What is Sustainable Cotton?
Kater Hake
Cotton Incorporated
Convey the complexity of cotton sustainability by sharing some new concepts

Recognize that answers must be locally tailored

Encourage optimism and your collective and individual actions
Every practice was good:
• No-till
• Cover crops
• Tile drains

Outcome was bad:
• Phosphorus loss
• Contamination of lakes
• Methane production

J. Environ. Qual. 2015 44:460-466
Nat. Comm 2021 12-s41467
Just now recognizing the methane opportunity in Climate Change

86X more potent than CO$_2$ over 20 years  Decade life span versus millennia for CO$_2$

Science 2021 374 667
Methane from P contamination of freshwater lakes & rivers is targeted to increase GHG by 18% to 33% of annual fossil fuel emissions.

Nature Communications 2019 10:1375
What is Sustainable Cotton?

With a long timeframe, we need to consider trajectory
~15,000 years for livestock domestication
~10,000 years for plant cultivation
~ 6,000 years for cotton cultivation

With a near timeframe, we can consider impacts
50 years our grandchildren
20 years for methane reduction
  5 years to change our carbon emissions behavior
A mural at the recent climate summit in Glasgow, U.K., exhorts nations to take steps to limit global warming to 1.5°C.

**CLIMATE CHANGE**

**Glasgow pact leaves 1.5°C goal on life support**

Goal of preventing dangerous warming slipping away, but nations boost emissions cuts

Published by AAAS
Climate Change is the biggest threat to human Sustainability

Other threats are secondary so Sustainability must address Climate Change

Focusing just on food, feed and fiber production, temperature and rainfall variability are our biggest threats
Rainfall Intensity

same area
7 % / °C more moisture

Rev. Geophys 2014 52:552-555
Nutrients are a second sustainability concern

When consumed as food most nutrients are not recycled

Unlimited supply of N (nitrogen) but cost to the environment is huge

Limited supply of P (phosphorus) and environmental costs is also huge
Nitrogen Fertilizer

We have known about N fertilizer impacts.

In cotton production LCA, N fertilizer has the biggest total and climate impact.

Energy to create N fertilizer and N\textsubscript{2}O emissions are largest contributors to Climate Change.

Just now recognizing impact of NH₃ (ammonia)

Livestock manure contributes 60% of global ammonia emissions. When combined with sulfur from coal creates dangerous PM₂.5.
Just now recognizing impact of NH$_3$ (ammonia)

Livestock manure contributes 60% of global ammonia emissions. When combined with sulfur from coal creates dangerous PM$_{2.5}$

Manure & NH$_3$ releasing fertilizer on the soil surface pollute the air and are lost to crops.

How ammonia feeds and pollutes the world

Science 2021 374:685 and 686
Pest Susceptibility and Cotton’s Attractiveness

Few ways to kill insect, weed, fungal, bacterial or nematode pests WITHOUT impacting humans

Know of some ways to make crops less attractive to pests

Gene editing is a tool to make “unattractive cotton”
Herbicides have not kept up with weed evolution

www.weedscience.org
Genome Editing of cotton with CRISPR Cas9

Target sequence

[TGCTTTTTCAAGATACCCAGATCATAT-GAAGGGCAACGACTTCTTCAGAGCGCCATGCCT 0]
[TGCTTTTTCAAGATACCCAGATCATAT-AAGCGGCAACGACTTCTTCAGAGCGCCATGCCT -1]
[TGCTTTTTCAAGATACCCAGATCATAT-AAGCGGCAACGACTTCTTCAGAGCGCCATGCCT -2]
[TGCTTTTTCAAGATACCCAGATCATAT-AAGCGGCAACGACTTCTTCAGAGCGCCATGCCT -3]
[TGCTTTTTCAAGATACCCAGATCATAT-AAGCGGCAACGACTTCTTCAGAGCGCCATGCCT -2, +1]
[TGCTTTTTCAAGATACCCAGATCATAT-AAGCGGCAACGACTTCTTCAGAGCGCCATGCCT -2]
[TGCTTTTTCAAGATACCCAGATCATAT-AAGCGGCAACGACTTCTTCAGAGCGCCATGCCT -1]
[TGCTTTTTCAAGATACCCAGATCATAT-AAGCGGCAACGACTTCTTCAGAGCGCCATGCCT -3]
[TGCTTTTTCAAGATACCCAGATCATAT-AAGCGGCAACGACTTCTTCAGAGCGCCATGCCT -3]
[TGCTTTTTCAAGATACCCAGATCATAT-AAGCGGCAACGACTTCTTCAGAGCGCCATGCCT +1]
[TGCTTTTTCAAGATACCCAGATCATAT-AAGCGGCAACGACTTCTTCAGAGCGCCATGCCT -8]
[TGCTTTTTCAAGATACCCAGATCATAT-AAGCGGCAACGACTTCTTCAGAGCGCCATGCCT -4]
[TGCTTTTTCAAGATACCCAGATCATAT-AAGCGGCAACGACTTCTTCAGAGCGCCATGCCT -2]
Genome Editing of cotton with CRISPR Cas9

More recent Cas9 editors have greater precision:
- SaCas9,
- CjCas9,
- eSpCas9,
- HFCas9,
- HypaCas9,
- Sniper Cas9

Baohong Zhang in Scientific Reports 2017
Plant-synthesized oxylipins make the phloem sap more palatable to pests and pathogens.

The **LOX1&5** genes making oxylipins are targets for gene edited resistance.

Gene editing in meristems alters seeds.

Disarmed virus infects the plant and edits cells in the meristem.

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Roisin McGarry & Brian Ayre – Univ. of North Texas
Cotton makes agriculture more sustainable – a source of optimism

Recovers nutrients left by shallow rooted crops

Highly drought and salt tolerant

Provides food, feed, fiber and cash

Farmers use expertise and innovations from cotton in all their crops across all their fields and pass these along to the next generation
Policy developments around the world (10/2021)

**Canada:** Product based approach; Health Canada draft guidance released, under review

**US:** Final USDA revised biotechnology regulation exempts certain products; EPA proposed rule exempt certain products; FDA conducted request for information from the public, policy TBD

**Argentina, Chile, Brazil, Paraguay, Colombia, Honduras, Guatemala:** Case-by-case approach, excluding certain edited products

**Costa Rica:** Draft regulation excluding certain edited products

**Europe:** ECI decision that genome targeted mutagenesis products are GMOs, but legal initiative to update law announced by EU Commission

**Norway:** Discussion of a “tiered” approach

**UK:** Positive draft Ag bill, public consultation

**Russia:** Decree for R&D program clarifying that genome editing products are “conventional-like”

**China:** Unofficial “GMO-lite” proposal

**Taiwan/South Korea/Thailand:** Discussion of options

**Indonesia:** Growing consensus to exempt certain gene editing appl.

**Singapore:** Draft proposal to exempt certain edited products under consultation

**Japan:** Excluding certain edited products

**India:** Draft guidelines, tiered approach, too excessive info needs

**Philippines:** Draft guidance excluding non-transgenic products

**Australia:** Revised gene tech regulation excludes some gene editing applications

**NZ:** High Court decision that a few specific techniques are GMOs

**South Africa:** Ongoing discussion, direction unclear

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Positive Decision
No formal decision, but positive direction
Discussion started, direction unclear

Restrictive Decision
Andrew Conner, BASF
The Cotton Plant is ideal to address Climate Change

Tap root and lateral roots can slowly explore a large root volume for residual water and nutrients

Desiccation tolerance allows long term flowering even when fully wilted that ensures some seed set despite severe heat and drought

Generates 2X and 3X harvests when rainfall cooperates without addition growing season inputs

Highly responsive to 4 to 6 inches of timely rainfall or or placed precisely irrigation
Collaborating with Cotton & Climate Scientists to keep cotton sustainable
1 meter row separates these plots

Zero-till  Tilled Annually

--------28 years of corn/cotton rotation--------
GETTING THE BIG PICTURE OF BIODIVERSITY

Satellites and other remote sensing tools offer new ways to study ecosystems—and maybe even save them

By Elizabeth Pennisi
Technology allows growers to share innovations that address local concerns

Hybrid cotton forces long season
pest management

Pest resistance and rainfall
reliance are impediments

Chinese and Pakistani cotton are fed by
glacier meltwater
“Sustainable Cotton” addresses critical human needs and challenges