The International Leakage Effects of Land Retirement: Evidence from The Conservation Reserve Program

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Motivation

- The U.S. is a major agricultural exporter, and its domestic policies significantly impact global agricultural production, markets, trade flows (Rossmiller and Nugent 1991), price stability (Mayrand et al. 2003) and welfare (Alston, Sumner, and Brunke 2007).
  - U.S. agricultural policies, as shaped by U.S. farm bills, have effects beyond its borders.
- Climate-smart agriculture implemented to build resilience in agricultural operations, benefiting both producers and the environment.
  - The USDA offers various voluntary programs and funding opportunities to support farmers and ranchers in implementing climate-smart solutions, such as the Conservation Reserve Program and the Environmental Quality Incentives Program.
- The CRP is one of the main efforts to address climate change in agriculture in the U.S., and in 2021, the USDA announced plans to enroll up to 4 million new acres (WASHINGTON, April 21, 2021).
  - If there is international leakage, it can undermine the environmental benefits of managing a global pollutant like GHG gases!

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Research question

- How does the U.S. Conservation Reserve Program affect land cover, agricultural markets, and welfare across regions of the world?
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Literature review

- The global impact of U.S. farm bills (Winders 2018)
  - Cotton (Sumner 2006), corn (Shetty and Winch 2015), biofuel (FAPRI 2008)
- Domestic and environmental effects of CRP:
  - Environmental benefits (Yin et al., 2021)
  - Farmer participation (Wallander et al., 2017)
  - Land use change (Wu, 2000; Wu, 2005)
  - Economic spillovers (Wu and Lin, 2010; Li and Ando, 2023)
- Methods in studying the economic effects of CRP:
  - OLS (Sullivan et al., 2004; Li and Ando, 2023)
  - I-O (Sullivan et al., 2004; Mundell, 2002; Hyberg, Dicks and Hebert, 1991)
  - CGE (Boyd, Konyar and Uri, 1992; Joh, 1998; Taheripour, 2006)

Contribution

- Contributes to the literature on the impacts and international implications of the CRP, while informing the current focus of the program as a climate mitigation strategy.
- Expands the growing body of research on the spillover effects of conservation programs (Robalino and Pfaff, 2012).

Similar land retirement programs in other countries

- Canada
  - Permanent Cover Program (PCP)
- EU
  - Farmers receive up to \$784 ha^{-1} annually for setting aside land for 20+ years to prevent soil erosion and improve water quality.
  - Afforestation scheme to reduce wood shortage.
- China (regional)
  - Grain-to-Green Program (GTGP)

CRP history

- Administered by Farm Service Agency since 1985.
- Compensates for converting sensitive cropland to conservation uses, enhancing environmental benefits.
- Before 2000, accounted for over 90% of U.S. Farm Bill conservation expenditures.
- As of FY 2022, it's USDA's largest conservation program by spending (USDA ERS 2023).

Acreage cap	*Year*
40-45 million	1986-1991
38 million	1992-1995
36.4 million	1996-2001
39.2 million	2002-2008
32 million	2009-2015
25 million	2016-2022

Figure 1: CRP caps

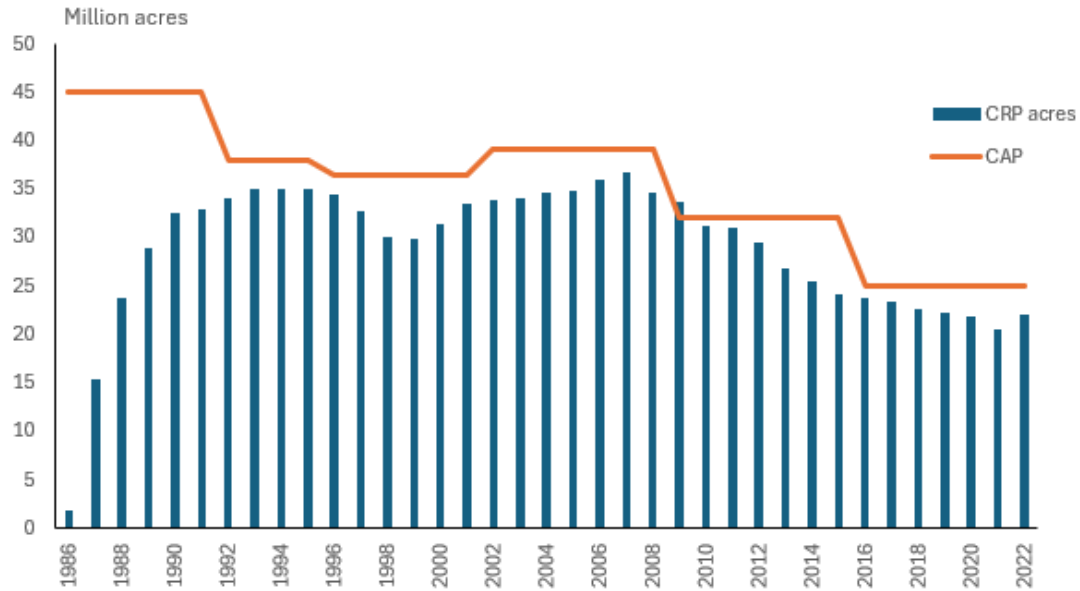
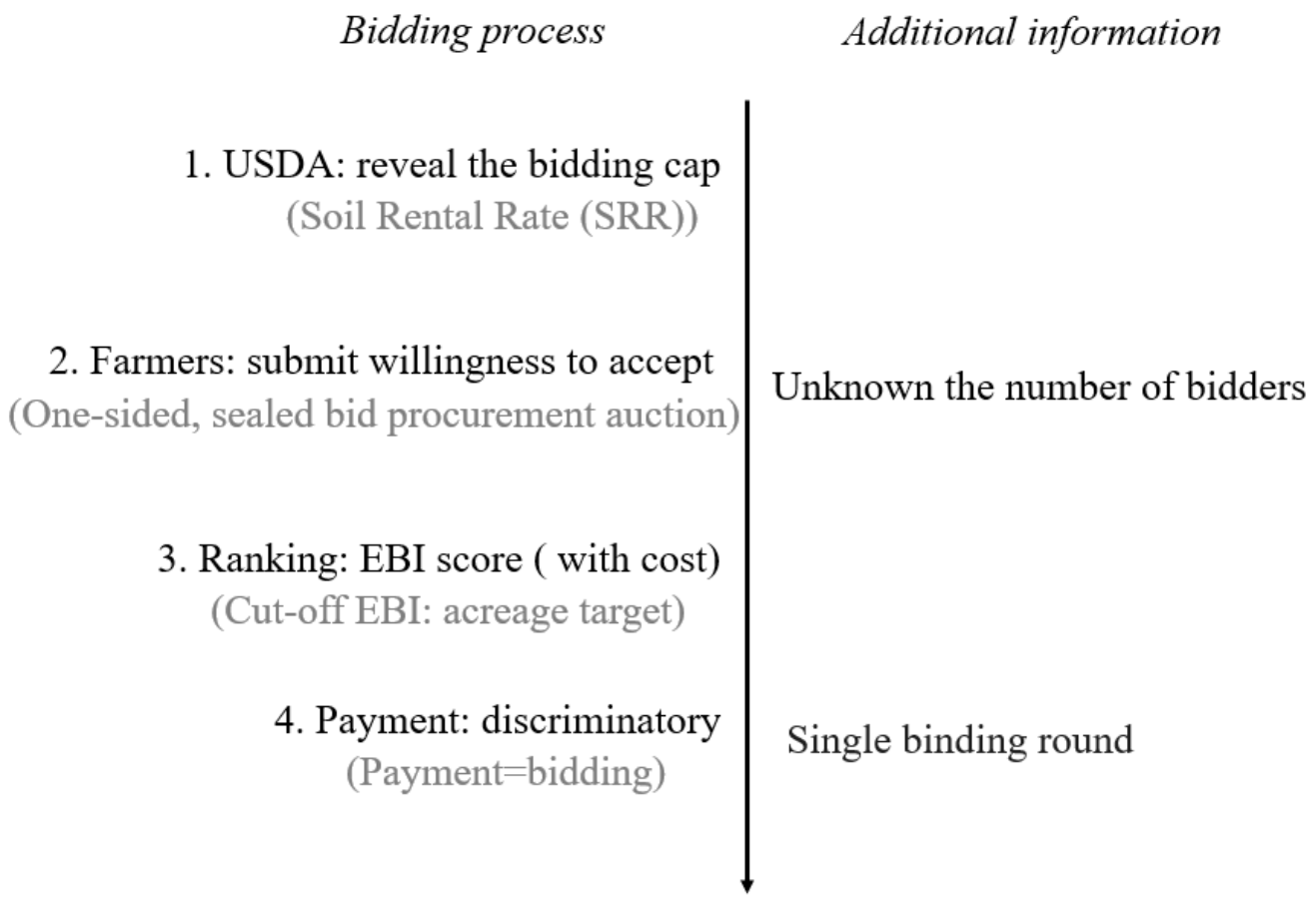


Figure 2: Cumulative CRP acres and the CRP cap

CRP allocation rules



- Competitive market (Plantinga, Alig, and Cheng, 2001; Aspelund and Russo, 2024)

Figure 3: Auction features of the CRP General Signup

CRP acceptance rates

Table 1: CRP acceptance rates

	Offers		Acres		Acceptance Rates		Payments	
Signup	**Received**	**Accepted**	**Received**	**Accepted**	**Offers**	**Acres**	**Total($/Year)**	**Per Acre**
2022	22,919	19,981	2,290,000	2,069,638	87.2%	90.4%	106,659,056	51.54
2016	26,279	4,842	1,860,000	407,116	18.4%	21.9%	2,548,2767	62.59
2013	27,821	24,213	1,900,000	1,680,000	87.0%	88.4%	108,253,928	64.44
2012	47,934	42,010	4,500,000	3,900,000	87.6%	86.7%	198,595,184	50.92
2011	38,715	29,878	3,750,000	2,830,000	77.2%	75.5%	136,201,438	48.13
2010	50,094	45,000	4,840,000	4,340,000	89.8%	89.7%	200,164,926	46.12

Note: Data from USDA FSA. The USDA published only these six signups.

Global implications of CRP

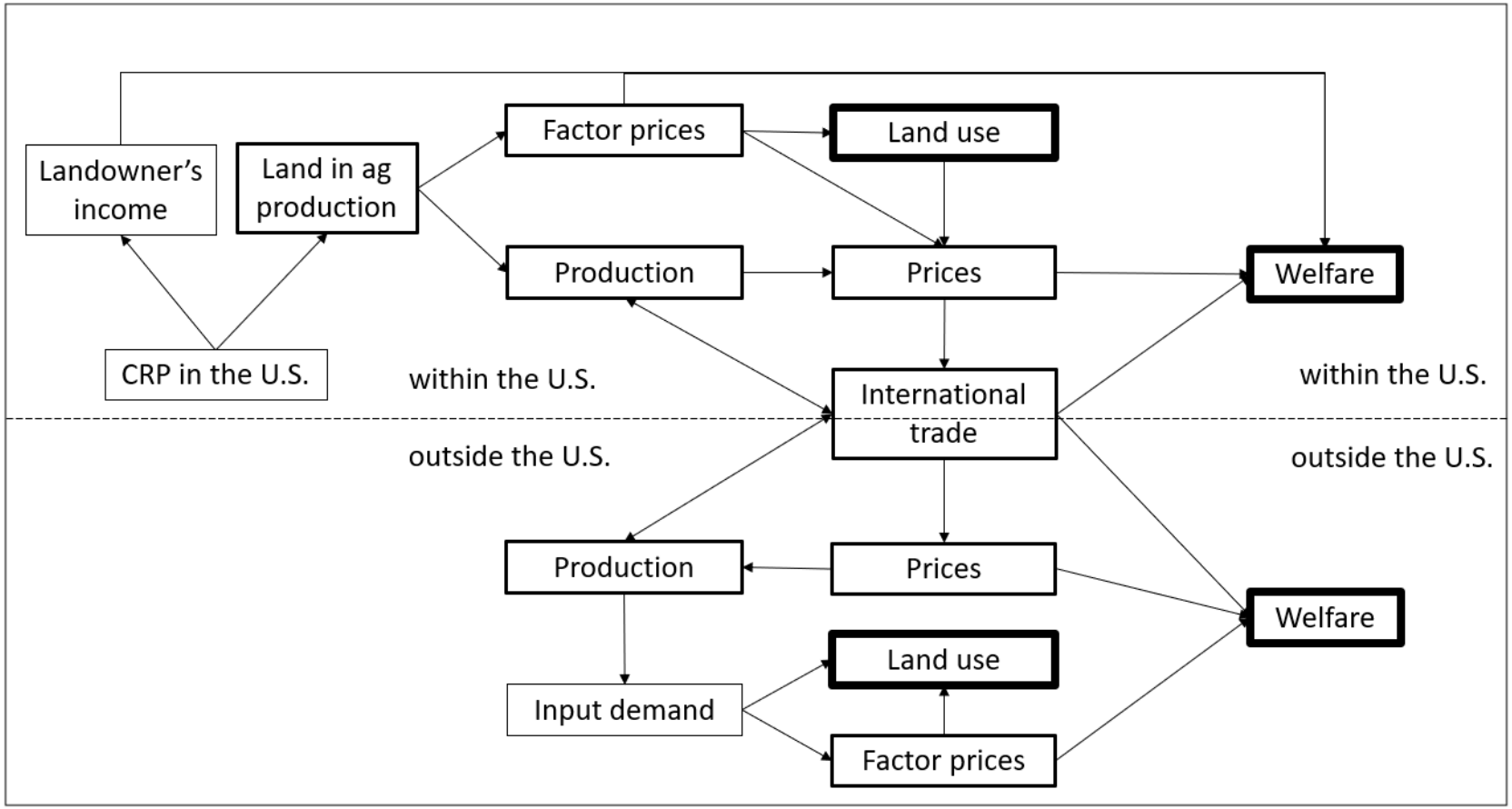


Figure 4: Conceptual model illustrating the global economic impact of CRP

Global Trade Analysis Project (GTAP)

- GTAP-AEZ
  - Standard GTAP: A multiregion, multisector, CGE model (Hertel,1997).
    - Regional household: allocates income for consumption, government, savings.
    - Firms: Maximize profits (CES production), paying regional households for endowments use.
    - *Land: Assumed to be universally transformable.*
  - GTAP-AEZ (Lee, 2005)
    - Land use data: 18 agro-ecological zones (AEZs), varies based on "length of growing period" (LGP)
    - Land mobility: restricted by constant elasticity of transformation (CET) frontier
    - Production function: unique to each land-using sector within an AEZ.
- **GTAP-CRP**
  - A new sector: CRP, with production function $Q_{CRP} = f(L_{AEZ})$
  - A new land cover: CRPland

Structure of GTAP

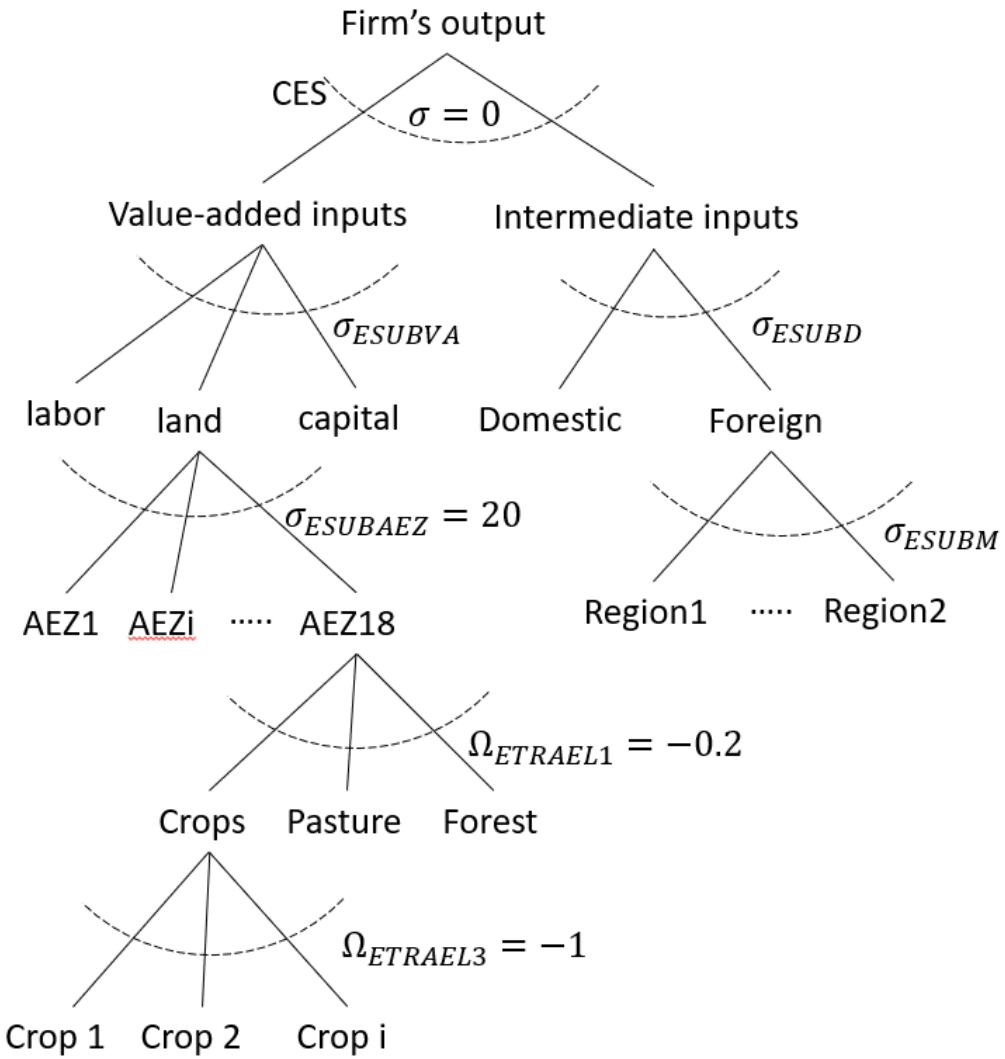


Figure 5: The structure of standard GTAP-AEZ model

Land supply in GTAP-CRP

- Land substitutability described by a nested constant elasticity of transformation (CET) function.
- $\Omega_{ETRAEL1}$ (GTAP-AEZ)
- $\Omega_{ETRAEL2}$ (Birur, 2010)
- $\Omega_{ETRAEL3}$ (standard GTAP)

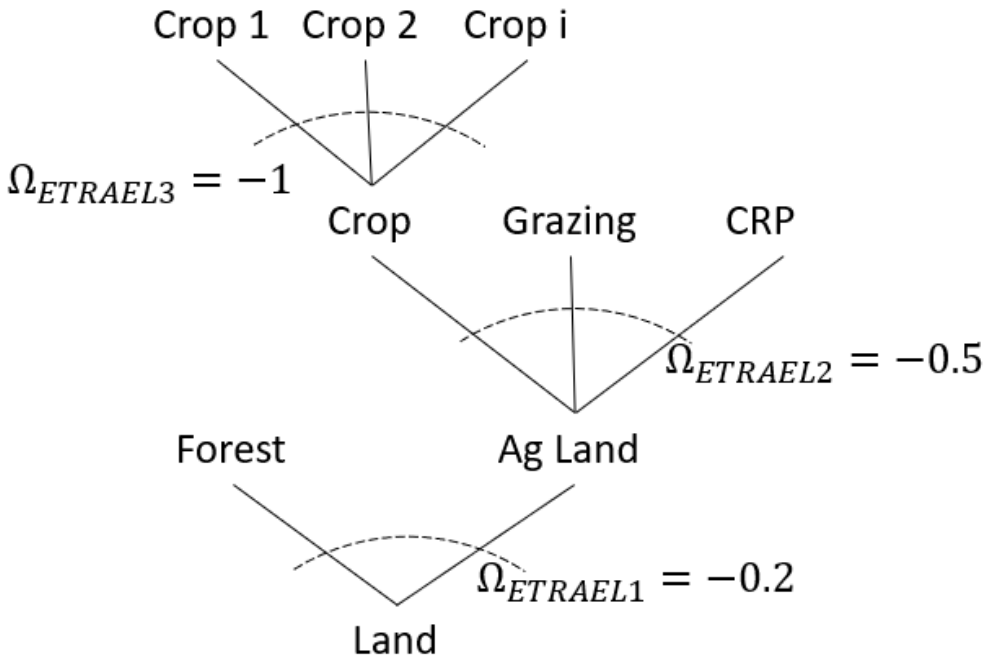


Figure 6: Land supply in GTAP-CRP Model

Data organization

- GTAP 10 database (Aguiar et al. 2022)
  - Reference year: 2014
  - 65 sectors to 13
  - 141 regions to 9

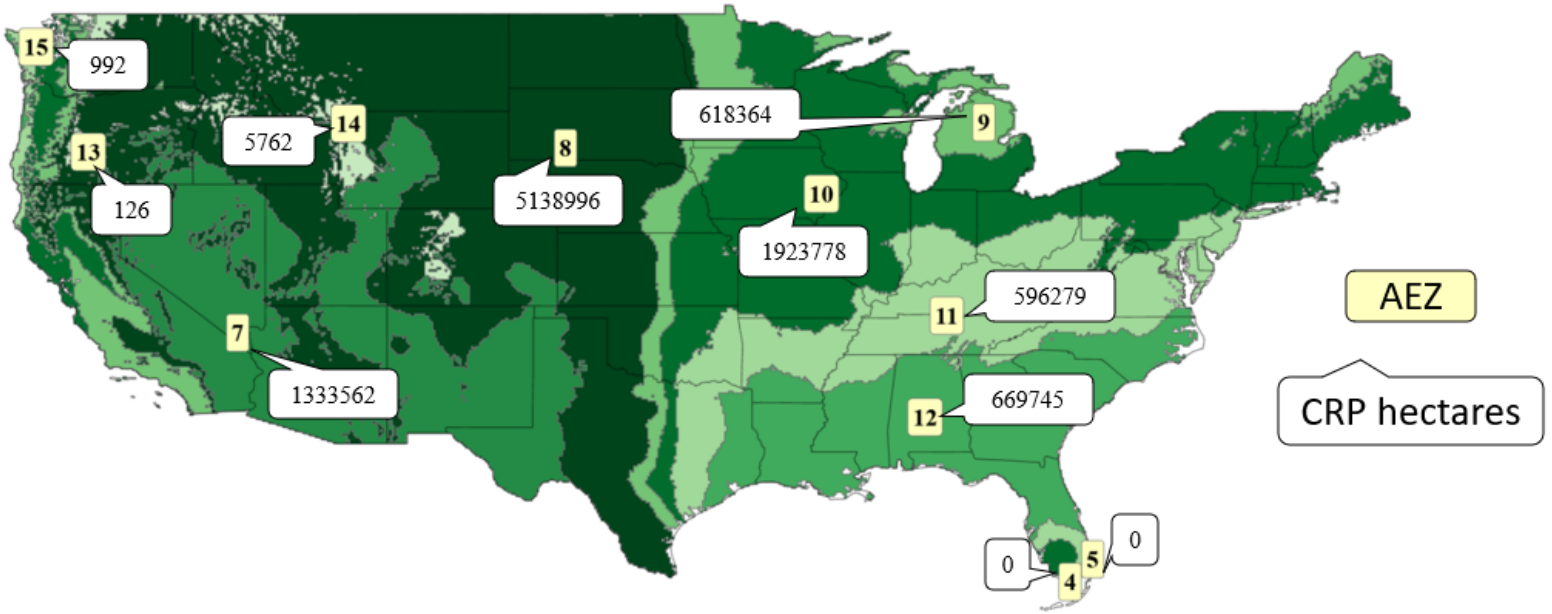
Table 2: Regions in GTAP-CRP

New Region	Description
US	United States
RNAmerica	Rest of North America
Chk	China and Hong Kong
Eur	Europe
SEAsia	Southeast Asia
RAsiaO	Rest of Asia and Oceana
CSAmer	Central and South America
MENA	Middle East and North Africa
CSAfri	Central and Southern Africa

Table 3: Sectors in GTAP-CRP

Sectors	Description
pdr	Paddy rice
wht	Wheat
gro	Cereal grains nec
vf	Vegetables, fruit, nuts
osd	Oil seeds
cb	Sugar cane, sugar beet
pfb	Plant-based fibers
ocr	Crops nec
Lstk	Livestock, row milk, wool
ProcFood	Processed Food
Mnfc	Manufacturing
Services	Services
CRP	CRP

CRP distribution



- Ranking
  1. AEZ 8
  2. AEZ 10
  3. AEZ 7
  4. AEZ 12
  5. AEZ 9
  6. AEZ 11
  7. AEZ 14
  8. AEZ 15
  9. AEZ 13

Figure 7: The distribution of cumulative CRP hectares across AEZs in 2014

Scenario design

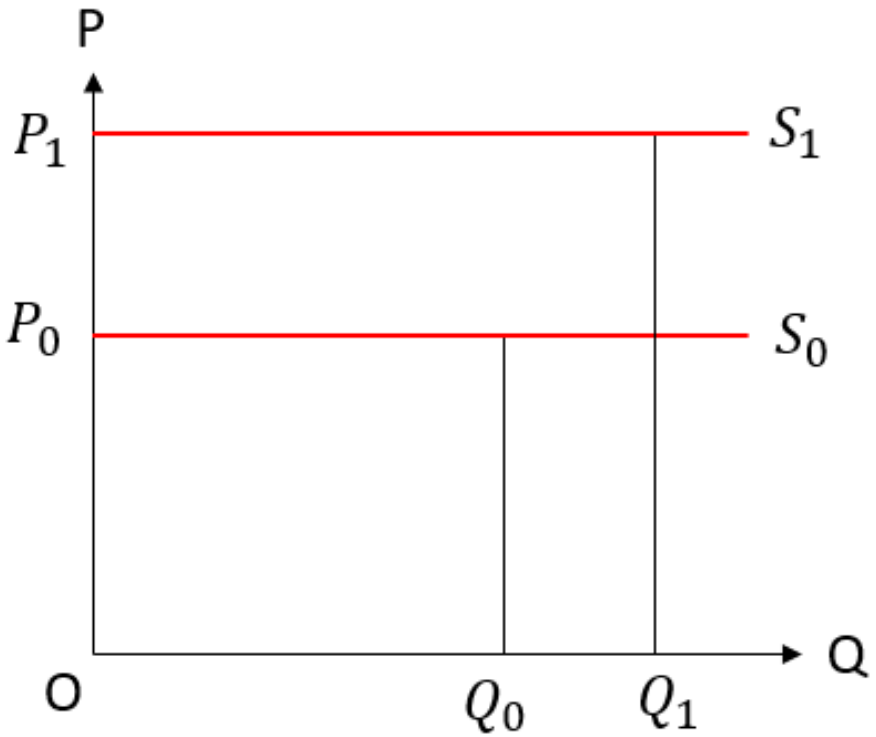


Figure 8: CRP supply and demand

- 4 more million acres is 15.7% increase in CRP with 2014 baseline acres.
- In GTAP-CRP, exogenously increase the CRP price until a 4-million-acre increase occurs endogenously.
- Closure
  swap to("CRP","US")=ps("CRP","US");
- Shock
  ps("CRP","US") = 112.14;

▸ Conceptual model

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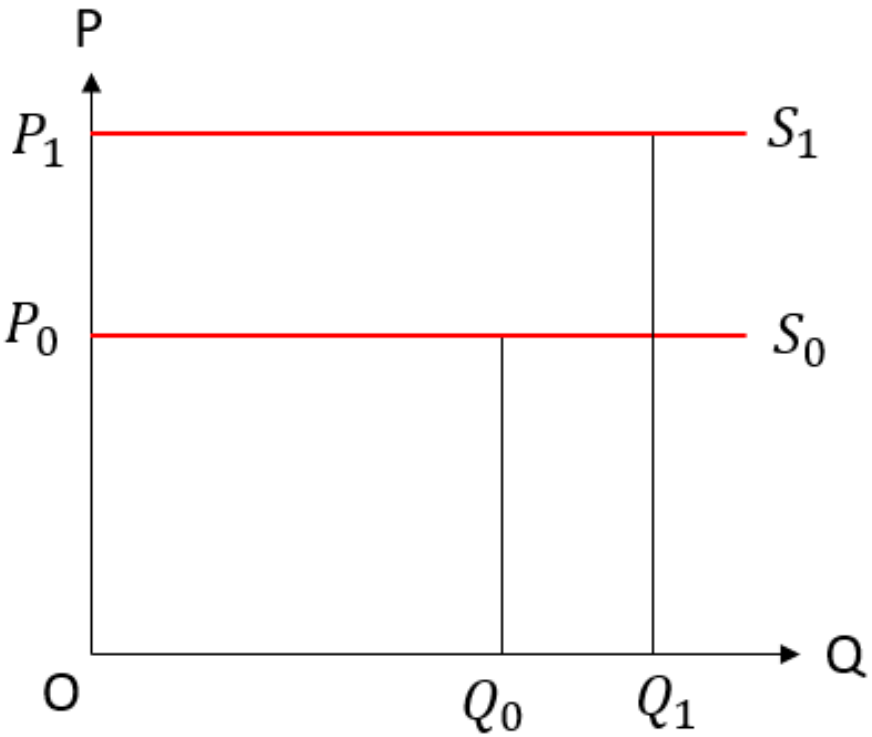

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Results: international slippage effects on land cover

- Every 100 acres of cropland and pastureland enrolled in CRP in U.S.:
  - In U.S.,
    17.05 acres of forestland will be transferred to crop or pasture land (Similar to Wu, 2000).
  - Outside the U.S.,
    20 acres of forestland and 8 acres of pastureland are transferred to cropland.

Table 4: Land cover changes across regions and globally

	US	RNA	China	Europe	CS Africa	SE Asia	R AsiaOceana	MENA	CS America	Global	Outside US
Forest	-0.68	-0.10	-0.07	-0.20	-0.07	-0.07	-0.10	-0.01	-0.19	-1.50	-0.82
	(-17.05%)	(-2.39%)	(-1.82%)	(-5.06%)	(-1.74%)	(-1.83%)	(-2.51%)	(-0.33%)	(-4.72%)	(-37.56%)	(-20%)
Crop	-2.78	0.08	0.14	0.29	0.11	0.07	0.23	0.05	0.17	-1.74	1.14
	(-69.5%)	(2.09%)	(3.41%)	(7.29%)	(2.64%)	(1.87%)	(5.66%)	(1.37%)	(4.27%)	(-43.49%)	(29%)
Pasture	-0.52	0.01	-0.06	-0.09	-0.04	0.00	-0.13	-0.04	0.02	-0.89	-0.33
	(-13.2%)	(0.3%)	(-1.6%)	(-2.3%)	(-0.9%)	(0)	(-3.1%)	(-1%)	(0.5%)	(-22.2%)	(-8%)

Note: The data are shown in million acres with the slippage as a percentage of the US CRP land increase in parentheses.

▸ Land changes in hectares in U.S. ▸ Land Price in U.S. ▸ Land share changes in U.S.

Results: impact on food market and welfare

- Sector output: U.S. decreases, other regions mostly increase.
- Sector price: ag commodity prices rise in all regions.
- Trade: U.S. exports drop, while other regions' exports, especially of rice, wheat, and grain, rise.

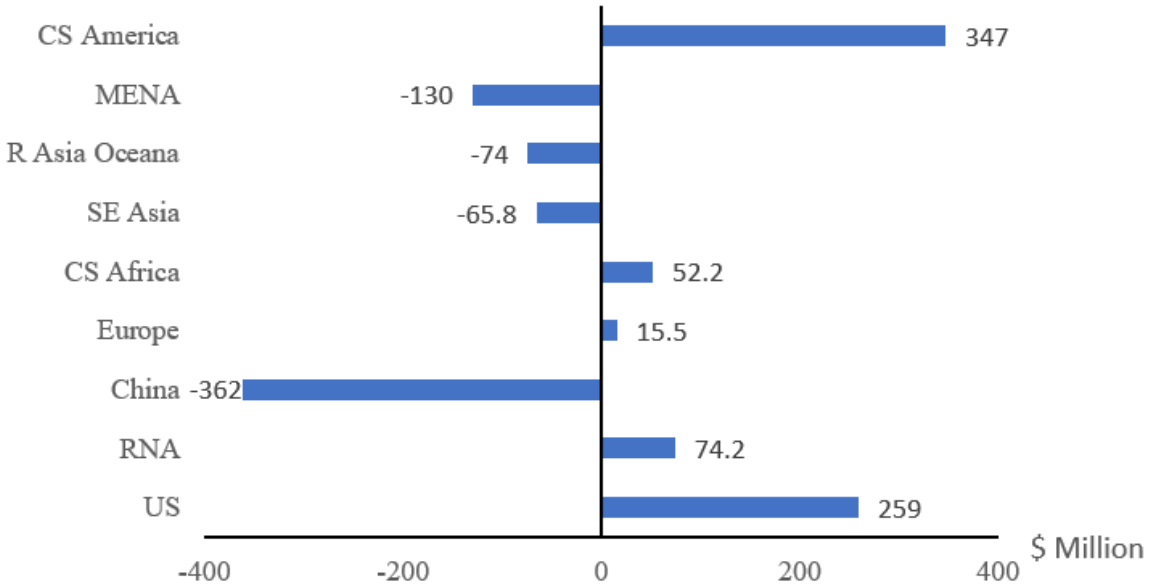

Figure 9: Changes in welfare valued in millions of US dollars.

Conclusion and next steps

- Conclusion:
  - Quantifies CRP-induced land use changes globally.
  - Emphasizes the need to consider conservation programs' unintended consequences driven by international markets.
    - Particularly relevant for global pollutants.
  - Suggests potential reduction in greenhouse gas mitigation effectiveness.
- Limitations:
  - Based on specific assumptions.
  - Cannot fully capture the heterogeneity in CRP enrollment by region and land type.
- Next steps:
  - Explore CRP bidding alternatives and implications.
  - Investigate CRP's emissions impacts and climate mitigation potential.
  - Conduct elasticity sensitivity analysis.

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Thank you!

Questions?

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Land changes in the U.S. in thousand hectares

Table A.1: The land changes in thousand hectares in the U.S.

	Forest	Cropland	Pastureland	CRPland
AEZ1	0	0	0	0
AEZ2	0	0	0	0
AEZ3	0	0	0	0
AEZ4	0	0	0	0
AEZ5	0	0.001	-0.001	0
AEZ6	0	0	0	0
AEZ7	-11.5	-61.1	-134	207
AEZ8	-79	-529	-190	797
AEZ9	-30.6	-67.7	1.16	97.1
AEZ10	50	-436	74.2	312
AEZ11	-63.5	-52.7	21.3	94.9
AEZ12	-132	21.1	5.48	106
AEZ13	-0.681	0.013	0.668	0
AEZ14	-8.23	0.191	7.07	0.964
AEZ15	-0.188	0	0.026	0.161
AEZ16	0	0	0	0
AEZ17	0	0	0	0
AEZ18	0	0	0	0

Note: All values are expressed in thousands of hectares.

back

CRP effects on land prices for different land covers in U.S.

Table A.2: The impact of CRP on land prices for different land covers in U.S.

	Forestland	Cropland	Pastureland	CRPland	U.S. total
AEZ1	0	0	0	0	0
AEZ2	0	0	0	0	0
AEZ3	0	0	0	0	0
AEZ4	-0.081	2.77	2.26	0	2.86
AEZ5	-0.09	2.86	2.25	0	2.96
AEZ6	0	0	0	0	
AEZ7	-0.018	2.04	1.82	111	6.36
AEZ8	0.063	2.52	1.9	111	5.76
AEZ9	0.251	2.9	2.09	112	3.71
AEZ10	-0.345	3.05	1.49	110	4.56
AEZ11	0.121	2.69	1.96	111	3.39
AEZ12	0.425	2.72	2.27	112	2.27
AEZ13	0.487	3.71	2.33	112	0.66
AEZ14	0.273	3.21	2.12	112	1.78
AEZ15	0.047	2.75	1.89	111	2.88
AEZ16	0.471	0.122	2.32	0	0.48
AEZ17	0	0	0	0	0
AEZ18	-0.582	0.597	1.74	0	2.43

Note: All values are expressed in percentages. The zero values occur because the AEZs are not located in the U.S.

back

Land changes in the U.S. relative to targeted retired land.

Table A.3: Land changes as a share of the intended retired land in U.S.

	Forest	Cropland	Pastureland	CRP
AEZ1	0	0	0	0
AEZ2	0	0	0	0
AEZ3	0	0	0	0
AEZ4	0	0	0	0
AEZ5	0	0	0	0
AEZ6	0	0	0	0
AEZ7	-0.7%	-3.8%	-8.3%	12.8%
AEZ8	-4.9%	-32.7%	-11.7%	49.4%
AEZ9	-1.9%	-4.2%	0.1%	6.0%
AEZ10	3.1%	-27.0%	4.6%	19.3%
AEZ11	-3.9%	-3.3%	1.3%	5.9%
AEZ12	-8.2%	1.3%	0.3%	6.6%
AEZ13	0	0	0	0
AEZ14	-0.5%	0	0.4%	0.1%
AEZ15	0	0	0	0
AEZ16	0	0	0	0
AEZ17	0	0	0	0
AEZ18	0	0	0	0

Note: The shares are calculated relative to the 4 million acres increase in CRP.

back

Land prices changes across regions and AEZs

Table A.4: The impact of CRP on land prices

	US	RNA	China	Europe	CS Africa	SE Asia	R Asia&Oceana	MENA	CS America
AEZ1	0	0.36	0	0	0.115	0	0.177	0.166	0.358
AEZ2	0	0.254	0	0	0.119	0	0.183	0	0.297
AEZ3	0	0.361	0	0	0.114	0.228	0.157	0	0.316
AEZ4	2.76	0.338	0.19	0	0.093	0.222	0.119	0	0.326
AEZ5	2.86	0.198	0.158	0	0.088	0.196	0.137	0	0.313
AEZ6	0	0.291	0.139	0	0.033	0.202	0.181	0.071	0.23
AEZ7	6.1	0.346	0.144	0.232	0.112	0	0.188	0.201	0.319
AEZ8	5.52	0.379	0.135	0.256	0.099	0	0.193	0.177	0.315
AEZ9	3.57	0.274	0.185	0.251	0.11	0.227	0.188	0.156	0.342
AEZ10	4.38	0.261	0.181	0.174	0.08	0.177	0.16	0.163	0.354
AEZ11	3.26	0.295	0.167	0.188	0.093	0.088	0.153	0.202	0.346
AEZ12	2.19	0.36	0.192	0.193	0.116	0.192	0.136	0.219	0.326
AEZ13	0.648	0.026	0.097	0.205	0	0	0.124	0.152	0.122
AEZ14	1.72	0.087	0.106	0.041	0	0	0.136	0.031	0.063
AEZ15	2.76	0.117	0.041	0.081	0	0	0.15	0.065	0.06
AEZ16	0.475	0.219	0.187	0.062	0	0	0.079	0	0.038
AEZ17	0	0	0	0	0	0	0	0	0.023
AEZ18	2.34	0	0.124	0.272	0	0	0	0.139	0.278

Note: All values are expressed in percentages.

back

Sector output changes across regions

Table A.5: The impact of CRP on sector outputs

	US	RNA	China	Europe	CS Africa	SE Asia	R Asia&Oceana	MENA	CS America
rice	-0.167	0.004	-0.004	0.002	-0.002	-0.001	-0.002	0	0.017
wheat	-0.269	0.012	0.003	0.01	0.008	0.003	0.027	0.002	0.005
grain	-0.171	0.034	0.009	0.027	0	0.02	0.046	0.005	0.02
veg&fruit	-0.22	0.006	0.01	0.004	0.002	0.015	0.011	0.002	0.008
oil seeds	-0.219	0.019	0.03	0.033	0.006	0.03	0.035	0.006	0.016
cane&beet	-0.03	0.007	0	0	-0.001	0	-0.003	-0.002	0.002
fibre crops	-0.233	0.004	0.003	-0.002	0.004	0.009	0.007	0	-0.002
other crops	-0.235	-0.005	0.005	0.007	0.003	0.001	0.008	0	-0.005
livestock	-0.083	0	-0.001	-0.002	0	-0.002	-0.003	-0.002	-0.002
CRP	15.2	0	0	0	0	0	0	0	0
processed food	0	0	0	0	0	0	0	0	0
manufacturing	-0.002	0	0	0	-0.001	-0.001	0	0	0
services	0	0	0	0	0	0	0	0	0

Note: All values are expressed in percentages. The region descriptions are the same as those in Table 3.

back

Sector prices changes across regions

Table A.6: The impact of CRP on commodity prices

	US	RNA	China	Europe	CS Africa	SE Asia	R Asia&Oceana	MENA	CS America
rice	0.52	0.50	0.12	0.21	0.04	0.17	0.13	0.19	0.38
wheat	0.33	0.28	0.17	0.26	0.24	0.25	0.25	0.22	0.28
grain	0.70	0.49	0.21	0.32	0.10	0.27	0.32	0.29	0.41
veg&fruit	0.46	0.33	0.21	0.24	0.15	0.23	0.21	0.22	0.29
oil seeds	0.47	0.41	0.34	0.37	0.29	0.29	0.35	0.35	0.39
cane&beet	2.17	0.33	0.15	0.12	0.06	0.16	0.12	0.09	0.25
fibre crops	0.25	0.18	0.16	0.15	0.17	0.18	0.16	0.12	0.19
other crops	0.27	0.20	0.18	0.17	0.18	0.18	0.16	0.18	0.19
livestock	0.36	0.17	0.05	0.08	0.06	0.06	0.08	0.05	0.13
CRP	112	0	0	0	0	0	0	0	0
processed food	-0.01	-0.01	-0.02	-0.01	0.00	-0.01	-0.01	-0.01	0
manufacturing	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0
services	-0.01	0.01	-0.03	0.00	0.02	-0.01	-0.01	-0.01	0.03

Note: All values are expressed in percentages. The region descriptions are the same as those in Table 3.

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Impact of CRP on trade

Table A.7: The impact of CRP on commodity exports in FOB weights

	US	RNA	China	Europe	CS Africa	SE Asia	R Asia&Oceana	MENA	CS America
rice	-0.687	-2.57	0.516	0.309	1.17	0.131	0.336	0.225	0.467
wheat	-0.35	0.008	0.719	0.046	0.249	0.181	0.161	0.293	0.184
grain	-0.462	-0.028	0.53	0.084	0.483	0.234	0.129	0.242	0.02
veg&fruit	-0.591	-0.005	0.173	0.052	0.317	0.116	0.166	0.129	0.059
oil seeds	-0.299	0.012	0.22	0.08	0.407	0.4	0.187	0.195	0.03
cane&beet	-6.01	0.918	0.441	0.02	1.11	0.595	0.618	0.825	0.09
fibre crops	-0.325	-0.002	0.029	0.093	0.028	0.099	0.08	0.193	-0.017
other crops	-0.473	-0.004	0.06	0.04	0.044	0.021	0.158	0.057	-0.006
livestock	-1.11	0.097	0.238	0.068	0.067	0.208	0.106	0.116	0.062
processed food	0.026	-0.017	0.04	-0.002	-0.019	0.005	0.001	0.01	-0.034
manufacturing	0.007	-0.003	0.007	-0.001	-0.005	0.001	-0.001	0	-0.02
services	0.031	-0.053	0.067	-0.007	-0.085	0.022	0	0.004	-0.122

Note: All values are expressed in percentages. The region descriptions are the same as those in Table 3.

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