2015 Drought and Agriculture

A Study by the Washington State Department of Agriculture

February 2017

Washington State Department of Agriculture

Derek I. Sandison, Director

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Greetings,

This report, "2015 Drought and Agriculture: A Study by the Washington State Department of Agriculture," represents a milestone for the agency. Since 1970, Washington has experienced more than half a dozen droughts and, in all that time, this is the first attempt to quantify the impacts of these disastrous climatological events.

Our Natural Resources Assessment Section (NRAS) has spent the past year identifying metrics that give some measure of the economic impact the 2015 drought in Washington State had on our farmers and ranchers.

The work was challenging and labor intensive. It entailed numerous meetings with farmers, ranchers and organizations involved in agriculture. The NRAS staff conducted surveys and visited farms around the state. We partnered with agriculture organizations, academic institutions, and conservation districts.

The resulting estimate places economic damage from the 2015 drought at somewhere between $633 million to $773 million dollars statewide. There are a number of caveats to those figures that the report explains in detail, but they result from the best available data.

Earlier estimates made at the first signs of drought in May 2015 anticipated even higher losses, based on what could happen if nothing were done to mitigate the effects of the drought. But much was done, by state and federal agencies, agriculture industry organizations, irrigation districts and farmers themselves.

This report is the first successful attempt to tally the impacts of the drought on Washington agriculture and it lays the groundwork to improve the accuracy of future drought impact projections.

I want to thank the Department of Ecology for funding this effort, and all of those in Washington's agriculture community, our other state and federal partners, and everyone who assisted with the development of this report. Without your cooperation, this work would not have been possible.

Derek Sandison
Director, Washington State Department of Agriculture

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2015 Drought and Agriculture

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Executive Summary

The 2015 growing season in Washington State was one of the driest on record due to early, rapid snow melt. In addition, temperatures during the 2015 water year (October 1, 2014 – September 30, 2015) were far above average. Due to high temperatures, precipitation at high elevations that would ordinarily result in snow accumulation (sustaining irrigation networks through the summer) fell as rain instead. As a result, summer streamflow throughout the state was much lower than usual. During the last week of August, the height of the 2015 drought, 85% of Washington was in "extreme drought status."

In mid-November 2015 Washington State Department of Agriculture's (WSDA) Natural Resources Assessment Section (NRAS), at the request of the Washington State Department of Ecology (Ecology), began additional analysis of the 2015 drought. WSDA completed an interim report with qualitative analysis of the financial losses to affected farms on December 31, 2015. This final report draws from all available quantitative data on the 2015 harvest and drought impacts.

The economic impact of drought from other extreme climatic events has not previously been quantified at a statewide level. WSDA conducted this analysis in order to measure the effects of the 2015 drought and also collect information that could be used to improve future drought relief efforts. Through this work, WSDA has also established a starting place for ongoing data collection and future analysis of the impact of extreme weather events on Washington agriculture.

WSDA used the best available information from a variety of sources and partnerships with agriculture groups and other government agencies to estimate losses to agriculture from the 2015 drought. WSDA focused on top commodities, some specific regions of the state, and a survey of the livestock industry. The objective was to assess the gross value of lost production, as well as some additional expenses growers incurred due to the drought. Staff did not attempt to quantify net losses to affected growers. In addition, WSDA did not attempt to quantify net statewide effects of drought; there were certainly some who benefited from higher commodity prices or the opportunity to lease water rights. Finally, this drought was accompanied by extreme heat that also affected farmers. This report does not attempt to distinguish between the effects of heat and drought.

This final report includes some data from the interim qualitative report, however the majority of the data in this final report is new. Regional highlight areas were the Kittitas Reclamation District (KRD), the Roza Irrigation District (Roza), the Wapato Irrigation Project (WIP), and Skagit County. WSDA collected data in these regions through targeted mapping, anonymous interviews, and information collected by Washington State University's Skagit County Extension. In addition to the regional highlight areas, WSDA reviewed data from the United States Department of Agriculture's National Agricultural Statistics Service (NASS) for a selection of 15 crops which account for 77.5% of the cultivated acreage in Washington. NRAS staff assessed drought impact on dairy and cattle operations in Washington as well through an online survey focusing on increased expenses for feed purchase, lease of additional land for grazing, and productivity losses.

Based on information from commodity-specific and regional grower's groups, WSDA estimates Washington State blueberries grown from 2015 were reduced in yield, size, and quality, with losses of $7.76 million. Red raspberries were reduced in both size and quality, with losses of $13.9 million. Across the Yakima Valley growers reported reductions in both yield and quality, increased fallowing, and changes in crop rotations. Some growers deferred planting permanent crops depending on access to emergency drought wells.

In the KRD, the analysis was based on targeted mapping work by WSDA, supported by KRD staff, and focusing on unharvestable or fallowed fields. The mapping survey included discussions with growers within the KRD to verify damage was drought related and gather qualitative information. Most of the damage was observed in timothy hay, alfalfa, and pasture, consisting of reduced cuttings on hays and dry pastures and reduced grazing opportunities. Additionally, WSDA observed losses in apple, oat, pear, and other grass hays. The amount of acreage affected was paired with the 5-year average price per acre (2010-2014) to determine a total economic impact of $11,401,115.

In the Roza, WSDA also conducted mapping work to identify unharvestable or fallowed fields, as well as anonymous individual interviews with growers to identify additional expenses incurred due to drought. Mapping results identified dry, dead, unharvestable, or fallowed fields in apricot, nectarine/peach, pear, triticale, and wheat. WSDA interviews with growers documented reduced size, quality and yield in apple, cherry, hops, blueberry, wine grape, juice grape, field corn, and alfalfa. Growers also reported increased costs for pest and weed control, emergency drought wells, and expected continued impacts during the 2016 growing season. Total losses for the Roza Irrigation District growers are estimated at $75,783,834.

WSDA conducted anonymous interviews with growers relying on water from the Wapato Irrigation Project. Growers reported losses in timothy, alfalfa, mint, carrot seed, wheat, apples, cherries, and potatoes, although losses were not consistent over the entire area. Based on consultation with the WIP board and growers, WSDA applied these losses to 90% of the acreage and estimate a total loss of $32,691,211.

Information on drought effects in Skagit County were compiled by Washington State University's Skagit County Extension, which estimated a 10% loss throughout the county on average, with a total loss of $27,200,000.

WSDA used data from NASS to identify additional losses across the state in a selection of crops that constitutes 77.5% of the total cultivated acreage in Washington. Data from 2015 was compared to historic results (2010-2014 5-year average) for total crop acreage, price per acre, and yield per acre to assess losses due to reduced yield, reduced quality, or unplanted acreage. The 15 crops selected were wheat, barley, dry peas, lentils, apples, mint, dry beans, hops, sweet corn (processed), sweet corn (fresh), hay (excluding alfalfa), pears, cherries, alfalfa, and field corn. Based on these 3 methodologies losses of $501,002,853 were estimated statewide.

WSDA, with the assistance of the Washington State Dairy Federation, invited dairy and cattle producers to respond to a short online survey about their location, operation size, and potential additional costs incurred through the purchase of feed, rental of additional grazing land, milk or calving losses, and the potential for continued increased costs or losses in 2016. Respondents reported purchases of additional feed, both timothy and alfalfa, leasing additional land for grazing, and reductions in milk production. These results were extrapolated to all dairy producers based on advice from the Washington State Dairy Federation. Because there were relatively few responses from cattle producers, the analysis was not extended to the cattle industry in Washington. Total losses to the dairy industry are estimated at $33,279,564.

As a final step WSDA requested assistance from the Washington State Academy of Sciences (WSAS) to review and comment on the analysis and report. Comments and recommendations from the Academy were incorporated where possible, and included as recommendations for future work. The full review is included in this report as Appendix B: Washington State Academy of Sciences Review.

WSDA concludes that the estimated economic loss due to the 2015 drought reached between $633 million and $773 million. WSDA recommends that this report serve as a starting point rather than a final summary.

Among the agency's recommendations is that an assessment should be conducted of the statewide distribution of irrigation districts, identifying which growers rely on surface and groundwater, which have water rights that are susceptible to curtailment in low water years, and where access to emergency drought wells exists. In addition, now is the time to develop a robust plan for continued data collection. Required data and strategies for collection and ongoing analysis need to be identified in order to give Washington State the ability to assist growers and plan for a future that will include increased incidence of severe weather events such as the 2015 drought.

Introduction and Background

The final statewide drought declaration by Governor Jay Inslee on May 15, 2015 and subsequent completion of the state budget gave the Washington State Department of Ecology (Ecology) funds to conduct drought mitigation activities and provide grants to government organizations focused on reducing the impact of the drought. The Washington State Department of Agriculture (WSDA) received funding to conduct a study on the impacts of the drought to state agriculture. The purpose of this study, funded by Ecology, is both to measure the effects of the 2015 drought and improve future drought relief efforts.

While drought impacts are difficult to isolate and even more difficult to quantify, this report attempts to assess some of the economic impacts of the 2015 drought to agriculture using the best available data. This analysis includes harvested acreage and yield information from NASS for the 2015 season as well as 2010-2014 average values. All yield losses and crop impacts are reported in dollars.

This report quantifies gross loss of economic potential to farmers negatively impacted. No attempt has been made to identify net losses to Washington's agricultural industry as a whole, or to identify net losses to farmers negatively impacted. In addition, this assessment does not include cash and non-cash expenses, or other sources of farm income (insurance payments, sales of goods and services, etc.). WSDA did not attempt to quantify effects due to drought experienced off-farm, in packing houses, due to changes in farm labor needs or expenditures, or any other secondary or indirect effects.

A draft copy of this report was provided to the Washington State Academy of Sciences (WSAS) for review in October 2016. The review was completed and provided to WSDA by mid December 2016. WSDA incorporated many comments from the review into this final report. The WSAS review included many recommendations on how to make improvements to this assessment for future studies; some of which are outlined in the conclusions of this report. A copy of the review can be found in Appendix B.

Agriculture in Washington

Washington State benefits from rich volcanic soils, a diverse climate, and some of the largest irrigation systems in North America. The state's location makes it ideal for overseas exports, with deep water ports and easy year-round accessibility to Asia. Washington produces more than 300 crops annually, placing the state second behind California in total agricultural exports (WSDA, 2016). Washington State is divided into two distinct regions separated by the Cascade mountain range. Western Washington is highly urbanized, and farms tend to be smaller in scale. Dairy products, poultry, hay, and berries are the dominant products. Eastern Washington tends to be more rural and the farms are larger, producing the majority of Washington's tree fruit, wheat, barley, pulse crops (dry peas and lentils), wine and juice grapes, and potatoes.

The 2013 crop production value in Washington exceeded $10 billion, and food processing brought another $15 billion in revenue (this is the most recent crop value information available from NASS). The agricultural industry supports over 160,000 jobs throughout the state and agriculture makes up 13-15% of the state's economy each year (NASS, 2015b).

Apples dominate the economic output of farming in Washington, with a 2013 crop value of $2.19 billion (22% of the state's total crop value). This was followed by milk ($1.298 billion), wheat ($1.014 billion), potatoes ($792 million), and cattle and calves ($706 million). In the context of U.S. production, Washington is the top producer of a wide variety of crops, which include the following (percent of total U.S. production grown in Washington in parentheses) (NASS, 2015c):

- hops (78.7%)
- spearmint oil (69.6%)
- wrinkled seed peas (77.7%)
- peppermint oil (26.4%)
- apples (63.9%)
- Concord grapes (51.5%)
- sweet cherries (65.1%)
- pears (50%)
- processing green peas (32.6%).

Agriculture is a constantly developing industry, with changes in cropping systems and commodities grown driven by external pressures like increasing temperatures, water uncertainty, market prices, new technology, and available growing space. This changing landscape also makes it more difficult to quantify the impacts of drought. An analysis of acreage in different crop groups since 2007 shows slight increases in fruit, grain, and vegetable production although the total number of crop acres has remained relatively stable (Figure 1). Washington has recently seen a significant increase in wine grape production, with more than 50,000 acres in production in 2015. Much of this acreage was already in crop production, likely in Concord juice grapes. Juice grapes are grown in locations that may be favorable for wine grapes, but with less sophisticated irrigation systems; the higher market price that wine grapes command drives the conversion of acreage. Technology development and adoption is frequently stimulated by external pressures like water uncertainty. Washington growers have become more efficient irrigators as cropping systems have evolved. The central Washington orchards full of large trees have been replaced by orchards using a trellis system that allows increased fruit production on the same acreage.

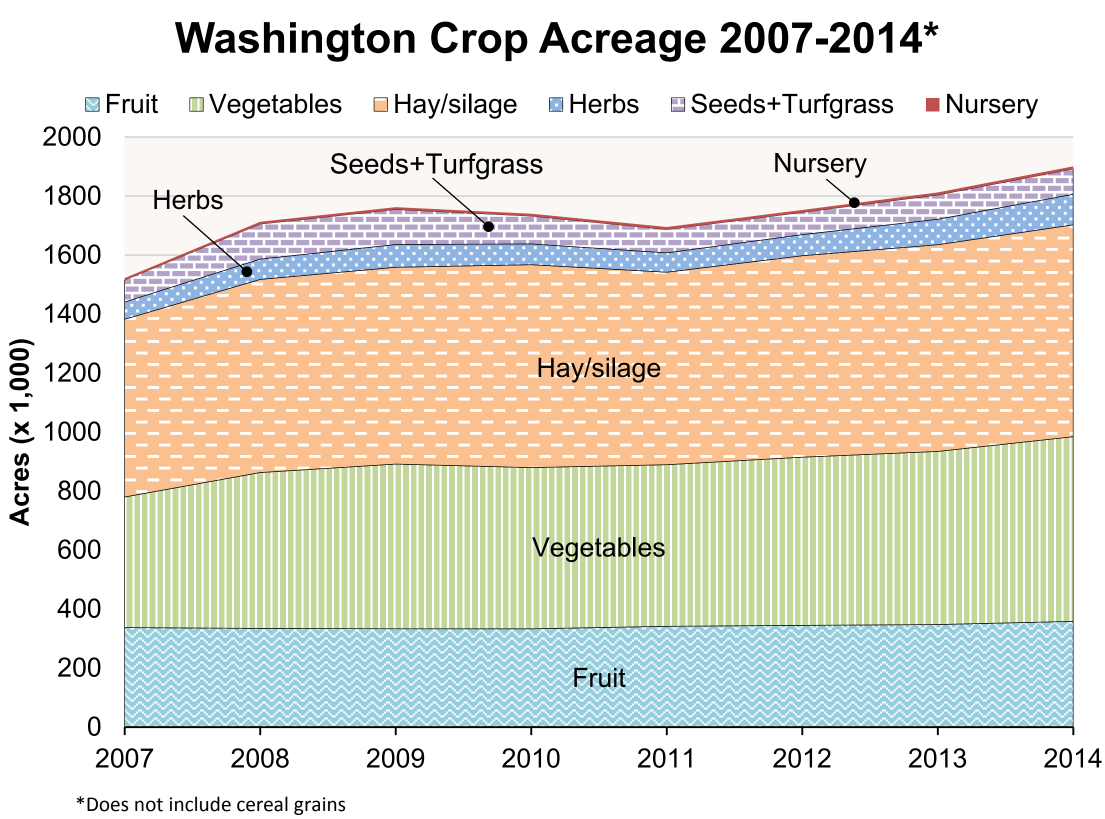

Figure 1. Washington crop acreage 2007-2014 (excludes cereal grains)

Many of Washington's counties include livestock or milk production as top commodities. Washington ranks 10th in the nation in total milk production (NASS, 2015b). Both milk and cattle/calf production are regularly top 10 commodities in Washington State, and both commodities can be impacted by water uncertainty and under producing pastures and feed crops. Agricultural producers already adjust their practices regularly to keep up with market changes, new technology, and other external factors. Similarly, producers have some control over how they prepare for and respond to drought conditions. Producers can control (list taken from the Washington State Academy of Sciences review, WSAS, 2016):

- acreage decisions for crops (including whether to fallow)
- number of head decisions for livestock
- timing of planting and harvest
- pruning, crop load manipulation, and other horticultural practices
- increased pumping of groundwater or development of new sources of water
- fertilizer and other nutrient input investment decisions
- longer-term investment decisions (e.g., number of head for breeding)

Producers cannot control:

- price of outputs (likely higher due to leftward shifting of supply curve)
- price of inputs (e.g., the price livestock/dairy producers might pay for feed)
- yield of commodity
- size of commodity
- quality of commodity

Farmers consistently use the tools at their disposal to prepare for anticipated droughts and adjust to drought conditions midseason; they are often able to moderate the effects, although not eliminate them.

2015 External Pressures

There were an unusually large number of external pressures affecting the market value of Washington State's 2015 crops. A mid-winter port slowdown along the West Coast dramatically slowed shipping times, often meaning crops sat waiting to be loaded on or off ships. Depending on the crop type, this affects storability, marketability, and final values for 2014 crops. It also affected marketing of early-harvested 2015 crops (spring wheat and timothy hay).

Temperatures were extreme across most of Washington State during 2015. By early May, temperatures were already 2-4°F above normal across central and eastern Washington; the rest of the state was trending approximately 2°F above normal. Temperatures during the first week of July ranged 9-15°F above normal throughout most of Washington State. This heat exacerbated the impacts of little to no snowpack accumulation during the winter and extremely low stream flows throughout the state (OWSC, 2015).

Wildfires impacted a large portion of central Washington during the summer of 2015 (for some of this region, it was the second straight year of fire damage). Affected facilities included fruit packing houses, rangeland, pasture, and orchard edges; outcomes were either complete loss or damage during the fires. These historic wildfires burned over 1 million acres and cost the state $178 million to fight.

Analyzing the impact of drought is extremely difficult. Of the factors listed above, extreme heat is very difficult to isolate from standard drought conditions; WSDA has chosen to evaluate the impact of the low water year and extreme heat in combination. Impacts to agriculture reported in this document are estimated losses from drought and extreme heat. This report does not cover losses from the port slow down or the wildfires.

Washington Water Supplies

Approximately 80% of Washington water withdrawals are for agricultural purposes (WSU, 2015). Water for Washington agriculture comes from two main sources: surface water and groundwater. Surface water is the largest source, accounting for approximately 75% of agricultural water needs on average (WSU, 2015). Some farmers and ranchers have surface water rights administered by Ecology, while others have contracts with entities like the U.S. Bureau of Reclamation in the Yakima Valley.

In some parts of Washington, demand for water greatly exceeds availability. In the Yakima Basin, water right holders are divided into junior water right holders (with water rights granted after 1905) and senior water right holders (with water rights granted before 1905). Due to western water law's prior appropriation doctrine (first in time, first in right), junior water right holders are often curtailed or prorated in drought years, while senior water right holders receive their full water right. Since 1992, there have been 6 low water availability years (1992, 1993, 1994, 2001, 2005, and 2015) where proratable irrigation districts in the Yakima Basin received far less than their full allocation of water (Roza Irrigation District, 2015).

Groundwater withdrawals account for approximately 25% of irrigation water use in Washington (WSU, 2015). In drought years, emergency drought well permits are issued and groundwater may be more heavily used. A water user with an emergency drought well permit may use their well during a drought declaration as long as their use is mitigated (Ecology, 2015). Ecology requires mitigation water to offset the use of the wells, in an effort to prevent groundwater levels from dropping. The most recent USGS Water Use Trends in Washington report (1985-2005) reported an average increase of 16% in crop-irrigation withdrawals during that 20-year period (Lane, 2009). During this time, surface water withdrawals for crop irrigation increased by 22% while groundwater withdrawals for crop irrigation increased 10% (Lane, 2009).

There are 1,977,177 acres of irrigated farm land in Washington and 5,958,652 acres of non-irrigated farm land (Figure 2, WSDA, 2016). Although there are more acres of non-irrigated land, the majority of crops in the state are grown with irrigation (for example: berries, orchards, vineyards, nurseries). Exceptions are the categories cereal grain (91% grown without irrigation) and oilseed (74% grown without irrigation). There are 97 irrigation districts that serve the irrigated land in the state. Irrigation districts can have multiple water rights, some of which may be junior or senior to instream flow rules. At this time, there is no database that contains information on which water rights have been curtailed in past years and what the associated irrigated acres are for those water rights. In the future, it would be worthwhile for WSDA to work with partners at Ecology to gain information on water rights curtailments and affected irrigated acres.

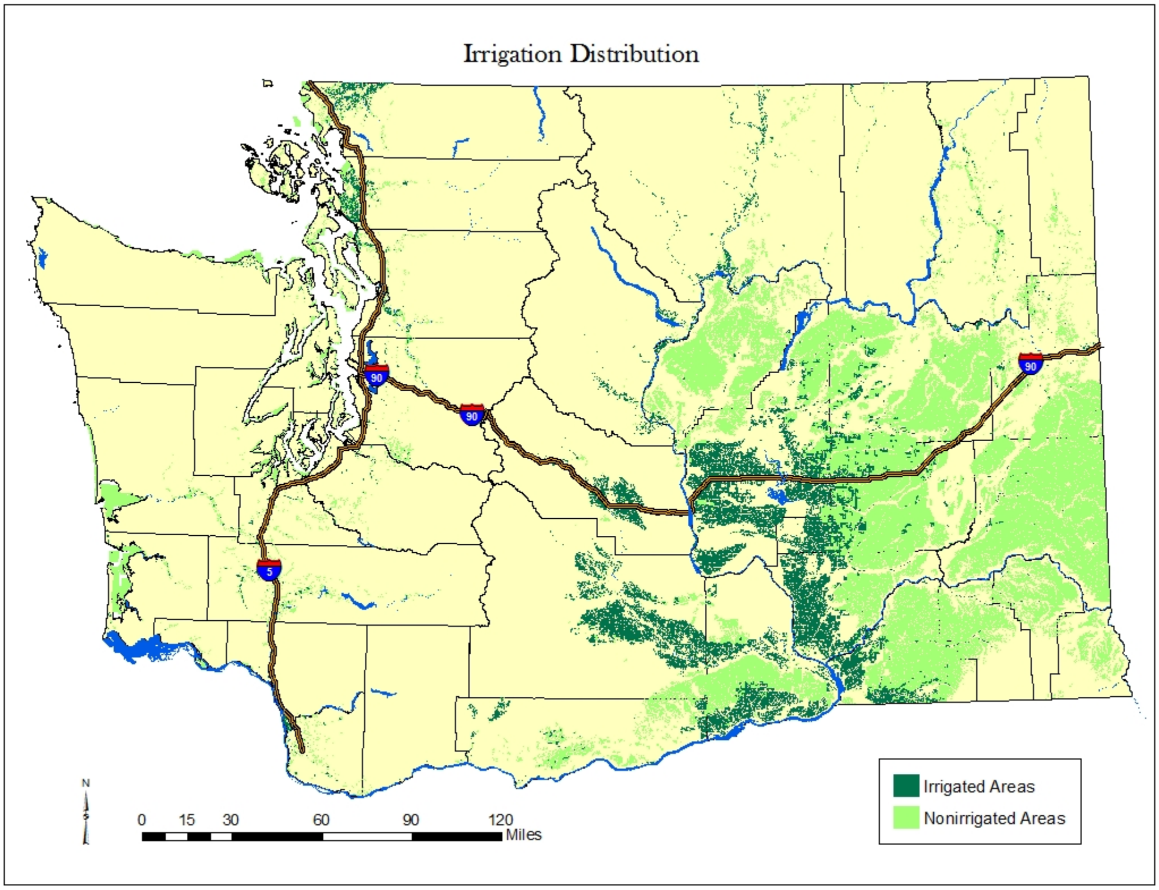

Figure 2. Irrigated and non-irrigated crops in Washington State

2015 Drought

Snowpack is considered to be an additional reservoir, and is an important water source for rivers as lowland precipitation tapers off in the late spring/early summer. During the winter of 2014-2015, much of the precipitation in the mountains fell as rain rather than snow due to above average temperatures. This resulted in low snowpack which was the initial driver of the 2015 drought. On March 13, 2015, Governor Jay Inslee declared a drought in 3 regions in Washington state: the Olympic Peninsula, the east side of the central Cascade mountains (including Yakima and Wenatchee), and the Walla Walla region. This declaration included a total of 11 watersheds (6 west and 5 east of the Cascades). Water supply dropped quickly, leading to a second drought declaration by the governor on

April 17, 2015. After this declaration, nearly half of the state (44%) was declared a drought emergency area. This state declaration included 24 of 62 total river basins (16 basins in western Washington and 8 basins in eastern Washington). Snowpack in April was much lower than normal with a statewide average snow water equivalent of 25% of normal. Water supply conditions throughout the state continued to decline, leading to a final statewide drought declaration on May 15, 2015. By the May declaration, about one-fifth of the state's rivers and streams were at record lows. The peak of the drought occurred during the last week in August, when 85% of the state was categorized as "extreme drought" (shown in red below) (Figure 3).

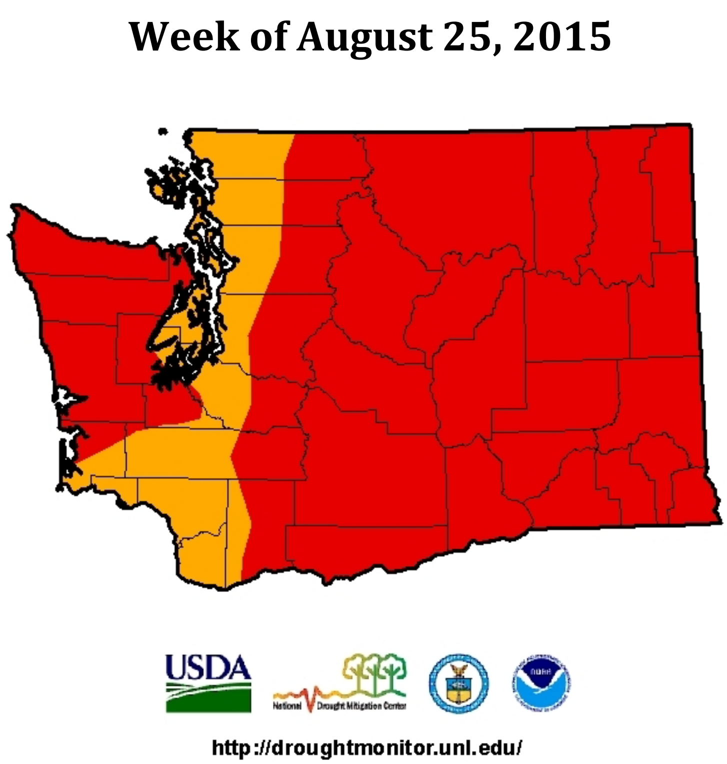

Figure 3. USDA Drought Monitor Map August 25, 2015.
Red (or darker) shade depicts region of extreme drought.

Methodology

Data collection was completed by WSDA staff through emails, online surveys, field visits, telephone conversations, and in-person meetings. NASS crop data was heavily relied on for this report. Data collected by Skagit County Extension is also included.

WSDA staff relied on a variety of diverse data sources for this assessment, which reported data at different levels of accuracy. Results of all intermediate calculations are reported here with the same accuracy as the source data. The estimated total economic loss has been rounded to the nearest million dollars.

Crops and regions that are analyzed in this report are displayed in Figure 4. Focus regions are outlined and crops surveyed are displayed as green polygons.

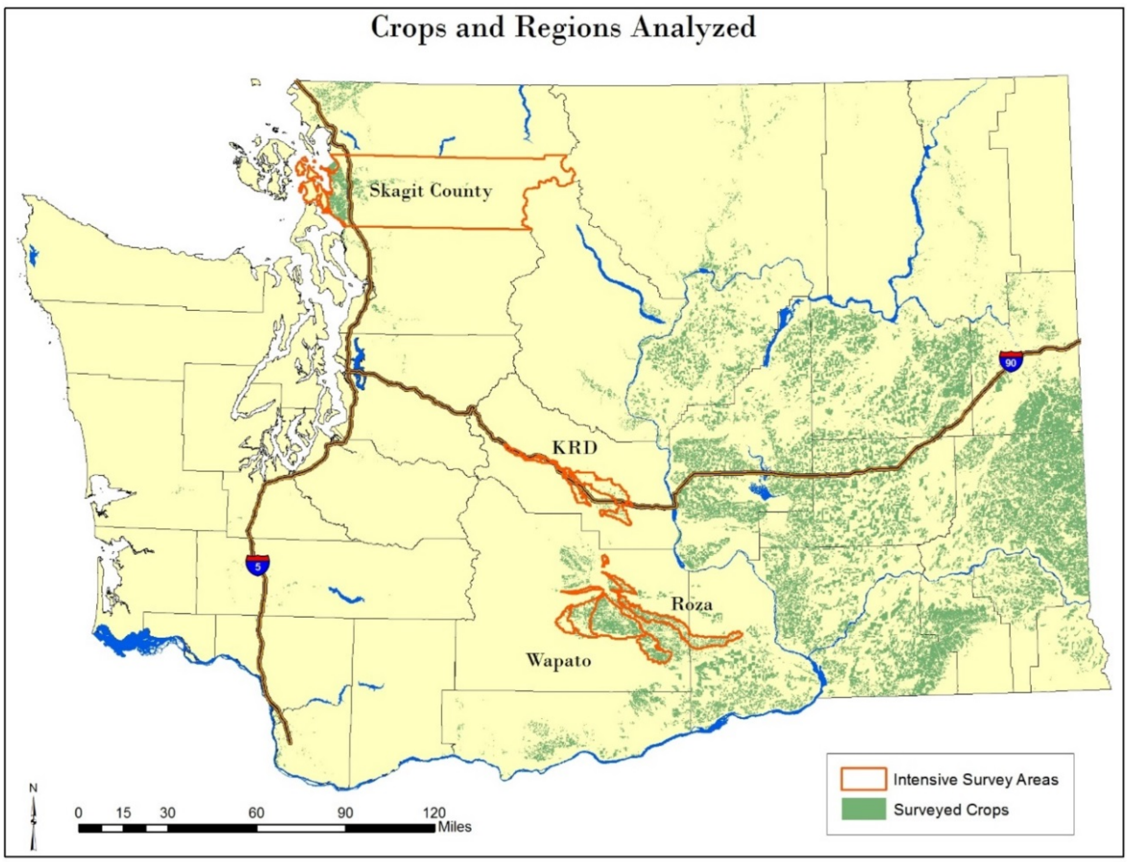

Figure 4. Crops and regions analyzed

Analysis Limitations

Washington State supports an incredibly diverse agricultural economy. There are over 300 different crops grown throughout the state. Given the time and resources allocated to this analysis, it was not feasible to gather data on the state's entire agricultural economy. The effects of the 2015 drought on Washington were wide-ranging. This report attempts to capture that range but there were limitations.

This report quantifies lost economic potential and is based on gross rather than net revenue lost. Economic impact estimates are based on costs to farmers negatively impacted. Future studies may consider estimating net impacts to agriculture depending on the goals of the assessment.

A primary limitation of this analysis is the inability to distinguish between heat effects on agriculture and the effects of reduced water availability. Extreme heat certainly exacerbated the effects of the reduced water supply on Washington's agriculture, but extreme heat is not considered a direct impact of drought. It is possible to have a drought during a period of average air temperature. With the methods relied on in this report, it was not feasible to parse out the effects of reduced water supply from extreme heat.

Another key limitation was the time it takes to collect detailed data. For this reason, WSDA collected specialized data in regions that were predicted to have more severe impacts than the rest of the state. In Eastern Washington, WSDA focused on the Roza Irrigation District (Roza), the Kittitas Reclamation District (KRD) and the Wapato Irrigation Project (WIP). In Western Washington WSDA relied on data collected by the Skagit County Extension for the Skagit County area. Total acreage for these areas was removed from the larger statewide analysis to avoid double accounting. If time and resources permitted, WSDA would have conducted a similar detailed analysis on several more agricultural regions throughout the state.

This report relies on data provided by growers in these highlighted areas where there were no means to collect data on crop yield or quality by direct field measurement. This type of self-reported data from growers can introduce inherent bias.

WSDA chose to focus on a subset of crops for a statewide analysis instead of reviewing NASS data for all crops grown in Washington. The NASS data was analyzed for 15 crops, accounting for 77.5% of the cultivated acreage in the state (NASS, 2016). That is clearly a significant portion of the state crop yields, but WSDA is aware of the data gap created by not gathering information for every commodity produced in Washington. In addition, small acreage farmers are not as well represented in these statewide datasets, even though these producers may feel the effects of a drought more acutely. WSDA prioritized gathering information on large acreage commodities in an attempt to cover as much acreage as possible throughout the state.

An additional limitation was in the data gathered for animal agriculture. The information on impacts of the 2015 drought to animal agriculture was limited to dairy and cattle operations. Additional animal agriculture operations such as poultry (layers and fryers) farming were not included in this report. Producers who suffered drought losses may have been more likely than those who didn't to participate in the survey, which may mean that extrapolating those results to all dairy producers in Washington results in an overestimation.

Finally, no data was collected on secondary or indirect effects of the 2015 drought. There were certainly additional costs incurred by growers for additional mitigation work, as well as effects in the agricultural industry and agricultural communities due to changes in farm spending, labor impacts, and the effects on consumers. WSDA did not research whether impacts were different for female, minority, tribal, veteran farmers, or small farms.

Given the various limitations cited above, it is likely that the total tallied economic impact from the sources that are included in this report are actually an underestimation of the agricultural economic impact of the 2015 drought. Total economic impact will be presented in a range in attempt to account for some of this uncertainty.

Meetings (phone, email, in-person)

WSDA NRAS staff conducted a number of meetings with commodity groups to gather yield and quality information throughout the state. Quantitative data for blueberries and red raspberries has been included. Due to significant increases in acreage and yield in the past 5 years, these two commodities are not well evaluated using NASS data. These meetings were conducted between November 10, 2015 and September 15, 2016 and contain quantitative information when available. Additional qualitative information is included for cherries and the lower Yakima Valley.

Focus Areas

Kittitas Reclamation District- Targeted Mapping

WSDA expected impacts from this drought would be most severe in the areas served by prorated irrigation districts in the Kittitas and Yakima valleys. To assess field level impacts, NRAS staff conducted new visits to all fields within the boundaries of the KRD.

The KRD is a proratable irrigation district in the Kittitas Valley in Central Washington. KRD receives less than its full entitlement of water in drought years. In September 2015, WSDA staff surveyed KRD by visiting and mapping fields to analyze crops for drought impacts. KRD staff participated in the data collection process. Staff specifically looked for dry or unharvestable crops and other signs, such as land left fallow due to drought. Site specific data was recorded for all crops impacted. Other impacts of the drought, such as yield reductions or changes in crop rotation were not documented. The survey included meetings with growers to discuss specific water shortage issues.

The mapping survey was used to obtain data on the total acreage impacted for each commodity. The total acreage impacted was then multiplied by the USDA NASS 2010-2014 average value/acre for each commodity to determine the total economic loss associated with each commodity. For crops with partial losses this estimate was adjusted to reflect the true drought impact. For example, if in a normal year a grower can expect to get 2 cuttings of timothy hay but because of the drought the grower only receives 1 cutting, a correction factor must be applied to adjust the loss of this acreage to 50% because there was not a total loss to this crop. KRD growers and board members were consulted to determine the appropriate correction factor for these crops. The results section of this report provides a detailed description of how these correction factors were applied.

Roza Irrigation District- Mapping and Special Survey

In September 2015, WSDA staff completed agricultural land use surveys of the 72,000 acre Roza Irrigation District in the Lower Yakima Valley to analyze crops for impacts from drought. Specifically, staff looked for dry or unharvestable crops and signs such as land left fallow in 2015 due to drought. WSDA contacted some growers to discuss water shortage issues and gain access to collect data and photos for this report. Only crops that were 100% impacted (dried out, dead, or being removed) were noted in this initial survey.

After discussions with the Roza Board of Directors, Roza growers, the Washington State Tree Fruit Association, and others, WSDA determined that additional data collection was needed to accurately describe the 2015 drought impacts in the Roza. Large acreages of high value permanent crops (apples, cherries, blueberries, etc) in the Roza drove this decision. Drought conditions can dramatically reduce the yield and quality of these commodities without completely destroying the crop.

In March 2016, WSDA conducted individual, anonymous grower interviews in the Roza. Participants in the anonymous survey were identified by the Roza district staff and represented producers of a variety of commodities and varying farm sizes. Growers were asked about yield impacts, size and quality reductions, and the associated economic impact of these effects. Growers were also asked about additional costs to the farming operation associated with drought wells, increased pest pressure, and other costs incurred. The goal of these interviews was to gain a representative sample for the large acreage commodities in the Roza. Interviews were conducted with growers from small and large operations that were spread throughout the district. Results from the mapping survey and the interviews are both described in the results section of this report.

Wapato Irrigation Project- Special Survey

During the data collection process, it was clear that there were areas that warranted regional focus sections other than KRD and Roza. With assistance from the U.S. Bureau of Reclamation, additional data was collected for the WIP. Anonymous grower interviews conducted in the WIP were similar to those conducted in Roza. Participants in the anonymous survey were identified by U.S. Bureau of Reclamation staff and represented producers of a variety of commodities and varying farm sizes.

Skagit County- Skagit County Extension Study

Washington State University's Skagit County Extension completes an annual compilation of agricultural production statistics. Through this effort, they generated estimated drought impact data. Results from their study are included in this report.

NASS Data

USDA NASS is the national leader in gathering and synthesizing quantitative information about commodities produced throughout the country. Because Washington produces over 300 crops, many of which rank in the top 10 for national production, data collected by NASS can be an extremely useful tool for quantifying impacts from extreme events. The data is also collected regularly, allowing for multi-season averaging of prices, yields, and acreage.

Based on information from grower groups and specialists, the effects of drought were felt through different mechanisms for different crop types. These effects could be described as yield loss, quality loss, and unplanted/unharvested acreage. As a result, WSDA evaluated losses differently for the different crop types in order to improve the loss estimates. Below are the crops and how loss was evaluated:

- Yield loss -- wheat, barley, dry peas, lentils, apples, hops, mint, dry beans, sweet corn (processed), sweet corn (fresh), hay (excluding alfalfa), and pears.
- Quality loss -- cherries
- Unplanted/unharvested acreage -- alfalfa and field corn.

NASS collects data on commodity prices, acres harvested, yield, crop condition and grading, and many other parameters. WSDA used the NASS Quickstats® database to collect information on 15 crops, accounting for 77.5% of the cultivated acreage in the state (NASS, 2016). In order to complete a statewide assessment, NASS data was used to collect the most recent 5-year average (2010-2014) and the 2015 values for: crop acreage, price per acre, and yield per acre (NASS, 2015a; NASS, 2016). Formulas described below were used to evaluate quality and quantity changes observed in the 2015 numbers that differ from those historical averages. In order to lessen the effect of annual price fluctuations, the 5-year price average is used throughout these calculations. This also reduces the uncertainty caused by other external forces (port shutdowns, global commodity gluts, market closures) in the final dataset.

Value Lost in Yield

For most commodities, the difference caused by the drought and extreme heat was seen in the crop yield (Washington State Tree Fruit Association, 2015; Roza, 2015; WIP, 2016). Drought and extreme heat led to reduced crop sizing (i.e. smaller apples) and reduced pounds/tons harvested. For that calculation, WSDA compared the 2015 yield with the most recent 5-year average yield, multiplied the resulting difference by the 5-year average price, providing a per acre estimated value for yield reductions. That number per acre was then multiplied by the statewide total acreage for each commodity (excluding acreage in regional highlighted areas – Roza, KRD, WIP, and Skagit) to give an estimated loss statewide.

Value Lost in Quality

While the yield evaluation captured impacts felt by the majority of the commodities hard-hit by the drought and extreme heat, in some cases, the impact of the drought was observed in the quality of the harvest rather than the yield, and those impacts were evaluated differently. Price differences for the 2015 cherry crop, for instance, were dramatic due to degradation in quality – firmness, color, etc. (Washington State Tree Fruit Association, 2015). To assess these quality impacts, WSDA compared the 5-year price average with the 2015 price. The formula used that difference as a multiplier against the 5-year acreage average, resulting in a per acre estimate of quality losses. That per acre number was multiplied by the statewide total acreage for each commodity (excluding acreage in regional highlighted areas – Roza, KRD, WIP, and Skagit) to give an estimated loss statewide.

Value Lost in Acreage Not Harvest/Planted

For alfalfa and field corn, two specific field crops impacted by the drought, the estimate of impacts was calculated by assessing the drop in acreage planted/harvested in 2015 as compared to the 5-year average. This was an important distinction from other commodities. Washington has very consistent acreage for these two crops to support livestock agriculture, and harvested acres were significantly reduced in 2015 (Prest, 2016). This yield loss was then multiplied by the 5-year average value per acre for the crop to estimate the dollar value associated with the reduction in yield. The total number of acres was taken from NASS data and acreages from KRD, Roza, WIP, and Skagit were removed to avoid double accounting. It should be noted that this estimate assumes that the entire reduction in yield between 2015 and the 2010-2014 average resulted from drought impacts. It is possible that yields were impacted from other causes. The NASS data was chosen as the best available data to run these estimates. If additional resources were available, it would still be difficult to parse out the value of impacts other than drought.

Online Survey for Cattle/Dairy Operators

In June 2016, WSDA circulated a 15-question online survey targeting information on the impacts of the 2015 drought to dairy and cattle operations. The survey questions were grouped separately for dairy and cattle operators and included an option to answer both sets of questions for producers with both a cattle and dairy operation.

The survey questions were:

1. Do you operate a Dairy?
2. Do you operate a Cattle operation?
3. In what county(ies) do you operate?
4. Which size category best fits your dairy operation? Number of animals: Mature dairy cattle
5. Which size category best fits your cattle operation? Number of animals: Beef cattle
6. Did you purchase additional feed in 2015 due to drought?
7. How much? (Units standard in tons)
8. What types of feed were purchased (in percentage of total purchased)?
9. Did you rent additional grazing land?
10. Total additional acres rented?
11. Cost per additional acre per month?
12. If you are a dairy owner, did you experience milk losses as a result of extreme heat or drought conditions?
13. Average pounds per head per day?
14. Did drought or extreme heat affect calving?

15. Do you expect the 2015 drought to impact you financially in 2016?

Data collected on additional feed purchased and milk losses were extrapolated to estimate a statewide impact for those factors. The Washington State Dairy Federation (WSDF) provided assistance in determining assumptions for the calculations in the results section.

Washington Academy of Sciences Review

The draft version of this report was sent to the Washington Academy of Sciences for an unbiased evaluation of methodology and results. WSDA incorporated as many comments and suggestions from this review as possible in the short period between receiving the review and the due date of this report. Additional recommendations are outlined in the conclusions section of this report.

Results

Meetings (phone, email, in person)

The acreage of blueberries and red raspberries has grown rapidly in the last 5 years (NASS, 2016), making it difficult to evaluate loss in yield using previous harvest and acreage data. Additionally, these crops don't reach full production for 2-4 years after planting. Therefore, additional acreage reported in NASS data does not reflect the true yield potential. Losses presented below are a comparison of late season harvest estimates and the final 2015 harvest. The Washington Blueberry and Red Raspberry commissions were consulted prior to using this methodology.

Blueberries

Washington is third in the nation in blueberry production. The majority of production (about 65%) occurs in northwest Washington (Whatcom and Skagit counties) and is processed (i.e., frozen, juiced, etc.). In recent years, significant certified organic blueberry production destined for the fresh market has been established in eastern Washington. This report attempts to capture some of the effects on fresh market berries in the Roza section.

Western Washington growers reported impacts on yield, size, and quality. Prior to harvest, growers estimated that in a normal year, production of blueberries for processing would have been approximately 112 million pounds. The final harvest totals were only 104 million pounds, a loss of 8 million pounds. Meetings with producers attributed all of that loss to high temperatures immediately before and during harvest (Washington State Blueberry Commission, 2015).

Estimated loss: 8 million pound loss (Washington State Blueberry Commission, 2015) and $0.97/lb price for processed blueberries based on NASS 5-year price average (NASS, 2015a), approximately $7.76 million.

Red Raspberries

Washington State is the largest grower of red raspberries in the nation. In 2015, Washington State recorded 12,528 acres planted in red raspberries or other caneberries (WSDA, 2016). Of this acreage, 84% is in northwest Washington (Skagit and Whatcom counties). Red raspberry growers in this region reported both size and quality impacts from this year's drought and extreme heat.

Estimated loss: 26% crop loss (based on 2014 yield of 72.6 million pounds, Washington State Red Raspberry Commission, 2015) at an average price of $0.735/lb – (5-year price average, NASS 2015a), approximately $13.9 million.

Cherries

The cherry harvest started almost 3 weeks early in 2015, mostly due to high temperatures in prime fruit growing regions of the state (central Washington and the Columbia Basin). The crop itself sustained less damage from the low water and high temperatures in 2015. Due to food safety requirements and targeted export markets, cherries are picked immediately when ripe and cooled to prevent spoilage. Size was smaller than normal, which did impact some Asian export markets which desire large, brightly colored cherries.

Yakima Valley Information

Growers reported reduced yields and quality, additional fallowing, and impacts on crop rotation. Growers without emergency drought wells in place reported a hesitancy to planting "permanent" crops (i.e. apples, cherries, pears, hops) due to future water uncertainty. Permanent crops are only fallowed as a last resort during low water years due to upfront capital costs, required infrastructure, subsequent fixed costs, and replanting cost. Although impacts were more severe on acreage within Roza, many of the valley crops suffered in some way due to the drought and extreme heat.

Kittitas Reclamation District- Targeted Mapping

The KRD mapping survey highlighted the fact that most of the damage was concentrated in the northern, western, and eastern portions of the Kittitas valley. The dominant crops affected by drought within the KRD boundaries were timothy hay, alfalfa, and pasture. Discussions with KRD growers and board of directors confirmed that in the KRD, timothy hay usually has 2 cuttings and alfalfa has 3 or 4 cuttings. In 2015, most of the KRD had only 1 cutting of timothy hay and 2 or 3 cuttings of alfalfa. Additionally, the yield of the first cutting of timothy hay was reduced by up to 25% as growers reduced water use in an attempt to stretch their water supply as late in the season as possible. Alfalfa fared better than timothy hay because it is an earlier crop and is more drought tolerant.

The majority of the pastures in the district were dry, greatly reducing the carrying capacity for cattle. One grower stated that cattle were taken off the pastures and put into the timothy hay fields after the first cutting. Many growers were concerned about drought impacts continuing into 2016, forecasting yield reductions of 25% as a result of the 2015 drought. The results include values for crop losses and assumes pasture grazing reductions occurred in most of the district.

The results of the mapping survey identified 445 impacted fields (13,051.39 acres) and 685 impacted pastures (20,201.90 acres) within the boundaries of the KRD (Table 1). Site specific information was documented to describe each field. The identified fields were paired with the most recent 5-year average NASS value per harvested acre estimates (NASS, 2016) to determine the total economic impact for that crop (Table 1).

Alfalfa and alfalfa/grass hay values were based on half of the normal cuttings (50% of documented average 2010-2014 crop value/acre). USDA does not have a specific value per acre for timothy hay. The economic value per acre for timothy used in this report is based on grower interviews in conjunction with USDA statistics for non-alfalfa hay. Results used were $400/ton based on information from growers and a 5-year average yield for all other hay of 3 tons per acre (NASS, 2015c). This value per acre is a mid-range value based on 1 cutting only with an additional reduction of up to 25% due to water rationing (Kittitas

Reclamation District, 2015). The value for fallowed land was set to $0/acre because actual cost cannot be calculated; the crop type that would have been grown is unknown. The value of pasture losses was determined through grower interviews. During a normal year growers would expect $200/acre of pasture for the grazing season of 4 months. During 2015 this value was reduced by half, resulting in $25/acre each month for the duration of 4 months for a final total value of $100/acre. This value of $100/acre is money that would have been earned by the grower for leasing the land on a regular year, but in the 2015 drought the land was not leased and this money was not earned. Site specific and local agricultural detail was contributed by KRD staff and board in this report.

Adjustment factors were used on specific crops as mentioned in the methodology section of this report. Alfalfa hay and alfalfa grass hay were reduced by 50% because growers still got 2 or 3 cuttings of alfalfa. Timothy hay received only 1 cutting which was reduced in quality by 25%, resulting in a final loss of 62.5% of the crop. The remainder of the crops mapped in the KRD were assumed to have complete losses. Economic impact for each crop was calculated by multiplying the acreage of the commodity by the value/acre and by the correction factor (when applicable). The total economic impact to these 11 crops in the KRD is $11,401,115. The two crops with the highest economic impact in the KRD are timothy hay and pasture, with a total impact of $8,057,325 and $2,020,190 respectively.

Table 1. 2015 Acreage and cost impacts for KRD

Impacted Crop	Acres Lost	Value/acre ($)	Correction factor	Impact ($)
Alfalfa Hay	771.28	$996.40	0.50	$384,252
Alfalfa/Grass Hay	132.73	$632.60	0.50	$41,982
Apple	13.11	$13,320.80		$174,636
Fallow	565.64	$0.00		$0
Grass Hay	632.25	$632.60		$399,961
Oat	38.65	$216.80		$8,379
Pear	24.73	$9,390.00		$232,215
Sudangrass	56.61	$632.60		$35,811
Timothy Hay	10,743.10	$1,200.00	0.625	$8,057,325
Triticale Hay	73.29	$632.60		$46,363
Pasture	20,201.90	$100.00		$2,020,190
Total	**33,253.29**			**$11,401,115**

Figure 5 shows the boundary of the KRD, as well as drought affected pastures and crops within the KRD.

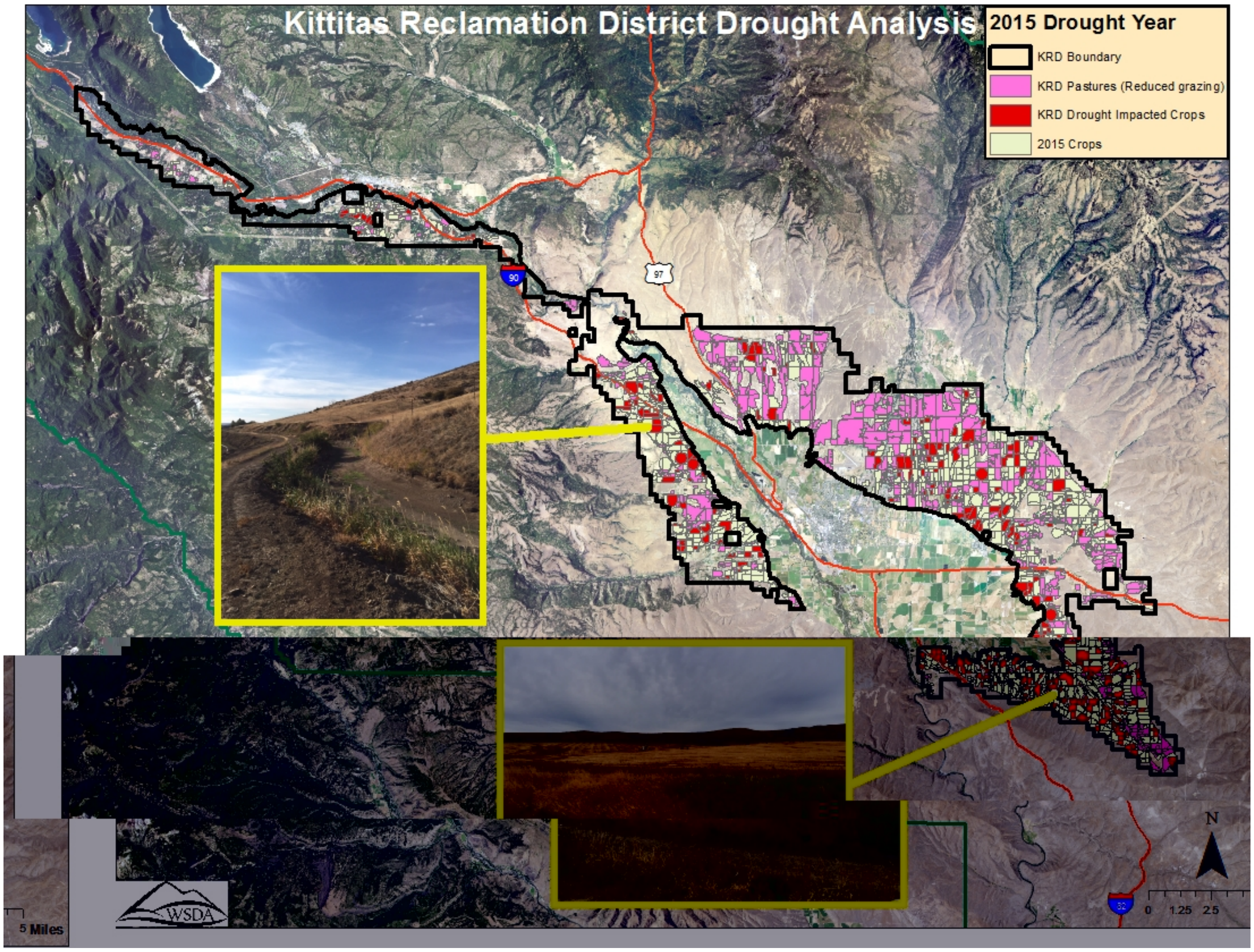

Figure 5. Targeted mapping results for Kittitas Reclamation District

Regional Data – Roza Irrigation District

Roza Drought Management

As a proratable irrigation district, Roza has management tools in place to mitigate some of the effects of drought. In April 2015, Roza leased 11,000 acre-feet of water from a senior water right holder. This additional water came at a cost of $190,000 per day and added 14 days of irrigation in their district. In May, the district board voted to shut down the entire canal system for 20 days, adding 18 days of available water for later season crops. The additional days of irrigation water likely reduced the impact of the 2015 drought. Roza completed other innovative water management activities, including flexible rules for pooling to facilitate fallowing, sharing, and within district water transfers between landowners. This qualitative information is included to provide context to the severity of the drought and serve as an example of management practices the Roza implements as a result of a drought. The cost associated with leasing senior water rights is not included in the estimate of drought impacts,

Mapping of the Roza

In order to avoid overestimation, crop losses were either assessed through mapping or through grower interviews, but not both. As mentioned above, the mapping survey in September 2015 only documented dry, dead, or otherwise unharvestable crops. To avoid potential double accounting, WSDA has chosen to include only mapping results of crops not surveyed in the grower interviews. Table 2 shows the acreage losses for 6 commodities in the Roza. The NASS average value per acre from 2010-2014 was used to determine the total loss (NASS, 2015a). The economic impact of loss of this acreage totaled $374,211.

Table 2. Crop losses from mapping survey

Crop	Acres	Value/Acre	Loss in $
Apricot	16.28	$6,650.00	$108,262
Fallow	349.60	$0.00	$0
Nectarine/Peach	7.06	$3,968.00	$28,014
Pear	16.56	$9,390.00	$155,498
Triticale	107.70	$632.60	$68,131
Wheat	32.41	$441.40	$14,306
Total	**529.61**		**$374,211**

Acreage Covered in Grower Interviews

In collecting information through interviews with growers, WSDA focused on 8 large acreage commodities. The Roza acreage accounted for in these interviews ranged from 4.88% to 47.04% for these commodities (Table 3). Ideally, at least 10% of each commodity would be accounted for in this type of survey. However, WSDA staff collecting the data were limited by time constraints on the data collection process and grower availability; interviews were scheduled during the growing season and some growers were unable to participate due to work obligations. For juice grapes, even through interviews the WSDA staff were unable to achieve the goal of having 10% of the commodity acreage accounted for in the data. For this reason, representatives of the Roza contacted the juice grape grower cooperative responsible for more than 85% of the juice grapes in Washington for more information. Information from this cooperative was used in place of interview data for juice grapes. The remaining commodities identified were represented at near or above the 10% coverage goal.

Table 3. Roza acreage covered in grower interviews

	Roza Acreage	Interview Acreage	% Acreage Included in Interview
Apples	20,076.95	1,791	8.92
Cherries	4,179.7	551	13.18
Hops	6,822.7	925	13.56
Blueberries	1,190.5	560	47.04
Wine Grapes	11,006.7	1,690	15.35
Juice Grapes	7,179.3	350	*4.88
Field Corn	3,439.2	880	25.59
Alfalfa	4,200	535	12.74

*The juice grape value reported in this table reflects the acreage covered from interviews. Acreage covered from the juice grape cooperative are not reflected in this value.

Average Economic Impact from Grower Interviews

Interview responses regarding loss per acre were combined and averaged for each commodity. These values are associated with reduced size, quality, and yield. Table 4 shows the average loss per acre for the top 8 commodities in the Roza. Apples and blueberries had the largest economic per acre impact at $3,437/acre and $3,500/acre, respectively. It should be noted that the blueberry value reported in the commodity meetings section of this report reflects impacts only to processed berries. Blueberries grown on the eastside are fresh market berries, which makes their losses unique and separate from processed. Juice grapes and field corn had the lowest economic per acre impact at $187.50/acre and $260/acre, respectively. The loss per acre reported from the juice grape cooperative was $125 to $250/acre. The average loss of $187.50/acre was applied to juice grapes in Roza. It should be noted that these values were derived from the Roza interviews and average loss/acre are different than other sections in this report.

Table 4. Average impact of top commodities in Roza Irrigation District

Commodity	Roza Acreage	Average Loss/Acre
Apples	20,076.95	$3,437.00
Cherries	4,179.7	$1,333.00
Hops	6,822.7	$1,150.00
Blueberries	1,190.5	$3,500.00
Wine Grapes	11,006.7	$818.00
Juice Grapes	7,179.3	$187.50
Field Corn	3,439.2	$260.00
Alfalfa	4,200	$337.50

Crop Impacts from Grower Interviews

Results from March 2016 grower interviews showed that the impacts to irrigated agriculture in the Roza varied throughout the district. The Roza board was consulted to help WSDA determine the percent of the district it would be appropriate to apply the average impact/acre values (Roza, 2016). The board determined that applying these impact scenarios to 75% of the Roza would accurately reflect the drought impacts to the district as a whole. To calculate the impact for each of these commodities the Roza acreage was multiplied by the average loss/acre and then multiplied again by 75%. Applying the interview impact/acre values to 75% of Roza acreage produces a total crop loss of $74,437,623. The commodities with the highest total losses are apples and wine grapes, with a total loss of more than $51.7 million and more than $6.7 million, respectively. This data is displayed in Table 5 below.

Table 5. Estimated losses of top commodities from Roza Irrigation District

Commodity	Roza Acreage	Average Loss/Acre	75% Roza Affected
Apples	20,076.95	$3,437.00	$51,753,358
Cherries	4,179.7	$1,333.00	$4,178,655
Hops	6,822.7	$1,150.00	$5,884,579
Blueberries	1,190.5	$3,500.00	$3,125,063
Wine Grapes	11,006.7	$818.00	$6,752,610
Juice Grapes	7,179.3	$187.50	$1,009,589
Field Corn	3,439.2	$260.00	$670,644
Alfalfa	4,200	$337.50	$1,063,125
Total Loss			**$74,437,623**

Figure 6 displays this data on a map of the Roza. The dollar impact per acre for each commodity is categorized into 3 groups: low, medium, and high. This figure provides a visual representation of the impacts throughout Roza. Crops with high impacts from the drought are spread throughout the district but are concentrated in the western half.

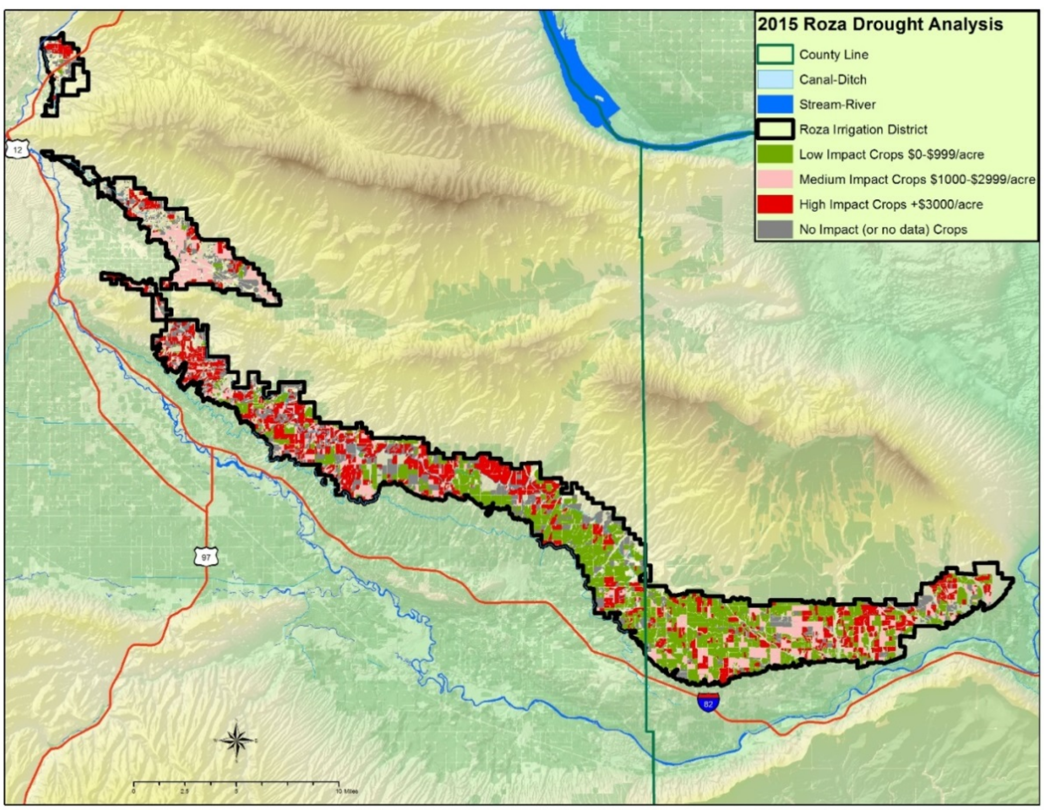

Figure 6. Map of surveyed Roza Irrigation District impacts

Drought Wells

During the interviews, growers were asked about additional effects to their operations from the 2015 drought. The economic impact of maintaining and operating an emergency drought well had the largest effect out of all non-crop impacts discussed. Use of emergency drought wells in Roza had not been permitted since 2005. This 10-year lag meant that many growers needed to repair their systems before using them and maintain them during the drought months. Repairs included work on dry wells, setting pumps lower, and replacing pumps and electrical systems. Of the well owners interviewed, the cost was estimated at $25,000 - $85,000 per well owner. Many interviewees had multiple wells, so in some cases this value included maintenance of more than one well (Roza, 2016). There were 45 emergency drought wells used in Roza in 2015 and 13 wells were accounted for in the survey, about 29% of total wells. The average cost of maintenance per well was $13,800. The following calculation was used to estimate the total cost of well maintenance in the Roza:

Total Cost of Maintenance= $13,800/well * 45 total wells= $621,000

In addition to repairing and maintaining drought wells, there is also fuel or electricity cost associated with running the well. Interviewees included a variety of growers operating both diesel and electric wells. The average estimated cost of running a drought well for the season was $7,800. The following calculation was used to estimate the total cost of running drought wells in the Roza:

Total Cost of Operating Wells= $7,800/well * 45 total wells= $351,000

The total estimated cost of maintaining and operating drought wells in 2015 is $972,000.

No data was collected on costs for connection to irrigation district systems and whether or not any of these costs were reduced as a result of water limitation.

Additional Operational Impacts

Some interviewees mentioned additional costs associated with the drought for which this report did not gather data. These additional operational impacts included increased costs associated with pest and weed control, such as an increased need to mow between rows and more frequent application of pesticides. Some growers also reported that they diverted water from low value crops to higher value crops that needed more water. Additionally, many interviewees stated that they expected the 2015 drought to affect their 2016 growing season.

There is a high degree of variability in each of these additional operational impacts and each is farm specific. For that reason, readers should use caution in assuming that the per acre losses from reduced quality, size, and yield include the full on-farm impact growers felt in the Roza during the 2015 drought.

Regional Highlights- Wapato Irrigation Project

Drought impact data for the WIP was collected in anonymous grower interviews similar to those conducted in Roza. Water management issues exacerbated high heat and low water availability in this district. Those management issues were widespread and resulted in varying impacts throughout the district. Some of those impacts are seen below (Wapato Irrigation Project, 2016).

Acreage Covered in Interviews

Eight large acreage commodities were targeted in the interview process. These commodities are identified in Table 6. The WIP acreage accounted for in these interviews ranged from 7.97% to 100% for each commodity (Table 6). Ideally, at least 10% of each commodity would be accounted for in this type of survey. WSDA staff collecting the data were limited by time constraints on the data collection processes and low grower availability. Discussions with WIP members confirmed that the interview pool was representative of the impacts encountered throughout the district (Wapato Irrigation Project, 2016).

Table 6. WIP acreage covered in grower interviews

	Wapato Acreage	Interview Acreage	% Acreage Included in Interview
Timothy	1,555	1,555	100.00
Alfalfa	14,198.04	1,341	9.44
Mint	9,068.99	722.74	7.97
Carrot Seed	156	156	100.00
Wheat	9,567.05	1,398.23	14.62
Apples	9,191.37	820	8.92
Cherries	732.97	70	9.55
Potatoes	636.05	155.39	24.43

Average Economic Impact

Interview responses regarding loss per acre were combined and averaged for each commodity. These values are associated with reduced size, quality, and yield. Table 7 shows the average loss per acre for the 8 commodities covered in interviews in the WIP. Carrot seed and apples had the largest economic per acre impact at $2,810/acre and $2,500/acre, respectively. Wheat and alfalfa had the lowest economic per acre impact at $192.25/acre and $350/acre, respectively.

Table 7. Average impact of top commodities in Wapato Irrigation Project

Commodity	WIP Acreage	Average Loss/Acre
Timothy	1,555.00	$377.00
Alfalfa	14,198.04	$350.00
Mint	9,068.99	$504.25
Carrot Seed	156.00	$2,810.00
Wheat	9,567.05	$192.25
Apples	9,191.37	$2,500.00
Cherries	732.97	$500.00
Potatoes	636.05	$900.00

Crop Impacts

Results from the interviews with growers in the WIP showed that the impacts to irrigated agriculture in the WIP varied. The WIP board and growers were consulted to determine what percent of the district it would be appropriate to apply the average impact/acre values. The board determined that applying these impact scenarios to 90% of the WIP would accurately depict the impacts to the district because the 2015 drought impacts were severe and widespread in this region (Wapato Irrigation Project, 2016). To determine the total impact per commodity, the WIP acreage was multiplied by the average loss/acre and then multiplied by 90%. Applying the interview impact/acre values to 90% of WIP acreage produced a total economic loss of $32,691,211 (Table 8). The commodities with the highest total loss were apples and alfalfa, with a total loss of over $20.6 million and over $4.4 million, respectively (Table 8).

Table 8. Estimated losses of top commodities from Wapato Irrigation Project

Commodity	WIP Acreage	Average Loss/Acre	90% WIP Affected
Timothy	1,555	$377	$527,612
Alfalfa	14,198.04	$350	$4,472,383
Mint	9,068.99	$504.25	$4,115,734
Carrot Seed	156	$2,810	$394,524
Wheat	9,567.05	$192.25	$1,655,339
Apples	9,191.37	$2,500	$20,680,583
Cherries	732.97	$500	$329,837
Potatoes	636.05	$900	$515,201
Total Impacts			**$32,691,211**

Regional Highlights- Skagit County

The Skagit County Extension conducted their own investigation on the 2015 drought impacts to agriculture. This data was collected from growers, processing companies, agricultural organizations and agencies, field representatives, news articles, and extension agent experience (Washington State University Extension Skagit County, 2016). The following information was provided for use in this report.

The Skagit County Extension determined that there was a 10% average economic loss on agricultural production throughout Skagit County as a result of the 2015 drought (Washington State University Extension Skagit County, 2016). Some regions and commodities of the county were hit harder than others, particularly commodities that are less resistant to high temperatures and lack of water. These regions and commodities likely experienced losses much greater than 10%. Conversely, there are likely regions or commodities that experienced less than a 10% loss. WSDA has elected to apply the 10% average loss estimate provided by the Skagit County Extension to determine an estimated total economic loss for the county. The most recent county agricultural value comes from the 2012 USDA Census of Agricultural. The value of agricultural production in Skagit County in 2012 was $272 million. The 10% loss estimate results in a $27,200,000 loss for producers in 2015.

NASS Data

The data collected from NASS included price, yield, and acreage information for 15 commodities (wheat, barley, dry peas, dry beans, lentils, apples, hops, mint, pears, feed corn, alfalfa, sweet corn (fresh), sweet corn (processed), hay (excluding alfalfa), and cherries) from 2010-2015. The losses presented in each category below includes most recent 5-year average data (2010-2014) as well as specific 2015 data for comparison. While this data only covers 15 of approximately 300 commodities produced in Washington, their combined acreage totals 77.5% of the total cultivated crop acreage in the state. Losses are divided into 3 categories for evaluation: yield loss, quality loss and unplanted/unharvested acreage. The formulas used for each of the calculations, as well as all of the data used to generate the loss estimate, are listed below (Table 9, Table 10, and Table 11).

Value Lost in Yield

Total losses = (2015 adjusted acreage x average price)* (average yield – 2015 yield)

Table 9. Estimated losses in yield of top commodities from NASS

Crop	2015 Acres	Avg. Price	Avg. Yield	2015 Yield	Estimated Loss
Wheat	2,200,336	$6.92/bu	63.5 bu/acre	50.4 bu/acre	$199,464,859
Barley	97,218	$4.34/bu	69.8 bu/acre	48 bu/acre	$9,197,989
Dry Peas	102,000	$0.153/lb	2,080 lb/acre	1,400 lb/acre	$10,612,080
Lentils	59,000	$0.2922/lb	1,280 lb/acre	750 lb/acre	$9,137,094
Apples	118,638	$0.33/lb	41,760 lb/acre	40,200 lb/acre	$61,074,678
Hops	25,335	$3.27/lb	2,071 lb/acre	1,849 lb/acre	$18,391,690
Mint	22,415	$19.77/lb	122.9 lb/acre	117 lb/acre	$2,614,553
Pears	19,476	$499.8/ton	19.46 tons/acre	18.3 tons/acre	$11,291,776
Sweet Corn (proc.)	78,800	$106.16/ton	10.14 tons/acre	9.17 tons/acre	$8,114,446
Sweet Corn (fresh)	25,151	$35.36/cwt*	163.4 cwt/acre	136 cwt/acre	$24,367,898
Hay & Haylage (excl. alfalfa)	388,283	$211.60/ton	3.36 tons/acre	2.98 tons/acre	$31,221,075
Dry Beans	109,000	$0.323/lb	1,746 lb/acre	1,450 lb/acre	$10,324,480

*hundredweight

Value Lost in Quality

Total losses = (2015 adjusted acreage x average yield x average price) – (2015 adjusted acreage x 2015 yield x 2015 price)

Table 10. Estimated losses in quality/value for cherries from NASS

Crop	2015 Adjusted Acreage	Avg. Yield (tons/acre)	2015 Yield (tons/acre)	Avg. Price ($/ton)	2015 Price ($/ton)	Estimated Loss
Cherries	30,087.33	5.942	6.36	$2,326	$1,970	$38,869,581

Value Lost in Acreage Not Harvest/Planted

Total losses = (average acreage – 2015 acreage) x (average price x average yield)

Table 11. Estimated losses in acreage not harvested/planted from NASS

Crop	Avg. Acreage	2015 Acreage	Average Price	Average Yield	Estimated Loss
Alfalfa	405,081	375,081	$198.60/ton	5.02 tons/acre	$29,909,160
Feed Corn	157,186	128,186	$5.84/bushel	215 bushels/acre	$36,412,400

Online Large Animal Livestock Survey

The 15-question online dairy and cattle operation survey was emailed to dairy and cattle operations throughout Washington State in June 2016. The majority of survey respondents operated a dairy. Out of 52 survey responses, 46 respondents reported operating a dairy, while only 15 reported operating a cattle operation. The overlapping 10 respondents are assumed to have both a dairy and a cattle operation.

Respondents to the survey operated a dairy, cattle, or both types of operations in 20 of the state's 39 counties. Some respondents had operations in multiple counties. Whatcom and Yakima counties had the greatest number of responses with 14 and 9 responses, respectively (Figure 7).

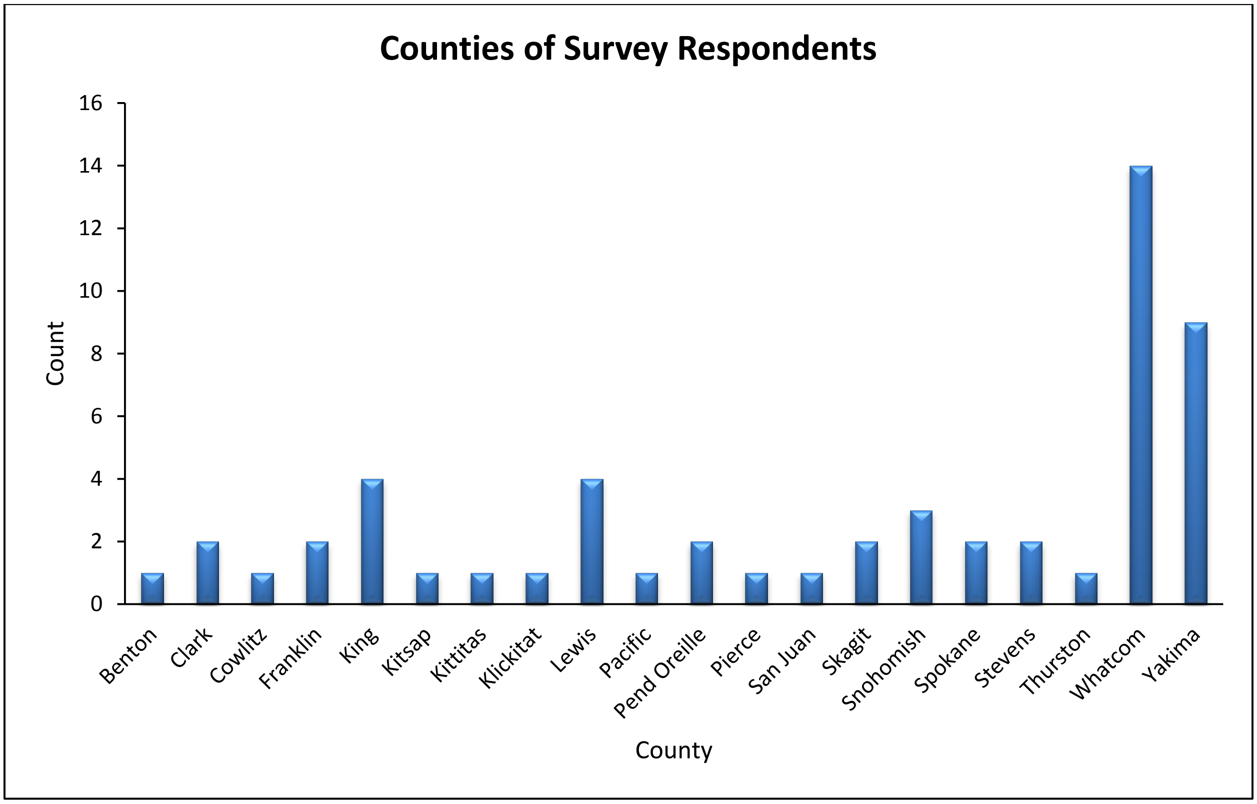

Figure 7. Animal livestock respondents by County

Size of Operation

A wide range of dairy operation sizes were represented in this survey. The smallest dairies had 1 to 37 mature dairy cattle while the largest had 6,840 or more (Figure 8).

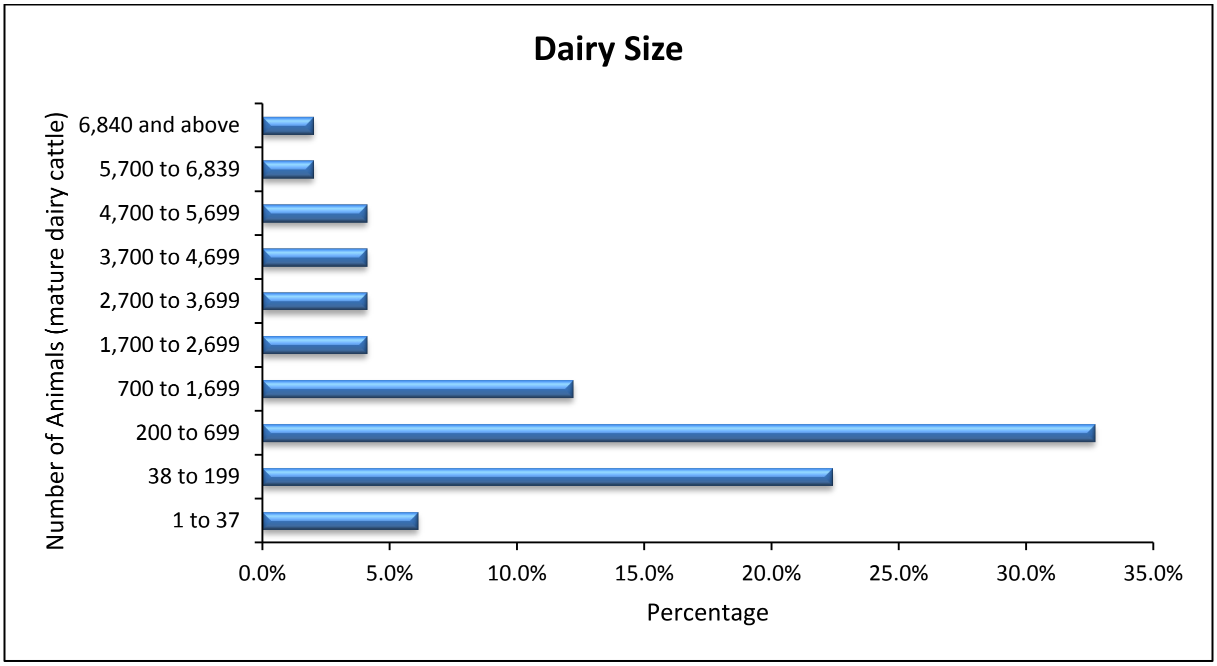

Figure 8. Dairy size by number of animals

Cattle operation size also varied greatly between respondents. The smaller operations had 1 to 19 beef cattle and the largest operations had 1,000 to 5,999 beef cattle. The most commonly chosen size category for cattle operations was 20 to 159 beef cattle.

Additional Feed Purchased

A majority (63%) of operators responded that they purchased additional feed in 2015 due to drought. Only 70% of respondents who purchased additional feed indicated how much was purchased. The total amount of feed purchased due to the 2015 drought from all 23 operators was 48,728 tons and the average total amount of feed purchased was 2,119 tons. Splitting results between east side and west side operations, operators purchased more feed on average on the east side. East side operations purchased 3,418 tons of feed on average, while west side operations purchased an average of 1,550 tons. Operators were also asked to provide percentages of the feed that were timothy hay, alfalfa, grass hay, or silage. Table 12 below shows the amount of each type of feed purchased.

Table 12. Respondent results for feed purchases

	Timothy	Alfalfa	Grass Hay	Silage Corn
Amount(tons)	120	7,823	7,640	33,145

Only 1 respondent reported having purchased timothy hay, while 15 respondents purchased alfalfa hay. A few operators included notes explaining that they never had to purchase feed before because normally they are able to grow their own feed.

Estimating that approximately 50% of operations purchased feed in 2015 is likely a conservative approach, considering 63% of those surveyed stated that additional feed was purchased for their operations. WSDA's Dairy Nutrient Management Program provided data on how many dairy operations exist throughout Washington. Due to the fact that 75% of survey respondents were dairy operators and not cattlemen, calculations of statewide impact are only included for dairies. For this reason, estimated total feed values are only applied to dairy operations in the state. Additionally, estimates were only made for silage corn (~68% of feed purchased) and alfalfa (~16% of feed purchased) because the majority of feed purchased was one of these two commodities. NASS 2010-2014 average values for alfalfa were used. NASS does not collect information on the separate value of silage corn in Washington. WSDF provided WSDA with an average price of $50/ton for silage corn (Washington State Dairy Federation, 2016). According to WSDF, the cost for silage corn varies year to year and also depends on the timing of the season because early contract prices for silage are often less expensive than later season purchases. WSDF recommended applying the loss estimates to 50% of the dairies in Washington in order to accurately represent the losses felt by the dairy industry. No information was gathered on the origin of the additional feed purchased to determine whether or not the transaction was an in state transfer of funds or not. Regardless of whether the money used to purchase additional feed stayed within state lines, the cost associated with these purchases is considered a negative impact to dairy operators for the purpose of this report. The following calculations were performed to estimate the total amount of feed purchased as a result of the drought to support dairy operations in 2015:

<u>Western Washington Feed Purchased Estimate</u>

Total Feed Purchased = 1550 tons/operation * 272*(1/2) dairies = 210,800 tons total

Total Cost of Purchased Feed= 210,800 tons * (.68)* $50/ton of silage + 210,800 * (.16)* $198.60/ton alfalfa= $13,865,581

<u>Eastern Washington Feed Purchased Estimate</u>

Total Feed Purchased = 3418 tons/operation * 121 *(1/2) dairies = 206,789 tons total

Total Cost of Purchased Feed= 206,789 tons * (.68)* $50/ton of silage + 206,789 tons * (.16)* $198.60/ton alfalfa= $13,601,753

Total Cost of Feed Purchased to Support Dairies= $13,865,581+ $13,601,753= $27,467,334

Additional Land Leased

Only 12% of operators surveyed reported having leased additional land due to drought impacts. The total land leased by 6 operators was 490 acres and the average cost of leasing the land was $214/month. Both dairy and cattle operators reported leasing land in 2015. There is not enough data to attempt to extrapolate a statewide estimate for this loss.

Reduction in Milk Production

A slight majority (57%) of dairy operators surveyed reported milk losses as a result of extreme heat or drought. Dairy operators were asked to report the average loss of milk production in pounds per head per day. The average reported loss was 12.2 pounds/head-day. Average milk losses on the west side of the state were 11.6 pounds/head-day while average losses on the east side were 12.8 pounds/head-day. The total number of milking cows for the east and west side of the state were provided by the Dairy Nutrient Management Program at WSDA. These values were used to extrapolate the reduction in milk production to a statewide value.

Similar to the feed calculation, estimates of economic impact from reduction in milk production were applied to 50% of the dairy operations in the state to provide a conservative value; this assumption was reviewed and supported by WSDF. Additionally, it is assumed that the duration of reduced milk production was from June 10, 2015 to July 20, 2015 which was likely the peak stress period for the animals given the climatic conditions (Washington State Dairy Federation, 2016). This 40-day period was identified by WSDF as the highest stress period in 2015. Reduction in milk due to high heat occurs annually, but the heat stress during this time period was anomalous and attributed to drought conditions (Washington State Dairy Federation, 2016). The extreme heat in 2015 was not consistent throughout this period and appeared in heat waves. For this reason, the calculations below are only applied to 50% of the 40 day period, or 20 days (Washington State Dairy Federation, 2016). The price used to calculate dollars lost due to reduced milk production is the most recent (2010-2014) 5-year average price per pound of milk reported by NASS. The following calculation was performed to obtain this estimate:

<u>Western Washington Milk Losses</u>

Total Milk Lost = 82,164 milking cows (1/2) * 11.6 pounds/head/day * 20 days = 9,531,024 pounds

Value of Milk Loss= 9,531,024 pounds * $0.2012/pound= $1,917,642

<u>Eastern Washington Milk Losses</u>

Total Milk Lost = 151,225 milking cows (1/2) * 12.8 pounds/head/day * 20 days = 19,356,800 pounds

Value of Milk Loss= 19,356,800 pounds * $0.2012/pound= $3,894,588

Total Cost Associated with Reduction in Milk Production = $5,812,230

Conclusions and recommendations

WSDA is aware that the data collected in this report does not represent all of the economic harm to Washington farmers, ranchers and the rest of the agriculture industry resulting from the 2015 drought. Given the limitations in gathering data, the time and resources available for this work, the total economic loss can only be estimated. It is as accurate an estimate as WSDA can provide at this time. Table 13 displays the total estimated economic loss from the data WSDA staff were able to collect for this report.

Table 13. Total estimated losses from all sections of report

Section of Report	Loss ($)
Blueberry Meeting	$7,760,000
Raspberry Meeting	$13,900,000
KRD Mapping	$11,401,115
Roza Impacts (crop losses and drought wells)	$75,783,834
WIP Interviews	$32,691,211
Skagit Report	$27,200,000
Livestock Survey	$33,279,564
NASS Data*	$501,002,853
Total Estimated Loss**	**$703 million**

*Estimated losses from NASS data do not include acreages of commodities covered in other sections of the report.

**Total loss estimate has been rounded to the nearest million.

There are inherent uncertainties and limitations associated with the data collection process. In an effort to account for some of this uncertainty, this report offers a 10% range for the total estimated economic loss. Applying that 10% range to the total loss results in an estimated loss of $633 million to $773 million.

The impacts from the 2015 drought were not limited to certain crops, or certain regions, or even certain times of the year. Negatively affected farmers felt a variety of effects, including yield or quality reduction. Many of these impacts were not quantifiable in the scope of this report.

Drought effects were widespread and will be ongoing. Drought damaged permanent crops will take time to recover fully, if they ever do recover fully. Changes that growers made to crop rotations and plantings choices will take time to normalize. We will not truly know the impact of this drought for 2 - 4 years, and that is only if another drought does not occur during this time. If climate and weather changes like those seen in 2015 become more regular some farming operations will struggle to stay solvent despite technological innovation and new practices.

Based on this report, WSDA has some recommendations for future work to improve our ability to assess future drought impacts and better inform policy makers about options:

- More background information on water rights and irrigated acres in Washington State would be extremely helpful. Involved agencies could develop a report and geodatabase delineating irrigation districts, water sources (surface or ground water), allocation of junior and senior water rights holders, and which users are likely to receive less water in a drought year. This would enable Ecology and WSDA to identify growers likely to be affected by future droughts and make contingency planning more effective.
- In addition, WSDA should develop strategies for ongoing data collection. The data collected in this report is a good example of the type of data that needs to be monitored regularly in order to more easily monitor events like the 2015 drought. WSDA needs to review available data sources, identify data needs, and plan for ongoing data collection. A good foundation of historic meteorological and agricultural data would provide reliable information for growers regarding planting decisions and anticipated climate change related changes to Washington's agricultural regions. Much of this data is already collected by other state and federal agencies and the main work would be identifying needed data, aggregating it, and analyzing patterns and trends.
- The WSAS review also recommends that future studies be based on a defined and recognizable economic foundation. The review provides background and describes 3 theoretical models that would be appropriate for this type of analysis. Collaboration with agricultural economists, use of a clearly defined economic model, and a statistically-based sampling approach would enhance the accuracy and credibility of this type of study for future efforts.

The efforts of the WSDA research team demonstrate that in order to conduct this data collection efficiently and better account for quantifiable impacts, a sound data network and consistent economic methodology would need to be created that monitors a representative subset of each portion of the agricultural industry. Collecting this type of data will require significant resources. However, the advantage of such efforts include providing a more informed understanding of the economic impacts of drought, which could assist decision makers when determining where to apply resources for most significant benefit.

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Appendix A: Ecology Grant Scope of Work

Economic Impact Assessment: 2015 Drought and Agriculture

Introduction

The water year that began in October 2014 was one of the driest years on record for Washington State. The winter of 2014 was quite dry, with little to no snowpack in the Cascade Mountains. That snowpack feeds rivers, streams, lakes, reservoirs, and irrigation systems throughout eastern and western Washington during the dry summer months.

Ecology approached the Washington State Department of Agriculture to request an analysis of the 2014 water year and subsequent 2015 drought declaration on Washington agriculture. This study, when complete, will provide both qualitative and quantitative data on the impact of the 2015 drought on Washington agriculture. This information will then be available to agencies and the legislature when conducting future drought planning and identifying key impact areas throughout the state.

Applicable Documents

A significant amount of the data needed to complete a true economic assessment of the impacts of the 2015 drought on agriculture will not be available for quantification until late 2016. The ripple effect of the drought on 2016 crops is also yet to be determined. Due to data availability, this project will be broken into multiple deliverables to allow for incorporation of data as it becomes available.

Requirements and Tasks

Task 1: Project Management
Due Date: December 31, 2016

WSDA will administer the project. Responsibilities will include, but not be limited to: maintenance of project records; submittal of payment vouchers, fiscal forms, and progress reports; compliance with applicable procurement, contracting, and interlocal agreement requirements; application for, receipt of, and compliance with all required permits, licenses, easements, or property rights necessary for the project; and submittal of required performance items.

WSDA must manage the project. Efforts will include conducting, coordinating, and scheduling project activities and assuring quality control. Every effort will be made to maintain effective communication with the WSDA designees; Ecology; all affected local, state, or federal jurisdictions; and any interested individuals or groups. The WSDA must carry out this project in accordance with any completion dates outlined in this agreement.

WSDA must ensure this project is completed according to the details of this agreement. WSDA may elect to use its own forces or it may contract for professional services necessary to perform and complete project related work. Required Performance:

1. Effective administration and management of this grant project.
2. Maintenance of all project records.
3. Timely submittal of all required performance items including reports and vouchers.

Task 2: Agricultural Land Use Mapping of Most Affected Areas
Due Date: December 31, 2015

WSDA agricultural land use mapping staff will complete a field survey of all farms being served by water in the Roza Irrigation district. Data collected will include information about crop being produced, irrigation type, field boundaries, and any qualitative information easily discerned via field surveys (i.e. tree health status - good, stressed, dead and requiring replacement). Acres impacted directly by drought will be quantified and included in a report on other drought impacts, and all fields in the affected areas will be placed in a geodatabase and sent to Ecology staff for their records.

Task 3: Initial Qualitative and Quantitative Drought Impacts Data Collection
Due Date: December 31, 2015

WSDA's senior natural resource scientist and hydrogeologist will work with stakeholders in agricultural communities throughout the state to quantify known impacts of the 2015 drought. This includes talking to major commodity producers and grouping data into regions (western, central, Columbia Basin, eastern) and commodity buckets (fruit, field crops, dryland). Prorated irrigation districts that were anticipated to have greater impacts will be detailed separately within the report. Data will include (when available) quantifiable impacts on yields. When available, WSDA staff will also collect information on secondary drought impacts (changed planting/harvest schedules, additional costs for running pumps on drought wells and mitigation payments, labor impacts, etc.)

Task 4: Final Qualitative and Quantitative Drought Impacts Data Collection
Due Date: December 31, 2016

WSDA will use all available quantifiable data as well as interviews with commodity representatives to complete data collection for the 2015 drought impacts on agriculture. This will include phone calls, in person meetings, and emails to representatives throughout the state. USDA NASS data will be used when it is available. The final product will encompass all data analysis and methods of both collecting and analyzing the data.

Task 5: Interim and Final Report
Due Dates: December 31, 2015 (interim) and December 31, 2016 (final)

Ecology will receive an interim report with all data available through December 10, 2015 and a final report with all data available through October 15, 2016. WSDA staff will also prepare a fact sheet for this report. All documents prepared for the project will be made available via WSDA's website.

Task 6: Subcontract draft final report for review and analysis by Washington State Academy of Sciences
Due Date: December 31, 2015

WSDA will deliver a draft report to WSAS for review and comments prior to finalizing and submitting the report to Ecology.

Project Budget

TASK	TASKS	BUDGET
1	Project Management	$5,500.00
2	Agricultural Land Use Mapping of Most Affected Areas	$3,000.00
3	Initial Qualitative and Quantitative Drought Impacts Data Collection	$8,000.00
4	Final Qualitative and Quantitative Drought Impacts Data Collection	$12,500.00
5	Interim and Final Report	$10,000.00
6	Subcontract draft final report for review and analysis by Washington State Academy of Sciences	$6,000.00
	TOTAL PROJECT BUDGET	$45,000.00

Appendix B: Washington State Academy of Sciences Review

SCIENCE

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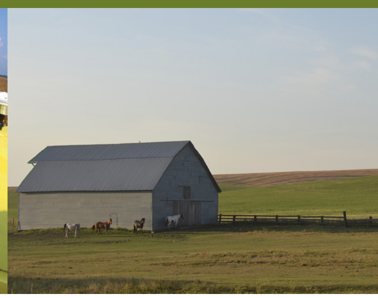
Academy of Sciences

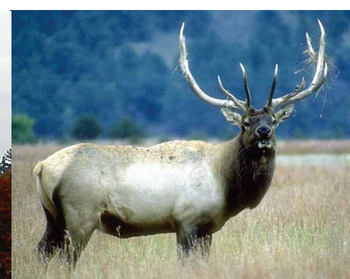



Evaluation with Recommendations by the Washington State Academy of Sciences of

Interim Report: 2015 Drought and Agriculture

Washington State Department of Agriculture






December 2016

Evaluation with Recommendations by the Washington State Academy of Sciences of

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Washington State Department of Agriculture

December 2016

About the Washington State Academy of Sciences

The Washington State Academy of Sciences (WSAS) is an organization of Washington State's leading scientists and engineers dedicated to serving the state with scientific counsel. Formed as a working academy, not an honorary society, WSAS is modeled on the National Research Council. Its mission is two-fold:

> To provide expert scientific and engineering analysis to inform public policy making in Washington state, and
>
> To increase the role and visibility of science in the state.

WSAS was formed in response to authorizing legislation signed by Governor Christine Gregoire in 2005. Its 12-member Founding Board of Directors was recommended to the governor by the presidents of Washington State University and the University of Washington, and duly appointed by the governor. In April 2007, WSAS was constituted by the Secretary of State as a private, independent 501(c)(3).

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Table of Contents

Executive Summary

The Washington state "water year" October 1, 2014, to September 30, 2015, was one of the driest on record, due to lower-than-normal precipitation and higher-than-normal temperatures. Because precipitation in the Cascade Mountains fell mostly as rain and not snow, and because the snow that did fall melted early, snow-water available for irrigation in the Yakima and Kittitas valleys was only 25 percent of normal. In October 2015, the Washington State Department of Ecology (DOE), the state's lead on drought monitoring and mitigation, asked the Washington State Department of Agriculture (WSDA) to analyze the economic impacts of the 2015 drought on Washington agriculture. The task of quantifying the effects of the drought on agriculture fell to the WSDA's Natural Resources Assessment Section (NRAS). An interim report describing the qualitative effects was submitted to the DOE on December 31, 2015, and a final report quantifying effects of the drought is due at the DOE on December 31, 2016. In early October 2016, the WSDA-NRAS asked the Washington State Academy of Sciences (WSAS) to review the science supporting the methodologies and interpretation of the results of its study, available at http://agr.wa.gov/FP/Pubs/docs/104-495IterimDroughtReport2015.pdf. As a working academy, "The Washington State Academy of Sciences provides expert scientific and engineering analysis to inform public policy-making, and works to increase the role and visibility of science in the State of Washington."

The WSAS Committee (Committee) that reviewed the WSDA interim report commends the WSDA-NRAS for its impressive effort to provide a reasonably thorough, timely, and quantitatively-based report on the economic impact of the 2015 drought on Washington agriculture. The authors of this study have successfully contributed to a more informed policy discussion and more effective implementation approach to future droughts, while offering an investigative approach that can be assessed and improved for future applications.

The report would benefit from an overview of total irrigated acres and diversion rights across the state, including a best approximation of the total number of irrigated acres that receive less water in a drought year and the 600,000 acres of the Columbia Basin Project not curtailed during droughts. A brief discussion of the amount of crop and pasture land that is irrigated relative to the total crop and pasture land, and the value of output associated with crops that are irrigated and not irrigated, would also be helpful to readers. Much of the production value of the livestock industry and of major crops such as wheat and other small grains are from non-irrigated ranch and farm land in eastern Washington.

The report needs to be clear about whether the study's objective was to quantify net effect of the drought at the state level or to quantify losses to negatively affected farms without including an offset for farms that may have increased their net returns compared to a year when there was no drought. It is a political question for WSDA, DOE, and the Legislature as to whether they are more interested in quantifying the harm to farmers that were negatively affected. Much of farm policy at the federal level is focused on creating stability in the farming sector by providing assistance through price supports or subsidized yield insurance. Another way to say this is that there is a distributional goal that is politically defined and which supersedes a goal based on economic efficiency.

This lack of clarity on economic effects statewide or on individual farms is most pronounced by the inclusion of the $2.66 million Roza payment to the senior water rights holder. This payment is simply a transfer from one water-rights holder to another within the state, so it should not be included as a drought impact. All that should be included is the net revenue associated with the lost production to the water-rights holder that leased the water. If this is what is requested, there should be some recognition that it is not the same as the net economic cost to the state, because some farmers likely benefited either through higher commodity prices or leasing water. This is a political rather than an economic decision.

The Committee recommends that future analyses and reporting on the economic impacts of a drought or other meteorological event be based on a clearly defined and recognized economic foundation. As an example, this interim report adds up several different types of values (e.g., Table 13), but this can lead to errors. Further, the direction of the error is not always clear because there is no clearly stated theoretical model. This type of study can be conducted using an Economic Welfare model, Input/Output model, or Computable General Equilibrium model, each of which is described in this WSAS committee evaluation. Any one of these models could have served as the theoretical foundation for this study and should be used for similar studies conducted in the future.

The economic effects of the 2015 drought described in this interim report are based on gross rather than net revenue lost. This can account for an incongruity between the estimated gross revenue lost stated in this report and the fact that net farm income for Washington in 2015 was higher than in any of the previous four years by a significant amount. In economic terms, the supply curve of the commodities affected by the drought would have shifted to the left, raising the price received by producers. Similarly, the economic loss to the farmer from a drought is not foregone gross revenue. If the farmer's gross revenue is $5,000/acre, but $4,000 goes toward expenses for items such as herbicide, pesticides, fertilizer, diesel, labor, etc., then the farmer loses only $1,000/acre if, because of a drought, they are forced to fallow the field rather than plant.

This reinforces the need in future studies of economic impacts that any analysis is 1) based on a defined economic foundation, 2) clear about whether the objective of the study is to calculate net impacts to agriculture or costs to farmers negatively impacted by the drought, and 3) provides an overview of production that includes an accounting of water rights, diversions, and curtailments.

Among several minor suggestions and edits in this Committee review is that the report acknowledge indirect economic impacts of the 2015 drought on farms, referred to by the DOE as secondary drought impacts, e.g., changed planting/harvest schedules, additional costs for running pumps on drought wells, mitigation costs, and labor impacts. The Committee also recommends that effects on consumers due to higher prices or lower quality of food be acknowledged even though they are not part of this study. Similarly, the disruptive threat and reality of significant irrigation water shortages creates a chaotic management situation for many farmers and, especially in labor-intensive crops, for a significant portion of the state's agricultural work force.

Introduction

The 2015 Far West "water year" of October 1, 2014, through September 30, 2015, was one of the driest on record, due to a combination of lower-than-normal precipitation and higher-than-normal temperatures, resulting in a greatly reduced snowpack extending from the Cascade Mountains in Washington to the Sierra Nevada mountains in California. The average statewide October 2014-March 2015 temperature in Washington was 40.5 F, the warmest such period on record (Washington State Climatologist, April 15, 2015). Because precipitation in the Cascade Mountains fell mostly as rain and not snow, and because the snow that did fall melted early, snow-water available for irrigation in the Yakima and Kittitas valleys was only 25 percent of normal. The drought was exacerbated by above-normal summer temperatures, increasing the evaporative demand and adding to plant water stress for rainfed and irrigated crops alike. In Washington, July 2015 was the hottest month on record and, by late August, 85 percent of the state was declared in "extreme drought" status.

In October 2015, the Washington Department of Ecology (DOE), the state's lead on drought monitoring and mitigation, asked the Washington State Department of Agriculture (WSDA) to analyze the economic impacts of the 2015 drought on Washington agriculture. No equivalent attempt had previously been made to quantify the economic impact of a weather event on statewide agriculture. Even the impact of ash fall from the Mount St. Helens eruption on May 18, 1980, was reported in qualitative terms (Cook et al. 1981) with no attempt to quantify the effects, positive or negative, on crops and livestock. The task of quantifying the effects of the drought on agriculture fell to the WSDA's Natural Resources Assessment Section (NRAS). An interim report describing qualitative effects was submitted to the DOE on December 31, 2015, and a final report quantifying the drought's economic effects is due at the DOE on December 31, 2016. Prior to the 2016 due date, the WSDA-NRAS asked the Washington State Academy of Sciences (WSAS) to review and make recommendations regarding the science supporting the methodologies and interpretation of the results in their report.

As a working academy, "The Washington State Academy of Sciences provides expert scientific and engineering analysis to inform public policy-making, and works to increase the role and visibility of science in the State of Washington." It is in this context that the WSAS agreed to form a committee (Committee) (Appendix I), and report back to WSDA-NRAS by December 16, 2016, with recommendations for improving the 2016 interim report and to increase the scientific quality and utility of this and future reports.

Undertaking this scientific review of the WSDA report on the 2015 drought's statewide economic impacts on agriculture is not the first work of the WSAS concerning the water resources and their management in Washington. Of the symposia held as part of its past nine annual meetings, the 2012 symposium was on Water, Washington and the World, http://www.washacad.org/about/files/annual_meetings/12symposium/2012Symposium_review_web_4_18.pdf and the 2016 symposium was on the Columbia River Treaty: Issues for the 21st century.

General Comments and Recommendations

The WSDA-NRAS has made an impressive effort to provide a reasonably thorough, timely, and quantitatively-based assessment of the 2015 drought's impact on Washington agriculture. This reporting started with an interim report on qualitative effects that was due at the DOE on December 31, 2015; the current report on quantitative effects is due at DOE by December 31, 2016. Given the diversity of crops affected, their geographic dispersion, patchiness of data on costs and returns at the individual operator level, and even less data on economic impacts for associated activities, it is a major challenge to assemble, analyze, and report robust conclusions by crop or region or in aggregate at the state level. Indeed, the DOE's expectation that the report "provide both qualitative and quantitative data on the impact of the 2015 drought on Washington agriculture" is dauntingly broad. However, this study will contribute to a more informed policy discussion and effective implementation approach to future droughts, while offering an investigative approach that can be assessed and improved for future applications. Moreover, as far as the Committee knows, this report is unlike any other about drought impacts in that it provides a historical assessment of the drought. Related efforts on statewide, regional, and national events are more typically conducted as a drought unfolds and hence are used partly as planning tools.

The report would benefit from an overview of total irrigated acres and diversion rights across the state. Perhaps this will be included in a companion report to be written by the DOE, but it belongs in this WSDA report; it is more relevant than much of the summary provided on pages 8-9, for example. The summary needed is a best approximation of the total number of irrigated acres that receive less water in a drought year. There is a lot of uncertainty over exactly how much less water is received across Water Resource Inventory Areas (WRIAs) in the state. Yakima is one of the best understood regions, due in part to the basin-wide adjudication that is nearing completion. A research team led by Dr. Jennifer Adam (WSU Department of Civil and Environmental Engineering) has worked with the DOE to get a better understanding in other WRIAs as part of the Office of Columbia River (OCR) -funded Water Supply and Demand Forecast. There are still significant gaps, but an accounting can be started to get a sense of these values.

For example, start with the total irrigated acres for Washington from the 2013 United States Department of Agriculture (USDA) Farm and Ranch Irrigation Survey, which is 1.6 million acres. A large share of this total, about 600,000 acres, is part of the completed portion of the Federal Columbia Basin Project, which is not curtailed during droughts. Exact acreages for the Yakima irrigation districts are also known and can be translated into the shortfall of water during droughts. Acreage for land irrigated from deep groundwater, like the Odessa region, is also well characterized. Walla Walla is another WRIA with surface water rights that are subject to instream-flow rules. Adding up these values should get pretty close to the 1.6 million acres and a somewhat reasonable estimate of the number of drought-affected irrigated acres. The WSDA Cropland Data Layer also makes it possible to estimate reduced water use by crop type. The information WSDA collected based on field- and farm-level data is made much more powerful when incorporated into a state-level accounting as recommended here.

While the introduction focuses on impacts to irrigated agriculture, which is hugely important in Washington and was uniquely impacted by the snowpack drought, much of the production value of Washington's livestock industry and of major crops such as wheat and other small grains are from non-irrigated ranch and farm land in eastern Washington. The Committee recommends making more use of the National Agricultural Statistics Service (NASS) data of yields and acreage and broadening the coverage to more than two-thirds of farm production in Washington. The NASS data are relatively easy to use, and there seems no compelling reason not to use the complete coverage of commodity value in comparing the pre-drought period to 2015. A brief discussion of the amount of crop and pasture land that is irrigated relative to the total, and the value of output associated with crops that are irrigated or not, would also be helpful to readers.

The authors should consider adding a couple of words to the title, or at least in the introduction, acknowledging that the report is also about impacts of extreme heat independent of the 2015 drought. Western Washington blueberry producers, for example, attributed all of the low yield, small size and reduced quality of the 2015 blueberry harvest to high temperatures immediately before and during harvest. Eastern Washington sweet cherry producers reported a similar situation.

The discussion in the introduction focuses on "crops." Later, it seems as though livestock commodities are included in "crops." The introduction also focuses on food production, even though feed crops and ornamental horticulture are important in Washington. A clearer or more consistent terminology should be used in defining crops and livestock.

Similarly, the introduction discusses agriculture without defining terms. For example, this report is about farming, which accounts for about 1 percent of the Washington economy, and not about all the related activities and rippled impacts on other sectors that may correspond to 5 percent or 10 percent of the economy depending on how broadly one defines "agriculture." Some explicit statement of definition or scope is needed.

It would also be helpful near the beginning of the report and for the uninformed reader to have a section where all of the ways that drought can affect the agricultural economy are grouped into those over which producers have control and those beyond or mostly beyond their control. For example:

Aspects over which an individual producer has control:

- Acreage decision for crops (including whether to fallow)
- Number of head decision for livestock
- Timing of planting and harvest
- Pruning, crop load manipulation and other horticultural practices
- Increase pumping of groundwater or development of new sources of water
- Fertilizer and other nutrient input investment decisions
- Longer-term investment decisions (e.g., number of head held for breeding)

Aspects over which an individual producer has no control:

- Price of outputs (likely higher due to leftward shifting of supply curve)
- Price of inputs (e.g., the price livestock/dairy producers might pay more for feed)
- Yield of commodity
- Size of commodity
- Quality of commodity

Each of these aspects is currently identified in the report, but pulling the examples together in one place early in the report will help clarify the methodology and results. The distinction between the two groups is also important to the extent that producers can respond to changing conditions, mitigating the economic effects of the drought. This occurs without government assistance. This is also where a formal economic model would be useful (see examples below). Economic theory recognizes that there are typically substitution possibilities that are possible or other adaptation mechanisms that lessen the impact of any adverse shock to the economic system.

Finally, this report needs to be clear on whether the objective is to quantify the net effect of the drought at the state level or to quantify the losses to negatively affected farms without including an offset for farms that may have increased their net returns compared to a year (or previous five years) in which there was no drought. Any one of the modeling frameworks described below would focus on the net effect. However, it is a political question for WSDA, DOE, and the Legislature as to whether they are more interested in quantifying the harm to farmers that were negatively affected by the 2015 drought. It is fair to say that much of our farm policy at the federal level is focused on creating stability in the farming sector by providing assistance through price supports or subsidized yield insurance. In other words, there is a distributional goal politically defined that supersedes a goal based on economic efficiency.

This lack of clarity is especially pronounced by the inclusion of the $2.66 Roza payment to the senior water rights holder. This payment is simply a transfer from one water rights holder to another within the state, so it should not be included as a drought impact. All that should be included is the net revenue associated with the lost production to the water rights holder that leased the water. If this is what is requested, there should be some recognition that it is not the same as the net economic cost to the state, as some farmers likely benefited either through higher commodity prices or leasing water. This is a political rather than an economic decision.

Methodology

The Committee recognizes that the authors of this report will not be able to make more than a few of the revisions and additions recommended, having only two weeks between December 16, when the WSAS Committee report is due to the WSDA-NRAS, and December 31, when their revised WSDA Interim Report is due at the DOE. Nevertheless, the Committee encourages the authors of the WSDA report to make as many of the minor recommended changes and any major changes they deem possible within their tight schedule, and to include other major recommendations of the Committee as part of future ongoing assessments of the economic impacts of meteorological events.

Any future analysis and reporting on the economic impacts of a drought or any other meteorological event should be based on a clearly defined and recognized economic foundation. This interim report adds up several different types of values (Table 13), but this can lead to errors in many cases, and the direction of the error is not always clear because there is no clearly stated theoretical model. This type of study can be conducted using an Economic Welfare model, Input/Output model, or Computable General Equilibrium (CGE) model. Ideally, one of these models should have served as the theoretical foundation for the study and should be used for similar studies conducted in the future.

Economic Welfare Model

A welfare economics foundation would have been most consistent with the studies in this report, because it is the theoretical foundation for Benefit-Cost Analyses (BCA). Such studies have been performed for many water development projects in Washington state in the past 30 years, mainly because each BCA study for a new reservoir, pipeline, water bank, etc., has to model a "with" and "without" scenario, where the "without" scenario is the total economic profit without the project. This includes a description of how agricultural production is affected by drought. The modeling framework for any of these studies could be used for WSDA's drought impact assessment. This is also an excellent opportunity to update many of the assumptions made in these studies with the new information the WSDA has collected.

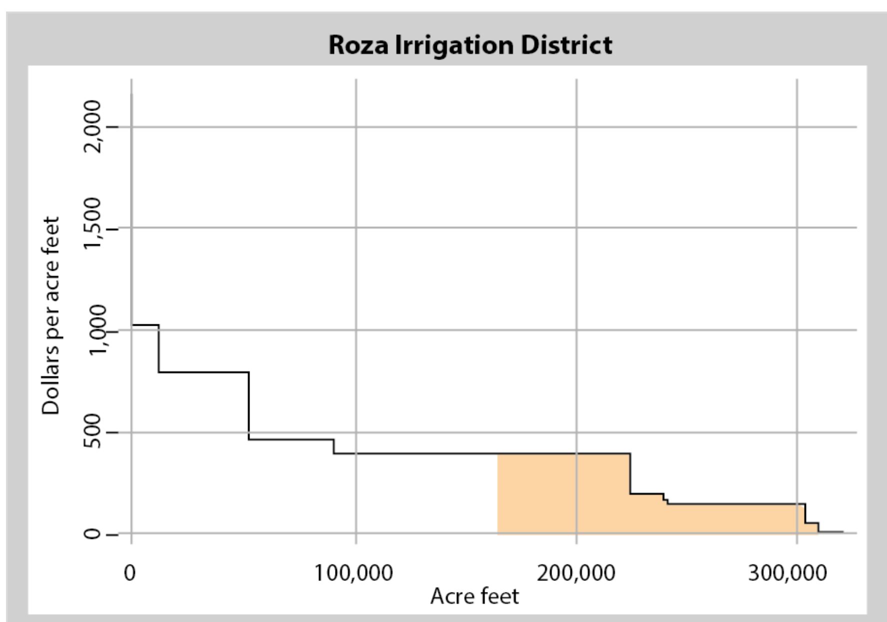
For future assessments, the Committee recommends building from the Scott et al. (2004) model that was the basis for the EcoNorthwest BCA of the Yakima Basin Integrated Plan, referred to as the "Four Accounts" report. This model makes assumptions on the two key values needed: 1) net revenue per acre for the major crop groups; and 2) water use per acre by crop. These values for the major crop groups in Washington are shown in Tables B-2 and B-3 of the Four Accounts report. This WSDA interim report has made fairly strong assumptions, necessarily, for gross revenue, which are "best guesses" from experts and the lagged five-year average values for prices. Assumptions about net revenue per acre are not much stronger. There are updated enterprise budgets from the University of Idaho, Oregon State University, and Washington State University that provide reliable estimates of gross revenue and production costs for a large number of crops. Sensitivity analyses can be performed by varying this value, which is already done in most enterprise budgets. The WSU group led by Jonathan Yoder, School of Economic Sciences, enhanced this model to more easily consider different levels of drought. This work received awards from both WSU and the Agriculture and Applied Economics Association for policy analysis, so it has been reviewed by experts for its validity.

The approach of Yoder et al. (2014) was to use step functions as described by Burt (1964). This is demonstrated in Figure 1 [Figure 19 from Yoder et al. (2014)], which shows the step function for the Roza Irrigation District. The x-axis represents the amount of water made available to Roza in a production year. The maximum value is water use in their non-drought year. All of the Yakima irrigation districts use less than their full entitlement in non-drought years, as discussed in the Four Accounts report. The y-axis shows an estimate of the value of water for each crop [($/ac-ft.)/(ac-ft/acre)]. The crops are then ordered from lowest to highest value from right to left. The width of the steps represents each crop group's water allocation.

When a drought occurs and Roza is prorated, the district receives only a fraction of its entitlement. The economic loss due to the drought is the area under the step function between the entitlement and the amount of water Roza was permitted to divert. For example, consider a situation where Roza receives only 160,000 ac-ft. The estimate of their economic loss (profit) is approximated by the pink area. This approach makes a potentially strong assumption that farmers are able to fallow or curtail lower-value crops first. While this makes economic sense, it is possible that many farmers do not have a diversity of low to high value crops that would permit them to prioritize which crops to curtail. While intra-district leasing allows some of this adjustment to happen among farms, it is likely that this approach would result in an underestimate of drought impacts. Therefore, Yoder et al. (2014) and the Four Accounts study used a second method, which assumes that all crops in an irrigation district are prorated in proportion to their water use. This would be consistent with a situation where all farms are highly specialized and there is very little movement of water among farms. For this, one needs the average value of water among crops weighted by the amount of water use. For example, the average value for Roza was estimated to be just over $400/ac-ft. in. the Four Accounts report. Of course, this value fluctuates with market conditions from year to year and should be thought of as an average across farms. With this information, one needs only to multiply the curtailment amount by this water value to calculate total economic loss for Roza. This provides fairly reasonable upper- and lower-bound drought cost estimates.

For illustration purposes, assume that Roza was curtailed by 60 percent. The curtailment rates for the Yakima irrigation districts are fairly precisely known using the hydrological model Yakima RiverWare™. Then, the type of information collected by WSDA-NRAS in terms of leases with water rights outside of the district and whether it is a senior rights holder or the Sunnyside Valley Irrigation District (SVID) can be used to adjust the value. A 60% curtailment of Roza means that they have 393,000 ac-ft.-393,000*0.6 = 157,200 ac-ft. Adding up the pink area in Figure 1 very roughly (60,000*480+90,000*230) gives $49.5 million in lost profit. To get the upper-bound cost estimate, calculate the value 393,000*.6*400 = $94.3 million. This may be considered a fairly big range, but it can be refined with the wealth of information WSDA-NRAS has collected. Of course, it may be wise to assume slightly higher or lower $/acre values for each crop group, as well as potentially incorporating multi-year yield impacts if it is likely that water stress affected yields of perennial crops in 2015. Going back to leasing adjustment, imagine that Roza leased 30,000 ac-ft. from SVID. How should this be counted in the cost estimate? If the goal is to estimate the net effect of the drought at the state level, then the amount that Roza paid to SVID should not be included. What should be included is the lost profit associated with the acreage in SVID that was fallowed as a result of the lease arrangement.

Figure 1. A step function for Roza Irrigation District where the pink area represents the lost profit in a drought where Roza is curtailed by 60 percent.



Economic Impact Analysis based on an Input/Output Model

Input/Output (I/O) models quantifying change in gross revenue are the theoretical foundation for economic impact studies. In an economic impact study, a change in the value of an industry output captures the economic losses that ripple through the economy through reduced purchases to intermediate good suppliers and the labor market, as well as lost income to business owners that would have been spent on services in the local economy. A more complex approach can be used by combining an I/O model with a Computable General Equilibrium model to permit market level feedbacks that result in changes in prices of inputs and outputs. While economic impact studies look at change in gross revenue, they are not inconsistent with an Economic Welfare theoretical foundation. This is because an I/O model defines a region of study and includes parameters called "regional purchase coefficients" that capture how much of an intermediate good is purchased within the "local" economy. For example, an input such as fertilizer likely has a very low regional purchase coefficient to reflect the fact that most of the cost of the fertilizer is generated outside of Washington state. Therefore, lost purchases of fertilizer do not credit a significant economic loss to the region. There is some loss in value- added to fertilizer sellers.

Computable General Equilibrium Models using IMPLAN Data

It's important to distinguish between the "IMPLAN® model" that is an off-the-shelf purchasable model often used by consultants and some academics for quick analyses, as compared to models that make use of the IMPLAN data but make different theoretical assumptions. The latter include Computable General Equilibrium (CGE) models, also known as Applied General Equilibrium (AGE) models. These models may be calibrated using IMPLAN data at the regional (or national) scale and rely extensively on economic theory. As with Benefit-Cost Analysis, a "with" and "without" scenario is created, but the approach may have greater detail on feedback effects, budget constraints, factor markets (including wages and employment effects), and effects on consumers. A variety of Input/Output models can also be created that use IMPLAN data; they share some aspects with CGE models but tend to be simpler; e.g., I/O models typically assume fixed responses to an economic shock on the part of producers and consumers. For jobs and related broader economic impacts, it is standard to insert revenue and related impacts into a model of the whole economy to calculate direct and indirect jobs impact and indirect gross state product impacts. The IMPLAN model is often used for such calculations, https://watershed.ucdavis.edu/files/biblio/Final_Drought%20Report_08182015_Full_Report_WithAppendices.pdf.

The IMPLAN data do not have a detailed breakdown of the agricultural industries for a region as diverse as Washington. It is possible to adjust I/O models to create customized disaggregation based on enterprise budgets (Willis and Holland, unpublished). Further, transparency of economic impact studies can be greatly improved by aggregating the industries that are not central to agriculture, including manufacturing and services. This greatly reduces the number of values that have to be assumed in the study, making it easier for someone to review assumptions. It is important to recognize that changes in employment, a commonly reported output in an economic impact study, should not be included in a drought economic impact study. There are a number of other fairly technical aspects to modeling droughts correctly in an I/O type model, which are summarized in an outline by Nadreau, Brady, and Yoder that can be provided upon request.

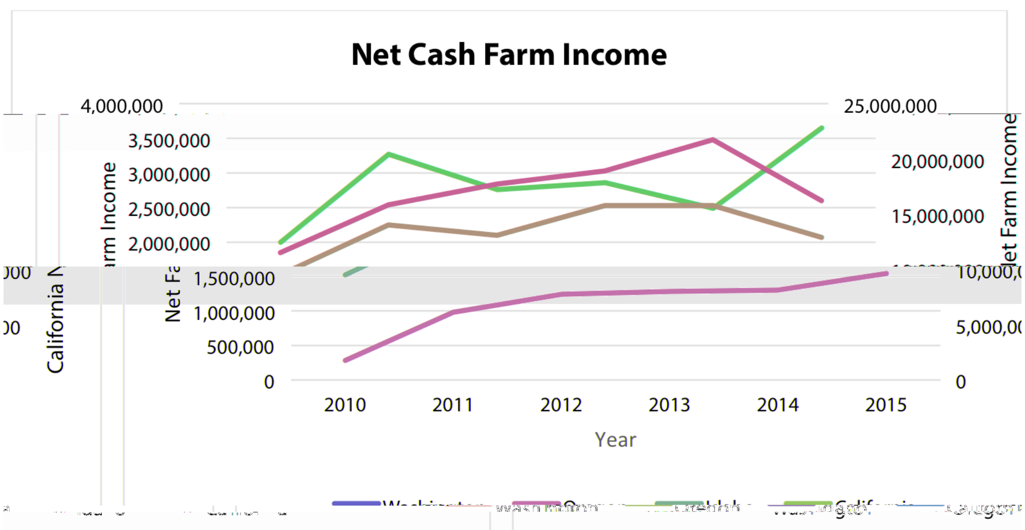
On page 37, the authors indicate that a comprehensive estimate of drought losses is not possible because "it is impossible to collect information on every commodity grown throughout the state at the farm scale," and with 37,249 farmers "it would be impossible to contact each of them individually." However, such a census is not necessary. Statistical theory tells us that random sampling can be highly accurate in making inferences about a population. Therefore, the fact that a census is not possible is not a good reason for not providing statewide coverage (this is not to imply, on the other hand, that developing a random sample is easy). A potentially viable alternative to a census or random sampling for calculating the 2015 drought's economic impact would be to construct a detailed economic model of the state's regions, e.g., constructing an AGE model based on IMPLAN data, and shocking it with some of the estimates used in this WSDA report. This could provide some relatively comprehensive estimates. The authors could mention this alternative possibility in a footnote.

Results

The results in this interim report are based on gross rather than net revenue lost. Lost economic welfare due to a drought is the total change in consumer and producer surplus. Producer surplus is the difference between the selling price and the cost of production, i.e., net revenue. Consumer surplus is the difference between what consumers are willing and able to pay for a good or service relative to its market price. In economic terms, the supply curve of these commodities would have shifted to the left, raising the price received by producers. Therefore, using the "market value" for 2015 may overstate the actual losses, because 2015 prices might have been unusually high due to the drought. Similarly, the economic loss to the farmer from a drought is not foregone gross revenue. If the Farmer's gross revenue is $5,000/acre but $4,000 goes towards expenses for items like herbicide, pesticides, fertilizer, diesel, labor, etc., then the Farmer looses only $1,000/acre if there is a drought and they must fallow the field rather than plant.

The importance of documenting the impact of the 2015 drought on net rather than gross income at the farm level is brought to the fore by the incongruity between the WSDA drought-cost estimates and Figure 2 showing the U.S. Department of Agriculture's estimates of net farm income by state for Washington, Oregon, California, and Idaho. How is one to reconcile that the net farm income for Washington in 2015 was higher than any of the previous four years by a significant amount when there was a drought in 2015 that imposed substantial financial harm on many farms in the state? Addressing the three issues identified above, namely, 1) an analysis based on a defined economic foundation, 2) whether the objective of the study is to calculate net impacts to agriculture or costs to farmers negatively impacted by the drought and 3) an overview of production that includes an accounting of water rights, diversions and curtailments, would go a long way toward making sense of this obvious incongruity. For example, if policy is shaped around mitigating drought costs to negatively affected farms, then there is no need to reconcile because it does not matter that unaffected farms may have had higher income due to lower input costs, higher output prices, or from leasing their water. An estimate of the total acres affected by drought at the state level would indicate whether the negative supply shock increased prices for some commodities enough to increase income in the aggregate. It could also mean reduced demand for labor and hence lowered input costs for farms that were still able to produce. If there is still a lack of resolution, then it would be valuable to involve the USDA NASS office in Olympia to provide additional perspective on their estimates.

Review Example: Report Figure 2. Net Cash Farm Income



Source: Economic Research Service, U.S. Department of Agriculture. U.S. and State-Level Farm Income and Wealth Statistics.

Table 13 (reproduced next page) shows that the total estimated losses from all sources is $634,453,584. Is this a big or small number? Ideally there would be a base number by which to compare this number. The authors indicate that these numbers are more comprehensive than those in the December 2015 interim report but still not comprehensive for Washington as a whole. This is understandable, but this number does not convey a sense of what proportion of the $634,453,584 figure represents Washington's likely total losses. For example, is it 50 percent or 90 percent? Further, without more context, it is difficult to evaluate the significance of the estimated $634,453,584 total economic impact and the authors forthrightly indicate they are aware their estimates have limitations. They also suggest that "Monitoring this type of data on a yearly basis would provide a means to relate agricultural impact data with future meteorological events" (p. 40), and that "a sound data network and methodology would need to be created to monitor a representative subset of each portion of the agricultural industry (p. 40). Obviously, it is impossible to collect information on every commodity grown throughout the state, but as stated in the Committee's review of methodology, properly conducted surveys are possible. This study itself provides valuable background for such surveys.

Review Example: Report Table 13. Estimated Losses from All Sources

SOURCE	LOSS ($)
Blueberry meeting	$10,560,000
Raspberry meeting	$13,900,000
KRD mapping	$11,401,115
Roza impacts	$78,443,834
WIP interviews	$32,691,211
Skagit report	$27,200,000
Livestock survey	$33,281,564
NASS data	$426,975,860
Total Estimated Loss	**$634,453,584**

Table 13 is somewhat hard to understand because the rows refer to sections of the text as opposed to variables that can recognizably be added. For example, are the NASS data meant to represent everything not covered in the preceding rows? This information might be in the main text, but the reader could use a clearer explanation of this table.

The authors could also broaden the coverage to more than two-thirds of farm production in Washington by making greater use of the NASS data of yields and acreage. The NASS data are relatively easy to use, and there seems no compelling reason not to use the complete coverage of commodity value in comparing the pre-drought period to 2015. Many of the commodities left out of this report will have relatively small drought impacts, but by leaving them out, the reader is left with questions that could be easily answered.

There is also little explicit discussion of impacts on pasture and range on a statewide basis. The beef cattle industry in Washington accounts for about 10 percent of farm and ranch revenue in the state. NASS reports data on drought conditions relevant to dryland pasture conditions weekly, and these data can be easily summarized for sub-regions within the state. See, for example, http://droughtmonitor.unl.edu/MapsAndData.aspx. NASS also reports weekly on pasture condition, data that can be quickly summarized to show that conditions were poor in much of the state's dryland pasture regions in 2015.

Milk prices were extremely low in 2015, which exacerbated impacts of drought on hay and silage production. Some explicit discussion of dairy feed availability and costs would be useful. It is likely that most concentrate feed is shipped in from the Midwest, but alfalfa and corn silage are from mostly local sources (with perhaps some hay from Idaho). Some explicit discussion of the forage situation (perhaps including prices from USDA Agricultural Marketing Service (AMS) would help the reader understand the impacts of the drought on dairy.

The study could be more useful with a more comprehensive evaluation of indirect economic impacts. Along those lines, the DOE indicated it was seeking "information on secondary drought impacts (changed planting/harvest schedules, additional costs for running pumps on drought wells and mitigation payments, labor impacts, etc." (p. 47), but obviously the authors were constrained by time and resources. From a specialty crop producer standpoint, with labor-intensive, high-risk operations, secondary impacts loom large. For example, managing the work force in the tree fruit industry and many others is an increasingly onerous role every producer must play, involving difficult paperwork, transportation, housing, medical care, etc. A commitment to a given timeline and quantity of workers via the H2A program carries high financial and management risks when timelines and quantities of workers are significantly perturbed by events like the drought. In areas with junior rights and no or decreasing access to ground water, such perturbations are a constant worry. The productivity of affected orchards and vineyards in the next couple years after a severe drought stress is also a significant horticultural concern that is difficult to mitigate.

Similarly, the authors might acknowledge effects of the 2015 drought on consumers in terms of higher prices and lower availability or quality of food products. This would be particularly relevant for fruits produced under a combination of water stress and high summer temperatures in the irrigation districts included in this study and in western Washington, where high temperatures prior to and during harvest reduced the yield and quality of berry crops.

Other Comments and Edits

- There are statistical methods for ex post weighting of survey responses that could be used to make more transparent estimates of the droughts effect on the entire population of affected farms.
- Figure 1 would be more useful if it were an area line chart rather than a bar chart.
- The first two cuttings for alfalfa and timothy are typically of higher value than a third or fourth cutting, so it is probably an overestimate to reduce the value of production in half if assumed that the number of cuttings was reduced by half.
- Use a phrase other than *"known loss"* for the commodity-specific results when extrapolated to a larger population from a sample that was interviewed; it sounds too certain.
- The methods for additional feed purchased should be considered in the same way as the leasing-cost transfer. If the feed is purchased within the state, then it is simply a transfer from one farm to another if state-level net effect is the outcome of interest. What should be included is the profit associated with the lost production on the farm that normally produces that feed.
- Some minor wording changes can be made throughout. The last sentence on page 12 is repetitive of the previous sentence. Lead sentences in the two initial paragraphs of the section on NASS Data (pp. 20-21) are repetitive. What is the reason for the significant difference in value of average $ loss/Acre for apple and cherry when comparing Wapato and Roza Distracts $2,500 vs. $3,400 and $500 vs. $1,500, respectively?
- When reading the report, it can be difficult to keep track of which areas of Washington are being sampled, and which are not. The reader would benefit from a map or two that clarifies the surveyed areas, and whether the results are associated only from these areas, or are being extrapolated to Washington as a whole.
- Page 8: Need to add "be" here: *"We also focused on 4 regions in the state where drought impacts were expected to **be** most severe."*
- Page 11 Need to add "while" here: *"Some farmers and ranchers have surface water rights administered by Ecology, **while** others have contracts with entities like the United States Bureau of Reclamation (USBR) in the Yakima Valley"*
- Page 12: *"Snowpack is considered to be a 'third reservoir"* Should this be considered surface water, since it mostly ends up in rivers?
- Page 15: *"windshield surveys"* This term is introduced without being well defined. Are there possible biases with such an approach? If so, what direction are these biases likely to run with respect to your final results?

- Page 16: (top paragraph) *"The survey included meetings with growers to discuss specific water shortage issues."* How were the interviewed growers located? Are they representative in a statistical sense? In general, it would be good for the authors to have more discussion of the sampling methodology (if any) that was used in the study.
- Page 17: *"During the data collection process, it was clear that there were areas that warranted regional focus sections other than the Kittitas and Roza irrigation districts"* In what way was it "clear"? This gets back to the need to provide an organizing section for how the sampling was done.

  On the bottom of page 21, the report states that land in permanent crops cannot be fallowed in a drought because of establishment costs. It is true that farmers will do all they can to not have this happen, but it is possible that some farmers who are significantly curtailed with only permanent crops are left with no choice. Whether this ever happens in practice is another question, but it is possible if a drought is severe enough. There were reports of it happening in California in the past five years.

  On page 25, it makes sense to avoid double counting, but it seems like it would be useful to have an additional exercise to determine if survey responses for crops surveyed matched up with what was observed in the mapping data.

Figure 2 depicts the drought monitor from the University of Nebraska-Lincoln. This is a nice image in some ways, but this measure has important drawbacks and is not taken very seriously by the scientific community. For example, atmospheric scientist Dr. Cliff Mass at the University of Washington expresses concerns about the usefulness and reliability of this measure here: http://cliffmass.blogspot.com/2016/02/is-oregon-still-in-severe-drought.html. For example, it is questionable whether this measure accounts for stream flows, snowpack, soil moisture indexes such as GRACE, and crop moisture indexes such as NOAA, among others.

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Appendix I: Washington State Academy of Sciences Review Committee

Washington State Academy of Sciences Committee to Review the Washington State Department of Agriculture Interim Report: 2015 Drought and Agriculture.

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