

# THE SUSTAINABLE WATER MANAGEMENT TEAM

OF THE AREQUIPA NEXUS INSTITUTE

Presents:

## OpAgri

User's Manual



**UNSA**  
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Discovery Park

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## INTRODUCCION TO TOOL

In areas like the Colca Valley, access to water is very limited, which can make crop production difficult. In addition, knowing which crop to plant to minimize water use or to have the highest profit can be a challenge. Optimizador Agrícola (Agricultural Optimizer), or OpAgri, is a tool for farmers to help them select a diversity of crops to plant that can optimize water use and profitability. It also shows options for planting a diversity of crops to increase harvest security in case something happens to a certain crop. It can be used to:

- Compare the water needs of up to four different crops;
- Evaluate if there is sufficient access to irrigation water for an entire season; and
- Calculate the expected profit for different areas of planting.

## TOOL DEVELOPMENT

This tool was created using the crop water use simulations generated by CROPWAT 8.0 (FAO 2019) and the calculation of five different planting scenarios based on additional user inputs. Simulations in CROPWAT required data on soil, weather, typical crop water use (kc), and crop planting dates. Three soil types were used based on the methods detailed in the data publication from Daneshvar et al. (2020), and available soil water was calculated based on these profiles (Table 1). Precipitation and temperature data were pulled from the climate maps from Moraes et al. (2020) based on weather station locations (Table 2). Windspeed was collected from the Global Data for SWAT database (CFSR 2019). Solar radiation and reference crop evapotranspiration (ET) were calculated based on other data. Typical crop water use (kc) values were based on local empirical data when available and default values in the CROPWAT manual when local data were not available (Table 3). Estimated dates from crop planting and harvest came from local experts in the Colca Valley. For more information on this method, see Watkins et al. (in prep).

In addition to these data, the tool provided default values for analysis, including expected market price in S/. per kg, planting cost in S/. per ha, and expected crop yield in kg per ha. Market prices were averaged from historical information available from MINAGRI's Supply and Price Information System (SISAP; MINAGRI 2010). Default values for expected planting costs and crop yields were estimated by local experts (Table 4). In addition to user inputs, the tool pulled water use values from a master use table created based on CROPWAT simulations by crop type, location, and soil type.

*Table 1: Soil profiles and plant available water in the Colca Valley*

Soil profile index	Soil Taxonomy	Primary Soil Texture	Plant available water (mm/meter)
CAL 11	Lithic Haplustand	Silt loam on clay loam	180
CAL 14	Typic Ustorthents	Sandy loam	110
CAL 19	Typic Haplustands	Silt loam on clay	160
CAL 23	Typic Haplustands	Sandy loam	110

*Table 2. Weather stations in the Colca Valley*

Weather Station	Elevation (m)	Latitude (°)	Longitude (°)
Chivay	3644	15°38'29.86"	71°36'6.08"
Madrigal	3276	15°36'35.96" S	71°48'23.56" W
Cabanaconde	3333	15°37'21.34" S	71°58'26.71" W

Table 3: Crop information used for water use simulations

Crop	Kc value			Planting month(s)	Harvested month(s)
	Initial	Mid	Late		
				-	-
Alfalfa	0.4	0.95	0.9	Perennial	12
Barley	0.3	1.15	0.25	January	4
Broad beans	0.4	1.15	0.35	June	5
Corn	0.35	1.5	1.4	September	8.5
Peas	0.4	1.15	0.35	June	5
Potato	0.3	1.35	1.2	October	4
Quinoa	0.52	1	0.7	January	5

Table 4: Tool Default values

Crop	Market price (\$/. per kg)	Planting cost (\$/. per ha)	Estimated yield (kg/ha)
Alfalfa	4.5	3982	5000
Barley	0.8	1200	230000
Broad beans	2	1233	6000
Corn	6	2936	3000
Peas	2	1500	3000
Potato	1	2784	8000
Quinoa	3.5	2176	4000

## USING THE TOOL

OpAgri can be used both on a computer through the Nexus SWM website, or as an app on the Google Play Store. You can access the online version of the tool through our website at [purdue.ag/nexus\\_tools](http://purdue.ag/nexus_tools).

The following steps show how you will see and use OpAgri through your mobile device.

1. OpAgri will allow you to tap to use your preferred language.

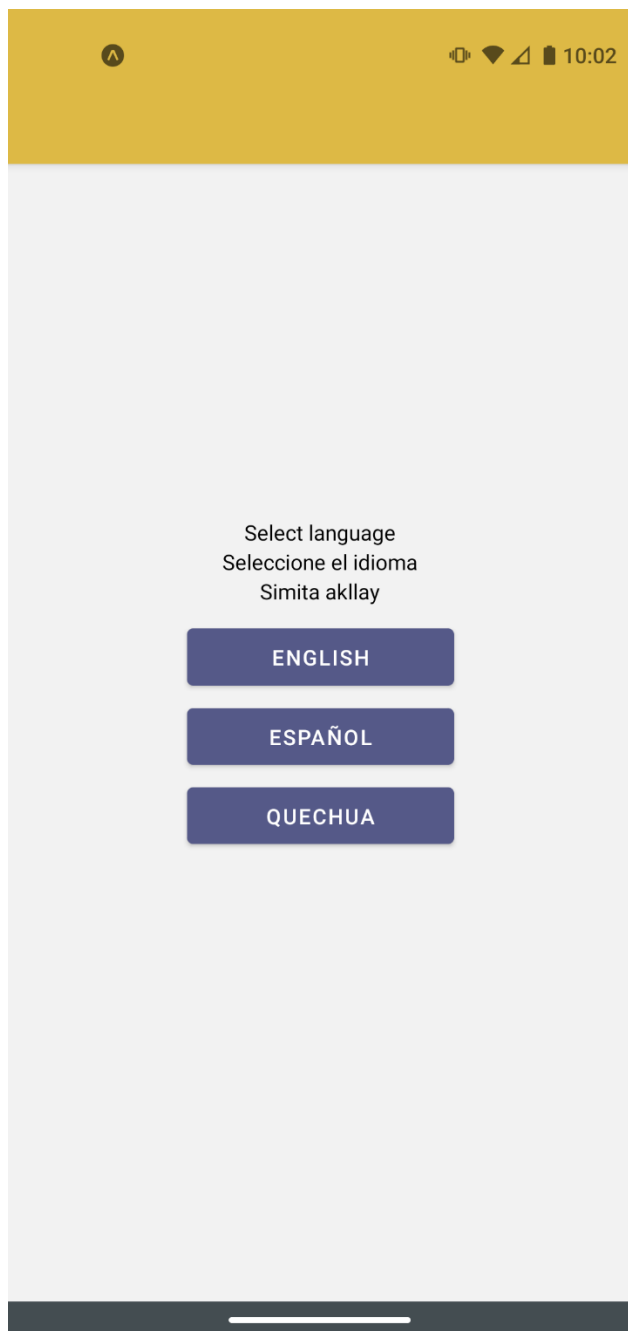


Figure 1. The language selection screen

2. You will then see this Welcome screen. Click continue.

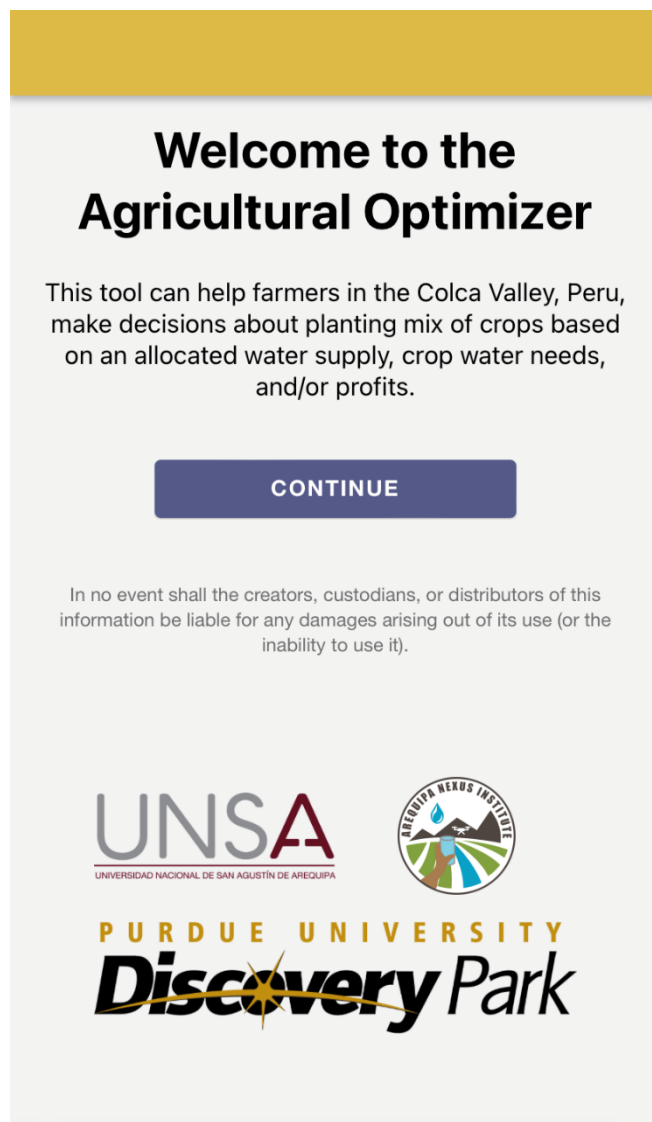


Figure 2. The app welcome screen

3. The app will ask you if it can use your location. You can click yes or no based on your preference. If you click 'Allow' and are in your field, the app will pick up the location of your field to access soil data.

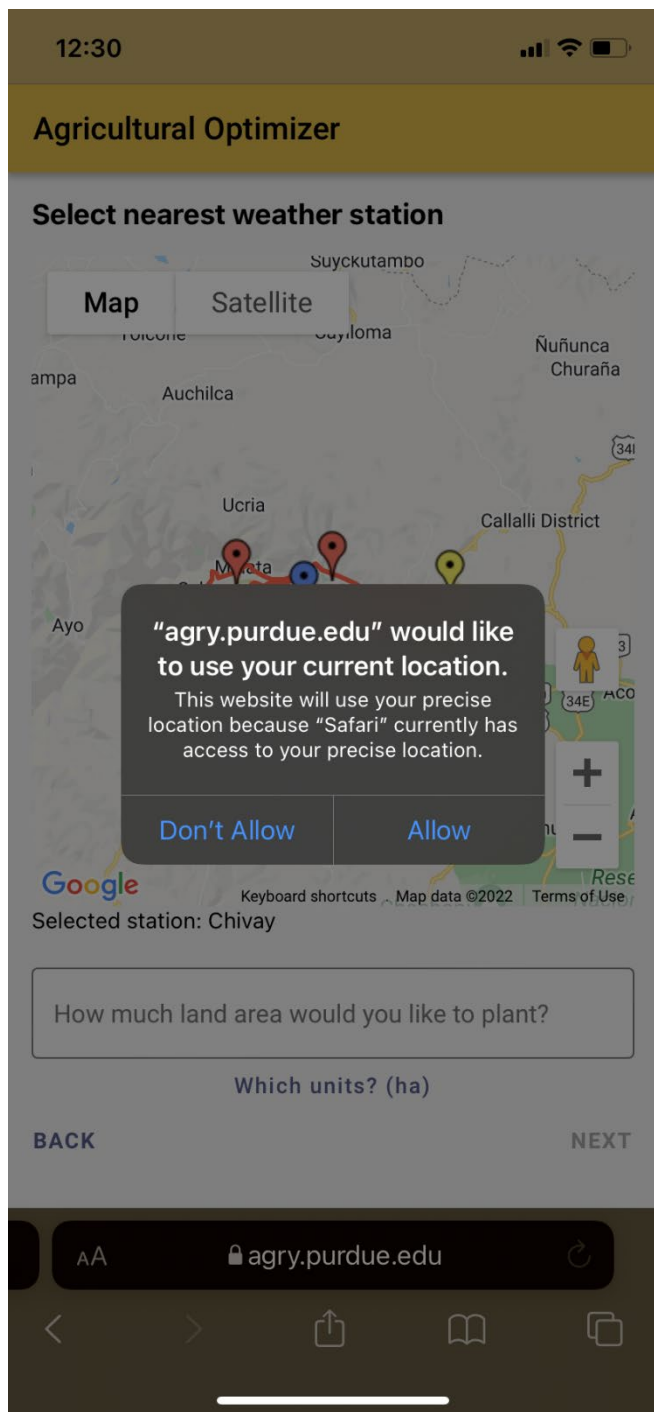


Figure 3. The location access screen allows the app to select the nearest weather station.

4. You can also click and drag the blue marker to indicate the exact location of your field. You can also just select one of the three weather stations to use if it is somewhat close to your field. Then you input the total land area you would like to plant and indicate the units. Then press "Next".

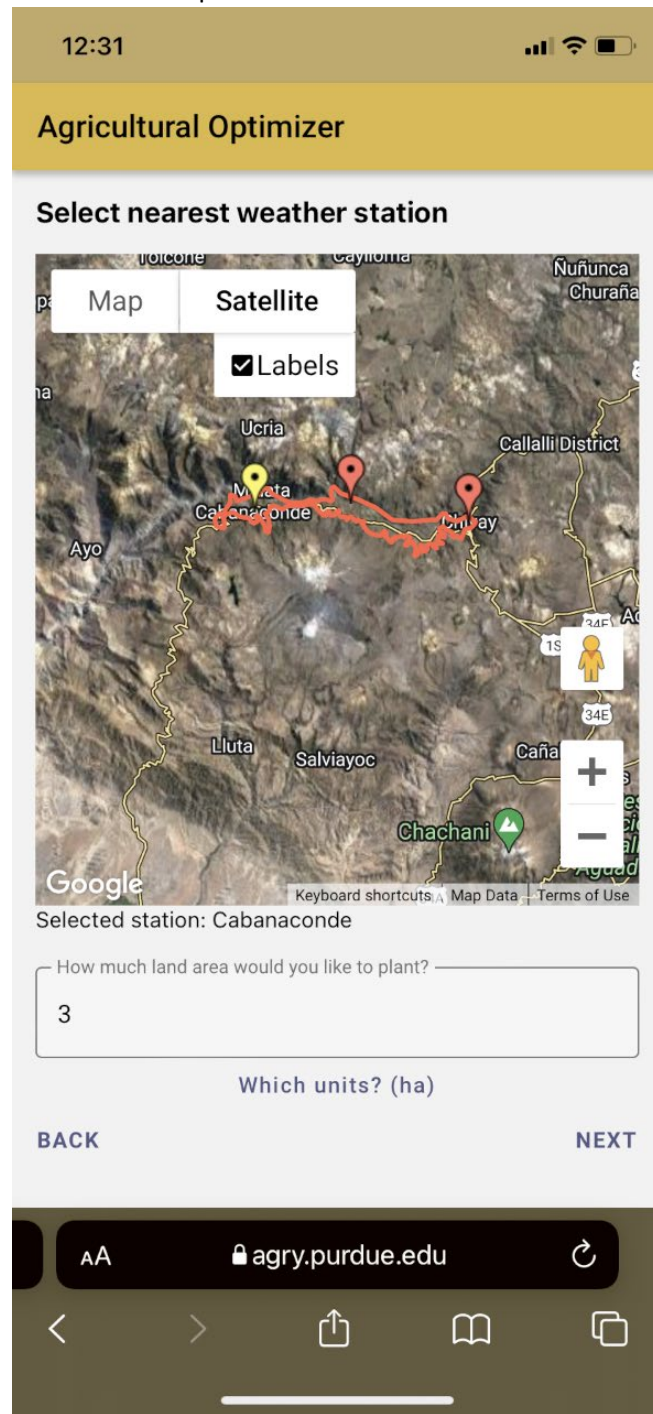


Figure 4. You can choose a weather station or other location that is not the closest to your current location by clicking on a different station. You can select area units at the bottom of the screen.

5. After selecting your area, you must input how much water you have available to you. The app asks how many times per month you have access to water (1,2,3, etc.), the number of hours you have water access each time, and the average flow rate available to you while irrigating. In the example below, water is available 2 a month for 8 hours. And the average flow rate of this irrigation water is 6 liters per second.

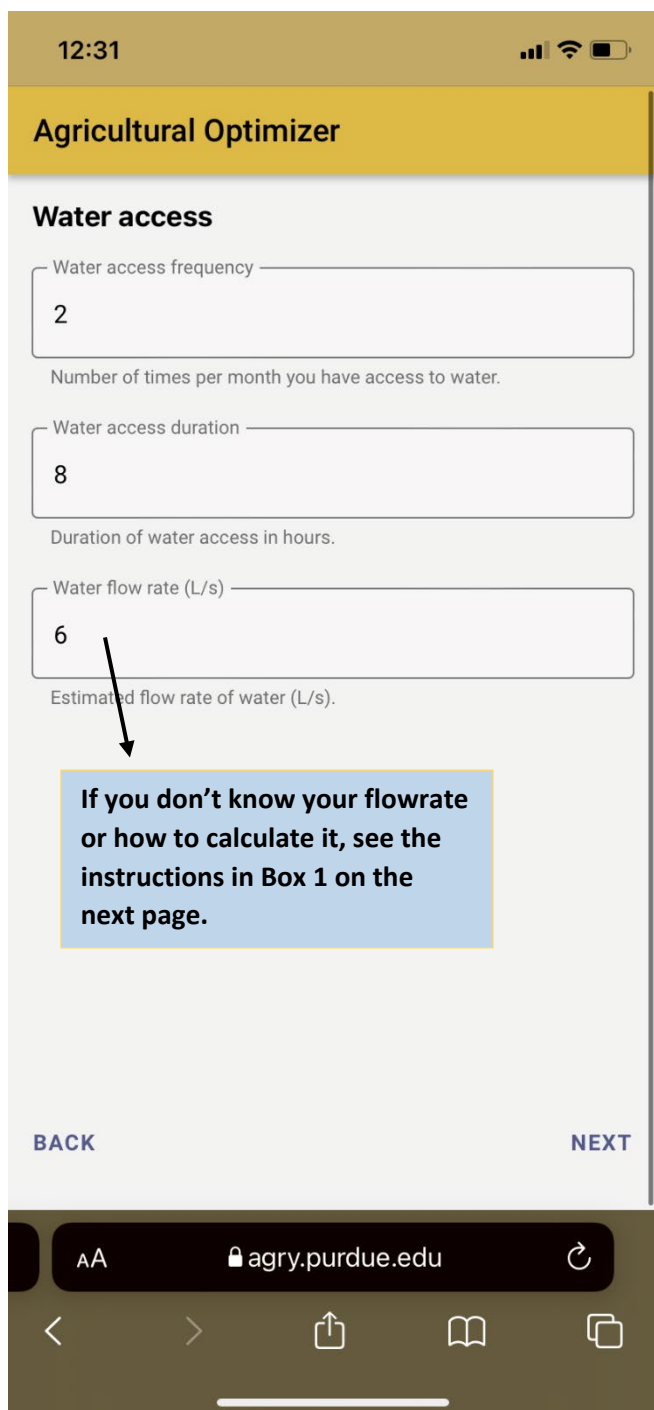


Figure 5. Input information that describes irrigation water availability for your situation.

6. You can then select crops you would like to plant. You can select up to four different crops. To see different options, it would be useful to select at least 2 or 3 crops. Select them by clicking the slider. Selected crops will turn purple and move circles to the right.

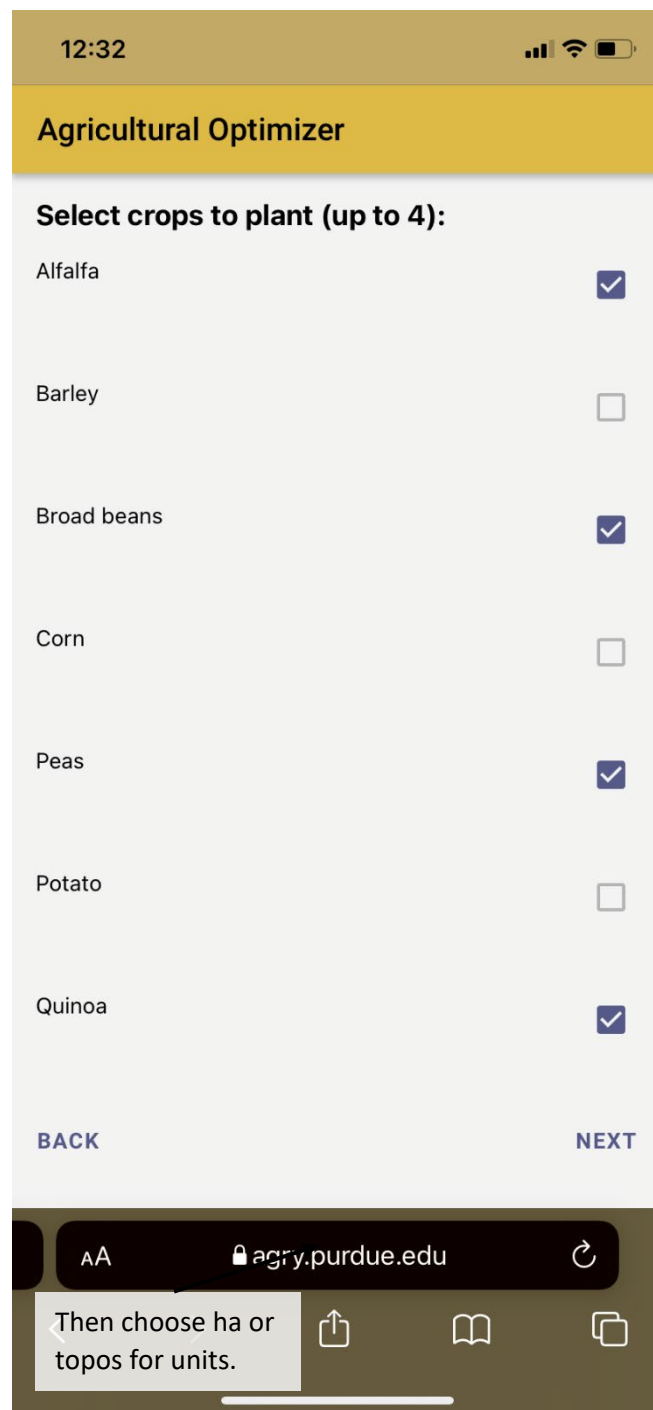


Figure 6. Choose crops by clicking on them.

**Box 1. How do I measure flowrate for my irrigation water?**

1. In your irrigation canal, measure a length (distance) like 5 meters.

2. Measure the depth and width of this canal in meters. Multiply these together to get area.

a. Depth = 0.5 m x

b. Width = 0.5 m

c. Area = 0.25 m<sup>2</sup>

3. Starting at the upstream end of the known distance, drop an orange or another floating object and time how long it takes to reach the downstream end in seconds. For example, this could be 50 seconds.

a. Time = 50 seconds

4. The flow in liters per second is the area times the length times 1000 L/m<sup>3</sup> divided by the time:

a. Flow =  $1000 \text{ L/m}^3 \times \text{Length} \times \text{Area} / \text{recorded time}$

b. Flow =  $1000 \text{ L/m}^3 \times 5 \text{ m} \times 0.25 \text{ m}^2 / 50 \text{ s} = 25 \text{ L/s}$  is your flow

7. The app then prompts you to input expected market price. The default values are average market price over time, but market prices fluctuate quite a bit. It would be better if you could put a market price expected at the time of harvest.

The screenshot shows a mobile application interface titled "Agricultural Optimizer". At the top, the status bar displays the time 12:32 and signal strength. Below the title bar, the section "Market price (S/. Per kg)" is displayed. A prompt asks the user to "Please review and modify the default numbers based on the best of your knowledge." There are four input fields with the following values: Quinoa (S/. Per kg) = 2, Peas (S/. Per kg) = 3.5, Alfalfa (S/. Per kg) = 0.8, and Broad beans (S/. Per kg) = 4.5. At the bottom of the app screen, there are "BACK" and "NEXT" buttons. Below the app screen, the mobile browser's address bar shows "agry.purdue.edu" and standard navigation icons.

Figure 7. The market price reflects the cost per kg of grain or product harvested that you hope to receive



8. The app then asks you what your average costs are to plant and maintain each crop. The default values are average Default values are based on local estimates, but you can change these values if you have a more accurate estimate.

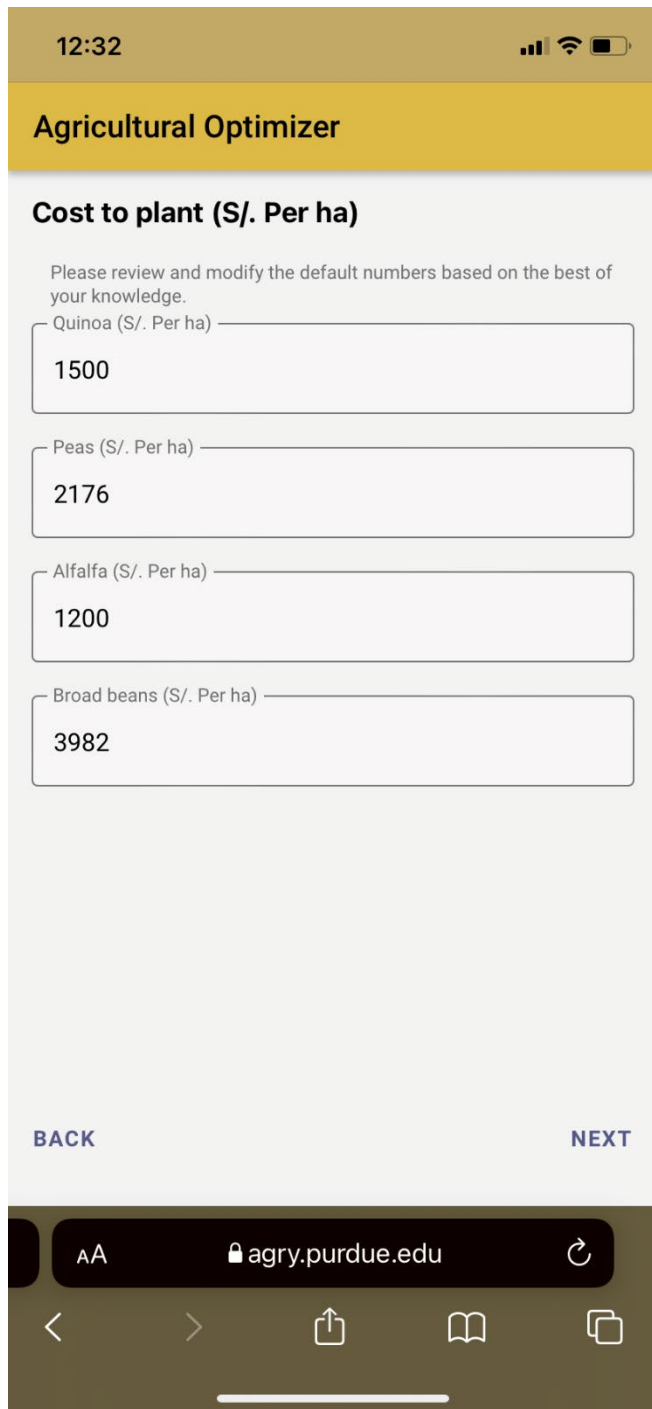


Figure 8. The planting costs reflect the costs of all inputs to your field, including seeds, manual labor, irrigation, fertilizer, pesticide, and herbicide.

9. The next page asks for your expected yield in your field for each selected crop. Values are already included as default values based on local estimates. You can change the expected yield to be more accurate to your field, then click Next.

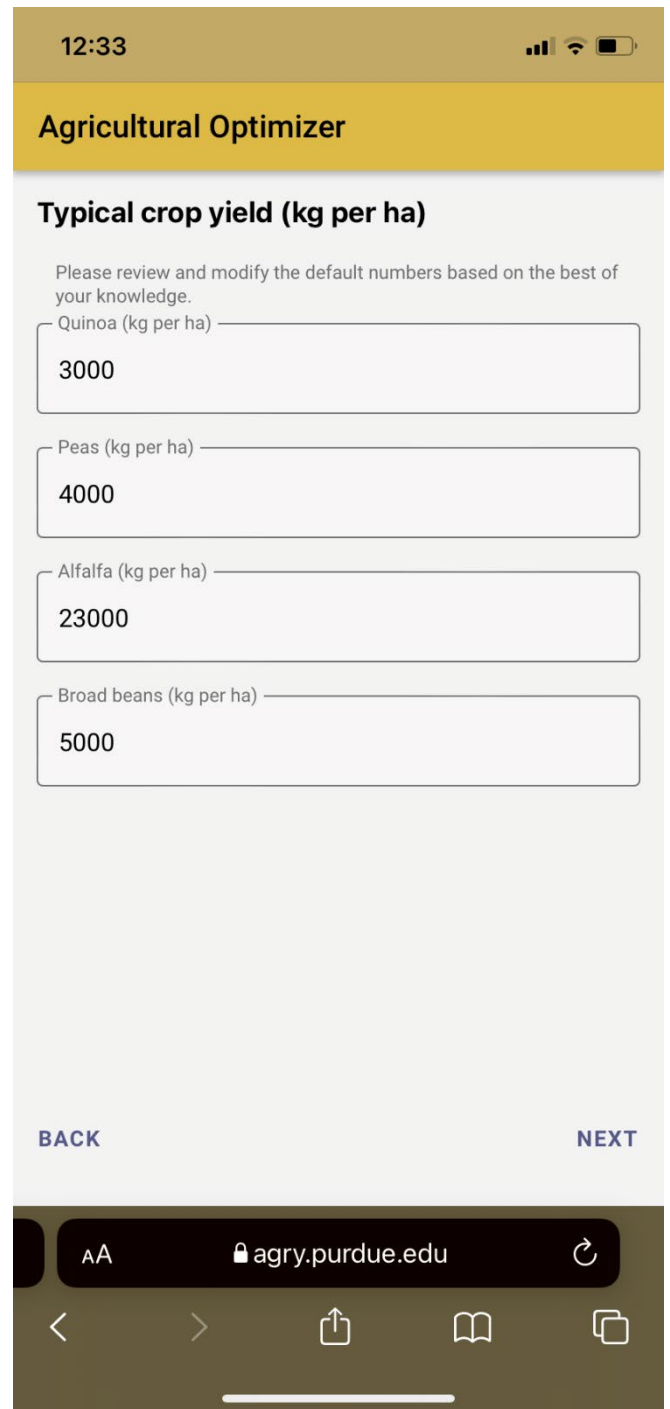


Figure 9. Insert the yield that you expect for each crop.

10. This page explains the five different scenarios that will be used to give you planting options. You can click or tap on each scenario to learn more about it.

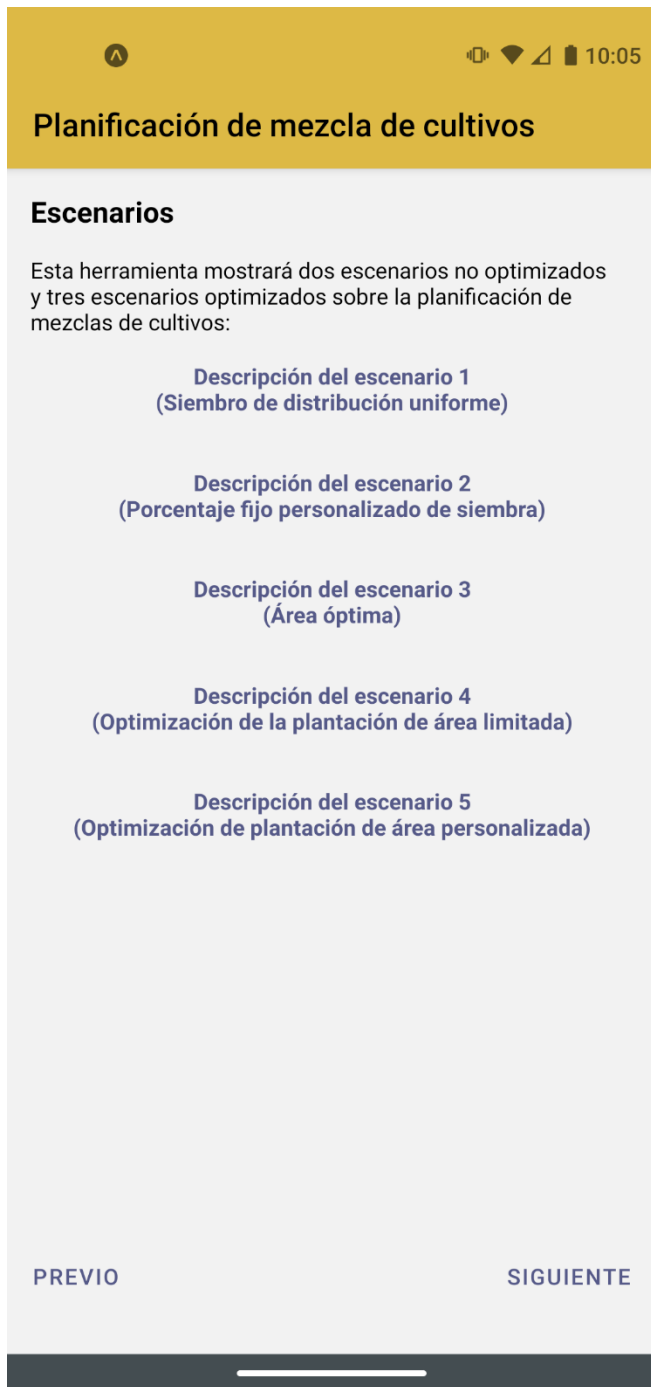


Figure 10. Click on the blue text to see a description of the different scenarios

11. When you click on a Scenario, a box will pop up with a description of what that scenario is.

For more details about how each different scenario is calculated, see Box 2.

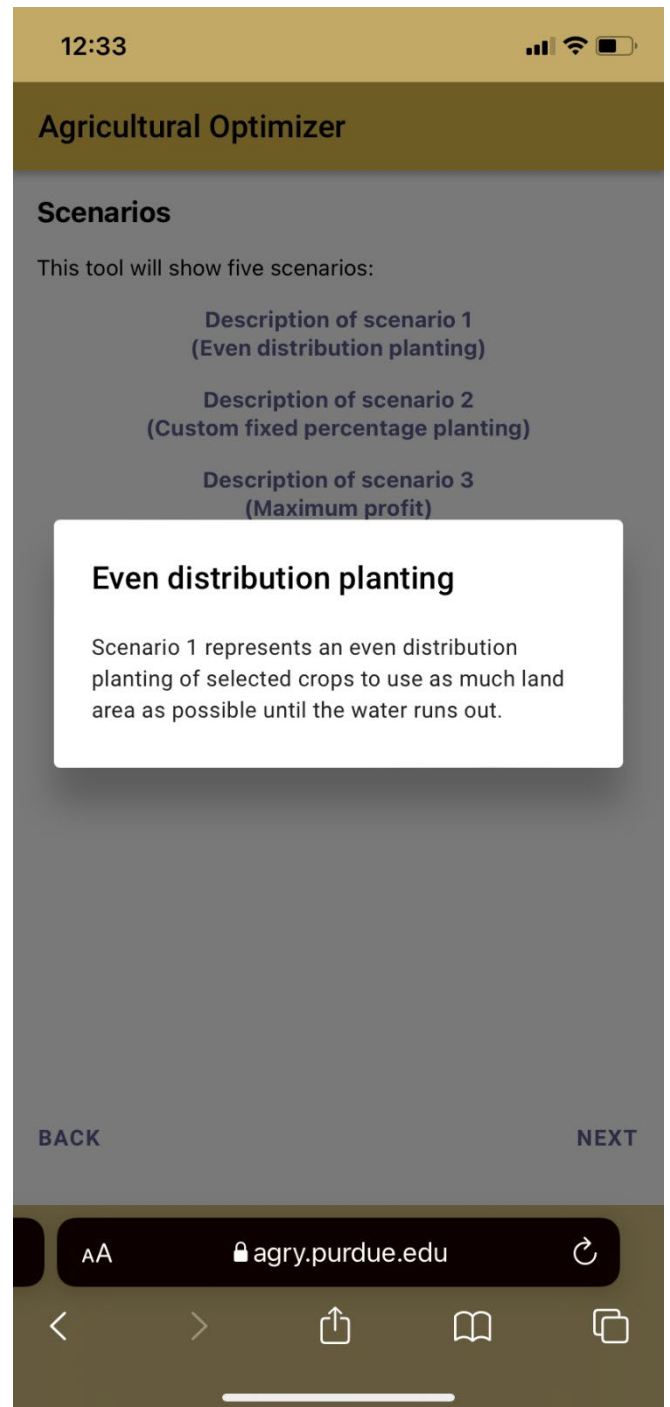


Figure 11. An example of text visible when you click Scenario 1

## Box 2: Optimization scenarios

This box provides details on how the crop area, total water use, and profit is calculated for each scenario. The following five variables are defined:

$A_i$  = the planting area for crop  $i$  in hectares; FieldArea is the total available area to plant

$n$  = the total number of crops that are being considered

$W_i$  = the depth of water needed each month for crop  $i$  in mm/month from CropWat simulations

$A_i \times W_i / 10000$  is the total volume of water needed for crop  $i$  per month (Liters/month)

Vol.Irrig = the volumen of water available for irrigation each month (Liters/month) = frequency of irrigation x hours of irrigation x flowrate x 3600 seconds/hour

Market $_i$  = the market price of crop  $i$  in soles per kg

Plant $_i$  = the cost of planting crop  $i$  in soles per hectare

Yield $_i$  = the yield of crop  $i$  in kg per hectare

The profit expected for crop  $i$ ,  $P_i = (\text{Market}_i \times \text{Yield}_i - \text{Plant}_i) \times A_i$

### Scenario 1: Uniform planting distribution

This scenario always gives the same planting area to each crop ( $A_1=A_2=\dots=A_n$ ), without considering the water use or the benefit. For example, if you have 4 hectares and 4 crops, each crop Will be planted on 1 hectare. However, if there is not sufficient water available to irrigate the entire area, the total planting area decreases by the same amount for each crop. That is:

$$A_i = \min \left( \frac{\text{FieldArea}}{n}, \frac{10,000 \cdot \text{Vol.Irrig}}{\sum_{i=1}^n W_i} \right)$$

### Scenario 2: Fixed personalized planting percentages

In this scenario, the user decides what percentage of land to dedicate to each crop. The total among the selected crops should always add up to 100%. That is:

$$A_1, A_2, \dots, A_n = \text{user\_input}$$

$$\sum_{i=1}^n \frac{100\% A_i}{\text{Field.Area}} = 100\%$$

### Scenario 3: Maximum benefit

This allows the user to obtain the maximum benefit in function of their crop options, land availability, and access to water. For this scenario, the algorithm is simplified to maximize total profit:

$$P = \sum_{i=1}^n P_i = \sum_{i=1}^n (\text{Market}_i \times \text{Yield}_i - \text{Plant}_i) A_i$$

Subject to the following restrictions:

$$\sum_{i=1}^n A_i < \text{FieldArea}$$

$$\sum_{i=1}^n \frac{A_i W_i}{10000} < \text{Vol.Irrig}$$

### Scenario 4: Restricted uiform planting

This uses the maximum benefit and water use to calculate the planting area, but it does not allow any one crop to be planted on more than 100%/n of your field. This is essentially a variation of scenario 1, but it allows the planting area to be different for each crop. In scenario 1, if water is limiting, the area of all crops is reduced by the same amount. In this scenario, if water is limiting, the area of the least profitable crops is reduced more. So, if  $P_i / A_i$  represents the profits ordered by unit area from the least to most, the area of the least profitable crop (1),  $A_1$  is reduced until:

$$\sum_{i=1}^n \frac{A_i W_i}{10000} < \text{Vol.Irrig}$$

If the water is still limiting when  $A_1 = 0$ ,  $A_2$  is reduced, etc.

### Scenario 5: Personalized area planting optimization

This option allows you to put a limit on the area that is available to plant for a given crop. For example, if you are considering 4 crops and, to minimize the risk of harvest loss, you do not want to plant any of your crops on more tan 40% of your land. So, each crop can be planted up to 40%, but no more of your land. This is an optimization scenario similar to scenario 3, but with the additional restriction that:

$$\frac{100\% A_i}{\text{FieldArea}} \leq \text{user\_input} \text{ for each } A_i$$

The user inputs can add up to more than 100% to allow for more planting flexibility.

12. For scenario 2, Custom fixed percentage planting, you can select how you want to break up your land by crop. You will input what percentage of your land you would like to dedicate to each crop. All values must add up to 100%. In this example, your land will be divided up as 20% alfalfa, 30% broad beans, 35% barley, and 15% quinoa.

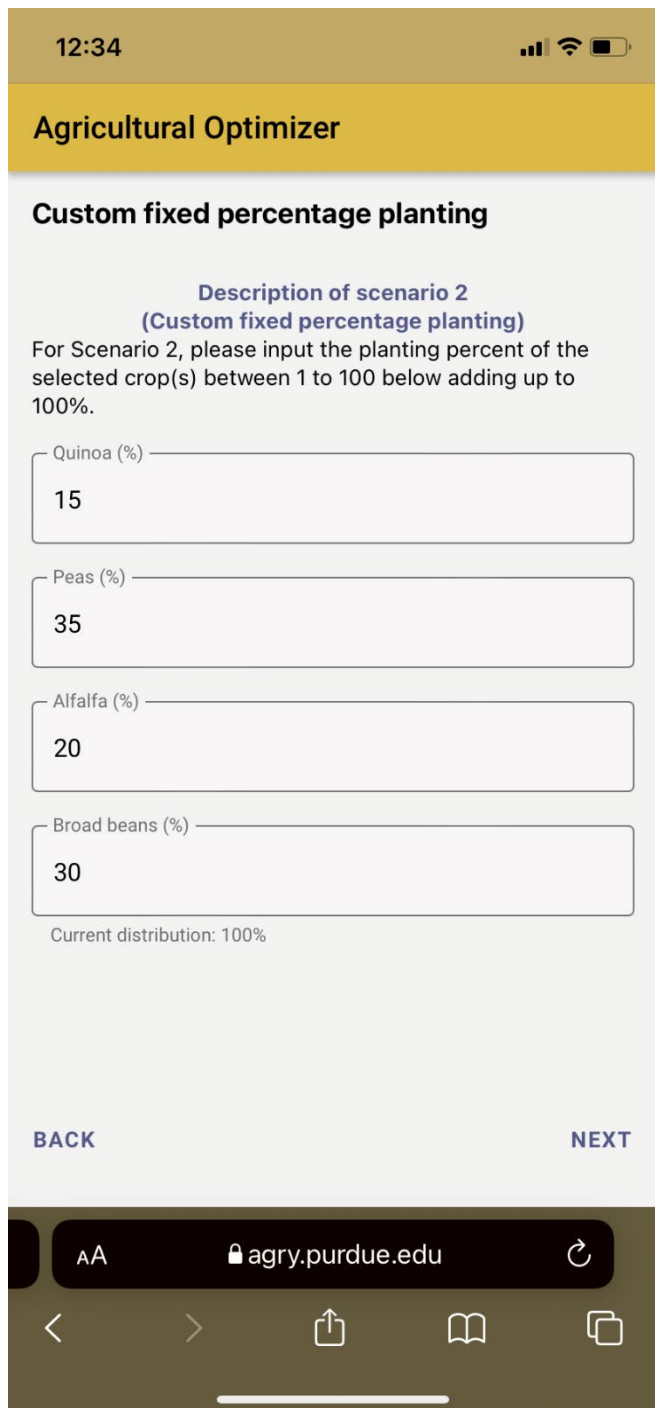


Figure 12. Insert the percentage of your land that should be dedicated to each crop

13. For Scenario 5, Personalized planting area, you can limit the maximum area that will be dedicated to any given crop. For example, if you have 2 ha and don't want to plant more than half of it with quinoa, you can put 50%. This will let the app provide information for planting *less than* or up to 1 ha with quinoa, but no more.

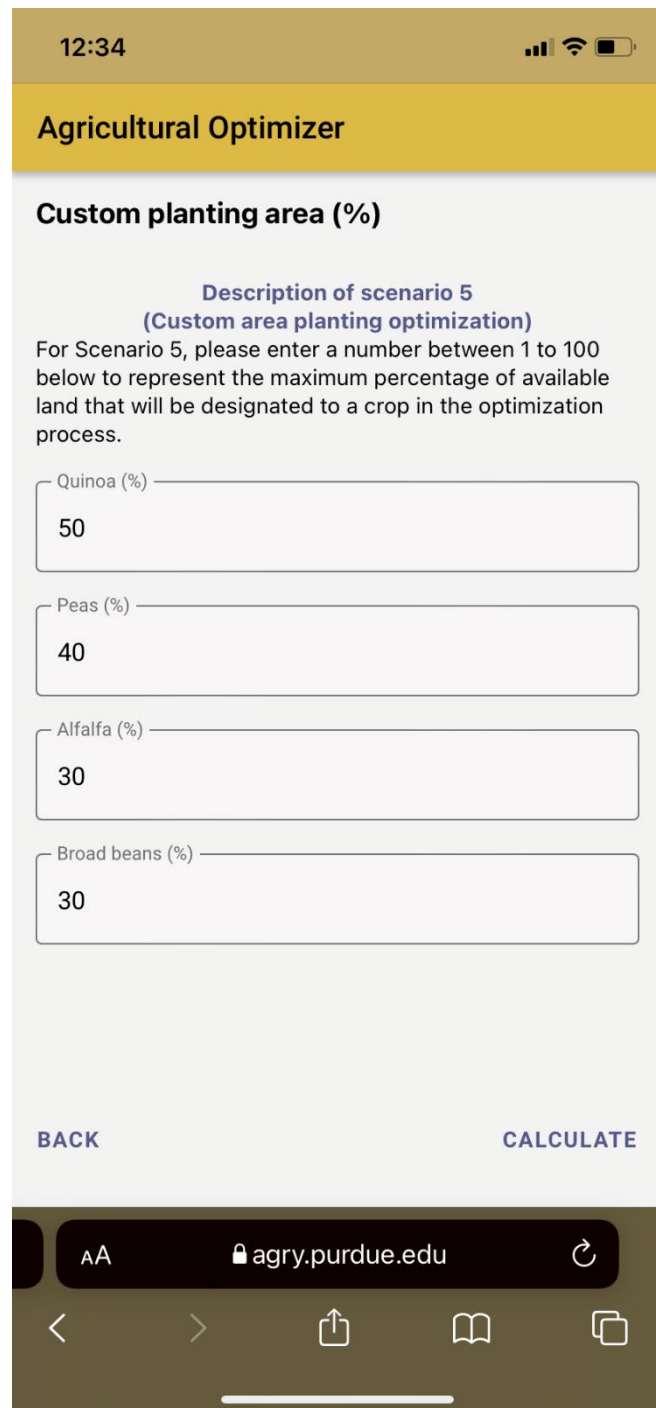


Figure 13. Insert the **maximum** percentage of your land that should be dedicated to each crop

14. After providing all the necessary inputs, you will receive outputs for the five different scenarios for the crops you selected. The first graph shows the land area calculated to plant for each crop. For example, in Scenario 1, you would plant 0.75 ha of each of the four crops. In Scenario 5, you would plant 0.9 ha of alfalfa, 0.9 ha of broad beans, 1.2 ha of barley, and no quinoa.

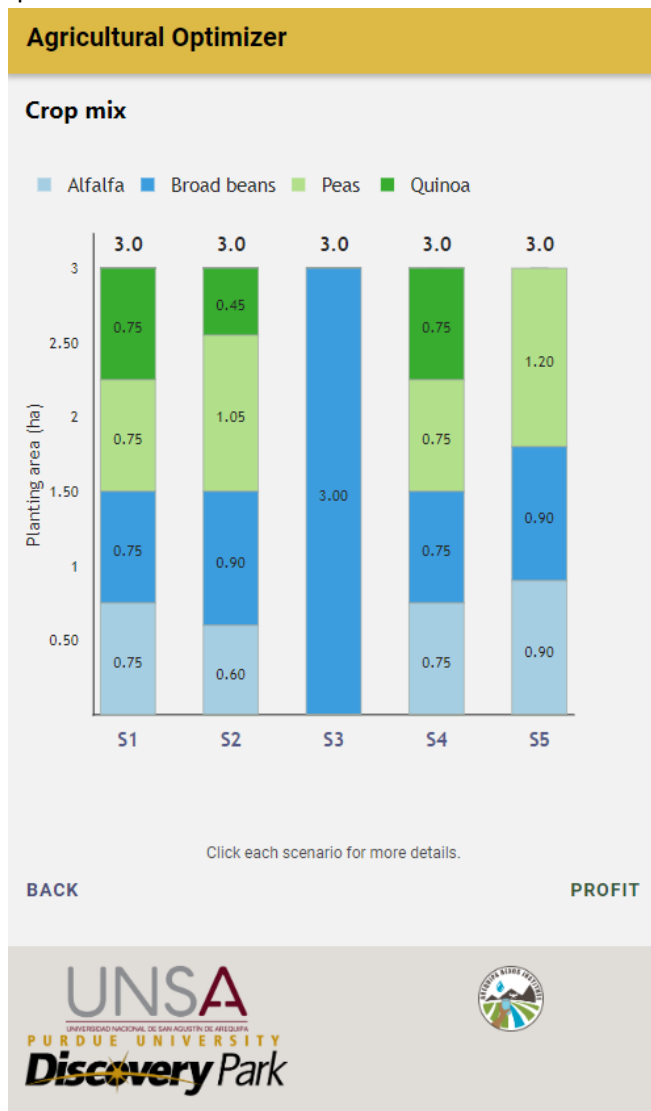


Figure 14. The first results screen shows the land area dedicated to each crop. You can see the legend on the top of the screen to learn what color indicates each crop.

15. The next graph shows profit for each scenario. In this example, Scenario 3 shows that planting just broad beans on all 3 ha would produce the highest profit based on your inputs. Scenario 5 has the second highest profit, and it also has a higher diversity of crops, and thus, less dependence on a single crop.

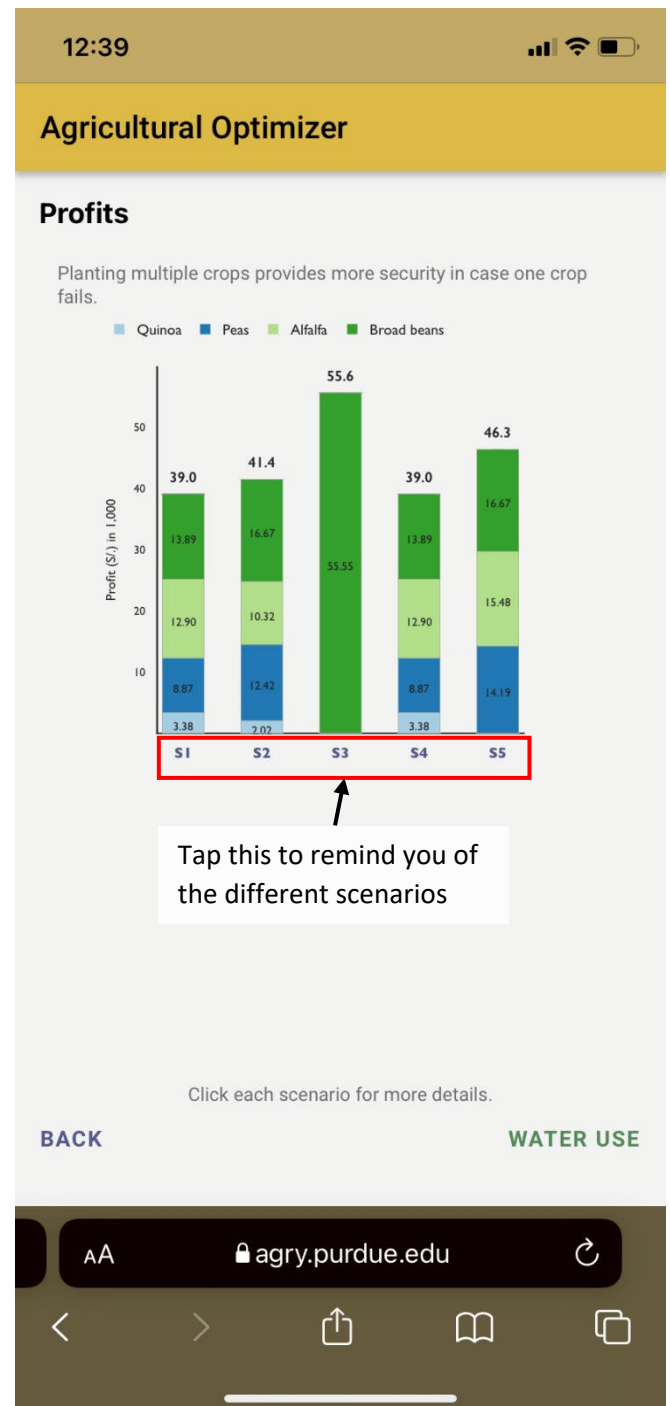


Figure 15. The second results screen shows the profits associated with each of the planting distributions from Screen 1 of the results

16. This graph shows you how much water would be needed for each scenario. In this graph, scenarios 1 and 3 (which are the same) use the least amount of water. You can also see how much water different crops need. Generally, quinoa needs the least water and alfalfa needs the most.

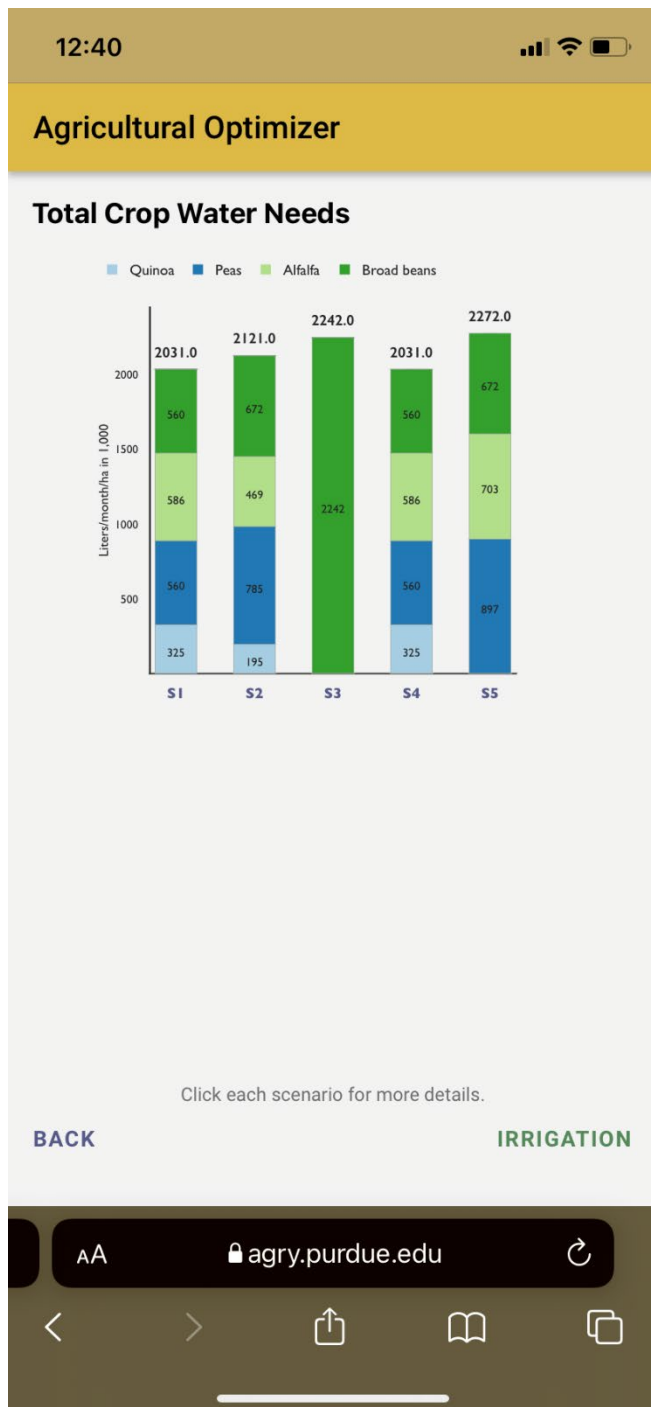


Figure 16. The third results screen shows the total water need for each planting scenario

17. The last graph shows you irrigation time needed for each crop in different scenarios. *Note:* This assumes that irrigation efficiency is 100%, and there is no water loss. In actuality, irrigation time needed will likely be higher.

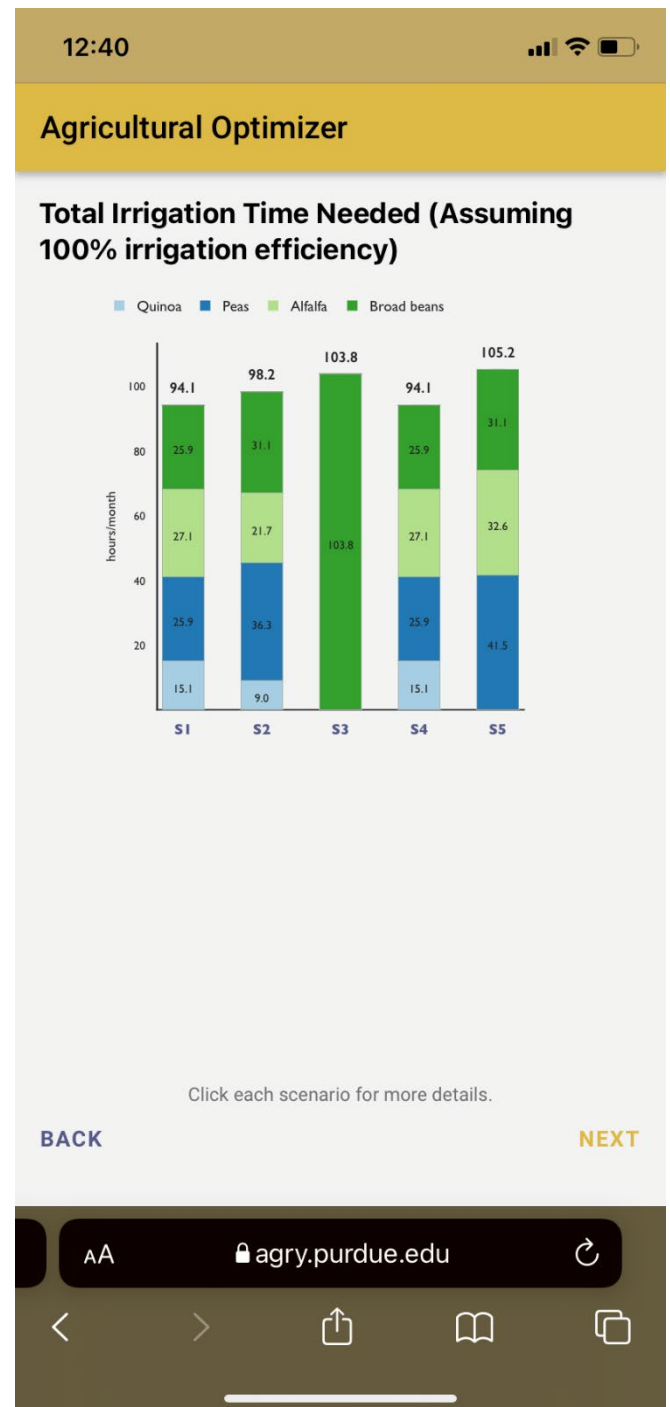


Figure 17. The final results screen helps to plan irrigation duration

## APPLICATIONS

OpAgri can be a tool in deciding which crops to plant and how much to plant of each crop. The different factors to consider from the tool outputs are 1) total profit, 2) crop variety, and 3) water use.

For example, let's look at the outputs from the example shown in the Steps to use the tool. We have three graphs below from left to right that are Planting area in ha, Total profit in Soles, and total water use.

The first graph, planting area, shows the different quantitative distribution of crops. You can see that in Scenario 3, which maximizes profit, only one crop, broad beans, is suggested. This is because based on total expected expenses versus average profit, broad beans are the most efficient per area. However, planting only broad beans makes the farmer most susceptible to unknowns that could damage specific crops or crop-specific market swings.

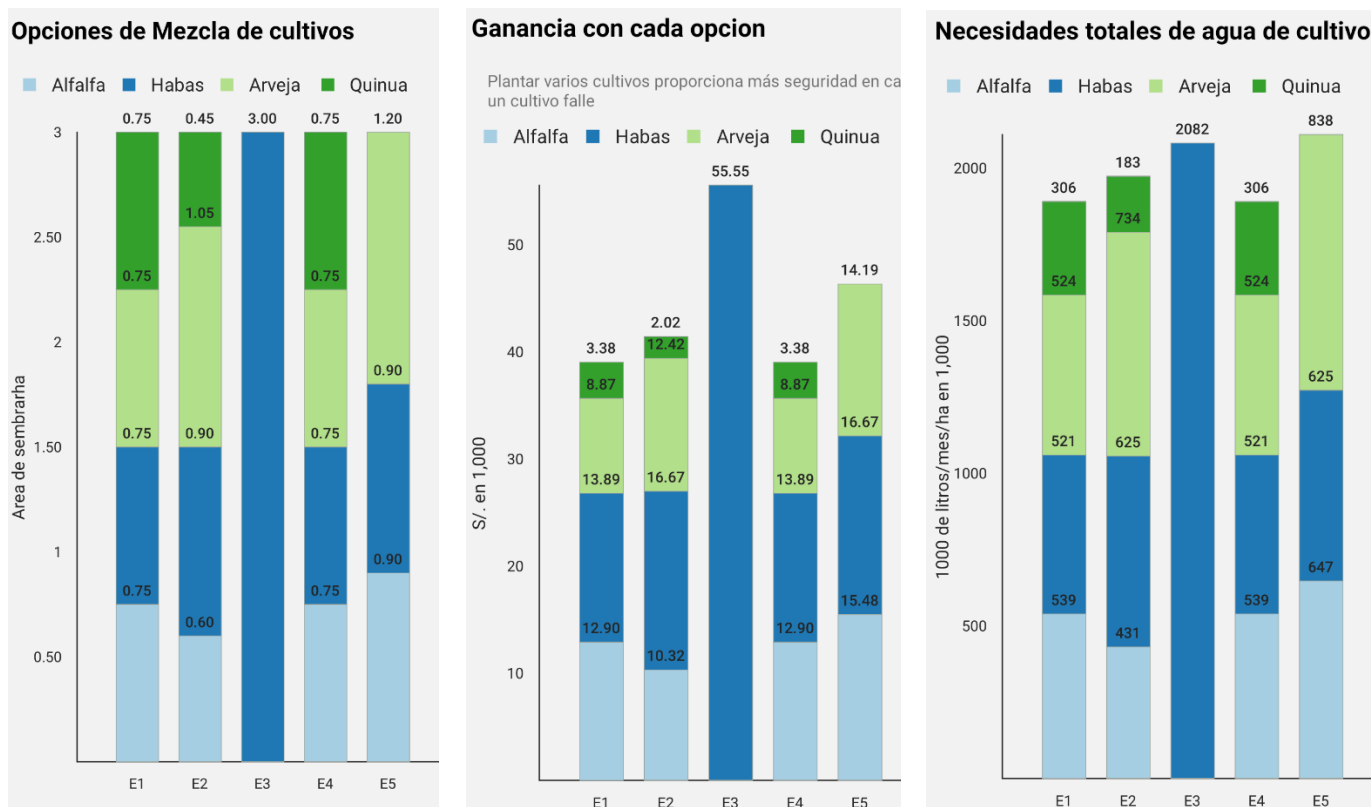
Looking at the second graph, which compares expected profit of the different scenarios, you can see that Scenario 3 is the highest, since that is what it is supposed to do. However, while this scenario predicts profit at over S/. 55.000, all scenarios predict profit that are at least S/. 40.000. This includes Scenario 5, which has a much more diverse crop distribution, while maintaining an expected profit of over S/. 45.000.

The last graph shows how much water each crop mix uses. Based on water use inputs, total monthly water available is:

$$6 \text{ L/s} \times 2 \text{ times per month} \times 8 \text{ hours} \times 3600 \text{ s/hour} = 96 \times 3600 = 345,600 \text{ L/month}$$

For an area of 3 ha, this is: 115,800 L/month/ha

In this example, some scenarios use less water than others. If a farmer is most interested in conserving water, picking an option that uses less water would be beneficial. However, the range of water used in each scenario only varies slightly. In this example, land was the limiting factor, where all available planting area was used in each scenario. In some cases, water is the limiting factor, and in that instance, different areas of land are suggested to plant.





Depending on your goals as a farmer – diversifying crop mix to increase security, maximizing profit, or minimizing water use, these three graphs can serve different purposes. Weighing the positives and negatives of these different factors may also help in selecting an option in between. In the example above, here are a few options to consider

Scenario 3 has the most potential for profit. However, only one crop is planted, which increases susceptibility to changing markets and crop failure. It also uses more water than most other scenarios.

Scenario 5 doesn't result in quite as much profit as Scenario 3, but there is more opportunity for profit than the other scenarios. There is also a good mix of crops, which reduces risk in case one crop fails or market prices change. The drawback of this option is that it uses the most water of all scenarios.

Scenarios 1 and 4 have the same results, and Scenario 2 is similar to these two. These have the highest crop diversity, but the lowest profit. In addition, these scenarios use the least amount of water.

Weighing the different factors and considering your goals when looking at the different options can help you select a mix of crops that works for you and your fields.

## ABOUT THE TEAM

### *Development team*

**Jingqiu Chen** is a Postdoctoral Research Associate of Agricultural and Biological Engineering at Purdue University. Her research focuses on model-based analyses and stakeholder engagement for developing locally-adapted water and soil management tools.

**Ben Hancock** is a programmer in the Department of Agricultural and Biological Engineering at Purdue University. He works with the Digital Agricultural Discovery (DAD) Lab to develop mobile and web-based decision support tools for use by researchers, farmers, public organizations, and students.

**Katy Mazer** is coordinator of the Sustainable Water Management team of The Nexus Institute at Purdue University. She engages with stakeholder groups in Arequipa, Peru to coproduce water management decision-making tools.

**Laura Bowling** is a professor of hydrology in the Department of Agronomy at Purdue University. Her research investigates the water resources impact of environmental change across multiple scales, climate regimes and ecosystems and communicates these findings to stakeholders.

**Dharmendra Saraswat** is an Associate Professor in the Department of Agricultural and Biological Engineering at Purdue University. His research focus is on investigating applications of Information, Communication, and Sensing Technologies (ICST) for addressing issues in plant production and natural resources management and disseminating research-based findings to stakeholders through mobile and web apps.

**José P. Pinto Cáceres** is a Professor in the Department of Agronomy at the Universidad Nacional de San Agustín de Arequipa. He conducts agricultural research and connects with interested associations to improve natural resource management.

**Bernard Engel** is Associate Dean for Agricultural Research and Graduate Education at Purdue University. He develops web-based spatial decision support systems that include web GIS, model, and database components to help users better understand and quantify hydrologic and ecological concepts.

### *Learn more*

This tool was part of the Sustainable Water Management project of the Arequipa Nexus Institute. To see more of our tools and learn more about the SWM team, please visit our website at <https://www.agry.purdue.edu/hydrology/projects/nexus-swm/es/index.html>.



## ACKNOWLEDGEMENTS

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