Lincoln
31/08/2022

Regenerative Agriculture
An agronomists view

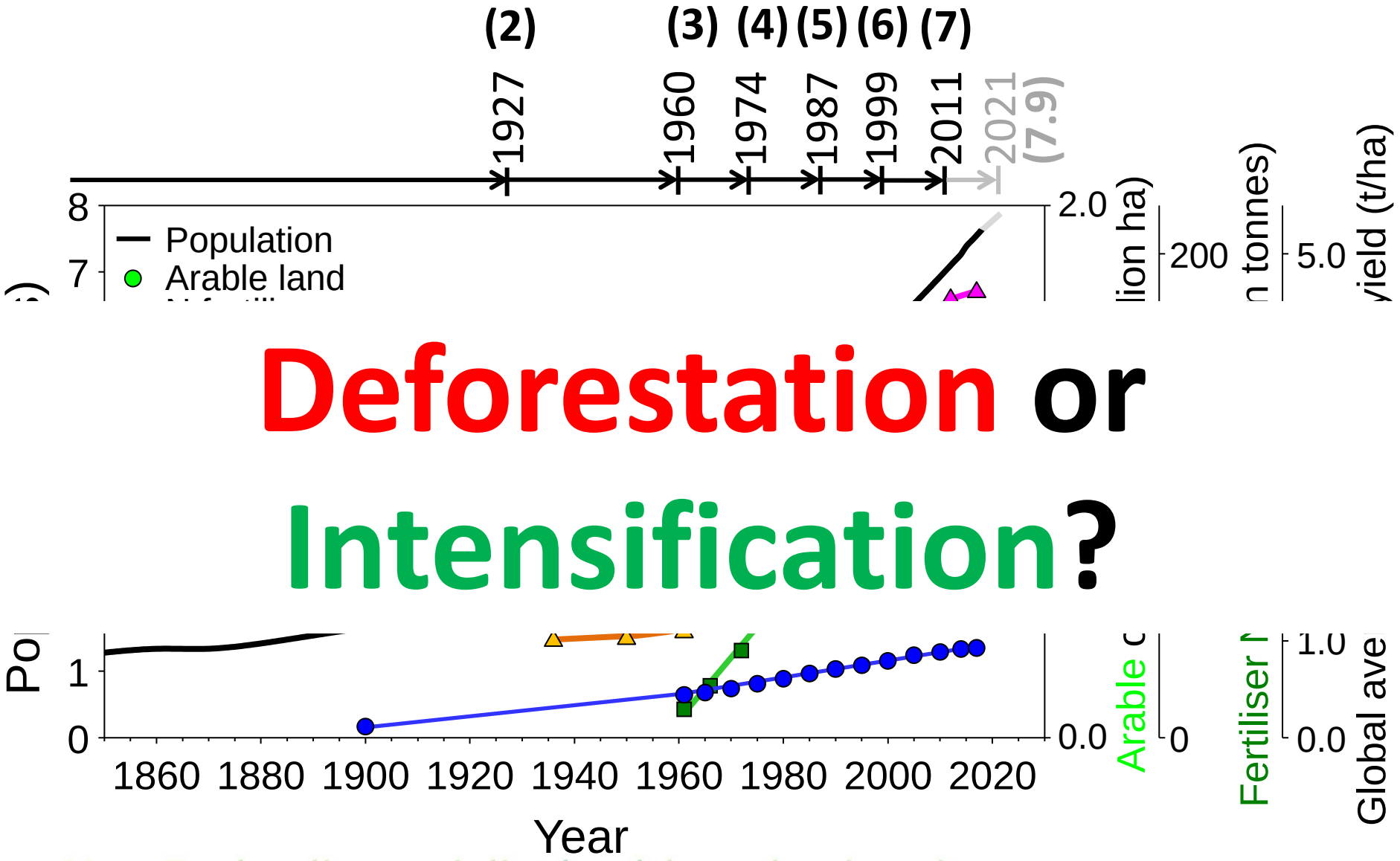
Professor Derrick Moot

New Zealand's specialist land-based university

Introduction

- Global food production
- RA – history, current status, future…….
- Soils focus…..
- NZ context – pastoral?
- Climate change

How do we feed 10 BN

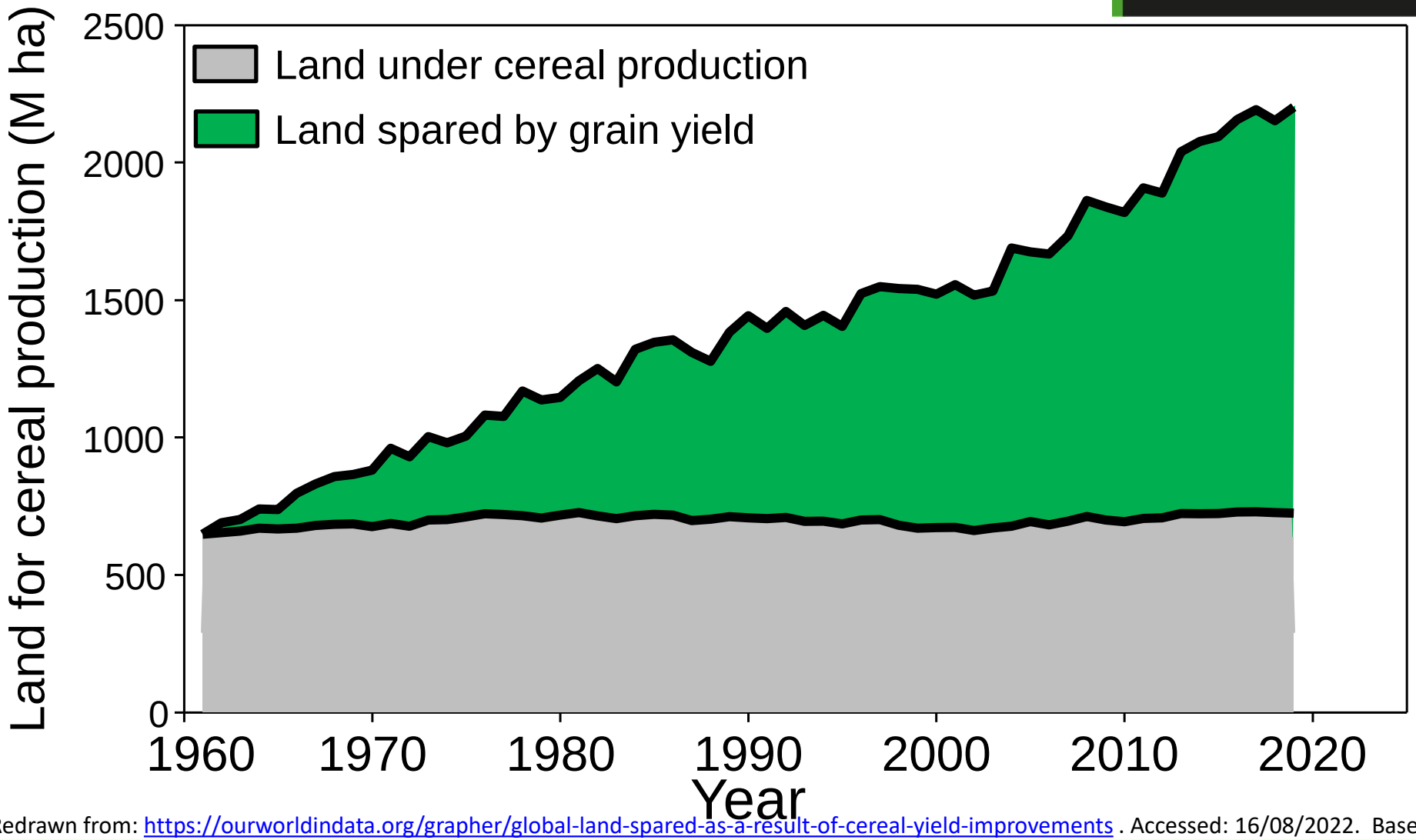


Deforestation or Intensification?

New Zealand's specialist land-based university

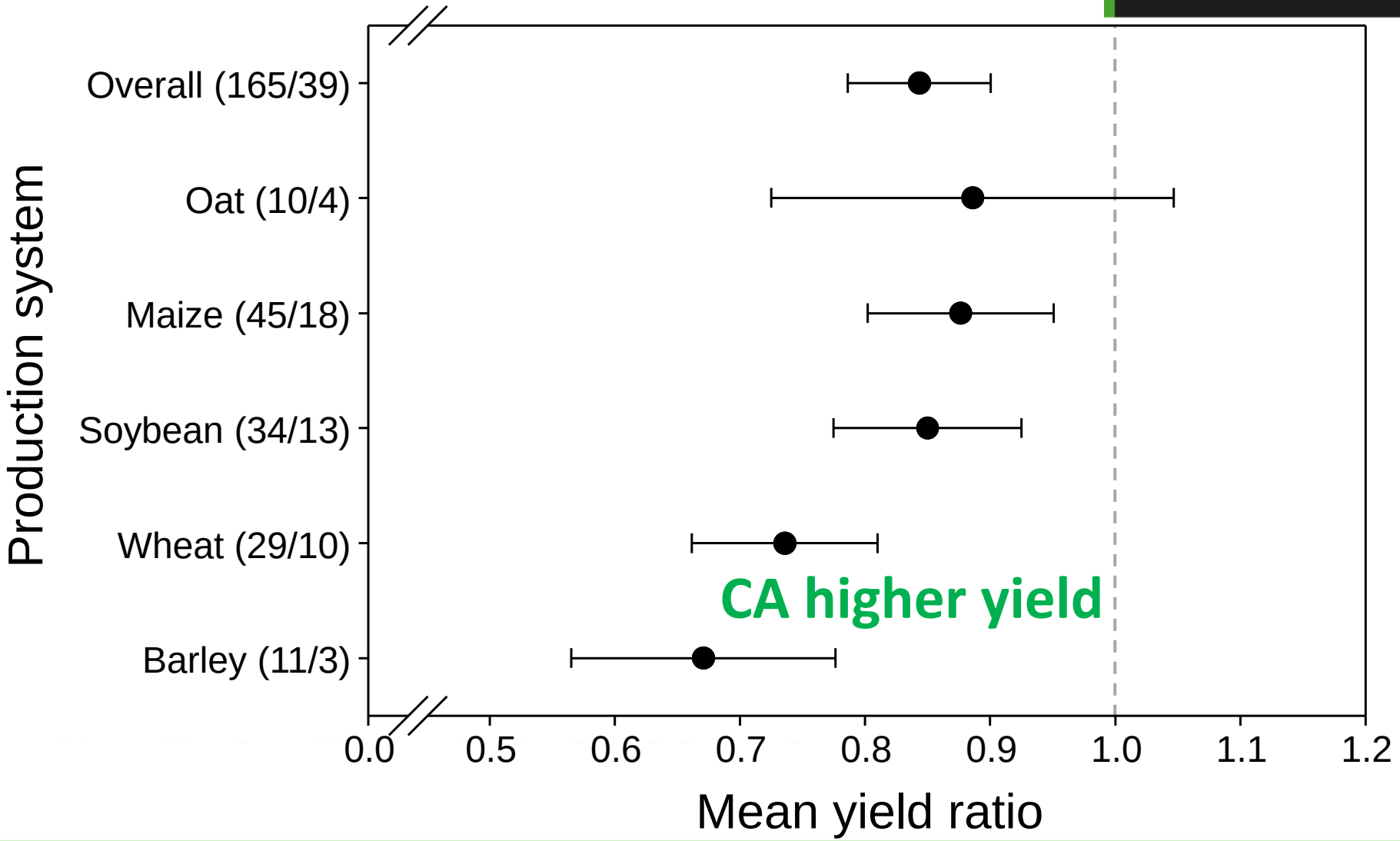
Recreated from Evans 1998, M.K. van Ittersum & FAOSTAT (2019)

Impact of G x E x M



Redrawn from: https://ourworldindata.org/grapher/global-land-spared-as-a-result-of-cereal-yield-improvements . Accessed: 16/08/2022. Based on data sourced from: http://data.worldbank.org/data-catalog/world-development-indicators. Accessed: 16/08/2022.

Mean yield ratio – CA vs. Organic



Food

The most damaging farm products? Organic, pasture-fed beef and lamb

George Monbiot
@GeorgeMonbiot
Tue 16 Aug 2022 13.26 BST

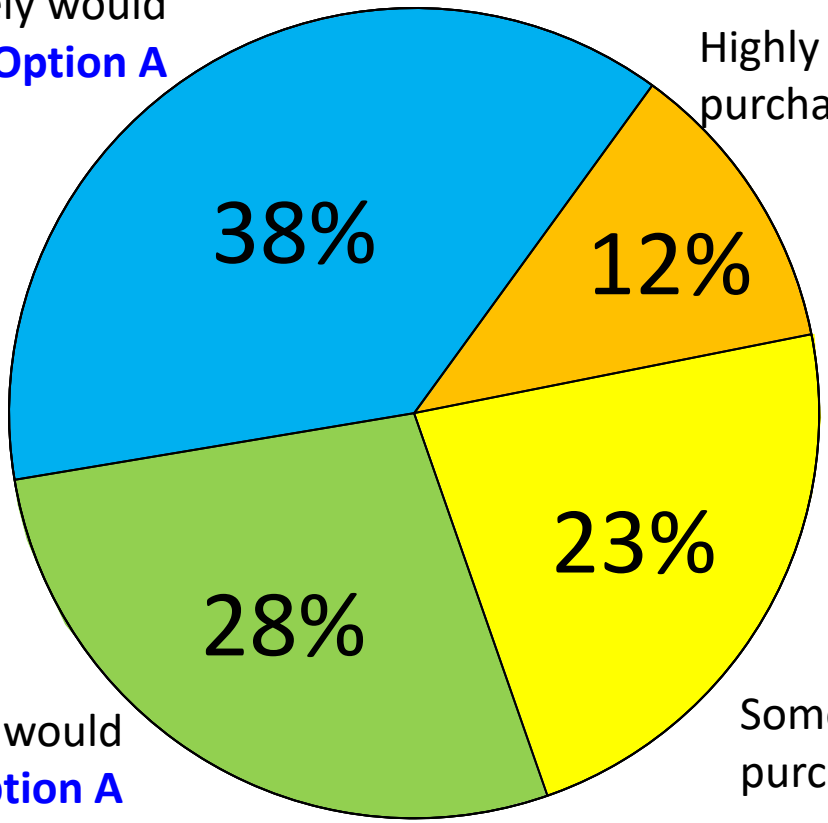
https://www.theguardian.com/environment/2022/aug/16/most-damaging-farm-products-organic-pasture-fed-beef-lamb Accessed 17/08/2022

Scenario: **Imagine you are going to the store to purchase a food or beverage you like. You see they have made a newer version of the product. Option A is the original product. Option B is the same product, but it is labelled, "grown using regenerative agriculture". Option B costs more than Option A.**

Food Insight

Highly likely would purchase **Option A**

Highly likely would purchase **Option B**



Option A: $3

Option B: $4

Somewhat likely would purchase **Option A**

Somewhat likely would purchase **Option B**

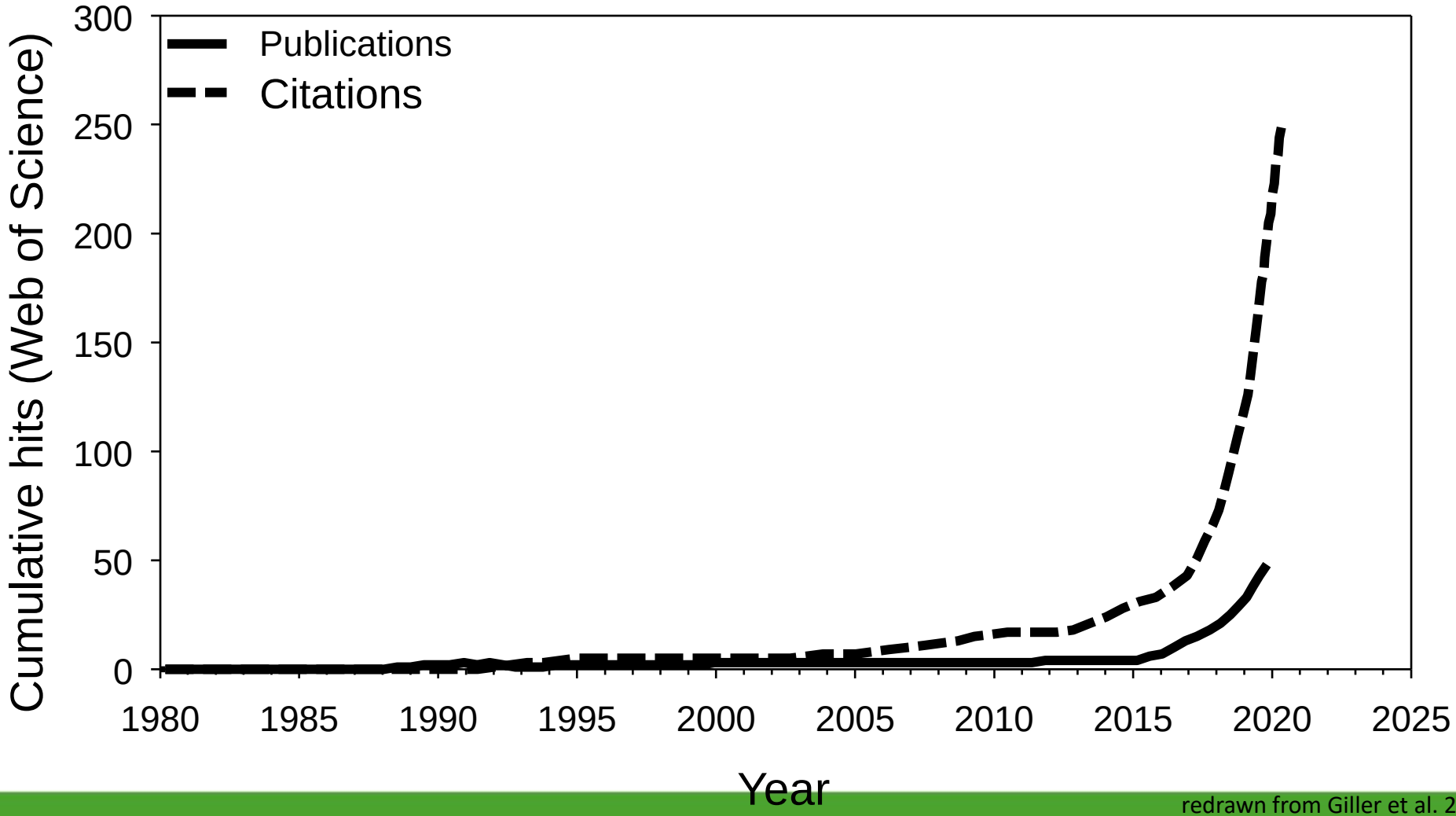
https://foodinsight.org/consumer-perspectives-on-regenerative-agriculture/ 10/02/2022. Accessed 18/08/2022

Regen Ag – and friends

- 1980-2015 – RA << Sustainable ag, organic ag, agroecology
- Regen Ag doubling in public items annually since 2016 - NGOs, multi-nationals etc.
- Public demand research funding…….Govt. has responded….no clear definition of what RA is…

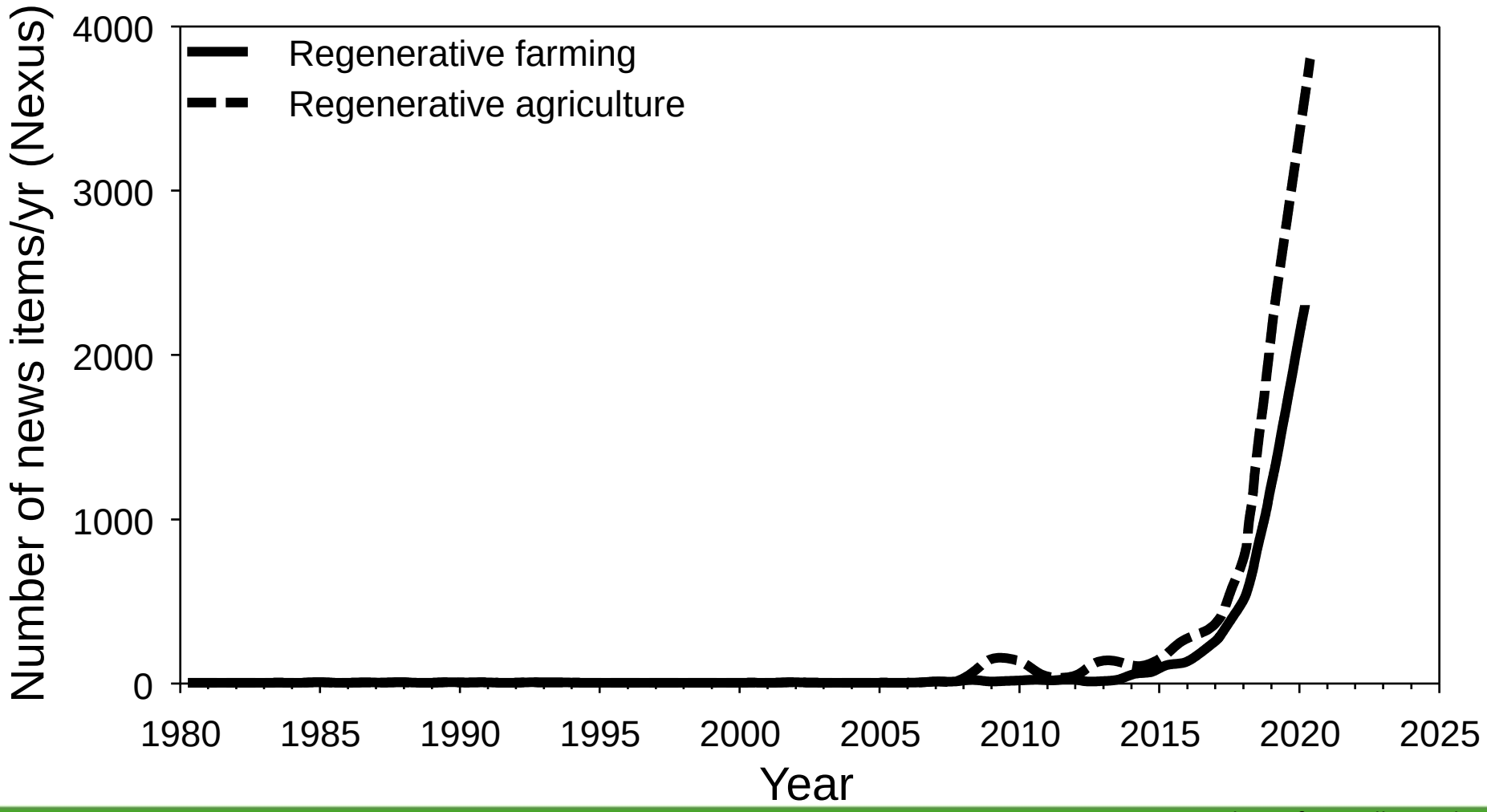
< 50 Science publications *Giller et al. 2020*

Cumulative times terms appear in science publications



redrawn from Giller et al. 2021

Times terms appear in popular media



redrawn from Giller et al. 2021

Regen Ag – Philosophy Harwood 1983

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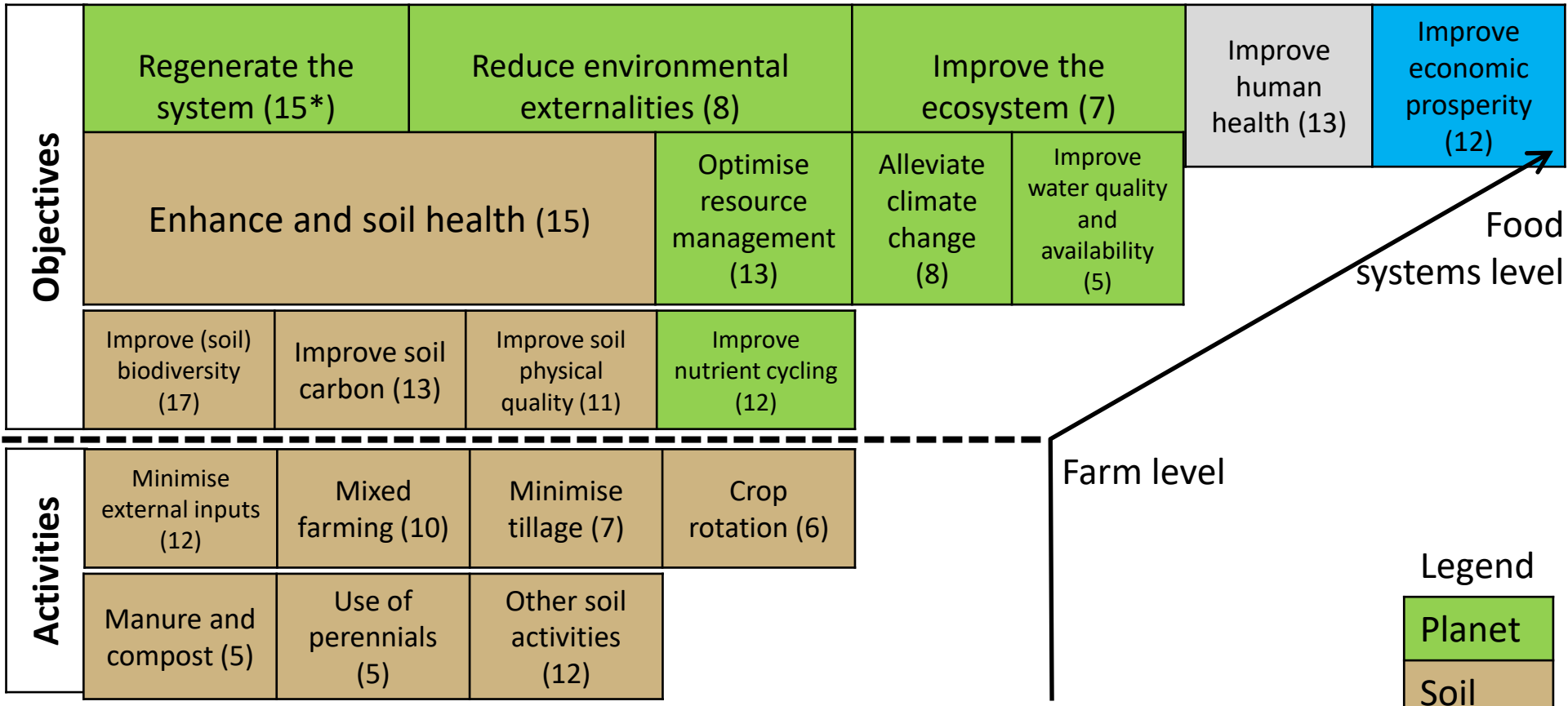
1. High yields free of biocides – Rodale institute
2. Increased soil productivity – depth and fertility
3. Soil genesis from upward flow of nutrients
4. Stable biological interactions – eliminate biocides
5. No synthetic fertilizers - manure
6. Intimate relationship between farmer and farm
7. Self-reliant for N – N fixation
8. Animals hormone free with no prophylactic antibiotics
9. Increased levels of employment

Beyond organic – increase productivity

Core themes of regenerative agriculture



*number in brackets represents the number of search records

Redrawn from Schreefel et al. 2020

Regen Ag = conventional Ag…..

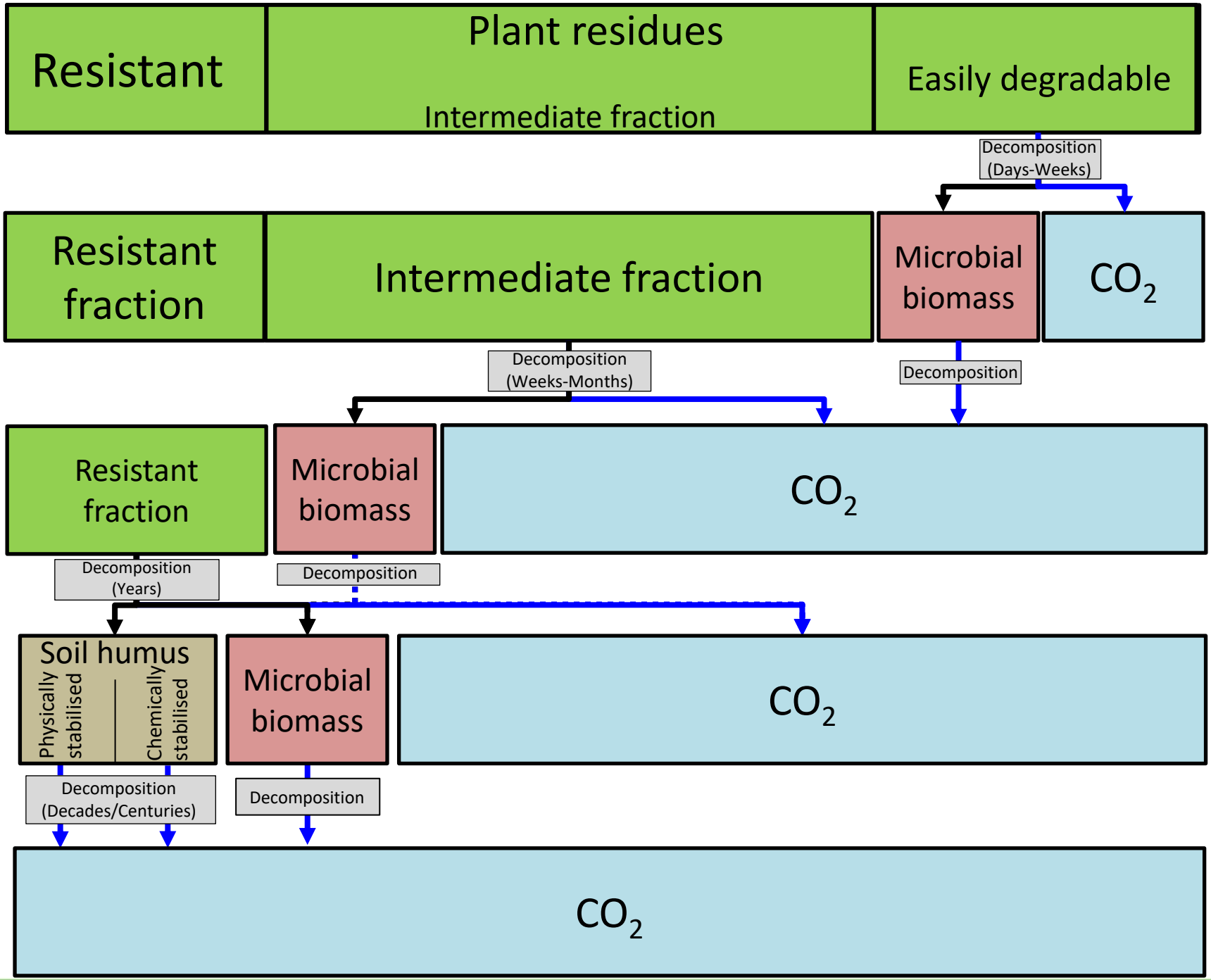
- ✓ Crop rotations
- ✓ Cover crops
- ✓ Minimum tillage – glyphosate
- ✓ Controlled traffic
- ✓ Soil Organic Matter for nutrient cycling
- ✓ Minimize soil erosion/agrichemical use
- ✓ Livestock grazing – rotational grazing

Encourage and promote

Regen Ag – crisis to address…

1. Soil Health = ?????? No definition
   - soil biology – no links with function
   - increased NO_3^- leaching, GHG emissions
   - trade-offs seldom discussed
   - forest to arable reduced SOM and soil C
   - forest to pasture increased SOM and soil C

Soil organic matter is NOT soil carbon



Stages of residue decomposition in soil. Changing box sizes indicates relative quantities of C in various fractions as decomposition progresses towards completion. Modified from Condron et al. 2010

200-300 t OM/ha in NZ pastures

Regen Ag - Soil health - nutrients?

- C storage – saturated in many NZ soils
- C storage rate is low and temporary for crops
- SOM – only increase yields if nutrient limiting
- Nutrients do not upwell – must be replaced
- N fixation requires P and S

Law of the most limiting- Leiberg

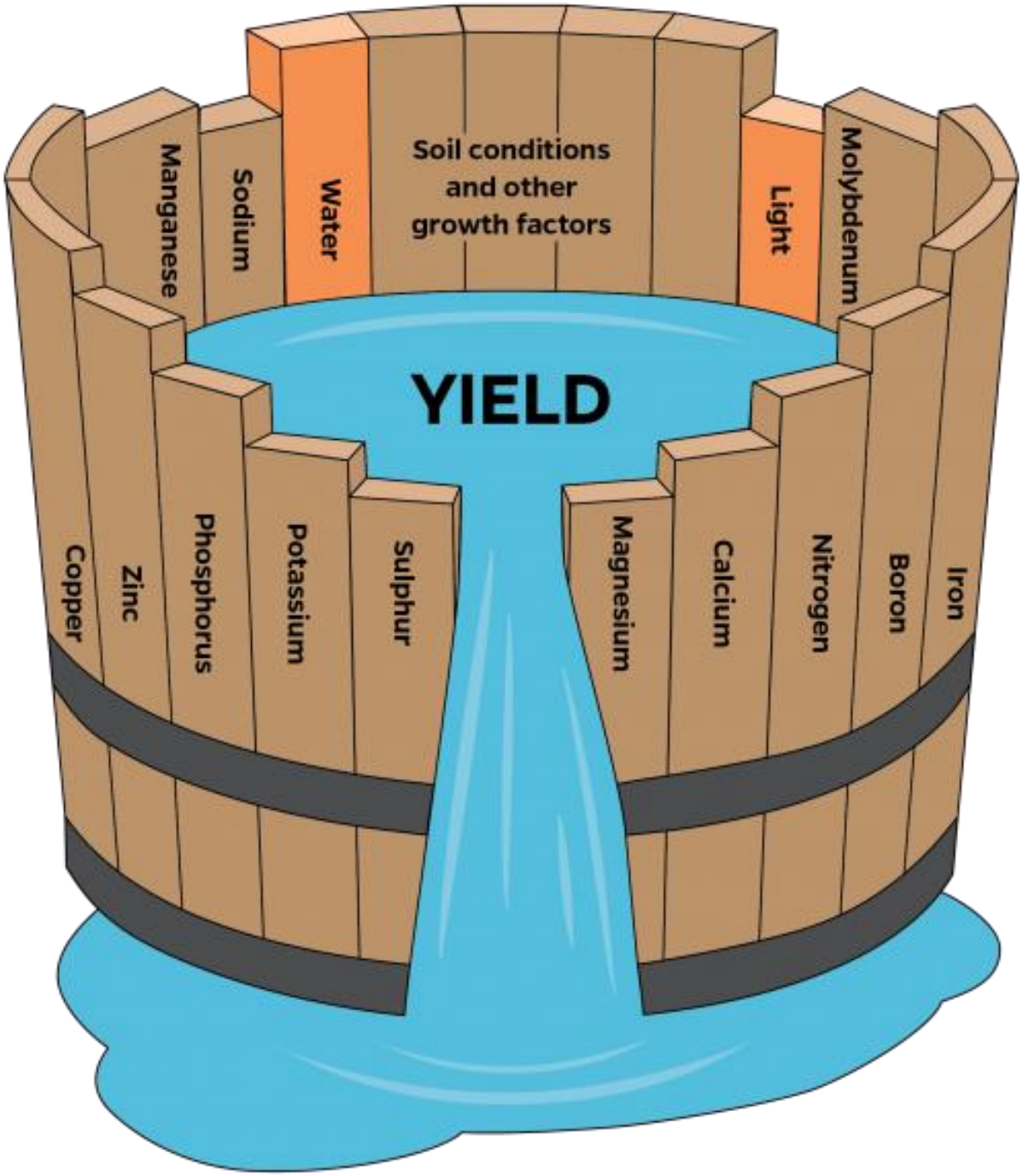


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Image sourced: https://arcosaspecialtymaterials.com/liebigs-law-of-minimum/ Accessed: 18/10/2021

Regen Ag – crisis to address…..

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2. Biodiversity
    - Soil biology – no evidence
    - Species – Multi >> Monocultures
    - Paddock or landscape?
    - national - developed/developing

Best land already used - yield gaps

Image source: https://scitechdaily.com/more-than-one-third-of-corn-belt-farmland-has-completely-lost-its-carbon-rich-topsoil/
Publication: University of Massachusetts Amherst. Accessed: 14/10/2021.
Associated reference: Evan A. Thaler E.A., Larsen I.J., Yu Q. 2021. The extent of soil loss across the US Corn Belt. *Proceedings of the National Academy of Sciences*. https://doi.org/10.1073/pnas.1922375118


Biodiversity at landscape scale

RA diversity at paddock scale

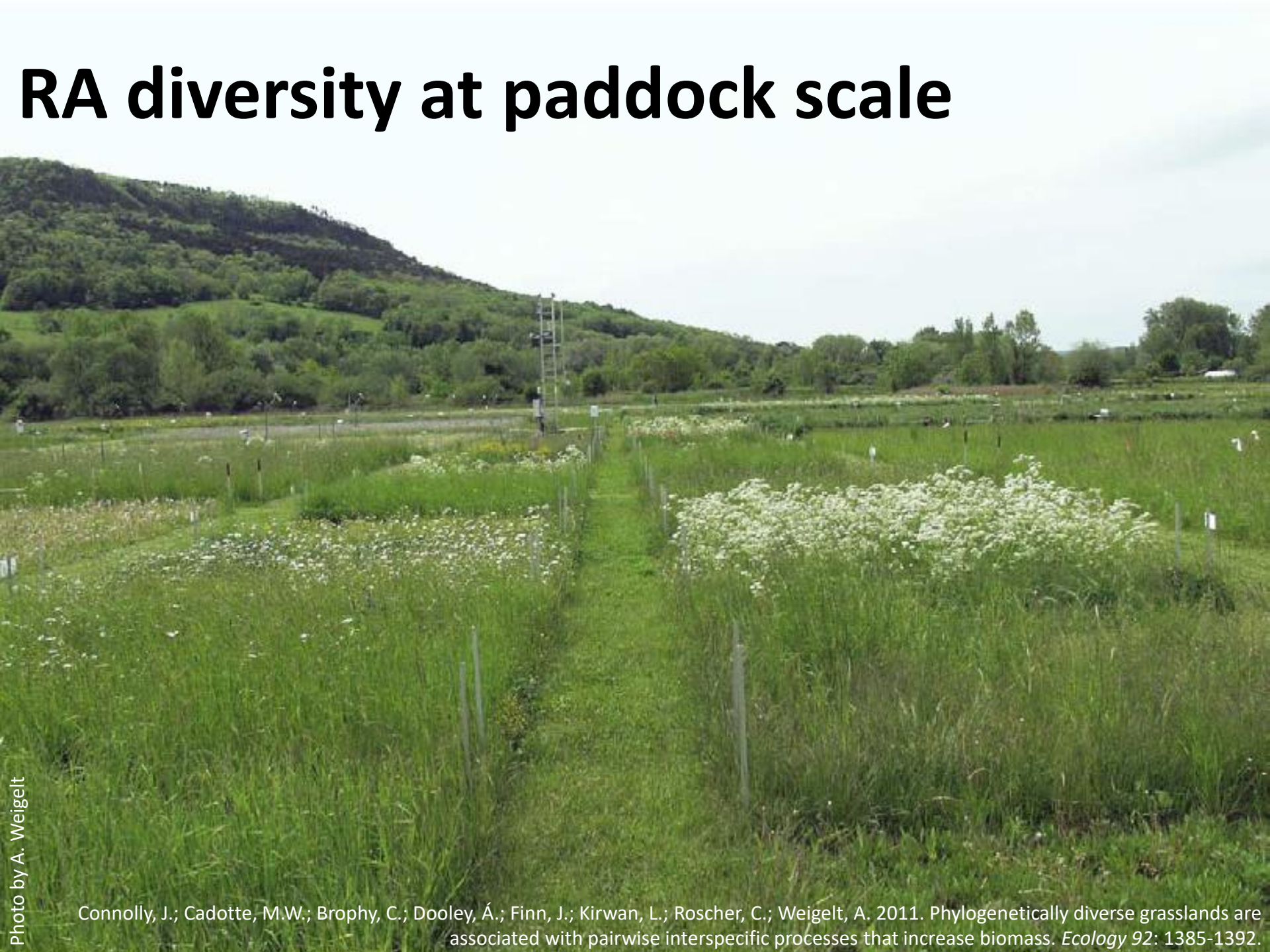


Photo by A. Weigelt

Connolly, J.; Cadotte, M.W.; Brophy, C.; Dooley, Á.; Finn, J.; Kirwan, L.; Roscher, C.; Weigelt, A. 2011. Phylogenetically diverse grasslands are associated with pairwise interspecific processes that increase biomass. *Ecology 92*: 1385-1392.

Seed mixtures – past


P.W. Smallfield (1917-18)

A 1910s recommendation for pasture renewal on pumice land near Rotorua (Smallfield 1949).

Species	Rate (lb/acre)	Species	Rate (lb/acre)
Cocksfoot	5	Cowgrass	2
Danthonia	½	Tall fescue	7
Browntop	2	Paspalum	½
Bay grass	⅛	Crested dogstail	1
Chewings fescue	1	Sheep's burnet	2
Poa pratensis	½	Yarrow	⅛
Birdsfoot trefoil	¼	Sheep's parsley	1
White clover	1	Perennial rye	2
			26


Summer 2015/16
2-3 species maximizes yield and quality

Regen Ag – crisis to address…

3. Climate change
    - Soil Carbon levels 10-15% - not NZ
    - nitrous oxide reductions from less N
    - nitrous oxide increases from manure
    - lower stocking rates = less methane/food
    - slower growing animals = more methane

Global deforestation to compensate

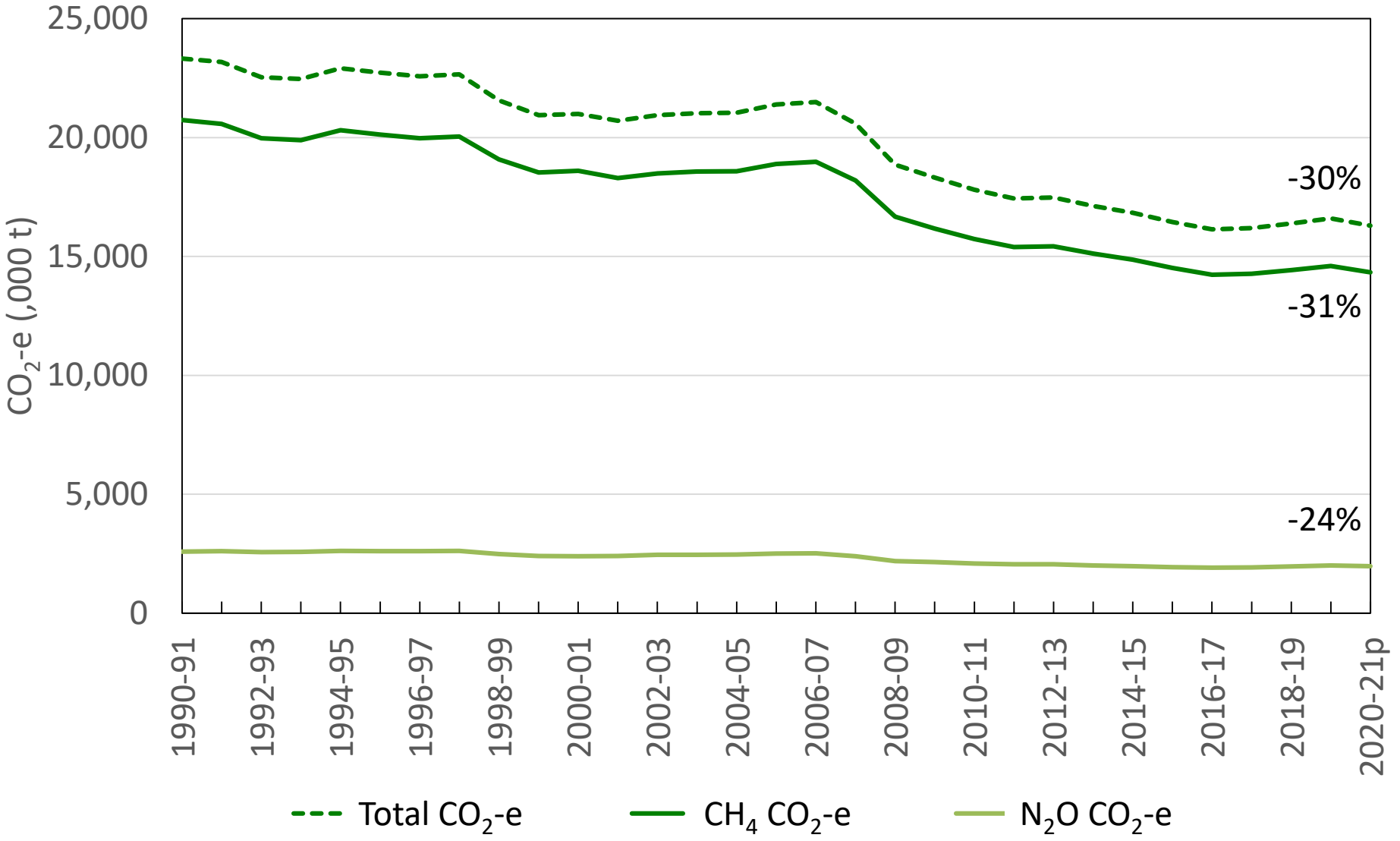
Regenerative or Intensive $CO_2 + CH_4$

Photos: DJ Moot
Lincoln University

Sustainable intensification

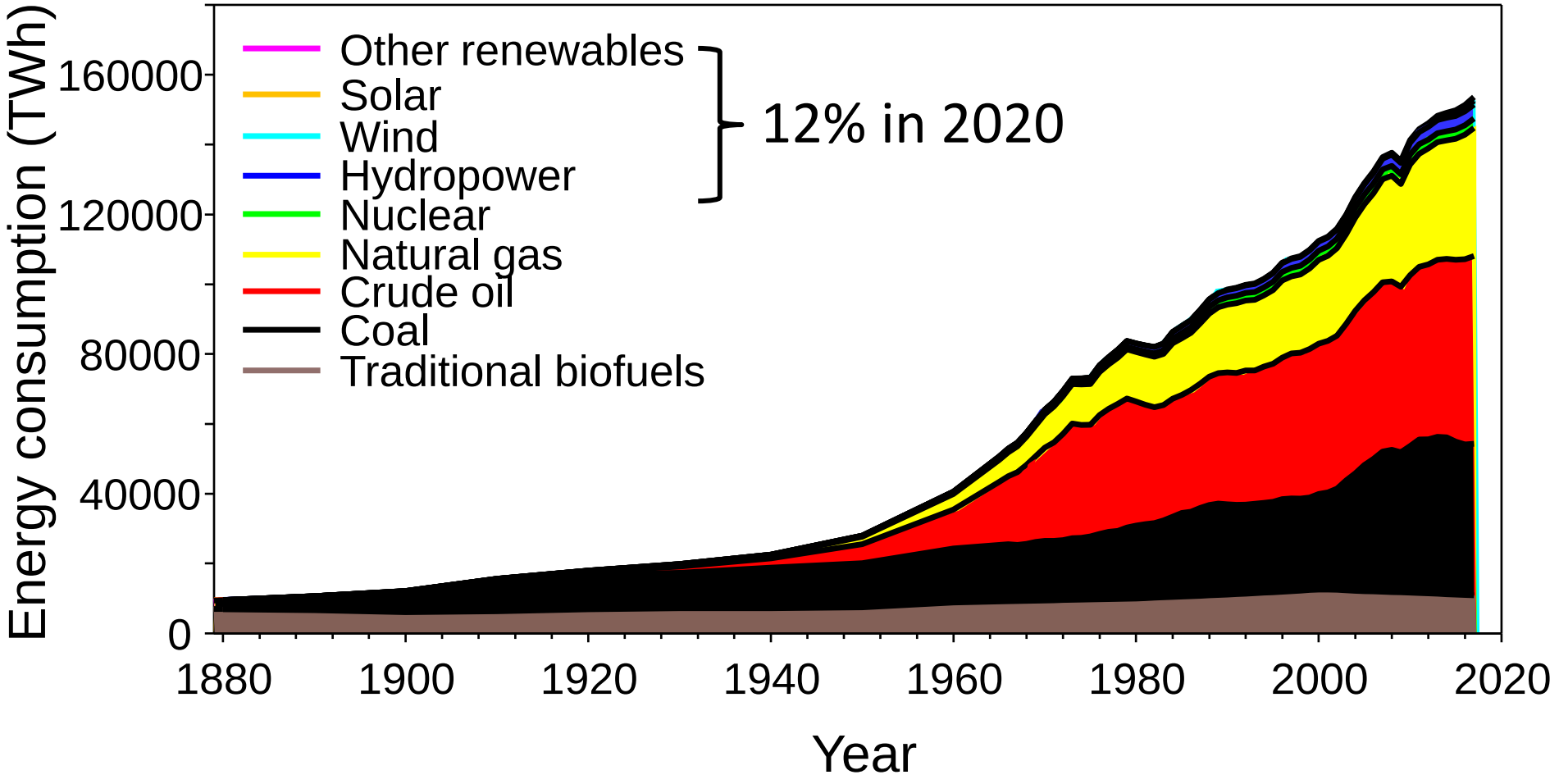
Photo supplied by John Chapman
Inverary Station

NZ Sheep and Beef Cattle CH_4 and N_2O warming



Source: R. Davison 2022, Beef + Lamb New Zealand Economic Service; MfE

Global energy supply



Redrawn from: https://ourworldindata.org/energy-production-and-changing-energy-sources. Accessed: 2/10/2019. Based on data sourced from Smil 2017. http://vaclavsmil.com/2016/12/14/energy-transitions-global-and-national-perspectives-second-expanded-and-updated-edition/ ; https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html.

Regen Ag - Questions

- What is the problem being fixed?
- What is regenerated?
- What agronomic practice will provide regeneration?
- Will it work economically and socially?
- What political/business forces are driving the use of any proposed solution?

Lacks an evidence base – NZ?

Conclusions

- “Fix agriculture” “failing food systems” old mantras
- RA = CA – in many areas – promote those
- RA – cropping basis – less pastoral data
- Soil health has no function…
- SOM becomes CO_2 and is not soil C
- RA is not a solution to CO_2 driven climate change

Politically expedient – market opportunity?

References

Brown, C. 1990. An integrated herbage system for Southland and South Otago. *Proceedings of the New Zealand Grassland Association*, **52**, 119-122.

Case B, Ryan C. 2020. An analysis of carbon stocks and net carbon position for New Zealand sheep and beef farmland. 29 p. Online: https://beeflambnz.com/sites/default/files/news-docs/BL_Carbon_report_for_review_final_submit.pdf.

Condron L, Stark C, O'Callaghan M, Clinto nP, Huang Z. 2010. The role of microbial communities in the formation and decomposition of soil organic matter. In: G. D & E. T Eds. *Soil Microbiology and Sustainable Crop Production*. Dordrecht: Springer. pp. 81-118. https://doi.org/10.1007/978-90-481-9479-7_4.

de Klein CAM, Pinares-Patino C, Waghorn GC. 2008. Greenhouse gas emissions. In: McDowell RW Ed. *Environmental impacts of pasture-based farming*. Wallingford, UK: CAB International. pp. 1-33. https://doi.org/10.1079/9781845934118.0000.

Evans, L. T. 1998. Feeding the Ten Billion: Plants and Population Growth. U.K.: Cambridge University Press. 264 pp.

FAOSTAT. 2019. Global population, rice and wheat yields, N fertiliser consumption, Irrigated land area 1961-2018 sourced from: http://www.fao.org/faostat/en/#data/OA. Accessed 4/10/2019. (some points removed for clarity. General trend lines added by eye DPR Team, Lincoln University).

Giller KE, Hijbeek R, Andersson JA, Sumberg J. 2021. Regenerative Agriculture: An agronomic perspective. *Outlook on Agriculture 50*: 13-25. https://doi.org/10.1177/0030727021998063.

Harwood RR. 1983. International overview of regenerative agriculture. Presented at: *Proceedings of a Workshop on Resource-efficient Farming Methods for Tanzania*. Faculty of Agriculture, Forestry and Veterinary Science, University of Dares Salaam, Morogoro, Tanzania. 16-20 May 1983.

Ledgard, S. F. 2017. Assessing the environmental impact of sheep production. *In:* J. Greyling (ed). Achieving sustainable production of sheep. Cambridge, United Kingdom: Burleigh Dodds Science Publishing Limited, 407-430.

Mills, A., Moot, D. J. and Jamieson, P. D. 2009. Quantifying the effect of nitrogen of productivity of cocksfoot (*Dactylis glomerata* L.) pastures. *European Journal of Agronomy*, **30**, 63-69.

Mills, A., Moot, D. J. and McKenzie, B. A. 2006. Cocksfoot pasture production in relation to environmental variables. *Proceedings of the New Zealand Grassland Association*, **68**, 89-94.

Moot DJ, Davison R. 2021. Changes in New Zealand red meat production over the past 30 yr. *Animal Frontiers 11*: 26-31. https://doi.org/10.1093/af/vfab027.

New Zealand Fertiliser Manufacturers' Research Association. 2020. *Annual update (New Zealand Fertiliser Manufacturers' Research Association). 15 pp*. Retrieved 5/5/2011 from: http://www.fertresearch.org.nz/resource-centre/annual-updates. Additional data (2011-2019) via Pers. Comm.

Our Land and Water National Science Challenge. 2019. The 34 Influences That Will Drive the Future of Farming. https://ourlandandwater.nz/news/matrix-2019/. Date accessed 22/10/2021.

PGG Wrightson Seeds. 2017. Pasture Guide 2017. Accessed 20/7/2017. https://online.flippingbook.com/view/509844/

Schreefel L, Schulte RPO, de Boer IJM, Schrijver AP, van Zanten HHE. 2020. Regenerative agriculture – the soil is the base. *Global Food Security 26*: 100404. https://doi.org/10.1016/j.gfs.2020.100404.

Smallfield PW. 1949. Grassing of pumice land. *Proceedings of the New Zealand Grassland Association 11*: 59-67.

United Nations, Department of Economic and Social Affairs, Population Division. 2019. World Population Prospects 2019, custom data acquired via website: https://population.un.org/wpp/DataQuery/ . Date accessed: 22/10/2021.

van Ittersum, M. K. 2011. Future Harvest: the fine line between myopia and utopia. *In:* Inaugural lecture upon taking up the post of Personal Professor of Plant Production Systems at Wageningen University on 12 May 2011. (Wageningen University: Wageningen University, 34 pp. Online: http://edepot.wur.nl/169680.

External Data Sources

Slide 5:

Recreated from Evans 1998, van Ittersum 2011 & FAOSTAT 2019. FAOSTAT. 2019. Global population, rice and wheat yields, N fertiliser consumption, Irrigated land area 1961-2018 sourced from: http://www.fao.org/faostat/en/#data/OA. Accessed 4/10/2019. (some points removed for clarity. General trend lines added by eye DPR Team, Lincoln University).

Slide 51:

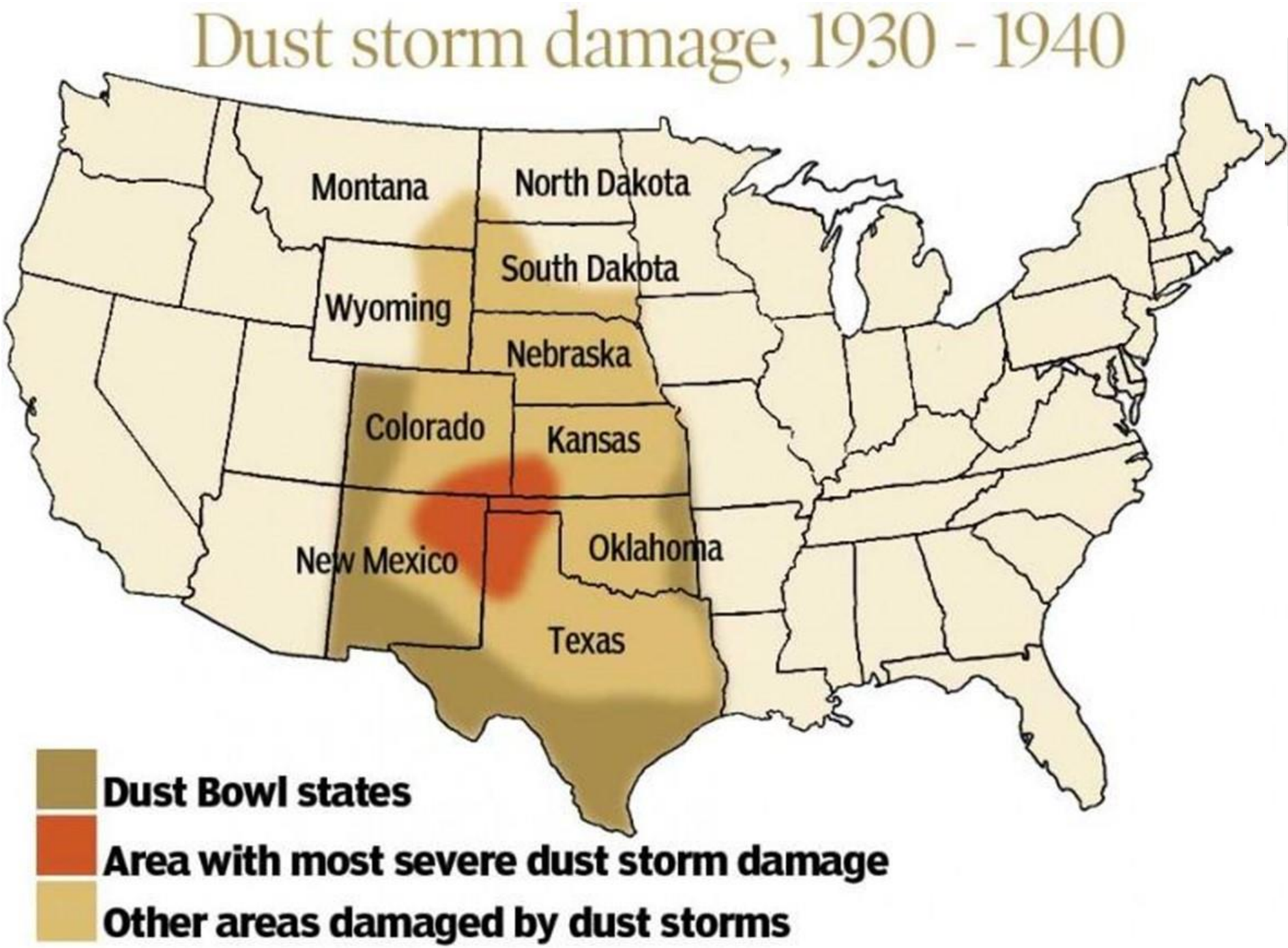
CO_2 at Muana Loa, Hawaii. Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (scrippsco2.ucsd.edu/). (28/5/2019).

Slide 52:

Data sourced from: https://ourworldindata.org/energy-production-and-changing-energy-sources Accessed 2/10/2019; Smil 2017; http://www.fao.org/faostat/en/#data/OA Accessed 4/10/2019. Regression equation fitted by DPR Team, Lincoln University.

Slide 53:

Energy consumption (TWh) graph data sourced from: https://ourworldindata.org/energy-production-and-changing-energy-sources. Accessed 2/10/2019. Original graph data derived from: Vaclav Smil (2017). Energy Transitions: Global and National Perspectives. & BP Statistical Review of World Energy. Online: http://vaclavsmil.com/2016/12/14/energy-transitions-global-and-national-perspectives-second-expanded-and-updated-edition/ ; https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html.



G. Moore, 2020 . Accessed 13/10/2021. https://footnote.wordpress.ncsu.edu/2020/07/23/black-blizzards-7-24-2020/

A Black Blizzard approaching Rolla, Kansas on May 6, 1935. Image from the FDR Digital Archives.

Sourced from: G. Moore, 2020 . Accessed 13/10/2021. https://footnote.wordpress.ncsu.edu/2020/07/23/black-blizzards-7-24-2020/

Global food system is broken

- Hunger
- Poverty
- Obesity
- Over reliance on fertilizer and pesticides
- Environmental degradation
- Animal welfare

Political and economic change

Crisis narrative – Blame CA

- Agriculture in crisis
- Soil health collapsing
- Biodiversity – 6th mass extinction
- Plateauing crop yields
- Climate change
- Industrialised agriculture

How to solve these problems?

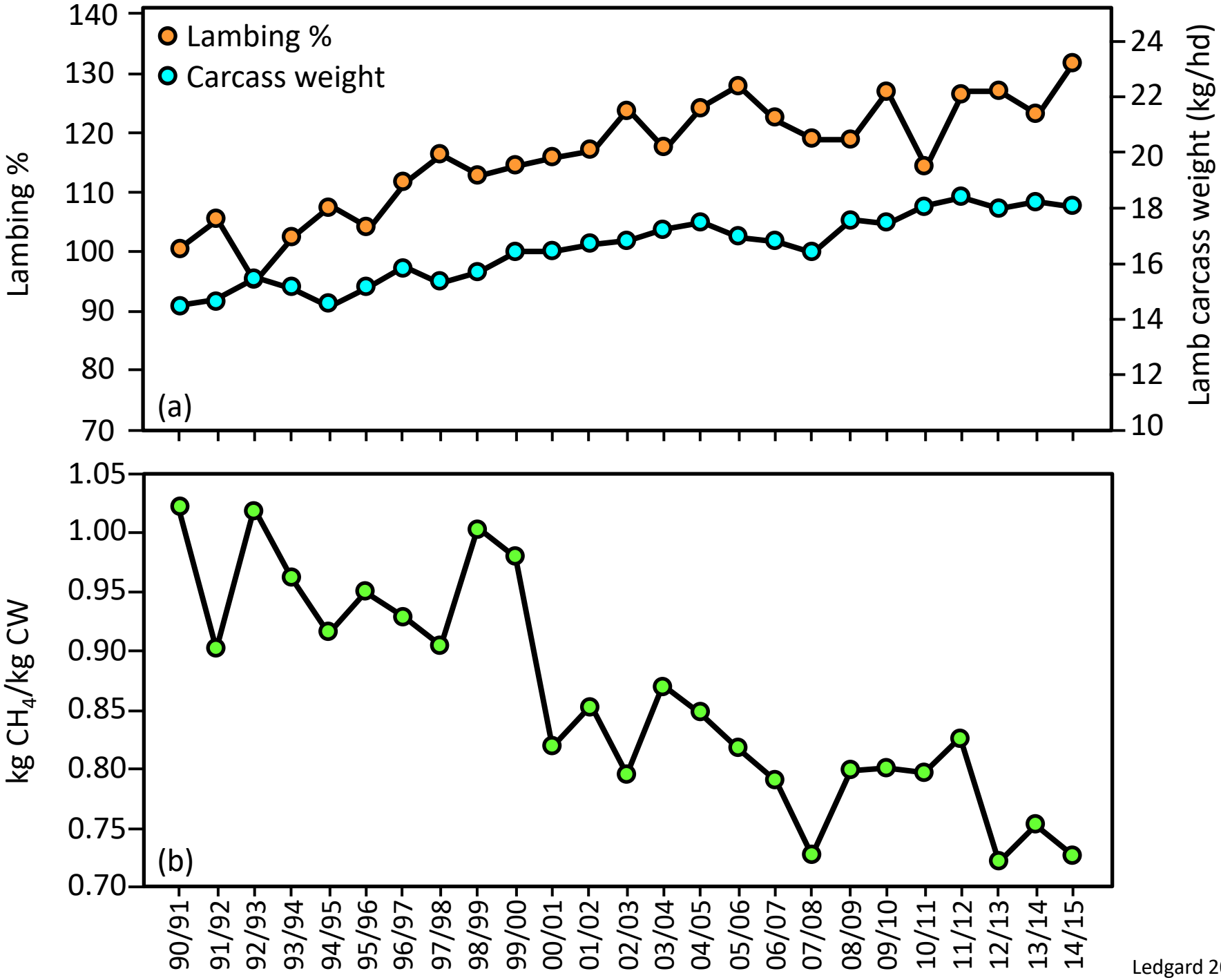
CH_4 reduced by faster LWG

Energy requirement (MJ ME) for lamb growth from 25 to 35 kg live-weight

Lamb growth rate (g/hd/d)	Days on farm	Energy consumed per lamb	*Methane g CH4/kg gain
100	100	1300	303
200	50	850 (↓53%)	199
300	33	726 (↓79%)	165

MJ ME: megajoules of metabolisable energy *11

Brown 1990 *de Kleine et al. 2008

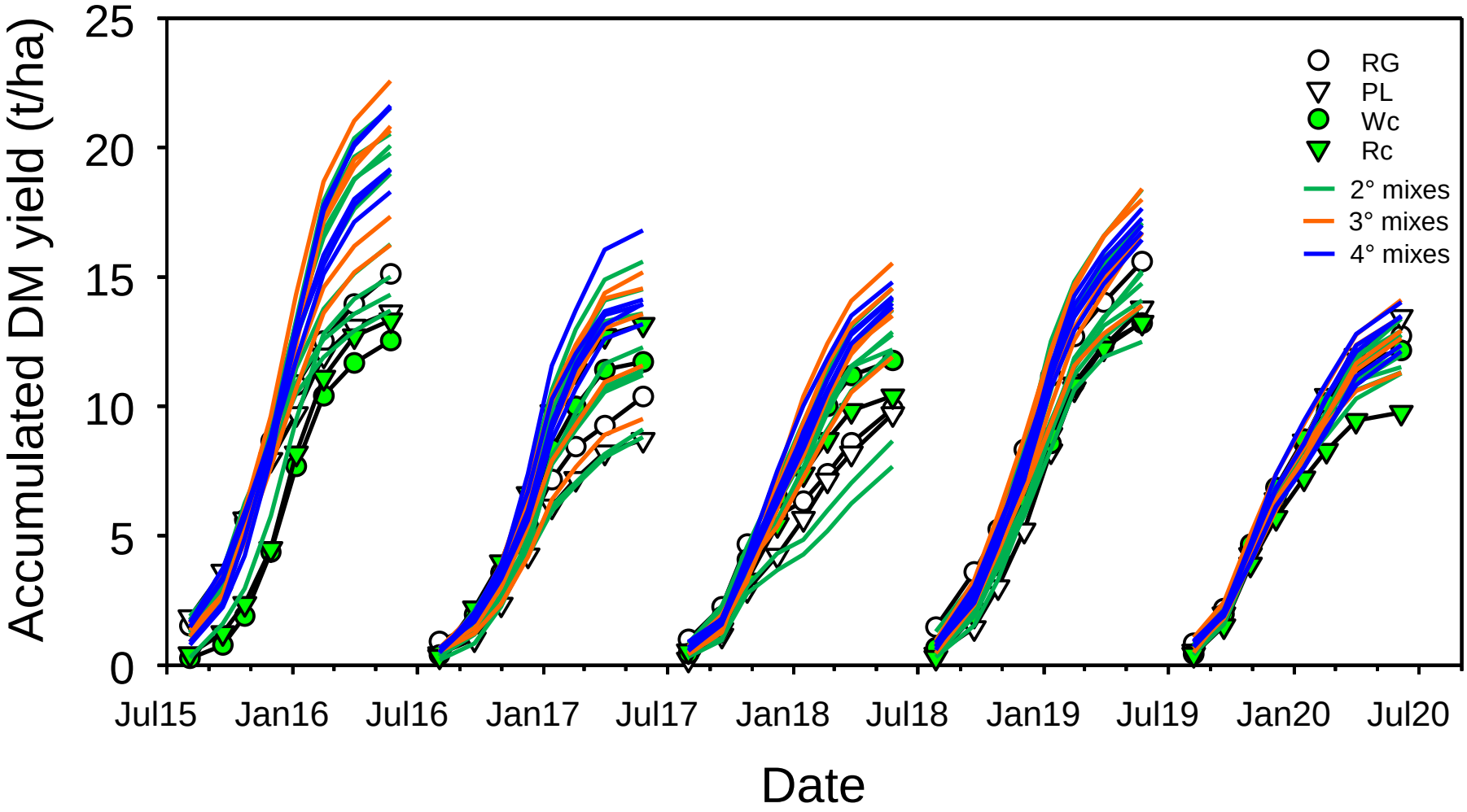


Ledgard 2017


Olsen P<6

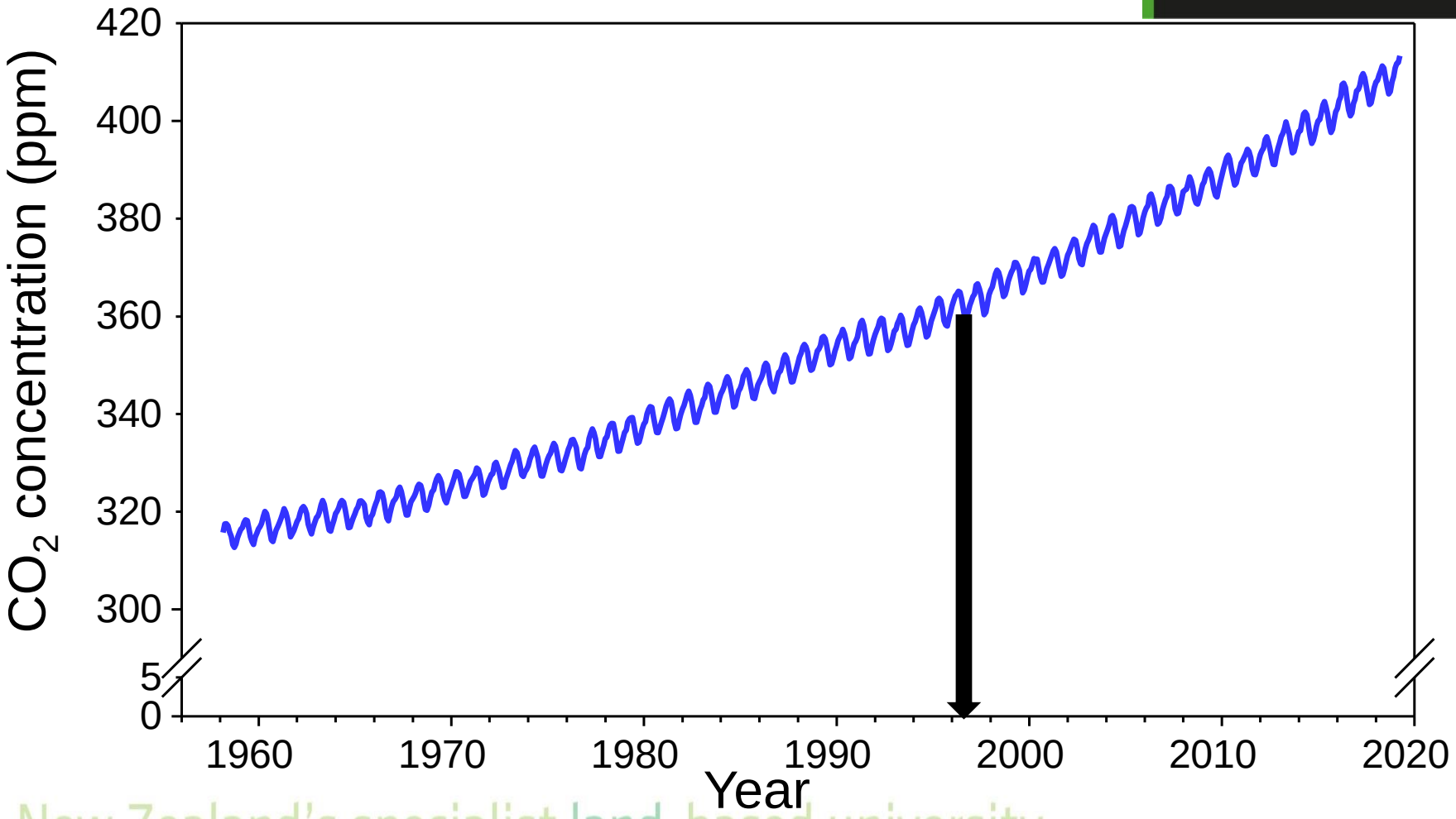

Olsen P>20

Dry matter production



Black et al. unpublished

CO_2 at Mauna Loa, Hawaii



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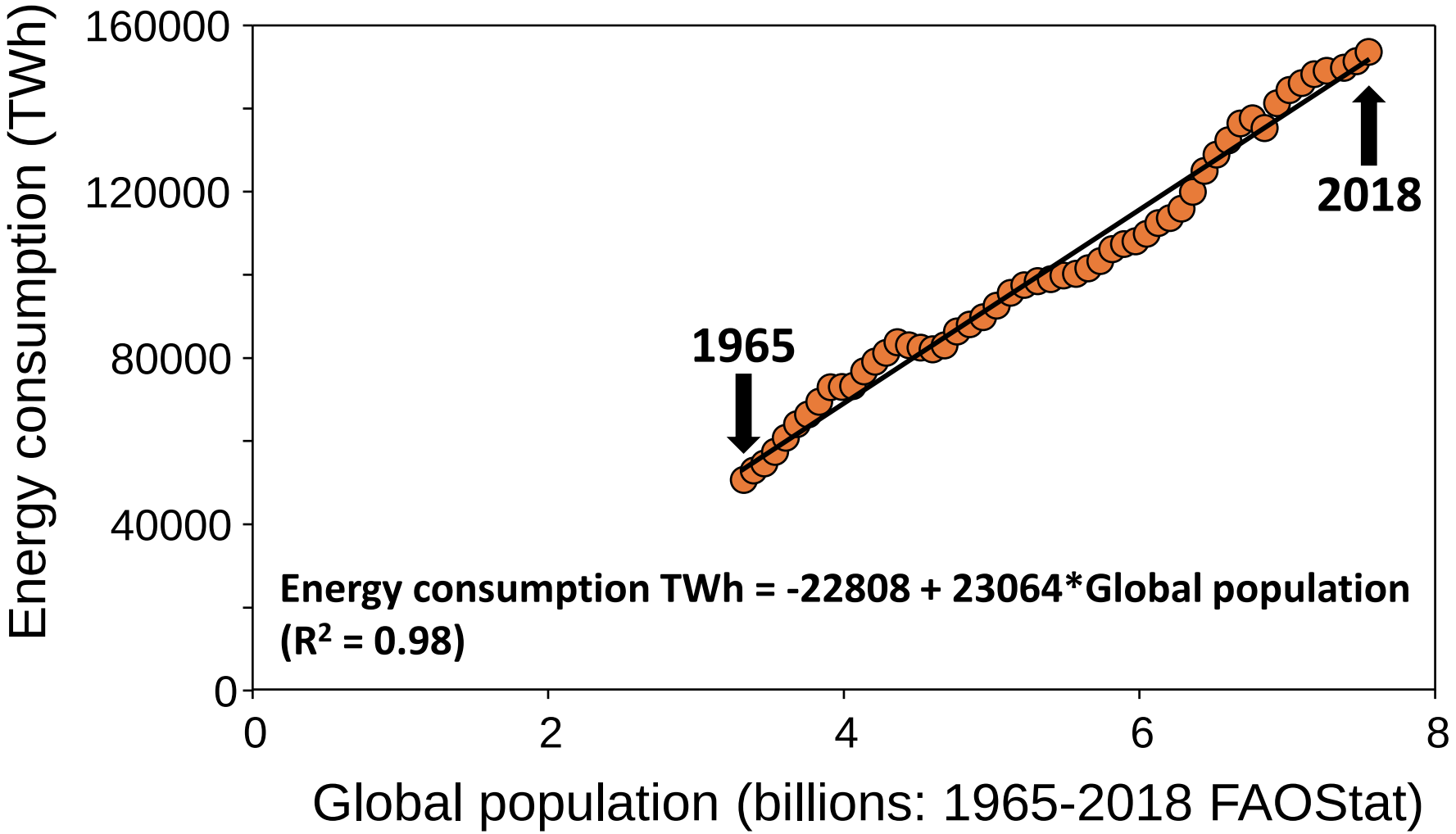
Energy consumption per capita



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Age old Battle – Food production

- Sustainable intensification vs agroecology
- Agrichemicals/fertilizer/irrigation vs sustainable ag, organics
- High input versus Low input systems
- Evidence versus faith

How do we feed 10 Bn people?