OpenAg

Release 0.2

UC Merced Water Systems Management Lab, Vicelab, and the Cer

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CONTENTS:

CHAPTER

ONE

CORE CONCEPTS IN OPENAG

1.1 The OpenAg Model

The OpenAg application utilizes Positive Mathematical Programming (Howitt et al. 2012) to model changes in land use, applied irrigation water, and gross revenue based on user-provided fine-grained adjustments to land and water availability, crop prices and yields, and crop land use constraints.

1.2 Regions

Each distinct model hosted in OpenAg will contain multiple regions. Regions represent real landcape areas, typically some meaningful unit where land use decisions may involve some coordination. The application stores land use data for each region and other economic values that are used in the PMP model. OpenAg optimizes regions independently, meaning that decisions in one region do not effect decisions in other regions, though users can simulate activities such as water transfers through specifically crafted inputs to the model.

1.3 Crops

OpenAg groups multiple crops into groups that it refers to as "crops", so in many cases data on individual crops, e.g. strawberries, may be aggregated into a larger group, such as "berries", for modeling. OpenAg's input data ties crops to regions along with information on prices, yields, and costs that allow for economic modeling of each crop in each region.

1.4 Model Runs (Scenarios)

Todo: This item should be updated/rewritten to be clearer - I'm not sure the language used clarifies the model significantly.

OpenAg's web application is principally designed for scenario analysis and decision support, in addition to viewing the raw economic input data. A scenario can be thought of as answering a "what if" question you have, such as "what if crop yields are reduced in a set of regions due to climate change?" OpenAg helps you answer these questions through `Model Runs`, which allow you to define changes to data and the model, then run the model and see the results as compared with a scenario with no modifications.

See also:

Viewing and Working with Model Runs

1.5 Modifications

When creating a model run, you will create a set of modifications to the model that come in two forms: modifications to region-level data, such as irrigated water availability, rainfall, and cropped land area, and modifications to crop-level data, such as price yield, and minimum/maximum land area.

See also:

Creating Model Runs

1.6 Cards

CHAPTER

TWO

HOW THE MODEL WORKS

OpenAg separately models irrigated and nonirrigated lands. Irrigated lands use a PMP formulation for optimizing revenue based on land use and resource choices while nonirrigated lands use a statistical regression model that estimates yield based on changes in rainfall.

2.1 Model Input Data

2.2 The Irrigated Lands PMP Model

2.3 The Nonirrigated Lands Regression Model

2.4 Model Outputs

2.5 How OpenAg Splits Data Between Irrigated and Nonirrigated Lands

By default, OpenAg uses the input data for each region to determine what data goes into the *irrigated land model* and what data goes into the *nonirrigated land model*. The input data contain values for the irrigated acreage and the nonirrigated acreage for each crop within each region.

When either irrigated or nonirrigated acreage is small for a crop in a region, the model changes its behavior in order to avoid the effects of optimizing small values, which could produce incorrect results. Before splitting data between the irrigated and nonirrigated models, it checks the irrigated and nonirrigated acreages for each crop to make sure that they're more than 5% of the total value for the crop. If the nonirrigated acreage is less than 5% of the total within the region, it will merge the acreage for the nonirrigated acreage with the irrigated acreage and run it through the PMP model. Similarly, if the irrigated acreage is less than 5% of the total acreage for the crop in the region, it will merge the irrigated acreage into the nonirrigaged acreage and run it through the regression model.

For example if we had the following crops and acreages in a region, we would send the outputs as shown in the table

Table 1: Example Crop Acreage in a Single Region

Crop	Irrigated Acreage	Nonirrigated Acreage	Acreage sent to PMP model	Acreage sent to Regression model
Corn	80 acres	20 acres	80 acres	20 acres
Grain	4 acres	96 acres	0 acres	100 acres
Beans	97.5 acres	2.5 acres	100 acres	0 acres

So, a crop like corn, which has a split of acres at 80% irrigated and 20% nonirrigated is sent to the models exactly as the inputs provide, with 80 acres used in the PMP model and 20 acres used in the regression model. But the other two crops in the region are modified slightly. Grain, with 96 nonirrigated acres and 4 irrigated acres has all 100 acres sent to the nonirrigated regression model. Beans, see the reverse, with 97.5 acres of irrigated land and 2.5 acres of nonirrigated land, it sees all 100 acres of its cropped area sent to the irrigated PMP model. These numbers add up to 100 for ease of percentages, but in reality, the area for each crop within a region would not match between crops.

These calculations are conducted for each crop and each region, so even though all grain acreage is sent to the regression model for this example region, in other regions it may still use the PMP model or a combination of the PMP and regression models, based on the acreages for each specific region.

2.6 Modeled Areas in OpenAg

Each distinct model in OpenAg is called a `Model Area`, encompassing regions, crop groups, and calibrated input data for the model. As of May 2021, OpenAg supports two model areas:

2.6.1 The Washington State Model

The model for Washington State is based primarily on the state's water resource inventory areas as regions, with minor modifications.

Crop Groups

The following table shows the crops included in each crop group in OpenAg for the Washington model. The pipe character | splits separate commodities, so, for example in the "Bean" row, the first commodity included as a bean is "Bean, Dry" and the second is "Bean, Garbanzo", etc. Any commodity not shown in the table is not included in the model.

OpenAg_Crop	WSDA_Level_1
APPLE	Apple
BEAN	Bean, Dry | Bean, Garbanzo | Bean, Green | Chickpea | Legume Cover | Lentil | Pea, Dry | Pea, Green | Pea/Vetch | Soybean
BLUEBERRY	Blueberry
CANEBERRY	Berry, Unknown | Caneberry | Cranberry | Currant | Strawberry
CHERRY	Cherry
CORN	Corn, Field | Corn, Sweet | Corn, Unknown
GRAIN	Alfalfa Seed | Alfalfa, Seed | Barley | Bean Seed | Bean, Seed | Beet Seed | Beet, Seed | Bluegrass Seed | Bluegrass, Seed | Broccoli Seed | Broccoli, Seed | Bromegrass Seed | Bromegrass, Seed | Brussels Sprouts Seed | Brussels Sprouts, Seed | Buckwheat | Burnet Seed | Burnet, Seed | Cabbage Seed | Cabbage, Seed | Camelina | Canola | Carrot Seed | Carrot, Seed | Cauliflower, Seed | Cereal Grain, Unknown | Cilantro Seed | Cilantro, Seed | Clover Seed | Clover, Seed | Conifer Seed | Conifer, Seed | Corn Seed | Corn, Seed | Fescue Seed | Fescue, Seed | Flax | Flax Seed | Grass Seed | Grass Seed, Other | Grass, Seed | Misc. Grass Seed | Mustard | Mustard Seed | Mustard, Seed | Oat | Onion Seed | Onion, Seed | Pea Seed | Pea, Seed | Pepper | Potato Seed | Potato, Seed | Quinoa | Radish Seed | Radish, Seed | Reclamation Seed | Rye | Ryegrass Seed | Ryegrass, Seed | Safflower Seed | Safflower, Seed | Seed, Other | Seed, Unknown | Sorghum | Spinach Seed | Spinach, Seed | Sugar Beet Seed | Sugar Beet, Seed | Sunflower | Sunflower Seed | Sunflower, Seed | Swiss Chard Seed | Swiss Chard, Seed | Triticale | Wheat | Wildlife Feed | Yarrow Seed | Yarrow, Seed | Yellow Mustard
GRAPE	Grape, Concord | Grape, Juice | Grape, Table | Grape, Unknown | Grape, Wine
HAY	Alfalfa Hay | Alfalfa, Hay | Alfalfa/Grass Hay | Alfalfa/Grass, Hay | Barley Hay | Clover Hay | Clover, Hay | Clover/Grass Hay | Grass Hay | Grass, Hay | Hay/Silage , Unknown | Hay/Silage, Unknown | Oat Hay | Rye Hay | Sudangrass | Timothy | Triticale Hay
HOPS	Hops
PASTURE	Pasture
PEAR	Pear
POTATO	Potato
VEGETABLE	Artichoke | Asparagus | Beet | Broccoli | Brussels Sprouts | Cabbage | Cantaloupe | Carrot | Cauliflower | Cucumber | Garlic | Kale | Kiwi | Leek | Lettuce | Market Crops | Melon, Unknown | Onion | Peanut | Pumpkin | Radish | Rhubarb | Rutabaga | Spinach | Squash | Sugar Beet | Tomato | Vegetable, Unknown | Watermelon

Supported Capabilities

The Washington model supports both the *irrigated lands model* and the *nonirrigated lands rainfall model*. The nonirrigated lands model is not used for all regions or crops. Most modeled regions include rainfall modeling but only four crops are used in rainfall modeling: grain, bean, hay, and corn.

2.6.2 The Sacramento San-Joaquin Delta Model

The Sacramento San-Joaquin Delta (Delta) occurs at the confluence of the two eponymous rivers and is a crucial cornerstone of water resource management in California. While important in supporting agriculture throughout the state by conveying water to key regions, the Delta itself hosts significant production of select crops, namely alfalfa, corn, pasture, and tomatoes, among others. Challenges facing the Delta align with anticipated climate change impacts rising sea level, saline intrusion, and increasing hydrological variability. The OpenDAP model was developed as a tool to assess economic impacts of changing economic, biophysical, water management and land management conditions in the Delta. It is assumed that changes in these systemwide conditions will likely affect production decisions including total area planted and production factors use, intensity in production factors use, and choice of crops such that returns to farm and management are maximized. The OpenDAP model was embedded in a user friendly web application which runs an economic optimization model in response to user-provided scenarios of land use and water management such that crop profitability is maintained.

The OpenAg/DAP Model

The OpenDAP Beta Version model was developed using economic and production input data for 2014, 2015, 2016, and 2017, and is calibrated based on average conditions from these four baseline years. Unit of analysis consists of Delta Islands and other agricultural clustered areas within the Legal Delta. The model is calibrated using the economic principles of Positive Mathematical Programming for disaggregate models (Howitt et al. 2012) and its architecture is based on the DAP model employed to study salinity effects in the Delta Agriculture (Medellin-Azuara et al. 2014). The calibrated model predicts decisions of farmers on cropland use and use of inputs including water within an island assuming profit maximizing behavior considering expected prices, subsidies, yields, and costs, as well as restrictions on land, water and crop specific restrictions. This is undertaken by solving the non-linear program described by equations 1 to 5 below.

Getting Access

The web platform is available now as a beta version at https://openag.ucmerced.edu. To get access for additional staff, please contact Nick Santos.

CHAPTER

THREE

VIEWING AND WORKING WITH MODEL RUNS

When viewing a model run page in OpenAg,

CHAPTER

FOUR

CREATING MODEL RUNS

By default, running the OpenAg model with no modifications will produce the output that most closely aligns with observed conditions, called the "Base Case". The OpenAg application is designed to allow you to create your own model runs, or scenarios, where you specify deviations or changes in conditions compared with the base case. You provide these in the form of two separate types of modifications to the model inputs and constraints: region modifications and crop modifications.

On this page:

4.1 An Overview of Model Run Creation

Within the application, creating a model run has three steps:

1. **Add Region Modifications:** Add adjustments to region-wide parameters either across the model or for specific regions in the *model area*. Modifications for regions will always include irrigated water availability and total cropped land availability and may include rainfall, depending on the model area and available data.
2. Add Crop Modifications:

See also:

The Model Input Hierarchy: Prioritizing Overlapping Inputs for more information on how OpenAg determines which values to use when inputs overlap.

4.2 Capabilities in the Application

Though we have attempted to make the application as straightforward and user-friendly as possible, before creating a model run it is important to spend time considering how to translate your scenario of interest into adjustments that the model accepts.

e.g. what can we actually change or control in the application

See also:

Translating Common Scenarios Into the Model

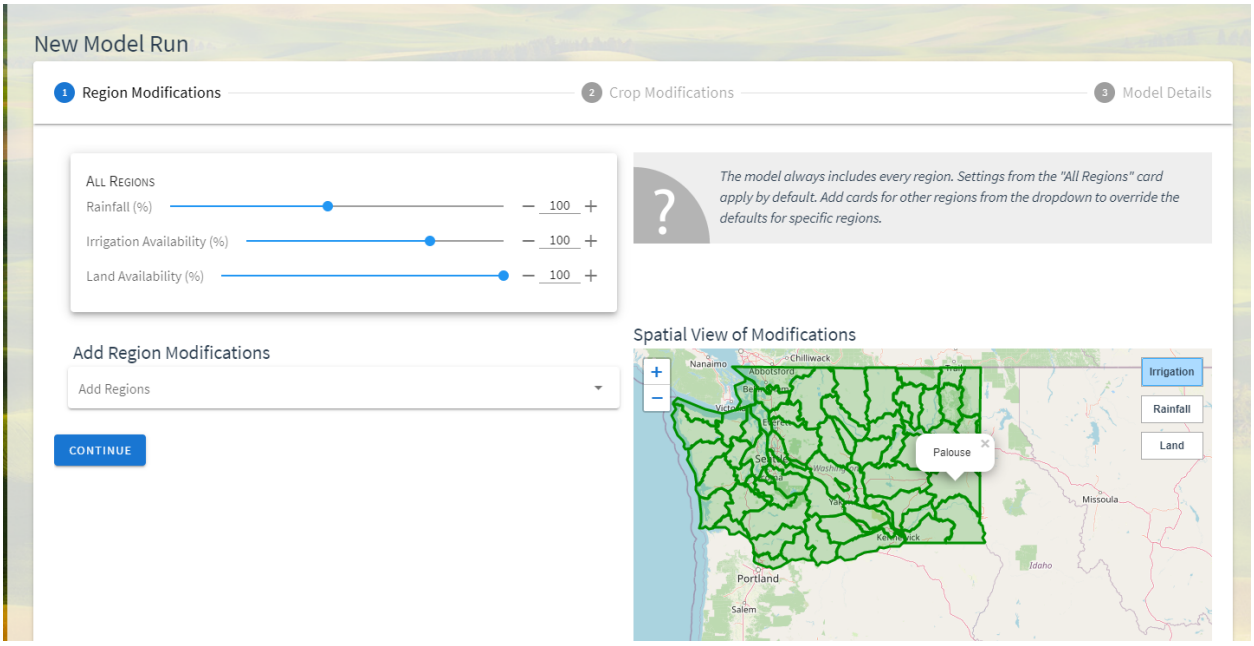
4.3 Overview of Modifications

When creating a new model run, most inputs are expressed as modifications relative to the base case. You can express these modifications for all regions or all crops, or provide modifications for specific regions or specific crops.

By default, OpenAg preserves the base case, so a model run with no modifications will produce identical results to the base case model run for the model area. All modification options default to 100%, meaning the application will keep the value exactly as in the base case. Adjusting the value then means making an adjustment relative to that item's normal value, rather than inputting an absolute value for the parameter. If you wish to input a specific quantity of a resource (e.g. irrigation water availability), then you need to first convert it to a percentage by comparing it to the amount available in the base case for the same unit of analysis, such as the individual region it applies to or all regions.

As a consequence of using relative values, for some scenarios, you will need to carefully consider your inputs. For example, if you want to simulate a water transfer between two regions, it would be incorrect to increase one region by 10% and decrease the other by 10% unless they both have the same amount of total available irrigation water. Instead, you would need to determine how much water is available in each region, using either the Input Data Viewer or viewing the base case, and then determine what percentage values for each region would indicate the same amount of water.

4.3.1 Overview of Region Modifications



See also:

Region Modifications

4.3.2 Overview of Crop Modifications

See also:

Crop Modifications

4.3.3 All Regions and All Crops

Resources not pooled - instead behaves as if an individual card was set up for each region or crop - optimization always happens per region, so changing water availability in all regions card will not produce water transfers between regions.

4.4 Summary and Review

4.5 Additional Reading on Model Run Creation

4.5.1 Region Modifications

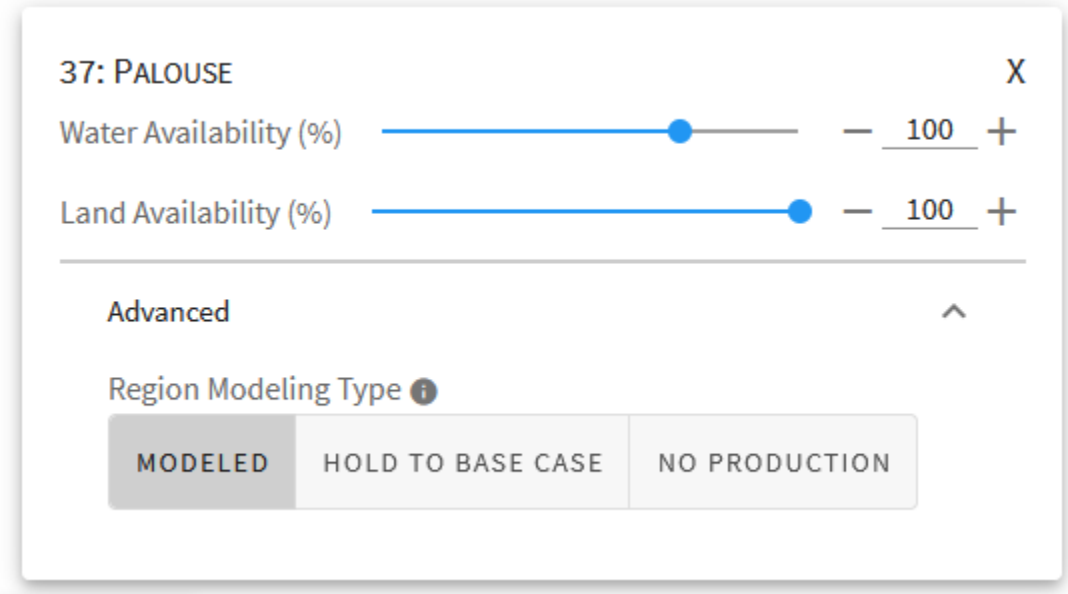
- *Advanced Region Options*
- *Additional Reading on Modifications*

Advanced Region Options

When working with region cards, you have the option to change advanced settings by clicking on the "Advanced" expansion panel at the bottom of the card. The advanced settings give you three options that adjust how the region is modeled. Since each region is modeled independently, you can change these settings for any given region without affecting the output of another region.

1. **Modeled:** The default behavior - the region will be run through the PMP model and, when applicable, through the nonirrigated agricultural yield model.
2. **Hold to Base Case:** In some cases, you may want to hold specific region's values as "static" - in this case, holding them to the base case prevents them from being modeled, and assumes that they won't change from the base conditions. The model run will provide the same outputs for the region as those in the base case.
3. **No Production:** Use this if you want to model the region as if it produced nothing over the model time period. In the San Francisco Bay Delta, for example, this can be useful for scenarios where an island floods and produces no agricultural output. An alternative is to model the region normally, but filter results in the output to remove the region, in case you want to assess results both with and without the region.

Note that these are high priority settings in that they take first precedence. A region held to base case will not be affected by the crop modification settings you choose. Results will appear exactly as in the base case for that region, while other regions will apply crop modifications as normal.



Additional Reading on Modifications

- *Overview of Modifications*
- *The Model Input Hierarchy: Prioritizing Overlapping Inputs*
- *Crop Modifications*

4.5.2 Crop Modifications

Overview

Crop modifications are the second step in *creating an OpenAg model run* and allow for adjustment of crop-specific parameters. By default, crop modification *cards* apply to data for the crop within every *region* where the crop is present, though it is possible to specify crop parameters per-region (see *Region-Linked Crops*)

Parameters

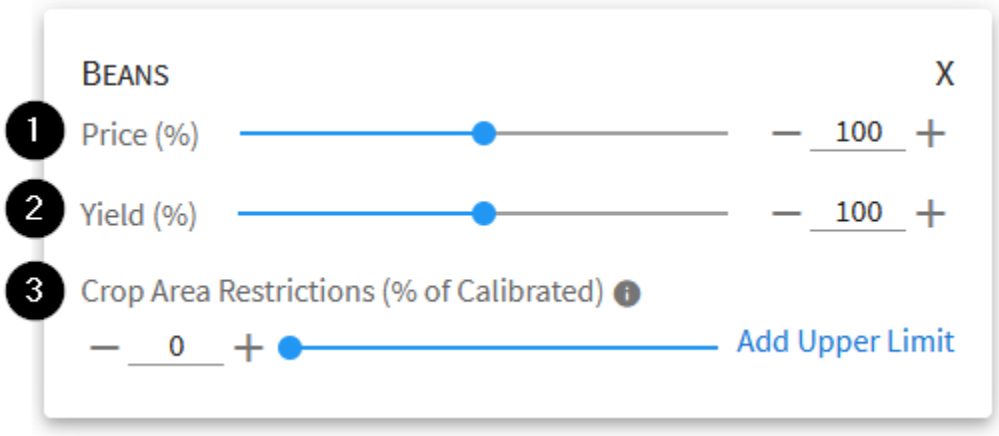


Fig. 1: A crop modification card, showing the three primary adjustments to crop data in OpenAg

Crop Cards support three parameters:

1. **Price:** OpenAg stores calibrated prices for each crop and region in dollars per ton ($/ton). You can use the controls on crop modification cards to increase or decrease the price of any or all crops by up to 20 percent relative to their calibrated values. For example, if we have crop A that sells for $1000/ton and crop B that sells for $5000/ton and you use the All Crops card to adjust prices up 20%, then crop A's price will be set to $1200 and crop B's price will be set to $6000.
2. **Yield:** Yield values, representing tons per acre of a crop, behave similarly to price values - you may adjust them up or down by as much as 20% relative to each individual crop's calibrated value for the model area. The yield slider does not apply to the *nonirrigated lands model* because yield is an output of that model rather than an input.
3. **Crop Area Restrictions:** Crop area restrictions (or constraints) behave differently than the previous two items. Where the previous two are numerical inputs to the optimization model, crop area restrictions are hard constraints that *must* be satisfied for the model to successfully run. Crop area restrictions allow you to place limits on how much of any crop it takes out of production to exchange for another crop in any region. Additionally, you may place an upper limit on the potential growth of a crop or even force a reduction by setting an upper limit that is below 100%. Crop area restrictions are useful in scenarios where a low value crop and a high value crop are grown in the same region and the model run reduces resource availability. In most cases, the model will be willing to take significant amounts of the low value crop out of production in order to keep the high value crop in production. If you know that limited amounts of the low value crop will go out of production, or want to test the impact of a smaller reduction in the low value crop to free up resources for the higher value crop, then setting a low-end limit on that crop's crop area restriction limits the model's ability to remove it from production.

Crop area restrictions should be used with care. Since they create a hard constraint in the model, misconfiguration of these constraints can lead to infeasible model runs. For example, setting all crops to a minimum crop area restriction of 100% while reducing resource availability such as water or land is likely to result in an infeasible model run since the model will not be able to take crops out of production to satisfy model conditions.

See also:

Diagnosing infeasible model runs

Automatic Addition of Crop Modification Cards

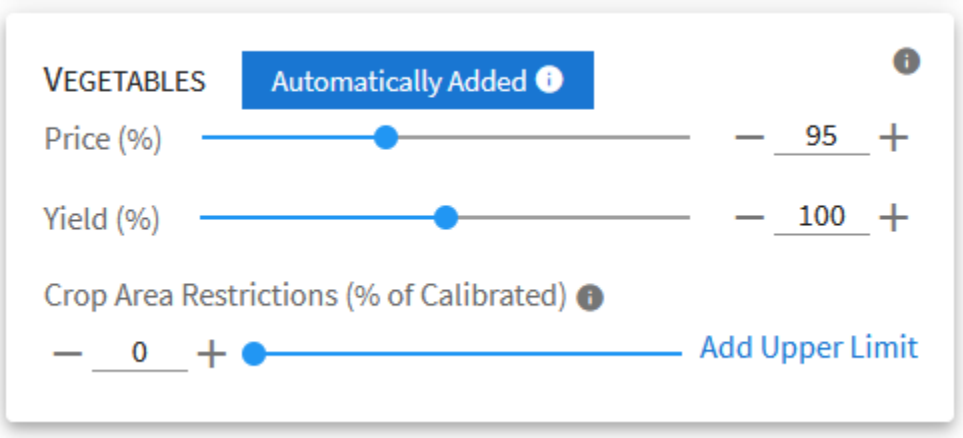


Fig. 2: Some crop cards may be automatically added, as shown here with the blue banner that says "Automatically Added"

While adjusting values for the *All Crops* card, OpenAg will sometimes automatically add cards for specific crops for you. It adds the cards because the settings on the All Crops card would make growing some crops economically infeasible - they would lose money growing the crops in at least one region in the model. You may intend for that as an input, but in some cases you may not, so in order to alert you to that condition and give you an explicit choice, the web application adds cards for crops before the settings change to push the crop into losing money. You may further adjust the crop-specific settings if you wish, however.

Once created automatically, cards will not be removed automatically, even if you change the All Crops card so that the crop-specific card is no longer needed. Instead, any time the All Crops setting would mean the crop loses money, the crop-specific card will be unremovable in the application. Where the `X` would be in the corner of the card it will show a help tooltip explaining that the card cannot be removed. If you remove the card from the crop-selection dropdown, it will be added back. If you adjust the All Crops card settings such that the card is no longer required, the card will again be removable.

Automatically added crops can be identified by their blue banner at the top that says "Automatically added" and has a help tooltip that is accessible by hovering over the icon to further explain what happened". If you make adjustments to a card that was automatically added, the banner will disappear since you have now customized its settings, allowing you to at a glance see which cards have been added without adjustment and which cards you have changed.

Region-Linked Crops

Additional Reading on Modifications

- *Overview of Modifications*
- *The Model Input Hierarchy: Prioritizing Overlapping Inputs*
- *Region Modifications*

4.5.3 The Model Input Hierarchy: Prioritizing Overlapping Inputs

OpenAg allows for inputs that can overlap each other, such as setting irrigation water availability for all regions and setting the same value for a specific region. In each case, only a single parameter will apply - no merging is done between overlapping parameters, and the model applies the most specific input parameters and discards less specific parameters.

Note: It is important to note that, while the web interface makes it appear as if one set of settings can apply across the whole model, OpenAg applies parameters individually to each crop and region combination present in a *model area*. The web interface simply provides a way to apply settings quickly across the whole model. A single value will always apply for each parameter for each region/crop combination, though they can have the same value.

Priority Orders

Highest priority items are first, and lowest priority items are last for each list

Region Modification Hierarchy

1. **No Production regions:** Regions that are set to *"No Production"* override *all* other settings that would apply to that region, including settings from crop cards. OpenAg drops the data for No Productions regions before running the model and the data for a removed region is not included in the model run.
2. **Hold to Base Case regions:** *"Hold to Base Case"* behave the same way as No Production regions. Setting a region as Hold to Base Case overrides all the other settings for the region for the model run, including crop modifications that would apply to the region. OpenAg drops the data for regions set to Hold to Base Case from the model and re-adds the base case results back for the region after modeling the non-fixed and non-removed regions.
3. **Specific region settings:** Input parameters on a specific region are the highest priority way to specific a single input, such as irrigation water availability. If the region is not fixed or removed and a value is set on a specific region modification card, then that value will apply.
4. **Region group settings (when available):** If region groups are available, then parameters provided for a region group will apply for all regions within the region group unless a card is added to the model run for a region within the group, in which case the region-specific card's settings would take precedence for that region, with the region group card applying to all remaining regions in the group.
5. **All Regions:** The All Regions card is the fallback card - it applies when a more specific setting from the items above has not been provided.

Crop Modification Hierarchy

1. **Region-linked crop value:** Specific crop cards that have been linked to a single region take the highest priority for crop parameters and will be used when present.
2. **Specific crop value:** Similar to region cards, a modification card for a single crop is used for crop parameters in each region the crop is present in, except in the case where a region-linked crop card is present for the same crop, in which case the region-linked crop card would supply the parameters for that single crop and region and the crop-specific card without a region-link would supply the parameters for the crop in all other regions it is present within.
3. **All Crops:** The All Crops card is the fallback card - it applies when a more specific setting from the items above has not been provided.

Warning: Crop adjustments never apply to regions that are set to "Removed" or "Fixed". These regions are not modeled directly and so will not include crop modifications, regardless of region-linking.

4.5.4 Translating Common Scenarios Into the Model

CHAPTER

FIVE

VIEWING MODEL INPUT DATA

- note somewhere that input data is not the same as the calibrated data that we use for model runs

CHAPTER

SIX

FINDING MODEL RUNS YOU'VE CREATED

CHAPTER

SEVEN

TROUBLESHOOTING

7.1 Diagnosing infeasible model runs

CHAPTER

EIGHT

CHANGELOG

Keep up to date on changes in the application here so you know what new features are available, where buttons have been moved, and if major changes or bugfixes are made to the model or applications.

Changelogs are structured by month, so you can click into any month to see details.

8.1 Visual Changelog - May 2021

8.1.1 Display the Difference Between Model Runs as a Percent

8.1.2 Settings Work Now + A New Setting To Increase Table Density

8.1.3 Better Communication of Disabled Region Adjustments

8.1.4 Removal of Regions with Disabled Sliders from Map

Fig. 1: Now, when normalizing to another model run, you can choose to display the differences as a percentage rather than as the raw values.

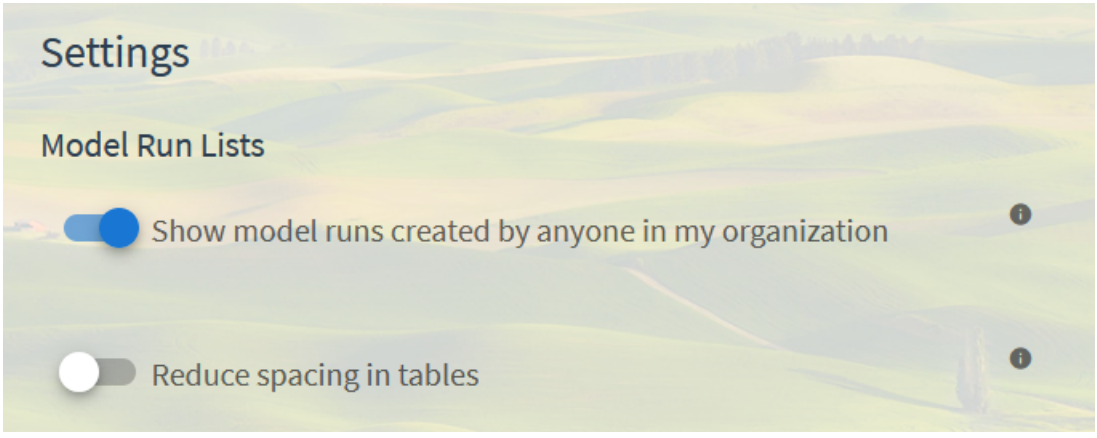


Fig. 2: We've had a settings section for a while, but it had a bug where you couldn't actually change anything. That's been fixed and you can now make use of the previously existing setting to change whether the list of model runs shows all model runs in your organization by default, or just yours. Additionally, we added a new setting that allows for denser table displays by removing some of the padding in each table cell.

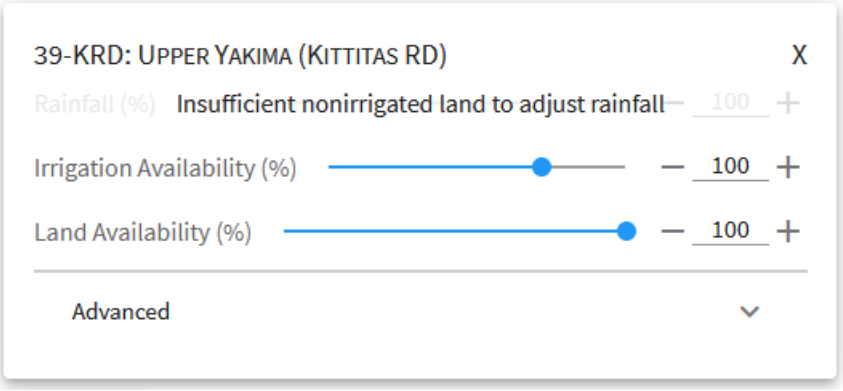


Fig. 3: Previously, when a model area supported an adjustment, such as rainfall or irrigation, but the region didn't support it, the slider would disappear from that region's card, creating confusion. Now the card disables the slider and displays text overlaying the slider explaining why the slider is disabled.

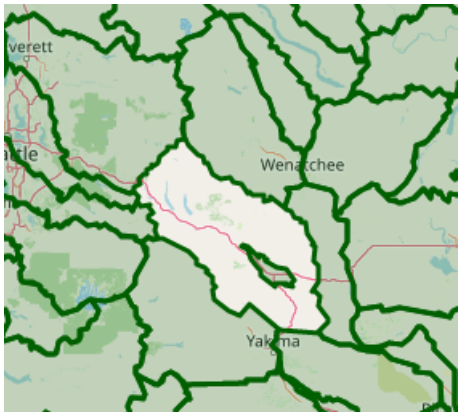


Fig. 4: When we disable a slider (such as for rainfall in the above example), the region will also be removed from the map on the page when viewing the cumulative input modifications. It does not currently remove a region that doesn't support rainfall or irrigation until it has a card created for modifications. That is, if a region doesn't support rainfall, it'll still show on the map with the all crops changes until a card is added for the region.

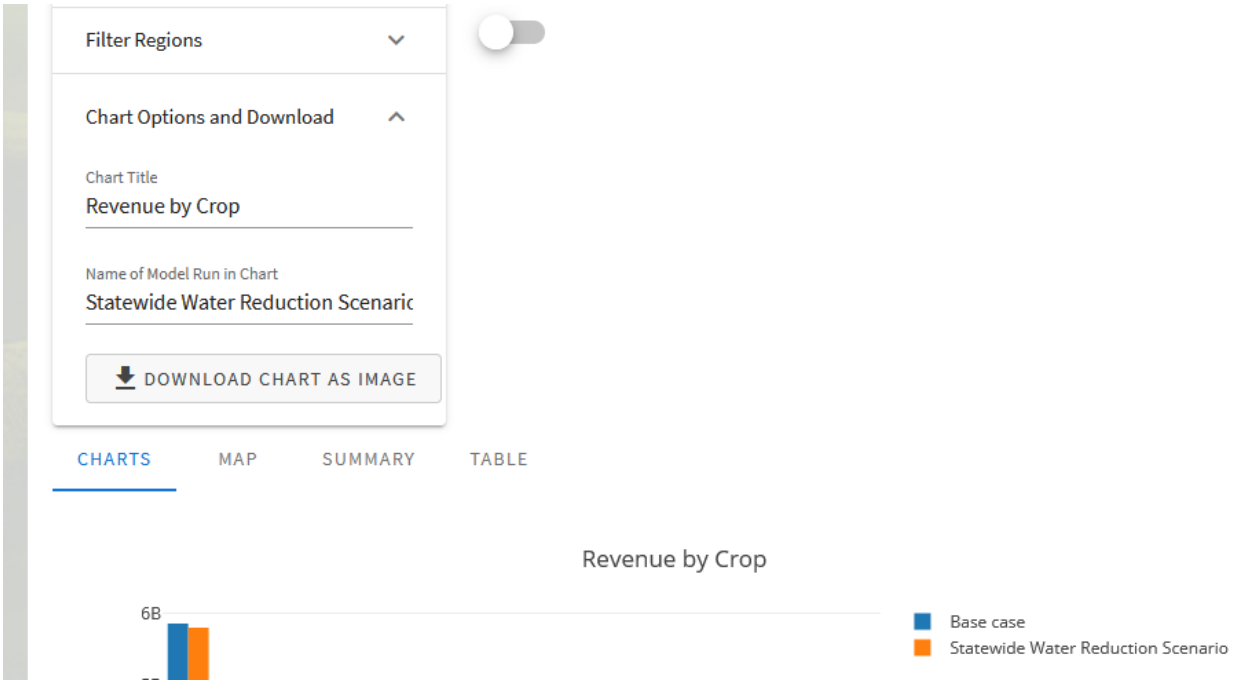
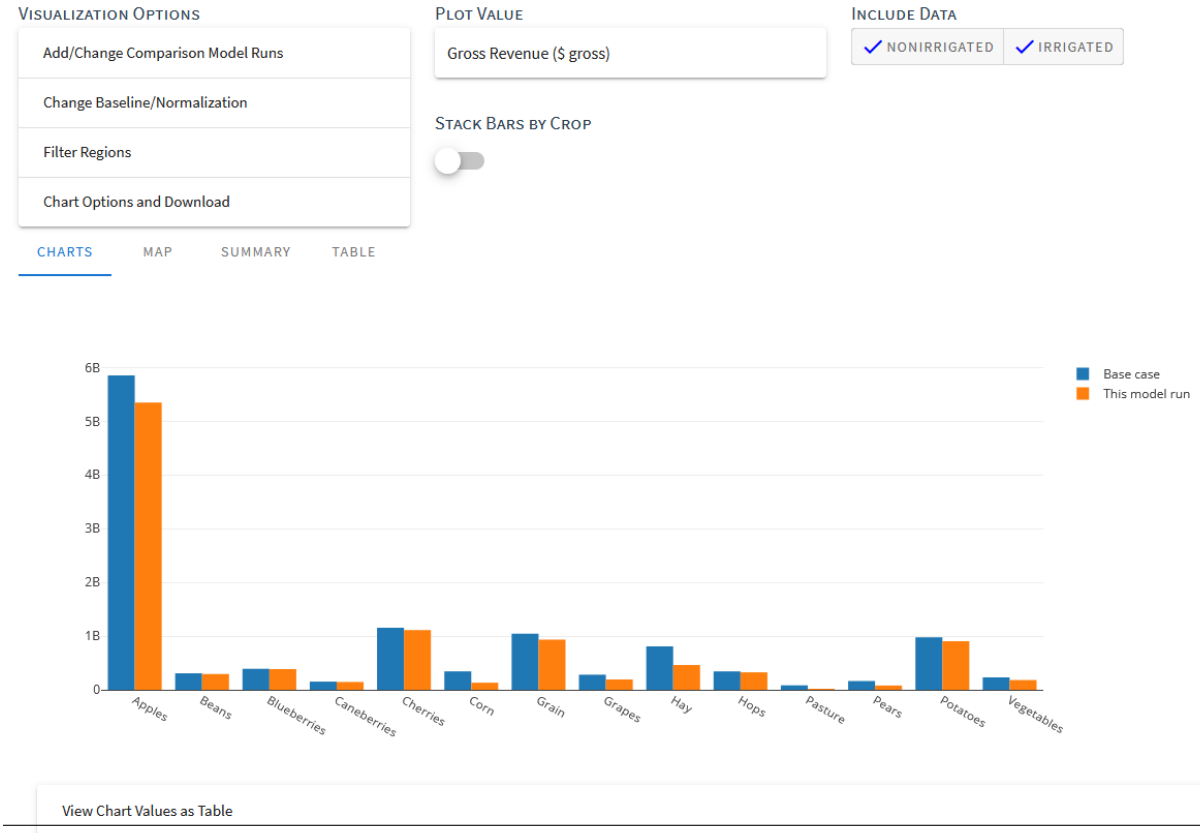


Fig. 5: OpenAg includes a new section to define basic information for the chart, to allow for more useful exports of charts to use in reports. Options include a chart title and renaming the legend entry for the model run in the chart (default is "This model run"). The download button for the chart has been moved into this section to allow for setting chart options and exporting in one spot.

8.1.5 New Chart Options: Set Title and Model Run Name



Todo: Add link to full PDF build of this guide

CHAPTER

NINE

INDICES AND TABLES