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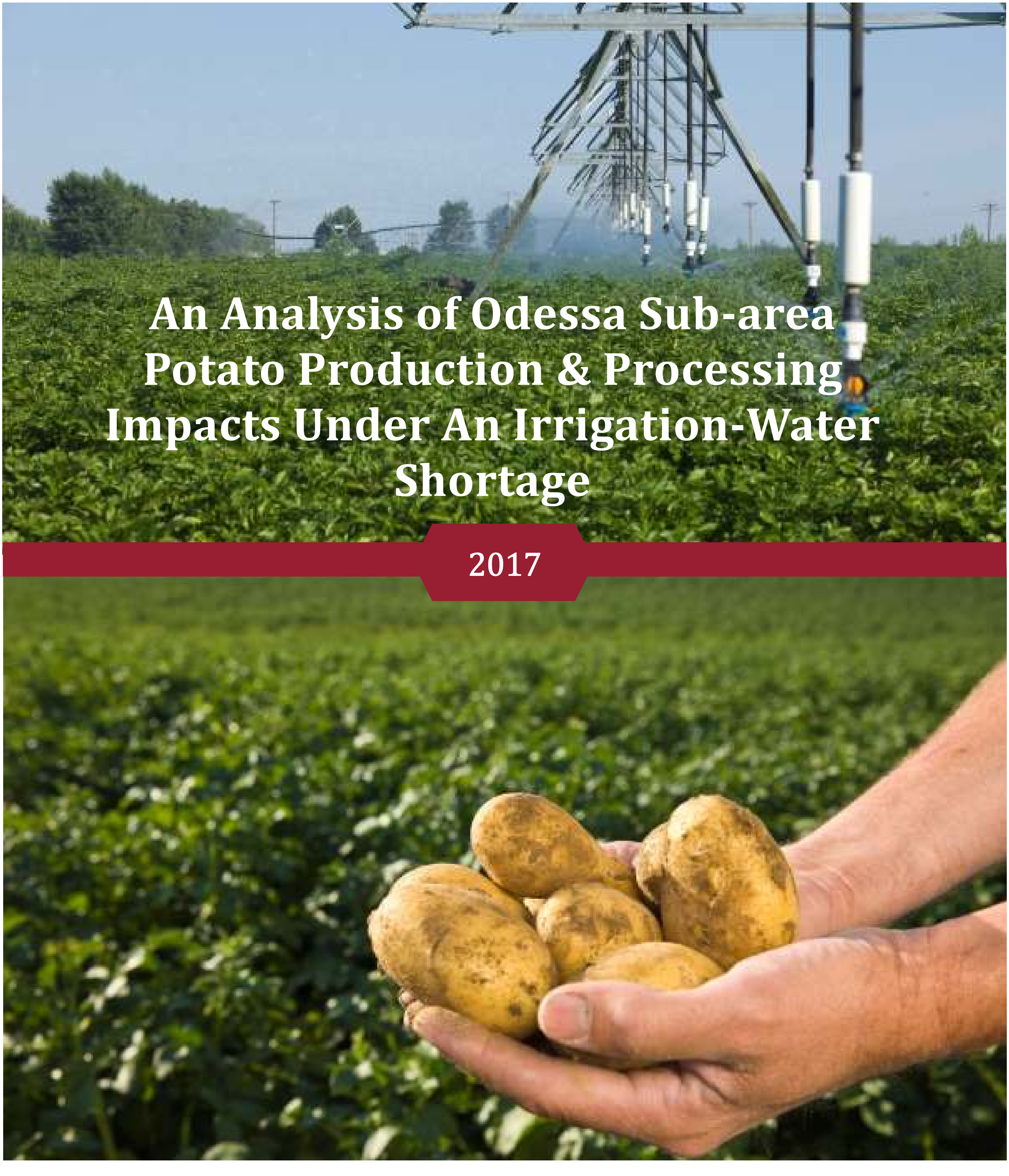
An Analysis of Odessa Sub-area Potato Production & Processing Impacts Under An Irrigation-Water Shortage



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Executive Summary

The Odessa Sub-area underlies Adams, Franklin, Grant, and Lincoln counties in East Central Washington. Water availability in the Odessa Sub-area aquifer is in decline, putting potato production and processing at risk. As the aquifer declines, deeper and warmer water that is of poor quality is being extracted for irrigation purposes. In the absence of irrigable land in the sub-area some of the most productive potato growing acres in the country will be lost. In 2005 acreage in potato production was 35,600 acres. In 2015, a decade later, 26,519 acres were under potato production in the sub-area. In the last decade irrigated potato acreage in the sub-area fell by over 25%.

Even with poor water and reduced acreage growers in the sub-area produced over 943,000 tons of potatoes worth nearly $119 million dollars. Table 1 in the main body of the text shows the concentration of potato production in the four-county area that includes the sub-area. The region is 132.4 times as concentrated in potato production as the average region in the United States. For comparison, Napa and Sonoma counties in California have a winery location quotient of 159. This data makes it clear that the region has a strong comparative advantage in potato production.

The costs from losing potato production in the Odessa Sub-area would exceed $37 million dollars, and roughly 1,100 jobs would no longer be supported. The long term impacts may extend even further if potato processing plants reduce their output. Under this scenario total reductions in regional output would exceed $138 million with the loss of nearly 3,000 jobs. Tables 15 and 16 summarize the lower and upper-bound economic consequences on the four-county region from losing potato production and processing.

Exports of processed potatoes bring new money into the region. That new money is then spent by the processors on employee wages, utilities, and raw potatoes. Employees spend their earnings on household goods (e.g., eating out at local restaurants, buying a new home, etc.). As that money ripples through the economy it creates additional rounds of spending and income until it finally leaks out of the region for the purchase of imports.

Table 14 shows that money brought into the economy through processed potato exports ripples through the economy longer and has a higher multiplier effect than the average dollar. The output from two full time equivalent jobs in potato processing supports an additional job in support industries such as trucking and utilities. This exceeds the average jobs multiplier of 1.16. Potato production and processing not only has a significant ability to bring new dollars into the region but keeps money in the region longer since it has deeper economic roots in the local economy.

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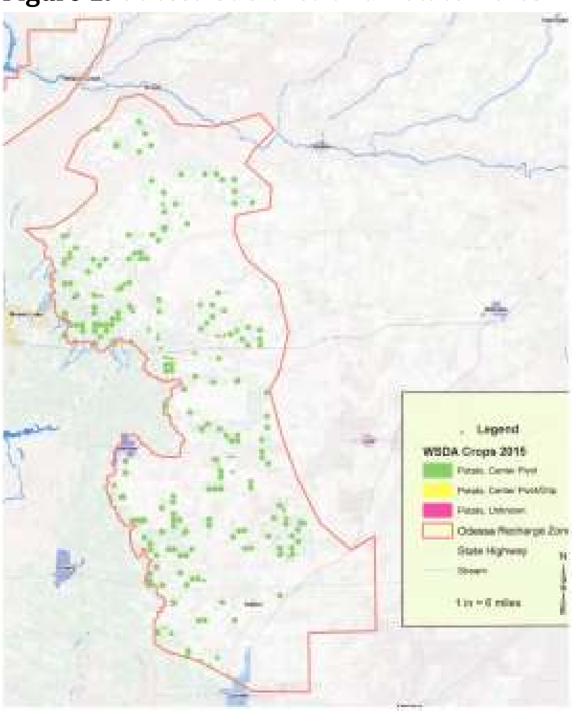
Introduction & Background

In 1930 the Bureau of Reclamation began the Columbia Basin Project (CBP) for the purpose of irrigating the eastern portion of Washington State. Due to various economic and political issues the CBP was never completed. The Odessa Sub-area is one region of the CBP that never received irrigation from the CBP and has relied on ground water pumping for irrigation water.

The Odessa Groundwater Management Sub-area was designated by Chapter 173-128A of the Washington Administrative Code (WAC) for the region of roughly 1800 sq. miles area under the Columbia Basin Project, commonly known as "Odessa Area" or "Odessa-Lind Area." The area extends from Odessa on the north to Lind on the south, and from the East Low Canal on the west to Ritzville on the east (see Figure 1). This area is semi-arid with a higher precipitation on its eastern side than that on its west. At the same time, the western part of this Odessa Area borders the fully completed portion of the CBP.

Figure 1: *Odessa Sub-area and Potato Acres*



Source: WSDA 2015 crop data reports and Harold Crose

Most groundwater wells were shallow in early years as the there was little irrigation and shallow wells provided enough water for local demand. With the development of sprinkler technology farmers began increasing irrigation and experienced remarkable increases in yields. Small diameter shallow wells were soon replaced with 16" diameter wells that could be as deep as 700 feet.

Though there has been some recharge to the aquifer do to surface water canal seepage the water levels in the Odessa Sub-area are still declining. In addition, the deeper wells are drawing older and warmer water that is not as high quality for irrigation purpose. In the absence of additional water supplies the economic returns to potato production are at risk.

In 2005 an analysis of these economic losses was conducted by Bhattacharjee and Holland, economists at Washington State University's School of Economic Sciences. The current analysis represents an update of the data and economics from the previous study. Since 2005 potato producing acres in the sub-area have declined from 35,600 to 26,519 acres (2015). Even though total acres in potato production have declined by over 25%, yields have increased from the 595 cwt/acre reported in 2005 to roughly 635 cwt/acre in 2015.

Odessa Sub-area Regional Description

Geography

Agricultural studies that have a basis in water allocation often specify the region of analysis using the hydrological rather than economic geography. Where production occurs and where contributions are felt are not always the same, however. Imagine a contribution analysis on the commercial fishing industry. If the region of analysis were chosen based on the production site, the analyst would need to isolate some region of the ocean, but few market transactions actually occur where the fish are caught.

For this reason, we cannot use the Odessa Sub-area alone as the geography for conducting the analysis. Because we are capturing the contributions of the potato growers, which are located in the Odessa Sub-area, we must include the Sub-area but also need to capture activity in the central economic region that benefits from the efforts as well. As such we use the four counties of Adams, Franklin, Grant, and Lincoln (see Figure 2).

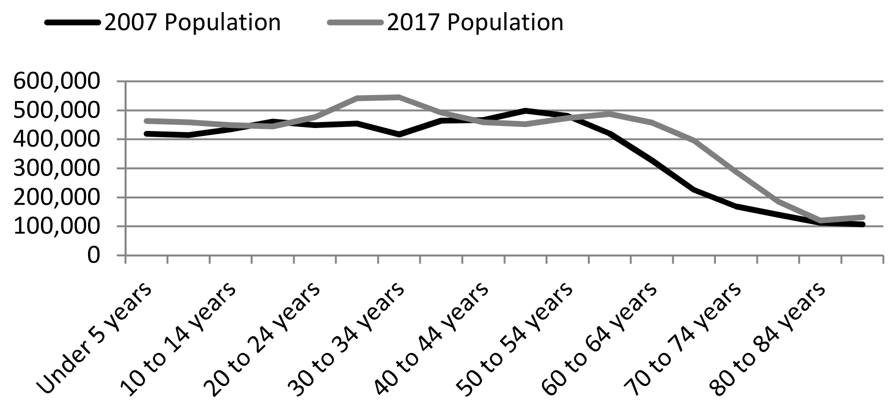
Figure 2: *Four-County Economic Region*

Source: Emsi 2017.1

Demographics

The 2017 population in the four-county region was just over 217,000; Males accounted for 106,000 and females the remaining 111,000. Population in the region has actually increased 22% over the past decade. Over the same time period Washington's population as a whole only grew by 13%, from 6.5 million to 7.3 million. Figure 3 shows the population in the four-county area by age for the years 2007 and 2017. You can see that the population has aged but the most interesting thing in the graph is the growth in the 25-40 year old cohorts. This suggests the growth in the population is largely due to, and synonymous with, the growth in the working age population.

Figure 3: *Four-County Population Trends by Age*

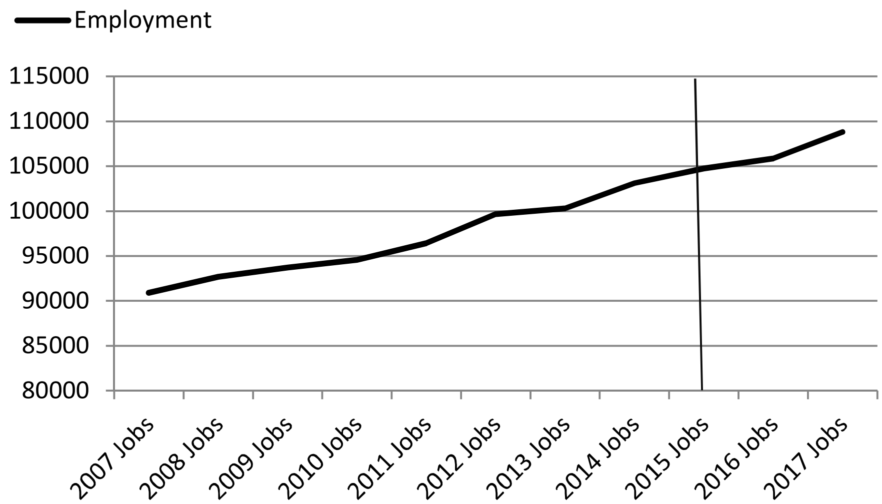


Source: Emsi 2017.1 data set

Total employment[1] in the four-county region was nearly 109,000 in 2017, with Crop and Animal Production being the largest industry at 24,290 jobs. Government and Manufacturing, largely food manufacturing, were the next largest employers with 18,263 and 10,879 jobs respectively. Employment in 2007 was approximately 91,000. Growth in employment over the last decade was 20%, close to the 22% growth in population. The four-county area employment growth can be seen in Figure 4.

[1] Employment reported here includes all workers, whether covered by employment insurance or not, self-employed workers, and extended proprietors.

Figure 4: *Four-County Employment Trend*



Source: Emsi 2017.1 Data set

Economy

Often regional economists compare an industry in one region with the same industry in a larger region to assess whether the region has a comparative advantage in production. We know, for example, that Napa County, California is highly concentrated in wine production relative to the nation as a whole. This measure of concentration is referred to as a location quotient (LQ). A location quotient of 1 simply says the industry is "average" or just as concentrated locally as it is nationally. A location quotient greater than 1 says the industry is more concentrated locally, and if it is less than 1 it is less concentrated. The LQ is calculated by taking an industry measure (output, employment, etc.) and dividing it by the associated total regional measure. The same calculation is then made for the same industry but at the national level. The ratio of the two then gives the industry's regional LQ.

$$LQ = \left(\frac{Industry\ Regional\ \ Output}{Total\ Regional\ Output}\right) / \left(\frac{Industry\ National\ \ Output}{Total\ National\ Output}\right)$$

When calculating the location quotient for potato production we find that Washington is roughly 8 times as concentrated as the nation, and that the four-county region is approximately 132 times as concentrated as the nation is in potato production (see Table 1).[2] It is clear from Table 1 that the region is highly specialized in potato production and thus highly dependent on water resources.

[2] Location quotients were calculated based on production volume.

Table 1: *Location Quotient for Potato Production ('000)*

Region	Potato Production (Sales)	Total Regional Sales	Location Quotient
Four-County Region	$201,293	$6,023,766	132.4
Washington State	$771,210	$362,656,959	8.4
United States	$3,750,246	$14,863,510,830	1.0

Source: USDA NASS Quick Stats, Emsi, and author's calculations

Table 2 shows the employment, earnings (labor), property income (capital), taxes, and value added for each industry in the four-county economy. The four counties contribute roughly $6 billion to Gross State Product, and employ roughly 16% of all agricultural employment in the state. What is of more interest is the nature of potato production and processing within the region.

Table 2: *Four County Economy Overview*

NAICS	Jobs	Earnings	Property Income	Taxes	GRP
Crop and Animal Production	23,837	$749,158,606	$98,540,402	$54,087,785	$821,307,098
Mining, Quarrying, and Oil and Gas Extraction	298	$13,355,406	$10,590,462	$3,576,329	$27,522,197
Utilities	111	$11,117,324	$15,186,761	$9,992,316	$36,296,401
Construction	4,512	$219,552,616	$60,290,076	$3,680,855	$283,523,547
Manufacturing	10,445	$585,856,661	$324,670,513	$48,289,023	$958,778,305
Wholesale Trade	4,632	$283,042,767	$141,264,871	$142,547,262	$566,854,900
Retail Trade	9,450	$292,139,498	$38,064,183	$121,587,563	$451,791,244
Transportation and Warehousing	4,103	$197,442,690	$41,832,394	$9,305,359	$247,670,703
Information	601	$29,066,993	$31,216,538	$6,735,105	$67,009,693
Finance and Insurance	1,916	$92,700,523	$44,668,120	$5,318,548	$142,664,663
Real Estate and Rental and Leasing	4,313	$128,225,050	$109,249,873	$29,994,962	$259,002,193
Professional, Scientific, and Technical Services	2,261	$84,192,970	$10,033,067	$4,002,985	$98,229,022
Management of Companies and Enterprises	51	$4,777,243	$480,055	$151,720	$5,409,018
Administrative and Support and Waste Management and Remediation Services	3,467	$103,054,185	$22,521,000	$4,077,342	$129,652,527
Educational Services	967	$30,163,050	$1,033,211	$1,009,009	$32,205,270
Health Care and Social Assistance	7,246	$293,883,806	$13,029,420	$8,287,212	$315,047,705
Arts, Entertainment, and Recreation	1,281	$23,542,317	$19,392,928	$5,916,752	$48,851,996
Accommodation and Food Services	5,110	$98,163,477	$22,721,845	$24,122,891	$145,008,213
Other Services (except Public Administration)	3,292	$78,806,706	$2,313,546	$6,834,130	$87,954,382
Government	17,948	$1,176,021,753	$124,762,277	$23,929	$1,298,987,132
Total	***105,842***	***$4,494,263,641***	***$1,131,861,543***	***$489,541,077***	***$6,023,766,212***

Source: Emsi 2017.1 Data set

Agricultural Land Use

The agricultural land in the four counties is dominated by wheat at 136,017 acres (225,252 if fallow acres are included). The next largest crop is potatoes at 26,519 acres. Crops by acreage are outlined in Table 3 below. Crops with less than 2,000 total acres across all four counties were combined in the "All Other" category. Part of the reason for the large potato production is because of the high quality and longer storage capabilities of the potatoes grown in the sub-area.

Perhaps the most important information provided by the table is the percentage of acres irrigated by crop. It is clear that in the absence of water availability the only feasible agricultural land use is dryland wheat production (at least based on current cropping patterns). While this report focuses on the loss of potato production and processing the reality is that if a water shortage were to occur, all crops other than dryland wheat would be lost. Thus, the only alternative agricultural land use based on historic cropping practices is non-irrigated wheat. As such we convert potato growing acres into wheat producing acres in our analysis.

Table 3: *Acreage by Crop Type, County, and Irrigation Rate*

Crop Type	Adams	Franklin	Grant	Lincoln	Total Acreage	Total Irrigated Acres	Percent Irrigated
Wheat	88,598	6,998	32,864	7,556	136,017	51,940	38%
CRP/Conservation	72,680	9,132	27,594	5,595	115,000	644*	1%*
Wheat Fallow**	62,421	5,190	16,409	5,216	89,235	9,382*	11%*
Potato	15,796	861	8,391	1,471	26,519	26,236	99%
Alfalfa Hay	2,935	1,165	4,712	1,055	9,867	9,702	98%
Pea, Green	5,785	175	3,291	0	9,251	9,228	100%
Corn, Field	2,923	401	2,582	10	5,916	5,916	100%
Bluegrass Seed	3,880	408	1,113	0	5,401	5,270	98%
Corn, Sweet	2,465	0	2,627	179	5,270	5,270	100%
Timothy	192	761	3,467	451	4,872	4,872	100%
Bean, Dry	2,688	148	1,173	132	4,141	4,049	98%
Onion	1,411	649	479	0	2,540	2,540	100%
Canola	900	0	504	619	2,024	1,874	93%
All Other	2,520	1,224	2,584	767	7,095	5,193	73%
Total	***265,194***	***27,112***	***107,791***	***23,051***	***423,148***	***142,116***	***34%***

* The data presented here reflects USDA survey data. The reader should not assume that CRP/Conservation or Wheat Fallow land is being irrigated. This land may have canals passing through it but the land is not being actively irrigated.
**Because this data is based on surveys some land was not under production in a given year. This land is on two year cycles.
Source: Washington State Department of Agriculture

Industry Descriptions

The data contained in the subsections below will represent the primary input to the modeling process. In order to conduct contribution analyses it is necessary to look at the growers and processors from an industry wide perspective. However, potato growers and processing do not have unique industry production functions in the Bureau of Economic Analysis (BEA) Input-Output (I-O) accounts (see Appendix A).

The goal is to isolate the average production technology for both the growers and processors in order to create unique production functions that can then be incorporated into the social accounting framework. This also allows for isolation of the broad expenditure patterns of each new "industry" and more closely tracks money as it flows through the economy.

The process for converting expenditure data into input-output accounts involves mapping the spending categories to industry accounts.[3] Once properly mapped, the data are converted from purchaser prices to producer prices using a margining technique. Lastly, we rid the accounts of imports and scale them to the regional level. Full detail of this process can be found in Willis and Holland (1997).

Adding Potato Production

According to the BEA NAICS manual potato producers are captured as part of the North American Industry Classification System (NAICS) as "111211 – Potato Farming: This U.S. industry comprises establishments primarily engaged in growing potatoes and/or producing seed potatoes." Unfortunately this industry is captured in the BEA accounts as part of "Vegetable and Melon Farming." It is necessary for us to separate potato farming out from vegetable and melon farming so as not to capture other crop production in our analysis.

In order to generate the basic expenditure data necessary for conducting this analysis we used focus group data at the state level. However, the four-county region was well represented in the focus group data since over 26% of production comes from this region. The expenditure patterns developed from the focus group are shown in Table 4 below. It is important to understand that this data is used for creating the production functions necessary to isolate the potato growing operations in the model. The actual shocks to the model are calculated and discussed separately in the following three sub sections.

[3] The Emsi SAM 2017.1 data, the most recent available at the time, was used to conduct the analysis.

Table 4: *2015 Washington Potato Production Enterprise Budgets*

Expenditures	Unit	Price/unit	Quantity	Total
Total Returns:	***tons***	***$165.00***	***31.5***	***$5,197.50***
Variable Costs:				
Soil Preparation & Planting				
Tillage	acre	$100.00	1	$100.00
Planting	acre	$100.00	1	$100.00
Seed	bags	$20.00	25	$500.00
Chemicals & Fertilizer				
Fertilizer	acre	$750.00	1	$750.00
Fumigation	acre	$280.00	1	$280.00
Fungicide & Insecticide	acre	$380.00	1	$380.00
Herbicide	acre	$70.00	1	$70.00
Irrigation				
Water and power	acre	$125.00	1	$125.00
Labor	acre	$75.00	1	$75.00
Harvest				
Digging	tons	$8.25	33.0	$272.25
Hauling	tons	$8.00	33.0	$264.00
Cleaning and Piling	tons	$7.50	33.0	$247.50
Storage	tons	$22.00	32.0	$704.00
Other Variable Costs				
Monitor Crop	acre	$25.00	1	$25.00
Interest on operating capital (4% of Variable Cost)	acre			$155.71
Total Variable Costs	***acre***			***$4,048.46***
Fixed Costs:				
Management, Administration and Overhead	acre			$125.00
Land rent	acre			$800.00
Interest on fixed cost (4% of FC)	acre			$37.00
Total Fixed Costs	***acre***			***$962.00***
TOTAL COSTS	***acre***			***$5,010.46***
ESTIMATED NET RETURNS	***acre***			***$187.04***

Source: Galinato and Tozer (2015)

The Direct Value of Potato Production

The standard USDA measure for reporting potato yields and prices are in cwt. Yields and prices in the following budgets were conducted on a tons per acre basis. However, it is the relative spending that is of primary importance in generating the production function for the I-O accounts. The five-year weighted average yield for the four-county region is 635 cwt/acre. If the entire 26,519 acres currently in potato production within the Odessa Sub-area are lost, that is a total output reduction of 16,839,565 cwt of potatoes. Assuming an

8% tare and shrink and average price of $7.70 per cwt, there would be a direct loss in output of $119.35 million.

It is assumed that the 26,519 acres of potato production in the sub-area would be put into dryland wheat production if irrigation water were lost. Assuming 41.4 BU/Acre and $4.20 per bushel for wheat,[4] there would be a gain of $4.62 million in crop production. The negative $119.3 million and the positive $4.62 million need to be entered simultaneously to determine the net effects of a loss in available irrigation water. It is true that farmers in this region can only use a summer-fallow rotation so the impacts shown here will not apply to fallowed years. However, impact analysis is done on a one-year basis rather than averaging over several years. The results shown below compare one production year of potatoes vs. one production year of wheat.

Potato Processing

Frozen Potato Processing is contained in NAICS "311411- Frozen fruit, Juice, and Vegetable Manufacturing: This U.S. industry comprises establishments primarily engaged in manufacturing frozen fruits; frozen vegetables; and frozen fruit juices, ades, drinks, cocktail mixes and concentrates." A careful study of this industry in the NAICS manual reveals that it includes frozen French fries and other frozen vegetable processing.

An unpublished 2016 report by Galinato and Tozer showed that for each dollar of raw potatoes purchased by frozen potato processors, the dominate type of processors in the four-county region, results in $3.08 worth of output. Thus, the $119.3 million in purchases from local potato growers would translate into $367.5 million in frozen potato products. We assume that all of this output is exported out of the four-county area.

One of the competitive advantages of the region is that the potatoes grown in the sub-area are of a higher quality, allowing them to be stored longer than potatoes grown elsewhere in the basin. The longevity of these potatoes allows processors to sustain output year-round by processing potatoes grown in lighter soils first and potatoes from the sub area later in the year.

Note that we are assuming that processors do not completely shut down, they merely reduce their output because they are no longer able to supplement their raw potato inputs from local sources. We are only losing the processing of locally grown potatoes. An alternative assumption would be that all potato processing in the four-county region is lost. This scenario is discussed in the sensitivity analysis provided in Appendix B. Under this more extreme scenario all of the $1.52 billion in frozen vegetable manufacturing would be

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[4] Even though this analysis is forecasting impacts 2014 acreage, yields, and prices were used to ensure consistency across data collection periods. Sensativity analysis on yields and prices are included in Appendix B.

lost. Still, only about 20% of total potato processing in the four counties comes from the Odessa Sub-area. It is likely that the processors would be able to cover those losses through increased imports of potatoes from elsewhere in the CBP or even Oregon.

Table 5 provides the percent of employment, and associated earnings by occupation for the fruit and vegetable processing industry. The table includes all occupations composing more than 1% of entire employment. The remaining jobs are included in the “All Other” category. This industry is the third largest employer in the region, behind crop production and local government. It is not surprising that the average regional wage for this industry is similar to the average for the region.

Transportation and Wholesale Trade

A point of deviation between this study and the previous Bhattacharjee and Holland study is that we do not include the forward-linked transportation and wholesale trade to the potato producing sector. Those losses primarily stem from the backward-linked effects from reductions in potato processing and are therefore claimed under the processing reduction scenario.

There are forward-linked transportation and wholesale trade revenues that are lost from the reduction in frozen potato processing as well. Those forward linked effects were estimated at a total of $54.74 million in rail and trucking transportation services and $30.13 million in wholesale trade services. Once these figures are multiplied by the regional purchase coefficient, the portion of those dollars going to local purchases are $25.1 million and $2.3 million, respectively. Thus, in the scenario where we reduce processor output, the total shock to the economy will be a reduction of $394.84 million.

Table 5: *Occupation and Wages in Washington's Fruit and Vegetable Processing Industry*

Occupation Title	SOC Code	Regional Avg. Hourly Earnings	% of Industry
Packaging and filling machine operators and tenders	51-9111	$14.16	14.2%
Food batchmakers	51-3092	$15.73	8.3%
Industrial truck and tractor operators	53-7051	$16.32	5.6%
Laborers and freight, stock, and material movers, hand	53-7062	$14.15	4.4%
Team assemblers	51-2092	$15.15	4.0%
Industrial machinery mechanics	49-9041	$28.68	3.9%
Helpers--production workers	51-9198	$12.98	3.8%
Inspectors, testers, sorters, samplers, and weighers	51-9061	$18.42	3.4%
Graders and sorters, agricultural products	45-2041	$13.25	3.2%
First-line supervisors of production and operating workers	51-1011	$32.86	3.2%
Food cooking machine operators and tenders	51-3093	$14.24	2.9%
Maintenance and repair workers, general	49-9071	$21.13	2.6%
Packers and packagers, hand	53-7064	$12.35	2.6%
Food processing workers, all other	51-3099	$12.38	2.0%
Janitors and cleaners, except maids and housekeeping cleaners	37-2011	$14.60	1.7%
Cleaners of vehicles and equipment	53-7061	$13.41	1.7%
Shipping, receiving, and traffic clerks	43-5071	$15.86	1.6%
Food and tobacco roasting, baking, and drying machine operators and tenders	51-3091	$15.53	1.5%
Industrial production managers	11-3051	$43.26	1.1%
All Other	-	$23.86	28.3%
Total, all occupations	***00-0000***	***$18.89***	***100.0%***

Source: BLS Employment Projections program, Emsi 2017.1

Odessa Sub-area Potato Production & Processing Impacts

In this section we discuss three different scenarios and outline the changes in economic activity and employment from two specific scenarios. In a regional economy, production loss has two major impacts on the economy. The first loss results from decreased purchases of intermediate inputs to the production process. This might be reductions in fertilizer, diesel purchases, etc. At the same time, the industry loses payment to the factor inputs of labor and capital, sometimes referred to as "value-added" sectors. In our case, value-added impacts are comprised of four factors, taxes on production and imports (TOPI), property incomes (capital payments), proprietary income, and employee compensation (labor payments). Under the above circumstances, the regional economic impact mainly consists of two major effects – direct and secondary.

Direct effects: the changes in economic activity that takes place in the directly affected industry. For our case, this involves the impacts on the potato industry.

Multiplier effects: these changes in economic activity emanate from the subsequent ripple effect of changes in directly affected industry spending. There are two types of secondary effects – indirect and induced.

> *Indirect effects* are the changes in economic activity within the region connected through "backward-links" to the industry of concern. These "backward-linked" industries are those who supply goods and services to the industry of interest. For example, the decreased sales of the fertilizer industry or the drop in agricultural services resulting from a decreased production in the potato industry.
>
> *Induced effects* reflect the change in economic activity resulting from reductions in employees' household consumption stemming from the industry of interest. For example, employees in the potato growing industry, and the supporting industries, may go out to eat less or curtail their other purchases because their income has gone down.

Scenario 1: Replacement of Local Potato Production

A scenario was proposed by Bhattacharjee and Holland where potato production in the Odessa Sub-area was eliminated but production in the remainder of the four-county region offset those losses. So the net change in potato production for the four-county economy was unchanged, resulting in zero economic impacts (see page 23 of their report).

In order for this scenario to be modeled correctly the acres taken out of potato production in the Sub-area should be replaced with wheat or some other dryland crop. In order for potato production in the four counties to remain unchanged additional potatoes will need to be grown outside of the sub-area. To achieve this, conservation land outside of the sub-area will have to be put into potato production or some other crop must be taken out of production to make room for the potatoes. In either case, if it is more valuable to grow potatoes on that land than to use it for its current purpose, then why hasn't the farmer already converted it to potato crops?

In the event that irrigation stops, this scenario would be extremely unlikely to play out. The following two scenarios provide what we see as the lower and upper bounds of economic activity changes in the four counties.

Scenario 2: Loss of Local Potato Production

In this scenario we remove the potato production in the Sub-area and analyze the backward-linked losses that result as local farm revenues fall. It is worth noting that since nearly all of the potato production in the region is sold to local processors we are not reducing regional exports. This scenario assumes processors continue to operate at their normal levels by importing more potatoes from non-local sources. The type of impacts we are measuring in this scenario are therefore not altering what is typically referred to as final demand. We are reducing intermediate demand resulting in what is referred to as contributions from "import-substitution," local potatoes being a substitute for non-local imports.

At the same time as we are reducing the potato production we are increasing the wheat production under the assumption that the farmers and land owners will not opt to let their land sit idle. As most wheat is exported this component of the analysis reflects the traditional "export base" contributions. By running both the potato loss and wheat gains simultaneously we arrive at the net change in economic activity knowns as economic impacts. Tables 6 through 9 show these impacts in terms of the lost sales, income, value added, and jobs. Because sales figures reflect double counting they should not be used in reporting impact measures. We include the changes in sales purely for the sake of completeness and to understand how transaction volumes are affected.

Table 6: *Sales Impacts from Lost Potato Production in the Odessa Sub-area ('000)*

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	-$119,348	-$4,016	-$39	-$123,403
Potato Processing	$0	$0	-$12	-$12
Agriculture	$4,619	-$4,745	-$15	-$141
Forestry	$0	-$20	$0	-$20
Mining	$0	-$76	-$3	-$79
Utilities	$0	-$88	-$25	-$113
Construction	$0	-$464	-$190	-$654
Processed food	$0	-$81	-$100	-$181
Manufactures	$0	-$1,450	-$84	-$1,534
Wholesale and retail trade	$0	-$1,465	-$927	-$2,392
Services	$0	-$3,909	-$2,035	-$5,944
Miscellaneous	$0	-$67	-$88	-$155
Institutions	$0	$0	-$1,840	-$1,840
Total	**-$114,729**	**-$16,381**	**-$5,359**	**-$136,469**

Source: Emsi 2017.1 and author's calculations

Whereas Sales Impacts measure total changes in transactions the value-added impacts in Table 7 removes all double counting of value and reflects the unique value of the regions production. Often times value-added is referred to as Gross Regional Product or (GRP). It does not include the payments to intermediate inputs to production.

Table 7: *Value-Added Impacts from Lost Potato Production in the Odessa Sub-area('000)*

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	-$29,187	-$982	-$10	-$30,179
Potato Processing	$0	$0	-$12	-$12
Agriculture	$1,130	-$3,781	-$8	-$2,659
Forestry	$0	-$16	$0	-$16
Mining	$0	-$42	-$2	-$44
Utilities	$0	-$62	-$17	-$80
Construction	$0	-$233	-$95	-$328
Processed food	$0	-$11	-$22	-$33
Manufactures	$0	-$424	-$31	-$456
Wholesale and retail trade	$0	-$972	-$571	-$1,543
Services	$0	-$1,973	-$1,085	-$3,058
Miscellaneous	$0	-$44	-$42	-$86
Total	-$28,058	-$8,540	-$1,895	-$38,493

Source: Emsi 2017.1 and author's calculations

Income Impacts from the loss in potato production are reflected in Table 8. Income is a subset of value-added, reflecting only the payments to employee and proprietor labor and the returns to capital received by owners, often called property income. The difference between Income and value-added is usually just payments to government for import and business taxes.

Table 8: *Income Impacts from Lost Potato Production in the Odessa Sub-area('000)*

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	-$20,289	-$683	-$7	-$20,979
Potato Processing	$0	$0	-$12	-$12
Agriculture	$785	-$3,616	-$6	-$2,837
Forestry	$0	-$16	$0	-$16
Mining	$0	-$20	-$1	-$21
Utilities	$0	-$23	-$5	-$28
Construction	$0	-$180	-$74	-$254
Processed food	$0	-$6	-$13	-$19
Manufactures	$0	-$189	-$16	-$205
Wholesale and retail trade	$0	-$502	-$352	-$854
Services	$0	-$1,171	-$850	-$2,021
Miscellaneous	$0	-$42	-$39	-$81
Total	-$19,504	-$6,448	-$1,374	-$27,326

Source: Emsi 2017.1 and author's calculations

Table 9 reflects the loss in employment supported by the Odessa Sub-area potato production. The 1,000 job losses in potato production are slightly offset by the 67 job gains in wheat farming. The total change in employment stemming from the net 933 direct job losses is -1,162 jobs supported.

Table 9: *Employment Impacts from Lost Potato Production in the Odessa Sub-area*

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	-1,000	-34	0	-1,034
Potato Processing	0	0	-12	-12
Agriculture	39	-107	0	-68
Forestry	0	0	0	0
Mining	0	-1	0	-1
Utilities	0	0	0	0
Construction	0	-4	-2	-5
Processed food	0	0	0	0
Manufactures	0	-4	0	-4
Wholesale and retail trade	0	-10	-11	-21
Services	0	-32	-27	-59
Miscellaneous	0	-1	-2	-3
Total	-961	-193	-55	-1,209

Source: Emsi 2017.1 and author's calculations

Scenario 3: Loss of Local Potato Production & Associated Processing

This scenario provides a reasonable long run upper-bound of the economic losses that the four-county region might sustain if irrigation and thus potato production are lost. The assumption is that processors are not able to augment the loss in local supply through importation of potatoes from non-local sources. Processing output in this scenario is reduced by exactly the amount they typically purchase from producers in the Sub-area. Approximately 18.3% of potatoes purchased by local processors came from the Odessa Sub-area, so it is unlikely that the processors would shut down completely. Three things are occurring in this simulation,

1) Potato processors in the four-county region reduce their local purchases of potatoes (this is shown in the Indirect Effects column).

2) Potato growing in the Odessa Sub-area ceases.

3) Acres that were in potato production within the Odessa Sub-area are converted to dryland wheat production.

Tables 10 through 13 show the net changes in economic activity within the four-county region that are likely to occur if processors reduce their output from the lack of input supply. A total of over $606 million in transactions would be lost. Table 10 shows the loss in potato production as a backwards-linked effect of the processors and can be seen in the negative $119 million in the Indirect Effect column.

Table 10: *Sales Impacts from Lost Potato Production and Processing ('000)*

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	$0	-$119,348	-$114	-$119,461
Potato Processing	-$367,591	-$11,264	-$34	-$378,889
Agriculture	$4,619	-$19,706	-$44	-$15,131
Forestry	$0	-$3	$0	-$3
Mining	$0	-$12	-$12	-$24
Utilities	$0	-$213	-$74	-$287
Construction	$0	-$285	-$894	-$1,179
Processed food	$0	-$21,288	-$254	-$21,542
Manufactures	$0	-$4,295	-$270	-$4,564
Wholesale and retail trade	-$2,291	-$12,179	-$2,698	-$17,168
Services	-$25,106	-$12,188	-$5,966	-$43,260
Miscellaneous	$0	-$396	-$251	-$647
Institutions	$0	$0	-$8,419	-$8,419
Total	**-$390,368**	**-$201,175**	**-$19,031**	**-$610,574**

Source: Emsi 2017.1 and author's calculations

Table 11 shows that the direct value-added lost from processing is $67.2 million. There is a gain of nearly $2 million from increased wheat production and forward linked effects of wholesale trade and transportation services of $1.5 million and $10.1 million are lost as well. The indirect effects are substantial for the processing. Note that the indirect effects in the previous scenario were a small portion of the overall impacts. This suggests that the processors are making much larger regional purchases relative to the producers. Total value-added impacts are roughly -$138.2 million.

Table 11: *Value-Added Impacts from Lost Potato Production and Processing ('000)*

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	$0	-$29,187	-$28	-$29,215
Potato Processing	-$67,163	-$2,058	-$6	-$69,227
Agriculture	$1,130	-$5,286	-$23	-$4,179
Forestry	$0	-$2	$0	-$2
Mining	$0	-$7	-$8	-$14
Utilities	$0	-$145	-$50	-$195
Construction	$0	-$143	-$448	-$590
Processed food	$0	-$3,810	-$58	-$3,868
Manufactures	$0	-$1,104	-$100	-$1,204
Wholesale and retail trade	-$1,523	-$8,118	-$1,663	-$11,304
Services	-$10,090	-$5,893	-$3,163	-$19,146
Miscellaneous	$0	-$230	-$120	-$350
Total	**-$77,646**	**-$55,981**	**-$5,667**	**-$139,294**

Source: Emsi 2017.1 and author's calculations

Table 12 tells much the same story. The income losses total -$114.1 million. Those losses are felt throughout the economy though the growers and processors feel the impact the most.

Table 12: *Income Impacts from Lost Potato Production and Processing ('000)*

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	$0	-$20,289	-$28	-$20,317
Potato Processing	-$53,752	-$1,647	-$5	-$55,404
Agriculture	$785	-$5,122	-$17	-$4,354
Forestry	$0	-$2	$0	-$2
Mining	$0	-$3	-$5	-$8
Utilities	$0	-$43	-$15	-$59
Construction	$0	-$110	-$347	-$457
Processed food	$0	-$2,932	-$33	-$2,964
Manufactures	$0	-$784	-$53	-$837
Wholesale and retail trade	-$769	-$4,140	-$1,022	-$5,930
Services	-$8,541	-$4,276	-$2,466	-$15,284
Miscellaneous	$0	-$238	-$112	-$349
Total	**-$62,276**	**-$39,587**	**-$4,104**	**-$105,967**

Source: Emsi 2017.1 and author's calculations

In markets that are struggling to see job recovery the loss of irrigation, potato production, and resulting declines in processing output could be devastating. Total direct losses would amount to 1,229 fewer jobs. The support industries would lose even more jobs, almost 1,450. Total job losses could exceed 2,800.

Table 13: *Employment Impacts from Lost Potato Production and Processing*

Industry	Direct Effect	Indirect Effect	Induced Effect	Total Effect
Potato Production	0	-1,000	-1	-1,001
Potato Processing	-1,099	-34	-1	-1,134
Agriculture	67	-164	-1	-99
Forestry	0	0	0	0
Mining	0	0	0	0
Utilities	0	0	0	-1
Construction	0	-2	-7	-9
Processed food	0	-44	-1	-45
Manufactures	0	-10	-1	-11
Wholesale and retail trade	-11	-79	-31	-122
Services	-185	-110	-79	-374
Miscellaneous	0	-5	-6	-10
Total	**-1,229**	**-1,448**	**-129**	**-2,805**

Source: Emsi 2017.1 and author's calculations

Conclusions

Potential changes in economic activity need to be considered when proposed water use and curtailments are considered. The Bureau of Reclamation needs to carefully weigh the benefits and costs to the economy of any proposed irrigation infrastructure investments. Given the high yields and soil quality in the region, removing this land from potato production would likely raise commodity prices for processors and consumers without seeing increased gains to local farmers.

The four counties of Adams, Franklin, Grant, and Lincoln represent one of the most concentrated regions of potato farming in the Pacific North West. In terms of potato output the region is more than 130 times more concentrated than the U.S. as a whole. In 2015 the Odessa Sub-area alone produced more than 934,000 tons of potatoes and they generated over $119 million in sales. Processors converted those raw potatoes into more than $367 million in wholesale value worth of French fries, chips, and other potato products.

Exports of processed potatoes bring new money into the region. That new money is then spent by the processors on employee wages, utilities, and raw potatoes. Employees then spend their earnings on household goods (e.g., eating out at local restaurants, getting the oil in their car changed, buying a new home, etc.). As that money ripples through the economy it creates additional rounds of spending and income until it finally leaks out of the region for the purchase of imports.

Table 14 shows that money brought into the economy through processed potato exports ripples through the economy longer and has a higher multiplier effect than the average dollar. For every dollar in processed potato exports an additional 56 cents in local economic activity is generated, 42 cents more than the regional average of 14 cents. The output from each full time equivalent job in potato processing supports an additional 0.46 jobs in support industries such as trucking and utilities. This exceeds the average jobs multiplier of 1.16.

Table 14: *Four-County Regional Multipliers*

	Regional Average	Potato Processing
Sales Multipliers	$1.14	$1.56
Value Added Multipliers	$1.17	$1.79
Income Multipliers	$1.13	$1.86
Jobs Multipliers	1.16	1.46

Source: Emsi 2017.1 and author's calculations

The economic losses that could result from removing potato production in the Odessa Sub-area range from a low of **-$37.4 million** to a high of **-$138.2 million** in value-added and from **-1,162 jobs** up to **-2,805 jobs**. Tables 15 and 16 synthesize the economic impacts of losing potato production and processing respectively.

Table 15: *Losses from Potato Production Alone*

	Sales	Value Added	Income	Jobs
Direct Effect	($111,384)	($27,240)	($27,853)	(933)
Multiplier Effects	($22,489)	($10,121)	($7,899)	(229)
Total Impacts	($133,873)	($37,361)	($35,752)	(1,162)

Source: Emsi 2017.1 and author's calculations

Table 16: *Losses from Potato Production and Processing*

	Sales	Value Added	Income	Jobs
Direct Effect	($387,024)	($76,828)	($61,070)	(1,229)
Multiplier Effects	($219,573)	($61,371)	($53,036)	(1,576)
Total Impacts	($606,596)	($138,200)	($114,106)	(2,805)

Source: Emsi 2017.1 and author's calculations

These losses may seem minor relative to the entire economy but they reflect only the losses from potato outputs. The real costs of losing water in the Odessa Sub-area would also affect forage producers; specialty crop producers including mint, pepper, onion, carrot; and wine grape growers. Even wheat producers that irrigate their crops would be put under pressure.

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Appendix A: A primer on Input-Output Accounts and Social Accounting Matrices

The Basic Input-Output model

Before jumping into the Social Accounting Matrices (SAMs) it will be helpful to discuss a system of accounts embedded in the SAM. The system of accounts known as Input-Output (I-O) represents an economist's version of double-entry book keeping for industries. Figure A.1 below shows a simplified version of an I-O matrix with just a hand full of industries.

Figure A.1: Aggregated form Input-Output Matrix

		Producers as Consumers						**Final Demand**			
		Agric.	Min.	Const.	Manuf.	Services	Other	Households	Investment	Government	Net exports
Producers	Agric.										
	Min.										
	Const.										
	Manuf.										
	Services										
	Other										
Value Added	Labor							Gross Domestic Product			
	Returns to Capital										
	Taxes										

Reading down a column of this table shows you what inputs an industry is buying in order to produce their output. If we look at the Agriculture column, farm businesses, for example, may buy seed from within their own sector, fertilizer and farm equipment from the manufacturing sector, and legal and accounting services from the service sector. Payments to their employees are captured in the "Labor" row, they receive the returns to the capital that they own, and they pay taxes to the government. Reading across a row tells us where an industry's income originates. Sticking with agriculture, they sell seed to others in the agricultural sector; their crops may be sold to processing plants in the manufacturing sector, or perhaps directly to consumers. A portion of a household's expenditures will go to buying agricultural goods, and even government may purchase agricultural goods. Lastly, the agricultural industry will sell its output abroad via the "Net exports" column.

Summing all of the labor, capital, and tax payments for all industries gives the sum of all value added and will equal the Gross Domestic Product (GDP) of the region. Similarly summing all of the expenditures of households, government, investment, and net exports yields the GDP of the region. These two methods of calculating GDP are known as the Income and Expenditure approaches, respectively, and they represent a check for ensuring all accounts balance. It is through the I-O system that we are able to trace the dollars through the economy and calculate multiplier effects.

The Social Accounting Matrix

The social Accounting Matrices (SAMs) are a bit more robust than the I-O tables. SAMs can be extremely detailed, embedding commodity purchases, occupations staffing matrices, detailed government accounts, and even demographic information. The social accounting framework used for this report was derived from the EMSI SAM and has a structure similar to Figure A.2.

Figure A.2: Example Social Accounting Matrix

		A	C	F	INST	T(FT)	T(DT)
		1	2	3	4	5	6
A	1		MAKE				
C	2	USE			IUSE	CEXPRT	CEXPRT
F	3	FD				FEXPRT	FEXPRT
INST	4		IMAKE	FS	TRNSFR	IEXPRT	IEXPRT
T(FT)	5		CIMPRT	FIMPRT	IIMPRT	TRNSHP	TRNSHP
T(DT)	6		CIMPRT	FIMPRT	IIMPRT	TRNSHP	TRNSHP

The interpretation of this matrix is slightly different than that of the I-O model. Here the rows and columns match so that the entire matrix is square. In this case A represents the set of industries, C is the set of commodities, F is the set of factors used in production (these are synonymous with the value added components of the I-O table), INST represents institutions such as households, governments, and other non-industry organizations, T(FT) represents foreign trade and T(DT) represents U.S. or domestic trade.

Segments of the SAM that are gray represent regions where there are no transactions. For example, in the SAM industries do not buy from other industries, they buy commodities and this shows up as the "USE" table. Industries also purchase land, labor, capital, and government services. Those purchases are displayed in the "FD" or factor demand segment of the SAM. Industry output is reported in the "MAKE" matrix, though institutions such as government can produce commodities as well. State run power facilities are a good example of institutions producing a commodity. Commodities may also be imported from other parts of the U.S. and from abroad via the CIMPRT tables. Institutions also buy commodities and transfer wealth amongst themselves. Those activities are captured in the "IUSE" and "TRNSFR" tables. Factors available for productive use are supplied by institutions, "FS", and may be imported in some cases "FIMPRT". The "FEXPRT" and "IEXPRT" represent factors of production and institutional output that are sold outside of the regional economy.

Appendix B: Sensitivity Analysis

The purpose of a sensitivity analysis is to show how the results of a study are altered under different values of assumed or critical variables. These sensitivity analyses also help to separate research and advocacy by providing reasonable upper and lower bound estimates of expected outcomes. Point estimates in impact analysis are rarely accurate. Providing decision makers and industry leaders with an expected range of results allows them to weigh the outcomes of their decisions under a variety of different scenarios.

In this analysis we run three distinct scenarios shocking: 1) potato yields, 2) annual acreage, and 3) the loss of all potato processing. In each case we show how the direct, multiplier, and total impacts would evolve when the base case assumptions are increased and decreased. Many other potential shocks are possible but these three influence the primary exogenous control variables. Shocks to technology and production techniques are regular occurrences in agriculture, but ultimately those shocks influence costs and output which we measure through production. The final scenario is the worst case scenario and is somewhat improbable. However, agricultural processing plants have closed in the past and significant reductions in available local inputs may cause processors to consider relocating.[5]

Potato Yield Variable

In scenarios 2 (loss of Odessa Sub-area potato production) and scenario 3 (loss of Odessa Sub-area potato production and associated processing) we assumed that the potato yields in the sub-area were 635 cwt/acre. This represents the base case from 2015. Yields over the last decade ranged from 580 to 701 cwt/acre. We run our analysis under these two yields and provide the impacts for both scenarios 2 and 3 in Tables B.1 through B.4 below.

Table B.1: Scenario 2 Changes in Value Added Due to Yield Adjustments ('000)

Industry	-7%	Base Case	10%
Odessa Sub-area Yields (cwt/acre)	590	635	701
Total Direct Effects	-$27,106	-$28,058	-$32,206
Total Multiplier Effects	-$10,070	-$10,435	-$11,964
Total	-$37,176	-$38,493	-$44,170

[5] The 70 year old Seneca asparagus carrot cannery in Dayton, WA closed in 2005. According to Emsi 2017.1 employment in Fruit and Vegetable Canning went from 213 jobs in 2005 to 36 in 2006. The location quotient fell from 268 to 50 during the same time period.

Table B.2: Scenario 2 Changes in Employment Due to Yield Adjustments

Industry	-7%	Base Case	10%
Odessa Sub-area Yields	590	635	701
Total Direct Effects	-928	-961	-1,103
Total Multiplier Effects	-239	-248	-270
Total	-1,168	-1,209	-1,373

Table B.3: Scenario 3 Changes in Value Added Due to Yield Adjustments ('000)

Industry	-7%	Base Case	10%
Odessa Sub-area Yields	590	635	701
Total Direct Effects	-$72,433	-$77,646	-$85,208
Total Multiplier Effects	-$57,509	-$61,648	-$67,651
Total	-$129,941	-$139,294	-$152,859

Table B.4: Scenario 3 Changes in Employment Due to Yield Adjustments

Industry	-7%	Base Case	10%
Odessa Sub-area Yields	590	635	701
Total Direct Effects	-1,146	-1,229	-1,348
Total Multiplier Effects	-1,470	-1,576	-1,729
Total	-2,616	-2,805	-3,077

Acreage Variable

Large changes in acreage devoted to potato production in the sub-area occurred between 2005 and 2015. This variable is clearly volatile and yet critical in determining the direct value of production. It should be noted however that returns to scale apply here and linear changes in acreage do not necessarily translate into linear changes in production costs. Adjusting acreage by just a few acres will have little effect on overall cost structures and linearity in costs/acre is a reasonable assumption. This is less the case when we start adjusting acreage by thousands.

Given the structure of the model we are forced into the linear assumption and, as such, these results should be understood in the context of the model constraints. Tables B.5 through B.8 provide a 25% band around our base case analysis for both scenarios 2 and 3. However, we are assuming linearity in cost structures per acre that are not realistic in extreme cases.

Table B.5: Scenario 2 Changes in Value Added Due to Acreage Adjustments ('000)

Industry	-25%	Base Case	25%
Odessa Sub-area Acreage	19,889	26,519	33,149
Total Direct Effects	-$21,890	-$28,058	-$36,484
Total Multiplier Effects	-$8,132	-$10,435	-$13,553
Total	-$30,022	-$38,493	-$50,037

Table B.6: Scenario 2 Changes in Employment Due to Acreage Adjustments

Industry	-25%	Base Case	25%
Odessa Sub-area Acreage	19,889	26,519	33,149
Total Direct Effects	-750	-961	-1,250
Total Multiplier Effects	-184	-248	-306
Total	-934	-1,209	-1,556

Table B.7: Scenario 3 Changes in Value Added Due to Acreage Adjustments ('000)

Industry	-25%	Base Case	25%
Odessa Sub-area Acreage	19,889	26,519	33,149
Total Direct Effects	-$59,367	-$77,646	-$95,925
Total Multiplier Effects	-$47,135	-$61,648	-$76,160
Total	-$106,502	-$139,294	-$172,086

Table B.8: Scenario 3 Changes in Employment Due to Acreage Adjustments

Industry	-25%	Base Case	25%
Odessa Sub-area Acreage	19,889	26,519	33,149
Total Direct Effects	-939	-1,229	-1,518
Total Multiplier Effects	-1,205	-1,576	-1,946
Total	-2,144	-2,805	-3,464

Processor Shutdown

In this portion of the sensitivity analysis we want to remove the potato processing from the four-county region. This is done through a process known as Hypothetical Extraction; see Miller and Lahr (2001). In this case we only need to run one scenario wherein potato processors are essentially removed from the regional social accounts and the new equilibrium is calculated. The difference between the equilibrium under the current regional accounts and the equilibrium after the potato processors are extracted represents the loss to the four-county economy. Total lost sales resulting from potato processing closures amounts to just under $1.85 billion. Losses in terms of value added and jobs are approximately $367.8 million and just over 7,400 jobs.

Appendix C: Glossary of Terms

Direct Effects	The effect in the economy on a sector or industry resulting from the final demand or change in the final demand of that same sector or industry.
Employment	Jobs, in the context of input-output analysis, reflect full time equivalent employment but do not capture each individual part time job.
Gross Regional Product / Value Added	The amount by which the value of a product is increased at each stage of the production process exclusive of the initial costs.
Income	Monies received by employees and owners of a firm whether from labor rendered or returns to physical assets.
Indirect Effects	The effect of business-to-business expenditures on an economy resulting from the final demand or a change in the final demand of an industry or sector.
Induced Effects	The effect of household-to-business expenditures on an economy resulting from the final demand or a change in the final demand of an industry or sector.
Input-Output Analysis	An economic model that allows the measurement of overall economic activity resulting from the final demand or a change in the final demand of a sector or industry.
Sales	The total value, as measured by dollars transacted, of goods and services bought and sold.