Assessing the Impact of Crop Diversification on Food Nutritional Production in the United States

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A Thesis Submitted to McGill University in Partial Fulfillment of the Requirements for the B.A.&Sc. in Environment Honours Degree

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Montreal, Quebec, Canada

May 2025

Acknowledgements

This project would not have been possible without the support of my supervisor, Dr. Graham MacDonald, who provided invaluable insight and whose expertise, dedication, compassion, thoughtful feedback, and R coding skills assisted me immensely. I am also extremely grateful for the support of Camille Bouvet-Boisclair, who guided me in the early stages of this project and whose research I am lucky to expand upon. Many thanks to the members of the Land and Food Lab for providing helpful feedback and for creating a welcoming and supportive lab environment. Lastly, I would like to express my gratitude to Ella Sloan, Leah Paukstaitis, and all other friends and family who patiently listened to me talk about this project for months on end and always encouraged me to take a break and go get a muffin.

Abstract

Agricultural production and food supplies exhibit patterns of increasing homogeneity, which can contribute to malnutrition, including micronutrient deficiencies. In this context, research on potential outcomes of crop diversification is salient. There are several environmental and agriculture benefits of crop diversification, including enhancing crop yields and soil quality. To examine food nutrient dimensions, my study aims to investigate how crop diversification would affect nutritional production at the national scale in the United States. To explore this relationship, I calculated nutritional production based on the results of a hypothetical crop diversification model that iteratively switches crops at the local level based on a predefined target of 'attainable' crop diversity (i.e., the 95th percentile of observed crop diversity in a given agro-climatic zone). When all crop groups are included, total nutritional production at the national level in the U.S. decreases slightly in this diversification scenario compared to baseline (2022 diversity); when maize and soy are excluded, nutritional production increases across all 23 included food nutrients in the 95% diversification scenario. Micronutrients increase more than any other nutrient group, with a 30% increase when maize and soy are excluded, while calories and other macronutrients increase by 19% and 18%, respectively. The nutrients that increase the most are vitamin A, vitamin C, sodium, calcium, folate, potassium, and riboflavin. In this scenario, only 20% of crop area and 7% of crop fields are changed, indicating that diversifying to the 95th percentile of attainable diversity would generate disproportionately greater benefits for micronutrient production. My analysis therefore highlights how increased food nutritional production is a co-benefit to other agroecological benefits of crop diversification at the national level.

1. Introduction

In the context of increasing homogeneity within agricultural and food systems, there is potential for agricultural diversification to provide numerous benefits (Khoury et al., 2014; Remans et al., 2014). Simplified agricultural landscapes lead to harmful ecological effects, such as soil degradation, reduced water quality, habitat degradation, and reduced species diversity; this can in turn be detrimental to ecosystem services that are essential for agricultural production, which include pollination, soil nutrients, and pest management (Burchfield et al., 2019). Over the long term, simplification of agricultural systems may have adverse effects on ecosystems and crop production, and agricultural diversification may be a necessary solution.

Crop diversity can be defined as the number of crop species in a certain geographic area and has both spatial and temporal dimensions (Aguilar et al., 2015; Bouvet-Boisclair & MacDonald, 2025). A key metric used to measure crop diversity is Shannon diversity, which is an index that considers both species richness and prevalence of dominant species (Aguilar et al., 2015). In the United States, several studies have investigated associations between crop diversity and variables such as dietary diversity and food supply diversity (Jones, 2017a; Remans et al., 2014; Sibhatu & Qaim, 2018). However, nutritional production is a key intermediate variable that affects food supply and diets and can be directly derived from crop production. As such, my study aims to investigate the effects of crop diversification on nutritional production at the national scale in the United States.

1.1: Literature review

Globally, modern agriculture exhibits a pattern of increasing homogeneity, with fewer, larger farms producing fewer crops (Khoury et al., 2014; Remans et al., 2014). There is increased reliance on major cereal and oil crops, and species richness is low in some countries (Khoury et al., 2014). This is reflected in the increasing homogeneity of national food supplies and has contributed to increasing malnutrition, increases in micronutrient deficiencies, and lower dietary diversity (Khoury et al., 2014; Remans et al., 2014). This pattern is concerning in the context of food security, and more research is needed to identify the specific connections between patterns of agricultural diversity, or lack thereof, and food and nutrition outcomes. For example, Gergel et al. (2020) found that landscape diversity in forested areas can support dietary diversity, and Herrero et al. (2017) conducted a global analysis of agricultural diversity and nutrient production by farm size. As opposed to metrics such as caloric yields or crop yields, research exploring outcomes relating to food nutritional diversity, such as dietary diversity, nutritional stability and production, and food supply diversity is essential to understanding the full picture of how agricultural diversity affects food and diets (Gergel et al., 2020; Remans et al., 2014).

From a purely agricultural standpoint, several studies have explored current patterns of crop diversity. Goslee (2020) characterized regional patterns of crop diversity in the United States and concluded that of the factors studied, temperature and water availability are the main barriers to crop diversity. Goslee (2020) also created a model for the 90th percentile of potential crop diversity based on soils and climate across regions and found that irrigation is the biggest factor that can aid in increasing crop diversity to this percentile under current agricultural systems. However, this will be increasingly difficult in the context of climate change; many regions struggle to maintain current levels of irrigation. Instead, there is a need to develop alternative agricultural systems to increase crop diversity without relying on irrigation (Goslee, 2020). It is important to note that like other similar studies, the study by Goslee (2020) only takes into account spatial diversity; however, temporal diversity plays a major role in crop diversity (Merlos & Hijmans, 2020). Temporal diversity employs crop rotation as the method of diversification, and the average temporal diversity in the United States is 2.1 (expressed as the effective number of species based on Shannon entropy), with common crops like maize, soybean, and wheat having the lowest average temporal diversity; these crops are typically grown on fields that have very low temporal diversity (Merlos & Hijmans, 2020). Because agriculture is dominated by these three crops in the United States, Merlos and Hijmans (2020) conclude that to increase crop species diversity, it is necessary to increase the area of more minor crops and decrease the area of these three major crops. Thus, my study aims to investigate the nutritional outcomes under diversification scenarios where minor crops replace fields of major crops like maize, soybean, and wheat.

Increasing agricultural diversity is a potential mechanism for enhancing agricultural productivity, food security, and benefits to ecosystems (Burchfield et al., 2024). Several studies have explored the effect of various diversification strategies on crop yield to determine the efficacy of crop diversification as an agricultural practice. The systematic review of meta-analyses by Beillouin et al. (2019) established a positive relationship between multiple diversification strategies and crop yield, with the important caveat that a combination of multiple diversification strategies is more effective at increasing crop yield than individual strategies. Also on the global scale, Dainese et al. (2019) conducted a synthesis exploring the effect of certain biodiversity measures, namely species richness, species abundance, and species dominance, on crop yields through the mediating effects of ecosystem service provision. They found that higher species richness and species abundance is associated with an increase in crop yields through higher provisioning of pollination and biological pest control. Similarly, they found that landscape simplification leads to lower crop production through the mediating variables of species richness and provision of ecosystem services. Madin and Nelson (2023) re-analyzed data from this study, confirming its results. They found that non-diverse landscapes were associated with lower crop yields, with lower provisioning of ecosystem services as the pathway by which this occurs. Conversely, they noted that non-diverse landscapes have other effects on crop yields that are not fully explored in either study.

Exploring one specific diversification method, crop rotation, Smith et al. (2023) investigated the effects of crop rotational diversity on yield in a set of longitudinal studies. They found that across Europe and North America, greater crop rotational diversity increased yields of small-grain cereals and maize, and this effect increased over time. This research provides evidence for the beneficial effects of crop diversification increasing crop yields over time. However, the two measures of diversity included in the study were crop species diversity and functional richness, so other diversification methods may require additional research to compare their effects on crop yield. Similarly, Marini et al. (2020) conducted long-term experiments in Europe to test the association between crop rotations and crop yields and compare this result to crop yields from monocultures, finding that crop rotations led to higher crop yields, especially in years with high temperatures and low precipitation. These conditions are more consistent with predictions of future conditions, due to climate change. Additionally, increases in crop yield stayed constant or increased over time, indicating a temporal benefit to crop rotation strategies. In an analysis across the United States and Canada, Bowles et al. (2020) found that temporal crop diversification led to increased maize yields, including in drought periods. As with other studies in this area, this has important implications for climate resilience measures as extreme weather events, such as drought, become more frequent due to climate change.

Turning to landscape diversity, Burchfield et al. (2019) studied the effect of landscape-scale diversity on corn, soy, and winter wheat in the United States, finding that areas with greater diversity had higher yields. They noted that the highest gain in yield when systems that were already diverse further diversified, suggesting an increase in the effect of crop diversification over time. At the state level, Nelson et al. (2022) found that landscape diversification increased crop yields for corn, soy, and winter wheat in Kansas, even after controlling for inputs such as pesticides and fertilizers. They extended this connection to increased resilience in the face of increasing adverse and variable weather conditions, a key strength of farming systems in the face of climate change. Similarly, Galpern et al. (2020) investigated the effect of landscape complexity on crop yields in Alberta for seven major grain crops, hypothesizing that this effect occurs through the provisioning of ecosystem services. They found that there is a slight but significant positive association between landscape complexity and crop yield, with other factors such as variability, soil, and climate serving as potential explanations for this effect. Contrary to other studies on this topic, Burchfield et al. (2024) found that increasing rotational complexity through crop rotation, a crop diversification strategy, was not always associated with an increase in crop yield; rather, the effect on crop yield depended on the study region within the United States. Furthermore, for regions that did experience an increase in crop yield, the effect was slight. Because the results of this study differ from other similar studies, it is important to note that different diversification strategies may produce varying results.

To connect crop diversity to human nutrition and health outcomes, several studies have specifically investigated the impact of agricultural diversity on dietary diversity, with many studies conducted in the Global South reporting a positive association (Ecker, 2018; Islam et al., 2018; Jones et al., 2014; Jones, 2017b; Koppmair et al., 2017; Tobin et al., 2019). Dietary diversity is defined as the number of different foods and food groups consumed over a certain period of time (Arimond et al., 2010). Sibhatu and Qaim (2018) conducted a meta-analysis of the relationship between production diversity and dietary diversity or nutrition across 26 countries and discerned a slight positive association between these variables. The authors report that studies on this topic contain mixed results, with few studies finding a consistently positive and significant association between agricultural diversity and dietary diversity. Nonetheless, these results are indicative of the potential benefits of crop diversification.

For example, a systematic review by Jones (2017a) revealed that there is a slight positive association between agricultural diversity and dietary diversity, but the focus is at the household and individual level in low- and middle-income countries. Other studies conducted in the Global South confirm this finding. In sub-Saharan Africa, Tobin et al. (2019) investigated crop diversity and diversity at the village level, concluding that crop diversity is associated with higher dietary diversity. They also found that for the crop diversity metric, measures of functional diversity are most effective in accounting for nutritional outcomes. Other measures, such as species richness and Shannon diversity, were not as effective in yielding an association with nutritional outcomes. This study provides some evidence that local consumption services as a pathway between crop diversity to better health outcomes, though there are many contextual factors that make it difficult to extrapolate these results to the United States. This research also takes place at the household level; higher levels of analysis are necessary to confirm its results. However, this study provides evidence that it is possible to improve dietary diversity through crop diversification. Similarly, Ecker (2018) found a strong positive association between agricultural production diversification and household dietary diversity in Ghana, while other researchers found the same association present in Malawi (Jones et al., 2014; Jones, 2017b; Koppmair et al., 2017). In Bangladesh, Islam et al. (2018) concluded that there is a small positive association between agricultural diversification and dietary diversity. Although Jones (2017a) identifies subsistence and income as pathways through which this effect occurs in low- and middle-income countries, further research is needed in other geographic contexts and scales to determine whether this association holds.

When discussing crop diversity and its implications for food security and human health, nutrition is a key intermediate variable to research. Wood (2017) stresses the need to move beyond crop yield as a metric for human nutrition and instead turn to more specific and targeted measurements, such as nutrient production, nutritional stability, and nutritional diversity. In a global analysis of agricultural diversity and nutrient production by farm size, Herrero et al. (2017) conclude that areas of the world with higher production diversity have higher nutritional production. As it relates to farm size, agricultural diversity and nutrient production decrease as farm size increases. Adding in detail on crop types, Herrero et al. (2017) found that vegetables, roots and tubers, pulses, fruits, and cereals are produced in diverse areas globally, while sugar and oil crops are produced in less diverse areas. For nutritional production, micronutrients and protein production occurs in diverse areas, while much of calorie production occurs in less diverse areas (Herrero et al., 2017). As I sought to research nutritional outcomes and their connection to crop diversity, this paper was instrumental in informing my research methods. Additionally, its results reveal an association between agricultural diversity and nutrient production at the global scale, which I hoped to confirm for the United States context.

In addition to nutritional production, other nutritional outcomes, such as nutritional stability, are relevant. To address the emergence of increasing natural disasters due to climate change, Nicholson et al. (2021) studied nutritional stability as a potential outcome of crop diversity, finding that crop diversity is positively associated with nutritional stability globally over the 55-year study period. However, this relationship was non-linear, and there was high spatial variation in patterns of nutritional stability. Additionally, though crop diversity increased over the study period, nutritional stability remained the same or decreased, suggesting that increases in crop diversity occurred for crops with fewer nutrients or crops that contributed to existing nutrients in local food systems. This has implications for long-term decreases in benefits of crop diversification and requires further study. However, the established positive relationship between crop diversity and nutritional stability reveals initial nutritional benefits of crop diversification strategies that may prove essential in the face of the growing climate crisis. Remans et al. (2014) connect these topics to health outcomes, finding a negative association between national food supply diversity, measured using species diversity and nutritional diversity, and the health outcomes of child stunting, wasting, and underweight globally. However, it is important to note that this study focuses on diversity of food supply, rather than food production; furthermore, the relationship between supply diversity and production diversity is not linear and depends on geographic context. Despite this, Remans et al. (2014) highlight the need to increase species diversity and nutritional diversity in order to improve human health outcomes due to nutrition.

While crop diversity is a useful and important metric, depending on the measure of diversity used, it can be limiting. Spatial and temporal diversification methods are both valuable and can have varying effects on yield and nutrition outcomes. In a global meta-analysis, Rasmussen et al. (2024) investigated the effect of five different diversification strategies on social and environmental outcomes, including crop yields, food security, biodiversity, and ecosystem services. They found that combining multiple diversification strategies had more positive outcomes, both social and environmental, than implementing a single diversification strategy. Accordingly, a diverse farming system is more beneficial than implementing specific agricultural diversification strategies by themselves (Rasmussen et al., 2024). However, when considering social outcomes of diversification, it is important to acknowledge structural barriers preventing farmers from diversifying, such as financial situation and supply and demand considerations (Rasmussen et al., 2024).

1.2: Research objectives

My study explores how crop diversification would affect nutritional production at the national scale in the United States. Nutritional production is a key intermediate variable between crop diversity and dietary diversity. Looking at small but positive results from several studies connecting crop diversity to dietary diversity in Africa, Asia, and South America (Ecker, 2018; Islam et al., 2018; Jones et al., 2014; Jones, 2017b; Koppmair et al., 2017; Tobin et al., 2019), I expanded the study area to the North American context, specifically the United States, and analyzed data at the national scale, as opposed to household-level data. As most positive associations identified in existing studies are weak, my study explored a potential mediating variable relating solely to nutrition. Dietary diversity takes nutrient levels and consumption patterns into account; I investigate the nutritional production aspect of dietary diversity. I also aim to identify potential co-benefits of agricultural crop diversification for human health and nutrition. Accordingly, I aim to answer the following question: How would the diversification of cropping systems affect nutritional production in the United States?

Though a breadth of research exists that connects crop diversity to crop yield and dietary diversity outcomes, I investigate nutritional outcomes in order to best capture how agricultural diversification can yield beneficial environmental, social, and human health impacts. Using a model from Bouvet-Boisclair and MacDonald (2025), I explore the association between crop diversification and nutritional production under the 95th percentile of attainable diversity scenario.

Methodology

2.1: Crop diversification model

To generate the crop diversification scenarios as the input for my analysis, I used the model by Bouvet-Boisclair and MacDonald (2025), which calculates scenarios of attainable diversity based on crop switches appropriate to soil and climate in a region. In this model, 'attainable diversity' is the target level of crop diversity that can be achieved using crops that farmers already grow in places with similar soils and climates, drawing from data for millions of crop fields in the U.S. based on the Crop Sequence Boundary (CSB) dataset, a remote sensing dataset produced by the U.S. Department of Agriculture (USDA) that includes a crop class for millions of individual crop fields across the conterminous U.S. (Bouvet-Boisclair & MacDonald, 2025). Bouvet-Boisclair and MacDonald (2025) used the technology extrapolation domain (TED) zones to identify over 900 zones of unique soil and climate. Within 5x5 km grid cells, their crop switching diversification model replaces crops in each field in descending order by crop proportion and field size until the grid cell reaches a diversity threshold. For my analysis, I chose the 95th percentile of 'attainable diversity' (which raises diversity to the 95th percentile of the maximum observed diversity in each TED zone; Bouvet-Boisclair & MacDonald, 2025); in this scenario, γ-diversity at the national scale increases by 89% over the baseline (year 2022) levels. I then applied crop areas *before* (baseline level of diversity for 2022) and *after* (95th

percentile of attainable diversity) in the modelled diversification along with nutritional coefficients from the Global Expanded Nutrient Supply (GENuS) model to calculate nutritional production as the product of these terms.

2.2: Calculating nutrient production

I calculated nutritional production from a crop switching diversification model using the 95th percentile of attainable diversity. This included 75 crops and 23 food nutrients. The data sources I used to calculate nutritional production were a crop diversification model from Bouvet-Boisclair and MacDonald (2025), crop yields for 2022 from the Food and Agriculture Organization of the United Nations (FAO) database FAOSTAT (FAO, 2022), and food composition tables from the Global Expanded Nutrient Supply (GENuS) model (Smith, 2018). The FAOSTAT database publishes yearly data on yield, production, and harvested area globally by country, including the U.S., and for national-scale crop yields for the United States in 2022, there is very little missing data (FAO, 2022). For the nutrient component, the GENuS model estimates nutrient supply globally by country, including data for many micronutrients (Smith et al., 2016). All nutritional production calculations were done in R version 4.4.1 (R Core Team, 2024).

To calculate crop production in both scenarios, I multiplied the crop areas before and after by the crop yields for 2022 from the FAOSTAT database. The food composition tables from the GENuS model provided water moisture content and nutritional coefficients for each crop (Smith, 2018). After converting the necessary units, I multiplied the crop production by dry matter content and multiplied the result by each nutritional coefficient to obtain nutritional production in tonnes. I treated missing data as a zero value, as the only cells that lacked data were proportion of dietary fiber in durum wheat and safflower.

After calculating nutritional production in tonnes, I used the U.S. Food and Drug Administration (FDA)'s Daily Reference Values (DRVs) and Reference Daily Intakes (RDIs), cumulatively referred to as Daily Values (DVs), to calculate how many people the initial and 95% scenario nutritional production could theoretically support. The FDA's Daily Values give estimates of how much of each nutrient the average adult requires (FDA, 2016), which makes it possible to calculate how many people the nutritional production from my analysis could theoretically support in 2022.

2.3: Crop matching and crop exclusions

From the 87 crops included in the model by Bouvet-Boisclair and MacDonald (2025), I excluded nine crops that are not used for human consumption (cotton, sod/grass seed, alfalfa, Christmas tree, triticale, tobacco, clover/wildflowers, switchgrass, and vetch), one crop that is not used for food (hop), and two crops that lacked yield data from FAOSTAT (herbs and mint). Table 1 shows the final list of included crops, as well as their FAOSTAT and GENuS equivalents. The model by Bouvet-Boisclair and MacDonald (2025) uses the USDA crop names.

To match with the FAOSTAT crop names, some yield data needed to be averaged and some crops used proxies. For camelina, an oil crop, the FAOSTAT category 'rape or colza seed' was a proxy, as there was no available yield data for the category 'other oil seeds, n.e.c.' (not elsewhere classified). The category 'other berries and fruits of the genus vaccinium n.e.c.' was used as a proxy for caneberry. For vegetables that did not have their own FAOSTAT category, which included celery and radish, the proxy 'other vegetables, fresh n.e.c.' was used. This category was also used as a proxy for the USDA category ‘other crops.’ For greens, the FAOSTAT proxy of cabbages was used. For honeydew melons, the FAOSTAT proxy was ‘cantaloupes and other melons.’ For the USDA category ‘other small grains,’ the FAOSTAT category ‘mixed grain’ lacked recent yield data. As a proxy, yield data from wheat, barley, oats, and rye were averaged. Similarly, for the USDA category ‘other tree crops,’ an average of the FAOSTAT categories ‘peaches and nectarines’ and ‘other nuts (excluding wild edible nuts and groundnuts), in shell, n.e.c.’ was used; peaches and nectarines were used because the yield data for the FAOSTAT category ‘other stone fruits’ was not available. The proxy for pecans was the FAOSTAT category ‘other nuts (excluding wild edible nuts and groundnuts), in shell, n.e.c.’ and ‘other fruits, n.e.c.’ was the proxy for pomegranates. For citrus, the FAOSTAT categories ‘lemons and limes’ and ‘other citrus fruit, n.e.c.’ were averaged. For the USDA category ‘miscellaneous vegetables and fruits,’ the FAOSTAT categories ‘other vegetables, fresh n.e.c.’ and ‘other fruits, n.e.c.’ were averaged.

The GENuS dataset has two sets of crop names corresponding to the overall GENuS crop list and the more specific food composition table (FCT) crop list. The FCT categories are subsets of the GENuS categories, but both the GENuS and FCT categories were used to derive nutritional information for different crops, so both were useful to this analysis. The GENuS names were derived from the FAO, so the crop name matching process was highly similar to the process of matching with FAOSTAT (Smith, 2018). For matching with the GENuS crop names, some proxies and averages were used. For camelina and flaxseed, the GENuS category ‘oilcrops; other’ was a proxy. For caneberry, the GENuS category ‘berries; nes’ (not elsewhere specified) was a proxy. Similarly to FAOSTAT, for vegetables that did not have their own GENuS category, such as celery and radish, the GENuS category ‘vegetables; fresh; nes’ was used. Both celery and radish were included in this category (FAO, n.d.). The GENuS match for citrus was an average of 'lemons; limes' and 'grapefruit.' The nutritional information for wheat served as a proxy for durum wheat. For the USDA 'greens' category, the GENuS category 'cabbages and other brassicas' was a proxy, since these greens were referring to collard greens (USDA NASS, 2022). For honeydew melons and cantaloupes, the GENuS category 'other melons (inc. cantaloupes)' was used. Nutritional information for the USDA category 'miscellaneous vegetables and fruit' was an average of the GENuS crops 'vegetables; fresh; nes' and 'fresh fruit; nes.' Similarly to FAOSTAT, 'vegetables; fresh; nes' was a proxy for the USDA category 'other crops,' and mixed grain was a proxy for the USDA category 'other small grains.' For the USDA category 'other tree crops,' the GENuS categories 'stone fruit; nes' and 'nuts; nes' were averaged. Pecans did not have their own GENuS category, so the proxy 'nuts; nes' was used, as pecans were included in this category (FAO, n.d.). Similarly, the proxy 'fresh fruit; nes' was used for pomegranates, as this category includes pomegranates (FAO, n.d.). For safflower, its GENuS proxy was 'oilcrops; other.' Sugarbeets were not included in the GENuS dataset, so the proxy 'sweeteners; other' was used. Sunflower was matched with the GENuS category sunflowerseed, rather than sunflowerseed oil.

To further refine the GENuS crop matches, the food composition table (FCT) names provide more specificity; they can be used to obtain nutritional information for each of the crops within larger GENuS crop groups. For example, for cantaloupes and honeydew melon, I derived the nutritional information from the FCT categories of cantaloupes and honeydew melon from the GENuS category 'other melons (inc. cantaloupes),' and the FCT celery category from the GENuS 'vegetables; fresh; nes' category. For durum wheat, I selected the FCT durum wheat category from the GENuS category of wheat. Flaxseeds were matched with the FCT flaxseed

seed category to provide a more exact match than the GENuS 'oilcrops; other' category. For greens, from the GENuS category of 'cabbages and other brassicas,' I selected the FCT category of 'collards, raw.' As there was no all-encompassing nutritional category for maize, I selected the FCT category 'corn grain, yellow.' For pecans, I selected the FCT pecan category from the GENuS category of 'nuts; nes' to provide more specific nutritional information, and for pomegranate, I selected the FCT pomegranate category from the GENuS 'fresh fruit; nes' category. Similarly, for radishes, I selected the FCT radish category from the GENuS 'vegetables; fresh; nes' category, and for safflower, I selected the FCT safflower seed kernels category from the GENuS 'oilcrops; other' category. For wheat, I selected the FCT category 'wheat flour, whole-grain' to better match the consumable portion of wheat crops.

Table 1: List of USDA crop names and corresponding GENuS and FAOSTAT crop name matches.

USDA Names	GENuS Names	FAOSTAT Names
Almond	Almonds; with shell	Almonds, in shell
Apple	Apples	Apples
Apricot	Apricots	Apricots
Asparagus	Asparagus	Asparagus
Avocado	Avocados	Avocados
Barley	Barley	Barley
Blueberry	Blueberries	Blueberries
Broccoli	Cauliflowers and broccoli	Cauliflowers and broccoli
Buckwheat	Buckwheat	Buckwheat
Cabbage	Cabbages and other brassicas	Cabbages
Camelina	Oilcrops; Other	Rape or colza seed
Caneberry	Berries; nes	Other berries and fruits of the genus vaccinium n.e.c.
Canola	Rape and Mustard Oil	Rape or colza seed
Cantaloupe	Other melons (inc. cantaloupes)	Cantaloupes and other melons
Carrot	Carrots and turnips	Carrots and turnips

Cauliflower	Cauliflowers and broccoli	Cauliflowers and broccoli
Celery	Vegetables; fresh; nes	Other vegetables, fresh n.e.c.
Cherry	Cherries	Cherries
Chick Pea	Chick peas	Chick peas, dry
Citrus	Lemons; Limes	Lemons and limes
Citrus	Grapefruit	Other citrus fruit, n.e.c.
Corn_veg	Maize; green	Green corn (maize)
Cranberry	Cranberries	Cranberries
Cucumber	Cucumbers and gherkins	Cucumbers and gherkins
Dry Bean	Beans	Beans, dry
Durum Wheat	Wheat	Wheat
Eggplant	Eggplants (aubergines)	Eggplants (aubergines)
Flaxseed	Oilcrops; Other	Linseed
Garlic	Garlic	Green garlic
Gourd	Pumpkins; squash; and gourds	Pumpkins, squash and gourds
Grape	Grapes	Grapes
Greens	Cabbages and other brassicas	Cabbages
Herbs	Spices; nes	Other stimulant, spice and aromatic crops, n.e.c.
Honeydew Melons	Other melons (inc. cantaloupes)	Cantaloupes and other melons
Lentil	Lentils	Lentils, dry
Lettuce	Lettuce and chicory	Lettuce and chicory
Maize	Maize	Maize (corn)
Millet	Millet	Millet
Mint	Spices; nes	Other stimulant, spice and aromatic crops, n.e.c.
Misc Vegs & Fruits	Vegetables; fresh; nes	Other vegetables, fresh n.e.c.
Misc Vegs & Fruits	Fresh fruit; nes	Other fruits, n.e.c.
Mustard	Rape and Mustardseed	Rape or colza seed
Nectarines	Peaches and nectarines	Peaches and nectarines
Oat	Oats	Oats
Olive	Olives	Olives
Onion	Onions	Onions and shallots, dry (excluding dehydrated)
Orange	Oranges; Mandarines	Oranges
Other Crops	Vegetables; fresh; nes	Other vegetables, fresh n.e.c.

Other Small Grains	Wheat	Wheat
Other Small Grains	Barley	Barley
Other Small Grains	Oats	Oats
Other Small Grains	Rye	Rye
Other Tree Crops	Stone fruit; nes	Peaches and nectarines
Other Tree Crops	Nuts; nes	Other nuts (excluding wild edible nuts and groundnuts), in shell, n.e.c.
Peaches	Peaches and nectarines	Peaches and nectarines
Peanuts	Groundnuts (Shelled Eq)	Groundnuts, excluding shelled
Pear	Pears	Pears
Peas	Peas; green	Peas, green
Pecan	Nuts; nes	Other nuts (excluding wild edible nuts and groundnuts), in shell, n.e.c.
Pepper	Chillies and peppers; green	Chillies and peppers, green (Capsicum spp. and Pimenta spp.)
Pistachio	Pistachios	Pistachios, in shell
Plum	Plums and sloes	Plums and sloes
Pomegranate	Fresh fruit; nes	Other fruits, n.e.c.
Potato	Potatoes	Potatoes
Prune	Plums and sloes	Plums and sloes
Pumpkin	Pumpkins; squash; and gourds	Pumpkins, squash and gourds
Radish	Vegetables; fresh; nes	Other vegetables, fresh n.e.c.
Rice	Rice (Milled Equivalent)	Rice
Rye	Rye	Rye
Safflower	Oilcrops; Other	Other oil seeds, n.e.c.
Sorghum	Sorghum	Sorghum
Soybeans	Soyabeans	Soya beans
Squash	Pumpkins; squash; and gourds	Pumpkins, squash and gourds
Strawberries	Strawberries	Strawberries
Sugarbeets	Sweeteners; Other	Sugar beet
Sugarcane	Sugar Cane	Sugar cane
Sunflower	Sunflowerseed	Sunflower seed
Sweet Potato	Sweet Potatoes	Sweet potatoes

Tomato	Tomatoes	Tomatoes
Turnip	Carrots and turnips	Carrots and turnips
Walnut	Walnuts; with shell	Walnuts, in shell
Watermelon	Watermelons	Watermelons
Wheat	Wheat	Wheat

2.4: Nutrient inclusions and exclusions

Of the 27 nutrients included in the GENuS food composition tables, I excluded choline, omega-3, manganese, and vitamin B12 due to a lack of data for many crops. Other micronutrients not in the GENuS food composition tables were also excluded. As such, my final analysis included the macronutrients calories, protein, fat, carbohydrates, dietary fiber, saturated fat, monounsaturated fat, and polyunsaturated fat and the micronutrients vitamin C, vitamin A, folate, calcium, iron, zinc, potassium, copper, sodium, phosphorus, thiamin, riboflavin, niacin, B6, and magnesium for a total of 23 nutrients.

Results

3.1: Changes in total nutritional production from initial to 95% diversity scenario

Overall, when all crop groups are included, total nutritional production at the national level in the U.S. experiences a slight decrease in the 95% diversification scenario compared to baseline. Figure 1 shows this decline in nutritional production for calories, all nutrients, and micronutrients. Additionally, as shown in Table 2, when all crops are included, calories and macronutrients decrease by 9%, while micronutrients decrease by 11%.

As maize and soy are dominant in U.S. agriculture, making up 68% of the initial total crop area and 58% of the total crop area in the 95% scenario, it is useful to exclude them from analysis. When maize and soy are excluded, total nutritional production increases at the 95%

diversity scenario compared to initial crop diversity. As seen in Figure 1, micronutrients increase by a greater magnitude than other nutrient groups, which is an important finding. According to Table 2, when maize and soy are excluded, calories increase by 19%, macronutrients increase by 18%, and micronutrients increase by 30%. Refining the focus to vegetables as a crop group subset, the percent increase in nutrients from the initial scenario to the 95% diversity scenario is 280% for calories, 296% for macronutrients, and 344% for micronutrients, demonstrating the importance of this crop group to nutritional production in the 95% crop diversification scenario.

Excluding maize and soy, nutritional production for all nutrients increases at the 95% diversity scenario. Micronutrient production also increases by 30% when maize and soy are excluded, which is a greater percent increase than any other nutrient group. In the 95% diversity scenario, where γ-diversity at the national scale increases from baseline by 89%, only 20% of crop area and 7% of crop fields are changed (Bouvet-Boisclair & MacDonald, 2025). Thus, diversifying to the 95% scenario would generate disproportionately greater benefits for micronutrient production.

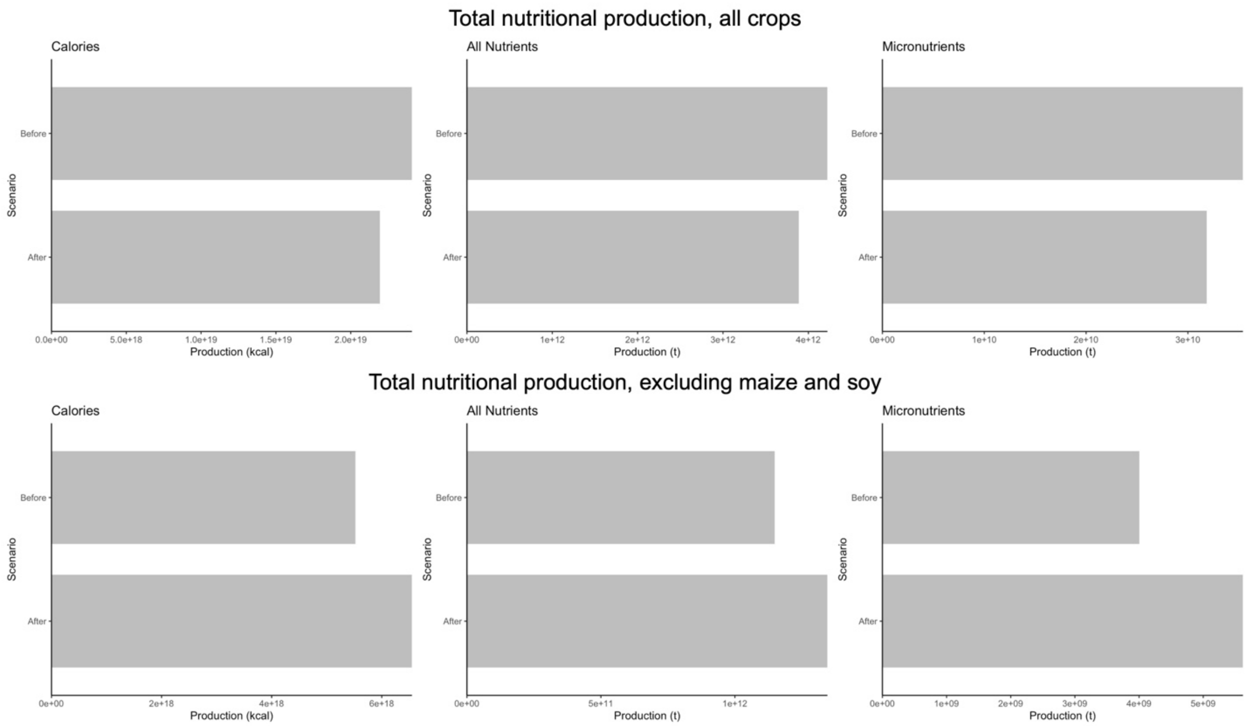

Figure 1: Bar graphs showing total change in nutritional production in tonnes from the 'before' scenario (initial crop diversity) to the 'after' scenario (95% crop diversification) for calories (kcal), all other nutrients excluding calories (expressed as tonnes, t), and micronutrients (t). Change in nutritional production is displayed for all crops and excluding maize and soy.

Table 2: Percent change in total nutritional production nationally for calories, macronutrients, and micronutrients under three crop subsets.

	All crops	**No maize or soy**	**Vegetables only**
Calories	-9%	19%	280%
Macronutrients	-9%	18%	296%
Micronutrients	-11%	30%	344%

3.2: Key nutrient increases and key crop groups

While total nutritional production declines from baseline to the 95% scenario when all crops are included, vitamin A and vitamin C increase in production. This effect is more pronounced when maize and soy are excluded. In this scenario, all nutrients increase in production at the 95% diversity level. When excluding maize and soy, the nutrients that exhibit the greatest percent increase at the 95% diversity scenario, in descending order, are vitamin A

(615%), vitamin C (335%), sodium (104%), calcium (49%), folate (47%), potassium (40%), and riboflavin (37%). Figure 2 highlights the crop groups that are responsible for these key increases in nutritional production in the 95% diversity scenario. Vegetables produced a notable increase in vitamin A and vitamin C, and a smaller increase in calcium, folate, and potassium. Fruit and tree crops were also important for the increase in vitamin C production. Pulses were key for increasing folate production, as well as for calcium and potassium, to a lesser extent. Increases in other cereals, including barley, buckwheat, millet, oats, and rice, were important for potassium, riboflavin, folate, and calcium production. Declines in nutritional production from a decline in wheat production in the 95% crop diversification scenario are evident across nutrients, including calcium, folate, potassium, and riboflavin, but the contributions of other increasing crops cumulatively make up for nutrients lost from wheat and facilitate an increase in nutritional production across all nutrients, despite declines in wheat production. Notably, sugar crops were important for increases in riboflavin and calcium; this may be due to the high nutritional content of unprocessed sugarcane and sugarbeets, the two sugar crops included in this analysis. However, this effect may not materialize in either the food supply or in diets, as these crops are often highly processed and refined before consumption. Further adjustment for edible and inedible portions of crops may minimize this effect.

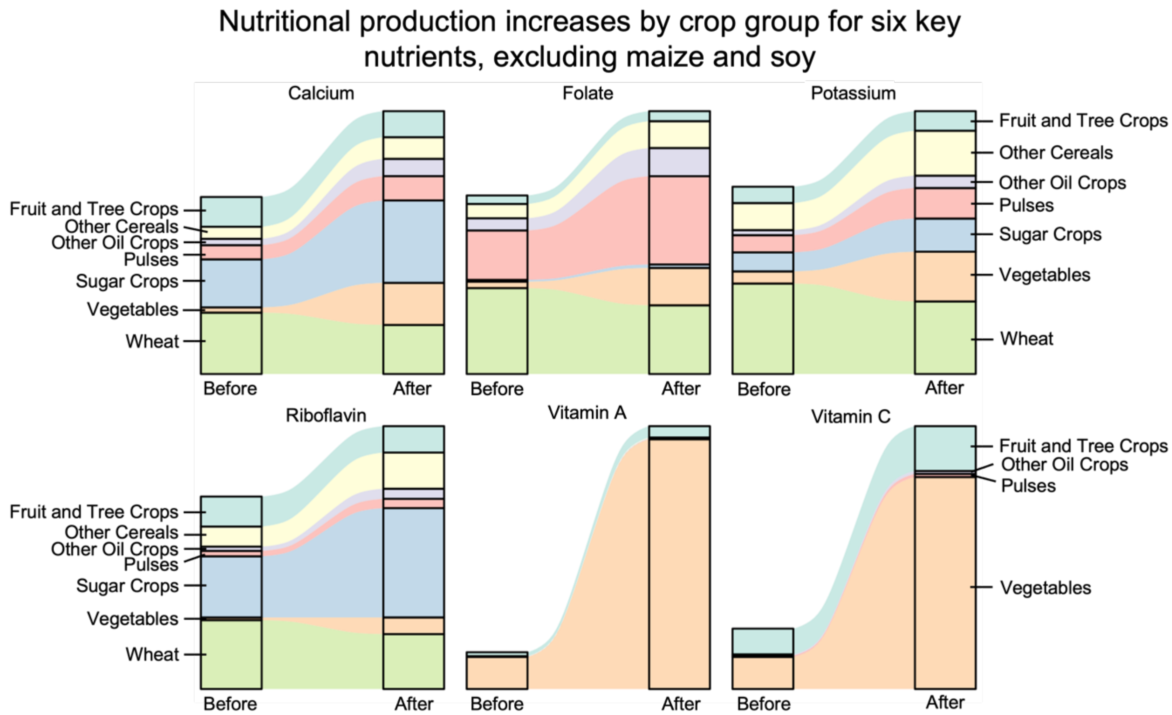

Figure 2: Alluvial plots showing change in nutritional production for key nutrients at the initial (before) and 95% diversity (after) levels with maize and soy excluded by crop group. Excluding maize and soy, the nutrients that exhibit the greatest percent increase at the 95% diversity scenario, in descending order, are vitamin A, vitamin C, sodium, calcium, folate, potassium, and riboflavin, six of which are depicted.

3.3: Key changes in nutritional production

When comparing nutritional production in the before (initial) and after (95% diversity) scenarios at a logarithmic scale, it is possible to see that small changes add up. Using a logarithmic scale allows for comparisons between crops, since crop areas vary greatly from each other in scale. Crops with a smaller area have a relatively larger increase and cumulatively influence the overall nutritional production. For the nutrients shown in Figure 3, protein production follows a narrower pattern, while minor crops for micronutrients like vitamin C, zinc, and magnesium exhibit greater increases.

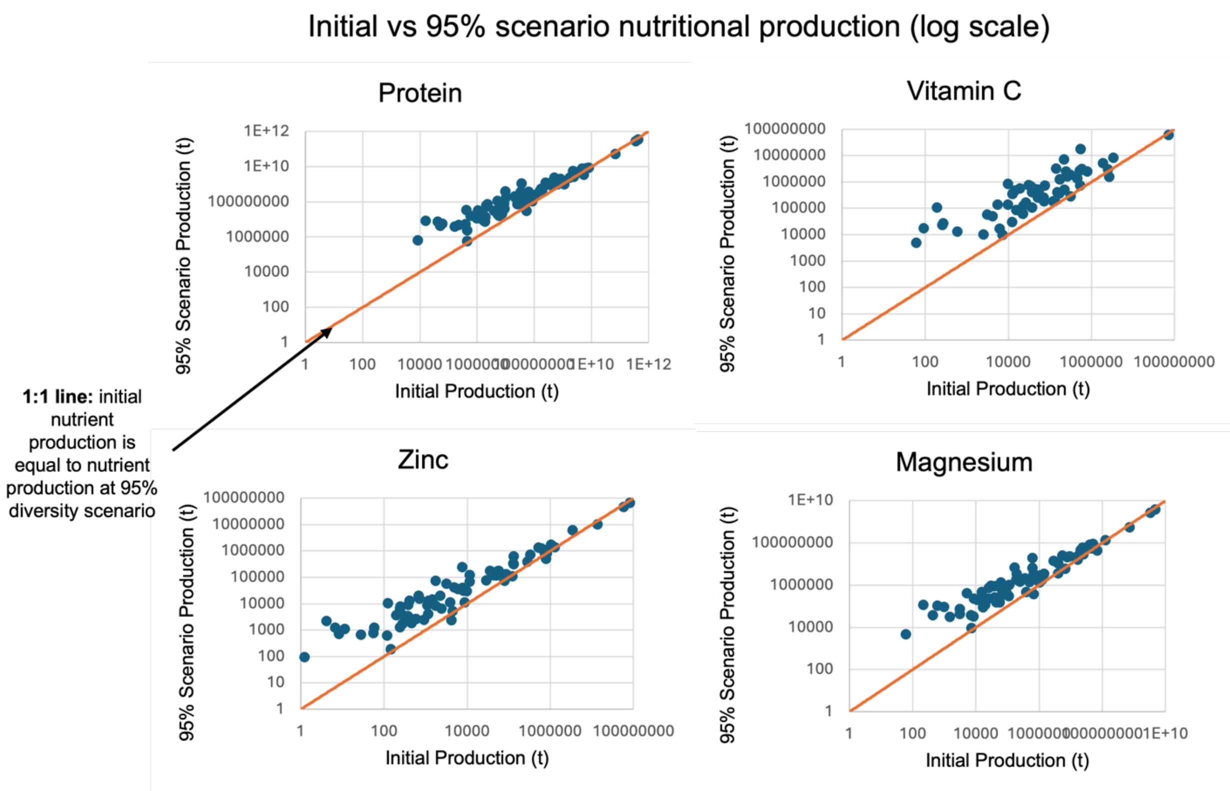

Figure 3: Scatterplots depicting initial (year 2022 baseline) nutritional production versus 95% diversification scenario nutritional production in tonnes for four nutrients with a logarithmic scale.

Discussion

4.1: Effects of maize and soy

When all crops are included, the slight decrease in total nutritional production is largely due to the effect of changes in the two most dominant commodity crops, maize and soy. In the 95% crop diversification scenario, much of the crop area that contains maize and soy in the initial scenario changes to other crops, such as vegetables. Maize and soy are also fairly nutrient-dense crops and are currently grown in very large amounts. Because of this, slight decreases in maize and soy production affect the overall nutritional production to such a degree that they are largely responsible for decreasing the total nutritional production in the 95% diversity scenario. This effect is evident in that when maize and soy are excluded, the percent change from before (initial crop diversity) to after (95% diversity scenario) changes from an overall decrease to an overall increase.

4.2: Implications for nutrient intake outcomes

The increase in nutritional production for all nutrients included in this analysis at the 95% diversification level is a key finding; it indicates that a major potential benefit of crop diversification would be an increase in nutritional production across many food nutrients. Additionally, the larger proportional increase in micronutrient production is significant in the context of rising micronutrient deficiencies among the United States population and globally. Over two billion people globally experience micronutrient deficiencies, particularly in iron, zinc, iodine, and vitamin A (Lowe, 2021). Micronutrient deficiencies can be present in a diet with a sufficiently high level of caloric consumption as diets shift to being nutrient-poor but energy-dense (Lowe, 2021). In the United States, vitamin A, vitamin C, and zinc are among the most prevalent nutrient deficiencies (Reider et al., 2020). Using the National Health and Nutrition Examination Survey (NHANES) for 2005-2016, Reider et al. (2020) determined that 45% of the U.S. population consume inadequate amounts of vitamin A, 46% of the U.S. population consume inadequate amounts of vitamin C, and 15% of the U.S. population consume inadequate amounts of zinc. After diversification, excluding maize and soy, production of vitamin A increases by 615%, production of vitamin C increases by 335%, and production of zinc increases by 23%. In this scenario, only 20% of farm area and 7% of crop fields change (Bouvet-Boisclair & MacDonald, 2025), indicating a disproportionately greater benefit for production of these key nutrients. Given that production of vitamin A and vitamin C increase substantially under the crop diversification model in my analysis and zinc also experiences an increase after diversification, implementing agricultural diversification strategies has potential to improve nutrient supply, dietary diversity, and human health outcomes related to nutrient intake. However, these outcomes are complicated and depend on variables relating to access, markets, and other dimensions. Additionally, the U.S. exports some of its crops and food products, and imports make up a major part of the food supply; what farmers grow in the U.S. cannot necessarily be translated into diet and health outcomes. Though outcomes like nutrient supply and dietary diversity are complex, this analysis establishes a scenario in which U.S. cropping systems can produce the necessary nutrients to address nutritional deficiencies.

4.3: Number of people that nutritional production could support, based on Daily Values

Based on the FDA's Daily Values, nutritional production at both the initial and 95% scenario levels could theoretically support the U.S. population many times over (FDA, 2016). As shown in Table 3, even with slight decreases in the production of most nutrients due to a decrease in crops like maize and soy, this would still more than support the current U.S. population by several orders of magnitude. This is purely theoretical, however, and most of what is grown in the U.S. is not consumed by the U.S. population. For example, Cassidy et al. (2013) found that in the U.S., only 27% of crop calorie production is used for food, revealing how many factors affect these estimates and reduce their direct applicability to nutrient supply for the U.S. population. Non-human consumption of crops, types of food use, and crop losses remain problematic, potentially lowering these estimates.

Table 3: Number of people that nutritional production could support for each nutrient in trillions, based on Daily Values published by the FDA, under the initial and 95% diversity scenarios. This was calculated for all crops and when excluding maize and soy. Percent change in the number of people that could be supported was also calculated and corresponds with percent change in nutritional production for each nutrient.

	All crops included			**Excluding maize and soy**		
Nutrients	Number of people that could be supported, based on DV (in trillions)		Percent change	Number of people that could be supported, based on DV (in trillions)		Percent change
	Before	*After*		*Before*	*After*	
Vitamin A	1	2	46%	0.1	1	615%
Vitamin C	3	4	52%	0.5	2	335%
Sodium	2	2	-4%	0.2	0.4	104%
Calcium	8	8	-8%	1	2	48%
Folate	38	34	-11%	3	5	47%
Potassium	21	19	-10%	2	3	40%
Riboflavin	42	38	-10%	5	7	37%
Fat	17	16	-9%	3	4	32%
Saturated fat	9	8	-10%	1	2	31%
Copper	107	94	-12%	13	16	25%
Vitamin B6	50	44	-12%	6	7	24%
Zinc	41	36	-11%	6	8	23%
Calories	33	28	-14%	8	9	19%
Carbohydrates	42	39	-8%	11	13	17%
Thiamin	65	57	-12%	10	11	17%
Magnesium	60	52	-12%	8	9	17%
Iron	48	42	-13%	5	6	17%
Dietary fiber	45	40	-11%	8	9	15%
Phosphorus	41	36	-12%	7	7	14%
Niacin	33	30	-10%	7	8	14%
Protein	49	42	-13%	6	7	13%

4.2: Policy implications and current barriers to increasing crop diversity

From this analysis, it is evident that U.S. policy should seek to diversify crop production in order to harness nutritional and health benefits alongside other agroecological benefits of crop diversification. This analysis highlights an additional potential benefit of crop diversification, adding to other established benefits of higher crop diversity levels. However, there are numerous barriers to diversification, several of which effective policy can alleviate. Structural barriers such as subsidies, crop insurance programs, and market demand reinforce a dependence on crops like maize and soy (Nowatzke et al., 2024; Roesch-McNally et al., 2018; Spangler et al., 2022a). Maize and soy are highly input-intensive, which creates a dependence on inputs like pesticides, herbicides, fertilizer, and genetically modified seeds that can be difficult to escape once established (Spangler et al., 2022a). What farmers grow is highly driven by the market and by corporate interests, and diversifying is seen as a risk. Price volatility adds to this risk and farmers tend to produce crops there is an established need for; a lack of markets for crops other than maize and soybean dissuades farmers from diversifying (Nowatzke et al., 2024; Roesch-McNally et al., 2018; Spangler et al., 2022a).

Federal policies like subsidies and crop insurance also incentivize production of staple crops like maize and soy and disincentivize diversification (Spangler et al., 2022a). Though farmers acknowledge the agroecological benefits of crop diversification, they experience difficulty surpassing structural and economic barriers to diversification, partially due to corporate control over agricultural markets reducing farmer autonomy (Roesch-McNally et al., 2018; Spangler et al., 2022b). As such, in accordance with Roesch-McNally et al. (2018), policy that can support crop diversification includes providing financial incentives to overcome the upfront costs of diversification and changing the crop insurance system to incentivize diversification. At the federal level, investing in programs to develop markets for alternative crops may also support farmers in overcoming structural barriers to crop diversification.

4.3: Limitations and uncertainties

One major factor affecting the results is the prevalence of maize and soybean in agricultural production in the United States. Maize and soy are the two dominant crops grown in the United States. In this analysis, maize and soy together make up 68% of the initial area and 58% of the area in the 95% diversification scenario. Because of the large percentage of area that they take up and the 10% reduction in area after diversification, maize and soy influence nutritional production to a far greater degree than any other crop. As these crops are rich in calories, macronutrients, and most micronutrients included in this analysis, the significant decline in maize and soy after diversification affects nutritional production across all nutrients, causing production of most nutrients to decline by the same or similar magnitude as the maize and soy crop areas decline. Additionally, much of their usage goes towards livestock, biofuels (especially ethanol), and other uses not involving human consumption (Cassidy et al., 2013). Thus, as this analysis focuses on the nutritional production for human consumption, it is useful to exclude maize and soy from analysis to elucidate the effects on nutritional production for other crops.

There is also the potential for definitional issues to serve as sources of error in this analysis. From the starting list of 75 crops from the USDA crop categories, those crops were matched with a slightly different list of crops from the FAO; discrepancies in crop group definitions may result in inaccurate estimates of crop and nutrient production. To check for definitional issues, the calculated initial crop production in 2022 from this analysis was compared with the FAOSTAT crop production statistics for 2022. Table A1 shows the crop production comparisons and the percent difference between calculated crop production and FAOSTAT crop production. However, it is important to note that crop areas from the USDA Crop Sequence Boundary dataset are calculated differently than crop areas from FAOSTAT, potentially contributing to a greater discrepancy between the two crop production estimates. The USDA crop area is the ‘cultivated area,’ or physical area of crop fields, derived from a remote-sensing dataset that classifies field areas by their crop type, while the FAOSTAT crop area is the ‘harvested area,’ which is derived from surveys and other administrative data reported by the U.S. (FAO, 2024). A notable difference between cultivated area and harvested area is that harvested area encompasses the number of times crops are harvested from the same field in a year, which can occasionally be more than once, while the cultivated area only counts each field once, leading to some differences between the two conceptions of crop areas. The cultivated area will also count crops that were not eventually harvested, due to crop failures or other reasons, leading to an overestimate.

When comparing the differences in calculated crop production and crop production from FAOSTAT, while several crops fall within a reasonable 15% difference and a majority of the crops are less than 80% different, some key crops differ greatly in crop production between the two data sources. For example, definitional issues in this analysis may play a role in the large percent differences for miscellaneous vegetables and fruit, other small grains, other crops, camelina, and citrus. However, for crops that have exact matches with FAO, like mustard, squash, buckwheat, broccoli, eggplants, turnips, cauliflower, durum wheat, apricots, nectarines, gourds, cherries, and peas, their high percent difference between data sources is likely due to differences in how the data were collected. Lastly, the effect of FAO’s less specific crop categories may play a role for crops like honeydew melons, celery, and pomegranate, which were matched with ‘cantaloupes and other melons,’ ‘other vegetables, fresh n.e.c.,’ and ‘other fruits, n.e.c.,’ respectively. These larger classification groups mean that the yield that was used to calculate the crop production in this analysis is not specific to this crop, but rather indicative of the crop group it is part of, causing discrepancies when comparing calculated crop production to the crop production figures published by FAOSTAT.

For the food nutrient component, the GENuS crop names are highly similar to the FAO crop names, so this was likely not a source of definitional issues. The GENuS dataset also offers a greater level of specificity with its food composition table (FCT) crop names, which allow nutrient data to be extracted for a certain crop within a group of crops, eliminating some of the issues with using less specific crop categories in this analysis. However, the most recent GENuS nutrient data is from 2011, so it does not take into account changes in nutrient contents that may have occurred from 2011-2022. The GENuS dataset is also a national estimate, so it does not take into account regional or local differences in soil quality, nutrient uptake, or other site-specific nutrient composition variables.

Lastly, each of the data sources used in this analysis have inherent errors and uncertainties. For the USDA Crop Sequence Boundary dataset that serves as the input for the model by Bouvet-Boisclair and MacDonald (2025), the classification accuracy is 85-95% (USDA NASS, n.d.). It is not possible to determine the accuracy of the FAOSTAT yield figures, as this depends on the accuracy of what is reported by each country, but each country carries out checks for its data, and the FAO implements a data validation process on the data received (FAO, 2024). The GENuS dataset employed several methods of validation to assess the accuracy of their model and found that there was reasonable agreement in calculations of nutrient supply between their model and the corresponding USDA dataset. However, they found that their data for sodium is an underestimate due to the exclusion of processed foods and their data for dietary fiber is a slight overestimate for the same reason (Smith et al., 2016). Given that this analysis also excludes processed foods, these slight differences are not relevant and likely have a minimal impact on the calculation of nutritional production.

4.4: Implications for future research

My analysis explores the nutritional outcomes of a widespread crop diversification scenario in the United States, serving as the first step to future research that could refine this relationship and apply the findings to nutrient consumption outcomes. My analysis explores the impact of crop diversification on nutritional production, rather than a variable more indicative of food consumption. Nutritional production is a purely theoretical variable, and the pathway from nutritional production to food consumption has many intermediate steps that could render the amount of nutrients consumed less than the amount of nutrients produced. As such, further research is needed to determine the effects of the attainable diversity crop diversification model by Bouvet-Boisclair and MacDonald (2025) on nutrient or food supply. There is also potential for food loss in the form of waste, spoilage, or other losses from the food supply; thus, crop diversification from this model could also be extended to food consumption to determine a more realistic estimate of nutrient consumption under a crop diversification scenario. Additionally, this is a national-scale analysis that incorporates national estimates of crop production and calculates nutritional production at the national scale, but future research could refine this to a finer spatial scale, such as the state or county level. This may provide location-specific patterns that could further clarify the relationship between crop diversity and nutritional production throughout the United States. Lastly, as mentioned earlier, farmers face many social and economic barriers to diversification that are not incorporated into the model by Bouvet-Boisclair and MacDonald (2025). Rather, this model takes into account the physical and geographic capacity of farms to diversify their crops. Future research could incorporate social and policy factors to make the model more realistic to the barriers that farmers face or model potential changes in crop diversity that could occur as a result of policy changes.

Conclusions

Looking at how nutritional production changes after crop diversification, using the model by Bouvet-Boisclair and MacDonald (2025), I found that when all crops are included, nutritional production experiences a slight decrease from the initial level of diversity to the 95% diversification scenario. However, when maize and soy are excluded, nutritional production increases for every nutrient in the 95% diversification scenario. This effect is especially pronounced for micronutrients, which increase by 30% after diversification. In comparison, in the 95% diversification scenario, only 20% of crop area and 7% of crop fields experience a change in crop type, illustrating the disproportionately greater benefits of diversification for micronutrient production. In this study, I demonstrate that increased nutritional production is a potential co-benefit of crop diversification alongside other agroecological benefits. This study represents a first step to investigating the nutritional outcomes of widespread crop diversification scenarios in the United States.

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Appendix A: Tables

Table A1: Percent difference between crop production calculated using crop areas from the model by Bouvet-Boisclair and MacDonald (2025) and 2022 yields from FAOSTAT and crop production figures for 2022 published by the FAO. I carried out this comparison to check for definitional issues in my analysis, though inherent differences in data collection may also play a role for crops with a high percent difference. Four crops have repeat entries due to matching the USDA crop with an average of multiple FAOSTAT crops when calculating yield. Repeat crops are labelled with the corresponding FAOSTAT name in parentheses. Crops are sorted from lowest to highest percentage (%) difference in production.

Crop Name	Percent difference
Flaxseed	0%
Onion	0%
Tomato	0%
Other Tree Crops (Other nuts (excluding wild edible nuts and groundnuts), in shell, n.e.c.)	0%
Sunflower	2%
Avocado	3%
Sugarbeets	6%
Sweet Potato	7%
Canola	7%
Barley	7%
Dry Bean	8%
Peanuts	9%
Soybeans	9%
Rice	9%
Lentil	12%
Garlic	13%
Peaches	13%
Corn_veg	13%
Pear	14%
Chick Pea	14%
Plum	17%
Potato	17%
Maize	18%
Grape	20%
Pecan	23%
Sugarcane	23%
Wheat	28%
Prune	28%
Blueberry	29%

Walnut	30%
Caneberry	31%
Greens	34%
Almond	39%
Pistachio	43%
Orange	43%
Carrot	46%
Apple	47%
Olive	48%
Cucumber	49%
Safflower	50%
Asparagus	55%
Cabbage	58%
Cantaloupe	69%
Pepper	69%
Oat	70%
Rye	70%
Watermelon	73%
Radish	73%
Strawberries	75%
Cranberry	75%
Millet	77%
Pumpkin	77%
Lettuce	77%
Sorghum	78%
Other Tree Crops (Peaches and nectarines)	79%
Mustard	87%
Squash	89%
Misc Vegs & Fruits (Other vegetables, fresh n.e.c.)	89%
Buckwheat	91%
Broccoli	93%
Other Small Grains (Rye)	94%
Eggplant	95%
Honeydew Melons	96%
Durum Wheat	96%
Turnip	96%
Celery	97%
Other Small Grains (Oats)	98%
Cauliflower	98%

Apricot	98%
Other Crops	99%
Nectarines	99%
Other Small Grains (Barley)	100%
Camelina	100%
Gourd	100%
Other Small Grains (Wheat)	100%
Cherry	132%
Citrus (Lemons and limes)	437%
Peas	796%
Citrus (Other citrus fruit, n.e.c.)	>1000%
Pomegranate	>1000%
Misc Vegs & Fruits (Other fruits, n.e.c.)	>1000%