Bradyn Kawcak
ENVIR 492
9/21/15
<u>ANNOTATED BIBLIOGRAPHY</u>

Research Questions

I. Is there economic validity for incorporating a single succession, vegetable dominant intercropping system on a small, urban commercial farm?
II. Is the alternate growing method of intercropping an environmentally and socially sustainable option for food production, relative to the current practice of monoculture?

Tol, Richard S.j. "The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties." Energy Policy 33, no. 16 (June 5, 2004): 2064-074. Accessed September 14, 2015. doi:10.1016/j.enpol.2004.04.002.

Richard Tol's paper in the *Energy Policy 33* academic journal statistically analyzes marginal damage estimations of carbon emissions from a pool of published studies. The data is collected from 28 different sources, consisting of 103 dollar valued estimations. Empirical averages and content observations were examined resulting in the conclusion that "One can therefore safely say that, for all practical purposes, climate change impacts may be very uncertain but, is unlikely that the marginal damage costs of carbon dioxide emissions exceed $50/tC and are likely to be substantially smaller than that," (p. 2073). Tol's reasoning is a substantial piece of my carbon impact estimations from my experimental plots.

Even though numerical values were found in this study, it is apparent that there is a lack of general consensus among these estimations. In attempt to analyze the data based on the quality of the reports, Tol compared the marginal damage estimations between peer-reviewed studies and the entire pool of studies. "The peer- reviewed work is less pessimistic about the impacts of climate change. The mean marginal damage cost, for instance, is $50/tC in the peer-reviewed literature but $93/tC in all literature," (p. 2070). The discrepancies between the estimations in this paper's semi-skewed data made Tol a little more conservative about the real marginal damage cost. One reason for this relative optimism about carbon emission impacts is based on what he calls equity weighting between studies. Citing a different reference, Tol says, "There are two ''ethical'' parameters that flow into a marginal damage cost estimate. The first is the aggregation over time (the discount rate). The second is the aggregation over countries (equity weighing). Equity weighing leads to a higher estimate of the marginal damage costs and particularly to greater uncertainty," (p. 2072). It should be noted that it has been theoretically established that including equity weighting is necessary in secondary analyses such as the one in this paper.

The marginal damage estimate is key part of the economic translations for my carbon and soil nutrient calculations. In order to validate the number I use, I reference the reasoning of this paper by saying that there is a $50 price on the environment, and society, for every ton of carbon emitted into the atmosphere. I endorse using this estimate in my project, because this source concludes that the actual estimate probably doesn't exceed $50, and by the fact that $50 was the mean estimate for all peer-reviewed studies.

Jeavons, John. How to Grow More Vegetables: (and Fruits, Nuts, Berries, Grains, and Other Crops) than You Ever Thought Possible on Less Land than You Can Imagine. Berkeley: Ten Speed Press, 2012.

This book was one of the many garden guides I examined during my literature review, and Jeavon's section on companion planting helped me setup and design my experimental plots. He defines the term companion planting as "the placing together of plants with complementary demands," (p.53). These complementary demands are the leading supporting argument for why intercropping might be a valuable growing alternative. Jeavons emphasized that intercropping systems need proper structure, thereby assisting my project by giving spacing and crop variety information. There is not a lot of scientifically backed guidelines for how to appropriately space an intercropped bed, however this gardening book gives a very brief and logical rule to follow when planting companions; "To figure out spacing for intercropped vegetables, add up their recommended spacing and divide by the number of different vegetables being planted," (p.137). While designing my plot I followed this rule and ended up having a uniform spacing regimen of 2.33 ft. on the three-intercrop plots. At the end of the companion planting section, Jeavons lists what crops have known to work well together, including a relationship between cucumbers and lettuce, as well as cucumbers and beans (p.66).

The biggest downfall of this source is that there is no scholarly backing to this book, however this has been a common problem in my research. There is plenty of academic work on the effects of intercropping, but little to no information on appropriate intercropping design. In order to overcome this problem I researched multiple gardening guides that included information on intercropping or companion planting. Most of these sources included similar spacing and vegetable companion recommendations, however this source is by far the most explicit and well explained of them all.

Sutton, Mark A. The European Nitrogen Assessment: Sources, Effects, and Policy Perspectives. Cambridge, UK: Cambridge University Press, 2011. Accessed September 16, 2015. http://www.nine-esf.org/ENA-Book.

Agricultural manipulation of nitrogen affects the terrestrial, marine, and atmospheric pools of the chemical element, and the *European Nitrogen Assessment* tries to value the fluctuations between these pools. Chapter 22 (p.513) outlines the costs and benefits of nitrogen in the EU-27 environment, therefore including empirical data on estimated damages of nitrogen pollution to the ecosystem, health, and climate of the geographic region. I directly use the damage cost estimates of gaseous N20 and NOx found on Table 22.13 (p. 554), in order to predict the value my plots have on emitting the compounds in the form of potential fertilizer application. On key element about this table is that it gives average percentages for how much of the agriculture industry is responsible for the external damage being caused. I implement these percentages when using the damage estimates for N20 and NOx emissions. On issue with this data is that the units for the damage estimates are not applicable to the amount applied nitrogen fertilizer. This assessment solves this problem by recommending "combining unit damage costs for N-compounds in Table 22.13 with emission factors for N-compounds per unit of N application (see e.g. Velthof *et al.*, 2009)," (p. 533). Because of this reference recommendation, which is apart of this annotated bibliography, I am able to use some of my soil data to calculate the social and environmental costs of N20 and NOx emissions caused by replacing nitrogen in my agricultural plots.

Even though this paper gives me a way to calculate an important economic translation, it does have some disadvantages. Obviously the data is collected from 27 different European countries, addressing nothing about agriculture in the United States. However, I feel that because the assessment has such a massive sample size the estimates are fairly general for all agriculture above the Tropic of Cancer. In addition, the paper separates damage estimates based on the country being observed. During the research I do during ENVIR 492 I could collect damage estimates only from countries that have similar climates and ecosystems to the Pacific Northwest. Many people don't think about the effect fertilizers have on the air we breathe, and I think this paper addresses this by showing what that effect might financially look like.

Velthof, G.l., J.p. Lesschen, J. Webb, S. Pietrzak, Z. Miatkowski, M. Pinto, J. Kros, and O. Oenema. "The Impact of the Nitrates Directive on Nitrogen Emissions from Agriculture in the EU-27 during 2000–2008."Science of The Total Environment 468-469 (2014): 1225-233. Accessed September 19, 2015. doi:10.1016/j.scitotenv.2013.04.058.

There are three main types of nitrogen based gaseous pollutants that result from the use of fertilizer: NH4, N20, and NOx. The amount of nitrogen applied to an agricultural field, in the form of fertilizer, causes a negative environmental and social externality due to the emissions of these nitrogen pollutants. This academic report provides me with information about what percent of applied nitrogen gets emitted in the form of gaseous compounds N20 and NOx; I refer to these numbers as emissions factors. Table 4 on page 32 gives the emission factor estimation of N2O on arable clay soil as .75%. This essentially means that for every pound of nitrogen fertilizer applied to my plots, .0075 lbs. will be emitted in the form of atmospheric N20. Similarly, the authors of this paper reference a different study by stating "They calculated an average fertilized induced emission of 0.55% of the N applied for NOx," (p. 34). Combining these emission factors to the empirical data on the *Sutton 2011* report will allow me to calculate the value of nitrogen based fertilizer emission if fertilizer had to be applied to the plots after the experiment concluded.

The drawbacks of this assessment paper match the drawbacks of the *Sutton 2011* report. Most of the modeling tools, references and data in this report are European, making it not perfectly representative of the region my plots are growing in. In addition, "The general objective of this project was to assess the effects of measures in the Nitrates Directive on gaseous nitrogen (N) emissions to the atmosphere," (p. 5), which does not have much to do with the economic implications of these emissions. However, the data provided in this paper act as a crutch to the damage estimates in the *Sutton 2011* paper.

Botterweg, Peter, Lars Bakken, and Eirik Romstad. "Nitrate Leaching from Agricultural Soils: Ecological Modelling under Different Economic Constraints." Ecological Modelling 75-76 (1994): 359-69. Accessed September 18, 2015. doi:10.1016/0304-3800(94)90032-9.

Similar to what I want to do with my project, this academic paper evaluates economic theory with ecological systems through modeling tools and potential environmental tax rates. The authors of this paper establish a theoretical relationship between environmentally accounted tax levels and the amounts of expected fertilizer use, as seen on Table 1 (p. 363). Then using ecological modeling of Maximum Plant Uptake (MPU) and fertilizer application, they were able to establish what level of MPU efficiently used up the fertilizer. After taking every thing it to account, they were able to express the estimated reduction in nitrogen leaching based on what the tax rate of nitrogen-based fertilizer could be. These results can be summarized on Table 3 of the paper (p.367).

I closely work with the numbers on Table 3 in two ways. First, I use my soil data to see how much fertilizer would be needed after harvest to replace the amount of nitrogen lost. I use this calculation to see what equivalent tax would be given the amount of needed fertilizer. Secondly, using my replacement cost of fertilizer N estimate, and the tax estimates of the paper, I am able to create a dollar value for the environmental cost of nitrate leaching from my experiment. Sadly, levels of nitrate leaching are not consistent on every farm in the world; therefore the authors admit, "that the effect of taxes can hardly be measured in field experiments, because of the variation in leaching caused by variability of the weather between years," (p. 368). Given this fact, my comparisons between the environmental costs of nitrogen leaching might need to be taken with a grain of salt.

West, Tristram O., and Gregg Marland. "A Synthesis of Carbon Sequestration, Carbon Emissions, and Net Carbon Flux in Agriculture: Comparing Tillage Practices in the United States." Agriculture, Ecosystems & Environment 91, no. 1-3 (2002): 217-32. Accessed September 16, 2015. doi:10.1016/s0167-8809(01)00233-x.

This paper is very valuable to my project in that it addresses two relevant agricultural subjects, carbon sequestration and carbon emissions. In essence, this paper puts potential agricultural sequestration of CO2 against the energy level from inputs found on a typical commercial farm, in order find a net carbon flux for agriculture. "The environmental service by farmers and other landowners could provide a source of carbon-emission credits to be sold to emitters of C and hence provide an additional source of income to farmers," (p. 218). The authors reasoning for this added source of income validates why I use a marginal damage estimate on carbon emissions when considering soil and biomass carbon for my experiment. I think it is important to include some positive externalities in my analysis, such as this carbon sequestration idea, because most of the external evaluations of this project have negative costs to the environment.

There are a lot of different carbon emission sources on a farm, and this paper tries to capture a handful of these sources by collecting national tillage, seed production, irrigation, pesticide implementation, and fertilizer production energy requirements. Even though all of these empirical assessments would have been very relevant to my project, most of the content is not applicable to the operations of the UW Farm. For instance, Table 6 on page 224 has data that pertains to costs, fossil fuel energy requirements, and carbon emissions from a handful of different seed production inputs, however cucumbers, lettuce and beans were not part of the seed listing. Even though this is the case for most of the carbon emitting sources being analyzed, Table 3 on page 221 has numerical data that is very useful to my project. Table 3 gives carbon emissions levels for every Mega gram of nitrogen, phosphorus, potassium, and limestone fertilizer produced in the United States. Once again using my marginal damage of carbon emissions estimate, I can calculate a part of the environmental cost for replacing soil nutrients on my plots, by analyzing production emissions of fertilizer replacements.

Silva, George. "Factsheet on Soil Fertility and Nutrient Management." Accessed September 18, 2015. http://www.nine-esf.org/ENA-Book.

This factsheet written by George Silva at Michigan State University might be the shortest source of this bibliography, but it contains very important economical figures on the costs of fertilizer. Silva simplifies some market features for soil fertility using fertilizers that contain nitrogen, phosphorus, and/or potassium as the goods being sold. The purpose of identifying fertilizer characteristics is because "growers should be aware of the potential volatility of prices and understand their best options for purchasing fertilizer to suit their cropping system," (p. 1).

My project does not focus on volatile fertilizer markets, however evidence related to fertilizer prices helps me fiscally evaluate replacement costs of fertilizer. The most helpful aspect of this source is that Silva collected 2011 USDA data about the prices per pound of single nutrient fertilizers. The statement, "a pound of N cost $0.55, a pound of P_2O_5 cost $0.69 and a pound of K_2O cost $0.48," (p. 3) allows me calculate the input costs for three of the chemicals found in my soil quality analysis. However, the phosphorus and potassium data in my soil results is not in the form of P205 and K20, whereas the prices listed on this factsheet are in compound form. The factsheet solves this problem by including the basic chemistry "conversion factors that convert the oxide form to elemental form: Equation 1. $P = P_2O_5/2.29$. Equation 2. $K=K_2O/1.21$," (p. 1). Even though these two components are very beneficial to the economic translations of my project, it should be mentioned that single nutrient fertilizer prices change daily. This inconsistency is mentioned on the factsheet, but hopefully using 2011 financial data should not drastically underrepresent current prices.

Drechsel, Pay, and Lucy A. Gyiele. The Economic Assessment of Soil Nutrient Depletion: Analytical Issues for Framework Development. Bangkok: Internat. Board for Soil Research and Management, 1999. PDF.

This economic assessment condenses and analyzes observations from studies about soil nutrient depletion in African countries. Even though the paper mainly focuses on a modeling system known as NUTMON, it also outlines methods for economically analyzing soil nutrient depletion in an academic project. Unlike the other academic journals referenced, I take no empirical data from this source, rather information on how to collect replacement costs for soil nutrient data. The paper focuses on a Replacement Cost Approach, which "uses the costs that would have been incurred to replace a damaged asset. Although the technique uses market prices the valuation is based on potential behavior," (p. 29). I build on this approach by assuming throughout my project that a loss, or gain, in soil nutrients can be applicable to the amount of fertilizer needed to make up the difference. This methodology has thematic similarities to some of the steps taken in my soil nutrient based economic translations.

It is hard to calculate the fluxes of nutrients both in and out of agricultural beds because there are a lot of factors that need to be taken into account. Given the data I collect, I want to capture as many of these factors as I can in order to conduct a more accurate cost-benefit analysis. This paper gave me some ideas of what environmental variables I could collect by stating, “Fertilizer efficiency, i.e. the real costs of replacement, would be higher if we take, for example, leaching of applied N and K into account during the replacement process…Fertilizer retail price… Increase in atmospheric carbon due to additional consumption of fossil carbon for fertilizer production,” (p.30). Outlining how to conduct a Replacement Cost Approach with soil nutrient depletion data, and expressing what variables need to be collected in order to make an accurate real cost estimate are by far the two big benefits I obtained from researching the contents of this economic assessment. It should be noted that the replacement cost approach was one of three economic methods explained in this paper, but I did not feel that I needed to include every methodology since my data is not applicable to some of the othersteps described.

Stone, R.P., and D. Hilburn. "Universal Soil Loss Equation (USLE)."SpringerReference, 2011. Accessed September 21, 2015. doi:10.1007/springerreference_225394.

There is no form of agriculture that doesn’t somehow disturb the soil, making soil loss a common aspect of farming. A model known as the Universal Soil Loss Equation (USLE) has become a widely adopted method for calculating the amount of soil lost within a specific region. This factsheet outlines how to estimate the amount of soil lost in tonnes per hectare, which becomes a key variable in the Off-Site Cost of Soil Loss economic translation. This translation includes the five variables that are apart of the USLE, which I calculate given the context of my plots. For example, the C variable “is the crop/vegetation and management factor. It is used to determine the relative effectiveness of soil and crop management systems in terms of preventing soil loss,” (p. 1). In order to calculate this value I had to choose a crop type factor and a tillage method factor from their respected tables on Table 4A and 4B, located on page 4, and then multiply the two factors to get the C value. The cost of soil lost translation builds quite heavily on the USLE value, making it the only translation I conduct that doesn’t rely on any tangible collected data. Therefore, this source, and another, completely represents the estimated cost of soil loss in my cost-benefit analysis.

One drawback to this source is that it is not the direct methodology used in the original establishment of USLE. It is instead a secondary description of how to collect USLE variables, through data tables provided on the factsheet. In addition, the factsheet is not sourced from an academic journal, making it subject to controversial content. However, due to the specificity of the factsheet, and the fact that it was published through a governmental organization, I feel pretty confident in the figures and methodology descriptions. Either way, I felt that having a value for soil erosion was better than not having one.

Poe, Gregory L. "Maximizing the Environmental Benefits per Dollar Expended": An Economic Interpretation and Review of Agricultural Environmental Benefits and Costs." Society & Natural Resources 12, no. 6 (1999): 571-98. Accessed September 21, 2015. doi:10.1080/089419299279452.

The main focus of this paper is to establish the notion that environmental benefits can be calculated and used to provide thoughtful and knowledgeable policies, explained through an agricultural perspective. Even though this paper did provide some useful, historically backed economic points, such as “proclaiming a regulatory philosophy, President Clinton's 1993 Executive Order 12866 states that agencies should adopt regulations only upon a reasoned determination that the benefits of the intended regulation justify the costs," (p. 7), this paper has mainly provided me with important soil loss damage estimates. The regionalized dollar value of soil loss per ton, found on Table 4 of page 45, has proven to be the key variable is estimating the cost of soil loss for my experimental plots. For now the cost of soil loss translation is the only translation pertaining to land degradation, but if I conduct further research on this topic during the autumn quarter, I could then re-use this estimate to transform scientific data in financial numbers.

One problem with using this specific damage estimate is that it is not an updated source. A lot of research has been done in the last fifteen years on the environmental effects of erosion, making the damage estimate from 1999 no longer truly representative. However, it is an academically approved paper that sources heavily from a wide array of interdisciplinary topics. Given this, and the need for a marginal damage of soil loss estimate, I am satisfied with using the papers data.