The Societal Costs of Animal Agriculture in the United States

An Honors Thesis (HONR 499)

by

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Abstract

Plant-based diets are on the rise, but the costs surrounding a transition to a plant-based diet are highly debated. Many believe that consuming a plant-based diet is expensive or even unattainable. One must know the costs surrounding an omnivore and a plant-based diet, in order to make the best dietary choices for their personal situation. An analysis of six costs surrounding a plant-based lifestyle and animal agriculture bring to light some of the true costs and savings of adopting a plant-based lifestyle. These costs are all on the individual citizen of the United States, whether directly or indirectly. Through an analysis of food, medical, environmental, land, water, and incalculable costs, one can have a greater understanding of the impact of an omnivore diet on one's wallet, health, and the earth.

Acknowledgments

I would like to thank Curtis Gary Dean for advising me throughout this thesis. He has helped me to not only produce my best work, but to provide an objective actuarial mind frame. I am so grateful for everything he has done for me.

I would like to thank Kathryn, Abby, Rasa, and my partner Pat for helping me to live and adopt a lifestyle worth sharing.

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I. Process Analysis Statement

This thesis provided me with an entirely new outlook on a plant-based diet. I was initially drawn to write a thesis about this topic because of my own personal passion about veganism. I have been a vegan for over two years and a vegetarian for over four. Throughout my transition to this lifestyle, I have tried to be as knowledgeable as possible about this topic. I have watched numerous documentaries, read books, and watched speeches about why everyone should be vegan. Yet, throughout this learning process, I found many conflicting messages. It seemed like most of the information about veganism was coming from individuals who were so passionate about veganism that their information seemed less objective or even stretched; or it came from groups who have been paid by the animal agriculture industry, which seemed to provide biased data as well.

Though I understand the irony of attempting to write an unbiased thesis about a plant-based diet, when I am vegan and passionate myself, I decided to try anyway because I truly have a unique look on this topic. My majors are Actuarial Science and Mathematics of Economics. The true goal of both of these areas of study is to create the most objective and accurate information possible. This sets me up to have the tools to try to create an objective study.

A struggle that I had while researching for this thesis, and keeping my objectivity at the forefront, was trying to figure out what sources to use. There is little data and research done on vegans, and most of the information is produced by the biased sources I previously mentioned. After countless hours of research, I decided to use most of my information from the United States Department of Agriculture and other sources directly from the United States government.

The data from these sources is the most indisputable and raw information that relates to the different costs I analyzed in this thesis.

Once I gathered my data, I had to work on conscientiously bringing these values to my comparative 2018 and 2050 dates. Unfortunately, most of the data provided by the USDA and other sources had a small number of observations, which does not make for a perfect time series regression. So, I ended up doing a line of best fit regression for most of the calculations that I performed. Like any prediction, the numbers calculated are not perfect. Because of this and the controversial topic of veganism, I created a comprehensive appendix, which explains and shows the calculations I performed for each of the results. This is unusual but being as transparent and as trustworthy in my calculations as possible was crucial to the credibility of this thesis.

I found that most of my calculations were significantly lower than many of the statistics provided by alternative vegan sources. The statistics that I have created, as well as any vegan statistics, should be closely examined in order to find out the truth for oneself. It is important for the readers of this thesis to understand that a plant-based diet is highly debated in its costs and benefits. Furthermore, the purpose of this paper is not to push a plant-based diet on any individuals. The purpose of this paper is to purely educate American citizens about the costs of an omnivore diet compared to a plant-based one.

II. Introduction

When discussing the costs of a plant-based diet, it is crucial to understand exactly what a plant-based diet consists of. An individual who consumes a plant-based diet, also known as a vegan, does not consume any animal products. This includes meat, milk, cheese, or any other dairy products. To many Americans this seems extreme or unattainable, but to about 1.6 million[1] Americans this is the way of life. Alternatively, 97.5% of American citizens consume an omnivore diet, which consists of plants and animal products.

This thesis will examine the costs of a plant-based diet in the United States. Food, medical, environmental, and land costs are analyzed to provide a comprehensive look at how expensive a plant-based diet can be in comparison to the typical American omnivore diet. These costs are then projected out to 2050 as a comparison to see how costs may rise over the next thirty or so years. Other incalculable costs are also discussed, as a transition to a plant-based diet can have other effects on an American besides just their wallet.

Each section of this thesis contains tables showing the results of the research and calculations. The final sum of the total costs for a plant-based diet compared to an omnivore diet can be seen in the summary at the end. These costs will demonstrate the effect that a plant-based diet can have on a grocery budget, human health, and the health of planet Earth.

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[1] http://veganbits.com/vegan-demographics-2017/

III. Assumptions

Many assumptions are used throughout the calculations of this thesis. The first and most important assumption is the adaptation to a plant-based diet. It is assumed that individuals, once adapted to a plant-based diet, only consume plant-based foods. They do not consume *any* animal products. It should be noted that many individuals who adopt a plant-based lifestyle, choose to not purchase other nonfood-based products that contain animal byproducts. These may include makeup products, shampoo, soap, silk, wool, and many others. They also may choose to not buy any product that has been tested on animals. Though these are important aspects of a plant-based *lifestyle*, they are not a part of a plant-based *diet*. A plant-based diet will be analyzed in this thesis, not a plant-based lifestyle.

Another important assumption for this thesis is that the current American climate remains relatively unchanged. This includes the political climate, where it is assumed that no drastic or significant laws are passed around the animal agriculture industry. For example, farming regulations and subsidies remain the same. Though it is inevitable that regulations and laws will change by the year 2050, since the costs are compared to 2018 and are in 2018 dollars, this assumption will more accurately represent a true cost comparison between the two years.

The final main assumption for this thesis, mostly used for the 2050 projections, is that the percentage of vegetarians and vegans in the United States does not increase or decrease throughout the time frame calculated. This is important to demonstrate the costs that will be faced in 2050, if the American society does not change its ways.

All other assumptions made will be noted in the appendix.

IV. Food Budget

There is no cost more directly applied to the consumer, related to a plant-based diet, than the cost of food itself. Since Americans on average spend about 9.9%[2] of their disposable income on food, it is clear the cost of food is important. In order to calculate the cost, or the change in cost when adopting a plant-based diet, the pattern of food consumption in the United States is taken into account. In 2014 a study, "Patterns of Food Consumption Among Vegetarians and Non-Vegetarians," was conducted comparing the patterns of food consumption and quantity of food consumption between vegans, non-vegetarians, and other groups. This study analyzed how much food from each of the selected categories the subjects were consuming each day. This study is used to determine how much an individual may save or spend when converting to a plant-based diet (Orlich).

In the top food categories, the difference is taken between the average consumption of non-vegetarians, then compared to the average consumption of vegans. The study, "Patterns of Food Consumption Among Vegetarians and Non-Vegetarians," looks at the daily mean consumption in grams per day; the two columns for vegans and non-vegetarians are used in this thesis.

The grams per day for non-vegetarians is subtracted from the grams per day for vegans. This creates the difference in grams per day, which is then converted to pounds per year. This allows for an easier comparison for the amount of money spent on the pounds of food each year. It should be noted that the study "Patterns of Food Consumption Among Vegetarians and Non-Vegetarians" represents all food consumed, whether in the home or at a restaurant. The

[2] https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/food-prices-and-spending/

calculations and prices below represent the cost if all of these were consumed in the home. The results of this may vary depending on patterns of food consumption in the home compared to in a restaurant.

Prices of food vary significantly throughout the country depending on location, store, and brand. The prices in Table 1 are taken from a variety of sources and analyzed in order to find a price that more accurately represents the average cost per pound for each food item listed below. The fruit, vegetable, and meat prices are taken from the United States Department of Agriculture (USDA). Some of the other categories, such as the meat alternatives, are taken from outside sources, because the USDA does not report on these food categories; these sources are represented in the footnotes. More descriptions on the selection of different fruits and vegetables as well as other calculations and explanations can be found in the appendix.

A large concern when discussing a plant-based diet is the amount of protein consumed, or the lack thereof. According to Reed Mangels, PhD, author of *Simply Vegan*, “Nearly all vegetables, beans, grains, nuts, and seeds contain some, and often much, protein.” He continues, “Vegans eating varied diets containing vegetables, beans, grains, nuts, and seeds rarely have any difficulty getting enough protein as long as their diet contains enough energy (calories) to maintain weight” (Mangels). The recommended daily allowance of protein from the Institute of Medicine of the International Academies is .80 g per kg of body weight per day.[3] This ends up being about .36 g per lbs. of body weight per day. The average weight of an American is 182.1 lbs.[4] Thus, the average recommended protein intake is about 65.5 grams a day. The following plant-based diet provided by “Patterns of Food Consumption Among Vegetarians and Non-

[3] https://www.nap.edu/read/10490/chapter/1
[4] https://www.cdc.gov/nchs/fastats/body-measurements.htm

Vegetarians" shows a protein intake of approximately 70 grams of protein per day,[5] thus assuring the protein recommendation is met.

A. Table 1: Change in Annual Food Budget and Consumption

Change in Annual Grocery Budget and Consumption			
Food	**Difference in Consumption (lbs)**	**Price per lb**	**Total**
Fruit			
Avocados	7.56	$ 2.24	$ 16.94
Berries	7.16	$ 2.52	$ 18.05
Citrus	36.05	$ 1.10	$ 39.81
Tomatoes	16.17	$ 2.02	$ 32.64
Other Fruit	95.52	$ 1.63	$ 155.36
Vegetables			
Cruciferous Vegetables	11.99	$ 1.93	$ 23.11
Leafy Greens	13.20	$ 1.09	$ 14.44
Onions	5.87	$ 1.05	$ 6.19
White Potatoes	-0.08	$ 0.60	$ (0.05)
Sweet Potatoes	1.93	$ 1.05	$ 2.04
Other Vegetables	36.45	$ 1.12	$ 40.99
Grains and Nuts			
Whole Grains	108.55	$ 2.01	$ 218.30
Refined Grains	-40.23	$ 1.27	$ (50.90)
Legumes	25.67	$ 1.57	$ 40.20
Tree Nuts[6]	8.61	$ 0.22	$ 1.91
Animal Products			
Cow/Pig	-14.08	$ 4.76	$ (67.04)
Chicken	-18.51	$ 1.20	$ (22.21)
Fish	-14.97	$ 4.99	$ (74.69)
Milk	-139.94	$ 0.33	$ (46.42)
Cheese	-19.55	$ 5.36	$ (104.81)
Eggs	-11.35	$ 2.39	$ (27.15)
Butter[7]	-3.06	$ 2.29	$ (7.02)
Other			
Tofu[8]	25.51	$ 2.50	$ 63.77
Meat Analogues[9]	6.28	$ 7.60	$ 47.73
Soy Milk[10]	60.51	$ 0.70	$ 42.22
Total			$ 363.41

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5 See Appendix for Calculations
6 https://ycharts.com/indicators/us_peanuts_price_received
7 https://www.ams.usda.gov/mnreports/dywdairyproductssales.pdf
8 https://health.usnews.com/health-news/blogs/eat-run/2014/06/05/4-ways-vegetarian-living-can-help-your-wallet
9 http://www.shoprite.com/pd/Gardein/Garden-Grown-Protein-Crispy-Chicken/10-oz/842234000742/
10 http://www.costhowmuch.com/f/milk.htm

V. Medical Costs

A highly debated topic in the medical world is the health effect of the consumption of animal products and their alternatives. For example, it is easy to find several articles arguing that soy products (tofu, many meat analogues, and soy milk) are detrimental for human health; however, it is easy to find just as many articles saying they are safe and healthy alternatives to animal products. It is difficult to determine the truth. As many studies continue, the link between diet and health outcomes is always changing, nothing is final. For the purpose of this thesis, some landmark studies have been chosen as a starting point. Though, Americans as a whole must strive to be as educated as possible in order to make these decisions for themselves, so that they may live long, happy, and healthy lives.

One landmark study on human health, *The China Study*, which claims to be the "most comprehensive study of nutrition ever conducted," looks at many health aspects and problems, including two important problems that will be discussed in this thesis. Two of the most detrimental health problems facing America that are closely related to the consumption of animal products are cardiovascular disease and diabetes.

A. Cardiovascular Disease

In 2018 cardiovascular disease affected the health of about 28%[11] of all Americans, which totals to about 92 million individuals. This is a huge problem, and in fact, it is the number

[11] See appendix for calculations.

one cause of death in the United States (Benjamin). It is a problem that could not only be helped by a plant-based diet, but possibly eradicated. This is a problem caused by cholesterol.

Cholesterol is made up of two main components, HDL (high-density lipoprotein) and LDL (low-density lipoprotein). LDL, also known as the "bad" cholesterol comes from animal products and is completely non-existent in plant-based products. LDL is also usually exclusively referenced on nutritional labels as "Cholesterol;" HDL is not factored into these numbers. HDL is extremely important in maintaining a healthy lifestyle. It can absorb LDL and carry it back to the liver to be flushed out ("LDL & HDL: Good & Bad Cholesterol."). While LDL and HDL are naturally produced in the body, diet still accounts for about 25%[12] of cholesterol on the body. Thus, diet is vital in maintaining healthy cholesterol levels.

In 1946 a study was done to compare individuals with a high animal product-based diet and individuals with a lower animal product-based diet. This was one of the studies that inspired Dr. Campbell to start *The China Study*. The conductor of the study, Dr. Morrison, found that, "the more animal protein you eat, the more heart disease you have." This was then confirmed by Dr. Esselstyn through his research study. In his study, he restricted his patients' diets to only consume foods free from added fat and animal products. Up to eight years before his study, his eighteen patients had suffered forty-nine coronary events; these included: heart attacks, bypass surgery, angina, strokes, and angioplasty. In the following eleven years after he started his patients on a plant-based diet, there was only one coronary event between all eighteen individuals. This event was caused by a patient who had not strictly followed the diet for two years. Dr. Esselstyn argued, "Not only has the disease in these patients been stopped, it has even

[12] https://jonbarron.org/article/understanding-liver-and-cholesterol

been reversed. Seventy percent of his patients have seen an opening of their clogged arteries." (Campbell 111-133). This is the basis for the calculations of the cost of heart disease in the United States.

In 2011, the American Heart Association (AHA) published a study entitled, "Forecasting the Future of Cardiovascular Disease in the United States." Then in 2018 the AHA published a statistical update which contains updated projections and statistics that will be used in the table below. Most of their statistics used data from 2015 and then projected the costs out to 2035. These projections were adjusted to meet the comparison between 2018 and 2050 for this study. It is important to note that each of these statistics include Americans with some form of cardiovascular heart disease (CVD). This includes, "stroke, congenital heart disease, rhythm disorders, subclinical atherosclerosis, coronary heart disease, heart failure, valvular disease, venous disease, and peripheral artery disease" (Benjamin). These will all be categorized in this thesis under "cardiovascular disease."

The statistics used for this thesis come from the section entitled, "Economic Cost of Cardio Vascular Disease." The only statistic used in Table 2 that is from 2018 is the number of Americans with CVD, 92,100,000. According to the AHA, "by 2035, 45.1% of the US population is projected to have some form of CVD." This number can be attributed to population trends as well as lifestyle trends. When talking about direct medical costs, "between 2015 and 2035, total direct medical costs of CVD are projected to increase from $318 billion to $749 billion. Of this total in 2035, 55.5% is attributable to hospital costs, 15.3% to medications, 15.0% to physicians, 7.2% to nursing home care, 5.5% to home health care, and 1.5% to other costs." The indirect costs for CVD, "are estimated to increase from $237 billion in 2015 to $368 billion in 2035, an increase of 55%” (Benjamin). The indirect costs and direct costs are rising so quickly because of an increase in individuals with CVD as well as the rising costs of medical treatment. Indirect costs do not include lost productivity among the affected individuals who are unable to work. It does include the lost productivity due to early mortality and thus falls into the “Early Mortality” category instead of the “Reduced Productivity” category. Unfortunately, since the AHA did not calculate the lost productivity among the affected individuals who are unable to work, the “Reduced Productivity” category below was based off of a ratio from “Early Mortality” and “Reduced Productivity” for Diabetes (see Table 3). This allowed for a more accurate total amount of cost of CVD than leaving out all of the costs associated with “Reduced Productivity.” These statistics taken from the AHA were used to create Table 2 below. All calculations to produce the statistics in Table 2 can be found in the appendix.

i. Table 2: Cost of Cardiovascular Disease

Cost of Cardiovascular Heart Disease per Year		**2018**		**2050**
Americans with CVD		92,100,000		225,226,573
Percent of Americans with CVD		28%		58%
Direct Medical Costs	$	406,071,241,200	$	1,095,671,241,200
Reduced Productivity	$	958,046,850,452	$	3,854,119,943,920
Early Mortality	$	272,359,033,200	$	481,959,033,200
Average Cost per Person with CVD	$	17,768	$	24,117
Average Cost per Citizen	**$**	**4,976.58**	**$**	**13,968.22**

B. Diabetes

Diabetes is an extremely prevalent problem in the United States, affecting approximately forty-two million Americans. Diabetes also has many unforeseen complications. For example, individuals with diabetes are 2-4 times more likely to experience death by heart disease and stroke, diabetes is the leading cause of blindness in adults, and there are many other complications (Campbell 145-155). This is another disease that could be prevented by a plant-based diet and could help to prevent Americans from suffering the complications as well.

Concerning the development of diabetes, the food that is consumed in the human body has a control over blood sugar levels and the insulin produced (the two main functions causing diabetes). *The China Study* examines several different studies that scientists from around the world have conducted which resulted in the populations who ate a low-fat, close to a plant-based diet, were less likely to develop diabetes. One of the studies examined in great detail is the study done by Dr. James Anderson. He studied the effects of a high-fiber, high-carbohydrate, and low-fat diet on Type 1 and Type 2 diabetes. His patients were all taking insulin shots and none of them were overweight. He put his patients on a plant-based diet for three weeks. Once the three weeks were over, the Type 1 patients safely lowered their insulin medication by 40%. Their cholesterol levels also dropped by 30%. The patients with Type 2 diabetes had even more impressive results. Twenty-four of the twenty-five individuals were able to completely discontinue their insulin medication. The one individual of the twenty-five who was unable to completely stop his insulin medication reduced it from an original thirty-five units a day to only eight units a day. He continued the plant-based diet for an additional five weeks, totaling eight weeks, and then was able to completely discontinue his insulin medication. These results were not an anomaly. Similar results were discovered by all of the studies conducted. When combining these results of a plant-based diet as well as healthy exercise levels, diabetes can be defeated (Campbell 145-155).

The cost of diabetes has been thoroughly calculated by the American Diabetes Association. In 2018, the ADA did a study entitled, "Economic Costs of Diabetes in the U.S. in 2017." The results of this study were as follows, "The total estimated cost of diagnosed diabetes in 2017 is $327 billion, including $237 billion in direct medical costs and $90 billion in reduced productivity… care for people with diagnosed diabetes accounts for 1 in 4 health care dollars in the U.S., and more than half of that expenditure is directly attributable to diabetes." Concerning the breakdown of indirect costs, "increased absenteeism ($3.3 billion) and reduced productivity while at work ($26.9 billion) for the employed population, reduced productivity for those not in the labor force ($2.3 billion), inability to work because of disease-related disability ($37.5 billion), and lost productivity due to 277,000 premature deaths attributed to diabetes ($19.9 billion)." All of these indirect costs, except for lost productivity due to premature deaths, are categorized as "Reduced Productivity," and lost productivity due to premature deaths is categorized as "Early Mortality." All of these numbers are adjusted only for inflation to attain the numbers for 2018, which categorizes them as conservative estimates (Petersen).

The U.S. Global Change Research Program conducted a statistical analysis in order to predict some of the costs for certain diseases in the coming years. For diabetes, they predicted, "if recent increases continue, prevalence is projected to increase to 33% of Americans by 2050" (*Climate and Health Assessment).* This was used to help project the future costs of diabetes in 2050. All calculations to produce the statistics in Table 3 can be found in the appendix.

i. Table 3: Cost of Diabetes

Cost of Diabetes per Year		**2018**		**2050**
Americans with Diabetes		42,056,363		128,325,367
Percent of People with Diabetes		13%		33%
Direct Medical Costs	$	241,740,000,000	$	737,614,277,889
Reduced Productivity	$	71,400,000,000	$	217,860,757,182
Early Mortality	$	20,298,000,000	$	61,934,700,970
Average Cost per Person with Diabetes	$	7,928	$	7,928
Average Cost per Citizen	**$**	**1,014.00**	**$**	**2,616.36**

C. Other

Though the only medical conditions examined in this thesis are cardiovascular disease and diabetes, it is important to note that *The China Study* argues that a plant-based diet and healthy lifestyle can reduce or even prevent breast, prostate, colon, and rectal cancer, obesity, autoimmune diseases, and bone, kidney, eye, and brain disease. These topics are arguably not as directly correlated with a plant-based diet as CVD and diabetes, and thus are not represented in this thesis. More research is required to include the costs of these diseases. One must note that there is indeed some correlation with these diseases that would allow the total cost per citizen to rise; the amount that it would rise remains uncertain. Though this may cause the cost to rise, there also exist other factors that may cause the calculated cost of CVD and diabetes to drop as individuals who follow a plant-based diet may have other existing conditions that would cause them to be more likely to experience these diseases. For the purpose of this thesis, these two main considerations are assumed to be a wash.

VI. Environmental Costs

A cost that has been brought into the light more recently regarding the consumption of animal products is the environmental costs. In regard to environmental damage, there are three main gases to consider: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These gases have global warming potentials of one, twenty-five, and two hundred and ninety-eight, respectably. This means that nitrous oxide will harm the earth and the ozone layer two hundred and ninety-eight times faster than carbon dioxide ("Inventory of U.S. Greenhouse Gas Emissions and Sinks" ES-3). All three of these gases are a costly problem.

These gases are produced through the process of raising the animals as well as dealing with their byproducts. Carbon dioxide is produced from urea fertilization, methane is produced from enteric fermentation as well as manure management, and nitrous oxide is also produced through manure management. In order to understand these concepts, urea fertilization is the spreading of a nitrogenous compound, $CO(NH_2)_2$, through animal urine[13], and enteric fermentation is the production of methane through digestion, mostly produced by cattle.[14]

The U.S. Environmental protection agency wrote a report entitled, "Inventory of U.S. Greenhouse Gas Emissions and Sinks." This study goes into depth of the different gases and sinks causing global warming in the United States. In their section for agriculture, they break down the different gas production of the main livestock categories in the United States from 1990 to 2017. These numbers were used to project the amount of gases produced in 2018 as well as 2050. These projections were done by finding the line of best fit and using linear regression.

[13] https://www.merriam-webster.com/dictionary/urea
[14] https://www.climate-change-guide.com/enteric-fermentation-definition.html

Table 4 breaks down the gas production of different livestock. Table 5 summarizes the findings in a more concise table. It is to be noted that these numbers are in million metric tons (MMT).

A. Table 4: Gas Production by Livestock

Gas Production by Livestock (MMT)										
Gas/Source	**1990**	**2005**	**2015**	**2016**	**2017**	**2018**	**2020**	**2030**	**2040**	**2050**
$C0_2$										
Urea Fertilization	2.4	3.5	4.7	4.9	5.1	5.066	5.26	6.23	7.2	8.17
Total	**2.4**	**3.5**	**4.7**	**4.9**	**5.1**	**5.1**	**5.3**	**6.2**	**7.2**	**8.2**
CH_4										
Enteric Fermentation										
Beef Cattle	119.1	125.2	118.0	123.0	126.3	121.1	121.2	121.7	122.1	122.5
Dairy Cattle	39.4	37.6	42.6	43.0	43.3	42.6	42.9	44.6	46.2	47.8
Swine	2.0	2.3	2.6	2.6	2.7	2.6	2.7	2.9	3.2	3.4
Horses	1.0	1.7	1.5	1.5	1.4	1.7	1.7	1.9	2.0	2.2
Sheep	2.3	1.2	1.1	1.1	1.1	0.8	0.8	0.3	0.0	0.0
Goats	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
American Bison	0.1	0.4	0.3	0.3	0.3	0.2	0.2	0.4	0.4	0.4
Mules and Asses	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manure Management										
Beef Cattle	3.1	3.3	3.1	3.3	3.4	3.2	3.2	3.3	3.3	3.3
Dairy Cattle	14.7	26.4	34.8	34.3	34.5	36.5	38.0	45.7	53.5	61.2
Swine	15.5	20.3	19.2	20.2	20.0	19.6	19.8	21.0	22.3	23.5
Horses	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sheep	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Poultry	3.3	3.2	3.4	3.4	3.4	3.4	3.4	3.4	3.5	3.5
Total	**201.2**	**222.5**	**227.3**	**233.4**	**237.1**	**232.4**	**234.6**	**245.7**	**256.9**	**268.4**
N_20										
Manure Management										
Beef Cattle	5.9	7.2	7.7	8.1	8.6	8.3	8.4	9.3	10.1	11.0
Dairy Cattle	5.3	5.6	6.1	6.1	6.1	6.0	6.1	6.4	6.7	7.0
Swine	1.2	1.6	1.8	1.9	1.9	1.9	1.9	2.2	2.4	2.6
Sheep	0.1	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.4	0.5
Poultry	1.4	1.6	1.6	1.6	1.6	1.5	1.6	1.6	1.7	1.8
Horses	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**14.0**	**16.4**	**17.6**	**18.1**	**18.6**	**18.0**	**18.3**	**19.9**	**21.4**	**23.0**

B. Table 5: Estimated Total Gas Production

Estimated Total Gas Production (MMT)							
Gas/Source	**1990**	**2005**	**2015**	**2016**	**2017**	**2018**	**2050**
$C0_2$							
Urea Fertilization	2.4	3.5	4.7	4.9	5.1	5.1	8.2
CH_4							
Enteric Fermentation	164.2	168.9	166.5	171.9	175.4	169.5	176.7
Manure Management	37.1	53.7	60.9	61.5	61.7	62.9	91.7
Total	201.3	222.6	227.4	233.4	237.1	232.4	268.4
N_20							
Manure Management	14	16.5	17.6	18.2	18.7	18.0	23.0

In order to calculate the amount that these gases cost the United States, the EPA created a concept called social cost. Social cost is the long-term damage done by one ton of these gases. It also includes, "the value of damages avoided for a small emission reduction." Long-term damage covers, "climate change damages and includes changes in net agricultural productivity, human health, property damages from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning." However, this is still a conservative cost. Since there is a lack of data on the precise damage, the social cost does not include, "all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature" ("The Social Cost of Carbon"). These calculated costs remain the most accurate assessment thus far to estimate the cost of greenhouse gases. The EPA provided cost estimates for various years starting at 2015 until 2050. Since 2050 estimates were given, only 2018 estimates needed to be calculated (can be found in the appendix). The costs that the EPA estimated can be found in Table 6 below.

C. Table 6: The Social Cost of Greenhouse Gases per Ton

The Social Cost of Greenhouse Gases per Ton				
Gas		**2018**		**2050**
$C0_2$	$	49.24	$	85.79
CH_4	$	1,392.58	$	3,108.44
N_20	$	17,655.92	$	33,571.11

Combining all of the information from the EPA, including the amount of gases produced and the social cost, the total cost of animal agriculture on the environment can be calculated. Results can be seen in Table 7.

D. Table 7: Total Cost of Greenhouse Gases from Animal Agriculture

Total Cost of Greenhouse Gases from Animal Agriculture				
Greenhouse Gas		**2018**		**2050**
$C0_2$				
Production from Animal Agriculture		5.1		8.2
Social Cost per MMT	$	49,240,000	$	85,790,000
Total Social Cost	$	251,124,000	$	703,478,000
Social Cost per Person	$	0.76	$	1.81
CH_4				
Production from Animal Agriculture		232.4		268.4
Social Cost per MMT	$	1,392,580,000	$	3,108,440,000
Total Social Cost	$	323,684,053,784	$	834,288,821,268
Social Cost per Person	$	984.33	$	2,145.45
N_20				
Production from Animal Agriculture		18.018		22.962
Social Cost per MMT	$	17,655,920,000	$	33,571,110,000
Total Social Cost	$	318,124,366,560	$	770,859,827,820
Social Cost per Person	$	967.43	$	1,982.33
Total Cost Per Person	**$**	**1,952.52**	**$**	**4,129.59**

VII. Land Costs

Most of the costs of animal agriculture have already been reflected in this paper. The cost of raising, feeding, slaughtering, storing, and all of the other costs that animal agriculture business' face are reflected in the final product price that is purchased in a grocery store. This cost to American citizens is already reflected in the food budget section above. The main negative externality produced by animal agriculture is in fact its environmental impact, which was reflected in the environmental costs section above.

Perhaps a less commonly discussed aspect of animal agriculture is the cost of land. Animal agriculture uses a total of approximately 842 million acres of land, about 86% of this land is for pasture and grazing while the other 14% is used for crops to feed the animals.[15] In order to calculate the land for livestock feed, it was found that 98%[16] of all soy crops in the United States are used for livestock feed as well as 33%[17] of all corn crops are used for livestock feed. If animal agriculture ceased to exist, the land for pasture and grazing would be up for market; it is important to take into account that the demand for soy products would increase drastically, thus demanding more land for soy production. This is accounted for in the total land saved, Table 10.

The USDA report, "Major Uses of Land in the United States," executed in 2007, shows the trend in grassland pasture and range from 1945 until 2007. This data was used to project the acres of livestock grazing in the U.S. for 2018 to 2050. These resulted in approximately 723 and 814 million acres of land for livestock grazing, respectably. The report "Land Values," also by the USDA, shows the trend in the cost of cropland and the cost of grazing land from 2013 to

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[15] Calculations can be found in Appendix
[16] http://www.wisoybean.org/news/soybean_facts.php
[17] http://worldofcorn.com/#corn-feed-by-species

2017. Combining the data from the USDA "Crop Production" report, along with the percentages of corn and soy fed to livestock, led to being able to calculate the acres for livestock feed in the U.S. The results of all of these calculations can be found below in Table 8 with the calculations themselves in the appendix.

A. Table 8: Cost of Land for Animal Agriculture

Cost of Land for Animal Agriculture				
		2018		**2050**
Cost of Crop Land	$	4,293.18	$	6,088.38
Cost of Grazing Land	$	1,441.26	$	2,714.22
Acres for Livestock Feed		112,179,420		145,824,000
Acres for Livestock Grazing		727,862,000		813,750,000
Total Cost	**$**	**1,530,644,828,476**	**$**	**3,096,528,450,120**

In order to maintain the typical vegan diet, as suggested in "Patterns of Food Consumption Among Vegetarians and Non-Vegetarians," there will be an increase in the demand for soy, which is needed to produce tofu, meat analogues, and soy milk. Using the data from Table 1 and adjusting it to meet the desired population, approximately an additional 12 billion and 14 billion pounds of soy will be needed in 2018 and 2050 respectably. Considering that 2,400 pounds of soy are produced in one acre,[18] the results from the total amount of land increase for the new demand in soy is shown below in Table 9.

[18]http://www2.ca.uky.edu/agcomm/pubs/agr/agr188/agr188.pdf

B. Table 9: Cost of Land for Increase in Soy Demand

Cost of Land for Increase in Soy Demand				
		2018		**2050**
Cost of Crop Land	$	4,293.18	$	6,088.38
Pounds of Extra Soy Needed		12,717,947,938		15,039,609,932
Pounds of Soy per Acre		2400		2400
Total Acres Needed		5,299,145		6,266,504
Total Cost	**$**	**22,750,183,219**	**$**	**38,152,858,465**

Table 10 below summarizes the total cost of land for animal agriculture with consideration for the increase in soy. It is to be noted that these costs saved per person are not direct costs. These costs are more likely considered to be economic costs, because they are costing society as a whole, more than the individual person. Though these costs are not directly implied on the individual, they are relatively high, and thus should at least be considered.

C. Table 10: Land Cost Saved if Plant-based Diet Implemented

Land Cost Saved if Plant-Based Diet Implemented				
		2018		**2050**
Cost of Land for Animal Agriculture	$	1,530,644,828,476	$	3,096,528,450,120
Cost of Land for Soy Increase	$	(22,750,183,219)	$	(38,152,858,465)
Total Cost Saved	$	1,507,894,645,256	$	3,058,375,591,655
Cost Saved per Person	**$**	**4,585.56**	**$**	**7,864.88**
Acres per Person		**2.54**		**2.45**

VIII. Water Usage

A cost from animal agriculture that cannot necessarily be monetized is water usage. According to UNESCO, “the water footprints of animal products can be understood from three main factors: feed conversion efficiency of the animal, feed composition, and the origin of the feed.” Furthermore, “most of the total volume of water (98%) refers to the water footprint of the food for the animals." As access to fresh water becomes a more prevalent issue as the global climate is changing, water consumption is an important aspect of the animal agriculture industry (Mekonnen 5-8).

In order to calculate the average water consumption if each individual, the data from "Patterns of Food Consumption Among Vegetarians and Non-Vegetarian" is used. This provides the difference in consumption in the table below. In order to find the gallons of water used to produce each item in the table, the information from the UNESCO – Institute for Water Education study is used. In 2010, UNESCO - IHE conducted a study, "The Green, Blue, and Grey Water Footprint of Farm Animals and Animal Products," to examine how much water was being used to produce a wide variety of consumed items, focusing specifically on many animal products. Their categories are matched with the data from "Patterns of Food Consumption Among Vegetarians and Non-Vegetarian" to create the table below. The numbers used are a sum of all green, blue, and grey water. Some of the categories that are not found in the UNESCO-IHE study have footnotes with the link to a study done by the Water Education Foundation, where the rest of the categories needed are found. This totaled to about twenty-eight thousand gallons of water can be saved every year if a plant-based diet is adopted.

A. Table 11: Total Water Footprint

Total Water Footprint			
Food Category	**Difference in Consumption (lbs. per year)**	**Gallons of Water (per lbs.)**	**Water Footprint**
Fruit	148.87	127.07	18,916
Vegetables	84.49	42.53	3,594
Starch	70.81	51.12	3,620
Tofu and Meat Analogues[19]	60.35	122.00	7,363
Soy Milk[20]	60.35	15.37	927
Nuts	14.48	1197.10	17,339
Drinking Water	352.45	8.33	2,936
Cow/Pig	-14.08	2036.11	(28,668)
Chicken	-18.51	571.27	(10,574)
Milk	-139.94	134.73	(18,854)
Cheese[21]	-19.55	896.00	(17,517)
Eggs	-11.35	431.26	(4,895)
Butter	-3.06	733.47	(2,244)
Total Water Saved			**(28,058)**

IX. Incalculable Costs

There are many other costs that are associated with plant-based and omnivore diets, though these are more conceptual than calculable. For example, the value that individuals put on their happiness based on the consumption of animal products varies greatly from person to person. One individual may be eager to make a lifestyle change that they believe will benefit them, thus their cost of giving up animal products is relatively low. On the other hand, some individuals have grown up with animal products as their main source of calories. There also may be traditions and memories associated with these animal products, that may make it seem

[19] https://www.watereducation.org/post/food-facts-how-much-water-does-it-take-produce
[20] https://www.watereducation.org/post/food-facts-how-much-water-does-it-take-produce
[21] https://www.watereducation.org/post/food-facts-how-much-water-does-it-take-produce

impossible to give up. Their cost of change will be extremely high. These individuals will also need to take time to become educated on how to consume a wholesome plant-based diet with the proper nutrients for their body. This will include research, finding new recipes they will enjoy, and perhaps even relearning how to cook. In summary, no matter how willing the individual is to adopt a plant-based lifestyle, it will at least cost them some adjustment time and perhaps even some of their happiness.

Another example is the cost of transitioning the food industry. Examples of this include initial layoffs of animal agriculture workers, reallocation of the resources used in animal agriculture industry (machinery, buildings, etc.), onboarding costs of the growing plant-based companies, redesign of grocery stores, etc. There is an incomprehensible amount of changes that would need to occur in society if every single person went plant-based. It is assumed that in the short run, especially during the initial time period of layoffs, the economy would suffer. There would also be a high demand for plant-based products that the market would not be able to fulfill. In the long run, the economy would bring itself back to equilibrium as society adjusts to the increase in the demand for plant-based products as well as the drastic decrease in demand for animal products. Eventually, the costs would total zero, but that does not mean that growing and changing pains were not experienced.

A final example of a cost produced by the animal agriculture industry is beauty. This, like the first example, is much more objective than subjective. Many areas around the U.S. are affected by additional negative externalities of animal agriculture. Slaughterhouses and farms that do not properly dispose of manure or other wastes can end up dumping or leaking these materials into nearby lakes or streams (Vijayan). This can kill fish, plants, and other wildlife, destroying a once beautiful ecosystem, both visibly and functionally. This will reduce tourism as well as overall general feelings of happiness and connection when these sites are visited. The destruction of ecosystems and the human connection to the earth are costs that are incomprehensible to how much damage could be done.

X. Summary

A. Table 12: Total Amount Saved Yearly when Adopting a Plant-Based Diet

Total Amount Saved Yearly when Adopting a Plant-Based Diet		
	2018	**2050**
Grocery Costs	$ (363.41)	$ (363.41)
Medical Costs		
Direct Cost of CVD	1,234.88	2,817.62
Direct Cost of Diabetes	653.03	2,234.07
Environmental Costs		
$C0_2$	0.76	1.81
CH_4	984.33	2,145.45
N_20	967.43	1,982.33
Economic Costs		
Indirect Costs of CVD	3,741.70	11,150.61
Indirect Costs of Diabetes	278.86	719.52
Land Costs	4,585.56	7,864.88
Total Amount Saved	**$ 12,083.13**	**$ 28,552.87**

After analyzing and considering many costs connected to a plant-based and omnivore diet, it is almost impossible to say truly how expensive it is for each individual to transition to a plant-based diet. The analysis of grocery, medical, environmental, and economic costs have provided a baseline assumption for how much one could save when adopting a plant-based diet. Though, the final number of $12,083 per person in 2018 seems like it may not be present in one's life today, this is the average cost per year, in 2018 dollars, that a person will spend throughout their entire life. With the world changing, in 2050, the average amount saved per year increases all the way to $28,552.87 (in 2018 dollars).

The analysis has shown that the only category where consuming a plant-based diet is monetarily more costly, is in the grocery budget. In the areas of medical, environmental, and economic, one can save a large sum of money by transitioning to a plant-based diet. Unfortunately, most individuals do not consider any of these three costs when considering a plant-based diet. The costs that are most often considered are the grocery cost or the incalculable mental costs when changing to a plant-based diet. These costs generate a negative outcome, which leads the individual to choose not to adopt a plant-based diet. It is crucial to consider all costs in order to make a fair cost analysis.

In conclusion, adopting a plant-based diet can save the average American citizen around twelve thousand dollars a year. It is up to each individual to decide whether they can overcome the incalculable costs of transitioning to a plant-based diet in order to save themselves from paying for it in the long run. For some, they may find with their current beliefs and traditions, it to still be more beneficial to continue their current dietary patterns. For others, perhaps they find that it is far more costly to continue on their current path of an omnivore diet. Regardless of the conclusion made by the individual, the costs surrounding a non-plant-based diet exist, are expensive, and are only increasing. This information must be shared.

References

"Average Retail Food and Energy Prices, U.S. and Midwest Region." *U.S. Bureau of Labor Statistics*, U.S. Department of Labor, www.bls.gov/regions/mid-atlantic/data/AverageRetailFoodAndEnergyPrices_USandMidwest_Table.htm.

Benjamin, Emelia J., et. al. "Correction to: Heart Disease and Stroke Statistics—2018 Update: A Report From the American Heart Association." *Circulation*, vol. 137, no. 12, 2018, doi:10.1161/cir.0000000000000573.

Campbell, T. Colin, and Thomas M. Campbell II. *The China Study: The Most Comprehensive Study of Nutrition Ever Conducted and the Startling Implications for Diet, Weight Loss and Long-term Health*. BenBella Books, Inc., 2006.

"Current Estimates and Future Trends in Chronic Health Conditions That Interact with the Health Risks Associated with Climate Change." *Climate and Health Assessment*, U.S. Global Change Research Program , health2016.globalchange.gov/climate-change-and-human-health/tables/current-estimates-and-future-trends-chronic-health-conditions.

"Food Facts: How Much Water Does It Take to Produce ... ?" *Water Education Foundation*, Water Education Foundation, www.watereducation.org/post/food-facts-how-much-water-does-it-take-produce.

"Fruit and Vegetable Prices." *USDA Economic Research Analysis*, USDA, 11 July 2018, www.ers.usda.gov/data-products/fruit-and-vegetable-prices.aspx.

"Inventory of U.S. Greenhouse Gas Emissions and Sinks." *EPA*, United States Environmental Protection Agency , Feb. 2019, www.epa.gov/sites/production/files/2019-02/documents/us-ghg-inventory-2019-main-text.pdf.

"Land Values 2017 Summary." *Land Values 2017 Summary*, USDA, 2017, www.usda.gov/nass/PUBS/TODAYRPT/land0817.pdf.

"LDL & HDL: Good & Bad Cholesterol." *Cholesterol* , Centers for Disease Control and Prevention, 31 Oct. 2017, www.cdc.gov/cholesterol/ldl_hdl.htm.

Mangels, Reed. "Protein in the Vegan Diet." *Simply Vegan*, 5th ed.

"Meat Price Spreads." *USDA ERS - Meat Price Spreads*, www.ers.usda.gov/data-products/meat-price-spreads.

Mekonnen, M. M., and A. Y. Hoekstra. "The Green, Blue and Grey Water Footprint of Crops and Derived Crop Products." *Hydrology and Earth System Sciences Discussions*, vol. 8, no. 1, 2011, pp. 763–809., doi:10.5194/hessd-8-763-2011.

Orlich, Michael J., et al. “Patterns of Food Consumption among Vegetarians and Non-Vegetarians.” *British Journal of Nutrition*, vol. 112, no. 10, 15 Nov. 2014, pp. 1644–1653., doi:10.1017/s000711451400261x.

Pettersen, Matthew P. “Economic Costs of Diabetes in the U.S. in 2017.” *Diabetes Care*, vol. 41, no. 5, May 2018, pp. 917–928., doi:10.2337/dci18-0007.

“Soybean and Oil Crops - Related Data & Statistics.” *USDA ERS* , USDA, 6 Oct. 2017, www.ers.usda.gov/topics/crops/soybeans-oil-crops/related-data-statistics/.

“The Social Cost of Carbon.” *EPA*, Environmental Protection Agency, 9 Jan. 2017, 19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html.

Vijayan, Aswin. “SLAUGHTER HOUSE: Polluting the Environment.” *The Environmental Impact by Nearby Businesses*, 8 Jan. 2012, businessimpactenvironment.wordpress.com/2012/01/08/slaughter-house-polluting-the-environment/

Appendix

The calculations below are presented to be as thorough as possible. Some numbers provided that do not have direct calculations are either calculated in previous steps or sections, or they are directly from sources which will be provided in the footnotes.

IV. Food Budget

A Table 1: Change in Annual grocery Budget and Consumption

Change in Annual Grocery Budget and Consumption			
Food	**Difference in Consumption (lbs)**	**Price per lb**	**Total**
Fruit[22]			
Avocados	7.56	$ 2.24	$ 16.94
Berries	7.16	$ 2.52	$ 18.05
Citrus	36.05	$ 1.10	$ 39.81
Tomatoes	16.17	$ 2.02	$ 32.64
Other Fruit	95.52	$ 1.63	$ 155.36
Vegetables[23]			
Cruciferous Vegetables	11.99	$ 1.93	$ 23.11
Leafy Greens	13.20	$ 1.09	$ 14.44
Onions	5.87	$ 1.05	$ 6.19
White Potatoes	-0.08	$ 0.60	$ (0.05)
Sweet Potatoes	1.93	$ 1.05	$ 2.04
Other Vegetables	36.45	$ 1.12	$ 40.99
Grains and Nuts			
Whole Grains[24]	108.55	$ 2.01	$ 218.30
Refined Grains	-40.23	$ 1.27	$ (50.90)
Legumes[25]	25.67	$ 1.57	$ 40.20
Tree Nuts[26]	8.61	$ 0.22	$ 1.91
Animal Products[27]			
Cow/Pig	-14.08	$ 4.76	$ (67.04)
Chicken	-18.51	$ 1.20	$ (22.21)
Fish[28]	-14.97	$ 4.99	$ (74.69)
Milk[29]	-139.94	$ 0.33	$ (46.42)
Cheese	-19.55	$ 5.36	$ (104.81)
Eggs[30]	-11.35	$ 2.39	$ (27.15)
Butter	-3.06	$ 2.29	$ (7.02)
Other			
Tofu	25.51	$ 2.50	$ 63.77
Meat Analogues[31]	6.28	$ 7.60	$ 47.73
Soy Milk[32]	60.51	$ 0.70	$ 42.22
Total			$ 363.41

[22] Strawberries were selected to represent berries, oranges for citrus, and apples as other.
[23] Broccoli was selected to represent cruciferous vegetables, iceberg lettuce for leafy greens, and mixed vegetables for other vegetables. Mixed vegetables are the only vegetables that are not fresh produce.
[24] Wheat bread was selected as whole grains and white bread was selected as refined grains.
[25] Lentils were selected as legumes.
[26] Peanuts were selected as tree nuts.
[27] The animal products that had several different cuts were averaged together. Cheddar was selected to represent cheese.
[28] Tilapia was selected as fish. The price is from http://www.fishermanscoveseafood.com/tilapia-fillet-price-per-pound/
[29] The price for milk was divided by 8.6, as there are 8.6 pounds of milk per gallon.
[30] The price for eggs was multiplied by 24, because there are 24 oz in a dozen large eggs. It was then divided by 16, as there are 16 oz in a pound. https://www.reference.com/food/much-egg-weigh-4d094c5fdcde9012
[31] The price for meat analogues was 4.99 for 10.5 oz, so the price was multiplied by 16 (16 oz in a pound) and then divided by 10.5
[32] Soy milk is assumed to weigh the same as dairy milk, 8.6 pounds per gallon

Protein Information: Discussed in IV.

Main Protein Sources	Amount Consumed (g)	Protein per Gram	Protein Consumed
Legumes	84.4	0.24	20.26
Cruciferous Vegetables	44.5	0.02	1.02
Leafy Greens	58.9	0.01	0.59
Whole Grains	292.8	0.10	27.89
Fake Meat	43.4	0.21	8.90
Tofu	40.2	0.11	4.25
Soy Milk	119.3	0.03	3.38
Tree Nuts	17.8	0.23	4.07
Total			**70.35**

a. "Amount Consumed"
   Data from: "Patterns of Food Consumption Among Vegetarians and Non-Vegetarians"

b. "Protein per Gram"
   The selections for each category from Table 1 were matched as closely as possible
   Data from: (Mangels)
   Conversions from: http://cookitsimply.com/measurements/

c. "Protein Consumed"
   Protein Consumed = Amount Consumed * Protein per Gram

V. Medical Costs

A. Cardiovascular Disease

i Table 2: Cost of Heart Disease per Year

Cost of Cardiovascular Heart Disease per Year		2018		2050
Americans with CVD		92,100,000		225,226,573
Percent of Americans with CVD		28%		58%
Direct Medical Costs	$	406,071,241,200	$	1,095,671,241,200
Reduced Productivity	$	958,046,850,452	$	3,854,119,943,920
Early Mortality	$	272,359,033,200	$	481,959,033,200
Average Cost Per Person with CVD	$	17,768	$	24,117
Average Cost per Citizen	**$**	**4,976.58**	**$**	**13,968.22**

a. "Americans with CVD"
2018: **92,100,000**
2050: **225,226,573**

Total Population 2050: 388,864,747[33]
Total Population 2018: 328,835,763[34]
Percent of People with Heart Disease 2018:

$\frac{92100000}{328{,}835{,}763} = .028008$

28.008%

Percent of People with Heart Disease 2035: 45.1%[35]
Heart Disease population percent increase per year

$\frac{0.451-0.28008}{20\ (number\ of\ years\ between\ two\ projections)} = .008546$

0.855% Change each year

Number of Years between 2050 and 2035 = 15
Percent of People with Heart Disease 2050:

$.451 + (.00855 * 15) = 0.57919$

Americans with some form of Heart Disease

$.57919 * 388{,}864{,}747 =$ **225,226,573**

b. "Percent of People with CVD"
2018: **28.008%**
2050: **57.919%**

c. "Direct Medical Costs"
2018: **$406,071,241,200**

Direct Medical Costs 2015: $318,000,000,000
Projection of Direct Medical Costs 2035: $749,000,000,000
Standard Inflation Rate: 2%
Change in Billions of Medical Costs Each Year

$\frac{749-318}{20} = 21.55$

Total Direct Medical Costs 2018:

$\big(318{,}000{,}000{,}000 + (21.55 * 1{,}000{,}000{,}000 * 3)\big) * 1.02^3 =$
$ **406,071,241,200**

2050: **$1,095,671,241,200**

Total Direct Medical Costs 2050:

$406{,}071{,}241{,}200 + (21.55 * 1{,}000{,}000{,}000 * 32) =$
$**1,095,671,241,200**

[33] https://www.populationpyramid.net/united-states-of-america/2050/
[34] https://www.populationpyramid.net/united-states-of-america/2018/
[35] https://www.ahajournals.org/doi/pdf/10.1161/CIR.0000000000000558

d. “Reduced Productivity”
2018: **$958,046,850,452**
Cost of Early Mortality 2018: $272,359,033,200
See Calculation Below
Cost of Reduced Productivity for Diabetes 2018: $71,400,000,000
See Calculation Below
Cost of Early Mortality for Diabetes 2018: $20,298,000,000
See Calculation Below
Ratio of Reduced Productivity
$\frac{71{,}400{,}000{,}000}{20{,}298{,}000{,}000} = 3.5176$
Cost of Reduced Productivity 2018:
$(3.5176 * 272{,}359{,}033{,}200) =$ **$958,046,850,452**
See Explanation of Calculation in Thesis
2050: **$3,854,119,943,920**
Cost of Early Mortality 2050: $481,959,033,200
See Calculation Below
Cost of Reduced Productivity for Diabetes 2050: $217,860,757,182
See Calculation Below
Cost of Early Mortality for Diabetes 2050: $61,934,700,970
See Calculation Below
Ratio of Reduced Productivity
$\frac{217{,}860{,}757{,}182}{20{,}298{,}000{,}00061{,}934{,}700{,}970} = 3.5176$
Cost of Reduced Productivity 2018:
$(3.5176 * 481{,}959{,}033{,}200) =$ **$3,854,119,943,920**
See Explanation of Calculation in Thesis

e. “Early Mortality”
2018: **$272,359,033,200**
Cost of Early Mortality 2015: $237,000,000,000[36]
Projection of Cost of Early Mortality 2035: $368,000,000,000[37]
Change in Billions of Medical Costs Each Year
$\frac{368-237}{20} = 6.55$
Total Costs of Early Mortality 2018:
$\left(237{,}000{,}000{,}000 + (6.55 * 1{,}000{,}000{,}000 * 3)\right) * 1.02^3 =$
$272,359,033,200
2050: **$481,959,033,200**
Total Costs of Early Mortality 2018:
$\left(272{,}359{,}033{,}200 + (6.55 * 1{,}000{,}000{,}000 * 32)\right) =$
$481,959,033,200

36

37

f. “Average Cost per Person with CVD”
2018: **$17,768**

$$\frac{406{,}071{,}241{,}200+958{,}046{,}850{,}452+272{,}359{,}033{,}200}{92{,}100{,}00} = \$\mathbf{17{,}768}$$

2050: **$24,117**

$$\frac{1{,}095{,}671{,}241{,}200+3{,}854{,}119{,}943{,}920\ +481{,}959{,}033{,}200}{225{,}226{,}573} = \$\mathbf{24{,}117}$$

g. “Average Cost per Citizen”
2018: **$4,976.58**

$$\frac{406{,}071{,}241{,}200+958{,}046{,}850{,}452+272{,}359{,}033{,}200}{328{,}835{,}763} = \mathbf{\$4{,}976.58}$$

2050: **$13,968.22**

$$\frac{1{,}095{,}671{,}241{,}200+3{,}854{,}119{,}943{,}920\ +481{,}959{,}033{,}200}{388{,}864{,}747} = \$\mathbf{13{,}968.22}$$

B. Diabetes

i. Table 3: Cost of Diabetes per Year

Cost of Diabetes per Year		**2018**		**2050**
Americans with Diabetes		42,056,363		128,325,367
Percent of People with Diabetes		13%		33%
Direct Medical Costs	$	241,740,000,000	$	737,614,277,889
Reduced Productivity	$	71,400,000,000	$	217,860,757,182
Early Mortality	$	20,298,000,000	$	61,934,700,970
Average Cost per Person with Diabetes	$	7,928	$	7,928
Average Cost per Citizen	**$**	**1,014.00**	**$**	**2,616.36**

a. “Americans with Diabetes”
2018: **42,056,363**

Total Population 2018: 328,835,763
Percent of Americans with Diabetes 2012: 9%
Percent of Americans predicted to have Diabetes 2050: 33%[38]
Change in Percent of Americans Every Year:

$$\frac{.33-.09}{2050-2012} = 0.00632$$

.632% Change Each Year

[38] https://health2016.globalchange.gov/climate-change-and-human-health/tables/current-estimates-and-future-trends-chronic-health-conditions

Americans with Diabetes 2018:

$$\left(.09 + \left(.00632 * (2018 - 2012)\right)\right) * 328{,}835{,}76 = \mathbf{42{,}056{,}363}$$

2050: **128,325,367**

Total Population 2050: 388,864,747

Percent of Americans predicted to have Diabetes 2050: 33%

Americans with Diabetes 2050

$$.33 * 388{,}864{,}747 = \mathbf{128{,}325{,}367}$$

b. "Percent of People with Diabetes"

2018: **13%**

Percent of People with Diabetes 2012: 9%

Percent of People with Diabetes 2050: 33%

Change in Percent of Americans Every Year: .623%

Percent of People with Diabetes 2018:

$$.09 + \left(.00623 * (2018 - 2012)\right) = .12789$$

12.789% is used in the actual calculations, but for the purpose of the table, it is rounded to **13%**

2050: **33%**

c. "Direct Medical Costs"

2018: **$241,740,000,000**

Direct Medical Costs 2017: 237,000,000,000

Standard Inflation Rate: 2%

Total Direct Medical Costs 2018:

$$237{,}000{,}000{,}000 * 1.02 = \$\mathbf{241{,}740{,}000{,}000}$$

2050: **$737,614,277,888.96**

Direct Medical Costs 2018: 241,740,000,000

Americans with Diabetes 2018: 42,056,363

Americans with Diabetes 2050: 128,325,367

Direct Medical Cost per Person with Diabetes 2018:

$$\frac{241{,}740{,}000{,}000}{42{,}056{,}363} = 5748.001$$

Total Direct Medical Costs 2050:

$$5748.001 * 128{,}325{,}367 = \$\mathbf{737{,}614{,}277{,}888.96}$$

d. "Reduced Productivity"

2018: **$71,400,000,000**

Increased Absenteeism 2017: $3,300,000,000

Reduced Productivity While at Work 2017: $26,900,000,000

Reduced Productivity for Those not in the Labor Force 2017: $2,300,000,000

Inability to Work from Disease-Related Disability 2017: $37,500,000,000

Standard Inflation Rate: 2%

Total Reduced Productivity 2017:

$$(3.3 + 26.9 + 2.3 + 37.5) * 1{,}000{,}000{,}000 = 70{,}000{,}000{,}000$$

Total Reduced Productivity 2018:

$$70{,}000{,}000{,}000 * 1.02 = \$\mathbf{71{,}400{,}000{,}000}$$

2050: **$217,860,757,182.39**

Reduced Productivity 2018: 71,400,000,000

Americans with Diabetes 2018: 42,056,363

Americans with Diabetes 2050: 128,325,367

Reduced Productivity per Person with Diabetes 2018:

$$\frac{71{,}400{,}000{,}000}{42{,}056{,}363} = 1697.722$$

Total Reduced Productivity 2050:

$$1697.722 * 128{,}325{,}367 = \$\mathbf{217{,}860{,}757{,}182.39}$$

e. "Early Mortality"

2018: **$20,298,000,000**

Early Mortality 2017: 19,900,000,000

Standard Inflation Rate: 2%

Total Early Mortality 2018:

$$19{,}900{,}000{,}000 * 1.02 = \$\mathbf{20{,}298{,}000{,}000}$$

2050: **$61,934,700,970**

Early Mortality 2018: 20,298,000,000

Americans with Diabetes 2018: 42,056,363

Americans with Diabetes 2050: 128,325,367

Early Mortality per Person with Diabetes 2018:

$$\frac{20{,}298{,}000{,},000}{42{,}056{,}363} = 482.638$$

Total Early Mortality Costs 2050:

$$482.638 * 128{,}325{,}367 = \$\mathbf{61{,}934{,}700{,}970}$$

f. "Average Cost per Person with Diabetes"

2018: **$7,928**

$$\frac{241{,}740{,}000{,}000 + 71{,}400{,}000{,}000 + 20{,}298{,}000{,}000}{42{,}056{,}363} = \$\mathbf{7{,}928}$$

2050: **$7,928**

$$\frac{737{,}614{,}277{,}888.96 + 217{,}860{,}757{,}182.39 + 61{,}934{,}700{,}970}{128{,}325{,}367} = \$\mathbf{7{,}928}$$

g. "Average Cost per Citizen"

2018: **$1,014.00**

$$\frac{241{,}740{,}000{,}000 + 71{,}400{,}000{,}000 + 20{,}298{,}000{,}000}{328{,}835{,}763} = \mathbf{\$1{,}014.00}$$

2050: **$2,616.36**

$$\frac{737{,}614{,}277{,}888.96 + 217{,}860{,}757{,}182.39 + 61{,}934{,}700{,}970}{388{,}864{,}747} = \$\mathbf{2{,}616.36}$$

VI. Environmental Costs

A. Table 4: Gas Production by Livestock

Gas Production by Livestock (MMT)										
Gas/Source	**1990**	**2005**	**2015**	**2016**	**2017**	**2018**	**2020**	**2030**	**2040**	**2050**
$C0_2$										
Urea Fertilization	2.4	3.5	4.7	4.9	5.1	5.066	5.26	6.23	7.2	8.17
Total	**2.4**	**3.5**	**4.7**	**4.9**	**5.1**	**5.1**	**5.3**	**6.2**	**7.2**	**8.2**
CH_4										
Enteric Fermentation										
Beef Cattle	119.1	125.2	118.0	123.0	126.3	121.1	121.2	121.7	122.1	122.5
Dairy Cattle	39.4	37.6	42.6	43.0	43.3	42.6	42.9	44.6	46.2	47.8
Swine	2.0	2.3	2.6	2.6	2.7	2.6	2.7	2.9	3.2	3.4
Horses	1.0	1.7	1.5	1.5	1.4	1.7	1.7	1.9	2.0	2.2
Sheep	2.3	1.2	1.1	1.1	1.1	0.8	0.8	0.3	0.0	0.0
Goats	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
American Bison	0.1	0.4	0.3	0.3	0.3	0.2	0.2	0.4	0.4	0.4
Mules and Asses	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Manure Management										
Beef Cattle	3.1	3.3	3.1	3.3	3.4	3.2	3.2	3.3	3.3	3.3
Dairy Cattle	14.7	26.4	34.8	34.3	34.5	36.5	38.0	45.7	53.5	61.2
Swine	15.5	20.3	19.2	20.2	20.0	19.6	19.8	21.0	22.3	23.5
Horses	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Sheep	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Poultry	3.3	3.2	3.4	3.4	3.4	3.4	3.4	3.4	3.5	3.5
Total	**201.2**	**222.5**	**227.3**	**233.4**	**237.1**	**232.4**	**234.6**	**245.7**	**256.9**	**268.4**
N_20										
Manure Management										
Beef Cattle	5.9	7.2	7.7	8.1	8.6	8.3	8.4	9.3	10.1	11.0
Dairy Cattle	5.3	5.6	6.1	6.1	6.1	6.0	6.1	6.4	6.7	7.0
Swine	1.2	1.6	1.8	1.9	1.9	1.9	1.9	2.2	2.4	2.6
Sheep	0.1	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.4	0.5
Poultry	1.4	1.6	1.6	1.6	1.6	1.5	1.6	1.6	1.7	1.8
Horses	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**14.0**	**16.4**	**17.6**	**18.1**	**18.6**	**18.0**	**18.3**	**19.9**	**21.4**	**23.0**

a. Data for Each Category from 1990 - 2017[39]

[39] https://www.epa.gov/sites/production/files/2019-02/documents/us-ghg-inventory-2019-main-text.pdf

b. The data was used to create lines of best fit, which can be seen for each section below. Y is the gas production in MMT, and x is the year.

Gas/Source	Line of Best Fit
$C0_2$	
Urea Fertilization	y = 0.097x - 190.68
CH_4	
Enteric Fermentation	
Beef Cattle	y = 0.043x + 34.37
Dairy Cattle	y = 0.1623x - 284.91
Swine	y = 0.0234x - 44.577
Horses	y = -0.0445x + 90.645
Sheep	y = -0.0009x + 2.109
Goats	y = 0.0161x - 30.832
American Bison	y = 0.0062x - 12.277
Mules and Asses	y = 0.1
Manure Management	
Beef Cattle	y = 0.0034x - 3.634
Dairy Cattle	y = 0.7716x - 1520.6
Swine	y = 0.1223x - 227.24
Horses	y = -0.0036x + 7.293
Sheep	y = 0.0036x - 3.864
Poultry	y = 0.2
N_20	
Manure Management	
Beef Cattle	y = 0.085x - 163.28
Dairy Cattle	y = 0.0305x - 55.52
Swine	y = 0.0248x - 48.191
Sheep	y = 0.0071x - 14.086
Poultry	y = 0.0071x - 12.786
Horses	y = 0.1

B. Table 5: Estimated Total Gas Production

Estimated Total Gas Production (MMT)							
Gas/Source	**1990**	**2005**	**2015**	**2016**	**2017**	**2018**	**2050**
$C0_2$							
Urea Fertilization	2.4	3.5	4.7	4.9	5.1	5.1	8.2
CH_4							
Enteric Fermentation	164.2	168.9	166.5	171.9	175.4	169.5	176.7
Manure Management	37.1	53.7	60.9	61.5	61.7	62.9	91.7
Total	201.3	222.6	227.4	233.4	237.1	232.4	268.4
N_20							
Manure Management	14	16.5	17.6	18.2	18.7	18.0	23.0

Each of these are a simple sum from the previous table, Table 4.

C. Table 6: The Social Cost of Greenhouse Gases per Ton

The Social Cost of Greenhouse Gases per Ton		
Gas	**2018**	**2050**
$C0_2$	$ 49.24	$ 85.79
CH_4	$ 1,392.58	$ 3,108.44
N_20	$ 17,655.92	$ 33,571.11

a. "$C0_2$"

2018: **$42.24**

Standard Inflation Rate: 2%

All data provided was in 2007 dollars[40]

3% Average 2015: 36

3% Average 2020: 42

Increase per Year

$$\frac{42-36}{5} = 1.2$$

2018:

$$\left(36 + (1.2 * 3)\right) * (1.02^{11}) = \$\mathbf{42.24}$$

[40] https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

2050: **$85.79**

Standard Inflation Rate: 2%

3% Average 2050: 69

2050:

$$(69 * (1.02^{11})) = \$\mathbf{85.79}$$

b. "CH_4"

2018: **$1,392.58**

Standard Inflation Rate: 2%

All data provided was in 2007 dollars[41]

3% Average 2015: 1000

3% Average 2020: 1200

Increase per Year

$$\frac{1200-1000}{5} = 40$$

2018:

$$(1000 + (40 * 3)) * (1.02^{11}) = \$\mathbf{1{,}392.58}$$

2050: **$3,108.44**

Standard Inflation Rate: 2%

3% Average 2050: 2500

2050:

$$(2500 * (1.02^{11})) = \$\mathbf{3{,}108.44}$$

c. "N_20"

2018: **$17,655.92**

Standard Inflation Rate: 2%

All data provided was in 2007 dollars[42]

3% Average 2015: 13,000

3% Average 2020: 15,000

Increase per Year

$$\frac{15{,}000-13{,}000}{5} = 400$$

2018:

$$(13{,}000 + (400 * 3)) * (1.02^{11}) = \$\mathbf{17{,}655.92}$$

2050: **$33,571.11**

Standard Inflation Rate: 2%

3% Average 2050: 27,000

2050:

$$(27{,}000 * (1.02^{11})) = \$\mathbf{33{,}571.11}$$

[41] https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

[42] https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html

D. Table 7: Total Cost of Greenhouse Gases from Animal Agriculture

Total Cost of Greenhouse Gases from Animal Agriculture				
Greenhouse Gas		**2018**		**2050**
$C0_2$				
Production from Animal Agriculture		5.1		8.2
Social Cost per MMT	$	49,240,000	$	85,790,000
Total Social Cost	$	251,124,000	$	703,478,000
Social Cost per Person	$	0.76	$	1.81
CH_4				
Production from Animal Agriculture		232.4		268.4
Social Cost per MMT	$	1,392,580,000	$	3,108,440,000
Total Social Cost	$	323,684,053,784	$	834,288,821,268
Social Cost per Person	$	984.33	$	2,145.45
N_20				
Production from Animal Agriculture		18.018		22.962
Social Cost per MMT	$	17,655,920,000	$	33,571,110,000
Total Social Cost	$	318,124,366,560	$	770,859,827,820
Social Cost per Person	$	967.43	$	1,982.33
Total Cost Per Person	**$**	**1,952.52**	**$**	**4,129.59**

a. Production from Animal Agriculture (MMT) is from Table 5.

b. Social Cost per MMT is from Table 6.

c. Total Social Cost = Production from Animal Agriculture * Social Cost per MMT

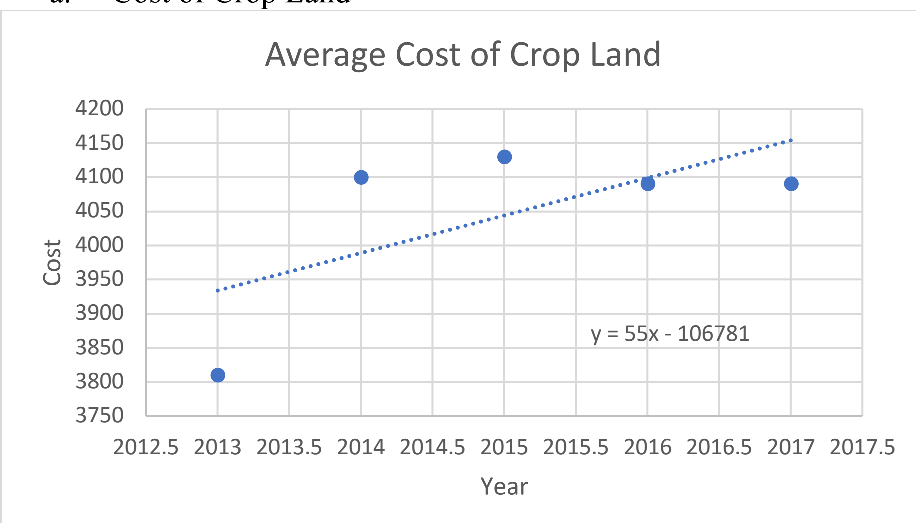
d. Social Cost Per Person = Total Social Cost / Population
Population 2018: 328,835,76
Population 2050: 388,864,747

VII. Land Costs

A. Table 8: Cost of Land for Animal Agriculture

Cost of Land for Animal Agriculture				
		2018		2050
Cost of Crop Land	$	4,293.18	$	6,088.38
Cost of Grazing Land	$	1,441.26	$	2,714.22
Acres for Livestock Feed		112,179,420		145,824,000
Acres for Livestock Grazing		727,862,000		813,750,000
Total Cost	**$**	**1,530,644,828,476**	**$**	**3,096,528,450,120**

a. "Cost of Crop Land"



2018: **$4,293.18**

Line of Best Fit: y = 55x – 106781

Data from 2013-2017[43]

Total Cost of Crop Land 2018:

$$(55 * 2018) - 106781 = \$\mathbf{4,293.18}$$

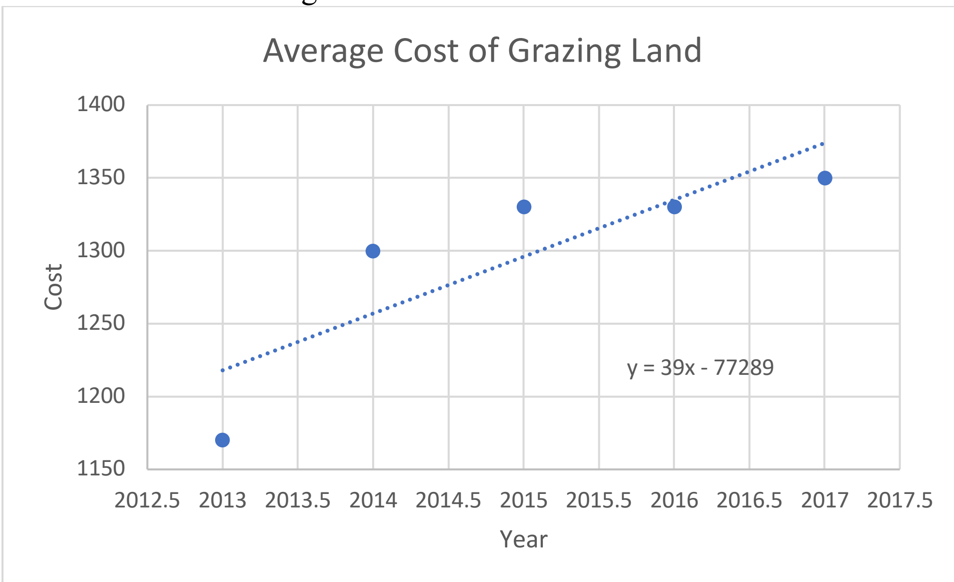
2050: **$6,088.38**

Total Cost of Crop Land 2050:

$$(55 * 2050) - 106781 = \$\mathbf{6,088.38}$$

[43] https://www.usda.gov/nass/PUBS/TODAYRPT/land0817.pdf

b. “Cost of Grazing Land”



2018: **$1,441.26**

Line of Best Fit: y = 39x – 77289

Data from 2013-2017[44]

Total Cost of Cropland 2018:

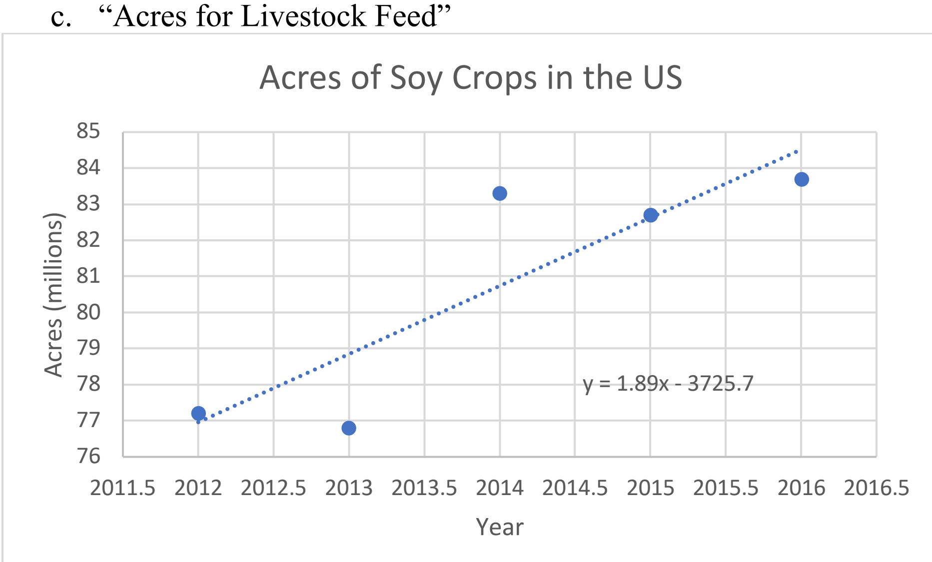
$$(39 * 2018) - 77289 = \$\mathbf{1{,}441.26}$$

2050: **$2,714.22**

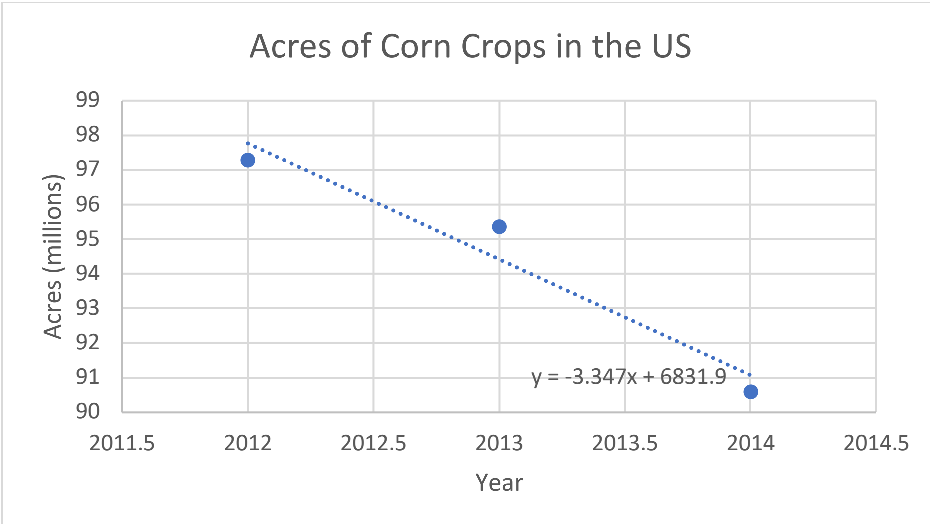
Total Cost of Cropland 2050:

$$(39 * 2050) - 77289 = \$\mathbf{2{,}714.22}$$

c. “Acres for Livestock Feed”



[44] https://www.usda.gov/nass/PUBS/TODAYRPT/land0817.pdf



2018: **112,179,420**

Percentage of Soy Crop Used for Livestock: 98%[45]

Percentage of Corn Crop Used for Livestock: 33%[46]

Data for Soy Crops from 2012-2016[47]

Data for Corn Crops from 2012-2014[48]

Line of Best Fit for Soy Crops: y = 1.89x – 3725.7

Line of Best Fit for Corn Crops: y = -3.347x + 6831.9

Acres of Soy 2018:

$$(1.89 * 2018) - 3725.7 = 88.32 \text{ million}$$

Acres of Corn 2018:

$$(-3.347 * 2018) + 6831.9 = 77.654 \text{ million}$$

Total Acres of Cropland for Animal Agriculture 2018:

$$(88{,}320{,}000 * .98) + (77.654 * .33) = \mathbf{112{,}179{,}420}$$

2050: **145,824,000**

Acres for Livestock Feeding 2018:

$$(1.89 * 2050) - 3725.7 = 148.8 \text{ million}$$

Acres of Corn 2050:

$$(-3.347 * 2050) + 6831.9 = 0^*$$

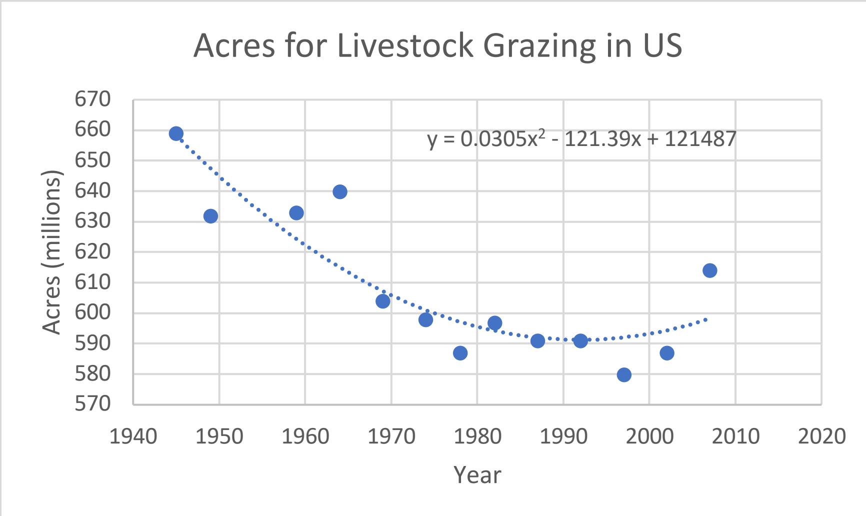
This results in a negative number, so zero is used.

Total Acres of Cropland for Animal Agriculture 2018:

$$(148{,}800{,}000 * .98) = \mathbf{145{,}824{,}000}$$

45 http://www.wisoybean.org/news/soybean_facts.php
46 http://worldofcorn.com/#corn-feed-by-species
47 https://www.usda.gov/oce/forum/2019/outlooks/Grains_and_Oilseeds.pdf
48 https://www.usda.gov/oce/forum/2019/outlooks/Grains_and_Oilseeds.pdf

d. "Acres for Livestock Grazing"



2018: **727,862,000**

Data for Acres for Livestock Grazing from 1945 – 2007[49]

Best Fit Line for Acres for Livestock Grazing:

$$y = 0.0305x^2 - 121.39x + 121487$$

Acres for Livestock Grazing 2018:

$(.0305 * 2018^2) - 121.39 * 2018 + 121487 =$ **727,862,000**

2050: **813,750,000**

Acres for Livestock Grazing 2050:

$(.0305 * 2050^2) - 121.39 * 2050 + 121487 =$ **813,750,000**

e. "Total Cost"

2018: $**1,530,644,828,476**

Cost of Crop Land 2018: 4,293.18

Cost of Grazing Land 2018: 1,441.26

Acres for Livestock Feed 2018: 112,179,420

Acres for Livestock grazing 2018: 727,862,000

Total Cost 2018:

$(4{,}293.18 * 112{,}179{,}420) + (1{,}441.26 * 727{,}862{,}000) =$

$1,530,644,828,476

2050: **$3,096,528,450,120**

Cost of Crop Land 2050: 6,088.38

Cost of Grazing Land 2050: 2,714.22

Acres for Livestock Feed 2050: 145,824,000

Acres for Livestock grazing 2050: 813,750,000

Total Cost 2050:

$(6{,}088.38 * 145{,}824{,}000) + (2{,}714.22 * 813{,}750{,}000) =$

$3,096,528,450,120

[49] https://www.ers.usda.gov/data-products/major-land-uses/major-land-uses/#Grassland%20pasture%20and%20range

B. Table 9: Cost of Land for Increase in Soy Demand

Cost of Land for Increase in Soy Demand				
		2018		**2050**
Cost of Crop Land	$	4,293.18	$	6,088.38
Pounds of Extra Soy Needed		12,717,947,938		15,039,609,932
Pounds of Soy per Acre		2400		2400
Total Acres Needed		5,299,145		6,266,504
Total Cost	**$**	**22,750,183,219**	**$**	**38,152,858,465**

a. "Cost of Crop Land"
Calculated in Table 8

b. "Pounds of Extra Soy Needed"
2018: **12,717,947,938**
Yearly Pounds per Person:
Meat Analogues: 6.27
Tofu: 25.51
Soy Milk: 60.51
Percentage of Soy Needed for Soy Milk: 12.5%[50]
Population 2018: 328,835,763
Vegetarian Population 2018: 6,576,715[51]
Vegan Population 2018: 1,644,178[52]
Total Pounds of Extra Soy Needed 2018:
$(6.27 + 25.51) * (328{,}835{,}763 - 6{,}576{,}715) + (60.51 * .125) * (328{,}835{,}763 - 1{,}644{,}178) = \mathbf{12{,}717{,}947{,}938}$
2050: **15,039,609,932**
Population 2050: 388,864,747
Vegetarian Population 2050: 7,777,294
Vegan Population 2050: 1,944,323
Total Pounds of Extra Soy Needed 2050:
$(6.27 + 25.51) * (388{,}864{,}747 - 7{,}777{,}294) + (60.51 * .125) * (388{,}864{,}747 - 1{,}944{,}323) = \mathbf{15{,}039{,}609{,}932}$

50 https://www.soya.be/how-to-make-soy-milk.php
51 http://veganbits.com/vegan-demographics-2017/
52 http://veganbits.com/vegan-demographics-2017/

c. "Pounds of Soy per Acre"
2018 and 2015: **2,400**
Bushels of Soy per Acre: 40[53]
Pounds per Bushel: 60[54]
Pounds of Soy per Acre
$$40 * 60 = \mathbf{2{,}400}$$

d. "Total Acres Needed"
2018: **5,299,145**
Pounds of Extra Soy Needed: 12,717,947,938
Pounds of Soy per Acre: 2400
Total Acres Needed 2018:
$$\frac{12{,}717{,}947{,}938}{2400} = \mathbf{5{,}299{,}145}$$
2050: **6,266,504**
Pounds of Extra Soy Needed: 15,039,609,932
Pounds of Soy per Acre: 2400
Total Acres Needed 2050:
$$\frac{15{,}03{,}609{,}932}{2400} = \mathbf{6{,}266{,}504}$$

e. "Total Cost"
2018: **$22,750,183,219**
Cost of Crop Land 2018: 4,293.18
Total Acres Needed 2018: 5,299,145
Total Cost 2018:
$$5{,}299{,}145 * 4{,}293.18 = \$\mathbf{22{,}750{,}183{,}219}$$
2050: **$38,152,858,465**
Cost of Crop Land 2050: 6,088.38
Total Acre Needed 2050: 6,266,504
Total Cost 2050:
$$6{,}266{,}504 * 6{,}088.38) = \$\mathbf{38{,}152{,}858{,}465}$$

[53] http://www2.ca.uky.edu/agcomm/pubs/agr/agr188/agr188.pdf
[54] http://www2.ca.uky.edu/agcomm/pubs/agr/agr188/agr188.pdf

C. Table 10: Land Cost Saved if Plant-Based Diet Implemented

Land Cost Saved if Plant-Based Diet Implemented				
		2018		**2050**
Cost of Land for Animal Agriculture	$	1,530,644,828,476	$	3,096,528,450,120
Cost of Land for Soy Increase	$	(22,750,183,219)	$	(38,152,858,465)
Total Cost Saved	$	1,507,894,645,256	$	3,058,375,591,655
Cost Saved per Person	**$**	**4,585.56**	**$**	**7,864.88**
Acres per Person		**2.54**		**2.45**

a. "Cost of Land for Animal Agriculture"
Calculated in Table 8

b. "Cost of Land for Soy Increase"
Calculated in Table 9

c. "Total Cost Saved"
Cost of Land for Animal Agriculture – Cost of Land for Soy Increase

d. "Cost Saved per Person"
Total Cost Saved / Population

e. "Acres per Person"
2018: **2.54**

Cost of Crop Land 2018: 4,293.18
Cost of Grazing Land 2018: 1,441.26
Cost Saved per Person 2018: 4,585.56
Acres for Soy Increase 2018: 5,299,145
Acres for Livestock Feed 2018: 112,179,420
Acres for Livestock Grazing 2018: 727,862,000
Acres Saved of Crop Land 2018:

$$112{,}179{,}420 - 5{,}299{,}145 = 106{,}880{,}275$$

Crop Land Percentage of Total Land 2018:

$$\frac{106{,}880{,}275}{727{,}862{,}000+106{,}880{,}275} = 12.8\%$$

Acres per Person 2018:

$$\frac{4{,}585.56}{(.128*4{,}293.18)+((1-.128)*(1{,}441.26))} = \mathbf{2.54}$$

2050: **2.45**

Cost of Crop Land 2050: 6,088.38

Cost of Grazing Land 2050: 2,714.22
Cost Saved per Person 2050: 7,864.88
Acres for Soy Increase 2050: 6,266,504
Acres for Livestock Feed 2050: 145,824,000
Acres for Livestock Grazing 2050: 813,750,000
Acres Saved of Crop Land 2050:

$$145{,}824{,}000 - 6{,}266{,}504 = 139{,}557{,}496$$

Crop Land Percentage of Total Land 2050:

$$\frac{139{,}557{,}496}{813{,}750{,}000+139{,}557{,}496} = 14.6\%$$

Acres per Person 2050:

$$\frac{4{,}7{,}864.88}{(.146*6{,}088.38)+((1-.146)*(2{,}714.22))} = \mathbf{2.45}$$

VIII. Water Usage

A. Table 11: Total Water Footprint

Total Water Footprint			
Food Category	**Difference in Consumption (lbs. per year)**	**Gallons of Water (per lbs.)**	**Water Footprint**
Fruit	148.87	127.07	18,916
Vegetables	84.49	42.53	3,594
Starch	70.81	51.12	3,620
Tofu and Meat Analogues[55]	60.35	122.00	7,363
Soy Milk[56]	60.35	15.37	927
Nuts	14.48	1197.10	17,339
Drinking Water	352.45	8.33	2,936
Cow/Pig	-14.08	2036.11	(28,668)
Chicken	-18.51	571.27	(10,574)
Milk	-139.94	134.73	(18,854)
Cheese[57]	-19.55	896.00	(17,517)
Eggs	-11.35	431.26	(4,895)
Butter	-3.06	733.47	(2,244)
Total Water Saved			**(28,058)**

[55] Tofu and Meat Analogues were multiplied by 2 to equal a full cup, which happens to be a pound of tofu/meat analogues.
[56] Soy Milk used the same number as tofu but was adjusted to reflect that only 12.5% was truly soy, and then the rest of the water was calculated for.
[57] Cheese was multiplied by 16 to be in lbs.

a. “Difference in Consumption”
   Difference in Consumption = (Vegans - Nonvegetarians)*365
   From “Patterns of Food Consumption Among Vegetarians and Non-Vegetarians”

b. “Gallons of Water”
   Most Data is in m^3/ton (Other is specified in footnotes)
   1 Cubic Meter of Water is 264.172 Gallons[58]
   1 Ton is 2000 lbs.
   Gallons of Water = $\frac{data\ (\frac{m^3}{ton})}{2000\,\frac{lbs}{ton}} \times 264.172\,\frac{Gallons}{m^3}$

c. “Water Footprint”
   Water Footprint = Difference in Consumption * Gallons of Water

[58] https://www.calculatorology.com/how-many-gallons-in-a-cubic-meter/