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Crude Oil Transport by Rail in NY State: Ecosystem Value at Risk

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Economics Thesis

Crude Oil Transport by Rail in NY State:
Ecosystem Value at Risk

Caroline Hobbs
April 6, 2016

Table of Contents

Acknowledgments

Introduction

Importance

Inspiration

Overview of Crude Oil

An Increase in the Supply of Oil

Oil Production and Transportation

Risk

The Impact of a Pipeline

Regulation and Policy: Agency and Response

The Need for Economic Analysis

Literature Review

Ecosystem Functions

Types of Ecosystem Services Valuation

Natural Capital & Ecosystem Services Valuation

Methods

Adaptation of Costanza and Liu's Study, *The Value of New Jersey's Ecosystem Services and Natural Capital*

Creation of a NY Specific Land Cover Typology

Table 1: Land Cover Typology Modification Flow Outline

Open freshwater and Estuaries

Value at Risk in the event of a crude oil train derailment and subsequent spill or explosion

Results

Table 2: Total Ecosystem Service Yearly Flows for Various Land Cover Types (NY State)

Table 3: Total Land Acreage by Land Cover Type, Ecosystem Functions, Cumulative Annual Value of ES for each Land Cover Type, and Total value for each ES in NY State

Discussion

Political Agency and Response

Policy Recommendations

Conclusions

Crude Transport in the context of Climate Change

References

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Introduction

The opportunity to write both a Capstone and a Thesis has provided me a unique opportunity to supplement what I've learned and what I hope to achieve in each discipline with the other. In my ES Capstone, I explore the decision-making processes of stakeholders in a local, risky, and hot topic area: crude oil transport by rail.

In my EC Thesis I address the same issue, but from a different angle. I use Robert Costanza's method of ecosystem valuation to value the ecosystem services in New York State via the benefit transfer method. I then predict the proportion of these services at risk if there were to be a train derailment, thereby placing monetary value on that environmental risk. I end by analyzing the current political status of the issue and making recommendations for future national, statewide, and local policies.

Importance

Ecosystem valuation is a difficult and controversial task (How do you put a price tag on nature?) but because natural resources often play an influential role in the economic decision making process for policy and program development, a clear and consistent valuation of resources is worthy, timesaving and beneficial in both the short and long run. Valuation of resources in the area will be quite a challenging task, but the importance of this issue and the clear potential for progress motivates me to work through any challenge presented during this process.

Inspiration

Part of my inspiration to confront the issue of crude oil transport from these two directions (ES and EC) is the clear gap between policy makers and community members. In this paper I aim to bridge this gap and provide the local government with information they may use to develop a more comprehensive risk management plan, and on a larger scale, aim to provide a disincentive for increased crude oil transport by rail in New York State. My Economics thesis aims to add a tangible economic disincentive to increased crude oil transport.

Overview of Crude Oil

Since 2010, the oil industry in the United States has expanded rapidly due to a considerable increase in the domestic oil supply (Maugeri, 2013). This increase is driven by natural capital and technological innovation, specifically two main factors: a rich store of crude

oil and natural gas discovered in North Dakota's Bakken Shale, and a technological innovation that has improved the efficiency of drilling for these energy resources, horizontal hydraulic fracturing (Price & LeFever, 2011). Meanwhile there exists a continued dependence on oil as a source of energy nationwide, and worldwide. With this rise in crude oil and natural gas supply, and a constant and ever increasing demand for domestic sources of energy, there is immense pressure to transport these unprecedented volumes crude oil from North Dakota to refineries on all coasts. While building new pipelines would be incredibly expensive and time consuming, already in existence, with no infrastructural hurdles to jump through, is a web of transportation that spans thousands of miles from Canada's resource rich Alberta tar sands, and North Dakota's Bakken Shale, to refineries on all coasts: railways. And so with the increase in crude oil supply in North Dakota, has come an extraordinary increase in the volume of crude oil transported by rail through the United States.

The Hudson River Valley in New York is a major link in this web, with New York State railways moving massive volumes of crude oil from the Bakken Shale and Canadian tar sands to the Port of Albany everyday, to be either rerouted or refined. Once this oil reaches Albany, billions of gallons are offloaded onto barges and ships, which will end their journey at various East Coast refineries; trains headed to refineries in the south are reloaded in Albany to continue their journey along the west side of the Hudson River, traveling through the Hudson River Valley Watershed and communities in Greene, Ulster, Orange, and Rockland counties.

An Increase in the Supply of Oil

The expansion of this web is the result of increased production of oil, specifically in the Bakken Shale and in the Canadian tar sands. Resources that would previously be inaccessible are now easily extracted with hydraulic fracturing and horizontal drilling technology. Hydraulic fracturing and horizontal drilling were first combined in 2000 in an oil field in Montana, where output proceeded to double every year, but few beyond the state paid much attention to the phenomenon (Levi, 2013, p. 54). Advances in computer technology have made extraction much more efficient (Montgomery and Smith, 2010, p. 31). Oil production via hydraulic fracturing has doubled in just three years. Total production of crude oil in the United States has increased from 1.9 billion barrels in 2009 to 3.1 billion barrels in 2014 annually (EIA 2015). The oil and gas boom is such that the EIA predicts that the U.S. will surpass Saudi Arabia as the world's top oil producer by 2020 (Chacon, 2013, p. 323). Increased production has led to demand for a comparable means of distribution, and in turn the expansive network of railways covering the United States is being utilized to transport over a million barrels of oil per day throughout the country, as of 2014. This is a sharp increase from the 2010 average of 55,000 barrels per day (Ingraham, 2015).

The utilization of a “virtual pipeline” or network of railways carrying oil across the United States has expanded vastly in the wake of the energy boom. According to North Dakota's Mineral Resources Department, the Bakken Shale is being exploited to meet, on its own, 1 million barrels per day or about 5% of the U.S.'s total oil consumption (Atkin, 2014). To contextualize, the Keystone XL Pipeline would transport only 830,000 barrels per day (Atkin, 2014). Canada is poised to quadruple its rail loading capacity from 180,000 barrels a day in 2013 to 900,000 barrels a day in the next few years (Krauss 2013). Needless to say, this is a growing industry (Blanchard, 2005).

Oil Production and Transportation

Much of the oil coming from the Bakken Shale and Canada is headed towards the Port of Albany, localizing the issue. If Hudson River Valley oil terminals reach their permitted throughput capacity via current proposed expansions, more than 7 billion gallons of crude oil will move through New York every year. Existing permits allow up to 5 billion gallons to move through NY per year (Riverkeeper, 2015). Much of the risk associated with this issue has come out of unpreparedness for the sudden increase in oil supply. This unexpected increase did not allow time for adequate infrastructure to develop to support the volume of oil coming out of the Bakken Shale (EIA, 2015). Currently, 70% of Bakken production is transported by rail. Often, transport by rail is the faster alternative to transport by pipeline, mainly because rail infrastructure already exists, connecting our nation's supply to an overwhelming demand.

Risk

The result of this supply increase and subsequent dependence on rail transport has meant a heightened risk to public safety, economic stability, and vital environmental systems that provide us with clean water, food, recreation etc. Three main factors associated with recent crude oil transport by rail are the leading sources of risk involved with this aspect of the oil industry: unprecedented volatility of the oil being transported, outdated and poorly regulated railways, and inadequate containers for the crude.

Bakken crude is some of the most volatile crude oil on record, up to 12 PSI (pounds per square inch). To put this in perspective, “Louisiana Light Sweet from the Gulf of Mexico has a vapor pressure of 3.33 PSI” (Atkin, 2014). The next most volatile after Bakken crude is Brent crude with a vapor-pressure reading of 6.71 PSI, from the North Sea. The third most volatile crude recorded is Basrah Light oil from Iraq, 4.8 PSI (Atkin, 2014). The oil’s volatility is its ability to evaporate and emit highly combustible gases. Bakken crude oil is more volatile than any crude oil that has been transported previously, which means we have less experience transporting it and an inevitably heightened risk.

The system of railways in the United States is plagued by outdated infrastructure: crumbling concrete, rust covered rail junctions, potholes, and run-down bridges (Kroft 2014). The current container for crude oil via rail is a DOT-111 railcar, a model which is too thin to be transporting such volatile oil. Hudson Riverkeeper describes these cars as “soda cans waiting to pop”. It has been suggested by various community influentials and interests groups that a double lining and thicker car should be required before the continued transport of crude by rail in NY State (and nationwide).

The volatility of the oil being transported coupled with inadequate railcars and outdated infrastructure has lead to 26 rail accidents in the past 5 years (Maugeri, 2013). Public safety is threatened by the potential for an explosion upon derailment; the oil spilled in an accident inevitably contaminates water supplies and poses an imminent risk to endangered species, such as the shortnose sturgeon, the piping plover, and the North Atlantic right whale by contaminating their critical habitat. The potential for an explosion upon derailment puts schools and property

in the area at a high risk, and would contaminate soil for decades, which would negatively impact the agricultural industry heavily- a significant concern for Saratoga County.

This threat has been made clear by a recent series of catastrophic derailments. The most fatal disaster occurred in Lac-Mégantic, Quebec, in July 2013, killing 47 people and burning a majority of the town's business district (Center for Biological Diversity, 2015). Another recent derailment and subsequent fire (February, 2015) affected the community of Mount Carbon, West Virginia, destroying a home and contaminating the local water supply (Riverkeeper, 2015). It is worth noting that despite railways and pipelines delivering over 99% of their crude oil safely, an increase in accidents is inevitable due to the increased volume of oil being transported in the US and the rapid growth in this sector (Ingraham, 2015). A derailment, oil spill and potential explosion would devastate Saratoga County, or any other county in NY through which oil trains pass. This devastation would cause incredible economic strain on NY- The Capital Region, and specifically Saratoga provides a significant portion of NY State's tax base (L. Greenholtz, Personal Communication, February 2016).

The Impact of a Pipeline

An oil pipeline has been proposed and would run from Albany to New Jersey, a transportation line that would open up Bakken Shale oil supplies to the Mid-Hudson Valley. Petroleum Solutions Management LLC, based out of FL has been actively seeking an appropriate route for this pipeline since March 2014 (Mid-Hudson News Network, 2015). Although this pipeline would alleviate pressure on barges and trains leaving the port of Albany, it would increase the frequency and pressure on the rail transportation routes incoming to Albany

from North Dakota and Alberta. The impetus for this pipeline is the result of the vast increase in supply of oil from the Bakken Shale.

Although a pipeline is a safer alternative to railways in that it does not pose the risk of an explosion upon derailment, a pipeline is a more dangerous alternative if there is a spill. Because railcars are containers (and this holds true with barges), only a finite amount of oil can spill into the environment. A pipeline, on the other hand, carries a *flow* of oil. If there is a breach in the pipeline that goes undetected for any given period of time, there is an unlimited amount of oil that could be spilled into the environment. Spills such as the Exxon Valdez disaster continue to have considerable effects on the Alaskan coastal ecosystem even twenty six years later. The environmental consequences are so longstanding that populations of orcas and Pacific heron are still suffering from the spill (Skirble, 2014). Similar, and becoming frequent, spills affect the environment and public safety on various spatial and temporal scales, contaminating water, endangering species, and posing different levels of risk to the safety of affected communities.

Regulation and Policy: Agency and Response

The rapid increase of crude oil supply and transport has been unanticipated, making it difficult for policymakers and regulations to keep up with the new reality of oil transport. Administrators on the state and federal level, such as the Association of American Railroads, have been slow to release new standards and regulations in response to increased production and transportation. Both the rail companies and the oil companies are displacing responsibility of improving safety standards. The rail cars are owned by the oil companies, which are responsible for the shipment of oil. In the wake of an accident, the railroad companies are typically held

accountable, but because they do not own the rail cars, they cannot address the problems associated with the type of car being unsuitable for the volatile oil. The railcar owners often receive amnesty from responsibility because of the poor state of the physical railroads. This, in turn, has nothing to do with the supply of oil they are providing. Oil companies, therefore, have no incentive to fix the railcars or spend the money to transition to safer cars (K. Hudson, Personal Communication, April 2015).

The rail infrastructure, which is owned by the American Association of Railroads, also poses problems with railroad safety. The American Association of Railroads carried out a round of railroad inspections in New York in late April of 2015 and the results pointed to many problems: bridges are crumbling; ties are not being held firmly to the tracks; and rail-braking systems are old and inadequate. These are the main problems leading to derailment and it is up to the railroad owners to maintain the infrastructure. Many of the sections in poor condition cross tributaries of the Hudson River and pose an ever-increasing threat to the wildlife and water safety of the area (K. Hudson, Personal Communication, April 2015).

The regulatory disconnect behind this issue is placed unfairly on the shoulders of the federal government, when in fact, states are issuing permits that have enabled the growth of the industry (K.Hudson, Personal Communication, April 2015). New York State's permitting actions have allowed the transloading of the oil that is coming into the Port of Albany both from the TT line (the Canadian Pacific line that comes down along the Adirondack Park along Lake Champlain) and the Effect Line that comes across from western New York. This has facilitated operational permits that enable the Global and Buckeye terminals in the Port of Albany to transload huge volumes to barges that are going downriver and to other train lines. The state also

has the ability to place fees on any oil that is crossing through their lands, therefore economically disincentivizing our dependence on oil.

The State Environmental Quality Review Act (SEQR) requires that anytime a state agency or local agency grants a decision on an application for expansion or construction, they have to first examine the environmental impacts associated with the proposed action. In all of the cases where the state approved permits to allow millions of gallons of oil to move through the Port of Albany, the applications were given a “negative declaration,” which essentially states there are no potential environmental impacts associated with the transportation (Riverkeeper, 2015). Though New York State may deem crude transport by rail to have no environmental impact, the derailment of oil cargo has the potential to severely degrade the environment through which such cargo passes. Crude oil transport by rail poses potential threats not only to humans, but also to environmentally sensitive areas, as well as important bodies of water that make up critical ecosystems. These areas would be devastated by a derailment resulting in an oil spill.

At the Federal level, there is the ability to provide new regulations to make oil transport safer. The United States has been waiting for these regulations for two years, since oil train explosions began threatening public safety. New regulations were put in place in May, 2015 by the US Department of Transportation. These changes are aligned with Canada’s modified regulations, which is a critical component that could have easily been overlooked. Changes include new, aggressive tank car standards, to which older tank cars are scheduled to adhere; enhanced braking standards that will ideally prevent pile-ups; new protocols for trains transporting flammable materials, including speed reductions; and new testing requirements, which will improve the way energy products are classified and transported (US Department of

Transportation, May 2015). Despite these improvements, environmental leaders believe that there will be a number of loopholes in the legislation based on the high intensity and level of lobbying done by the oil industry in Washington (K. Hudson, Personal Communication, April 2015). The federal government also has the authority to issue an emergency mandate requiring, for instance, that DOT-111 railway cars be phased out immediately over a relatively short time period. Canada has successfully phased these cars out over the course of a year, whereas the US government has proposed the timeline for DOT-111 cars phase out over the next 5 years.

The Need for Economic Analysis

There is a lack of urgency around the issue of crude oil transport in the US, arguably because we haven't yet had an accident to the scale of Lac-Mégantic disaster. It would be devastating for another accident of that scale to occur given we have the knowledge and means to avoid it. In the political decision making process around this issue, the value NY's ecosystems provide to NY's economy is indirectly considered; However, the complete worth of the environment is not adequately represented- especially when policy decisions are made with regard to the transport of crude oil in NY State. There is an immanent need for financial backing to support a ban on crude oil transport until stronger safety and rail regulations are implemented. A complete valuation of the ecosystem functions and services in NY State would allow for more comprehensive cost benefit analyses and in turn more successful policies coupled with an understanding of the depth risk involved with this issue and a subsequent urgency for meaningful policy and regulatory implementation.

Ecosystem Functions

Before attempting to place a monetary value on the worth of NY's natural capital it is important to understand the ecosystem functions and services that make up our ecological system. Ecosystem functions can be defined as "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly" (De Groot et al., 1992). There are four primary categories of ecosystem functions that must be defined in order to more broadly understand the scope of ecosystem functions: regulation functions, habitat functions, production functions, and information functions. Each of the functions used to value total ecosystem services in Saratoga County and NY will fall under one of these categories which together are completely responsible for the potential for life on earth, and any goods and services we enjoy.

Regulation functions can be defined as "the capacity of natural and semi-natural ecosystems to regulate essential ecological processes and life support systems through biogeochemical cycles and other biospheric processes" (DeGroot et al., 2002); in other words, the hydrologic cycle, the phosphorus cycle, the nitrogen cycle: services that provide us with clean air, water, and soil. Habitat functions encompasses the understanding that, "natural ecosystems provide refuge and reproduction habitat to wild plants and animals and thereby contribute to the (in situ) conservation of biological and genetic diversity and evolutionary processes" (DeGroot et al. 2002). Production functions includes widespread processes we are completely dependent on for the majority of goods and services consumed by humans; "Photosynthesis and nutrient uptake by autotrophs converts energy, carbon dioxide, water and nutrients into a wide variety of carbohydrate structures which are then used by secondary producers to create an even larger variety of living biomass" (DeGroot et al. 2002). The services provided by these integral carbohydrate structures ranges from food and raw materials to energy resources and genetic

material. Information functions are justified by DeGroot as the contribution natural ecosystems make to the maintenance of human health, “by providing opportunities for reflection, spiritual enrichment, cognitive development, recreation and aesthetic experience”; “Because most of human evolution took place within the context of undomesticated habitat, natural ecosystems provide an essential ‘reference function’.” (DeGroot et al. 2002).

A typology has been developed over the years to standardize ESV. This typology includes 23 ecosystem functions, each of which fall under one of the four larger categories explained above (De Groot et al. 2002). These functions are assessed for their significance in various land cover types during ESV; for example, gas regulation, climate regulation, disturbance prevention, water regulation, water supply, soil retention, soil formation, nutrient regulation, waste treatment, pollution and biological control are all regulation functions. Refugium function and nursery function both habitat functions. Food, raw materials, genetic resources, medicinal resources, and ornamental resources are all production functions; and aesthetic information, recreation, cultural and artistic information, spiritual and historic information, and science and education are all information functions. For this study, I have adapted twelve main ecosystem function categories: Gas/Climate Regulation, Disturbance Regulation, Water Regulation, Water Supply, Soil Formation, Nutrient Cycling, Waste Treatment, Pollution, Biological Control, Habitat/Refugia, Aesthetic/Recreation, Cultural/Spiritual.

While these functions have been established as the standardized functions through which to value ecosystems, land cover typology varies and is unique for every area that is assessed. The variety of land cover geology all over the world is the main source of error in a common compilation method used in ecosystem services valuation: the benefit transfer method. This method allows for land areas which have been valued using one of the many (or multiple)

methodologies, to be reflected onto an area of similar land cover and climate, thereby allowing an area's ecosystem services to be valued without new data being gathered for that particular area. This method ignores common monetary and temporal barriers to ESV and allows quick and efficient valuation of an area, given a previous valuation has been done on a similar geological land cover in a similar climate (Liu et al 2008).

Types of Ecosystem Service Valuation

In 1992, Dailey redefined modern economic systems management. He claims "three broad goals have been identified as important to managing economic systems within the context of the planet's ecological life support system:

1. assessing and insuring that the scale or magnitude of human activities within the biosphere are ecologically sustainable;
2. distributing resources and property rights fairly, both within the current generation of humans and between this and future generations, and also between humans and other species; and
3. efficiently allocating resources as constrained and defined by 1 and 2 above, and including both market and non-market resources, especially ecosystem services."

Cozanza acknowledges these goals in his work and responded by concluding, "one must do valuation from multiple perspectives, using multiple methods (including both subjective and objective), against multiple goals" (Costanza, 2000).

There are various methodologies used to value ecosystem services in different ways. The contingent valuation method, hedonic pricing method, and the damage-cost avoided method are

among the most commonly used. There is criticism and potential error incurred when using just one of these methods to value the ecosystem services of an area. To avoid this error, a mixture of the methods can be used. The benefit transfer method can be used to bring together studies already done on various land types, and to create a more comprehensive and wide scaled area of land valued for its ecosystem services. In 2007 Liu used the benefit transfer method to value the total ecosystem services for the State of New Jersey by compiling data from 94 ESV studies (all of which were cleared for transfer to New Jersey because of their completion in an area with a similarly temperate climate). This process was supported and carried out by Liu with the support and guidance of his thesis advisor, Costanza. The creators of ecosystem services valuation, along with the environmental protection agency used this value transfer method to successfully value the ecosystem services of an entire state. In this study, I adapt Liu's methodology, create a land use typology specific to NY State, and use the benefit transfer method to value NY's ecosystem service.

Natural Capital & Ecosystem Services Valuation

Natural capital is considered essential to human welfare; zero natural capital would mean zero human welfare. From there we can devise that certain aspects of natural capital are trivial to value for their service is crucial to human existence and therefore of infinite value. For example, the atmosphere or the infrastructure of soil rock and molten rock that makes up the Earth (d'Arge et al. 1997). While valuing such indispensable services such as those provided by the atmosphere are trivial, it is quite meaningful to note, assess, and value the changes in quantity and quality of various types of natural capital. These fluxes will have a direct and immediate impact on human welfare, and in fact, are already defining our development progress day to day by informing cost/benefit analyses; "Changes in quality or quantity of ecosystem services have value insofar as

they either change the benefits associated with human activities or change the costs of those activities” (d'Arge et al. 1997).

These changes in ecosystem services are linked to our welfare and progress so closely that in many cases the decision making process informed by these changes in resources may impact our continued existence in a given area. For example, the quantity of water available from Loughberry Lake, the drinking water source for Saratoga Springs, and the quality of that water is constantly informing decisions regarding the treatment and discharge of water for Saratoga County. Our continued inhabitation of the County is contingent upon a consistent and safe supply of water. A technological or natural disaster could easily upset this balance, in which case the value of the services provided to the County by the Loughberry Lake watershed would need to be known and assessed in order to make management and safety decisions moving forward. Needless to say, these decisions and therefore the quality of quantity of the water itself have serious monetary implications for Saratoga County.

There is much controversy about the legitimacy and point of ecosystem valuation. It is often argued that we can't “place a value on such intangibles as human life, environmental aesthetics, or long term ecological benefits; or that we should protect nature because of its intrinsic value, a value that cannot be quantified. These are mute points, however, because whether we say so explicitly or not, by choosing to build a highway to improve the safety of commuters, we are choosing to spend money to save lives and therefore placing an inadvertent value on human life. There are also moral arguments that also directly contradict the moral argument to protect ecosystems, for example the moral argument to end hunger, to end poverty (d'Arge et al., 1997). It is clear that these various arguments cannot be mutually exclusive, in fact, it is extremely important to take each into account and allow management decisions (which will

inevitably and in past, indirectly place value on “invaluables”) to couple moral agendas and strive for thoughtful and multifaceted solutions to the wicked problems we face today as humans.

Everyday we are making decisions as a society that imply valuations for ecosystem services whether we mean to, like it or not. We can make these decisions easier by utilizing our current understanding of ecological science (d'Arge et al., 1997). It is important to acknowledge the many imperfections, estimates and uncertainties that go along with ecosystem valuation, and even so appreciate the clear need that exists for more specific and thought-out valuation of ecosystem services that are already implicitly being valued everyday. Specific valuations will save time and money for policy makers, ease the development of various management plans and help inform safety and health regulations going forward. The explicit valuation of natural capital and ecosystem services that on the most basic level, allow for human welfare to exist and improve, will in turn speed up decisions making processes and progress surrounding human welfare on defined spatial and temporal scales. This aid to cost benefit analyses incurred on every level of decision making processes will inform and allow for efficient sustainable development, and pave an avenue for increasingly improved and equitable human welfare.

Payment for ecosystem services (PES) is becoming increasingly popular as a means to force ecosystem services into a market model and increase efficiency in various decision making processes (Farley & Costanza, 2010). Likewise, ecosystem services valuation is becoming increasingly respected as a way to progress toward more sustainable thinking and decision-making. The process itself has been refined since it's first global estimation by Costanza in 1997. The global estimate of ecosystem services value in 2011 was 145 trillion/year (Costanza et al., 2014), a significant increase in value since the 1997 estimate of 33 trillion/year (Costanza et al., 1997). The loss of ecosystem services between 1997 and 2011 due to land use change is estimated

at 4.3-20.2 trillion/year (Costanza et al., 2014). The fact that this loss can be recorded and observed monetarily based on ecosystem services valuation over the past decade is a significant step forward in combating global climate change. We must first acknowledge and value the magnitude of human actions and subsequent environmental, social, and economic losses before we can devise solutions to these wicked problems. The purpose of this study is to value the ecosystem services in New York State to create an impetus for future policy action. The aim of this study is to lessen the public health, economic, and environmental risk currently coupled with crude oil transport by rail.

Methods

In this study, I adapt the methodology used by Costanza and Liu to estimate the value ecosystem services in New Jersey in 2006. This study includes access to all of the information used for ESV, specific outlines of each step of the methodology, and a quality assurance plan that reiterates the processes undertaken and their reliability. Before adapting this study's methodology, each step of the process was verified by thorough cross-referencing with other peer-reviewed ESV benefit transfer studies and proposed typologies. In this study a land use typology is created specific to NY State, and the benefit transfer method via (Costanza et. al. 2006) is used to value NY's ecosystem services. Finally, the total ecosystem service values in New York State for each land cover type were compiled to create a GIS layer for future access and study.

Adaptation of Costanza and Liu's Study, The Value of New Jersey's Ecosystem Services and Natural Capital

Because so much of the methodology used by Costanza to value New Jersey's ecosystem services is adapted in this study, a brief overview Costanza's process is necessary to fully understand this study of New York's ecosystem services adapted methodology. The first step of Costanza and Liu's process was a value transfer in which 100 high quality studies of various ecosystem services in various locations were identified and applied to New Jersey ecosystems. These studies were chosen specifically based on the climates they were conducted in: temperate climates, which we can infer may most accurately represent similar ecosystem functions in other temperate climates. These 100 studies, 94 of which were published in peer reviewed journals, lent 210 individual value estimates, which were then translated into dollars per acre per year. From there, the average value for a given ecosystem service for a given land cover type was computed.

In this study of the value of ecosystem services in New York State, the per acre values for ecosystem services (Costanza et. al. 2006) for various land cover types were then multiplied by the average by the total NY statewide acreage for that land cover type.

$$V(ESV_i) = \sum_{i=1}^n A(LU_i) \times V(ES_{ki})$$

Where $A(LU_i)$ = Area of Land Use (i) and

$V(ESV_i)$ = Annual value of Ecosystem Services (k) for each Land Use (i)

Equations adapted from Costanza et al. 2006

Creation of a NY Specific Land Cover Typology

New York State Department of Environmental Conservation data provided GIS data for NY land cover types outlined in the table below. Each land cover type was analyzed and cross-referenced thoroughly and systematically placed into a land cover typology consistent with the typology in Costanza and Liu’s study. This reorganization and classification of land cover types made my data more compatible with the ecosystem function per acre values adapted from Costanza’s study. Thus allowing me to move forward with my valuation of ecosystem services in NY State.

Figure 1: Land Cover Typology Modification Flow Outline

NYDEC Land Cover Types	Modified Land Cover Types
Developed, High Intensity	Urban or Barren
Developed, Medium Intensity	
Unconsolidated Shore	
Bare Land	
Developed, Low Intensity	Urban Greenspace
Developed, Open Space	
Cultivated Crops	Cropland
Pasture/Hay	Pasture/Grassland
Grassland/Herbaceous	
Deciduous Forest	Forest
Evergreen Forest	
Mixed Forest	
Scrub/Shrub	
Palustrine Forested Wetland	Freshwater Wetland
Palustrine Scrub/Shrub Wetland	
Palustrine Emergent Wetland	
Estuarine Forested Wetland	Saltwater Wetland
Estuarine Scrub/Shrub Wetland	
Estuarine Emergent Wetland	
Open Water	Open Freshwater
	Estuary
Palustrine Aquatic Bed	Coastal Shelf

Most of the NYDEC Land Cover Types compressed into more general land cover types easily, however, the open water data was too general and needed to be organized into two more specific categories: open freshwater and estuary.

Open freshwater and Estuaries

To accurately account for the land area of estuaries in NY (since that data was not available in our original land use breakdown) we used the NYDEC website to define estuaries in NY as having brackish or salt water, and then differentiated that from open freshwater by defining all open water on the Hudson south of Poukipsie as estuary, and all other open water, for example, Loughberry lake, lake Champlain, or Lake Ontario, as open freshwater.

We did this in ArcGIS by first reclassifying all the data to isolate open water, so we could then manipulate it without worrying about all the other land cover data. We then converted all of the open water cells from raster to polygon so that our data could be represented by a complete shape instead of separate pixels.

We then selected all the vector areas of open water that are estuaries (which we define as south of Poukipsie (we added a base map to most accurately define the area in NY south of Poukipsie)- even in extreme drought, that is the highest point the salt comes -DEC) to differentiate NY land area of estuaries from open freshwater.

After selecting each of these brackish/salt water estuarine vectors we exported the data selected to create a new shape filed entitled NY Estuaries. We selected the rest of the open water

vectors that don't classify as estuaries and created a new shape file entitled open freshwater. So in summary, from open water data we created and were left with two separate data sets: estuaries and open freshwater.

*From the adapted study the Beach land cover type was omitted for lack of available data in NY State and the Riparian Buffer land cover type was omitted based on time constraints.

Once I classified each NYDEC land cover type to fit within the Modified Land Cover Types I converted the data for each type from cells representing 30 by 30 meter chunks of land to acres squared. I added those figures into the revised grid of land cover types and ecosystem function categories.

For this study, I have adapted twelve main ecosystem function categories: Gas/Climate Regulation, Disturbance Regulation, Water Regulation, Water Supply, Soil Formation, Nutrient Cycling, Waste Treatment, Pollution, Biological Control, Habitat/Refugia, Aesthetic/Recreation, and Cultural/Spiritual.

I then calculated Cumulative Per Acre Value of ES for each Land Cover Type and Total Value for each ES in NY. I also calculated the total value of ecosystem services for each land cover type. And from there, the total value of ecosystem services in New York State.

GIS

To convert the information I've calculated into an easily accessible format for future study and manipulation, I converted the dollar values for total ecosystem services of a given land cover type per acre into meters squared and then multiplied that by 30. I inputted these values

for each NY Land cover type and thus created a new layer of ecosystem service value for NY State.

Value at Risk in the event of a crude oil train derailment and subsequent spill or explosion

Results

The results of this study are summarized below; the figures listed include only ecosystem services, ecosystem or abiotic goods or secondary economic activity related to each of the given ecosystems are not presented.

1. Open freshwater provided the largest dollar value of ecosystem services: \$1.127 trillion dollars per year. Open water covers the largest land area in NY State.
2. Forests provided the second largest dollar value of ecosystem services: \$22.92 billion dollars per year. Forrest's cover the second largest land area in New York State.
3. Freshwater Wetlands provided the third largest dollar value of ecosystem services which is interesting given their relatively small percentage of land area: \$6.35 billion dollars per year.
4. Interestingly, Urban Green Space provided the fourth largest dollar value of ecosystem services, \$3.268 billion dollars per year.

The total value of ecosystem services provided in 2004 dollars in New York State was \$15.32 trillion per year.

Figure 2: Total Ecosystem Service Yearly Flows for Various Land Cover Types (NY State)

<u>Land Cover</u>	<u>Total ESV</u>
Coastal & Marine	
Coastal Shelf	\$10,976,224,682
Estuary	\$1,643,000
Saltwater Wetland	\$960,881,308
	\$335,749,648
Terrestrial	
Forest	\$15,318,826,493,952
Grass/Rangelands	\$22,926,106,296
Cropland	\$34,218,478
Freshwater Wetlands	\$64,180,764
Open Freshwater	\$6,352,908,177
Riparian Buffer	\$1,127,176,703,235
Urban Greenspace	Unavailable
Urban or Barren	\$3,268,259,294
	\$0

Figure 3: Total Land Acreage by Land Cover Type, Ecosystem Functions, Cumulative Annual Value of ES for each Land Cover Type, and Total value for each ES in NY State

Land Cover	Area (Acres)	Gas/Climate Regulation	Disturbance Regulation	Water Regulation	Water Supply	Soil Formation	Nutrient Cycling	Waste Treatment	Pollution	Biological Control	Habitat/Refugia	Aesthetic/Recreation	Cultural & Spiritual	Cumulative Annual Value of ES for each Land Cover Type
Coastal & Marine	1,396,111													\$7,862
Coastal Shelf	2,650				620									\$620
Estuary	1,342,013				49						364	303		\$716
Saltwater Wetland	51,448		1					6,090			230	26	180	\$6,526
Terrestrial	1,504,500,736													\$10,182
Forest	18,730,479	60			9				162		923	130		\$1,224
Grass/Rangelands	4,888,354	5				6						1		\$7
Cropland	2,790,468								8			15		\$23
Freshwater Wetlands	2,321,121			5,957	1,161						5	1,571		\$2,737
Open Freshwater	1,473,433,599				409							356		\$765
Riparian Buffer			88		1,921							1,370	4	\$3,295
Urban Greenspace	1,533,674	336		6								2,131		\$2,131
Urban or Barren	803,041													\$0
Total Value for each ES in NY	1.17662E+12 acres	\$1663584974	\$51,448	\$1383611984 1	\$6.05565E+11	\$29330124	\$0	\$313318320	\$30566613 42	\$0	\$1780016349 4	\$5.34347E+11	\$9,260,640	\$15,329,802,718,634

Discussion

The economic implications of a crude oil train derailment and subsequent spill or explosion are far reaching and would undoubtedly have long term and broad reaching ramifications. The Valuation of Ecosystem Services in New York State allows for the natural capital at risk to be adequately represented in the political decision making process. These values

for land cover are also significant in the formation of more localized emergency management response plans. These plans are often developed largely using GIS so the availability of Ecosystem Service data on that platform is key for ease of use and for fast information sharing. After the thorough assessment of the NY State level political situation with regard to Crude oil Transport by Rail, recommendations can be made for future policy to be implemented to curb the risk associated with this form of crude oil transport.

Political Agency and Response

A number of different agencies and policies govern crude oil shipments and railroad safety. The Federal Railroad Administration (FRA) has jurisdiction over railroad safety. The FRA maintains a staff of about 500 federal railroad inspectors and 179 state inspectors (U.S. DOT, 2015). Because federal rail safety laws preempt state laws, state inspectors have largely the same functions as federal inspections. FRA regulations cover “the safety of track, grade crossings, rail equipment, operating practices, and movement of hazardous materials” (Frittelli et al., 2014 p. 14). FRA enforces regulations created by the Pipeline and Hazardous Materials Safety Administration. Any incidents with crude oil transported via rail are handled by the National Transportation Safety Board (NTSB). NTSB was created as an investigatory agency and is responsible for recommending changes to regulations and policies based on the circumstances surrounding past accidents (Burton and Stretesky, 2014 p. 86). The NTSB is not required to take into account any economic costs when considering additional safety measures and it has no real regulatory authority. While the FRA collaborates with the NTSB and often agrees with the recommendations provided, new FRA regulations can take years (Frittelli et al., 2014 p. 15).

To prepare for an oil spill or crude by rail accident, the federal government provides leadership and support for preparatory actions, as part of a multi-agency National Response System. Within the National Response System are three main teams: the interagency team, the National Response Team, and the Regional Response Team. The interagency team is comprised of the EPA, the DOT, and the Federal Emergency Management Agency. This group is responsible for assessing states' preparedness for crude by rail accidents through a series of discussions with state representatives. The goal of these conversations is for the interagency team to gain a better understanding of states' abilities to mitigate damages after a disaster (Preparedness Initiatives in Crude by Rail Transport, 2015). The National Response Team (NRT) consists of one member from each of fifteen different federal agencies, is chaired by an EPA representative, and vice-chaired by a Coast Guard representative. In addition to acting as a support system for Regional Response Teams, the NRT has three primary responsibilities: to distribute information, plan for emergencies, and train for emergencies (EPA, *National Response Team*, 2016). There are thirteen Regional Response Teams, which are responsible for the response, planning, training, and coordination associated with a crude by rail disaster. This includes developing Area and Regional Contingency Plans, which delineate the responsibilities of government entities during a disaster (EPA, *Regional Response Team*, 2016).

The National Response Team has found that while states are aware that crude oil disasters pose a threat and have taken steps to increase their preparedness, they do not believe this threat is as significant as ones presented by other hazardous materials. States have acknowledged the lack of training and preparedness of their emergency response teams and have requested more training programs for first responders. In May 2014, the DOT released an emergency order that “required all railroads operating trains containing large amounts of Bakken

crude oil to notify State Emergency Response Commissions about the operation of these trains through their states” (DOT, 2014). “Large amounts” is defined as 1 million gallons or more, which is approximately 35 tank cars. In response to this Emergency Order, however, states claimed through the National Response Team that the 1 million gallon reporting minimum is too high and does not allow them to identify at-risk communities and help them prepare for a disaster (Preparedness Initiatives in Crude by Rail Transport, 2015).

The Emergency Planning and Community Right to Know Act (EPCRA) of 1986 was passed by Congress in response to concerns regarding the environmental and safety hazards posed by both the storage and handling of toxic chemicals. Concerns were initially triggered by a chemical disaster in India, which killed over 2000 people. The EPCRA was enacted to reduce the likelihood of a similar disaster in the United States. EPCRA requires state and local governments to report on any hazards and toxic chemicals in order to increase the public’s awareness of any potential environmental or health risks (EPA 2015). Sections of the Act that are most relevant to crude by rail transport are 301 - 303, 304, 311, and 312. Sections 301 - 303 require local governments to prepare chemical emergency response plans and to review those plans annually. Section 304 requires facilities to publically report any accidental release of hazardous substances. The Community Right-to-Know Requirements in Sections 311 and 312 require that facilities must make Material Safety Data Sheets available to officials and local fire departments.

In the case of an oil spill, train derailment, or other accident involving crude by rail, the National Oil and Hazardous Substances Pollution Contingency Plan, often referred to as the National Contingency Plan (NCP), requires state or local officials to be initially responsible for

immediate evacuations and damage control. Three federal environmental statutes authorized the development of the NCP: the Clean Water Act, the Oil Pollution Act, and the Comprehensive Environmental Response, Compensation, and Liability Act (Bearden and Ramseur, 2014). First responders have the authority to notify the National Response Center to request assistance from the federal government. If oil discharges into navigable waterways or onto any resources owned by or under the management of the federal government, the Clean Water Act and the Oil Pollution Act of 1990 give the federal government authority to respond directly to the incident without request from state or local governments (Bearden and Ramseur, 2014 p. 3).

In the wake of an accident, both rail and oil companies have been known to place blame on the other due to the disjointed nature of the ownership of the railroad and the rail car. The Oil Pollution Act of 1990 requires that “vessel owners and operators assume the burden of spill response, natural resource restoration, and compensation for damages caused by the spill up to a specified limit of liability.” When the polluter cannot pay, cannot be located, or is foreign, the Oil Spill Liability Trust Fund is used to cover damages (Government Accountability Office, 2007). Rail operators (such as CSX or CP) are responsible for moving the crude and maintaining the rails and infrastructure. However, they do not own the tank cars that the oil is shipped in or own the oil itself. Producers of the crude oil or the refiners typically own the crude and are responsible for shipping it. The shippers are often the owners of the rail cars or, in some cases, the rail cars are leased. Different entities have different legal responsibilities in the supply chain (Pumphrey et al., 2014 p. 2).

Recommendations

Based on the information collected and analyzed in this study, the political recommendations to support increased public safety, environmental protection, and economic gain are as follows:

1. Stricter regulation of and compliance with The Emergency Planning and Community Right to Know Act (EPCRA).
2. Tailored County Level Emergency Response Plans via GIS
3. A ban on the transport of crude oil by Rail in NY State until double layered and thicker DOT cars are required and immediately phased in
4. In the Case of a derailment and explosion both Rail and Oil companies are required to share the responsibility of Ecosystem Service Damages (a split which could be contracted and signed prior to a spill with the data provided by this study).

This study has various shortcomings and leaves significant room for future study of the Ecosystem Services on smaller more specific scales in NY State and in other areas, worldwide.

Conclusion

“Climate change, and its associated impacts, are challenging the very core of our natural, social, and economic systems, and it is now widely accepted that we must take steps to significantly reduce our global greenhouse emissions while simultaneously addressing the energy-related inequities that continue to plague so many human populations. The atmospheric concentrations of several greenhouse gases (e.g., carbon dioxide, methane, and nitrous oxide) have increased to unprecedented levels, in at least the past 800,000 years, and carbon dioxide levels are now hovering around 400 ppm, a concentration beyond the 350ppm concentration now widely recognized as a target level to preserve our social systems” (Kellogg & Hobbs 2016).

The production and utilization of fossil fuels by humans is a leading cause of carbon dioxide emissions. The flow of crude oil and the ease of transportation of this fossil fuel have implicit and explicit impacts on the spatial and temporal scales of climate change. Regulations on the production and consumption of climate change have the power to impact the energy industry in a way that could curb the negative impacts of climate change in future years. In the same regard they may aid in the continued global destruction guaranteed given the continued dependence on fossil fuels for energy.

The value of ecosystem services takes on a whole new meaning in the context of climate change; This studies aim was to put a monetary value on ecosystem services that would inevitably be taken into account in policy decisions regardless. But with specific values these ecological benefits can be fairly represented in the decision making process. While the immediate implications affect the issue of crude transport by rail in NY State, this issue reaches much further and affects the entire world through the lens of global climate change. The importance of ecosystem services valuation as described in this study is magnified through the interconnectedness and complexity of the issues of crude oil transport and global climate change. There is infinite room for further study on each of these topics and ever more room for continued valuation of ecosystem services.

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