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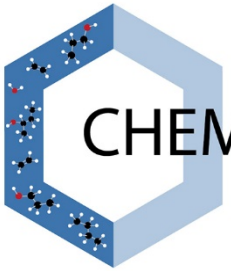


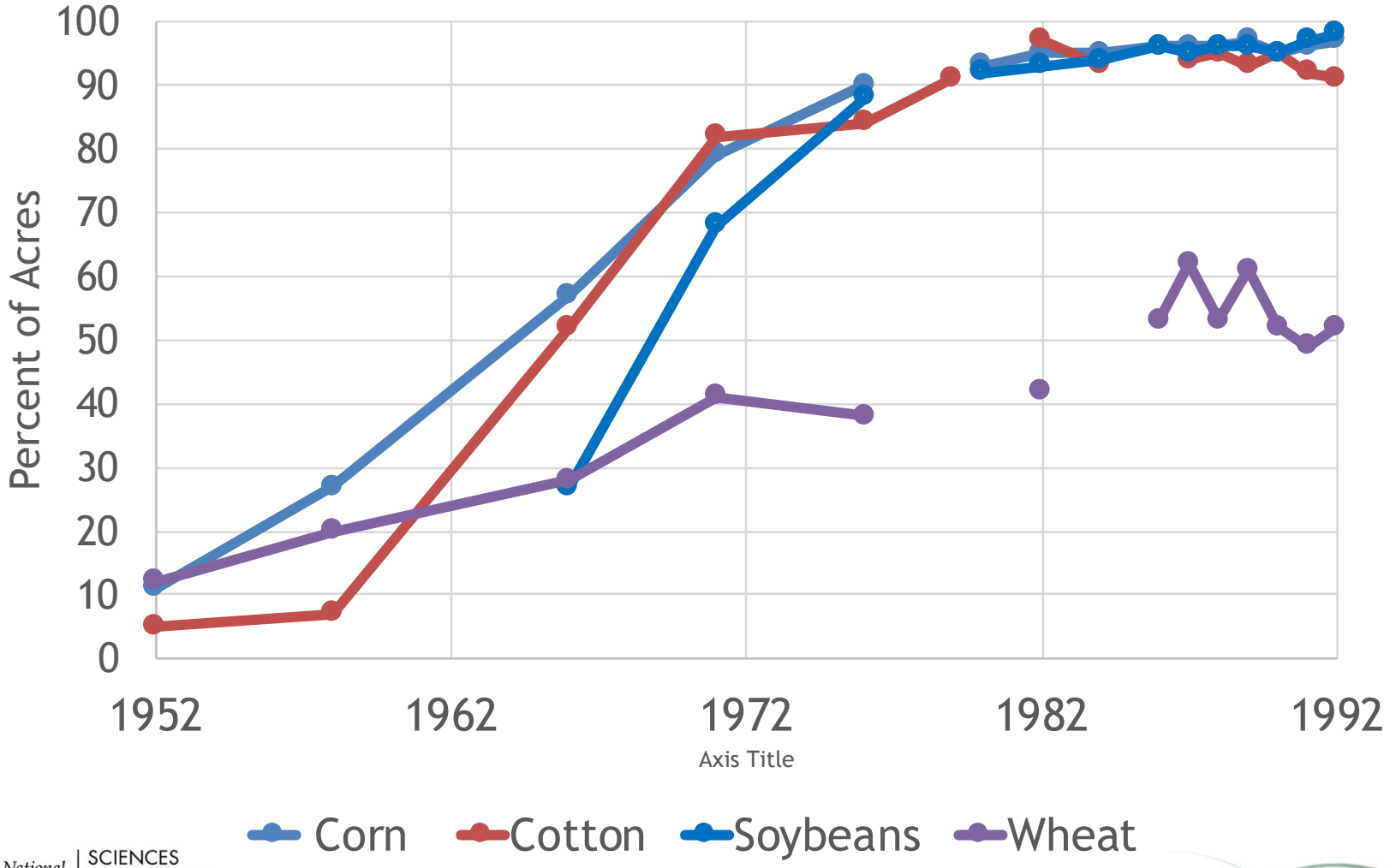
CHEMICAL SCIENCES ROUNDTABLE

The Future of Sustainable Agrochemistry Webinar Presentation

George Frisvold
University of Arizona

November 12, 2020

Acres treated with herbicides (Major US Crops)



Source: Osteen & Fernandez-Cornejo, *Pest Management Science* (2013)

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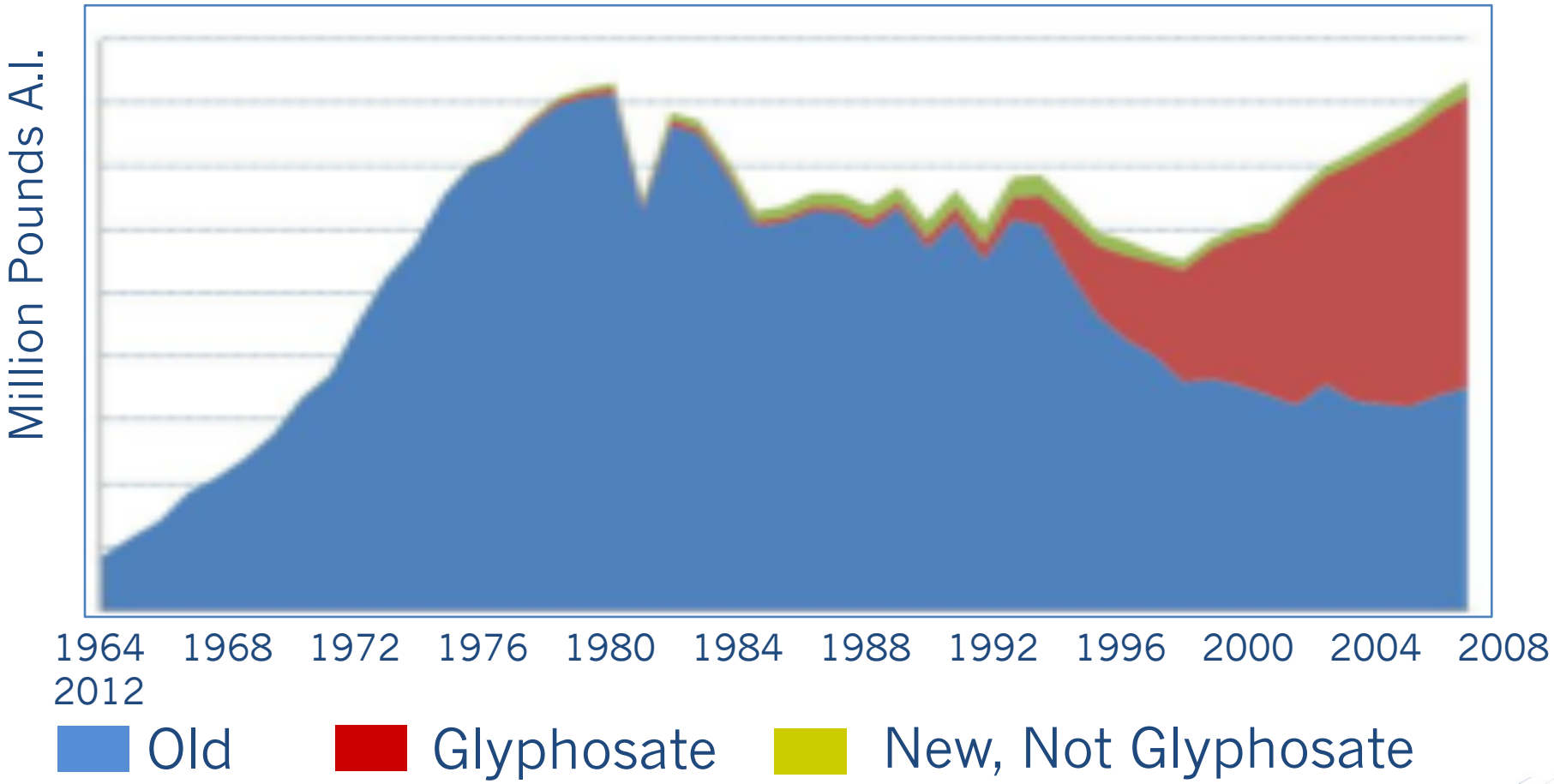
CHEMICAL SCIENCES ROUNDTABLE

Herbicides on 4 Major Crops



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CHEMICAL SCIENCES ROUNDTABLE

Source: Osteen & Fernandez-Cornejo, *Choices* (2016); Constructed from ERS and NASS, USDA data

Sustainability Issues

- Complementarity between HT crops, agricultural chemicals, & conservation tillage

- Evolution of herbicide resistance in weed species

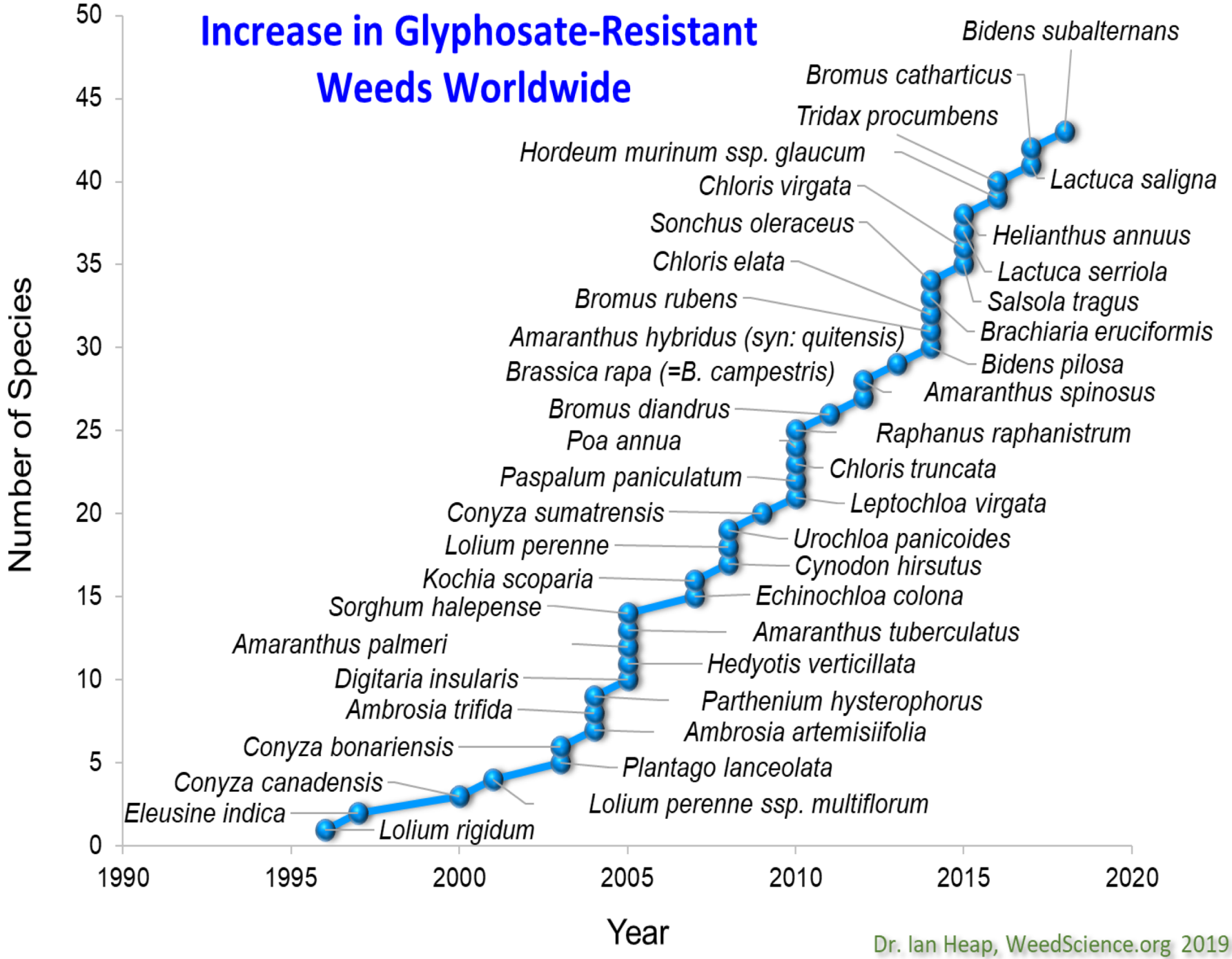
Complementarity of HT seeds with Conservation Tillage

Perry, E. D., Moschini, G., & Hennessy, D. A. 2016. Testing for complementarity: Glyphosate tolerant soybeans & conservation tillage. *Am J Ag Econ* 98, 765-784.

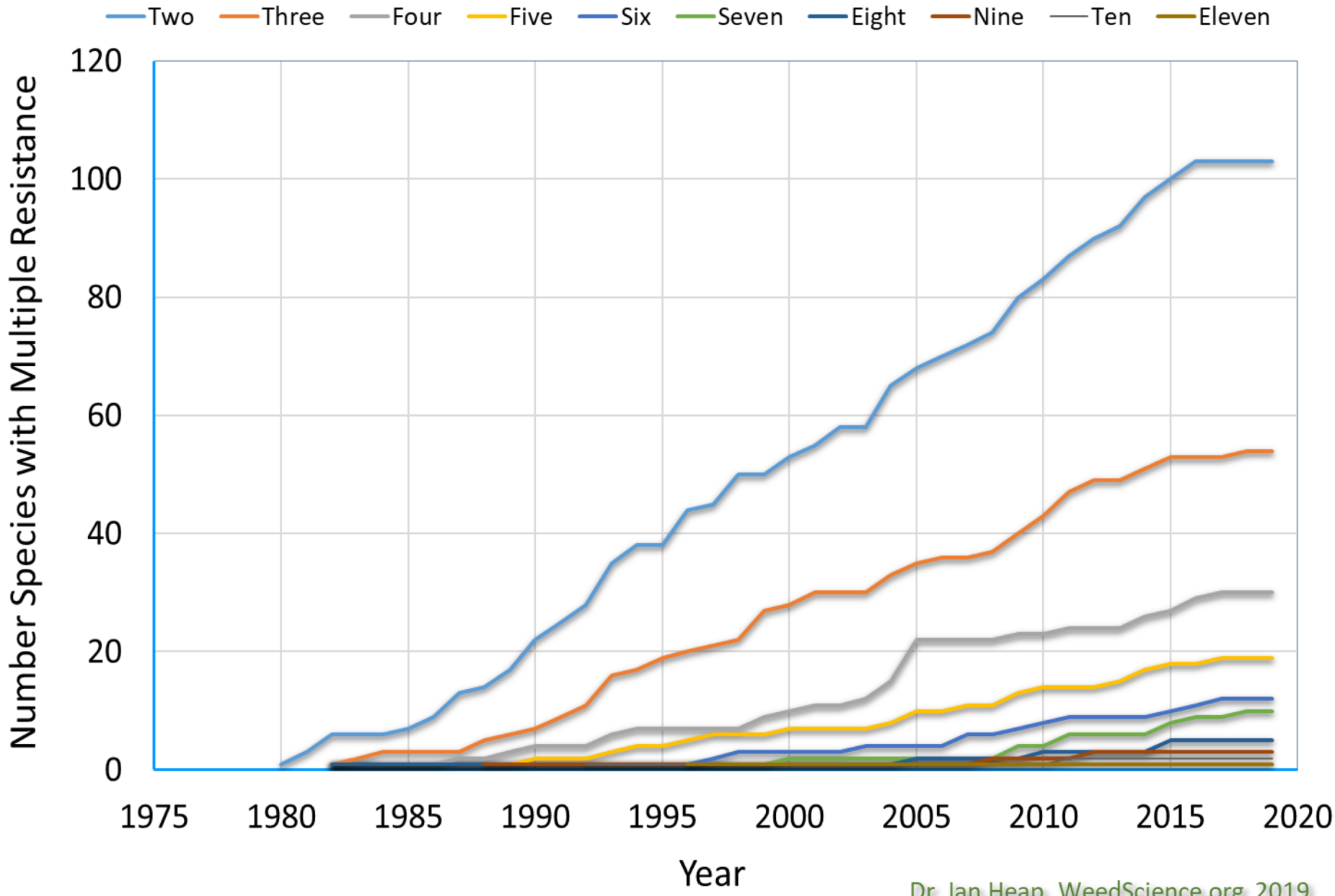
Roberts, R. English, B. C. Q. Gao, Q. & J Larson, J. 2006. Simultaneous Adoption of Herbicide-Resistant and Conservation Tillage Cotton Technologies. *J Ag & App Econ* 38, 629–43

Frisvold, G., A. Boor, A. & J. Reeves, J. 2009. Simultaneous Diffusion of Herbicide Resistant Cotton & Conservation Tillage. *AgBioForum* 12, 249–57

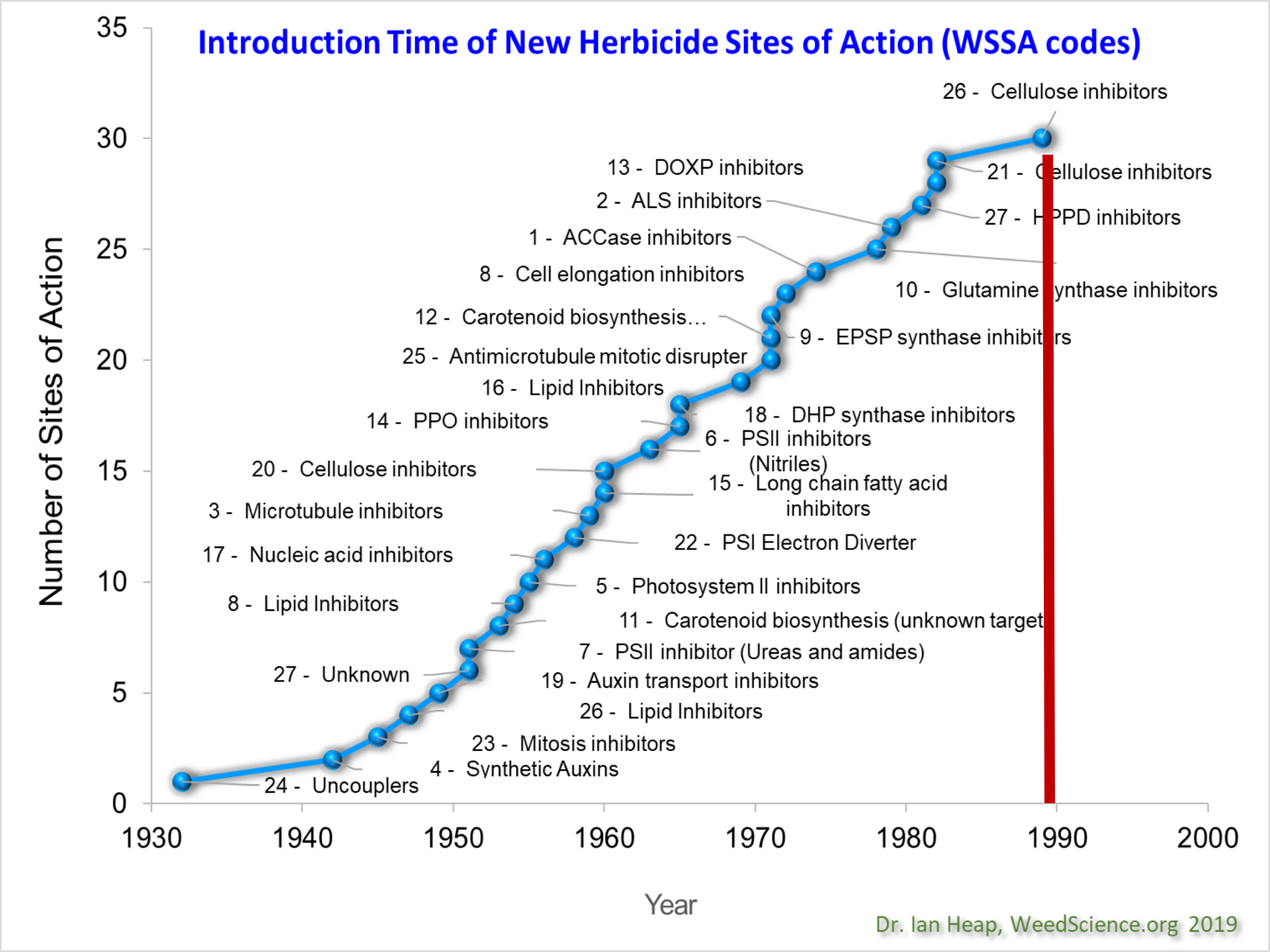
Fernandez-Cornejo, J., Klotz-Ingram, C. & S. Jans, S. 2002. Farm-level Effects of Adopting Herbicide-Tolerant Soybeans in the USA. *J Ag & App Econ* 34, 149–64

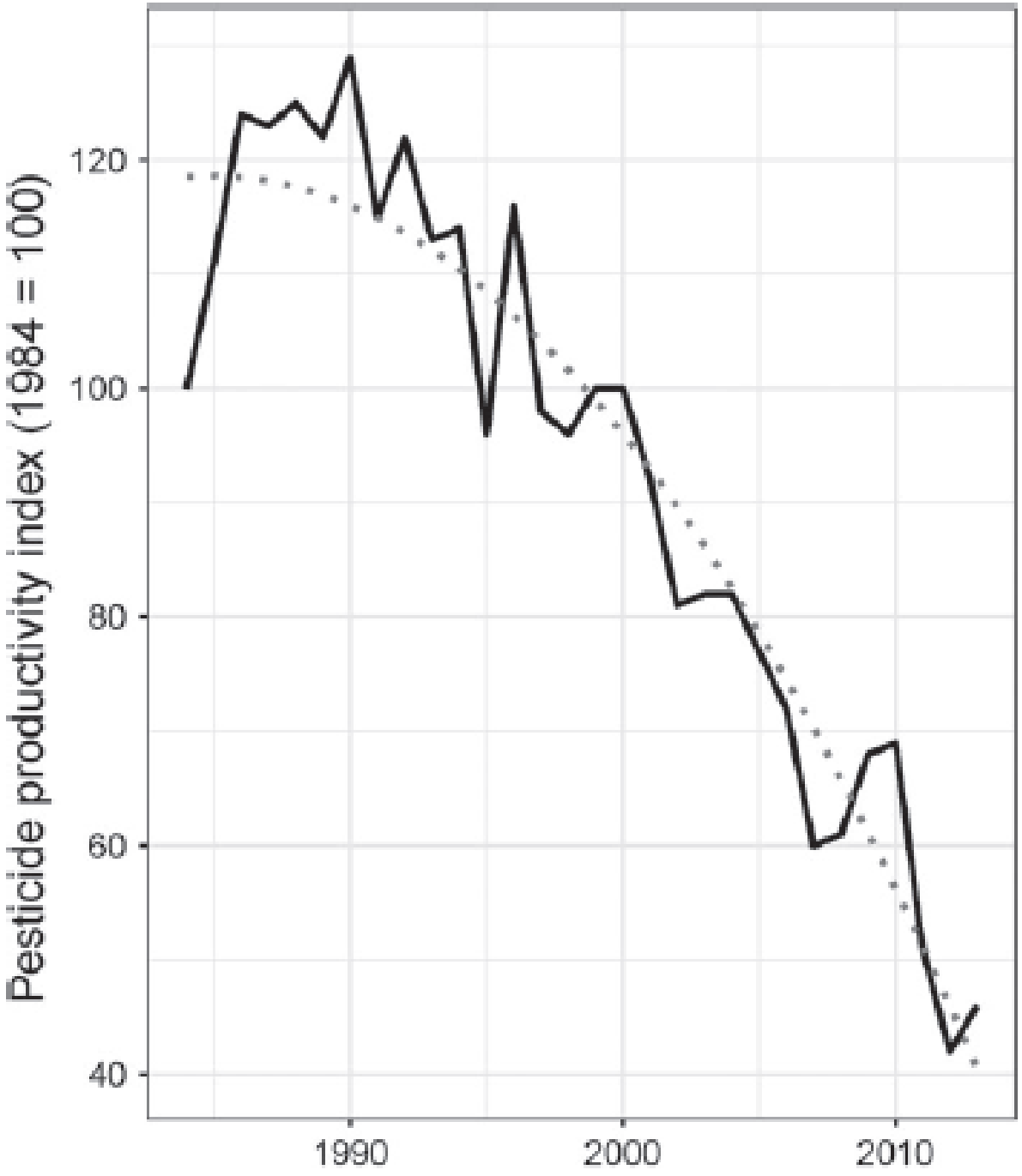

Increase in Glyphosate-Resistant Weeds Worldwide
Number of Species
Year
0
5
10
15
20
25
30
35
40
45
50
1990
1995
2000
2005
2010
2015
2020
Bidens subalternans
Bromus catharticus
Tridax procumbens
Hordeum murinum ssp. glaucum
Lactuca saligna
Chloris virgata
Sonchus oleraceus
Helianthus annuus
Chloris elata
Lactuca serriola
Bromus rubens
Salsola tragus
Amaranthus hybridus (syn: quitensis)
Brachiaria eruciformis
Brassica rapa (=B. campestris)
Bidens pilosa
Amaranthus spinosus
Bromus diandrus
Raphanus raphanistrum
Poa annua
Chloris truncata
Paspalum paniculatum
Leptochloa virgata
Conyza sumatrensis
Urochloa panicoides
Lolium perenne
Cynodon hirsutus
Kochia scoparia
Echinochloa colona
Sorghum halepense
Amaranthus tuberculatus
Amaranthus palmeri
Hedyotis verticillata
Digitaria insularis
Parthenium hysterophorus
Ambrosia trifida
Ambrosia artemisiifolia
Conyza bonariensis
Plantago lanceolata
Conyza canadensis
Lolium perenne ssp. multiflorum
Eleusine indica
Lolium rigidum
Dr. Ian Heap, WeedScience.org 2019

Weed Species with Resistance to More than One Site of Action



Dr. Ian Heap, WeedScience.org 2019


Introduction Time of New Herbicide Sites of Action (WSSA codes)
Number of Sites of Action
Year
0
5
10
15
20
25
30
1930
1940
1950
1960
1970
1980
1990
2000
24 - Uncouplers
4 - Synthetic Auxins
23 - Mitosis inhibitors
26 - Lipid Inhibitors
19 - Auxin transport inhibitors
7 - PSII inhibitor (Ureas and amides)
11 - Carotenoid biosynthesis (unknown target
5 - Photosystem II inhibitors
22 - PSI Electron Diverter
15 - Long chain fatty acid inhibitors
6 - PSII inhibitors (Nitriles)
18 - DHP synthase inhibitors
16 - Lipid Inhibitors
25 - Antimicrotubule mitotic disrupter
12 - Carotenoid biosynthesis…
8 - Cell elongation inhibitors
1 - ACCase inhibitors
2 - ALS inhibitors
13 - DOXP inhibitors
26 - Cellulose inhibitors
21 - Cellulose inhibitors
27 - HPPD inhibitors
10 - Glutamine synthase inhibitors
9 - EPSP synthase inhibitors
14 - PPO inhibitors
20 - Cellulose inhibitors
3 - Microtubule inhibitors
17 - Nucleic acid inhibitors
8 - Lipid Inhibitors
27 - Unknown
Dr. Ian Heap, WeedScience.org 2019



Crop output per unit of quality adjusted pesticide input has been declining

Source: Davis & Frisvold, *Pest Management Science* (2017); USDA, ERS

Efficacy of agricultural chemicals is an “exhaustible resource”

- Cycles of depletion and discovery (not unlike minerals or petroleum)
- Resistance management as a common pool resource management problem
- Resistance management as a “weakest-link public good”

Farmer Adoption of Resistance Management Practices

- Good news: Most farmers are adopting most practices most of the time
- Bad news: This appears to be insufficient to delay resistance in many cases
- Key question: What are critical adoption thresholds?
  - Is issue a traditional extension problem, or …
  - More akin to a pest or disease eradication problem?
  - When is private action sufficient; when is collective action necessary?

Moving Forward (Sustainably)

- Diversity is key
  - Diversity in herbicide strategies
  - Diversity of tactics overall (combining chemical & non-chemical tactics)
- Non-chemical innovations (infotech, precision ag, a.i., drones, robotics)
  - More precise, effective chemical applications (complementarity)
  - Improved non-chemical control (substitutability)

Emerging Business Models

- Selling pest management services vs. agricultural chemicals *per se*
- Ag chemical use will become more information- & skill-intensive
- Greater consumer & food processor attention to *how* crops are grown
- Medical analogy
  - Going to pharmacist vs. general practitioner
  - You don't start with pharmacist, but you may end up there

Thank You

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