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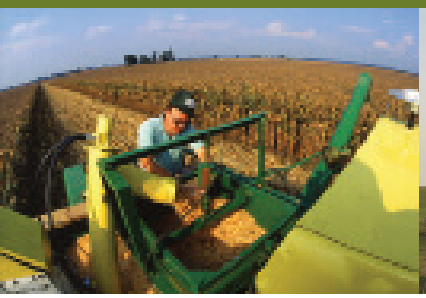
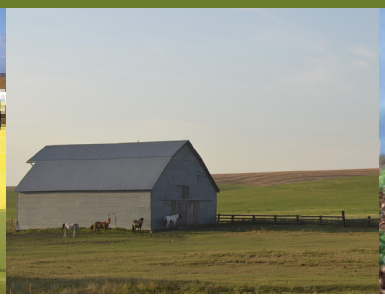

Evaluation with Recommendations by the Washington State Academy of Sciences of

2015 Drought and Agriculture

Washington State Department of Agriculture




December 2016

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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).

Washington State Academy of Sciences
410 11th Avenue SE, Suite 205
Olympia, WA 98501
wsas.programs@washacad.org
http://www.washacad.org
(360) 534-2321

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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 blue-

berry 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.

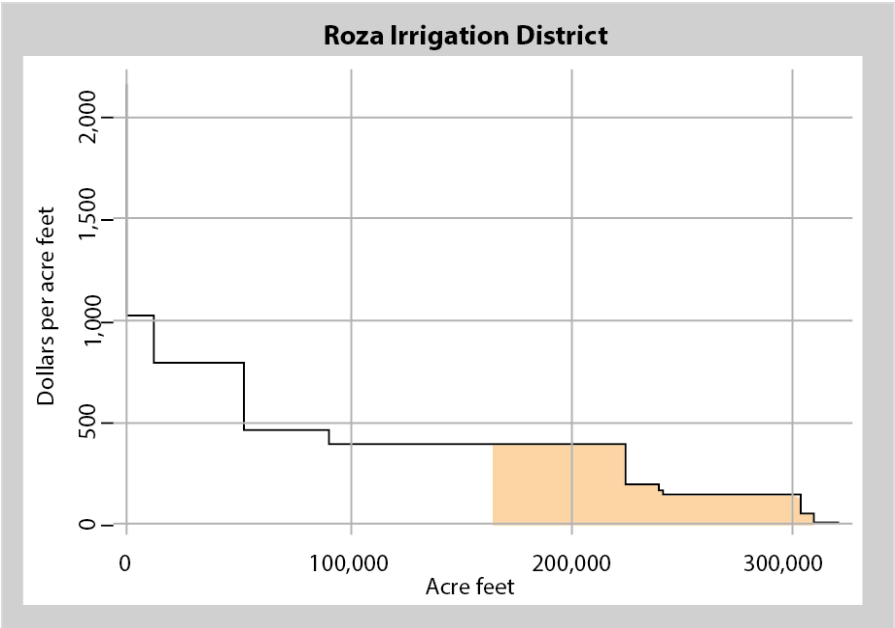
For future assessments, the Committee recommends building from the Scott et al. (2004) model that was the basis for the EcoNorthwest BCA of the Yakima Basin Integrated Plan, referred to as the "Four Accounts" report. This model makes assumptions on the two key values needed: 1) net revenue per acre for 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.

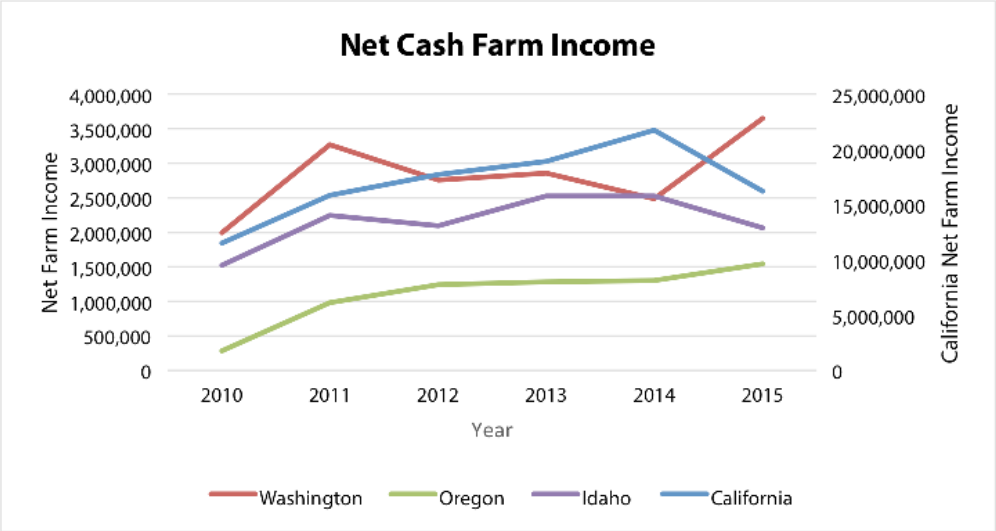
On page 37, the authors indicate that a comprehensive estimate of drought losses is not possible because "it is impossible to collect information on every commodity grown throughout the state at the farm scale," and with 37,249 farmers "it would be impossible to contact each of them individually." However, 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 com-

prehensive 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.

- ***R. James Cook***, Chair of the Committee and member of the Washington State Academy of Sciences and the National Academy of Sciences. Professor Emeritus, Department of Plant Pathology and Department of Crop and Soil Sciences, Washington State University, Pullman.
  rjcook@wsu.edu
  http://planthealthinternational.com
- ***Michael Brady***, Assistant Professor and Extension Economist, School of Economic Sciences, Washington State University, Pullman, WA.
  bradym@wsu.edu
- ***Jeff Reimer***, Associate professor, Department of Applied Economics, Oregon State University.
  Jeff.reimer@oregonstate.edu
- ***Jim McFerson***, Director, Tree Fruit Research and Extension Center, Washington State University, Wenatchee, WA. Until recently, Manager of the Washington Tree Fruit Research Commission.
  McFerson@treefruitresearch.com
- ***Daniel A. Sumner***, Frank H. Buck Distinguished Professor, Agricultural and Resource Economics, and Director, UC Agricultural Issues Center, University of California, Davis
  dasumner@ucdavis.edu

WASHINGTON STATE
Academy of Sciences

Washington State Academy of Sciences
410 11th Avenue SE, Suite 205
Olympia, WA 98501
wsas.programs@washacad.org
http://www.washacad.org
(360) 534-2321