Climate Change - What Do We Do About It? Economic Issues in Considering Agricultural Adaptation and Mitigation

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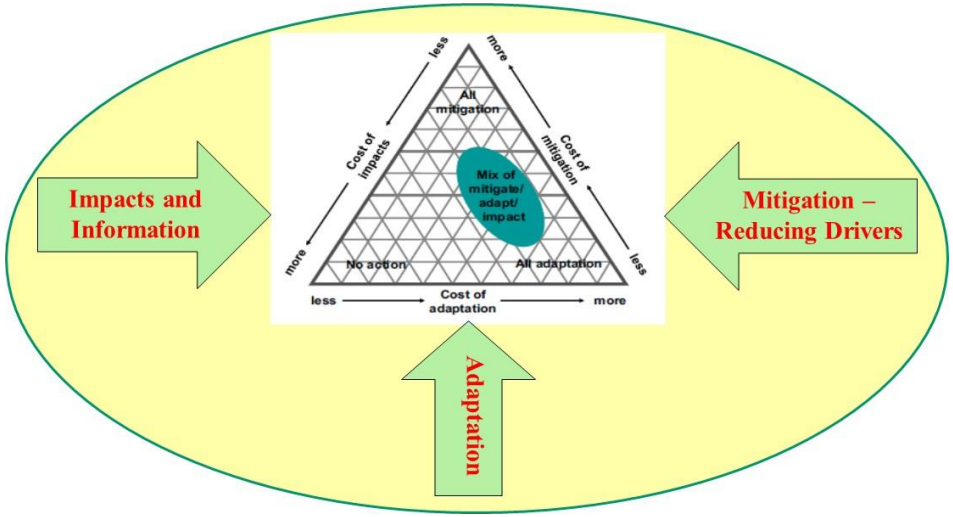
AAEA Fellow, 2005



Fellows Address Presented at AAEA meeting , New Orleans, July 2024

Version and earlier zoom recording posted at https://agecoresearch.tamu.edu/mccarl/papers/papers-on-climate-change/

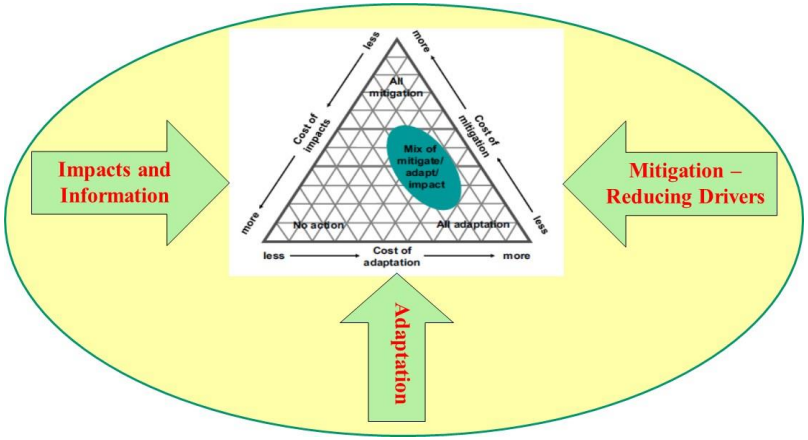
Climate Change Has Been Found To Have Major Implications For Agriculture

Many things have been found or projected
For example

- **A hotter future environment**
- **Altered precipitation quantity and intensity**
- **Altered crop and livestock productivity**
- **Altered pests**
- **Shifts in regional advantage**
- **Reduced technical progress**
- **Reduced total factor productivity**
- **Increases in water scarcity and competition**

So what do we do about this

What is Our Decision Space?



Impacts — Identifying what is happening and what is projected

Adaptation — Altering actions to lessen the damages done or exploit opportunities under a current and future changed climate (without any effect on what the climate will be)

Mitigation — Altering operations to reduce the amount of future change by limiting greenhouse gas emissions and/or altering other drivers of climate change like albedo

All will occur

McCarl, B.A., and T.W. Hertel, "Climate Change as an Agricultural Economic Research Topic", Applied Economic Perspectives and Policy, 40.1 (2018): 60-78.

Klein, R.J.T., S. Huq, F. Denton, T.E. Downing, R.G. Richels, J.B. Robinson, F.L. Toth, 2007: Inter-relationships between adaptation and mitigation. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press 745-777.

What Will Be Discussed Here?

Adaptation - main concentration not because of it being the primary concern bur rather because of lack of coverage in literature

- Why adapt
- Who acts and where is public action needed
- What have we seen
- What are potential pitfalls of action
- What work might economists undertake

Mitigation - lesser concentration

- Ag contribution to future climate change
- What type of actions are possible
- Economic need for incentives
- What are potential pitfalls of action
- Some policy issues
- What work might economists undertake

Impacts Not covered

What Will Be Discussed Here?

This will be an overview of many things I have done and learned in my program over around 40 years of work on various aspects of the topic plus lessons I have received from others.

Thanks to many with special call out to

- **Rich Adams, Darius Adams, Brian Murray, Pete Smith, John Reilly, Wally Tyner, Joel Smith**
- **Staff at EPA CCD, USDA OCE, IPCC, UNFCCC**
- **More than 50 of my grad students and post docs**

I will put in some references for those wishing to go deeper but note the literature is vast and I am just doing biased sampling mainly relying on my papers

Adaptation as a Course of Action

Adaptation -Why Might We Adapt?

Greenhouse Gas Forcing & Climate Change

Societal Momentum in GHG emissions caused by capital stock fixity, and income/population growth

Global externality and emissions from development in many countries

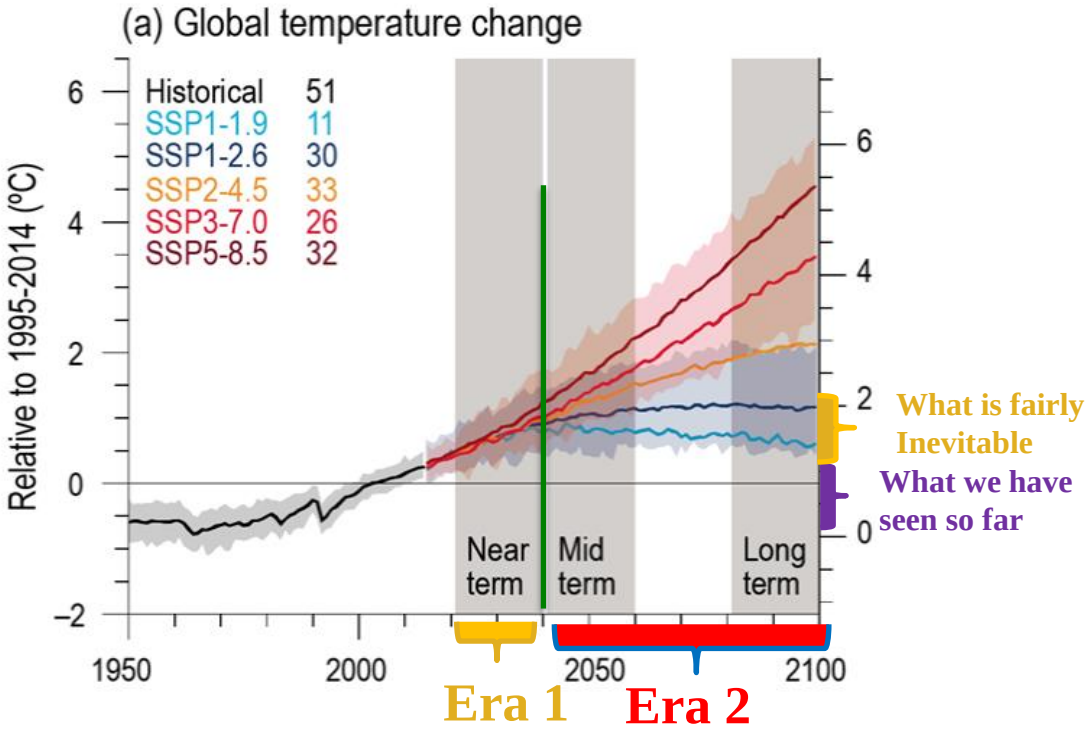
Resultant Inevitability of climate change

Lag in effect given GHG mitigation actions

Slow mitigation action

McCarl, B.A., "Elaborations on climate adaptation in US Agriculture", Choices, 30 (2), 1-5, 2015.
McCarl, B.A., A.W. Thayer, and J.P.H. Jones, "The Challenge of Climate Change Adaptation: An Economically Oriented Review", Journal of Agricultural and Applied Economics, Volume 48, Issue 4 November 2016, pp.321-344, 2016.

Additional Climate Change is Inevitable



Era 1 – From now until 2045 there is not much less climate change from limiting emissions.

An inevitable amount of climate change.

Era 2 – Between 2045 and 2100 mitigation has effects

- **In Agriculture climate change is impacting outcomes now.**
- **About 1^0 C of additional climate change appears inevitable which is as much temperature change as has happened in last 100 years**
- **To maintain productivity adaptation is needed**

McCarl, B.A., "Elaborations on climate adaptation in US Agriculture", Choices, 30 (2), 1-5, 2015.

Fundamental Ag Adaptation Forms with Examples

Crop/livestock/forest management

- Timing (earlier planting, maturity, rotation age etc)
- Stocking rates, Pest treatment, Irrigation, Drainage
- Can be reaction to positive opportunity

Importing southern, lower elevation patterns

- Heat and drought resistant or exploiting crops/livestock
- Land use – substitute use for Crop, Livestock, Forest, or Idle

Investment

- Research and extension, Moving processing infrastructure
- Transport infrastructure
- Some will occur due to obsolescence

Risk management

- Insurance, Leasing, contracts

Expanded Trade to exploit altered relative advantage

McCarl, B.A., Adaptation Options for Agriculture, Forestry and Fisheries, A Report to the UNFCCC Secretariat Financial and Technical Support Division, 2007. http://unfccc.int/files/cooperation_and_support/financial_mechanism/application/pdf/mccarl.pdf

McCarl, B.A., A.W. Thayer, and J.P.H. Jones, "The Challenge of Climate Change Adaptation: An Economically Oriented Review", Journal of Agricultural and Applied Economics, Volume 48, Issue 4 November 2016, pp.321-344, 2016.

Action Can Be "Natural" or "Autonomous" or "Planned"

Natural actions occur in ecosystem when species react to climate – for example altered bird migration, vegetation mix, species extinction

Autonomous actions (or in economic terms private actor actions by those acting in their own best interests) are voluntary moves – for example earlier planting, crop mix shift, more irrigation

Planned actions (in economics public actions addressing public goods) are interventions by governments or NGOs to address needs unmet by autonomous actions – for example water infrastructure investment, ag R&D, adaptation assistance

McCarl, B.A., A.W. Thayer, and J.P.H. Jones, "The Challenge of Climate Change Adaptation: An Economically Oriented Review", Journal of Agricultural and Applied Economics, Volume 48, Issue 4 November 2016, pp.321-344, 2016.

Adaptation Action Involves a Public Role

Public sector will play important roles within each type of action

- **Supporter of autonomous (private good) actions by**
  - **providing information**
  - **shaping market conditions and**
  - **developing technologies**
- **Direct actor (provider of public goods) by**
  - **developing strategies**
  - **providing financial and other resources,**
  - **building projects (infrastructure development).**
- **Influencer of natural adaptation by**
  - **managing the unmanaged (move species, habitat)**

McCarl, B.A., A.W. Thayer, and J.P.H. Jones, "The Challenge of Climate Change Adaptation: An Economically Oriented Review", Journal of Agricultural and Applied Economics, Volume 48, Issue 4 November 2016, pp.321-344, 2016.

What Adaptations Have We Seen
Some Background

Throughout history, people and societies have adapted to and coped with climate, variability, and extremes

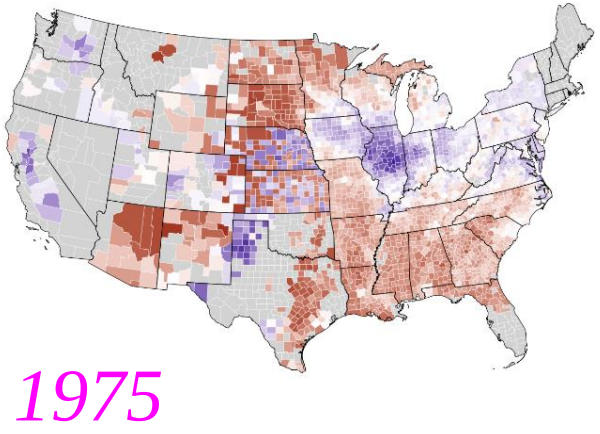
Adaptation is place- and context-specific, geographically differing approaches

Autonomous adaptation is pervasive, as are public goods actions in support

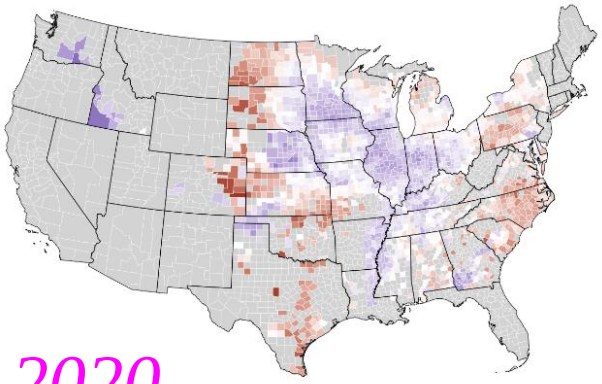
Chambwera, M., G. Heal, C. Dubeux, S. Hallegatte, L. Leclerc, A. Markandya, B.A. McCarl, R. Mechler, and J. Neumann, "Economics of Adaptation", IPCC WG II Contribution to The Fifth Assessment Report, Climate Change 2013: Impacts, Adaptation and Vulnerability, Cambridge University Press, 2014.

Corn Autonomous Adaptation Part I

County Corn Yields as Proportion of National Avg



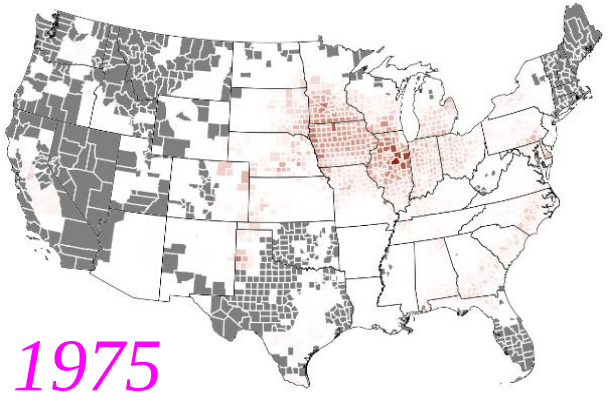
1975



2020

North and west shift in location of relative best yields

County Corn Planting - Adaptation



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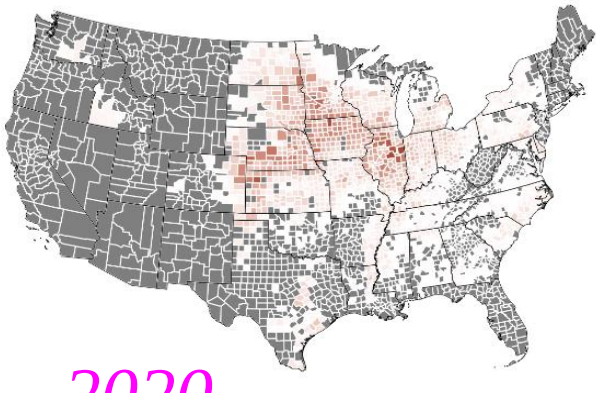
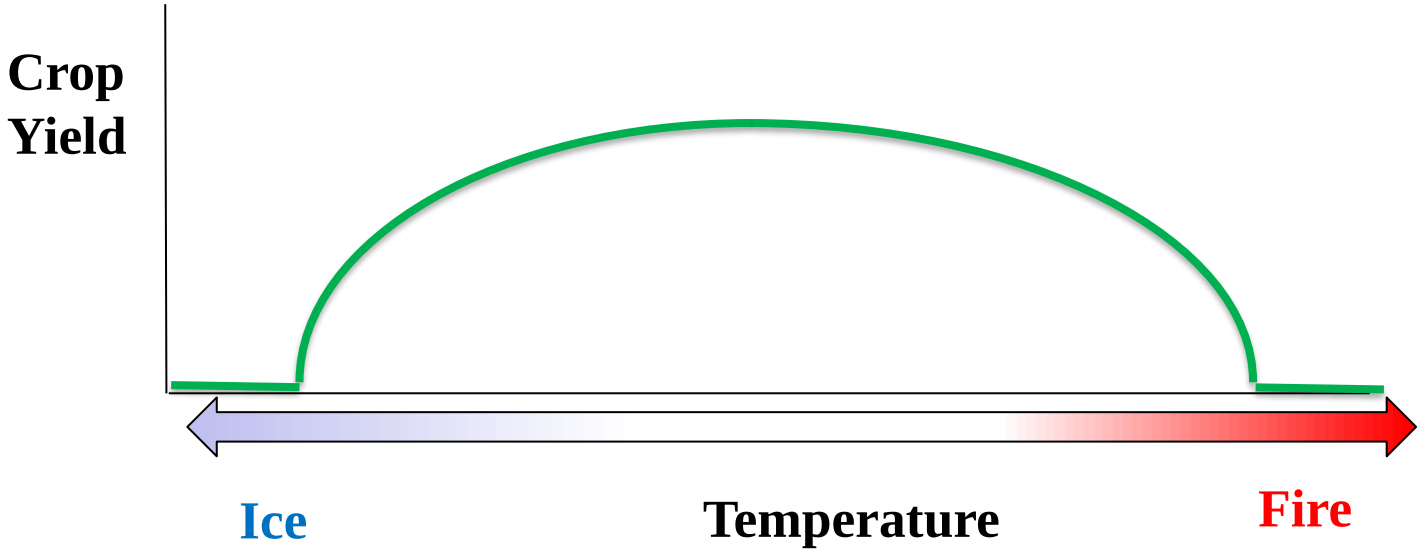


2020

North and west shift in location of planted area

Naomi Liu, Craig Carpenter, Chengcheng Fei and Bruce McCarl, Climate Change and Agricultural Infrastructure: Climate Adaptation is Causing Shifts in Grain Elevator Locations, Draft Article TAMU

Conceptual Framework for Climate Adaptation – Climate Effect on Yield



Crops become more and less desirable depending on temperature

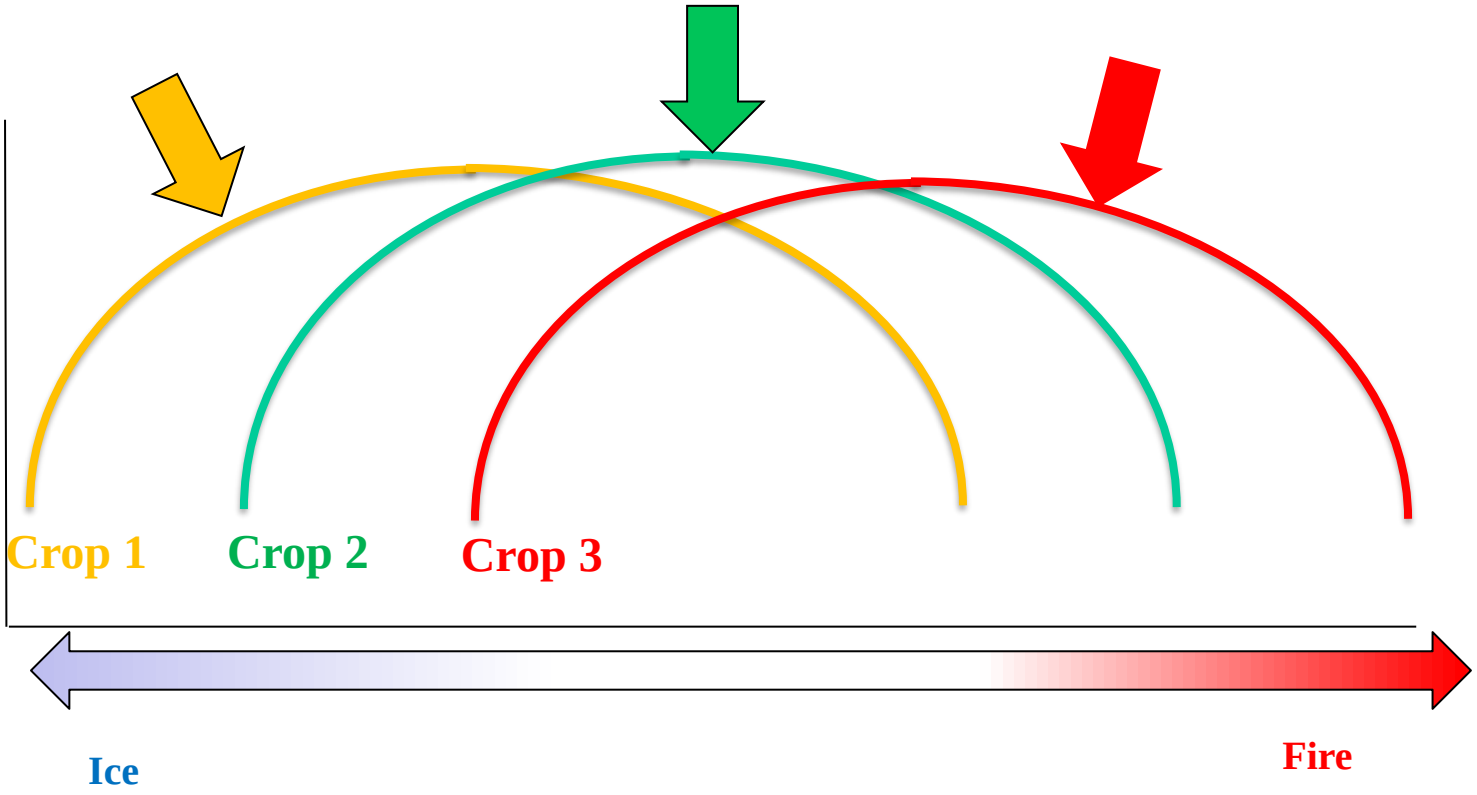
At extremes crops are ineffective

There is an inflection Point

Schlenker and Roberts and others have found such relationships

Schlenker, W. and Roberts, M.J., 2009. Nonlinear temperature effects indicate severe damages to US crop yields under climate change. Proceedings of the National Academy of sciences, 106(37), pp.15594-15598.

Multicrop Adaptation Framework

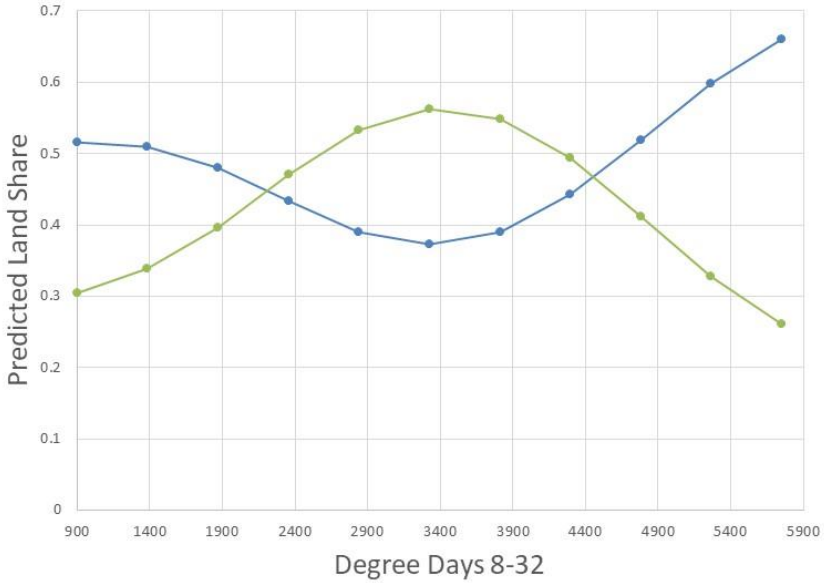


Best crop depends on temperature

Higher temperatures lead to crop and livestock switching

Zilberman, D., Liu, X., Roland-Holst, D. and Sunding, D., 2004. The economics of climate change in agriculture. *Mitigation and Adaptation Strategies for Global Change*, *9*, pp.365-382.

Land Use and Crop Adaptation from Econometrics on Historical Data

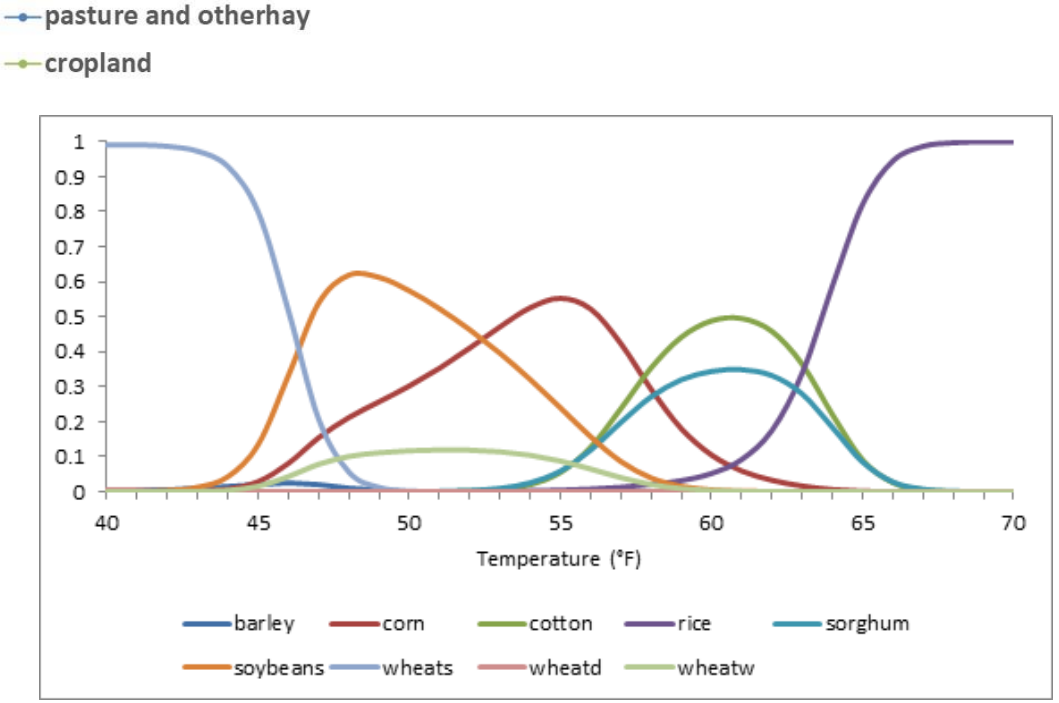


Lingyi Li, "Three Essays on Water Management Strategy, Climate Change Impacts on Agricultural Land Uses, and Grass-Fed Beef Market" Texas A&M University, August, 2024

Mu, J.E., B.A. McCarl, and A.M. Wein, "Adaptation to climate change: changes in farmland use and stocking rate in the U. S", Mitigation and Adaptation Strategies for Global Change, doi:10. 1007/s11027-012-9384-4, 2012.

Grassland vs crop analysis

Grasslands dominate at hot and cold temperatures



Jiyun Park, Essays on Impacts of Climate Change on the Agricultural Sector in the U.S., Ph.D. Dissertation, Texas A&M University, June 2012

Cho, S.J., and B.A. McCarl, "Climate change influences on crop mix shifts in the United States", Scientific Reports, volume 7, Article number: 40845, 2017

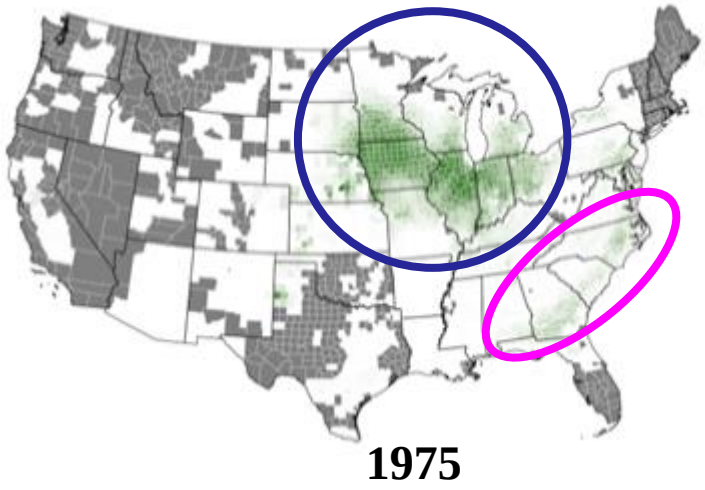
Older analysis ignoring grass

Wheat when cold

Then corn and soy

Then cotton and sorghum

Adaptation Corn Part II and Other Hay - Harvested Area



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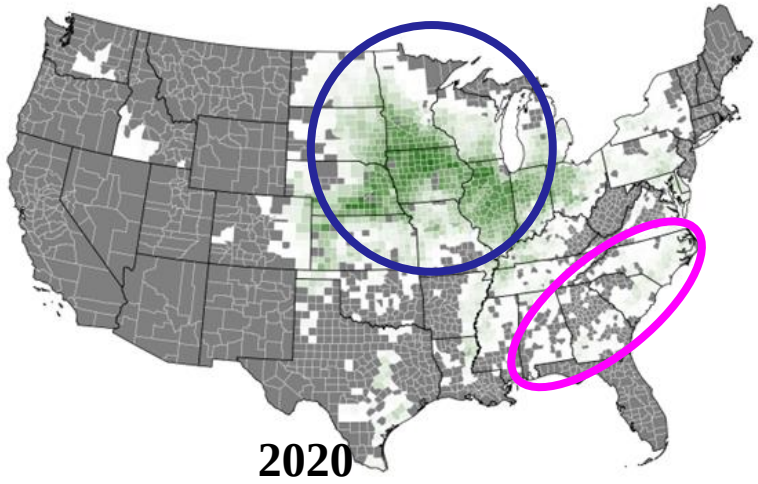
Corn



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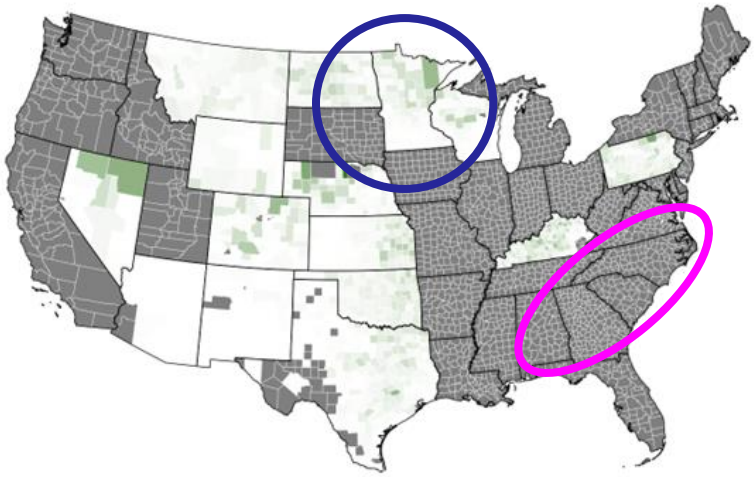
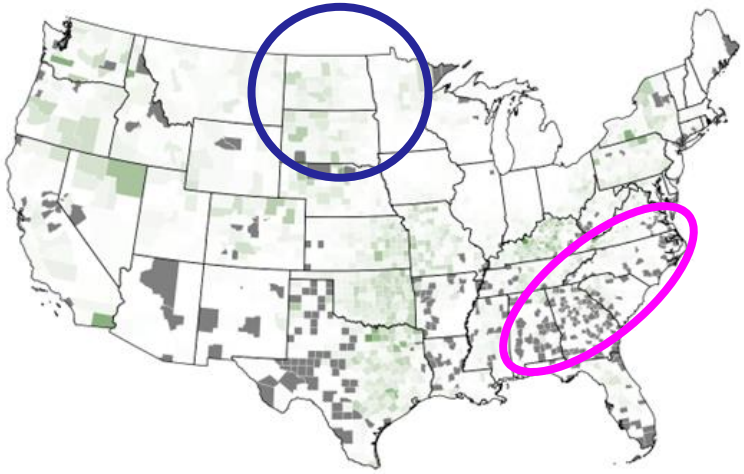


Other Hay

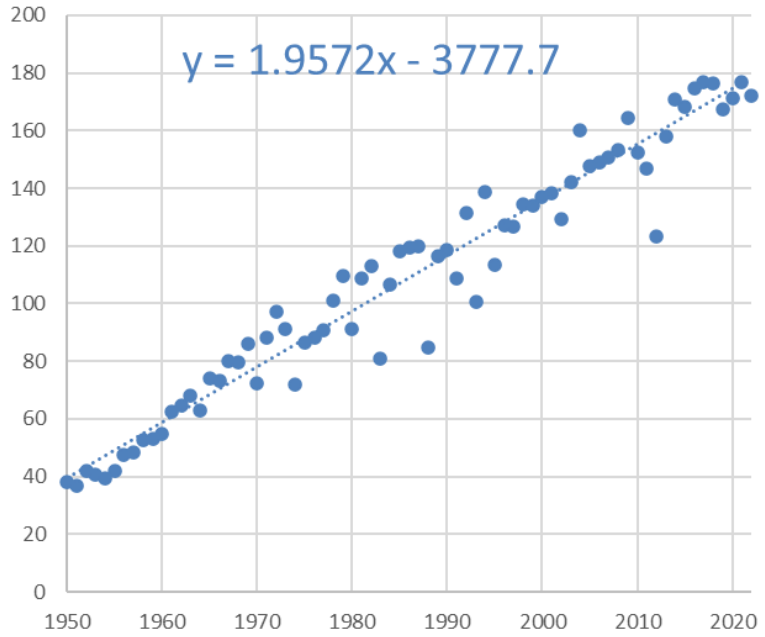


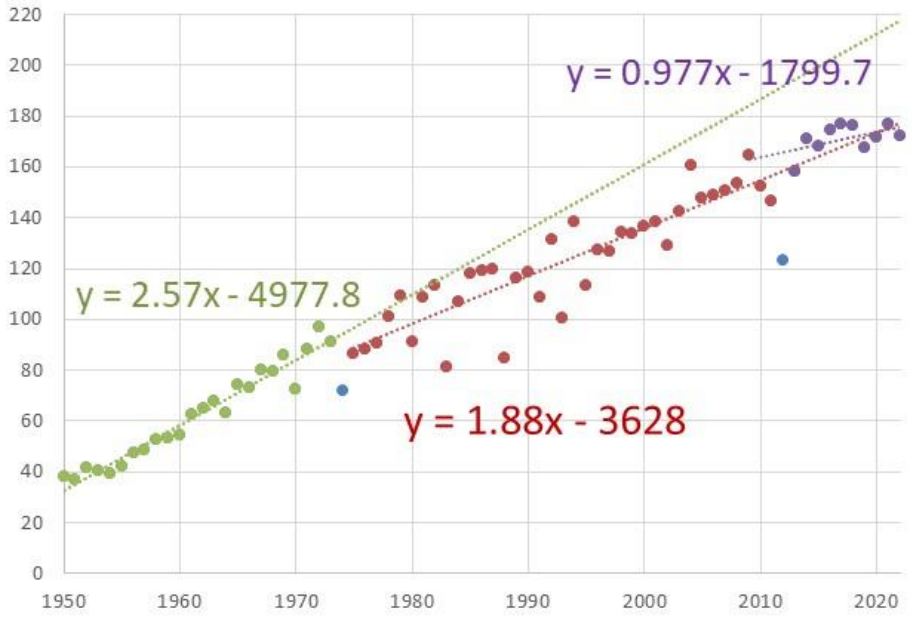
Other Hay moving in as corn moves out

In south other hay moving in and replacing corn

Naomi Liu, Craig Carpenter, Chengcheng Fei and Bruce McCarl, Climate Change and Agricultural Infrastructure: Climate Adaptation is Causing Shifts in Grain Elevator Locations, Draft Article TAMU

Can We Adapt Through R&D





Technical progress is slowing down

work shows part due to climate

Period	Avg Yield Increase Rates (bu/year)
1950-2022	1.96
1950-1973	2.57
1975-2011	1.88
2013-2022	0.977

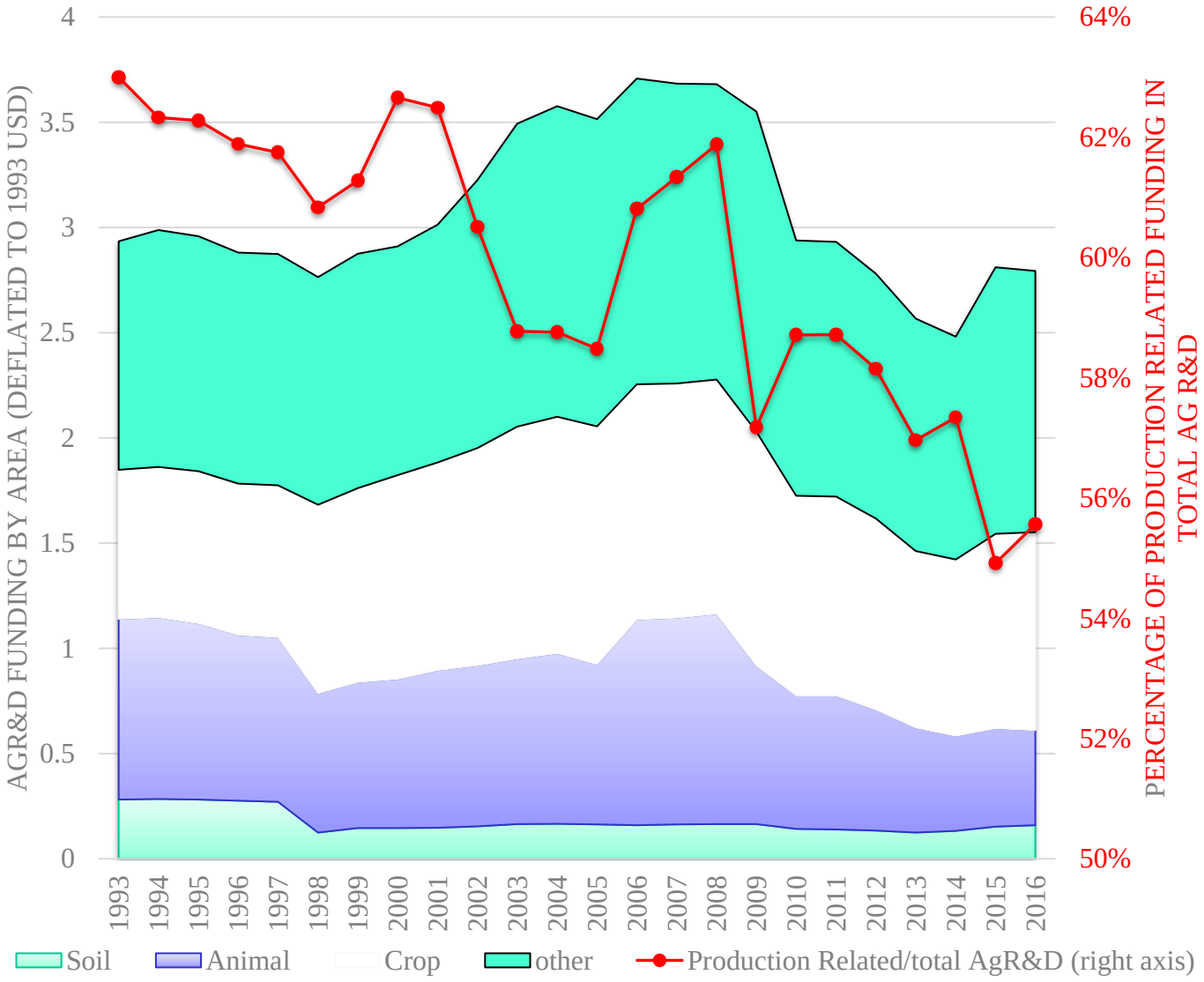
Villavicencio, X., B.A. McCarl, X.M. Wu, and W.E. Huffman, "Climate Change Influences on Agricultural Research Productivity", Climatic Change, Volume 119, Issue 3-4, pp 815-824, 2013.

Baker, J.S., B.C. Murray, B.A. McCarl, S.J. Feng, and R. Johansson, "Implications of Alternative Agricultural Productivity Growth Assumptions on Land Management, Greenhouse Gas Emissions, and Mitigation Potential", American Journal of Agricultural Economics, 95: 435-441, 2013.

Andersen, M. A., Alston, J. M., Pardey, P. G., & Smith, A. (2018). A century of US farm productivity growth: A surge then a slowdown. American Journal of Agricultural Economics, 100(4), 1072-1090.

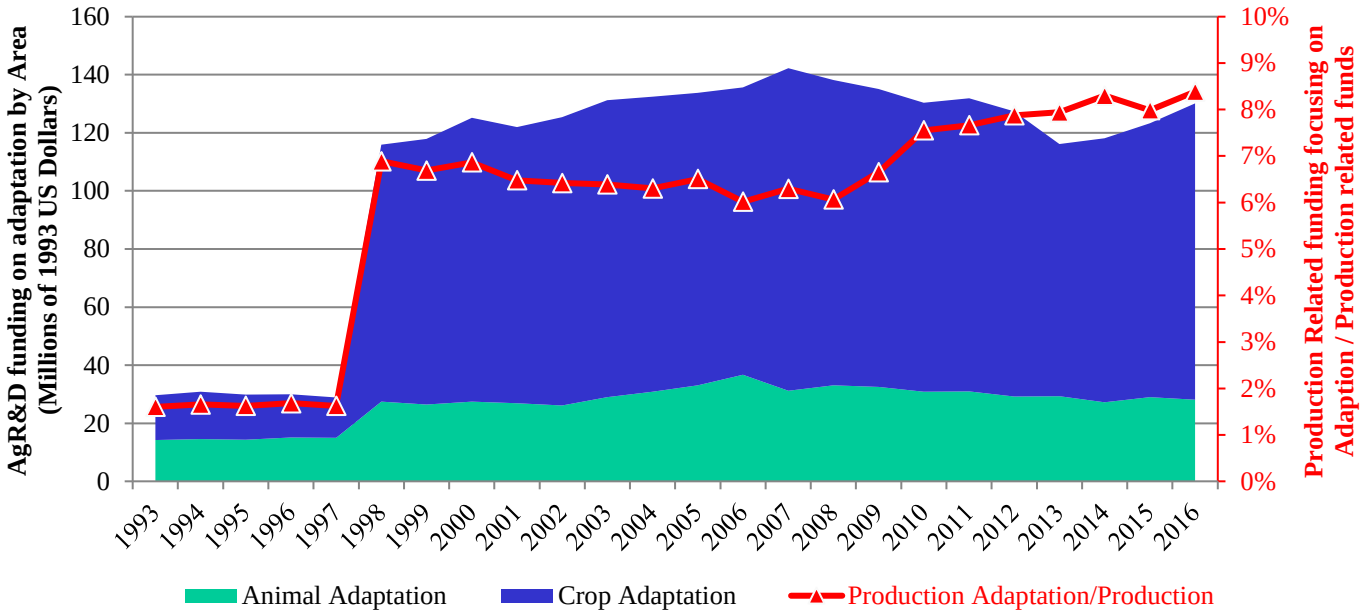
Can We Adapt Through R&D? Maybe Not As Funds Shifting Away From Production

- **Shift toward food processing, marketing and cost reduction (less on production enhancement) (Alston et al, 2009)**
- **Graph based on data from CRIS by Chengcheng Fei**
- **US public Agricultural R&D investment has trended downward since 2007 with a small increase since 2014**



Climate Change Adaptation and Mitigation Are Taking More of R&D Investment

- Adaptation and Mitigation are key tasks
  - To maintain the current productivity level and reduce further damage
  - Funding competition on adaptation from CRIS data



- **Climate change efforts are further diluting R&D productivity funds**
- **Mitigation also competing I have gotten a dozen or so contacts on sequestration in recent past**

Adaptation and the Treadmill

- Climate change and its continual progression raises a new demand on agriculture action as well as research and extension
- Traditionally in agriculture we adapted management or did research on yield improvement with some alterations for say pest resistance or adopting new varieties
- We could count on weather being stationary but now this is likely not so.
- So we must devote resources to changing management and technological adaptation to maintain productivity at a spot

What are Potential Pitfalls of Action

- **Adaptation cannot solve all problems. Residual damages are those damages that remain after adaptation actions are taken.**
- **Increasing adaptation effort tends to exhibit diminished avoided damages with per unit cost increasing with more adaptation.**
- **Adaptation is less effective as amount of climate change increases**
- **Adaptation deficit The gap between current state of a system and a state that minimizes adverse impacts from existing climate condition & variability.**
- **Maladaptation Actions that improve local adaptation now but lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future.**

Chambwera, M., G. Heal, C. Dubeux, S. Hallegatte, L. Leclerc, A. Markandya, B.A. McCarl, R. Mechler, and J. Neumann, "Economics of Adaptation", IPCC WG II Contribution to The Fifth Assessment Report, Climate Change 2013: Impacts, Adaptation and Vulnerability, Cambridge University Press, 2014.

Parry, Martin, et al. Assessing the Costs of Adaptation to Climate Change: A Review of the UNFCCC and Other Recent Estimates (2009): 6.

What are Potential Pitfalls of Action

- **Impermanent. Many adaptations effective for a limited time.**
- **Uncertainty Often not sure of the exact benefits**
- **Additionality Many adaptations are already being used and it is hard to say whether a new proposed one would have happened anyway.**
- **Maladaptation a number of actions that improve local adaptation now can worsen adaptation of others now or in the future.**
- **Adaptation capability varies with things like education, income, financial availability**
- **Often adaptation needs arise for those that are not creating climate change like low lying islands. Who should pay?**
- **Needs vary by region**
- **Adaptation effects differ across the landscape**

We Are Under Investing in Ag Adaptation

Limited evidence indicates a gap between global adaptation needs and current fund expenditures

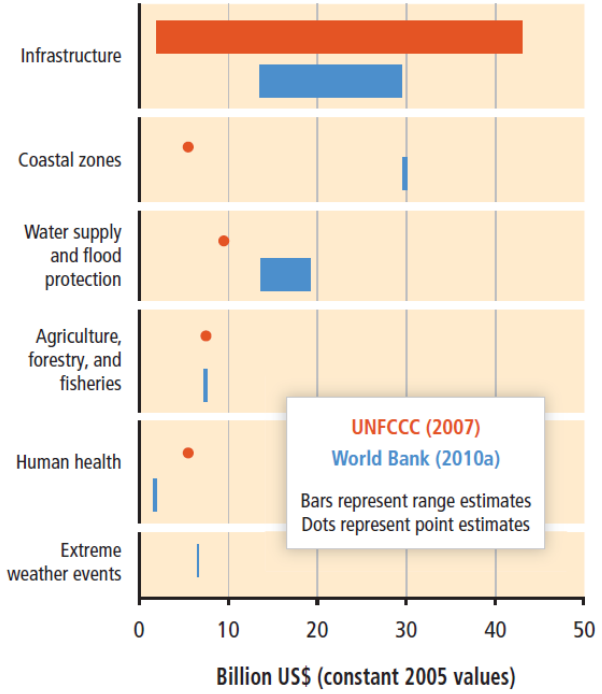


Figure 17-5 | Comparison of sectoral results on the costs of adaptation in developing countries across the UNFCCC and World Bank studies. Note: Bars indicate estimates using ranges; points indicate point estimates.

Global estimates of the need for adaptation funds are variously estimated in the range of US$70 to US$100 billion annually with $10 billion for agriculture,

Actual ag expenditures less than 5% in 2011 estimated at US$244 million, and in 2012 estimated at US$395 million

Chambwera, M., G. Heal, C. Dubeux, S. Hallegatte, L. Leclerc, A. Markandya, B.A. McCarl, R. Mechler, and J. Neumann, "Economics of Adaptation", IPCC WG II Contribution to The Fifth Assessment Report, Climate Change 2013: Impacts, Adaptation and Vulnerability, Cambridge University Press, 2014.

UNFCC ag estimate is from McCarl, B.A., Adaptation Options for Agriculture, Forestry and Fisheries, A Report to the UNFCCC Secretariat Financial and Technical Support Division, 2007. http://unfccc.int/files/cooperation_and_support/financial_mechanism/application/pdf/mccarl.pdf

What Work Economists Might Undertake

- Identify the economics of potential adaptation strategies and where the strategies are most relevant
- Identify actions that have been used and their broader implications
- Propose and evaluate incentive schemes and needs for private versus public adaptation support
- Develop adaptation proposal evaluation procedures
- Identify costs of adaptation including transaction costs

Mitigation as a Response

Role of Agriculture & Forestry in GHG Mitigation

Five roles with respect to net GHG emission reductions

- **Emission reducers**
- **A carbon or GHG sequestering sink that absorbs carbon from the atmosphere**
- **Offsetter of GHG emissions intensive goods through producing replacements like bioenergy and building materials**
- **Offsetter as host for wind and solar energy**
- **Operator in a mitigating world with higher prices**

- **Society is searching for low cost net emission reduction options.**
- **First place they will look is energy sector - 80% of US emissions.**
- **Will only come to ag and forest if cheaper or otherwise attractive.**

McCarl, B.A. , and U.A. Schneider, "US Agriculture's Role in a Greenhouse Gas Emission Mitigation World: An Economic Perspective", Review of Agricultural Economics, 22 (1), 134-159, 2000.

A Motivation for Mitigation Action
Social Cost of Carbon Emissions

- **Recent estimates have been developed on the social cost of carbon (damages from emitting a metric ton)**
- **Gives an estimate of NPV of all future monetized damages from a one ton increase in CO2 equivalent emissions in a given year.**
  - **Includes changes in agricultural productivity, human health, property damages from floods, ecosystem services, home heating/cooling and properties under sea level rise.**

Social Cost of Carbon in 2020 dollars per metric ton of CO2)

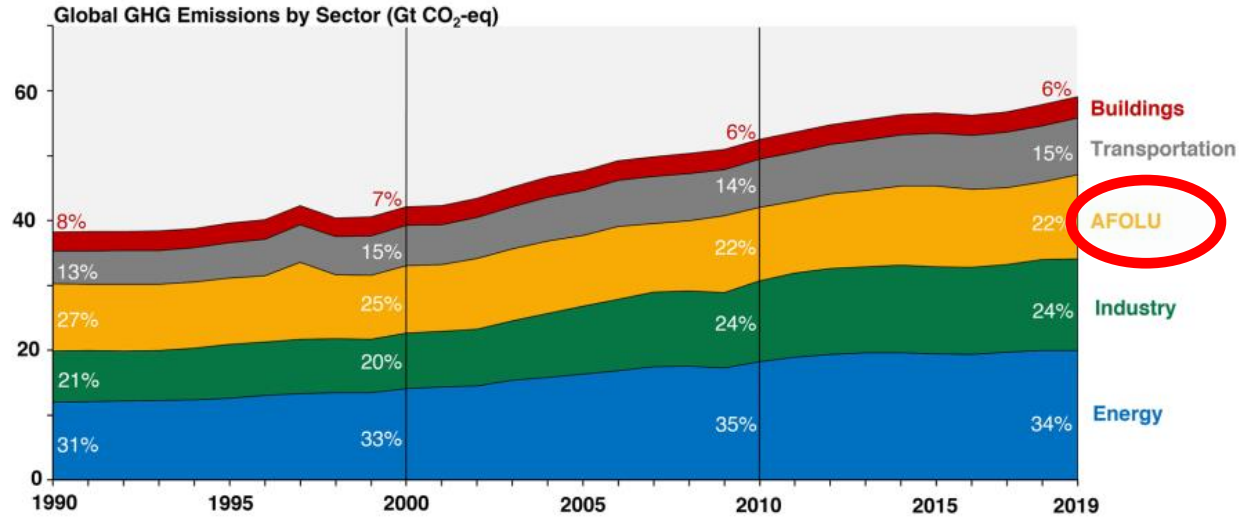
	Discount Rate		
Emission Year	**2.5%**	**2.0%**	**1.5%**
2020	**120**	**190**	**340**
2030	**140**	**230**	**380**
2050	**200**	**310**	**480**
2070	**260**	**380**	**570**
2080	**280**	**410**	**600**

www.epa.gov/environmental-economics/scghg

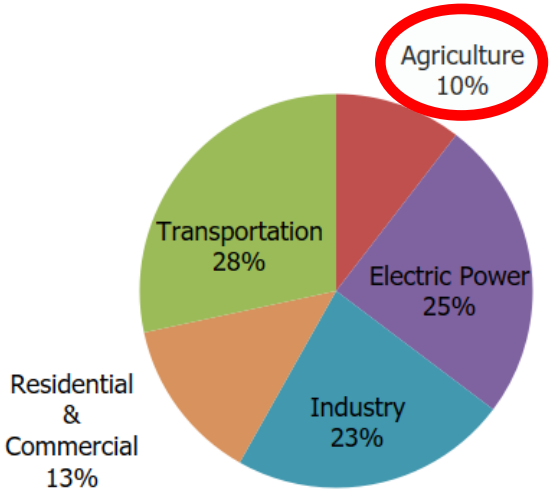
Rennert, K., Errickson, F., Prest, B.C., Rennels, L., Newell, R.G., Pizer, W., Kingdon, C., Wingenroth, J., Cooke, R., Parthum, B. and Smith, D., 2022. Comprehensive evidence implies a higher social cost of CO2. Nature, 610(7933), pp.687-692.

Why Agriculture as an Actor in Mitigation?

Global emissions 2019



US emissions 2022



Agriculture, Forestry, and Other Land Use (AFOLU) (22% of 2019 global greenhouse gas emissions):

https://www.epa.gov/ghgemissions

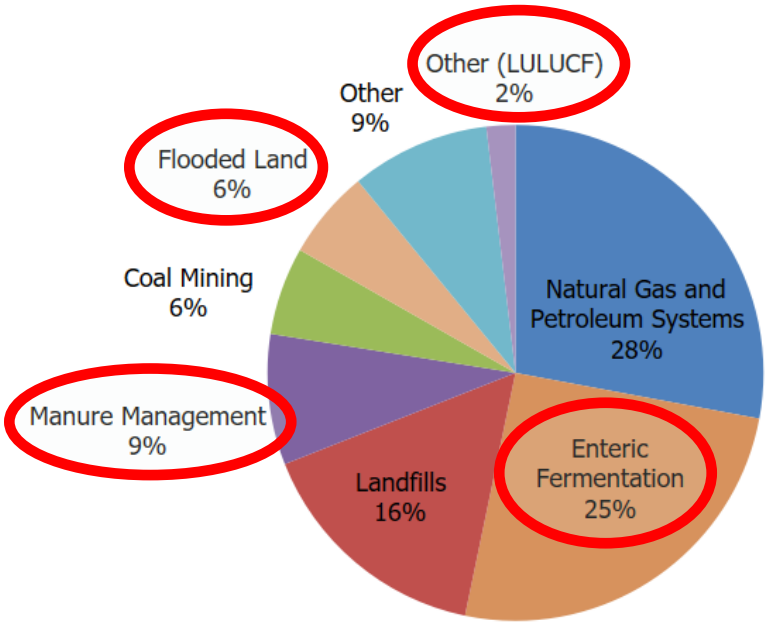
Why Agriculture as an Actor in Mitigation?
NON CO2

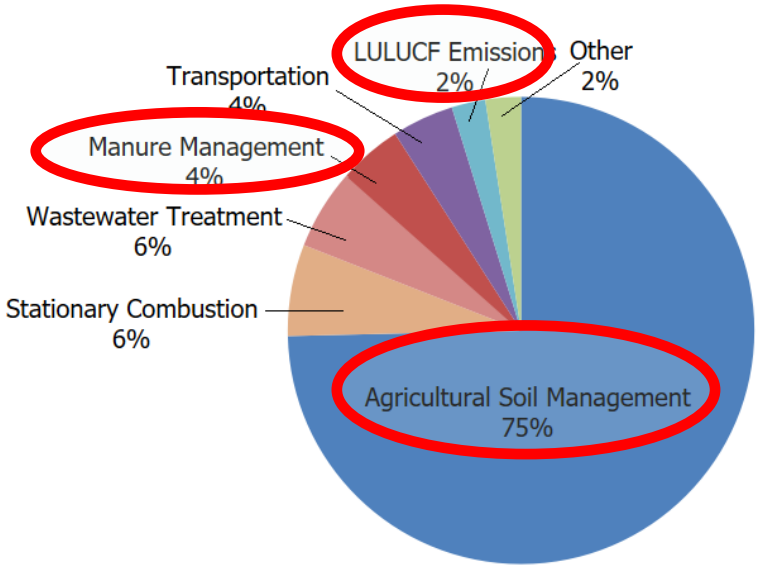
Globally in 2022 ag emissions share was

41% of methane **70% of N2O nitrous oxide**

In US on 2022 Shares were about

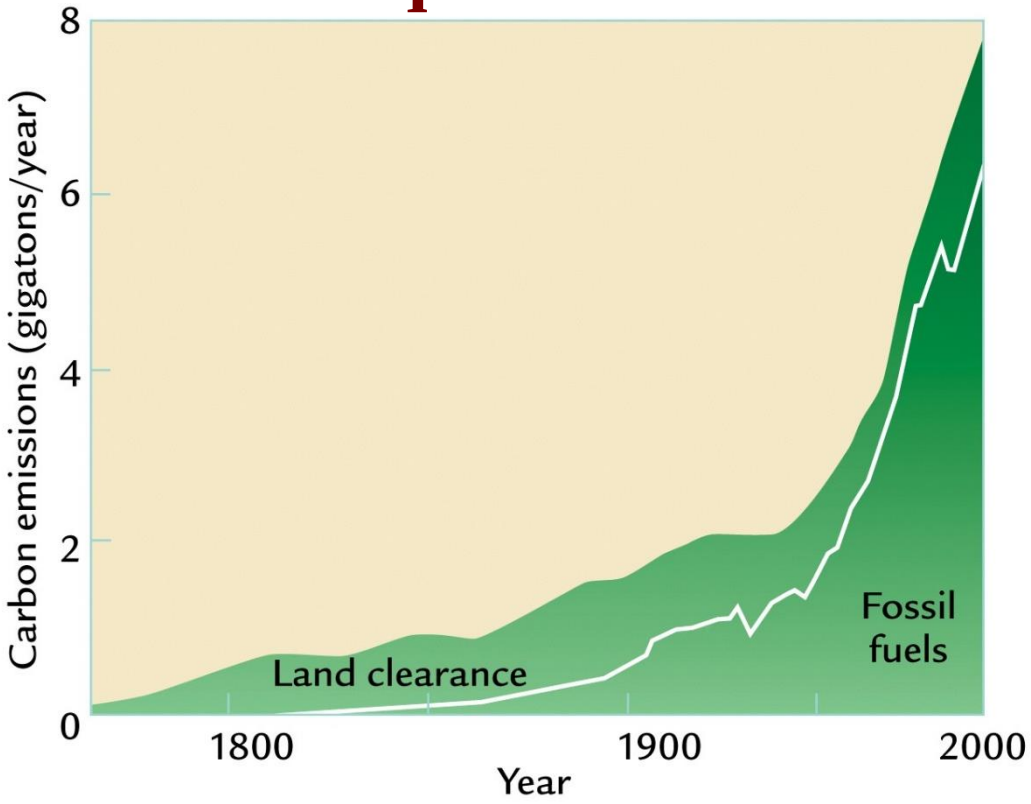
42% of Methane **81% of N2O**





Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2022. *Statistica*

Why Agriculture as an Actor in Mitigation?
Sequestration



Land Sequestration was historical source up until about 2000 of

25% of the historical atmospheric CO2 increase

Thus may have the potential to alleviate substantial amount

Apparently this was drawn from W. F. Ruddiman, 2001. Earth's Climate: Past and Future. W. H. Freeman and Sons, New York

Ag and Forest Mitigation Options

Strategy	Basic Nature	CO2	CH4	N2O
Crop Mix Alteration	Emis, Seq	X		X
Crop Fertilization	Emis, Seq	X		X
Crop Input Alteration	Emission	X		X
Crop Tillage Alteration	Emission	X		X
Grassland Conversion	Seq	X		X
Irrigated /Dry land Mix	Emission	X		X
Biofuel Production	Offset	X	X	X
Hosting Wind and Solar	Offset	X	X	X
Stocker/Feedlot mix	Emission		X	
Enteric fermentation	Emission		X	
Livestock Herd Size	Emission		X	X
Livestock Sys Change	Emission		X	X
Manure Management	Emission		X	X
Rice Acreage	Emission		X	
Afforestation	Sequest	X		
Existing timberland Mgt	Sequest	X		
Deforestation	Emission	X		

Smith, P., D. Martino, Z. Cai, D. Gwary, H.H. Janzen, P. Kumar, B.A. McCarl, F. OMara, C.W. Rice, R. Scholes, O. Sirotenko, M. Howden, T. McAllister, S.M. Ogle, G. Pan, V. Romanenkov, U.A. Schneider, S. Towprayoon, M. Wattenbach, and J.E. Smith, "Greenhouse gas mitigation in agriculture", Philosophical Transactions of the Royal Society B, 363 (1492), 789-813, 2008.

Mitigation - Economic Need For Incentives

- Many mitigation strategies are already well known or highly possible
- But many are not being used
- Generally they are economically inferior in the places they could contribute due to economics
- Either they have lower returns, high resource opportunity cost, or higher risk
- Incentives are needed

Antle, J.M., and B.A. McCarl, "The Economics of Carbon Sequestration in Agricultural Soils", Volume VI of the International Yearbook of Environmental and Resource Economics, edited by T.Tietenberg and H.Folmer, published by Edward Elgar, 278-310, 2003.

Today's Policy Setting

Global drive toward reducing GHG net emissions (UNFCCC) Lots of net-zero goals (cities and countries)

Portfolio of strategies – includes renewable fuel, electrification, discussed agricultural actions, IRA act subsidies, R&D on full use of carbon, emissions capture and storage (CCS) or utilization (CCU), avoided deforestation

Ag role – Ag is a Bridge to the future and is often advocated as a low cost way of getting to a lower carbon energy future. But controversial due to characteristics (see below) and the assertion that emitters must reduce emissions so the energy sector should be cut back

Markets in some places with widely varying rules. Ag is often excluded from emission caps but often allowed to sell offsets

Recent focus on methane (near-term impact - short half-life and high 20-year GWP ~85)

Emissions continue to rise at record rates due to societal momentum. Countries not always achieving international agreements

Possible Ag Strategy Shortcomings

Permanence – most sequestration strategies have carbon accumulation until a new equilibrium is reached (15 or so years for tillage, 25 or so for grass, 50+ for trees). They lose carbon upon strategy reversal

Uncertainty – the amount of GHG avoided is highly uncertain and varies from year to year especially for N2O from fertilizer, annual sequestration). Also for sequestration can we guarantee long term storage

Leakage - When the action lowers production of commodities in the marketplace we see increased production and emissions elsewhere to replace that market gap

Additionality – Many of the practices are already in use (no till for example or planting trees or not cutting trees). Many wish to only pay for new net reductions

Results heterogeneity – the effects of practices depend on climate, soils, individual management/practice in use. Results vary regionally and by individual

Resource competition – strategies overlap and in cases are mutually exclusive

Murray, B.C., Sohngen, B. and Ross, M.T., 2007. Economic consequences of consideration of permanence, leakage and additionality for soil carbon sequestration projects. Climatic change, 80(1), pp.127-143.

Smith, G.A., B.A. McCarl, C.S. Li, J.H. Reynolds, R. Hammerschlag, R.L. Sass, W.J. Parton, S.M. Ogle, K. Paustian, J.A. Holtkamp, and W. Barbour, Harnessing farms and forests in the low-carbon economy: how to create, measure, and verify greenhouse gas offsets, Edited by Zach Willey and Bill Chameides, Durham, NC: Duke University Press, 229 p, 2007.

Kim, M.K., McCarl, B.A. Murray, B.C., 2008. Permanence discounting for land-based carbon sequestration. *Ecological Economics*, *64*, 763-769.

Kim, M.K. McCarl, B.A., 2009. Uncertainty discounting for land-based carbon sequestration. *Journal of Agricultural and Applied Econ*, *41*, 1-11.

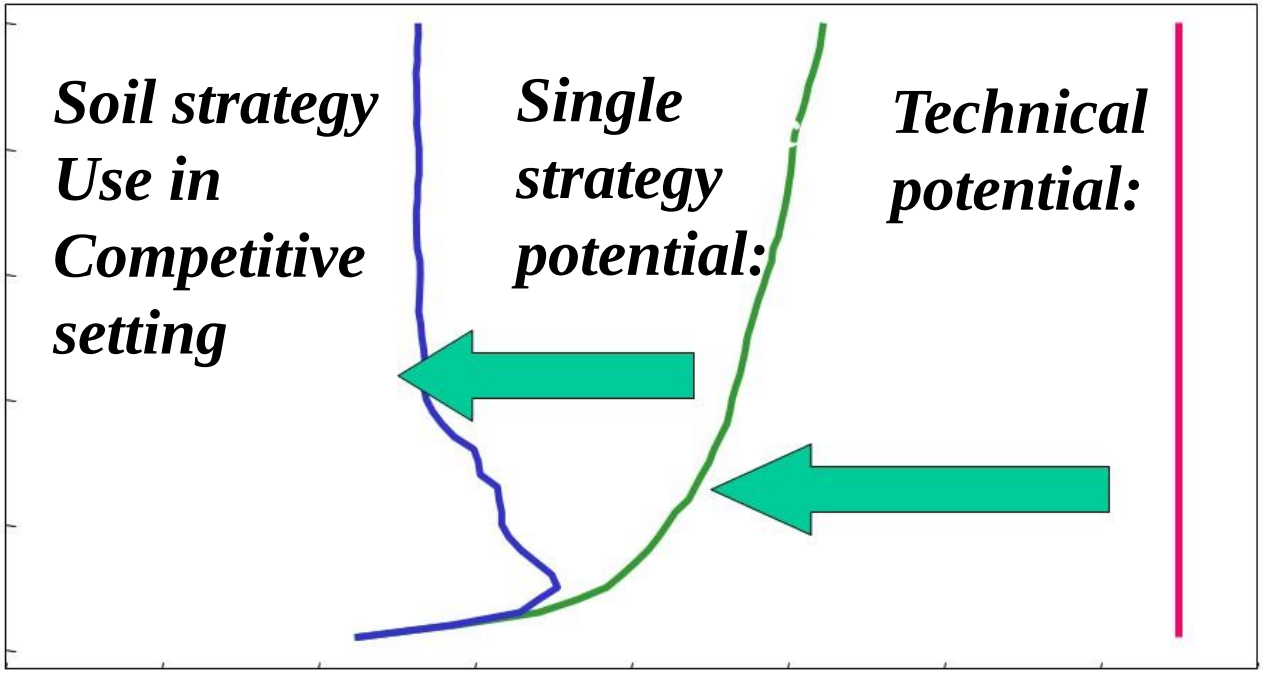
Kim MK, Peralta D, McCarl BA. Land-based greenhouse gas emission offset and leakage discounting. Ecological Economics. 2014 105:265-73.

Murray, B.C., McCarl, B.A. and Lee, H.C., 2004. Estimating leakage from forest carbon sequestration programs. *Land Econ*, *80*(1), pp.109-124.

Murray, B.C., A.J. Sommer, B. Depro, B.L. Sohngen, B.A. McCarl, D. Gillig, B. de Angelo, and K. Andrasko, Greenhouse Gas Mitigation Potential in US Forestry and Agriculture, EPA Report 430-R-05-006, November, 2005.

A Couple of Findings
Competitive Overlap in U.S. Ag & Forest Options

Example: U.S. ag soil potential:

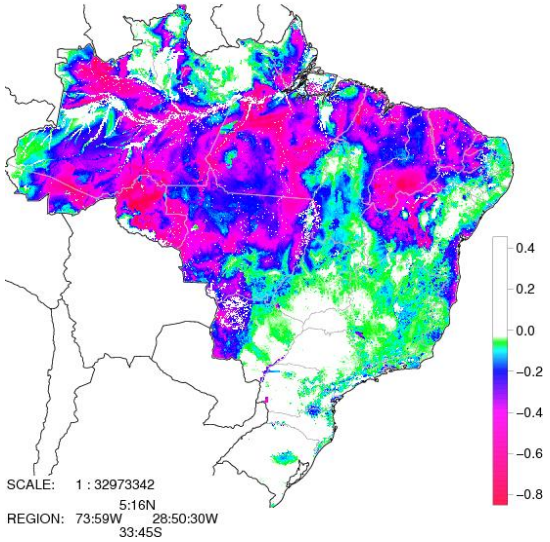


Economic estimate much less than technical engineering Resource competition reduces amount of soil strategy

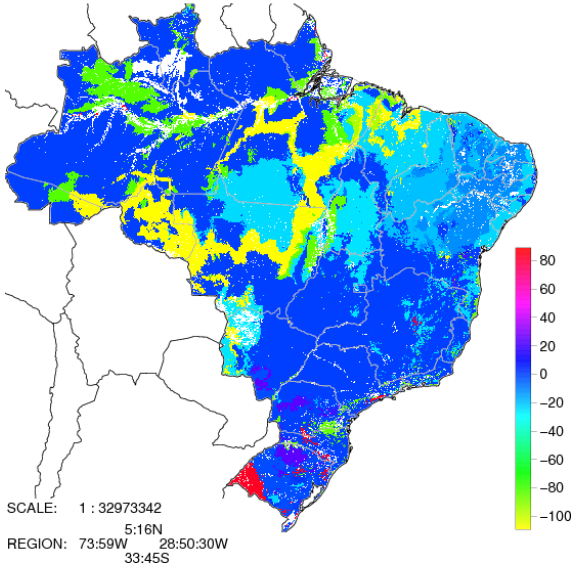
B. McCarl and U. Schneider, presented at 2001 EPA-USDA Forestry and Agriculture Greenhouse Gas Modeling Forum.
McCarl, B.A., and U.A. Schneider, "Greenhouse Gas Mitigation in US Agriculture and Forestry", Science, Volume 294 (21 Dec), 2481-2482, 2001.
Murray, B.C., A.J. Sommer, B. Depro, B.L. Sohngen, B.A. McCarl, D. Gillig, B. de Angelo, and K. Andrasko, Greenhouse Gas Mitigation Potential in US Forestry and Agriculture, EPA Report 430-R-05-006, November, 2005.

A Couple of Findings - Leakage

Nelson et al econometric projection of forest carbon sequestration responses in Brazil with a 25 % increase in corn price and 10% in sugar.



Change in probability of forest



Change in Carbon

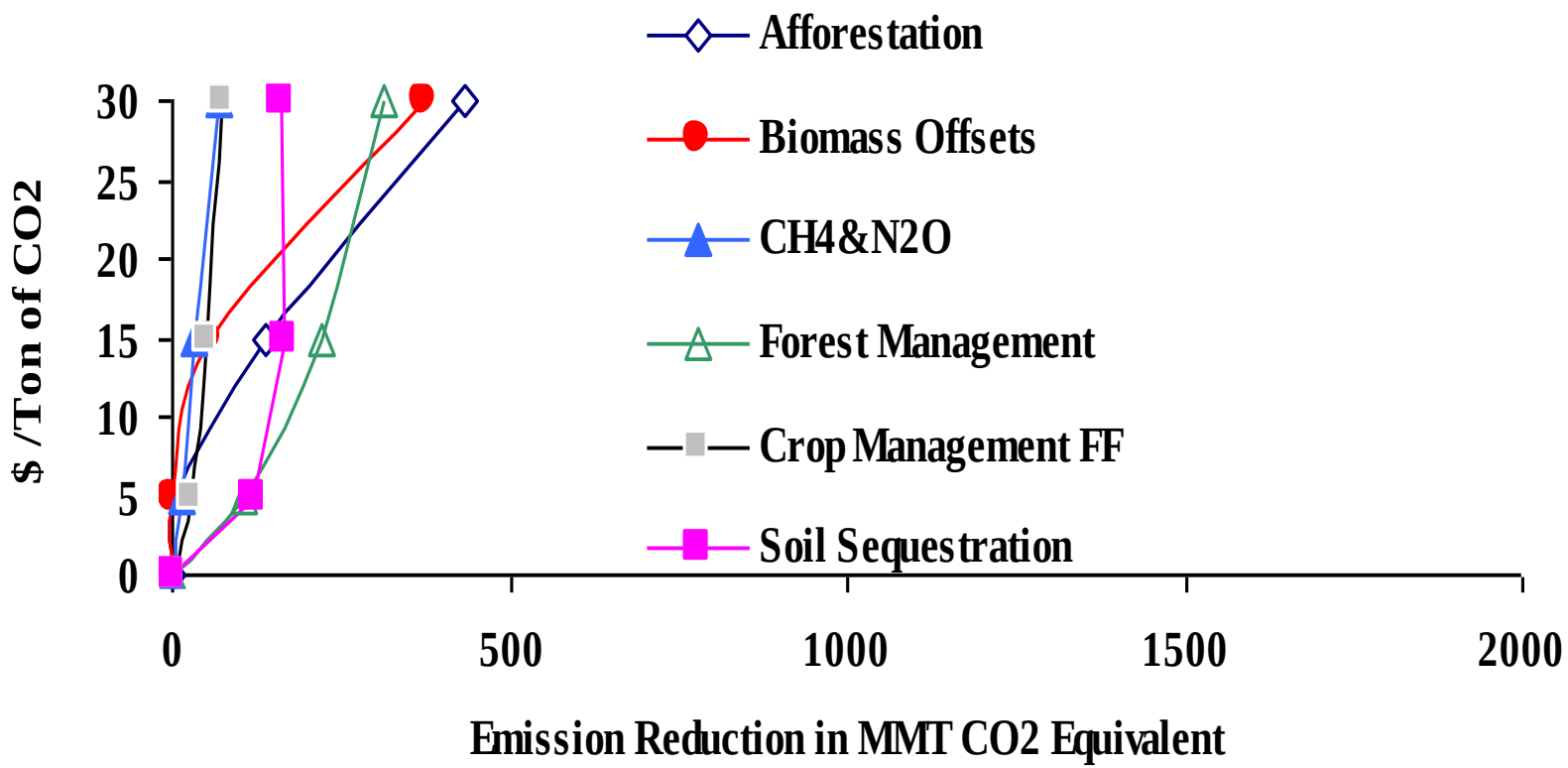
Leakage may be large due to strategies that reduce products flowing into market place (Murray et al) although not as large as once thought (Hertel et al)

G.C. Nelson and R.D. Robertson, "Green Gold or Green Wash: Environmental Consequences of Biofuels in the Developing World" Paper prepared for ASSA 2008 Invited paper session "Biofuels-Long-Run Implications for Food Security and the Environment". Review of Agricultural Economics '

Murray, B.C., B.A. McCarl, and H.C. Lee, "Estimating Leakage From Forest Carbon Sequestration Programs", Land Economics, 80 (1), 109-124, 2004

Hertel, T.W., Golub, A.A., Jones, A.D., O'Hare, M., Plevin, R.J. and Kammen, D.M., 2010. Effects of US maize ethanol on global land use and greenhouse gas emissions: estimating market-mediated responses. BioScience, 60(3), pp.223-231..

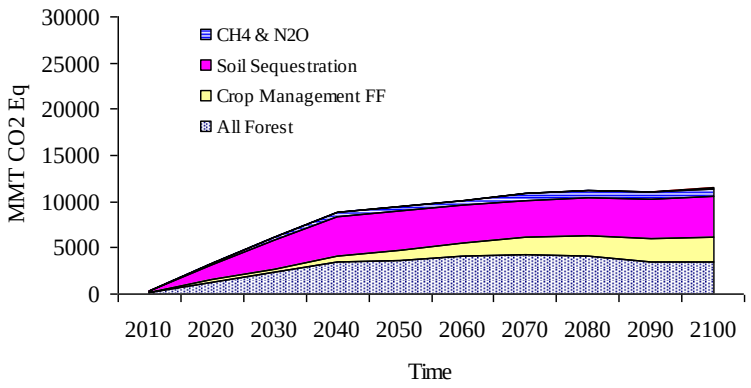
A Couple of Findings - Strategy Portfolio



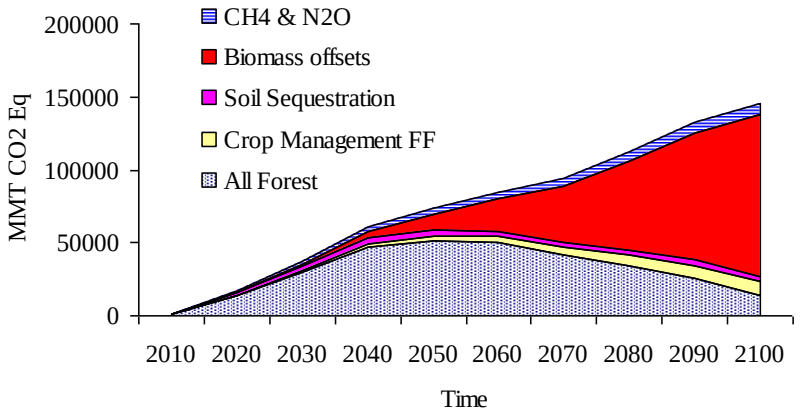
- Different strategies dominate at different price levels
- At low price complements but at higher substitutes
- Small importance of CH4 and N2O
- Varies by region

McCarl, B.A., and U.A. Schneider, "Greenhouse Gas Mitigation in US Agriculture and Forestry", Science, Volume 294 (21 Dec), 2481-2482, 2001.

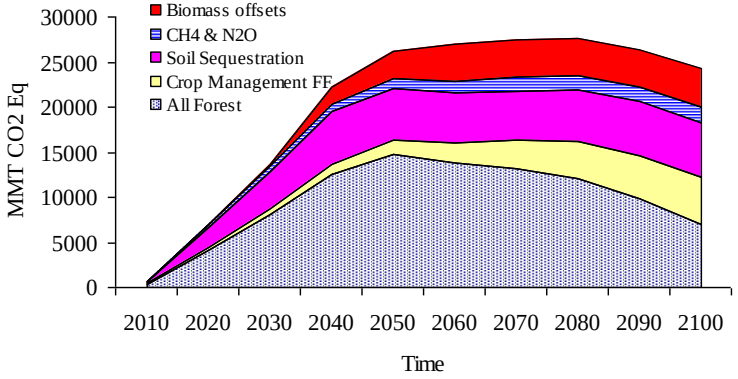
A Couple of Findings
Dynamics of U.S. Ag & Forest Options



Cumulative Contribution at a $5 per tonne CO2 Price



Cumulative Contribution at a $50 Price



Cumulative Contribution at a $15 Price

Note

Effects of saturation on sequestration
At low price complements
At high price biofuels takes over
Growing non co2 with price

Lee, H-C., B.A. McCarl, and D. Gillig, "The Dynamic Competitiveness of US Agricultural and Forest Carbon Sequestration", Canadian Journal of Agricultural Economics, 5, 343-357, 2005.

Some Findings
Bioenergy Offset Rates

Net Carbon Emission Reduction (%)

	Energy Form				
Commodity	Crop Ethanol	Cellulosic Ethanol	Biodiesel	Electricity Co-Fire 5%	Electricity fire100
Corn	31				
Sorghum	39				
Sugarcane	65				
Corn Residue		73		93	86
Wheat Residue		73		95	91
SwitchGrass		69		94	90
Energy Sorghum		79		98	96
Sweet Sorghum	61				
Sweet Sorghum Ratoon	63				
Soybean Oil			71		
Corn Oil			55		
Bagasse		90		100	100
Lignin				100	100

Ethanol offsets are in comparison to gasoline Power plants offsets are in comparison to coal.

Crop ethanol < cellulosic ≈ biodiesel < Electricity
Opportunities have different potentials

McCarl, B.A., "Bioenergy in a greenhouse gas mitigating world", Choices, 23 (1), 31-33, 2008.

Work Economists Might Undertake

- Identify the economics of potential mitigation strategies and where strategies are most relevant
- Identify ways to covey value of mitigation alternatives given their characteristics – grading standard
- Propose and evaluate incentive schemes and needs for private versus public adaptation support
- Develop optimum strategy mix portfolio by region
- Levels of investment across mitigation and adaptation versus traditional investment (see Wang, and McCarl, "Temporal Investment in Climate Change Adaptation and Mitigation", Climate Change Economics, Vol.4, No.2, 1350009, DOI: 10.1142/S2010007813500097, 2013.
- Identify costs of mitigation including transaction costs

A Couple of Concluding Comments

- **Both adaptation and mitigation action will be occurring**
- **Adaptation will change way ag does business in many places**
- **Mitigation extent depends on incentives and willingness to reflect externality cost on ag actions**
- **Efficiency in policy design will be important. Lots of chances to spend without a lot of effect**
- **Rich ground for economic effort**
- **Effects also important to understand moviation for mitigation and adaptations needed. Just not enough time to cover here**

Thank You For Your Attention

Questions?