Crop and Vegetation Diversity

Scott Gillespie M.Sc. P.Ag. CCA
Regenerative Agriculture Consultant
Plants Dig Soil Consulting Ltd.

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Outline of the Talk

- My experience
- The very, very long view on soils: approximately 10,000 years
- Regenerative agriculture, soil health, and the big claims
- How I differ and what I think is going on in reality
- Cover crops and cash crops – how diverse do they need to be?

- The slides are already up at www.plantsdigsoil.com/media
  - You can download now or get them later if you like
  - Links to additional reading if you want to dig deeper are on all the slides

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My Experience

- Grew up on a corn & soybean farm in Southern Ontario
- All my part time and summer jobs were agriculture related

- Completed B.Sc. (Agr.) University of Guelph (2001)
- Completed M.Sc. (Plant Science) University of Manitoba (2006)

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My Experience

- Moved to Alberta for a job in irrigated potato agronomy
  - Agricultural input supplier: Growers Supply Ltd. (2007-2011)

- Attained my Certified Crop Advisor designation (CCA) (2008)
- Attained my Professional Agrologist designation (P.Ag) (2009)

- Expanded my irrigated crop agronomy
  - Large crop farm: S-Scan Farms Ltd. (2011-2017)

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My Experience

- Started my consulting company (2018)
  - Specialize in independent agronomy, no products, software, or systems.
  - Self-taught myself cover crops and regenerative agriculture
- Started my podcast (2019)
  - Part creative outlet and part business promotion
  - Focus more time on #RealisticRegenAg to help break through the hype

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Timeline of Southern Alberta Soils

- Geologically young soil estimated to be 10,000 years old
- Agriculture as we know it has only been around for about 150 years

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Timeline of Southern Alberta Soils

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- Agriculture as we know it has only been around for about 150 years
- To help conceive of the timeline condense 10,000 years to one hour
  - You will only see agriculture develop in the last minute!
  - Regenerative agriculture would only be in the last 5 seconds!!

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Timeline of Southern Alberta Soils

- Geologically young soil estimated to be 10,000 years old
- Agriculture as we know it has only been around for about 150 years
- To help conceive of the timeline condense 10,000 years to one hour
  - You will only see agriculture develop in the last minute!
  - Regenerative agriculture would only be in the last 5 seconds!!
- The bar on the bottom of the slides represents our soil development visually
  - The green is for the entire length of the existence of our soils
  - The red on the right end represents the time of agriculture

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Human Management of the Soils

- Up until the 1700's the soils were managed sustainably
  - The number of people that could live on it was directly tied to what it could give
  - In our area the system was mostly based on the buffalo hunt
  - Active management of the soils was mostly centred on controlled burns

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Human Management of the Soils

- Up until the 1700's the soils were managed sustainably
  - The number of people that could live on it was directly tied to what it could give
  - In our area the system was mostly based on the buffalo hunt
  - Active management of the soils was mostly centred on controlled burns
- After contact with settlers
  - Horses and guns allowed a greater and more efficient harvest of buffalo
  - Colonists opened new trade networks for the excess
  - Greater migration and settlement lead to conflicts for land use

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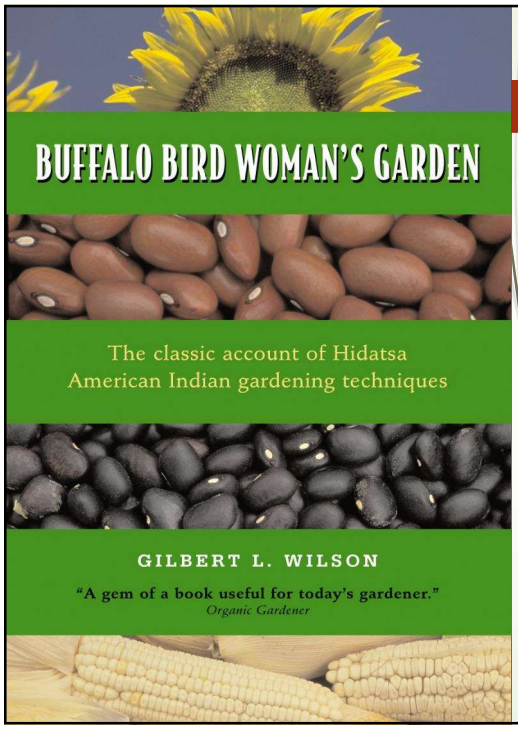

Buffalo Bird Woman

- The book is her story as told to anthropologist Gilbert L. Wilson
- She and all her tribe had already been moved to reserves (late 1800's)
- He was unlike most of his time in that he tried to just record what he heard and keep his viewpoint neutral
- Farming techniques were believed to have developed in the 12th century and evolved and improved over the following 700 years.

Gilbert L. Wilson. 1917. Buffalo Bird Woman's Garden: Agriculture of the Hidatsa Indians.
Full text online: https://digital.library.upenn.edu/women/buffalo/garden/garden.html
Current publishers' site: https://www.mnhs.org/mnhspress/books/buffalo-bird-womans-garden

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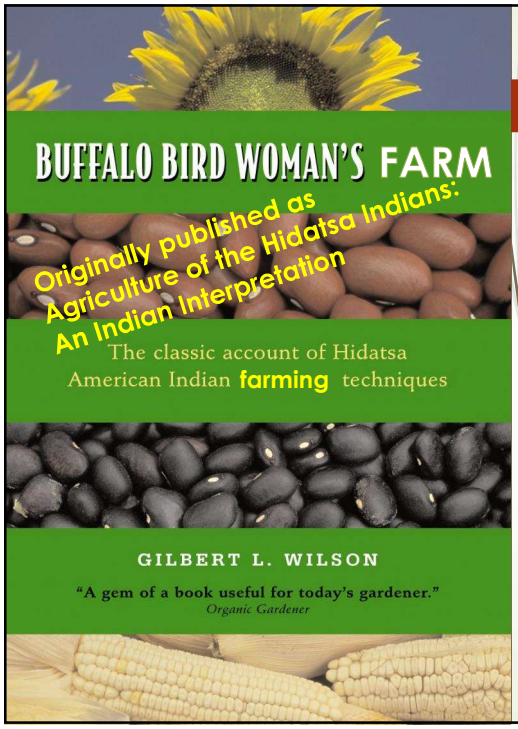

Buffalo Bird Woman

- Indigenous agriculture in what is now known as the Dakota's (United States)
- Adamantly kept up with weeding
- Carefully selected seed
- Broke new land and grew as long as they were productive
- Fallowed land to restore it; however admitted that eventually new land needed.
- Sustainable? If left for centuries perhaps?

Gilbert L. Wilson. 1917. Buffalo Bird Woman's Garden: Agriculture of the Hidatsa Indians.
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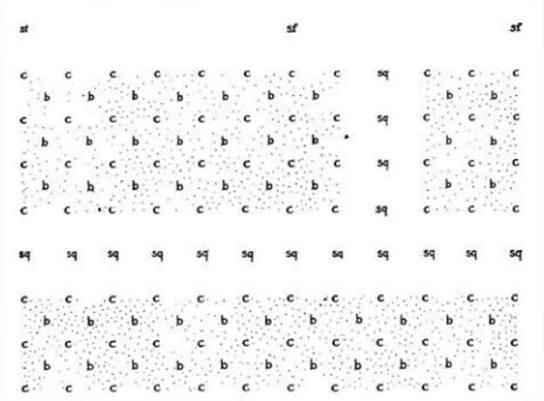
Buffalo Bird Woman's Crop Plans



- Same pattern followed every year (no rotation of crops)
- Main fertility came from burning grass & wood in the years of breaking the land
- Didn't allow any manure from horses on the land – saw the worms in it and didn't like it

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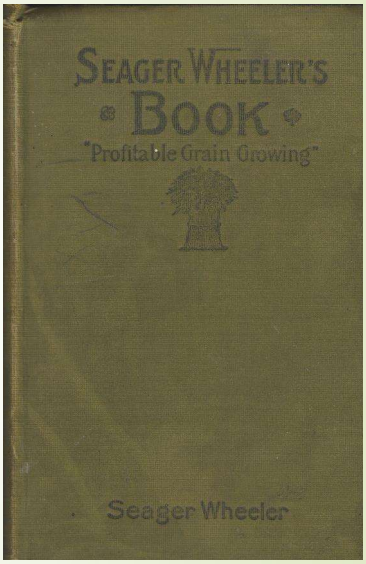
Seager Wheeler

- One of the early settlers north of Saskatoon*
- Widely known for his prize winning wheat
- Similar advice to Buffalo Bird Woman



*Seager Wheeler. 1919. Profitable Grain Growing.
(Not in print but some booksellers have used copies.)
Full text: https://www.canadiana.ca/view/oocihm.991508/8?r=0&s=1

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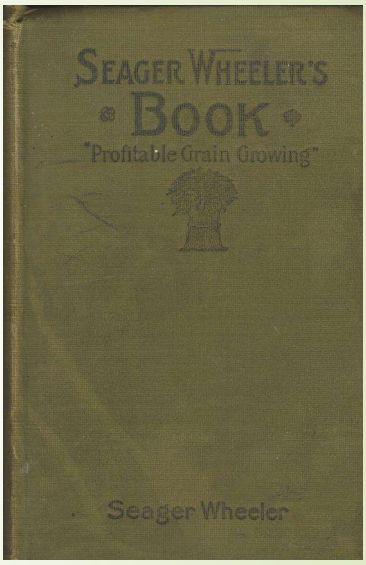
Seager Wheeler

- One of the early settlers north of Saskatoon*
- Widely known for his prize winning wheat
- Similar advice to Buffalo Bird Woman
- Differed from her in expectations
  - Believed proper tillage would unlock an inexhaustible supply of plant food
  - Appears to have subscribed to the theory that plants took up the mineral components of the soil and that you needed to pulverize the soil to powder**



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(Not in print but some booksellers have used copies.)
Full text: https://www.canadiana.ca/view/oocihm.991508/8?r=0&s=1

**University of Minnesota Extension. 2017?. Upper Midwest Tillage Guide
https://extension.umn.edu/soil-and-water/soil-management-and-health

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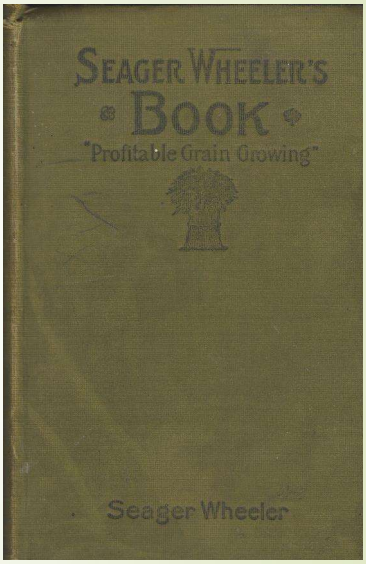
Seager Wheeler

- Monoculture
  - Growing the same crop in space
- Monocropping
  - Growing the same crop in time
- Fallow
  - Grow a crop one year
  - Let the ground "rest" for one year
  - Captures water, breaks down SOM for nutrients
  - No plants growing, constant tillage to control (Herbicides are used in modern time)



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What changed over the past 100 years?

- 1900's: Fertilizer sources, research, and use replaced the lost nutrients
- 1950's: Chemical controls allowed the weeds to be killed without tillage
  - This is truly revolutionary – no one else had such an easy way to kill weeds
- 1980's: No-till cropping allowed moisture to be saved
  - New machinery and the chemical weed controls allowed this
- 1990's: Genetic modification of crops opened more opportunities
  - No need to find chemicals that controlled the weeds and not the crop
  - Could just kill everything and leave the crop untouched

Together these solved the problem that fallow was used for

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So why are we switching to regenerative agriculture?

- Finite supply of nutrients to mine
  - Many sources over history from bat guano to excavating ancient buffalo jumps
- Nutrients leach and runoff – polluting groundwater and bodies of water
- Pests evolve to chemicals – always
  - Ex. Weeds now mimic rice where hand weeding has been used for centuries
- Public pressure and farmer weariness of more genetic modification
- Farmers getting tired of endless purchasing of new inputs
- Farmers getting tired of always killing things

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Soil Health Principles

- Keep the soil covered
- Minimize tillage
- Living root as long as possible
- Diverse plants
- Integrate animals

Exact origins of the principles unknown but Jay Fuhrer and colleagues from the Natural Resource Conservation Service in North Dakota having been talking about them the longest. They likely evolved in time from many people and many discussions.

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Soil Health can be boiled down to: **Plants Dig Soil**

- Leaves are taking the sun's energy and creating sugar from CO_2

  This is the only time that new energy is going in to the system

- Everything else supports the soil but the plants are the drivers
  - Microbes can be fed by root exudates and cells sloughing off
  - When plants are absent organic matter is the source
    - Soil fauna eating each other or eating soil microbes
    - Soil microbes eating each other or working on particulate organic matter
      - Over centuries even the mineral associated organic matter will be targeted by a microbe

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Common objections to me stating **Plants Dig Soil**

- Keep the soil covered
  - Leftover plant roots & shoots protect the soil until the next living roots
- Minimize tillage (or better minimize disturbance)
  - Plant roots essentially till the soil
  - Earthworms to bring the above ground residue down
  - Tillage to incorporate the residue if it does more good than harm
    - Example: allow more plants to grow, don't destroy aggregates, don't compact it and don't lead to the soil blowing or flowing away.
- Animals aren't essential, they are just one way to "pre-process" material
  - They can speed up the process but they can cause the same types of damage that too much tillage can (compaction, aggregate destruction, etc.)

How to increase living root days and the diversity of plants grown

- Start with a good cash crop rotation
- Fill in the shoulder seasons with cover crops
- Any crop that is planted with the intention that it will not be harvested but is left in place to benefit the soil in some capacity.
  - Stop erosion, build stable aggregates
  - Scavenge nutrients that would otherwise be lost
  - Unlock legacy P or fix atmospheric N
  - Suppress pests, increase beneficial insects, or crowd out weeds
  - Increase water infiltration and water storage capacity
  - Increase the organic matter to sequester carbon

The Claims: "No Fertilizer Needed"

- Many claims that diverse cover crops grow with no fertilizer.
- They believe they are tapping into microbial mined phosphorus
- In fact they are tapping into legacy P

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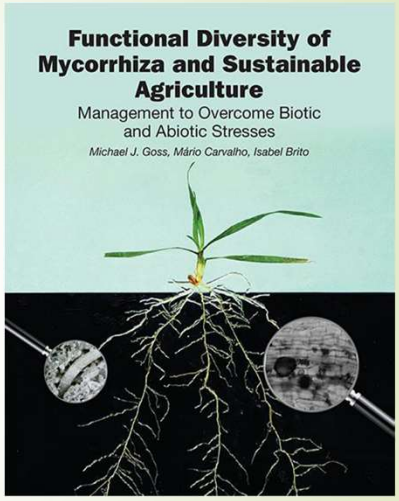
Microbial Mining of Soil Particles

- No mention in the book of microbial rates

Other sources:

- Dr. Monika Gorzelak from AAFC Lethbridge could not find any rates in literature searches
- Dr. Andrew McGuire says it may be higher than previously thought but nowhere near export rates for annual cropping systems.



Michael J. Goss, Mário Carvalho, and Isabel Brito. 2017. Functional Diversity of Mycorrhiza and Sustainable Agriculture.
https://www.sciencedirect.com/book/9780128042441/functional-diversity-of-mycorrhiza-and-sustainable-agriculture

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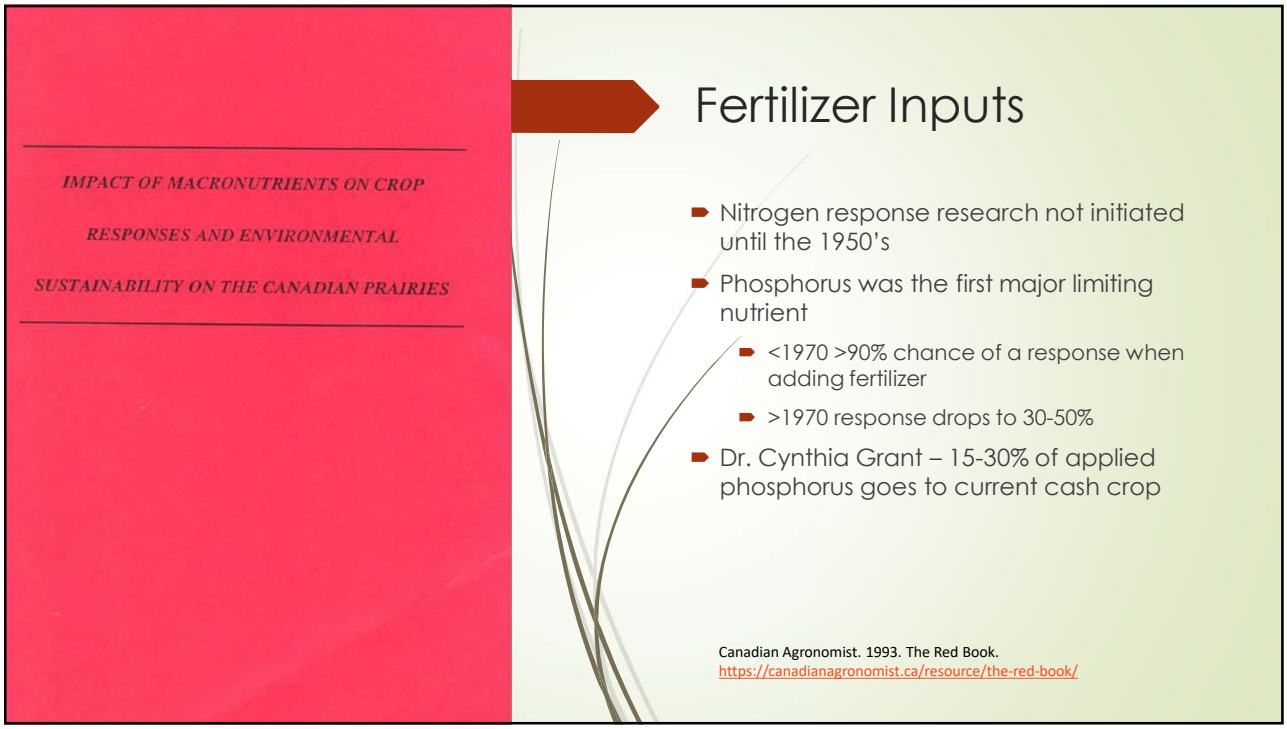

Fertilizer Inputs

- Nitrogen response research not initiated until the 1950's
- Phosphorus was the first major limiting nutrient
  - <1970 >90% chance of a response when adding fertilizer
  - >1970 response drops to 30-50%
- Dr. Cynthia Grant – 15-30% of applied phosphorus goes to current cash crop

Canadian Agronomist. 1993. The Red Book.
https://canadianagronomist.ca/resource/the-red-book/

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The Claim:
Celebrity ranchers no fertilizer systems

- They have converted to a grazing based system
- They may have decades or centuries of legacy phosphorus to use
- Legumes in their annual and perennial forages will replace the nitrogen

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Nutrient Removals (exports)

Crop	Yield	Nitrogen (lb/ac)	Phosphorus (lb/ac)
Peas	50 bu/ac	0	35
Wheat	40 bu/ac	60	25
Canola	35 bu/ac	65	35
Barley	60 bu/ac	60	35
Grass Forage	2 ton/ac	88	20
Alfalfa Forage	2 ton/ac	0	28
Cow-Calf Grazing	1 pair / 5ac	2	1

Government of Saskatchewan. Nitrogen Fertilization in Crop Production. https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/crops-and-irrigation/soils-fertility-and-nutrients/nitrogen-fertilization-in-crop-production
Government of Saskatchewan. Phosphorus Fertilization in Crop Production. https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/crops-and-irrigation/soils-fertility-and-nutrients/phosphorus-fertilization-in-crop-production
Arvid Aasen & Myron Bjorge. 2009. p 172. Alberta Forage Manual. https://open.alberta.ca/dataset/077326082x#summary
Arvid Aasen & Myron Bjorge. 2009. p 241. Alberta Forage Manual. https://open.alberta.ca/dataset/077326082x#summary

The Claim: Celebrity ranchers no fertilizer systems

- But also:
  - They capture more of the consumer dollar by direct marketing
  - Some have vertically integrated the processing, distribution, and wholesale
- Most ranchers are too far from these markets
- Most ranchers like to ranch and don't like to sell direct to consumers
- We still need grains, oilseeds, vegetables, and feed for cattle

The Claim:
The more diversity the better it is

- I hear the phrase "get the biology working for you" a lot
- Tend to cite natural systems or ecological studies
- Advocate for "cocktail" cover crop mixes
  - Usually this is 10-15 species (or more)
  - Tend to be very expensive blends
  - Tend to have many unfamiliar species (which could become weeds)

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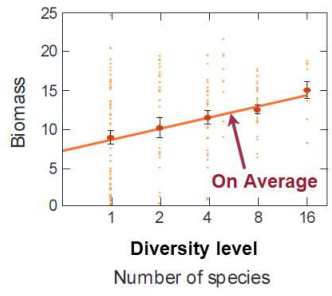
Nature



Andrew McGuire. 2021. Why Ecological Biodiversity Research Results Seldom Apply to Agriculture.
https://csanr.wsu.edu/why-ecological-biodiversity-research-results-seldom-apply-to-agriculture/

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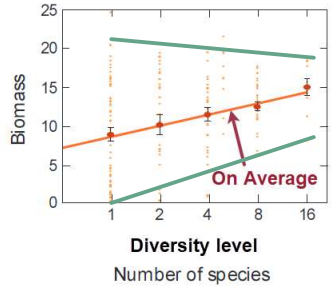
Nature



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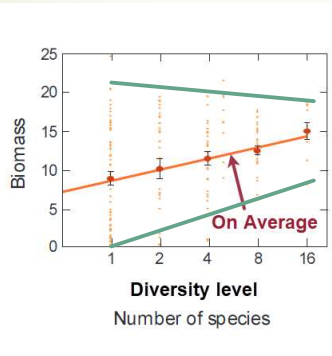
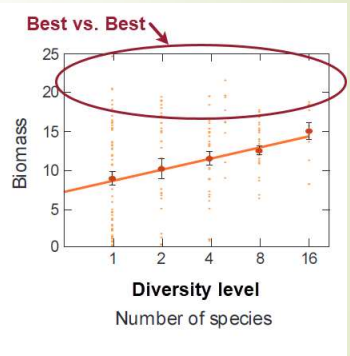
Nature

Agriculture





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Monoculture vs Diverse Mixture

- In 9 of 10 studies reviewed there was no statistical difference between single species & mixes

Andrew McGuire. 2020. Contrary Science; Cover Crop Mixtures, Monocultures, and Mechanisms. http://csanr.wsu.edu/contrary-science-cover-crop-mixtures-monocultures-and-mechanisms/

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Monoculture vs Diverse Mixture

- In 9 of 10 studies reviewed there was no statistical difference between single species & mixes
- In the remaining 1 of 10 studies the statistical difference was in favour of the monoculture over 80% of the time

Andrew McGuire. 2020. Contrary Science; Cover Crop Mixtures, Monocultures, and Mechanisms. http://csanr.wsu.edu/contrary-science-cover-crop-mixtures-monocultures-and-mechanisms/

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Diversity in Time & Space

- Crop rotation gives the diversity in time
- Rotating cover crops between
- Pick the best species or mix for the job and use it
  - The shorter the time period the lower the species amount should be
  - The smaller the area the lower the species amount should be
- Ex. in perennial pasture diversity should be there because the lifespan is expected to be 5, 10, 20 years or more.
  - But this doesn't apply to a mixture going in the ground for a month after harvest

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Excerpt from Abstract:

"Here we report on the traits and associated soil microbial communities that relate to aboveground biomass production, nutrient capture, weed suppression, erosion control and building particulate organic matter of 22 different full-season cover crops. All agroecosystem services were positively correlated with maximum canopy height and leaf area."

Open Access Article

Full-Season Cover Crops and Their Traits That Promote Agroecosystem Services

by Cameron Wagg [1,*], Aafke van Erk [1,2], Erica Fava [1], Louis-Pierre Comeau [1], T. Fatima Mitterboeck [1], Claudia Goyer [1], Sheng Li [1], Andrew McKenzie-Gopsill [3] and Aaron Mills [3]

[1] Fredericton Research and Development Center, Agriculture and Agri-Food Canada, 850 Lincoln Rd., Fredericton, NB E3B 4Z7, Canada
[2] Potatoes New Brunswick, 777 Everard H Daigle Boul, Grand Falls, NB E3Z 3C7, Canada
[3] Charlottetown Research and Development Center, Agriculture and Agri-Food Canada, 440 University Ave, Charlottetown, PE C1A 7Z5, Canada
* Author to whom correspondence should be addressed.

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(This article belongs to the Special Issue Plant–Soil Interactions and Agroecosystem Functioning)

https://doi.org/10.3390/agriculture11090830

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Grow big biomass, grow it often

- Mustard green manure ahead of potatoes for disease control
- Fall rye for weed suppression in organic soybeans
- Holding onto the soil after bean harvest

- If you mix them all together you dilute the effect

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Farmer Experience

- Cotton farmer in the Southern U.S.
- Been using cover crops for over a decade
- Host of the show asked him about adding some diversity to his mixes
- His response: I'm all about diversity but when I planted those mixes they didn't do what I needed them to do – control the pigweed.
- Field Work podcast
  - https://www.fieldworktalk.org/episode/2021/05/12/can-cotton-drive-american-ag-sustainability
  - https://www.fieldworktalk.org/episode/2021/05/19/how-conservation-saved-a-cotton-farmer

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Cover Crops

- Priority #1 is always to hold onto the soil
  - It doesn't matter what you are growing as long as you are holding your soil.
  - If your soil is blowing it really doesn't matter what is going on below the surface
- Priority #2 is bring benefits to your soil
  - Unlocking legacy phosphorus applications – ex buckwheat
  - Scavenging nitrogen before it leaches – ex radishes, cereals, fall rye
  - Fixing nitrogen from the air – ex. any legume crop – fababeans, peas, hairy vetch
  - Control pests – ex. mustards ahead of potatoes
  - Increase infiltration and water holding capacity
  - Increase organic matter and carbon sequestration

Methods to plant a cover crop

- After harvest
  - Minimal success – timeliness is critical and there is very little labour then
- Before harvest
  - Aerial or in crop spreading – works in high rainfall areas, not very well in dryland
    - Species limited to surface germinating small seeded crops
  - Relay seeding within crop
- Take a year out of production
  - Only profitable in high value crops and/or high impact disease/pest
  - Potential to combine with fallow system – if the cover crop transpires less than bare soil evaporates you can feed the system and not lose SOM

Cover crop the hills in the fall

- Top picture shows an end gun at the end of centre pivot for reference
- Bottom picture shows a cocktail mix in mid October that was planted in mid August
- The bare area to the front is due to a malfunction of the end gun that wasn't noticed when establishing and so didn't germinate until mid-September.
- The bare area illustrates the challenges we have here in the Prairies – very little time to grow anything worthwhile

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Potato production

- 620hp Quadtrac
- Toolbar only 18' wide and going 12-18" deep
- Lots of erosion potential
- Lots of disruption to the soil
- Rows are usually marked in the fall
- What can be done to help repair the soil?

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Cover crop the hills in the fall

- In November after a cold snap the cold hardy species are holding on
- Fall rye was not used because the intention is to have it all dead in the spring for ease of planting
- Powerhilling will still be required (roto-tilling and reforming the hills)
- Until potato planters can cut through and drop the seed in this is the best options (though there are growers working on this!)

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Cover crop the hills in the fall

- Instead of the diverse cover crop mix what about just volunteers?
- No cost – just made the hills as soon as possible after barley harvest (mid August)
- If really wanting to get technical you could use the variation across the field to create a fertilizer prescription using an NDVI
- Crop will winterkill on its own

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Simple mixes

- Processing peas harvested early August
- Deep rip (18") due to compaction from the harvesters
- Plant a five species mix and irrigate it in
- Tillage radish killed at emergence by flea beetles
- Clover doesn't like heat, never really grew
- Buckwheat killed at first frost (0C)
- Phacelia lasted until killing frost (-3C)
- Fall rye still going in March (pictured)

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Cocktail blends

- Green manure intention before potatoes
  - Harvested as silage – weeds and price was attractive
- 15 species were planted
- 2 species dominate (sunflower and tame oats)
- Learned what grows best
- Eliminate the laggards
- Or try over multiple years
- Or change the ratios
- Too many variables!

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Relay cropping

- In the southern U.S. growers establish next cash crop in existing one
  - Ex. plant soybeans between wide-row winter wheat before elongation
- Transfer the *principle* to cover crops
  - When it's harvested the cover crop is ready to go
- Think of how a field looks clean at harvest only to be weedy in a few weeks
  - This is because the weeds are small and established under the canopy

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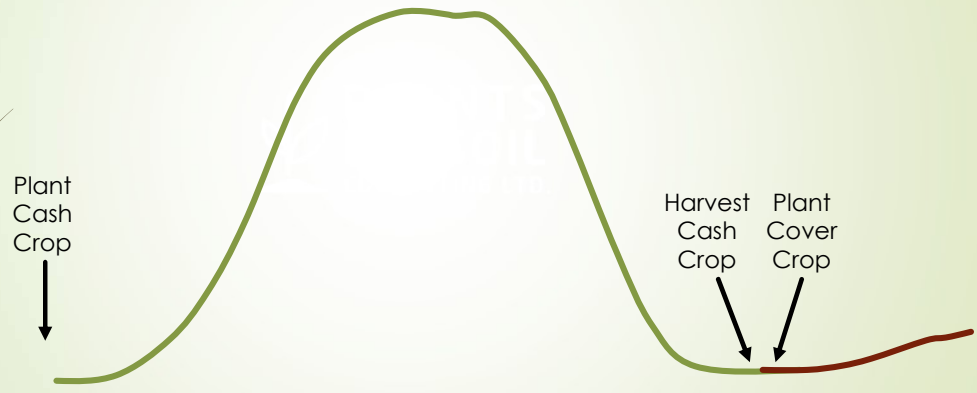

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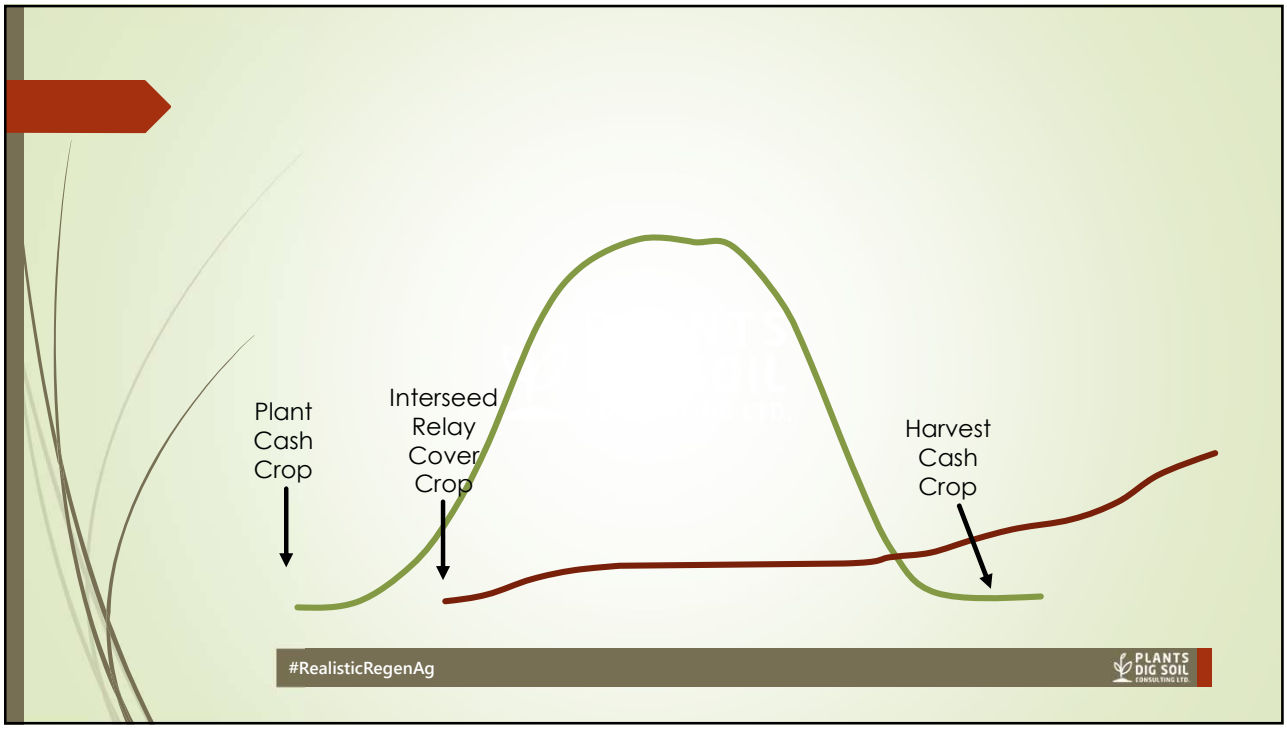
Plant
Cash
Crop
Interseed
Relay
Cover
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Harvest
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Crop
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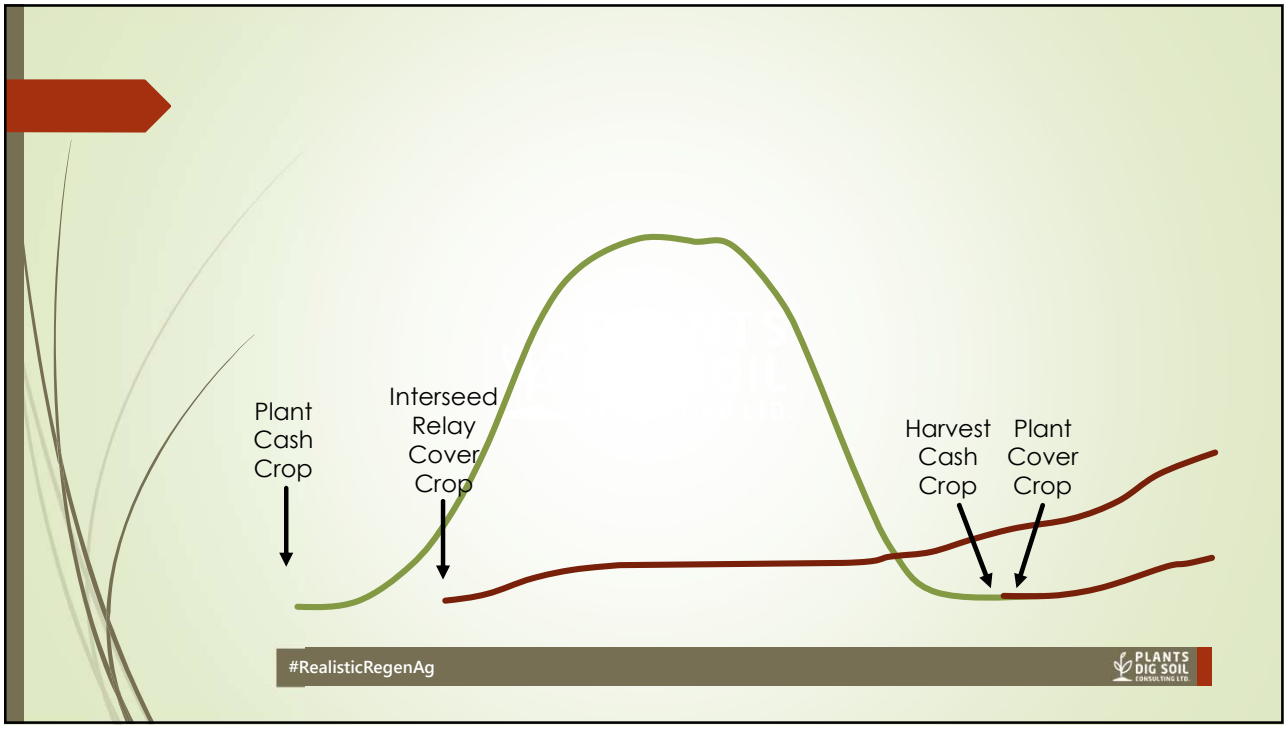
Plant
Cash
Crop
Interseed
Relay
Cover
Crop
Harvest
Cash
Crop
Plant
Cover
Crop
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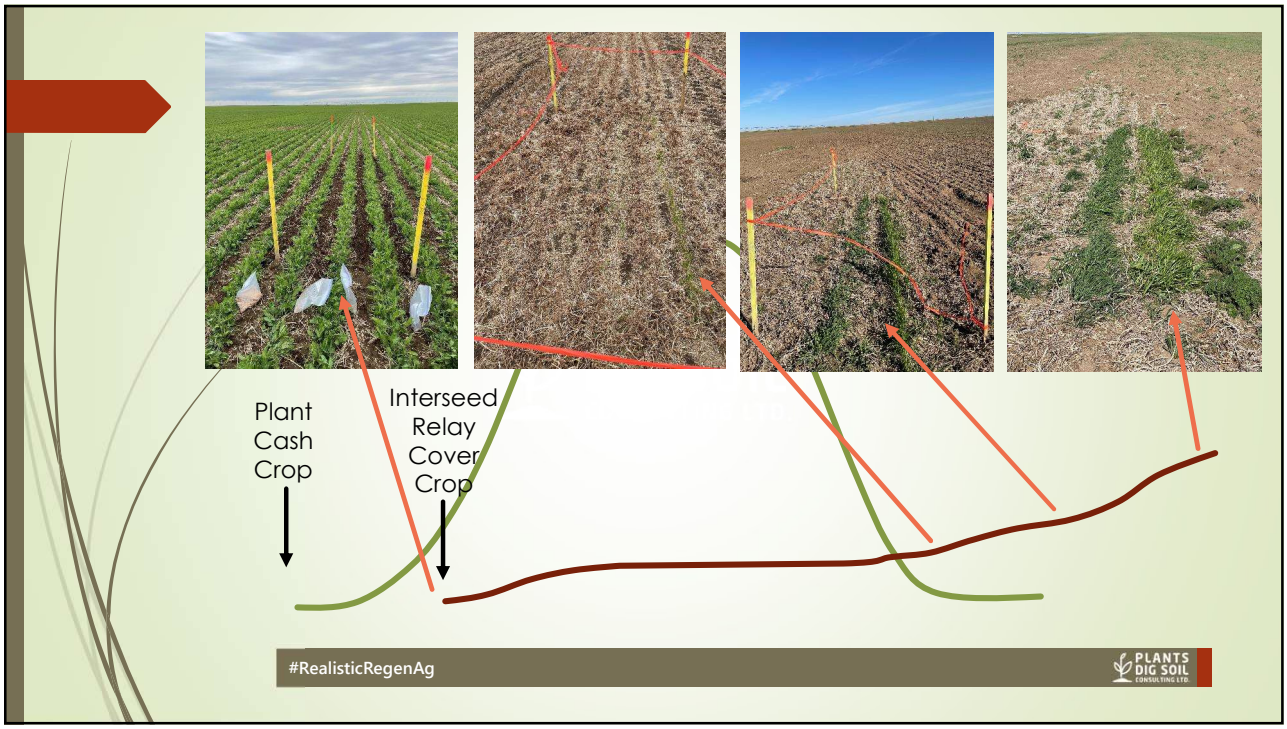

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Irrigation Interseeder

- Valmar blows seed to the shanks between rows
- Small harrow that the seeds blow onto
- Chain behind that drags over the seed
- 22" spacing for corn
- Broadcasting and/or harrowing only works well with irrigation and/or reliable rain

Gemstone Cattle Company on a tour by Union Forage August 2019.

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Dryland Interseeder

- Valmar blows seed to disc openers
- Packer behind to ensure good seed-to-soil contact
- 10" rows to go between air seeder rows
- Clover established between the wheat but is isn't competing with it

Josh Beck July 2020. Also see: https://www.grainews.ca/features/no-such-thing-as-failure-its-all-a-learning-experience/

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Summary

- Prairie soils took millennia to develop
  - They have supported humans for just as long
  - Keep this in mind when assessing regenerative claims
- Three pillars propping up regenerative agriculture
  - Inflated expectations of microbial mining
  - Using the legacy nutrients from decades of fertilizer application
  - Faulty accounting of nutrients
- It's all about keeping a living root – remember: Plants dig soil!
  - Use relay interseeding to help overlap the lag periods
  - Pick the best species for the job
  - Biomass is key in addressing whatever challenge you have

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Further learning

- Slides with references at: www.plantsdigsoil.com/media
- Search "Plants Dig Soil" in your podcast app or go here for links: www.plantsdigsoil.com/podcast
  - 016 What is Regenerative Agriculture?
  - 013 Caution on Carbon Payments
  - 012 Simplicity in Cover Crop Mixes
  - 022 Potatoes, Tillage, & Soil Health
  - 020 Relay Seeding Cover Crops

Stay in contact

- Monthly newsletter: www.plantsdigsoil.com/contact
- Direct contact:
  - Twitter: @scottcgillespie
  - LinkedIn: scottcgillespie
  - Email: scott@plantsdigsoil.com
  - Call/Text: 403-654-3096
- Contact me anytime about:
  - Consulting for your farm
  - Mentoring in agronomy
  - Follow up questions

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