The Effects of U.S. Agricultural Conservation Policy on Global Agricultural Production and Food Security: Evidence from The Conservation Reserve Program

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Abstract

With the significant rise in U.S. agricultural exports over the past 25 years, domestic policies, such as the Conservation Reserve Program, significantly influence global agricultural markets and food security, impacting farm households worldwide. This study utilizes a modified Global Trade Analysis Project Agro-Ecological Zone model to assess the impacts of expanding the Conservation Reserve Program in the U.S. on global agricultural markets. Preliminary findings suggest that an expansion of the Conservation Reserve Program in the U.S. will decrease cropland and pastureland on a global scale. Even though there are some increases elsewhere, these increases are not enough to offset the decrease in the U.S., and the expansion also results in a reduction of forest areas worldwide. Retiring additional land decreases crop production and causes land prices to rise across all Agro-Ecological Zones, influencing commodity prices and affecting international trade patterns.

Keywords— CRP, Global agricultural markets, Land use change, GTAP-AEZ

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1 Introduction

The United States (U.S.) is a major agricultural exporter, and its domestic policies significantly impact global agricultural production, markets, trade flows (Rossmiller and Nugent 1991), and price stability (Mayrand et al. 2003). While the impact of U.S. agricultural policies has been studied in many contexts (Baldwin et al. 2023), the effect of conservation policies, which have become more prevalent in recent years, is less studied. Moreover, existing studies on conservation policy impact primarily focus on domestic outcomes in the U.S. (Prokopy et al. 2019). Therefore, this paper aims to bridge the gap in the literature by examining the global implications of U.S. conservation policies on agricultural markets and trade.

U.S. agricultural exports have consistently increased over the past 25 years, rising from $62.8 billion in 1997 to $196 billion in 2022, making the U.S. the world's largest agricultural exporter (Beckman, Dyck, and Heerman 2017). Since 2011, around 20 percent of U.S. agricultural and food production value has consistently entered international markets, as indicated in Figure 1 (ERS 2021). The United States contributes to 32% of global maize exports and approximately 37% of worldwide soybean exports, implying that variations in the U.S. supply of these crops are likely to have significant impacts on global prices (Gilbert 2012). These trends underscore the pivotal role of U.S. agricultural policies in shaping global market dynamics and highlight the nation's sustained influence as a major agricultural exporter.

U.S. domestic policies exert substantial influence on global agricultural production and food security (Josling et al. 2007; Bruce and Nicholas 2012), with the costs of U.S. domestic support often falling on farm households in poor countries (Alston, Sumner, and Brunke 2007). For example, Alston, Sumner, and Brunke (2007) analyze the implications of eliminating agricultural subsidies in the U.S. for a farming household located in West Africa. They find that the financial benefits accruing from enhanced cotton price, quantified at approximately $100 annually for an average farm family, are sufficient to significantly improve the living conditions of that household. This amount is considered sufficient to ensure nutritional security for a child for a full year, or alternatively, to facilitate access to educational and healthcare services for multiple children within the family. Consequently, it becomes evident that agricultural cultivation practices and crop choices in the U.S., significantly shaped and guided by U.S. farm bills, have far-reaching and tangible impacts on communities and agricultural practices beyond its borders.

The U.S. Department of Agriculture (USDA) is actively participating in a whole-of-government effort to address climate change and safeguard the country's natural resources, including land, biodiversity, soil, air, and water. The Conservation Reserve Program (CRP), administered by the Farm Service Agency (FSA) since 1985, has played a pivotal role in agricultural conservation efforts in the United States. It is

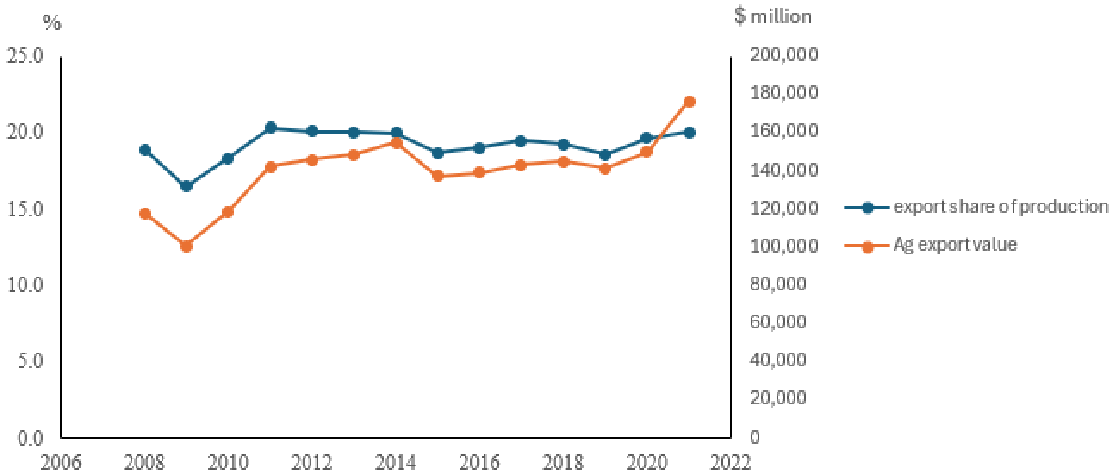

Figure 1: U.S. agricultural export value share of production, 2008-2021

Note: The export share of ag production value is displayed on the left y-axis, while the agricultural export value is displayed on the right y-axis. The export share data are sourced from U.S. Department of Agriculture (USDA) Economic Research Service (ERS), International Markets & U.S. Trade. The Agricultural export value data are sourced from USDA ERS, Foreign Agricultural Trade of the United States (FATUS), table "Value of U.S. agricultural trade, by calendar year".

a voluntary initiative that compensates landowners for converting environmentally sensitive cropland into conservation-oriented uses that provide significant environmental benefits. In the fiscal year 2022, CRP engaged approximately 22 million acres, supported by an annual budget nearing $1.8 billion. In 2021, the USDA announced plans to expand the CRP by enrolling up to 4 million additional acres and offering higher payments to farmers for setting aside their land. The expansion is expected to be facilitated through increased rental rates and the inclusion of a wider range of production practices. As of 2021, the CRP acreage cap stands at 25 million acres, with 20.8 million acres currently enrolled. Moreover, the cap is set to gradually increase, reaching 27 million acres by 2023. Therefore, our research contributes to understanding how these proposed changes to the CRP will likely affect regional welfare across the world, and especially in developing countries.

The global impact of U.S. farm bills has been extensively studied, particularly in relation to specific commodities, as evidenced by the substantial body of literature. Works such as Alston, Sumner, and Brunke (2007), Gillson et al. (2009), and Alston, Sumner, and Brunke (2007) have explored the effect of these policies on cotton, while the impact on corn has been documented by Spittler, Ross, and Block (2011) and Shetty and Ryan (2015). Additionally, the response of the biofuel sector to these policies is addressed in the Food and Agricultural Policy Research Institute (FAPRI) report (Westhoff, Thompson, and Meyer 2008). However, existing research primarily examines the global consequences of policies targeting specific commodities, such as the worldwide effects of removing all subsidies on cotton or corn, including impacts on global prices, production, and the welfare of developing countries. Fewer studies have explored the broader effects of agricultural conservation programs across various commodities. This research adds to the literature by examining the wider implications of U.S. agricultural conservation policies while covering multiple agricultural commodities.

The domestic and environmental effects of CRP have been extensively studied. First, the environmental benefits of CRP have been studied through water quality (Rao and Yang 2010; Yin et al. 2021), soil quality (Karlen, Gardner, and Rosek 1998), and land use changes (Wu 2000; Wu 2005). Domestic spillover effects have also been explored. For instance, Wu (2000) demonstrates that for every 100 acres of cropland retired under CRP, there was a corresponding conversion of 20 acres of non-cropland into cropland in the U.S., offsetting 9% and 14% of CRP water and wind erosion reduction benefits, respectively. However, the reliability of Wu's empirical findings has been contested by Roberts and Bucholtz (2005), who present evidence challenging the extent of this land conversion. But Wu (2005) provides further evidence in response to these critiques. Other economic spillovers of CRP have also been extensively studied. Young and Osborn (1990) found that with the implementation of CRP, agricultural production is projected to decrease by 3%, accompanied by a 2% decline in agricultural input industries and marginal decreases in household sector income, total gross output, and employment, with even lesser impacts on the agricultural processing sector. Wu and Lin (2010) demonstrated that CRP can boost average farmland values by 2% to 14%, varying by location within the US. Taheripour (2006) employed a general equilibrium framework and econometric analyses to assess CRP's broader economic impacts, concluding that at a reduction level of 34 million acres, the marginal cost of an additional dollar spent on CRP approximates $1.9 for the US economy. Li and Ando (2023) find enrollment in CRP significantly reduces employment in agricultural sectors. However, there is a notable research gap in understanding the broader implications of CRP on international trade, global agricultural production, prices, and welfare, particularly in developing countries. Addressing this gap is essential for fully grasping the international ramifications of CRP and for guiding future agricultural and conservation policies.

Various methodologies have been employed to analyze the impacts of CRP. Ordinary Least Squares (OLS) analysis, as used by Henderson, Tweeten, and Woods (1992), highlighted the differential impacts of CRP payments on retail sales in communities of varying sizes. Input-Output (I-O) modeling, employed by

Sullivan et al. (2004)and Mundell (2002), provided a more detailed view of the impact of CRP on rural economies, particularly in terms of employment and income. However, these methods have limitations in capturing the broader and interconnected economic effects of CRP, particularly on a global scale. The use of fixed effects in these models may not adequately capture the global impacts of the program, as they primarily focus on local or regional economies. In contrast, the Computable General Equilibrium (CGE) method (Taheripour 2006; Boyd, Konyar, and Uri 1992; Uri and Boyd 1996) offers several advantages for studying the impacts of CRP. CGE model provides a comprehensive framework that allows for the analysis of CRP impacts within the broader economic context, taking into account the complex interactions between various sectors, regions, and global markets. It enables the examination of the program's multifaceted effects across production, consumption, and government payments, making them ideal for assessing the full range of economic implications associated with CRP. Moreover, CGE model is particularly well-suited for capturing the global ramifications of CRP. By incorporating international trade flows and market linkages, these models can simulate how changes in U.S. agricultural production and land use, driven by CRP enrollment, affect global prices, trade patterns, and economic welfare in other regions. This comprehensive approach is crucial for understanding the full spectrum of CRP's economic implications, both domestically and globally.

To examine the impacts of land retirement through the CRP in the U.S. on global agricultural production, trade, and welfare, we extend the Global Trade Analysis Project (GTAP) model with Agro-Ecological Zones (AEZ) to create the GTAP-CRP model, incorporating the CRP as a new sector where land across various AEZs is the sole input. Our simulation results show that enrolling an additional 4 million acres into the CRP in the U.S. would lead to a decrease in agricultural output and exports, leading to price increases for most agricultural commodities, and welfare gains in the U.S. and some other regions due to improved resource allocation efficiency and international trade. We also estimate the slippage effect of the U.S. land retirement. The result shows that with a 100 acres land retired from gropland and pastureland, a 17 acres of forest will be transferred into the agricultural land within the U.S.

This study first contributes to the literature on the impacts of the CRP and studies examining the international implications of U.S. agricultural policies. While the domestic effects of the CRP on conservation and agricultural practices within the U.S. are well-documented, its broader impact on international agricultural markets, price stability, and global food security remains underexplored. By employing a CGE model to simulate the effects of CRP policies on global agricultural dynamics, this study not only provides a novel methodological approach but also offers insights into the global spillover effects of the U.S. agricultural conservation efforts. Our findings highlight the importance of considering the international ramifications of national agricultural policies, contributing to a more comprehensive understanding of how conservation initiatives like the CRP can influence global agricultural trade flows, commodity prices, and economic welfare, particularly in developing countries.

This study second contributes to the growing literature on the spillover effects of conservation programs, particularly in the context of the U.S. CRP. Previous studies have provided evidence of slippage in the CRP, with estimates ranging from 4% to 14% of the land area under the program (Wu 2000; Fleming-Muñoz 2010). However, the identification of slippage effects has been contested due to data limitations and potential unobservable factors (Roberts and Bucholtz 2005). Our study addresses these challenges by utilizing a modified GTAP-AEZ model, which allows for a more comprehensive analysis of the global spillover effects of the CRP. As highlighted by Pfaff and Robalino (2017), spillovers from conservation programs can occur through various channels, including input reallocation, market prices, learning, nonpecuniary motivations, and ecological-physical links. Our research specifically addresses the input reallocation and market price channel, examining how the CRP influences global land use changes, agricultural markets, and commodity prices.

This paper is organized as follows. The next section describes CRP market mechanism and the theoretical framework for analyzing the domestic and international economic impacts of CRP. Section 3 outlines the GTAP modeling framework, the method by which we extend the GTAP model, and the simulation scenarios. Section 4 describes the data, offering an exposition of summary statistics. Section 5 presents the primary results from our general equilibrium simulations. In the final section, we discuss our findings and conclude.

2 Background of CRP

2.1 CRP history and purpose

CRP was established in 1985 and initially designed to preserve soil quality (Mausbach 1996). Since then, CRP has expanded its focus to improve water and air quality, while also enhancing wildlife habitats (Hammerson et al. 2012). Under CRP contracts, enrolled land is removed from agricultural production for the duration of the contract, typically spanning 10 to 15 years. Before 2000, CRP accounted for more than 90% of conservation-related expenditures in the U.S. Farm Bill. Although its share of conservation funding decreased after the 2008 Farm Bill, CRP remained the largest conservation program in terms of funding (Coppess 2023). The program was initially designed to retire 40-45 million acres of land to address environmental concerns. Since then, it has seen fluctuating enrollment caps over time, ranging from 25 to 45 million acres. Initially, CRP enrollment was generally limited to 25 percent of the cropland within each county to avoid economic loss in farm-dependent communities. However, this cap essentially never binds (Aspelund and Russo 2024). As shown in Figure 2, which presents a scatter plot of CRP enrollments by county in 2017, the enrollment rates are lower than 5 percent in most counties.

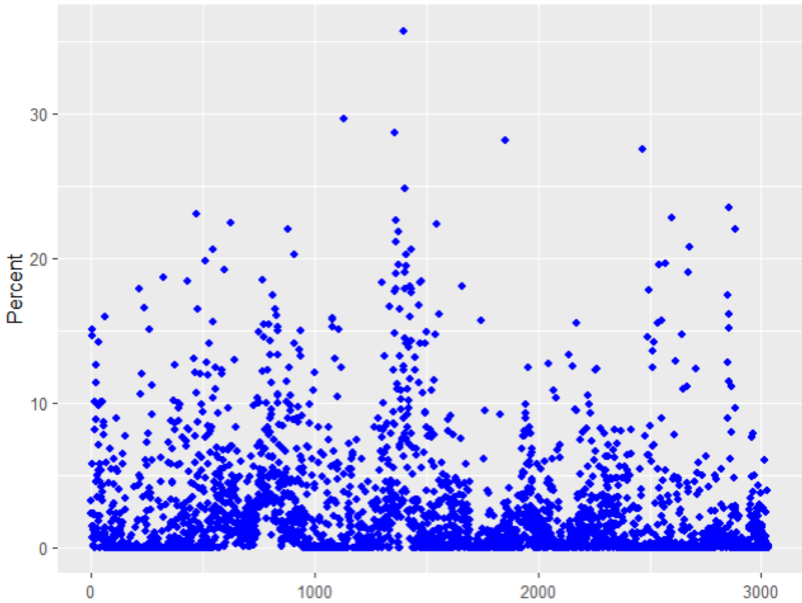

Figure 2: Percentage of CRP Land Relative to Cropland and Pastureland in Each County

Note: The figure is for 2017. CRP data are sourced from the USDA FSA; county cropland and pastureland data come from NASS Quick Stats. The x-axis represents each county.

CRP enrollment was capped at 38 million acres in 1992, but this limit was reduced to 36.4 million acres by 1996. CRP saw an increase in its enrollment cap to 39.2 million acres in 2002. However, the cap was lowered again to 32 million acres in 2009. The 2014 Farm Bill introduced a further restriction, stating that starting in 2016, enrollment could not exceed 25 million acres. Subsequently, the 2018 Farm Bill permitted a gradual rise in the cap, reaching 27 million acres by 2023 (ERS 2020). Figure 3 shows the cumulative CRP enrollment acres and the CRP acreage caps from 1986 to 2022, indicating that the national acreage caps are rarely binding either.

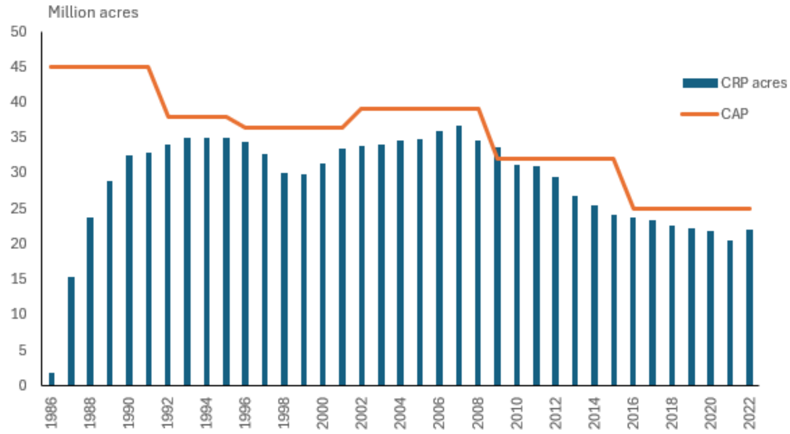

Figure 3: Cumulative CRP acres and the CRP cap

Note: The cumulative CRP data are sourced from the USDA FSA, and the cap data are summarized from ERS (2020).

2.2 CRP allocation rules

One of the key developments in the history of CRP was the introduction of the Environmental Benefits Index (EBI) in the early 1990s. The EBI is a scoring system designed to evaluate and rank the environmental benefits of land offered for enrollment in the CRP. Initially, CRP accepted all offers with acceptable rental rates, leading to the enrollment of only low-productivity lands. This approach did not attract lands with higher productivity and significant environmental concerns. The development of the EBI scores enabled the USDA to enroll environmentally sensitive yet highly productive lands into the program (Sullivan et al. 2004). The EBI scoring rule awards points based on the environmental sensitivity of the land, reflecting its relative importance in achieving overarching conservation objectives. This system allows the USDA to prioritize offers that provide the greatest environmental benefits. Over time, the EBI criteria have evolved to include factors such as wildlife habitat, water quality, air quality, and enduring benefits. Starting with signup 13th in 1995, the EBI score began accounting for the cost to the government of accepting a bid (Ribaudo et al. 2001).

The enrollment process for CRP utilizes an auction-based mechanism, strategically designed to optimize environmental benefits while ensuring fair compensation for landowners (Aspelund and Russo 2024). In the CRP auction, landowners submit sealed bids to enroll their parcels, specifying a rental payment and conservation practices. Bids are ranked using the EBI, which considers environmental benefits and cost. The program targets a rough acreage goal rather than a budget. Bids are subject to a parcel-specific bidding cap, the Soil Rental Rate (SRR), which is revealed to landowners before bidding (Hellerstein, Higgins, and Roberts 2015). CRP acreage in a county is limited to 25% of total cropland. The auction consists of a single binding round, but general signups are held periodically, usually annually, allowing rejected offers to be revised and resubmitted. CRP uses a discriminatory pricing rule, paying landowners their bid amount if accepted. The total number of bidders is unknown prior to the auction. Therefore, landowners must carefully balance their desire for higher rental payments and lower upfront expenditures on cover practices against the odds of their offer being accepted. There are arguments on the auction design of the CRP, some proposed that landowners are likely to bid at the bid cap (Hellerstein 2017), even though their opportunity cost is lower, others proposed that farmers bidding based on their marginal cost (Aspelund and Russo 2024).

Understanding the incentives that motivate farmers to participate is a key factor in analyzing the CRP market. For farm operators aiming to transition away from active farming—whether into retirement or alternative endeavors—the CRP presents an opportunity for steady income with minimal involvement, yet allows for the retention of landownership. Such operators often aim to maximize land enrollment to facilitate this transition, maintaining a connection to their land, whether as a homestead or an investment (Sullivan et al. 2004). The auction should theoretically reveal farmers' marginal willingness to accept to participate in the program (Aspelund and Russo 2024), but whether this occurs in practice has been questioned (Hellerstein 2017). According to the report by Sullivan et al. (2004), a significant portion of farm operator participants in CRP can be classified as either retirement or residential farm operators. Retirement farms are those managed by individuals who identify as "retired", whereas residential farms are managed by individuals who primarily identify with occupations outside of farming. These two farm categories also account for a significant portion of CRP acres and receive the majority of payments. Thus, the assumption of a competitive CRP market (Plantinga, Alig, and Cheng 2001) is substantiated. The method for modeling an increase in enrollment will be discussed in the Scenario Design section (Section 4.2).

Table 1 displays CRP acceptance rates for several sign-ups after 2010, revealing that the acceptance rates typically range from 75 percent to 90 percent, with the notable exception of an unusually low acceptance rate in 2016. This may be attributed to the 25 million acre cap implemented in 2016. For example, in 2022, the USDA received 22,919 offers covering 2.29 million acres of contracts, but accepted 87.2% of the offers, resulting in an average rental rate of $51.54. Rejection of offers may result from reaching the local or national acreage cap, or due to lower environmental benefits. CRP is implemented at the county level, thereby exhibiting a lot of heterogeneity across counties due to varying local environmental needs, land use practices, and conservation priorities. When studying the impact of CRP on global agricultural markets, it is necessary to aggregate CRP data to the national level and assume that this aggregated data accurately represents the majority of farmers' behaviors.

Table 1: CRP acceptance rates

	Offers		Acres		Acceptance Rates		Payments	
Signup	**Received**	**Accepted**	**Received**	**Accepted**	**Offers**	**Acres**	**Total($/Year)**	**Per Acre**
2022	22919	19981	2290000	2069638	87.2%	90.4%	106,659,056	51.54
2016	26,279	4,842	1860000	407116	18.4%	21.9%	2,548,2767	62.59
2013	27,821	24,213	1900000	1680000	87.0%	88.4%	108,253,928	64.44
2012	47,934	42,010	4500000	3900000	87.6%	86.7%	198,595,184	50.92
2011	38,715	29,878	3750000	2830000	77.2%	75.5%	136,201,438	48.13
2010	50,094	45,000	4840000	4340000	89.8%	89.7%	200,164,926	46.12

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

2.3 Global implications of CRP

CRP is a comprehensive initiative that significantly impacts the U.S. economy through changes in land use. Firstly, CRP directly supports farmers' incomes, thereby affecting welfare in the U.S. When farmers enroll their cropland and pastureland in CRP, the resulting scarcity of agricultural land leads to several consequential effects, as illustrated in Figure 4. This scarcity of agricultural land is expected to drive up land values, subsequently affecting factor prices (Taheripour 2006) and leading to a redistribution of land cover in the U.S. Secondly, the reduced availability of land for agricultural production may lead to a decrease in the output of agricultural commodities. This, in turn, could affect sector prices, thereby impacting welfare and international trade (Sumner 2003).

CRP is also likely to result in significant global spillovers through international trade. With higher production costs and increased export prices, U.S. production may be substituted by production from outside the U.S. Agricultural production could shift to countries with lower costs, further affecting production, factor prices, land cover, and welfare outside the U.S. All indicators within the bolded rectangle in Figure 4 represent the outcomes of interest in this study. Empirical evidence indicates that most crops can only grow under specific conditions of temperature, moisture, soil type, and landform (Lee 2005). This principle extends to land use in the livestock and forestry sectors as well. Therefore, the Agro-Ecology Zones (AEZs) (Lee 2005) must be considered when accounting for the transfer of crop production.

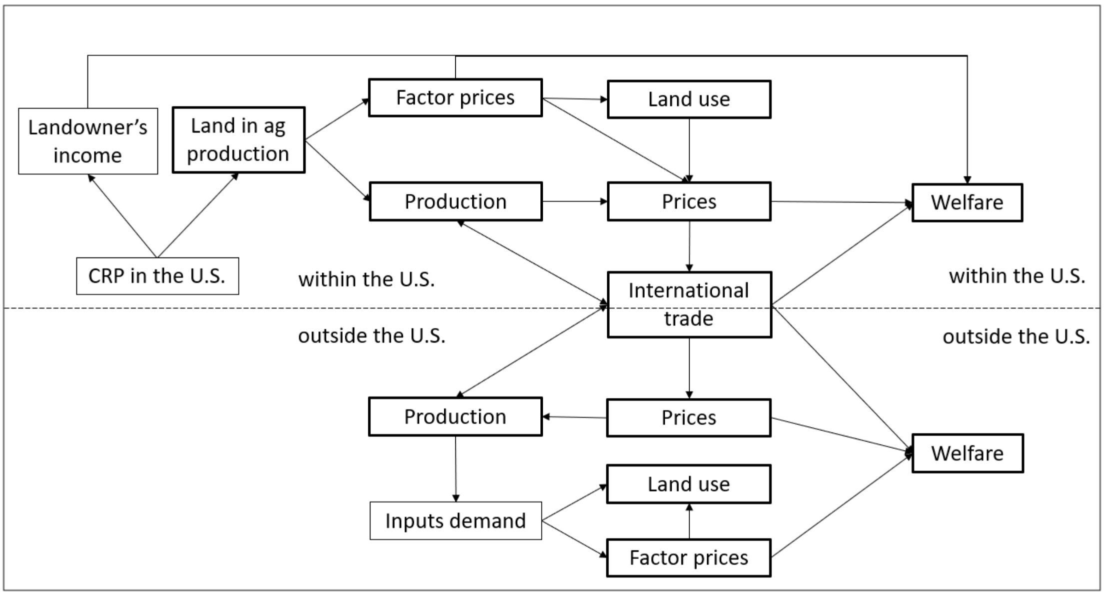

Figure 4: Conceptual model illustrating the global economic impact of CRP

3 GTAP-CRP model

To examine the impacts of CRP and land retirement in the U.S. on global agricultural production, trade, and welfare, we build on the Global Trade Analysis Project (GTAP) model. The GTAP model is a multi-region, multi-sector, computable general equilibrium model that captures the interactions between various economic agents, such as firms, households, and governments, across different regions and sectors of the global economy. We follow the approach of incorporating AEZs into the GTAP model, as introduced by Lee (2005), to account for the spatial heterogeneity in agricultural production. The AEZ approach allows for a more accurate representation of the differences in land productivity and the suitability of land for various crops across different regions. We then modify GTAP-AEZ to GTAP-CRP model, to specifically analyze the impacts of the Conservation Reserve Program.

3.1 Structure of GTAP model

The standard GTAP model is a comprehensive multi-commodity, multiregional CGE model, developed by Hertel (1997). This model facilitates the analysis of international trade flows, policy impacts, and global economic scenarios. It is predicated on the assumption of perfect competition across all markets, with prices adjusting according to Walras's law. Income generated within a region is aggregated by a regional household, which then allocates this income across three types of expenditures: consumption, government spending, and savings, following a Cobb-Douglas utility function (with a substitution elasticity equal to one). Firms in each sector maximize profits using Constant Elasticity of Substitution (CES) production functions within a competitive market framework, paying regional households for the use of endowments such as land, labor, capital, and natural resources.

In the standard GTAP model, firms engage in the production of final goods by amalgamating endowments with intermediate inputs, subsequently selling these goods to private households, governments, and for investment purposes within their region. This model, designed to simulate an open economy, incorporates the Armington assumption to address product heterogeneity, facilitating the export of tradable goods and the import of intermediate inputs globally. It differentiates in the mobility of resources, with land being imperfectly mobile, whereas labor and capital exhibit full mobility within regions but face constraints internationally. Government spending and private household consumption are modeled through Cobb-Douglas and non-homothetic Constant Difference of Elasticity (CDE) functions, respectively, allowing for consistent expenditure shares and varying income elasticities across commodities.

The GTAP model's equilibrium state is characterized by market balance, zero-profit conditions for firms, adherence to regional household budget constraints, equality of global investment and savings, and a neutral global trade balance, which collectively determine the international price levels of commodities. This framework ensures constant budget shares within the regional household's utility function, highlighting the complex relationship between production, consumption, and trade in a globalized economy.

3.2 Land Use Data

In the standard GTAP model, land serves as a sluggish endowment, reallocated in response to changes in relative land rents. Yet, the suitability of various crops within a country varies geographically, limited by local adaptability. Addressing this issue, Lee (2005) developed the land endowment representation in the standard GTAP by dividing national land into 18 AEZs, following the classification by the United Nations Food and Agricultural Organization (FAO) (FAO and IIASA 2000). The database offers a consistent global characterization of land in crops, livestock, and forestry, taking into account biophysical growing conditions. The AEZs vary based on the "length of growing period" (LGP) they can support, a key factor in crop farming. For example, AEZ 1 includes areas suitable for up to 60 days of growth annually, while AEZ 6 covers areas that can support a LGP of 270 to 360 days. This range of LGPs allows for the distribution of farming, livestock rearing, and forestry activities according to the climate and soil needs of each zone. In

Figure 5, Lee (2005) display these LGPs on a global map with 0.5-degree grid cells. The map uses different shades to represent the LGP length: lighter shades for shorter LGPs and darker shades (AEZ6, AEZ12, and AEZ18) for longer LGPs. The color coding varies by climatic zone: red for tropical zones (first six AEZs), green for temperate zones (middle six AEZs), and blue for boreal zones (last six AEZs). Documentation of the GTAP-AEZ model structure and data source can be found in Lee (2005).

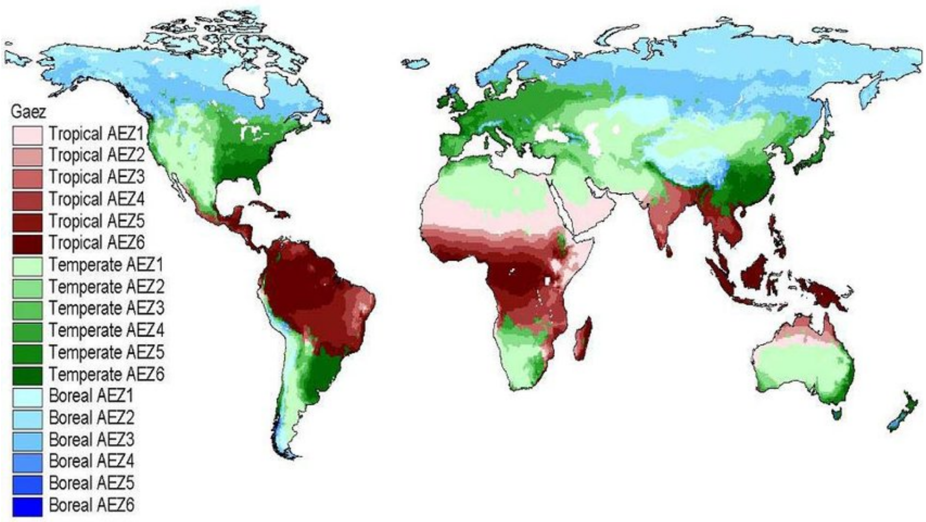

Figure 5: The Sage global map of the 18 AEZs

Source: Lee et al. (2005)

3.2.1 Structure of GTAP-AEZ

In the past decades, the standard GTAP model and its database have undergone frequent modifications and improvements to enhance their utility in analyzing the economic and environmental impacts of biofuel and energy policy. The GTAP-AEZ model is a modified version of the standard GTAP model that is specifically designed for detailed structural economic modeling of land use, emphasizing the opportunity costs of alternative land uses and accounting for the heterogeneity of land types. Central to the GTAP-AEZ model is its integration with land use data. In the standard GTAP model, land is considered universally transformable for activities such as crop growing, livestock breeding, or timber plantation, without considering climatic or soil limitations. While GTAP-AEZ operates under the principle that land does not freely move between alternative uses, constrained instead by a Constant Elasticity of Transformation (CET) frontier.

In GTAP-AEZ, as shown in Figure 6, a nested CET structure enables landowners to allocate land among uses such as forests, cropland, and grazing land, based on relative returns. In GTAP-AEZ model, each land-using sector within a specific AEZ operates under a unique production function. For example, the production function for the paddy rice sector in AEZ 1 varies significantly from that in AEZ 6, reflecting differences in land productivity due to climatic variations. This differentiation in production across AEZs within the GTAP-AEZ model provides a more accurate representation of sectoral land competition (Hertel et al. 2008). Despite these differences, paddy rice sectors across all AEZs produce a homogeneous output to meet market demand.

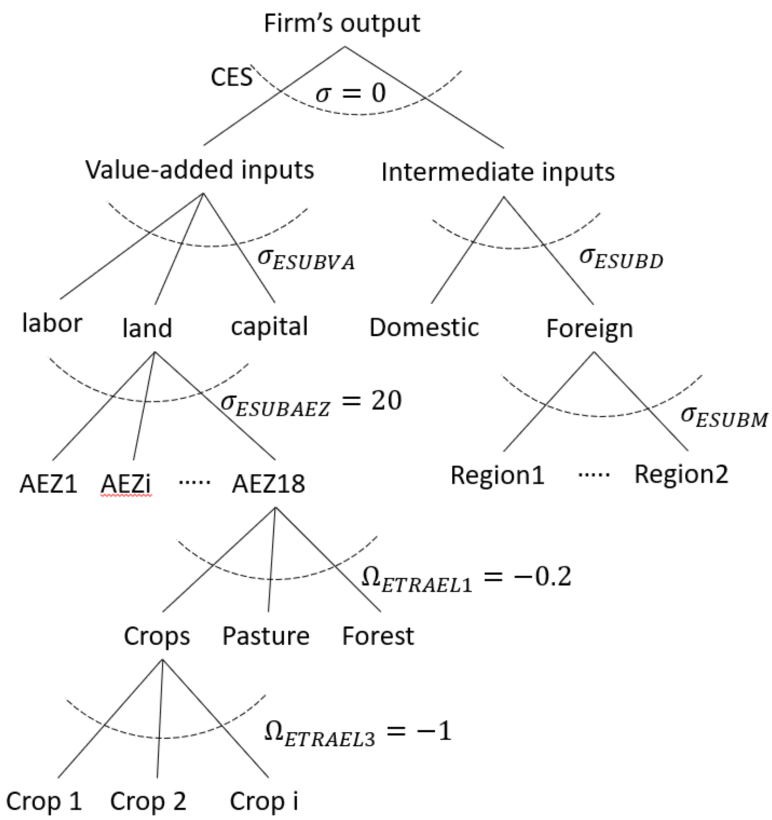

Figure 6: Production Structure of GTAP-AEZ Model

3.3 GTAP-CRP modelling framework

This research extends the GTAP-AEZ model to GTAP-CRP model to simulate the effects of expanding the U.S. Conservation Reserve Program on global agricultural markets. The standard GTAP and GTAP-AEZ models do not incorporate CRP land in the U.S., making the integration of CRP into the GTAP model a critical need for examining its spillover effects. A previous study by Birur (2010) treated CRP land as cropland in their analysis of the global impact of biofuels on agriculture, trade, and the environment. In his study, CRP land competes with other crops for returns in the land market, and the database is adjusted by equating the total CRP payments made by the government to a reduction in its capital endowment. He then examined the effects of biofuel policy on a fixed quantity of CRP land and compared these findings with scenarios that involved fixed CRP rents. In our study, to evaluate the global impact of increasing CRP acres in the U.S., we build upon Birur's research and update the land supply model to a 3-tier nested structure, allowing the land supply from pastureland to CRP land. Additionally, we update the GTAP and CRP databases to the latest versions.

In the GTAP-CRP model, we create a new sector called CRP, where land across various AEZs is the sole input for the CRP sector. As shown in Equation 1, Q_{CRP} is the output of CRP, and AEZ_i is the land in the specific AEZ. The government consumes all CRP output without engaging in international trade, so there is no private household demand for CRP. Landowners receive income from CRP land. This way, CRP payments are reflected as the supply price of CRP in the GTAP-CRP model.

$$Q_{CRP} = f(AEZ_i) \tag{1}$$

Given the constant total land constraint within each AEZ, CRP land competes with land allocated for agricultural production. To better understand land competition from different land uses, we develop a land supply framework based on Birur's model. Birur's approach incorporates a two-tier land allocation mechanism (Hertel et al. 2008) that utilizes a nested constant elasticity of transformation (CET) function. This model facilitates an analysis of how landowners optimize returns by allocating land. In our GTAP-CRP model, we expand this to a three-tier land supply structure and distinctly separate CRP land from the cropland nest, integrating it into the broader agricultural land nest as illustrated in Figure 7. Initially, landowners decide on the best use of a land parcel, choosing between agricultural usage or forestry. In the second stage, landowners choose among crops, pastures[1], or CRP enrollment, followed by the selection of specific crops in the third stage.

We adopt the elasticity of transformation from the GTAP-AEZ model as outlined by Hertel et al. (2008), setting the CET parameter at the lower tier of the land supply tree ($\Omega_{ETRAEL1}$) to -0.2. This reflects a relatively inelastic transformation between forest and agricultural land. For the upper tier of the supply tree, which dictates the allocation of land to specific crops, they utilize the elasticity from the standard GTAP

[1] The Grassland CRP, under the broader CRP, engages farmers to transition environmentally sensitive land from ranching to conservation (USDA FSA, Grassland CRP).

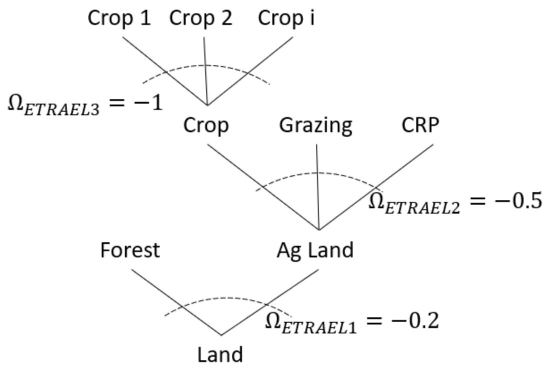

Figure 7: Land supply in GTAP-CRP Model

model, with a CET value of -1 ($\Omega_{ETRAEL3} = -1$). This value is informed by econometric evidence from U.S. land supply to crop sectors and indicates a more elastic supply, with an upper bound of one on this elasticity. For the intermediate level, which governs the transformation possibilities between grazing, CRP and cropland uses, we set $\Omega_{ETRAEL2} = -0.5$, aligning with the CET value from Birur (2010). This value is chosen as a median, reflecting a transformation elasticity that is less than that for crops but more than that for forestry and agricultural land, indicating an increase in land mobility as one ascends the supply tree.

4 Data and simulation

In this section, we describe the process of integrating CRP data into the GTAP land use database. Following the data integration, we outline the simulation scenario employed in our study.

4.1 GTAP-CRP data

The GTAP-AEZ model and the GTAP version 10 database (Aguiar et al. 2019) were utilized for this study, with the latest reference year being 2014[2]. Our model includes 13 sectors out of 65 and 9 regions out of 141, as detailed in Appendix A, with aggregation based on land use and agricultural trade. Initially, we separated the CRP sector from the "Lstk" (Livestock, raw milk, wool) sector[3]. Then, we added the government consumption, firms' purchases of endowments, and CRP land cover in the GTAP database. Subsequently, we employed GTAPAdjust to rebalance the GTAP database.

[2] The latest version of GTAP-AEZ is being released soon. Once we have access to the latest version of the database, with 2017 as the reference year, we will update both the model and the database accordingly.

[3] It does not matter from which sector the CRP is split, as we assign a zero weight to CRP. This approach is adopted because the database cannot generate a new sector; we can only split it from an existing sector.

According to Organisation for Economic Co-operation and Development (OECD) Producer Support Estimate (PSE) data, CRP is categorized as Group Commodity Transfers (GCT) and Other Transfers to Producers (OTP) payments. As illustrated in Table 2, CRP payments in the GCT category began in 2014 and accounted for less than 5% of the total CRP payments. It is clearly stated that agricultural domestic support in the GTAP database, derived from the OECD's Producer Support Estimates (Wang and Aguiar 2023), includes GCT payments as input subsidies. However, the majority of CRP payments, which are categorized under OTP, are not accounted for in the GTAP Database. This portion of the CRP data represents the retirement land payments. The categorization of CRP payments in the OECD PSE data provides guidance on how to integrate CRP into the GTAP model. The GCT payments, already included in the GTAP database as input subsidies, can be left unchanged. However, the OTP payments, which represent the majority of CRP payments and are linked to land retirement, need to be explicitly added to the database. This will ensure that the GTAP-CRP model accurately represents the scale and nature of the Conservation Reserve Program and its impact on the global economy.

Table 2: CRP payment in OECD database in U.S. million dollars

	2014	2015	2016	2017
CRP in GCT	65.00	31.00	65.73	94.91
	(3.4%)	(1.7%)	(3.5%)	(4.8%)
CRP in OTP	1841	1804	1830.572	1881.89
	(96.6%)	(98.3%)	(96.5%)	(95.2%)

Note: Data from OECD PSE database.

We aggregated cumulative county-level CRP hectares in 2014[4] to the AEZ level, as depicted in Figure 8, which presents CRP hectares distribution across the AEZs[5] in the continental U.S. Due to the lack of sufficient data for Alaska and Hawaii, we excluded these states from the figure to avoid potential misinterpretation, although there are CRP enrollments in both states. The figure uses bold numbers to identify each AEZ and superimposed numbers to denote the total CRP hectares within those AEZs. Darker shades correspond to higher CRP enrollment, highlighting AEZ 8 as the area with the most allocated CRP hectares, reflecting significant conservation efforts in the central U.S. AEZ 10 and AEZ 7 also show substantial CRP enrollment, with 1,923,778 and 1,333,562 hectares, respectively. In contrast, AEZ 13 and 15 have less than 1,000 CRP hectares, indicating minimal enrollment. Notably, AEZ 4 and 5 are present in the U.S. but have

[4]Since the GTAP-AEZ database currently extends only up to 2014, we will update the CRP data accordingly once the latest GTAP-AEZ data are released.

[5]For counties that span multiple AEZs, allocation will be made to the AEZ that contains the majority of the county's area.

no CRP hectares enrolled.

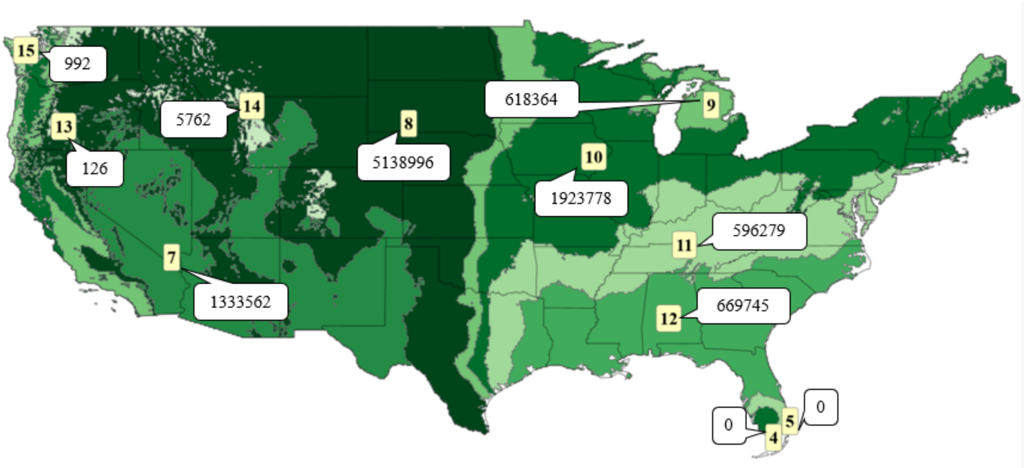

Figure 8: The distribution of CRP hectares across AEZs

Note: This figure displays the distribution of total CRP hectares across AEZs in 2014.

4.2 Scenario design

We start by simulating the policy announced by the USDA to enroll an additional 4 million acres into CRP in 2021. The data indicate that in 2021, CRP was capped at 25 million acres, with 20.8 million acres enrolled. Then the cap is set to increase to 27 million acres by 2023 (USDA 2021). Therefore, on the national level, the acreage cap will not be a binding constraint. We use the 2014 data as the reference year, with 25 million acres enrolled. To align with the policy and CRP market mechanism, we assume that the acreage cap will not be binding even with an additional 4 million acres. In Figure 9, Q_0 is the baseline acreage cap of CRP, with a marginal cost curve S_0. We assume that nothing is binding in the CGE model. Since production is constant returns to scale, the marginal cost curve is a flat line S_0, conditional on prices. With an exogenous increase in CRP land from Q_0 to Q_1, the marginal cost curve increases from S_0 to S_1.

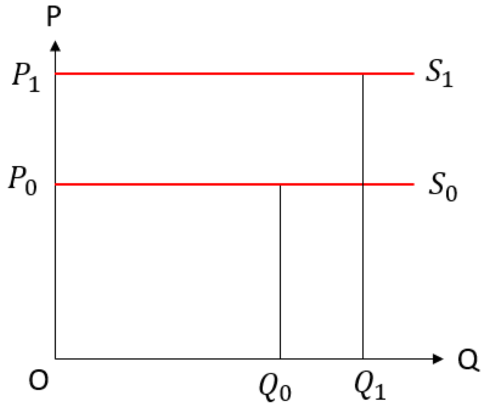

Figure 9: CRP market without an acreage cap binding.

Enrolling an additional 4 million acres to CRP represents a 15.7% increase in the CRP land in U.S. In the GTAP-CRP model, since the output is in value rather than quantity, to accurately simulate the policy, we exogenously increase CRP land cover in the U.S., then allow for the endogenous transfer of land from other land-use sectors to the CRP sector within each AEZ to accommodate a 15.7% increase in CRP land. The key results will highlight changes in prices, output, bilateral trade, and welfare. Additionally, the study anticipates shifts in land use among cropland, pastureland, and forest within the U.S. and beyond national borders.

5 Results

This section presents the primary results from our general equilibrium simulations. First, we present the international environmental slippage effects of CRP. To gain insights into the mechanisms behind these slippage effects, we use the U.S. as an example to show the price changes for different land uses. Second, we present the impact on the global food market, detailing the changes in sector prices, output, and trade flows. Lastly, we examine the changes in welfare.

5.1 International slippage effects on land cover

Table 3 presents the simulated results of land cover changes across various regions and globally, following a 4 million acre increase in the U.S. CRP land. The data is shown in million acres, with the slippage (leakage) expressed as a percentage of the increase of U.S. CRP land increase in parentheses. The results indicate that enrolling an additional 4 million acres into the CRP in the U.S. would result in a reduction of 2.78 million acres of cropland and 0.52 million acres of pastureland within the country, along with a decrease of 0.68 million acres in forestland. Globally, there is a reduction of 1.50 million acres of forest, 1.74 million acres of cropland, and 0.89 million acres of pastureland.

When looking at the slippage effect [6], the percentages in parentheses in Table 3 are the slippage rates, which indicate the proportion of the U.S. CRP land increase that is offset by land cover changes in each region. Domestically, the leakage of CRP is similar to the leakage estimate in Wu's paper (Wu 2000), which suggests that for every 100 acres of cropland enrolled in the CRP, 20 acres of non-cropland will be converted to cropland. However, in Wu's paper, pastureland cannot be enrolled in CRP. In our study, we conclude that for every 100 acres of cropland and pastureland enrolled in CRP, 17.05 acres of forestland will be transferred to these land uses. Outside the U.S., for every 100 acres of land enrolled in CRP in the U.S., an additional 29 acres of cropland are created outside the U.S., and 20 acres of forestland and 8 acres of pastureland are decreased outside the U.S.

Table 3: Land cover changes across regions and globally

	US	RNA	China	Europe	CS Africa	SE Asia	R Asia& Oceana	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%)
Cropland	-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%)
Pastureland	-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. In this table, "US" stands for the United States, while "RNA" represents the Rest of North America. "CS Africa" is shorthand for Central and Southern Africa. "SE Asia" denotes Southeast Asia, and "R Asia & Oceana" refers to the remaining countries in Asia and the Oceania region; "MENA" is used for the Middle East and North Africa, "CS America" covers all countries in Central and South America.

In GTAP-CRP, land cover changes are driven by the differences in land prices across each AEZ and the land prices for specific land uses, as well as by the elasticity of transformation. For example, in U.S., if the land price for forestland in AEZ8 is less than the market land price in AEZ8, then the forestland in AEZ8 will decrease. Changes in land price are determined by the market price of the sluggish endowment AEZ_i and by the production value share of land commodity i in AEZ_i. Table 4 presents variations in land rent among different land covers in the U.S., which could explain the observed decreases in cropland, forestland, and pastureland. It is observed that the rate of land price changes for cropland, forestland, and

[6] Slippage effects are quantified as the change in land cover expressed as a percentage of the U.S. CRP land increase.

pastureland is lower than the overall increase in land prices across the U.S. for all AEZs. This contributes to the decreasing utilization of these three land covers.

Table 4: 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.

In Table 4, the last column shows the overall U.S. land price changes. The highest increases in total U.S. land prices are observed in AEZs 7 (6.36%), 8 (5.76%), 10 (4.56%), and 9 (3.71%), which correspond to the Mountain, Southern Plains, and Northern Plains regions, respectively, as shown in Figure 8. These findings align with Wu (2005), which found that the CRP had the largest impact on farmland values in these regions, increasing them by 5% to 14% in the Mountain region, 4% to 6% in the Southern Plains, and 2% to 5% in the Northern Plains. The substantial land price increases in these AEZs can be attributed to the high concentration of CRP lands and the relatively higher CRP rental rates compared to the net returns to agriculture.

Table 5 details the changes in land supply across various AEZs in the U.S., revealing notable variations. AEZ8 serves as the primary source for CRP enrollments, with a significant reduction in cropland observed in AEZ8 and AEZ10. Meanwhile, forestland has expanded in AEZ10 but has significantly decreased in AEZ12. Pastureland has seen substantial reductions in AEZ7 and AEZ8, whereas an increase is noted in AEZ12.

This increase in pastureland is consistent with the grassland priority zones located in AEZ7 and AEZ8, as identified by the USDA FSA[7].

Table 5: 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.

5.2 Impact on food market and welfare

The results presented in Table 11and Table 7 provide a comprehensive overview of the impact of increasing CRP land in the U.S. by 4 million acres on agricultural sector outputs and commodity prices across various regions worldwide. In the U.S., the expansion of CRP land leads to a decrease in the output of key agricultural sectors, including rice (-0.167%), wheat (-0.269%), grain (-0.171%), veg and fruit (-0.22%), oil seeds (-0.219%), fibre crops(-0.233%), and other crops (-0.235%). This reduction in U.S. agricultural output is largely due to the reallocation of land from crop production to conservation purposes. In contrast to the U.S., most other regions experience an increase in agricultural output. For example, European countries, in particular, see significant increases in the output of rice, wheat, grain, and veg and fruit, and oil seeds sectors. These increases suggest that as U.S. agricultural output declines due to CRP expansion, other regions step in to fill the supply gap, leading to a reallocation of agricultural production on a global scale.

In the U.S., prices for most agricultural commodities increase, with “cane&beet” experiencing the largest

[7] USDA FSA Grassland CRP National Priority Zone MAP

increase at 2.17%, followed by grain at 0.7%, rice at 0.52%. These price increases are likely driven by the reduced domestic supply of these commodities due to the reallocation of land to CRP. For example, most sugar beets are planted in AEZ8, one of the regions with the highest CRP acres, which includes states such as Minnesota and North Dakota(*Sugar Beet Production by State* 2015). The increase in crop prices across all regions might be attributed to the rise in land prices worldwide. Other regions also experience price increases for agricultural commodities, although the magnitude of these increases is generally lower than in the U.S.

Table 6: 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.

Table 7: 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.

The impact of enrolling an additional 4 million acres of CRP in U.S. on international trade is shown in Table 8. The results show that the U.S. experiences a decrease in exports for most commodities, with the largest declines in rice (-0.687%), wheat (-0.35%), grain (-0.462%), and veg and fruit (-0.591%). In contrast, other regions generally see an increase in exports, particularly for rice, wheat, and grain. For example, China's exports increase by 0.516% for rice, 0.719% for wheat, and 0.53% for grain. These findings suggest that as the U.S. reduces its agricultural exports due to CRP expansion, other regions increase their exports to meet the global demand, leading to a redistribution of trade flows in the international agricultural market.

Table 8: 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.

The Welfare changes are shown in Figure 10. The U.S. observed a significant increase in welfare, totaling 259 million US dollars. Similarly, the rest of North America, Europe, Central and South America, and Central and South Africa also experienced gains in welfare. Furthermore, we conduct a decomposition analysis of the welfare changes, identifying international trade and resource efficiency allocation as the primary drivers of these changes.

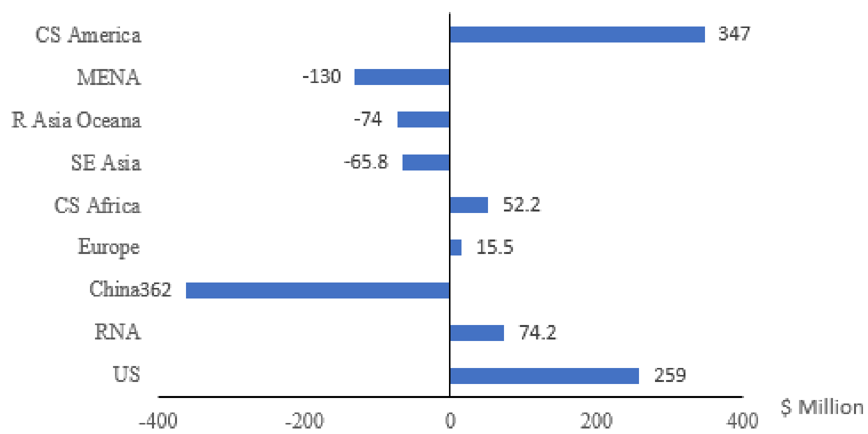

Figure 10: Changes in welfare valued in millions of US dollars.

Note: In this Figure, the region descriptions are the same as those in Table 3.

6 Conclusion and Discussion

The introduction of the Conservation Reserve Program in the U.S. and its recent expansion by an additional 4 million acres significantly impacts land cover changes both domestically and worldwide. Simulation outcomes indicate a substantial decrease in cropland, forestland, and pastureland within the U.S. A detailed analysis of land prices across AEZs provides insight into the economic mechanisms behind these land cover changes. Our study contributes to the existing literature on the slippage effect of conservation programs by quantifying the domestic and international land use changes resulting from the CRP expansion. We extend previous research by considering the enrollment of both cropland and pastureland in CRP and analyzing the spillover effects on forestland. Our findings suggest that for every 100 acres of total cropland and pastureland enrolled in CRP, around 17 acres of forestland will be transferred to these land uses. This highlights the importance of considering the unintended consequences of conservation programs on land use patterns beyond the targeted areas. Therefore, when implementing conservation policy like CRP in the U.S., it is crucial to recognize their broader implications, such as the slippage effects on land use. This aspect suggests that the program's effectiveness in mitigating greenhouse gas emissions may be significantly counterbalanced.

Furthermore, our findings demonstrate that the reallocation of land from agricultural production to conservation purposes in the U.S. leads to a decrease in the output of key agricultural sectors. The redistribution of agricultural production and trade flows resulting from the CRP expansion underscores the need for international cooperation and coordination in addressing global food security and environmental challenges. As countries implement conservation programs and alter their land use patterns, it is essential to consider the spillover effects on other regions and the potential for unintended consequences in the global market.

It is important to acknowledge the limitations of our approach. The CGE model used in this study relies on certain assumptions and is dependent on parameter values. Changes in these assumptions or parameters could potentially influence the results. The enrollment situation of CRP can vary significantly across different regions and land types. Factors such as soil quality, local conservation priorities, and landowner characteristics can influence the likelihood and extent of CRP participation. Although the model assumes a certain level of homogeneity in land quality and productivity within each AEZ, it may not account for all these region-specific and land-type-specific variations in CRP enrollment. However, this study still provides useful insights that highlight the balance between pursuing environmental conservation objectives and addressing the economic consequences for stakeholders at both local and global levels. It underscores the importance of thorough policy analysis and international collaboration in the development of environmental and agricultural policies.

There are few next steps for this study. First, estimating alternative assumptions on the CRP bidding mechanisms would provide valuable insights into how different policy designs might influence land use, agricultural production, and trade patterns. By exploring various scenarios and their outcomes, policymakers can make more informed decisions about the optimal design and implementation of conservation programs. Additionally, conducting an elasticity sensitivity analysis is crucial for understanding the robustness of slippage effects of CRP. Moreover, future research should aim to integrate a wider range of environmental indicators into the analysis, such as Greenhouse Gas (GHG) emissions.

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A Appendix

Table 9: Correspondence of Regions in GTAP-CRP and GTAP 10

Sector in GTAP-CRP	Description	Sectors in GTAP 10
pdr	rice: seed, paddy (not husked)	pdr
wht	wheat: seed, other	wht
gro	other Grains: maize (corn), sorghum, barley, rye, oats, millets, other cereals	gro
v_f	veg and fruit: vegetables, fruit and nuts, edible roots and tubers, pulses	v_f
osd	oil Seeds: oil seeds and oleaginous fruit	osd
c_b	cane and Beet: sugar crops	c_b
pfb	fibres crops	pfb
ocr	other Crops	ocr
Lstk	livestock row milk wool	ctl, oap, rmk, wol
CRP	CRP	
ProcFood	processed Food	cmt, omt, vol, mil, pcr, sgr, ofd, b_t
Mnfc	Manufacturing	frs, fsh, coa, oil, gas, oxt, tex, wap, lea, lum, ppp, p_c, chm, bph, rpp, nmm, i_s, nfm, fmp, ele, eeq, ome, mwh, otn, omf
Services	other services	elv, gdt, wtr, cns, trd, afs, otp, wtp, atp, whs, cmn, ofi, ins, rsa, obs, ros, osg, edu, hht, dwe

Table 10: Correspondence of Regions in GTAP-CRP and GTAP 10

Region in GTAP-CRP	Description	Regions in GTAP 10
US	United States	usa
RNAmerica	Rest of North America	can, mex, xna
Chk	China and Hong Kong	chn, hkg
Eur	Europe	aut, bel, bgr, hrv, cyp, cze, dnk, est, fin, fra, deu, grc, hun, irl, ita, lva, ltu, lux, mlt, nld, pol, prt, rou, svk, svn, esp, swe, gbr, che, nor, xef, alb, blr, rus, ukr, xee, xer, kaz, kgz, tjk, xsu, arm, aze, geo
CSAfri	Central and Southern Africa	ben, bfa, cmr, civ, gha, gin, nga, sen, tgo, xwf, xcf, xac, eth, ken, mdg, mwi, mus, moz, rwa, tza, uga, zmb, zwe, xec, bwa, nam, zaf, xsc, xtw
SEAisa	Southeast Asia	khm, idn, lao, mys, phl, sgp, tha, vnm, xse
RAsiaO	Rest of Asia and Oceana	aus, nzl, xoc, jpn, kor, mng, twn, xea, brn, bgd, ind, npl, pak, lka, xsa
MENA	Middle East and North Africa	bhr, irn, isr, jor, kwt, omn, qat, sau, tur, are, xws, egy, mar, tun, xnf
CSAmer	Central and South America	arg, bol, bra, chl, col, ecu, pry, per, ury, ven, xsm, cri, gtm, hnd, nic, pan, slv, xca, dom, jam, pri, tto, xcb

Table 11: The impact of CRP on sector outputs

	alloc(A1)	endw(B1)	tech(C1)	pop(D1)	tot(E1)	IS(F1)	pref(G1)	Total
US	94.152	0	0	0	231.192	-66.737	0	258.607
RNA	12.827	0	0	0	59.079	2.25	0	74.156
China	-74.128	0	0	0	-348.33	60.015	0	-362.443
Europe	39.426	0	0	0	-17.909	-5.986	0	15.532
CS Africa	8.556	0	0	0	41.755	1.892	0	52.202
SE Asia	-9.236	0	0	0	-54.907	-1.691	0	-65.835
R Asia&Ocrana	0.703	0	0	0	-66.043	-8.686	0	-74.026
MENA	-3.832	0	0	0	-127.777	1.12	0	-130.489
CS America	46.679	0	0	0	282.881	17.82	0	347.38
Total	115.146	0	0	0	-0.061	-0.002	0	115.083

Note: All values are expressed in million dollars. The region descriptions are the same as those in Table 3. “alloc (A1)” is allocative efficiency effect; “endw (B1)” is endowment effect; “tech (C1)” is technological change effect; “pop (D1)” is population effect; “tot (E1)” is terms of trade effect; “IS (F1)” is investment-savings effect; “pref (G1)”Iis consumer preference effect.