feeding-9-billion/
Food demand expected to increase disproportionately (to 2050)

Food Demand Increase ca. 25%-70%

Hunter et al. 2017 Bioscience 67(4) 386–391
Producing Human Nutrition Efficiently

Dempsey & Rimol 2014 Unpublished data
Food choices can affect:

- What’s grown where

Production efficiency (e.g. protein/acre):

- In general, meat production makes less efficient use of land, water, and fertilizer compared to plants

Important caveats:

- Ruminants on land that is not suitable for crop production can produce food on land that otherwise would not
- Protein quality of plant-based food is unbalanced; adequate essential amino acid intake important

Environmental quality elsewhere
Globally, demand for more food – especially meat in developing nations – drives deforestation to expand farmland.
Land Use Change: Farmland Loss

- Nationally, farmland is lost to development

FARMS UNDER THREAT: THE STATE OF THE STATES

Julia Freedgood • Mitch Hunter • Jennifer Dempsey • Ann Sorensen
Land Use Change: Farmland Loss

- Nationally, farmland is lost to development

Development Threatens Each State's Best Agricultural Land

This map shows conversion of non-federal farmland and rangeland to UHD and LDR land uses from 2000-2010. The threat to working farms and ranches is pervasive, often obtaining the most productive, versatile, and resilient lands in each state.
Regionally, we’re set to lose the most:

- Carolinas have 13.2 million ac. farmland (2017 census of ag)
- Expected to lose 1.63m – 2.26m ac. by 2040 (12-17%)
- ~80% of that due to low-density residential develop’t
Fertility Inputs: Phosphorus

- Phosphorus: majority of P fertilizer applied is mined as phosphate rock
- Cycles geologically: new rock available only over very long timescales (millions of years)
- Phosphate rock supply may be in decline
- Vulnerable to disruption
- Will have indirect effects on growers who don’t use phosphate rock (plant/animal byproducts)
Fertility Inputs: Phosphorus

- Phosphate rock supply may be in decline
Fertility Inputs: Phosphorus

- Phosphate rock supply may be in decline

Mohr & Evans 2013 "Projections of Future Phosphorus Production" University of Newcastle
Global phosphorus shortage will be aggravated by soil erosion

Alewall et al. 2020 Nature Communications 11 4546
The Hidden Challenge: Mindset

- Paradigm blindness
  - Ask a fish what it’s like to live under water

- So many examples:
  - Do you have to till to farm?
  - Weeds: Kill? Listen to? Useful?
  - Insects: Kill? Useful? How to sustain predators w/o pests? Effects on nutrient density?

- How to identify blind spots?
SO...WHAT TO DO WITH ALL THAT?

Pt. 2: SOLUTIONS & IMPLEMENTATION

John Wallace / Claire Keene
Freeze Agriculture’s Footprint

- Farmland lost to development: threat to food sovereignty and security
  - Food choices can make a difference for farmland protection (buy local)
  - Public policy favoring planned development could dramatically slow farmland loss
    - “Better built cities”: cut losses in half in Carolinas
      - 915,000 acres lost instead of 1.6-2.3 million acres
- Land Loss Prevention Project
- Land conservancies and land trusts
Freeze Agriculture’s Footprint

- Stop expanding into natural areas
  - Comes at an environmental costs
  - Biodiversity loss may affect our wellbeing too
- Can we take advantage of under-utilized space?
  - Fallow land
  - Lawns
  - Vacant lots
  - Etc.
Grow more things we can eat, fewer things we can’t

Pastures stay pasture: not suitable for crops & ruminant conversion of grass to food is amazing

Food gains can be made on cropland: Corn for ethanol and feed; soybeans for feed: conversion losses too great

J. Foley
nationalgeographic.com/foodfeatures/feeding-9-billion/
Grow More Food & Better Food

- Improve nutrient content of food
  - Better soil health = better food & better yields
  - Biofortification: breeding approach focusing on nutrient content in addition to yield

Dr. Dil Thavarajah (Clemson University) breeds lentils, peas and chickpeas for nutrient quality
Prioritize soil health

Reduce erosion – hardly a renewable resource

Healthy soil offers resilience in face of climate change

Will improve crop production: nutrient availability, resistance to pests and other stresses, better yields, better quality
SOIL HEALTH PRINCIPLES:

1. Keep the Soil Covered
2. Minimize Soil Disturbance / Reduce Tillage
3. High Crop Diversity
4. Live Plants 24/7/365
5. Livestock Integration / Build Organic Matter
Practice vs Outcomes based

- Proscriptive
- Observation

Do what you should vs Do what you love

Try crazy things. → Safe to fail

- How much land can you afford to lose crop on
- What’s the worst performing plot you have
Outcomes based farming:

1. **Reflection/Evaluation**
2. **Awareness**
3. **Information Gathering**
4. **Analysis**
5. **Visioning/Planning**
6. **Action**
Outcomes based farming:

- Choose your questions wisely
- What you measure = what you manage
- What are you measuring?
  - Yield vs nutrient density
  - Short term profit vs long term sustainability
  - Soil Health vs “idyllic” looking farm

- How many people have performed a VSA?
Visual Soil Assessment:

- Quantitative Vs. Qualitative analysis
- VSA Scorecard:
  - Template for qualitative to quantitative measurement
  - Track soil health over time on your own

Search: fao visual soil assessment field guide
https://www.fao.org/3/i0007e/i0007e00.htm

Soilmentor: soils.vidacycle.com
VSA Scorecard:

<table>
<thead>
<tr>
<th>Visual indicators of soil quality</th>
<th>Visual score (VS)</th>
<th>Weighting</th>
<th>VS ranking</th>
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<td>Soil texture</td>
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<td>x 3</td>
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<tr>
<td>Soil structure</td>
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<td>Soil porosity</td>
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<td>Number and colour of soil mottles</td>
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<td>Earthworms (Number = ) (Av. size =)</td>
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<td>Potential rooting depth (m)</td>
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<td>Surface ponding</td>
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<td>Surface crusting and surface cover</td>
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<td>Soil erosion (wind/water)</td>
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SOIL QUALITY INDEX (sum of VS rankings)
VSA Images:

Sampling Supplies
Dig a hole
VSA Images:

Measure depth of each layer
Soil Drop: assessing natural fracture lines
Drop #1
Soil Drop: assessing natural fracture lines
Drop #2
Soil Drop: assessing natural fracture lines
Drop #3
Earthworms are one measure of soil health
Soil clods: another measure of soil health (see VSA website for more info)
Sampling:

Boxed up to ship of for nutrient analysis
Slake Test:

Slake test:
How quickly a dry clod falls apart when placed in a jar of water — a measure of soil structure
Crop Diversity as Resilience Strategy

- Diversify rotations: buffer against single crop losses

High crop diversity on veggie farms

Ten Mothers Farm | No-Till Growers (YouTube)
Crop Diversity as Resilience Strategy

- Diversify plantings: more harvests per unit area
Crop Diversity as Resilience Strategy

- Diversify plantings: more harvests per unit area
Crop Diversity as Resilience Strategy

- Varietal diversity: resilience within a crop
Crop Diversity as Resilience Strategy

- Take advantage of under-utilized crops:

  - Tumeric
  - American ground nut
  - Ube
  - Taro
  - Bambara ground nut
  - Chayote
Crop Diversity as Resilience Strategy

- Genetic diversity, a resource for breeders: public, cooperative, farmer-led, etc.
Leverage soil biology: improve crop access to nutrients and water, resist stress
Do More With Less

- Leverage genetic diversity: improve nutrient use efficiency

Do More With Less

- Closing waste loops: reducing food waste
- 40%+ of food grown is not eaten
  - Post harvest losses in developing areas (transport, storage & processing)
  - Consumer-end losses in industrialized areas (restaurants & refrigerators)
Closing waste loops: animal manure

More efficient use:
- Pasture + crop integration
- Stored manure spread thinner over larger areas
  - Affected by where we raise crops vs. CAFOs
Closing waste loops: human waste

SOURCE SEPARATION AND TREATMENT OF ANTHROPOGENIC URINE

by:
Kimberly LeMonde Fewless
Sybil Sharvelle (PI)
Larry A. Roesner (Co-PI)
Colorado State University

Sustainability Challenges of Phosphorus and Food: Solutions from Closing the Human Phosphorus Cycle

Daniel L. Childers, Jessica Corman, Mark Edwards, James J. Elser


Published: 01 February 2011

Fate of pharmaceutical and biological contaminants through the preparation and application of urine derived fertilizers

Goetsch et al. 2015  DOI: 10.2175/193864715819541945

en.wikipedia.org/wiki/Urine_diversion
Do More With Less

- Closing waste loops: human waste

Towards ecological sanitation

Whilst having a sanitation system that eliminates all hygiene hazards is obviously a priority, a new approach, ecological sanitation (ES), minimises hygienic risk and protects the environment, returning nutrients to the soil, and conserving valuable water resources.
ANY QUESTIONS?

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Mark Dempsey, Carolina Farm Stewardship Association
Peter Brezny, Psycho Chicken Eco Farm
5 SOIL HEALTH PRINCIPLES:
A foray into crop management for better soil and resilience in the face of climate change

1. Keep the Soil Covered
2. Minimize Soil Disturbance / Reduce Tillage
3. High Crop Diversity
4. Live Plants 24/7/365
5. Livestock Integration* / Build Soil Organic Matter*

*in lieu of management details to integrate livestock (a topic in which the presenters have no expertise), the focus of Principle #5 is on building soil organic matter
PRINCIPLES #1: Keep it Covered

- Crops, cover crops, mulches
- Critical at crop and season transitions
- Multiple crops can overlap in space and time if they differ in architecture or light/temperature requirements
- Achieved with:
  - Tight rotations: minimal time with no crop
  - Relay cropping & inter-seeding
  - Inter-cropping
  - Mulches important, too
PRINCIPLE #1: Keep it Covered

Tight rotations on veggie farms
PRINCIPLE #1: Keep it Covered

Same-day bed flip:
PRINCIPLE #1: Keep it Covered

Relay cropping: “Sow and Mow”
- Cover crops into cash/cover crop
- Typically for season transition
- Residue greatly improves germination
PRINCIPLE #1: Keep it Covered

Relay cropping:

- Cash crop sown into cover crop
- Buckwheat frost-kills
- Cool season crops take over
Inter-cropping:

- Crops grown together
- Different crop architecture or light preferences
PRINCIPLE #1: Keep it Covered

Inter-cropping:

- Crops grown together
- Different crop architecture or light preferences
PRINCIPLE #1: Keep it Covered

Cover crop
inter-seeding
PRINCIPLE #1: Keep it Covered

Inter-seeded cover crops at and after corn harvest
PRINCIPLE #1: Keep it Covered

Red clover frost-seeded into wheat over winter has filled in by wheat harvest.
Reduce tillage or go no-till

- Typically herbicide based, but does not have to be
- Should involve cover crops regardless of herbicide use
- Can rely on supplemental mulching
  - Compost, wood chips, etc
  - Plastic or landscape fabric
  - Mulched crops chopped & spread
PRINCIPLE #2: Minimize Disturbance

- Control weeds by other means
  - Grow your own mulch
  - Added mulch (leaf mulch, compost, wood chips)
  - Synthetic mulches (landscape fabric, plastic)

- Big tillage event 1x/yr vs. multiple smaller events
  - Depends on cropping system: crops, mulch, equipment

- Fertility applied various ways
  - Cut in while tilling
  - Fertigation
  - Special equipment to inject into soil
Cover crop-based organic rotational no-till

Compared to traditional tilled organic corn-soybean-wheat:

- 27% less diesel fuel
- 31% less labor
- 13% less energy use
- 6% less GHG emissions


Slide credit: Matt Ryan (Cornell)
PRINCIPLE #2: Minimize Disturbance

I & J roller-crimper
(10.5-ft wide cylinder, 2625 lb water-filled weight)

Slide credit: Matt Ryan (Cornell)
PRINCIPLE #2: Minimize Disturbance

- Tillage-based management
- Cover crop-based, rotational no-till

Slide credit: Matt Ryan (Cornell)
PRINCIPLE #2: Minimize Disturbance

Tillage-based management

Cover crop-based, rotational no-till

Slide credit: Matt Ryan (Cornell)
PRINCIPLE #2: Minimize Disturbance

ROLLER-CRIMPER

Easier to kill, shorter-lived mulch
Consistent kill & suppression
Higher-tech but more versatile
Low-tech but labor-intensive

Slow and fuel-guzzling
Slow and labor-intensive

Bill Curran
extension.org
USDA Soil Dynamics Lab
PRINCIPLE #2: Minimize Disturbance

MOWER

- Harder to kill, persistent mulch
- Consistent kill & suppression
- Low-tech but highly specialized
- Low-tech but labor-intensive
- Fast and fuel-efficient
- Slow and labor-intensive

localrootsfarm.wordpress.com
qdma.com
fieldsofagape.com
PRINCIPLE #2: Minimize Disturbance

Growth Stages of Rye

Roller-Crimped at Early/Mid Flower:
Nearly acceptable kill level by rolling, but very high regrowth can compete with crop as it establishes

Roller-Crimped at Late Milk/Early Dough:
100% kill by rolling, but a lot of seed-set, which can become weedy later (in-season or next year)

Goal is to strike a balance between these two extremes
(aim for late flower to early milk)
PRINCIPLE #2: Minimize Disturbance

Flail Mower

Flail mower for walk-behind tractor
20”-35” width
$1,600-$2,300 (w/o tax + shipping)

daileysfarmandbcsshop.com
PRINCIPLE #2: Minimize Disturbance

Roller Crimper

CFSA Roller Crimper
- 30” width
- 400-500+ lbs
- $400 materials
- 50 hrs labor

Who’s idea was this again?

I&J Roller Crimper
- 5’ width
- 1200 lbs filled w/ water
- $1,000 (used)

Earth Tools Roller Crimper
- 30” width
- 220-500 lbs
- $975 w/o weights
- $1,500-$1,600 est. d w/ weights + shipping
PRINCIPLE #2: Minimize Disturbance

Manual Crimper

Homemade Crimper
18”-24”
$2-$5 in parts

Success depends on width, weight & growth stage
PRINCIPLE #2: Minimize Disturbance

TARP or FABRIC

ROLLER-CRIMPER MOWER

Lay down & crimp
Cut or chop
Harder to kill,
persistent mulch

Easier to kill,
shorter-lived mulch

Low-tech but
highly specialized

Higher-tech but
more versatile

Fast and fuel-efficient

Slow and fuel-guzzling

springforthfarmnc.com
arktarps.com.au
PRINCIPLE #2: Minimize Disturbance

TARP or FABRIC

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Crop diversity

- Break up pest cycles: weeds, insects, disease
- Crop diversity → Microbial diversity → higher likelihood of ‘good’ microbiology present

Diversity = redundancy

- A buffer against abiotic stress (drought/wet, heat/cold)
PRINCIPLE #3: Crop Diversity

Achieved by:

- Diversity of cash crops:
  - Longer rotations
  - Inter-cropping

- Extensive cover cropping between/relayed with cash crops – aiming for diverse mixes when possible
PRINCIPLE #4: Live Plants 24/7/365

- Cash & cover crops
- Protects against erosion
- Cover crops scavenge nutrients & fix N
- Maintain symbiotic microbes in off-season
- Can increase soil OM
  - Nutrients for crops
  - Build soil structure
  - CEC
Cover crops limit nutrient losses during off-season
- Reduces nitrogen leaching
- Phosphorus from erosion
- Keep nutrients on the farm
- Protect water ways
Achieved by the same strategies of “Keep it Covered”

- Tight rotations: minimal time with no crop
- Relay cropping & inter-seeding
- Inter-cropping: cash crops can coexist when they differ in architecture or light or temperature requirements
In the Southeastern US, soils are often highly-weathered clays or droughty sands.

- Degraded clay soils have low nutrient content, low CEC, low pH, and high aluminum
- Sandy soils also low nutrient content, CEC & water-holding capacity

Organic matter can improve both types of soil
PRINCIPLE #5: Build Organic Matter

- OM is the nutrient bank of soil
  - Nutrient release via decomposition
  - “Parking lot” for nutrients (CEC)
- Increase water-holding capacity
  - For every 1% organic matter gained, soil can hold ~20k gallons
- OM associated with good structure
  - Resists erosion
  - Better water infiltration
- Achieved with Priorities 2, 3 & 4
ANY QUESTIONS?

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