THE SUSTAINABLE WATER MANAGEMENT TEAM

OF THE AREQUIPA NEXUS INSTITUTE

Presents:

AguaRiego

User's Manual

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Arequipa Nexus Institute

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INTRODUCTION TO TOOL

The Crop Water Use Tables provide crop water use data and irrigation water needs data for typical crops in the Region of Arequipa, Peru including the Majes Irrigation District, the city of Arequipa, and the Colca Valley. It can be used to:

- Compare the water needs of different crops;
- Compare the water needs for different irrigation systems; and
- Evaluate if there is sufficient access to irrigation water for an entire season.

TOOL DEVELOPMENT

The Crop Water Use Tables 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. Crop water needs for three soil types were simulated based on primary profiles found in the region, and available soil water was calculated based on these profiles as described in the publication from Daneshvar et al. (2020) (Table 1). Precipitation and temperature data were pulled from the climate maps from Moraes et al. (2022) based on weather station locations (Table 2). Windspeed was collected from the Global Data for SWAT database (CFSR 2019). Solar Radiation was calculated based on location and time of year using the method of Thornton and Running (1999). Reference Crop ET was calculated using the FAO 56 method and the Penman-Monteith equation. 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 Chen et al. (in prep).

The model simulations are providing the ideal volume of water needed by the crop, to satisfy photosynthesis needs based on local weather conditions, but does not account for the losses of water in the irrigation distribution system and during application to the field. The app also provides a rough estimate of the total water to be applied to the field based on the average efficiency of the three primary irrigation methods: flood irrigation, sprinkler irrigation and above ground drip. Efficiency refers to the amount of water used by the plant divided by the volume of water applied to the field. The assumed efficiencies of each method are provided in Table 4. Please note that these represent edge of field water volumes needed. If there are substantial losses in the irrigation distribution canals, the amount of water diverted to individual farms will need to be greater.

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

Soil profile index	Soil Taxonomy	Primary Texture	Plant available water (mm/meter)
CAL 11	Lithic Haplustand	Silty loam on clay loam	180
CAL 14	Typic Ustorthents	Sandy loam	110
CAL 19	Typic Haplustands	Sandy loam on clay	160
CAL 23	Typic Haplustands	Sandy loam	110
CAL 08	Typic Anthracambids	Sandy loam	110
CAL 30	Lithic Haplocambids	Sandy loam	110
CAL 36	Typic Haplocambids	Sandy loam on loamy sand	97
CAL 67	Typic Haplotorrands	Sandy loam on loamy sand	95
S 01	Typic Haplotorrands	Silty loam	70

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'' E
Cabanaconde	3333	15°37'21.34'' S	71°58'26.71'' E
La Pampilla	2326	16°24’49.66” S	71°32’04.31” W
Huasacache	2200	16°27’ 27.87” S	71°33’58.85” W
Chiguata	2902	16°24’32.9” S	71°24’32.9” W
Pampa de Majes	1498	16°20’8.35” S	72°9’9.56” W

Table 3: Crop information used for water use simulations

Crop*	Kc values during the growing season		
	Early	Middle	Late
Garlic	0.5	1.4	0.3
Artichoke	0.3	1.65	1.4
Alfalfa	0.4	0.95	0.9
Peas	0.4	1.15	0.35
Broccoli	0.7	1.05	0.95
Pumpkin	0.45	1	0.75
Barley**	0.3	1.15	0.25
Onion	0.7	1.05	0.95
Red onion	0.35	1.25	1
Broad beans**	0.4	1.15	0.35
Lettuce	0.7	1.05	0.95
Corn	0.35	1.5	1.4
Potato	0.3	1.35	1.2
Quinoa	0.52	1	0.7
Tomato	0.45	1.15	0.8
Green beans	0.4	1.15	1

*The same Kc values are used in all locations

**These values came from the CropWAT manual because local data were not available

Table 4: Assumed Efficiencies of Different Irrigation Methods

Irrigation Method	Efficiency (%)
Flood Irrigation	60
Sprinkler Irrigation	75
Drip Irrigation	90

USING THE TOOL

AguaRiego 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.university/instrumentos_nexus.

Phone App Tutorial

1. The app allows you to choose your preferred language, here you can select one of the options.

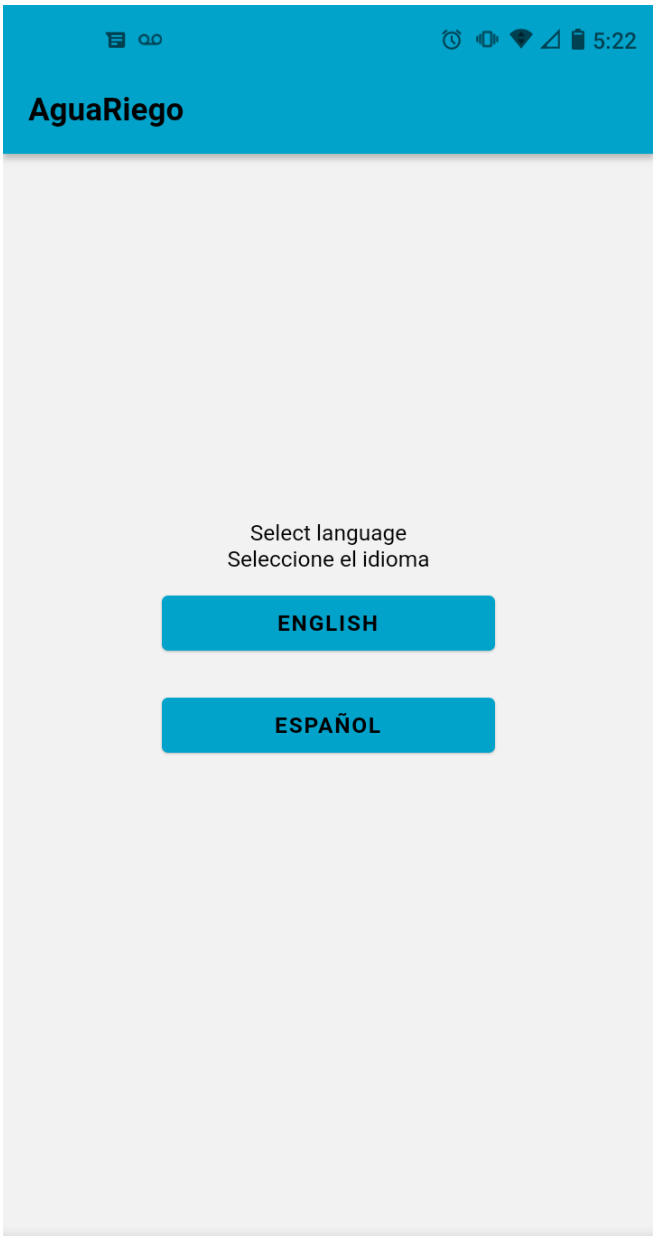

Figure 2. The app Welcome Screen

2. Then, you will see an introduction screen welcoming you to the app. Click “Continue” to start.

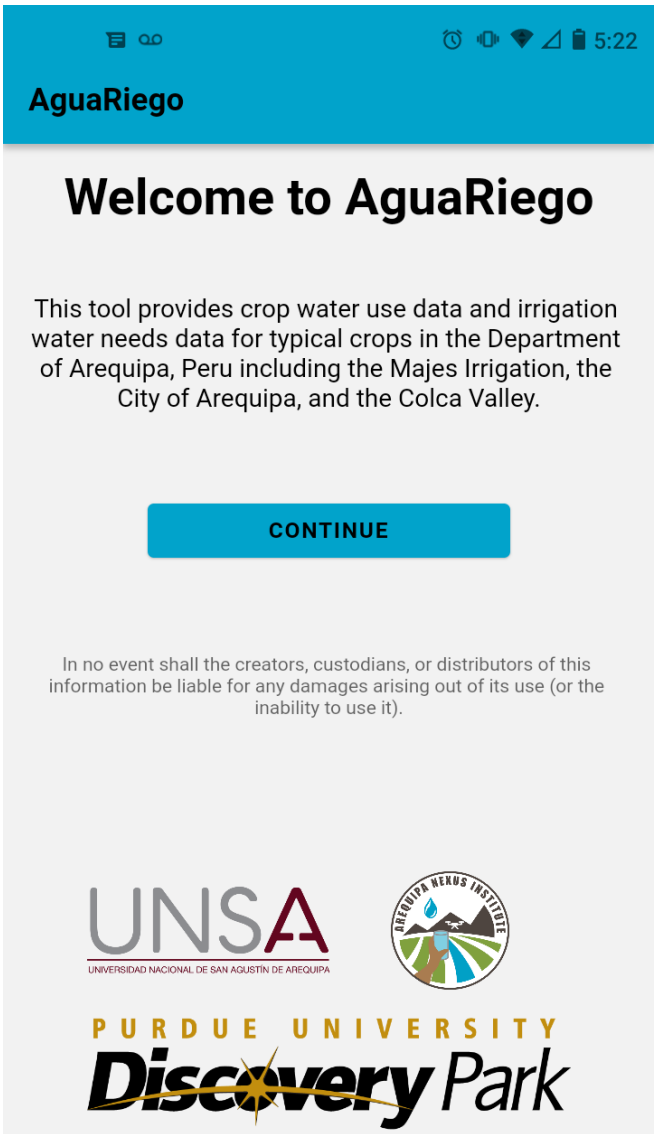

Figure 3. Language Selection Screen

3. The app will ask you to allow access to your location. If you do so, the app will use your location to identify weather and soil data. Click “Allow access” to automatically select location or click “Reject” to manually choose a weather station location.

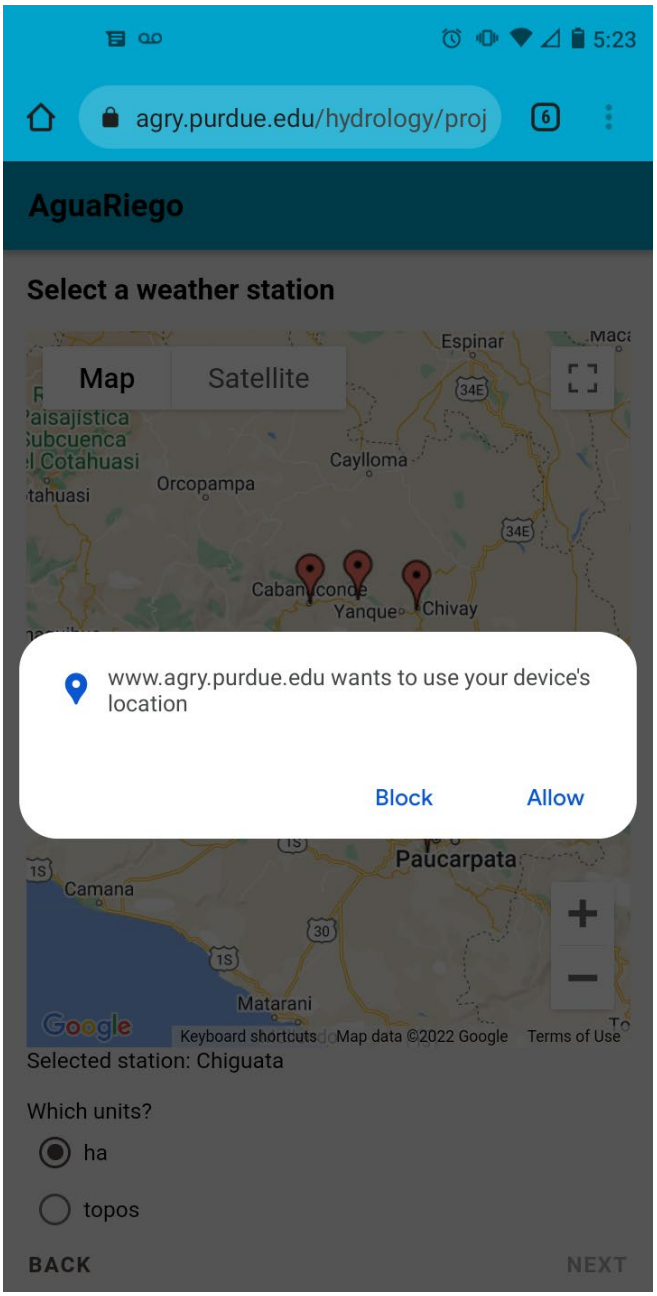

Figure 4. The location access screen allows the app to select the closest weather station

4. If you allowed access to your location, the closest weather station will automatically be highlighted in yellow. Otherwise, you can select a different weather station by tapping the one you would like to see crop water use data. Select the units for area that you would like to use, then click “Next”.

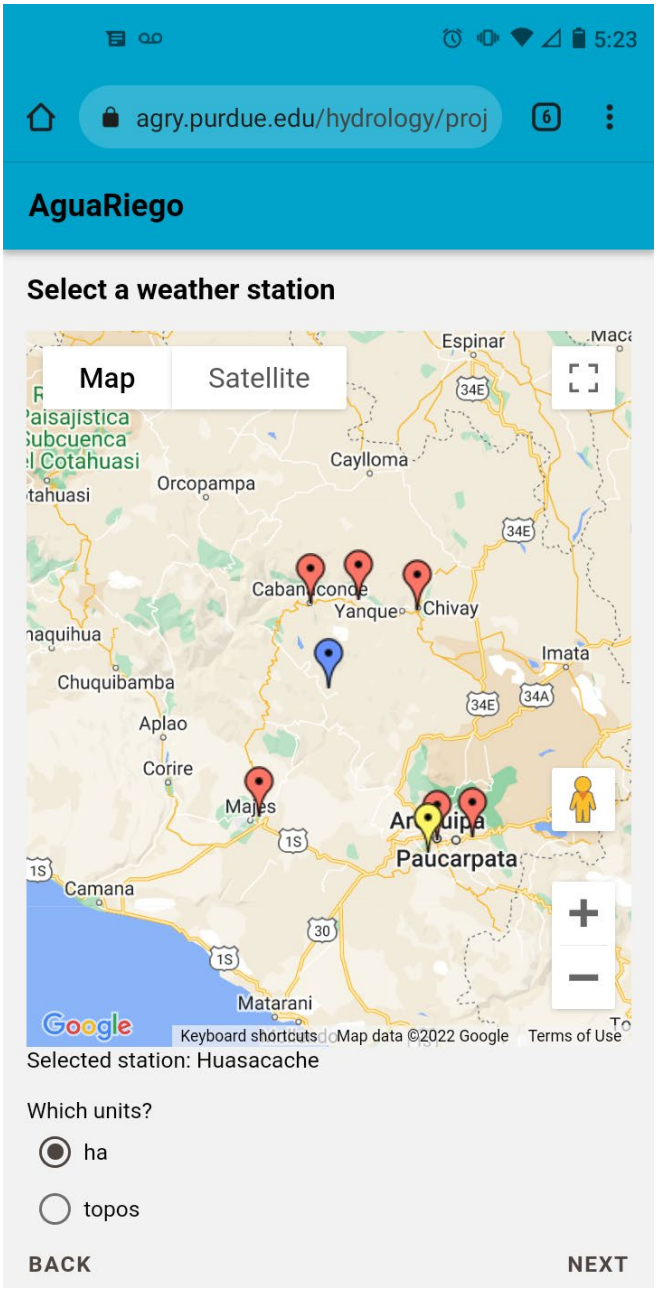

Figure 5. You can choose a weather station that is not the closest to your current location by clicking on the station on this screen, area units are specified at the bottom.

5. The app will provide options of crops to select to see water use. To include a crop, tap the box next to it. Purple boxes with checkboxes inside them have been selected. Also, you can tap the arrows at the bottom of the table to scroll to select more crops.

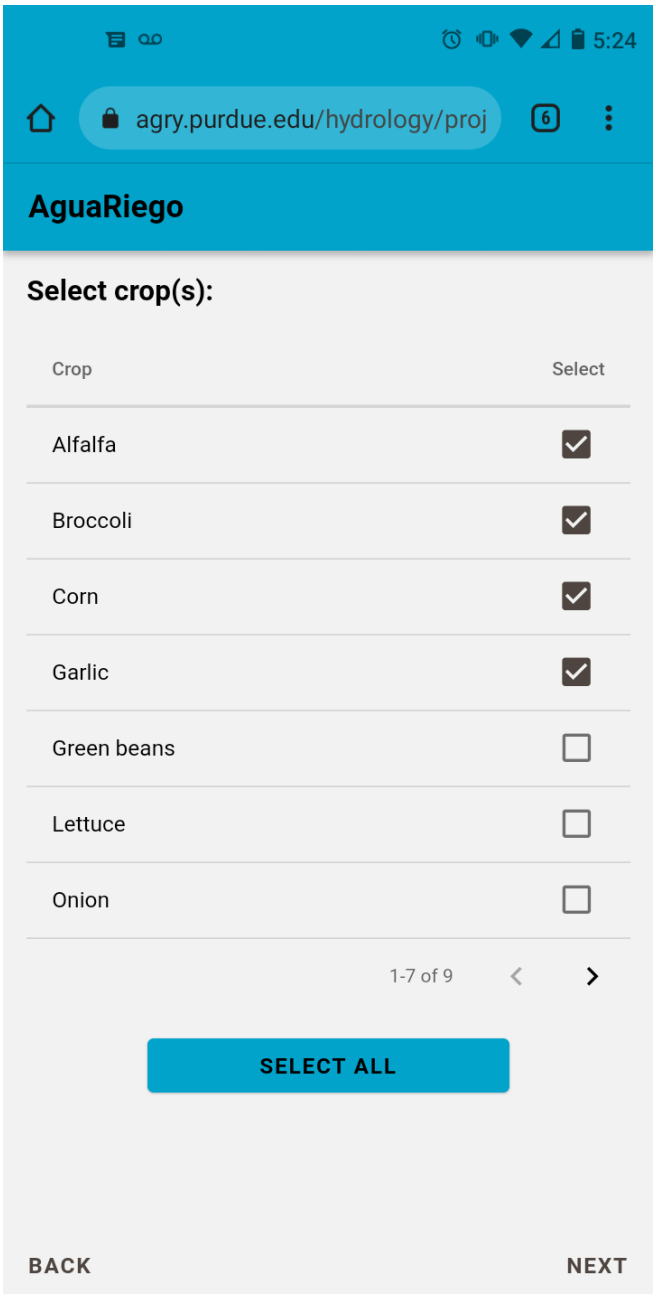

Figure 6. Select crops by tapping

6. The next page will show you crop water use for each of the crops you selected. This includes the total water volume needed by the crop for the entire growing season and average monthly water use. It will also show average number of months grown and typical planting month based on local input. Note that the crop water use does not account for irrigation losses. It is the ideal amount of water that the plant will take up through its roots for photosynthesis.

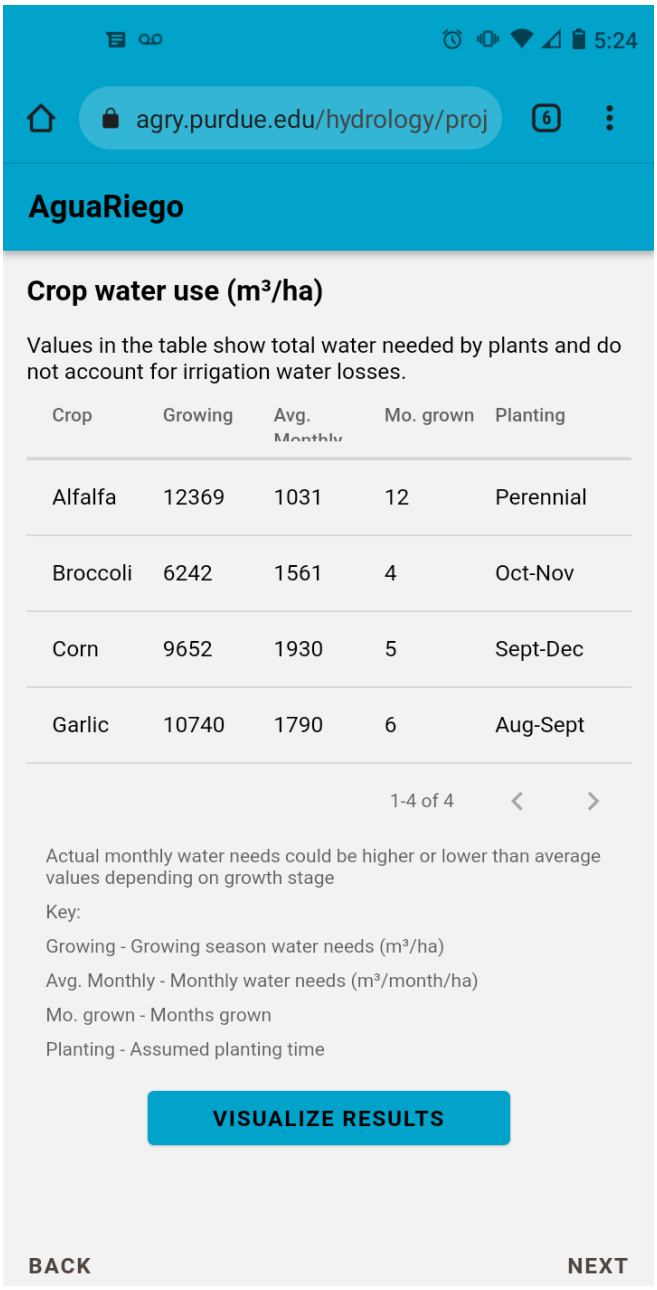

Figure 7. The results screen shows the volume of water needed by each crop.

7. The next page provides average estimated monthly water use for each crop using different irrigation methods.

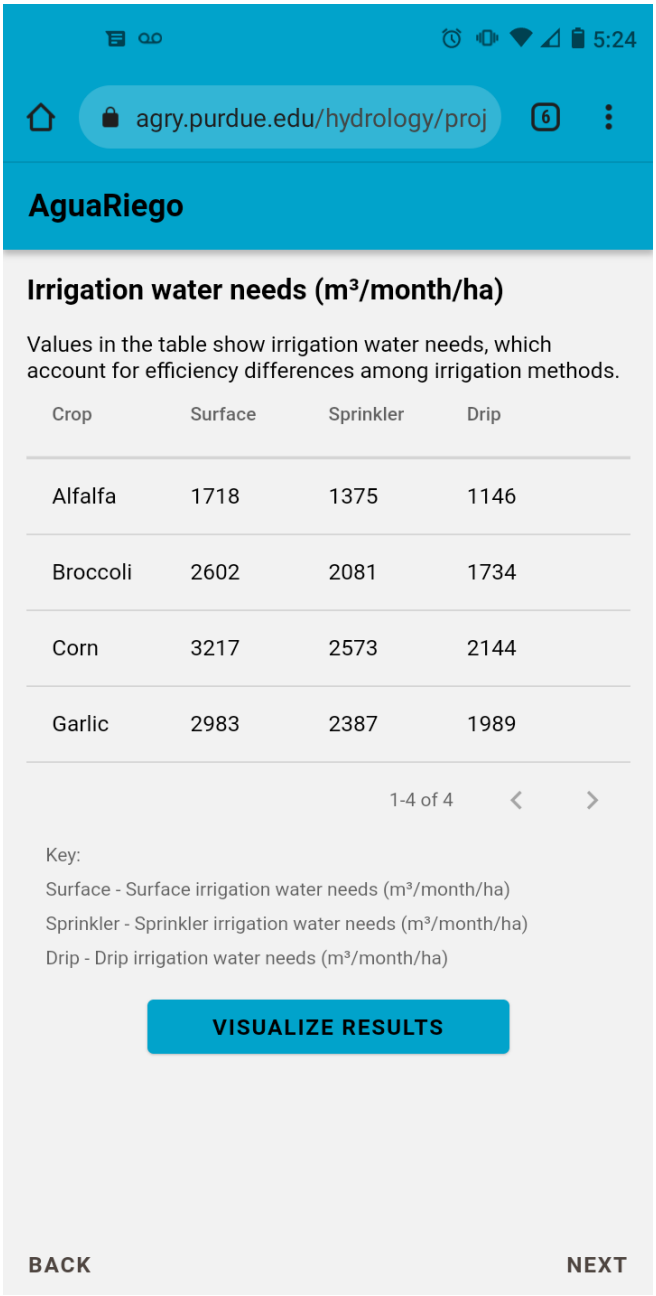

Figure 8. The total estimated edge of field water needs for each crop, using the assumed irrigation efficiencies presented in Table 4.

8. After viewing all tables, the last page provides a little more information about the tool, its sources, and the developers.

To looks at different crops or crops at another weather station, click the “Restart” button.

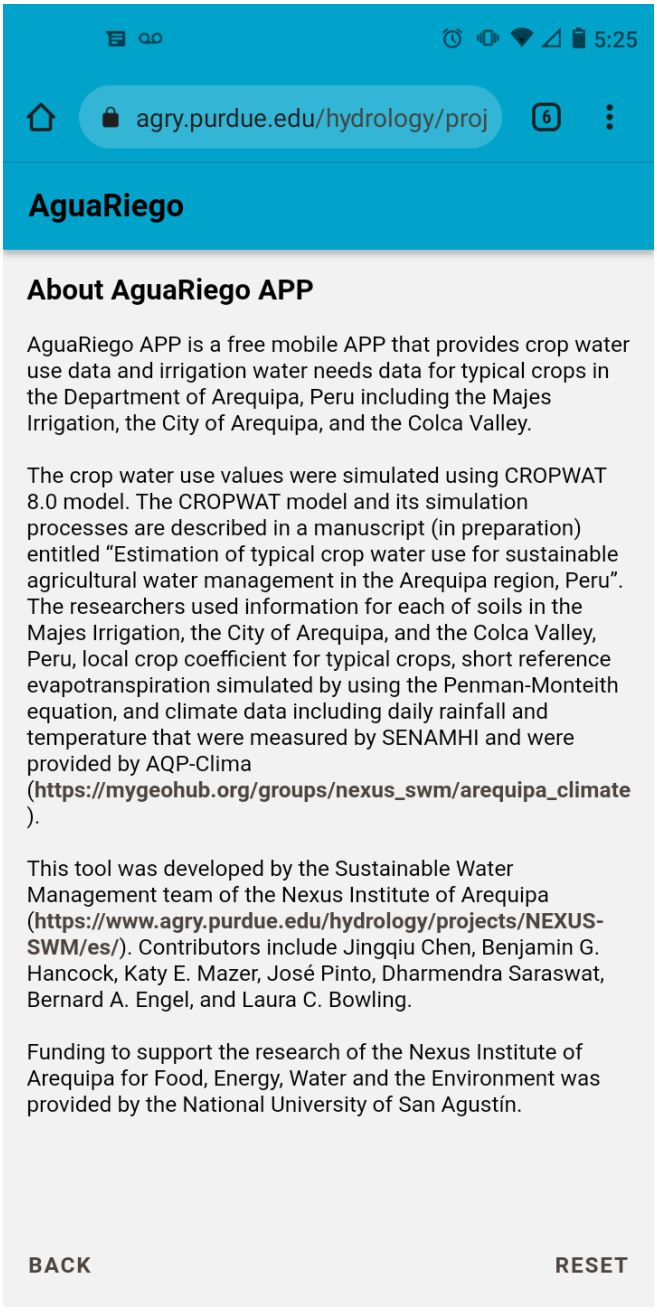

Figure 9. The final information screen.

Manual Look-up Tables

This section provides a manual look up table of seasonal and average monthly water use, as well as typical planting month and number of months grown in the area. The following data are the same as those that can be found using the phone app.

Table 5: Crop water use at the Huasacache weather station in Arequipa

Crop Name	**Soil Texture**	**Average monthly water requirement**		**Growing season water requirement**		**Months grown**	**Typical planting time**
		(m^3/month/ha)	*(m^3/month/topo)*	*(m^3/ha)*	*(m^3/topo)*		
Alfalfa	Sandy Loam	1031	344	12369	4123	12	Perennial
	Sandy Loam over Loamy Sand	1041	347	12486	4162	12	Perennial
	Silty loam	1034	345	12411	4137	12	Perennial
Broccoli	Sandy Loam	1561	520	6242	2081	4	Oct-Nov
	Sandy Loam over Loamy Sand	1528	509	6113	2038	4	Oct-Nov
	Silty loam	1543	514	6173	2058	4	Oct-Nov
Corn	Sandy Loam	1930	643	9652	3217	5	Sept-Dec
	Sandy Loam over Loamy Sand	1932	644	9659	3220	5	Sept-Dec
	Silty loam	1949	650	9746	3249	5	Sept-Dec
Garlic	Sandy Loam	1790	597	10740	3580	6	Aug-Sept
	Sandy Loam over Loamy Sand	1756	585	10533	3511	6	Aug-Sept
	Silty loam	1778	593	10668	3556	6	Aug-Sept
Green Beans	Sandy Loam	1583	528	5539	1846	3.5	Sept-Oct
	Sandy Loam over Loamy Sand	1583	528	5540	1847	3.5	Sept-Oct
	Silty loam	1583	528	5541	1847	3.5	Sept-Oct
Lettuce	Sandy Loam	1476	492	5165	1722	3.5	Oct-Nov
	Sandy Loam over Loamy Sand	1475	492	5164	1721	3.5	Oct-Nov
	Silty loam	1480	493	5179	1726	3.5	Oct-Nov
Onion	Sandy Loam	1490	497	7449	2483	5	Aug-Sept
	Sandy Loam over Loamy Sand	1489	496	7447	2482	5	Aug-Sept
	Silty loam	1492	497	7460	2487	5	Aug-Sept
Peas	Sandy Loam	1489	496	5957	1986	4	Sept-Oct
	Sandy Loam over Loamy Sand	1490	497	5958	1986	4	Sept-Oct
	Silty loam	1492	497	5969	1990	4	Sept-Oct
Quinoa	Sandy Loam	1226	409	6129	2043	5	Sept-Dec
	Sandy Loam over Loamy Sand	1226	409	6129	2043	5	Sept-Dec
	Silty loam	1242	414	6210	2070	5	Sept-Dec

Table 6: Crop water use at the Chiguata weather station in Arequipa

Crop Name	Soil Texture	Average monthly water requirement		Growing season water requirement		Months grown	Typical planting time
		(m^3/month/ha)	*(m^3/month/topo)*	*(m^3/ha)*	*(m^3/topo)*		
Alfalfa	Sandy Loam	843	281	10119	3373	12	Perennial
	Sandy Loam over Loamy Sand	846	282	10154	3385	12	Perennial
	Silty loam	860	287	10321	3440	12	Perennial
Broccoli	Sandy Loam	1328	443	5312	1771	4	Oct-Nov
	Sandy Loam over Loamy Sand	1350	450	5398	1799	4	Oct-Nov
	Silty loam	1383	461	5532	1844	4	Oct-Nov
Corn	Sandy Loam	1724	575	8622	2874	5	Sept-Dec
	Sandy Loam over Loamy Sand	1726	575	8631	2877	5	Sept-Dec
	Silty loam	1744	581	8718	2906	5	Sept-Dec
Garlic	Sandy Loam	1588	529	9527	3176	6	Aug-Sept
	Sandy Loam over Loamy Sand	1607	536	9642	3214	6	Aug-Sept
	Silty loam	1605	535	9629	3210	6	Aug-Sept
Green Beans	Sandy Loam	1464	488	5124	1708	3.5	Sept-Oct
	Sandy Loam over Loamy Sand	1466	489	5130	1710	3.5	Sept-Oct
	Silty loam	1468	489	5139	1713	3.5	Sept-Oct
Lettuce	Sandy Loam	1335	445	4672	1557	3.5	Oct-Nov
	Sandy Loam over Loamy Sand	1368	456	4788	1596	3.5	Oct-Nov
	Silty loam	1333	444	4664	1555	3.5	Oct-Nov
Onion	Sandy Loam	1365	455	6824	2275	5	Aug-Sept
	Sandy Loam over Loamy Sand	1373	458	6865	2288	5	Aug-Sept
	Silty loam	1365	455	6825	2275	5	Aug-Sept
Peas	Sandy Loam	1366	455	5462	1821	4	Sept-Oct
	Sandy Loam over Loamy Sand	1362	454	5447	1816	4	Sept-Oct
	Silty loam	1362	454	5447	1816	4	Sept-Oct
Quinoa	Sandy Loam	1086	362	5430	1810	5	Sept-Dec
	Sandy Loam over Loamy Sand	1079	360	5393	1798	5	Sept-Dec
	Silty loam	1092	364	5462	1821	5	Sept-Dec

Table 7: Crop water use at the La Pampilla weather station in Arequipa

Crop Name	Soil Texture	Average monthly water requirement		Growing season water requirement		Months grown	Typical planting time
		(m^3/month/ha)	*(m^3/month/topo)*	*(m^3/ha)*	*(m^3/topo)*		
Alfalfa	Sandy loam	1043	348	12520	4173	12	Perennial
	Sandy Loam over Loamy Sand	1043	348	12520	4173	12	Perennial
	Silty loam	1049	350	12588	4196	12	Perennial
Broccoli	Sandy loam	1570	523	6281	2094	4	Oct-Nov
	Sandy Loam over Loamy Sand	1543	514	6172	2057	4	Oct-Nov
	Silty loam	1544	515	6174	2058	4	Oct-Nov
Corn	Sandy loam	1964	655	9818	3273	5	Sep-Dec
	Sandy Loam over Loamy Sand	1978	659	9889	3296	5	Sep-Dec
	Silty loam	1967	656	9837	3279	5	Sep-Dec
Garlic	Sandy loam	1790	597	10740	3580	6	Aug-Sep
	Sandy Loam over Loamy Sand	1783	594	10699	3566	6	Aug-Sep
	Silty loam	1807	602	10839	3613	6	Aug-Sep
Green beans	Sandy loam	1580	527	5530	1843	3.5	Sep-Oct
	Sandy Loam over Loamy Sand	1580	527	5531	1844	3.5	Sep-Oct
	Silty loam	1581	527	5535	1845	3.5	Sep-Oct
Lettuce	Sandy loam	1497	499	5240	1747	3.5	Oct-Nov
	Sandy Loam over Loamy Sand	1496	499	5235	1745	3.5	Oct-Nov
	Silty loam	1501	500	5255	1752	3.5	Oct-Nov
Onions	Sandy loam	1487	496	7436	2479	5	Aug-Sep
	Sandy Loam over Loamy Sand	1487	496	7433	2478	5	Aug-Sep
	Silty loam	1490	497	7451	2484	5	Aug-Sep
Peas	Sandy loam	1485	495	5939	1980	4	Sep-Oct
	Sandy Loam over Loamy Sand	1485	495	5941	1980	4	Sep-Oct
	Silty loam	1485	495	5939	1980	4	Sep-Oct
Quinoa	Sandy loam	1259	420	6294	2098	5	Sep-Dec
	Sandy Loam over Loamy Sand	1260	420	6299	2100	5	Sep-Dec
	Silty loam	1259	420	6295	2098	5	Sep-Dec

Table 8: Crop water use at the Cabanaconde weather station in Colca

Crop Name	Soil Texture	Average monthly water requirement		Growing season water requirement		Months grown	Typical planting time
		(m^3/month/ha)	*(m^3/month/topo)*	*(m^3/ha)*	*(m^3/topo)*		
Alfalfa	Silty loam on clay	774	258	9290	3097	12	Perennial
	Sandy loam	782	261	9378	3126	12	Perennial
	Silty loam on clay loam	768	256	9220	3073	12	Perennial
Barley	Silty loam on clay	440	147	1761	587	4	January
	Sandy loam	448	149	1793	598	4	January
	Silty loam on clay loam	428	143	1710	570	4	January
Broad beans	Silty loam on clay	747	249	3736	1245	5	June
	Sandy loam	747	249	3736	1245	5	June
	Silty loam on clay loam	750	250	3748	1249	5	June
Corn	Silty loam on clay	644	215	5478	1826	8.5	September
	Sandy loam	681	227	5786	1929	8.5	September
	Silty loam on clay loam	660	220	5610	1870	8.5	September
Peas	Silty loam on clay	745	248	3724	1241	5	June
	Sandy loam	747	249	3736	1245	5	June
	Silty loam on clay loam	745	248	3724	1241	5	June
Potato	Silty loam on clay	1105	368	4420	1473	4	October
	Sandy loam	1161	387	4644	1548	4	October
	Silty loam on clay loam	1137	379	4547	1516	4	October
Quinoa	Silty loam on clay	438	146	2189	730	5	January
	Sandy loam	434	145	2169	723	5	January
	Silty loam on clay loam	434	145	2169	723	5	January

Table 9: Crop water use at the Chivay weather station in Colca

Crop Name	Soil Texture	Average monthly water requirement		Growing season water requirement		Months grown	Typical planting time
		(m^3/month/ha)	*(m^3/month/topo)*	*(m^3/ha)*	*(m^3/topo)*		
Alfalfa	Silty loam over clay	743	248	8920	2973	12	Perennial
	Sandy loam	744	248	8928	2976	12	Perennial
	Silty loam over clay loam	737	246	8841	2947	12	Perennial
Barley	Silty loam over clay	349	116	1396	465	4	January
	Sandy loam	378	126	1511	504	4	January
	Silty loam over clay loam	349	116	1396	465	4	January
Broad beans	Silty loam over clay	754	251	3772	1257	5	June
	Sandy loam	755	252	3777	1259	5	June
	Silty loam over clay loam	754	251	3772	1257	5	June
Corn	Silty loam over clay	537	179	4561	1520	8.5	September
	Sandy loam	636	212	5407	1802	8.5	September
	Silty loam over clay loam	542	181	4604	1535	8.5	September
Peas	Silty loam over clay	754	251	3772	1257	5	June
	Sandy loam	756	252	3781	1260	5	June
	Silty loam over clay loam	756	252	3781	1260	5	June
Potato	Silty loam over clay	864	288	3456	1152	4	October
	Sandy loam	968	323	3873	1291	4	October
	Silty loam over clay loam	832	277	3327	1109	4	October
Quinoa	Silty loam over clay	399	133	1995	665	5	January
	Sandy loam	399	133	1995	665	5	January
	Silty loam over clay loam	399	133	1995	665	5	January

Table 10: Crop water use at the Madrigal weather station in Colca

Crop Name	Soil Texture	Average monthly water requirement		Water requirement in the growing season		Months grown	Typical planting time
		(m^3/month/ha)	*(m^3/month/topos)*	*(m^3/ha)*	*(m^3/topo)*		
Alfalfa	Silty loam on clay	724	241	8692	2897	12	Perennial
	Sandy loam	731	244	8767	2922	12	Perennial
	Silty loam on clay loam	719	240	8627	2876	12	Perennial
Barley	Silty loam on clay	340	113	1361	454	4	January
	Sandy loam	359	120	1437	479	4	January
	Silty loam on clay loam	340	113	1361	454	4	January
Broad Beans	Silty loam on clay	699	233	3493	1164	5	June
	Sandy loam	703	234	3517	1172	5	June
	Silty loam on clay loam	694	231	3470	1157	5	June
Corn	Silty loam on clay	555	185	4717	1572	8,5	September
	Sandy loam	568	189	4830	1610	8,5	September
	Silty loam on clay loam	574	191	4877	1626	8,5	September
Peas	Silty loam on clay loam	694	231	3470	1157	5	June
	Sandy loam	699	233	3493	1164	5	June
	Silty loam on clay loam	699	233	3493	1164	5	June
Potato	Sandy loam on clay	996	332	3984	1328	4	October
	Sandy loam	1089	363	4355	1452	4	October
	Silty loam on clay loam	1035	345	4141	1380	4	October
Quinoa	Sandy loam on clay	408	136	2038	679	5	January
	Sandy loam	408	136	2038	679	5	January
	Silty loam on clay loam	408	136	2038	679	5	January

Table 11: Crop water use at the Pampa Majes weather station in Majes with Sandy Loam Soil on Sandy Loam

Crop Name	Growing campaign	Average monthly water requirement		Water requirement in the growing season		Months grown	Typical planting season
		(m^3/month/ha)	*(m^3/month/topos)*	*(m^3/ha)*	*(m^3/topo)*		
Corn	First	1611	537	6444	2148	4	Aug-Sept
	Second	1337	446	5348	1783	4	Dec-Jan
Potato	First	1034	345	4655	1552	4,5	Feb-Mar
	Second	1368	456	6155	2052	4,5	Aug-Sept
Red Onion	First	968	323	3871	1290	4	Mar-Apr
	Second	1308	436	4579	1526	3,5	Aug-Sept
Pumpkin	First	869	290	3911	1304	4,5	Feb-Mar
	Second	1160	387	4639	1546	4	Aug-Sept
Artichoke	First	1119	373	7835	2612	7	Feb-Apr
	Second	1424	475	8541	2847	6	August
Quinoa	-	888	296	3996	1332	4,5	May-Aug
Tomato	-	1034	345	4651	1550	4,5	May-Aug
Garlic	-	1155	385	5777	1926	5	Feb-Jun
Alfalfa		892	297	10701	3567	12	Perennial

Peak water use by crop

As shown in Figure 10, peak water use for a crop is always higher than the average monthly water use provided in Tables 1-8 above. For garlic, shown in figure 10…

Although the app provides the average monthly water requirement for each crop, the maximum water use for a crop is always higher than the average monthly water use depending on the growth stage. For example, for garlic, shown in Figure 10, the maximum water consumption is approximately 7.9 mm/day, while the average is 5.9 mm/day. You can convert this to m^3/ha/day by multiplying this depth by 10. This would equate to a maximum daily water requirement of 59 m^3/ha/day. Figures 10 to 25 show the water requirement trends for each crop during the growing season, although the magnitude of the maximum requirement may increase or decrease depending on location. Table 8 provides values for mean water use and maximum water use for different crops in each region shown in this tool, in order to adjust expectations for the maximum daily water use needed during the peak of the year. intense growing season.

Water use graphs during the growing season

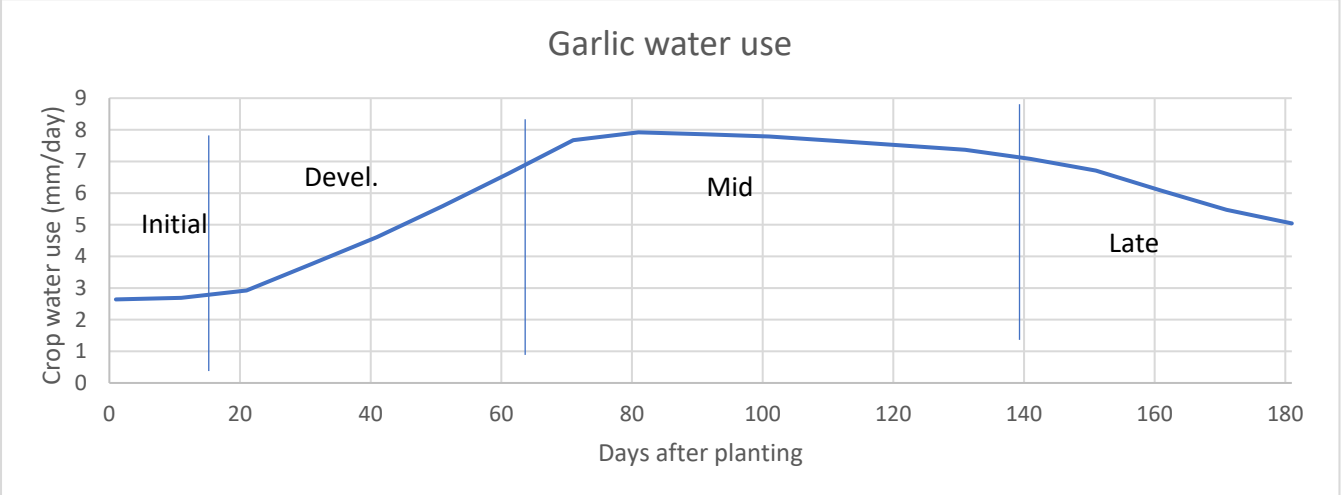

Figure 10. Garlic water use versus days after planting. Crop water use generally increases slowly with crop growth, peaking at 2/3 to ¾ of the crop growth cycle. Crop water use declines rapidly after physiological maturity.

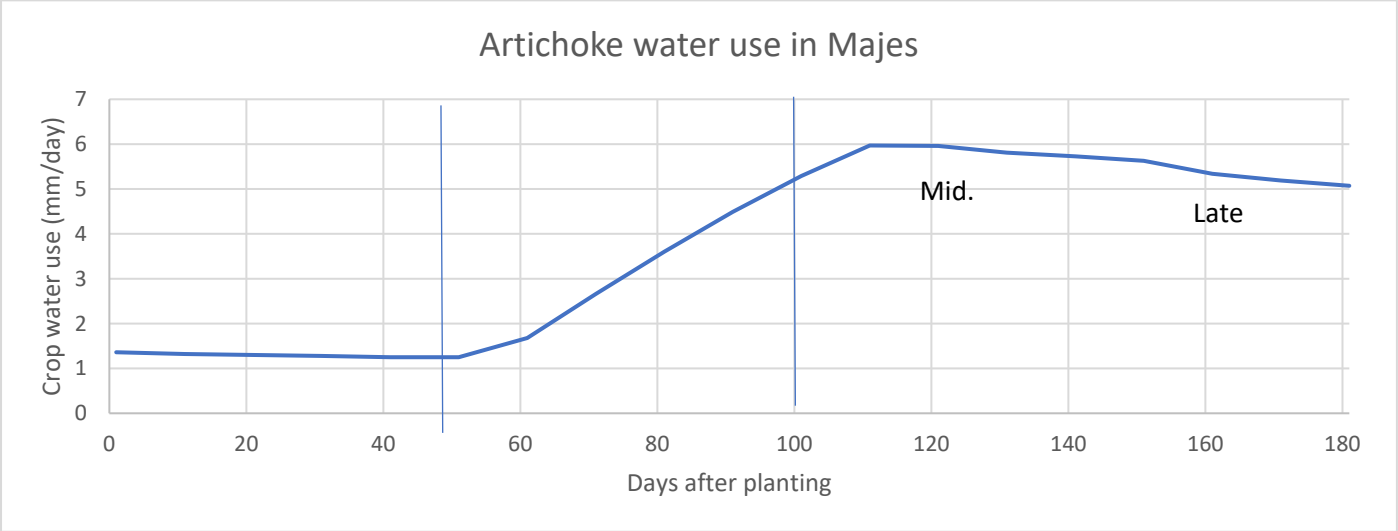

Figure 11. Artichoke water use in Majes Irrigation reaches a maximum of 6.0 mm/day.

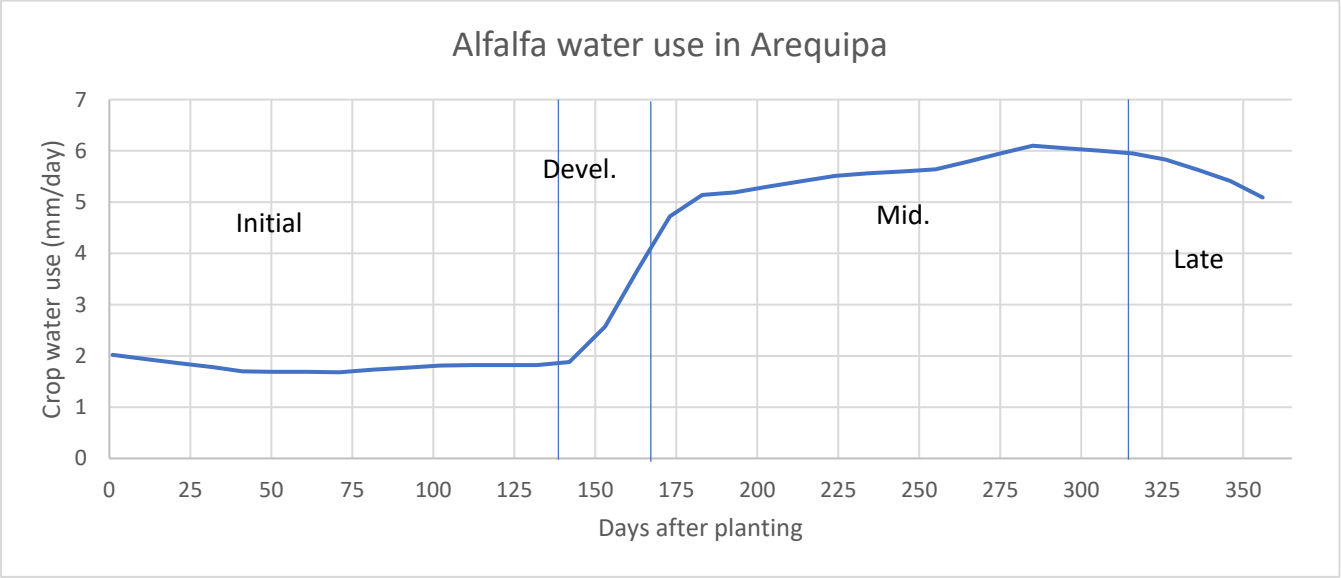

Figure 12. Alfalfa water use reaches a maximum of 6.1 mm/day in the city of Arequipa

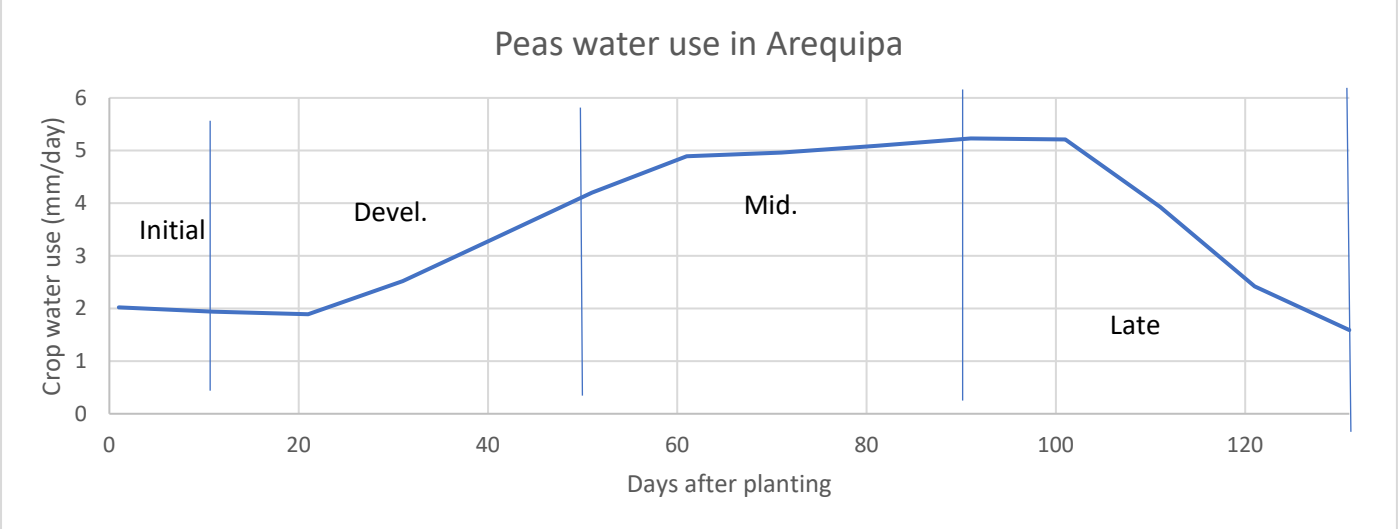

Figure 13. The use of water from peas reaches a maximum of 5.2 mm/day in the city of Arequipa

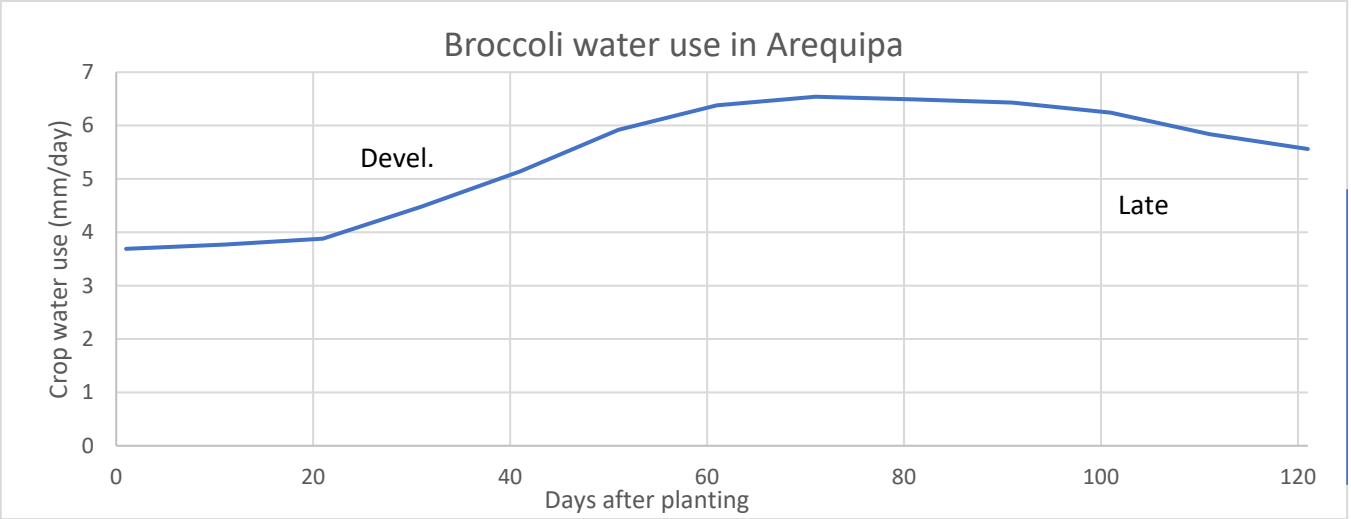

Figure 14. The use of water from broccoli reaches a maximum of 6.5 mm/day in the city of Arequipa

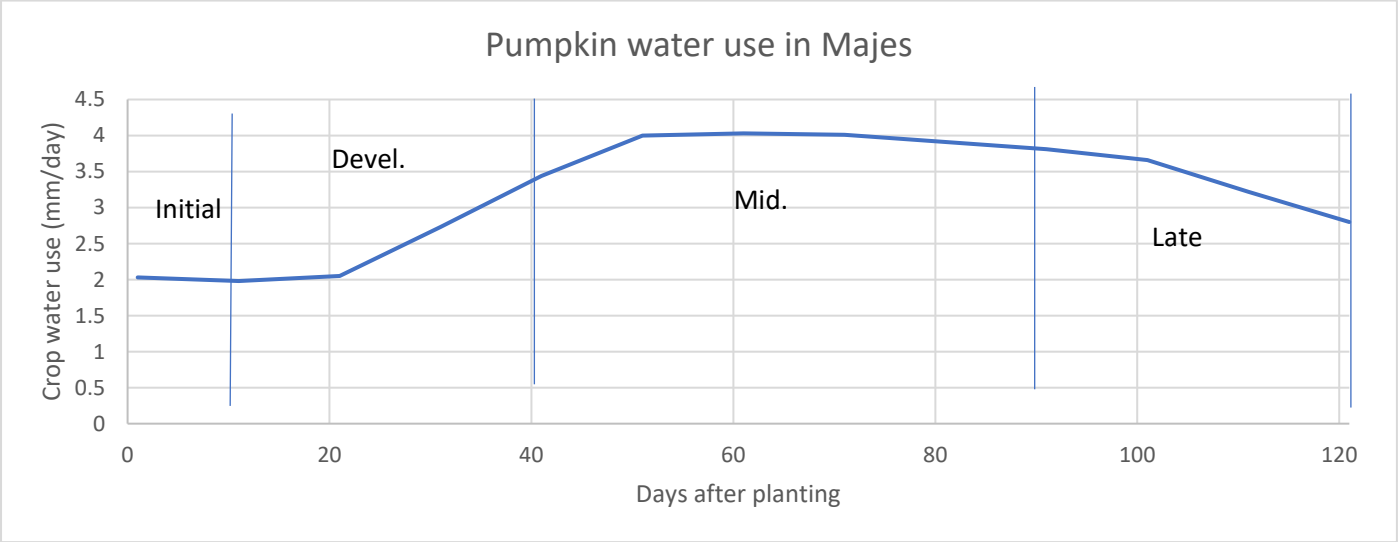

Figure 15. The use of water from pumpkin in the Majes Irrigation reaches a maximum of 4.0 mm/day

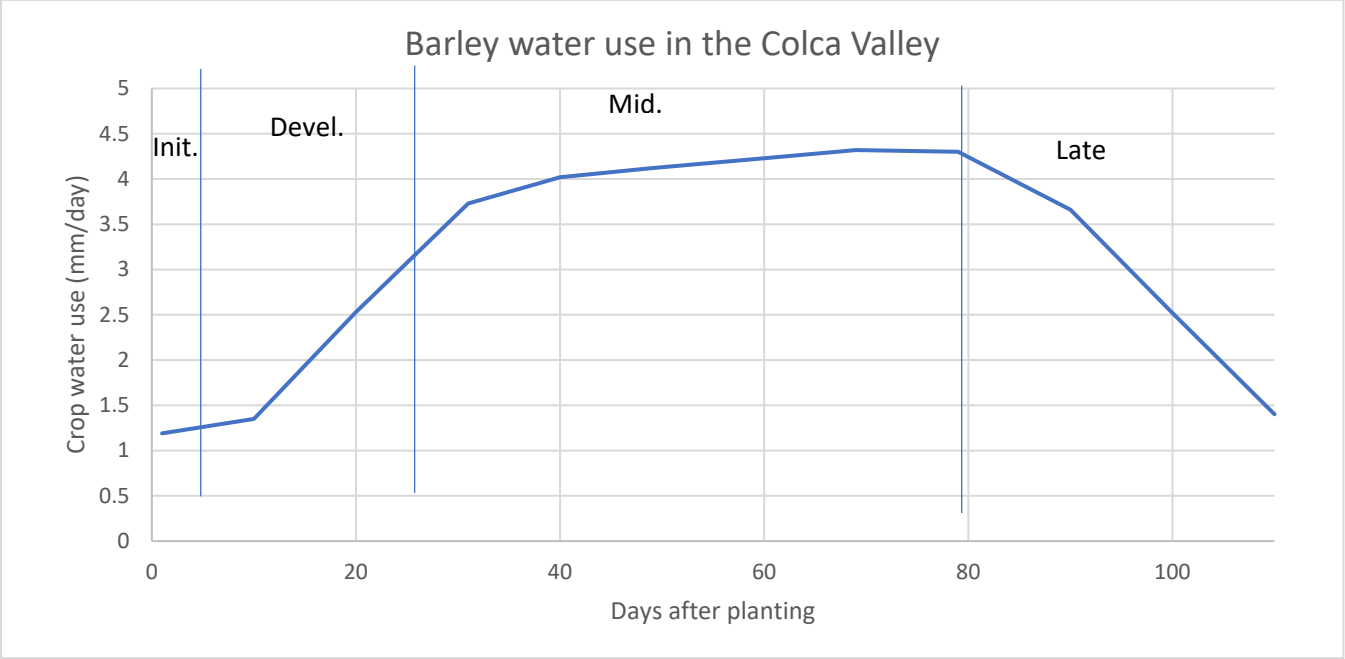

Figure 16. Barley water use reaches a maximum of 4.3 mm/day in the Colca Valley

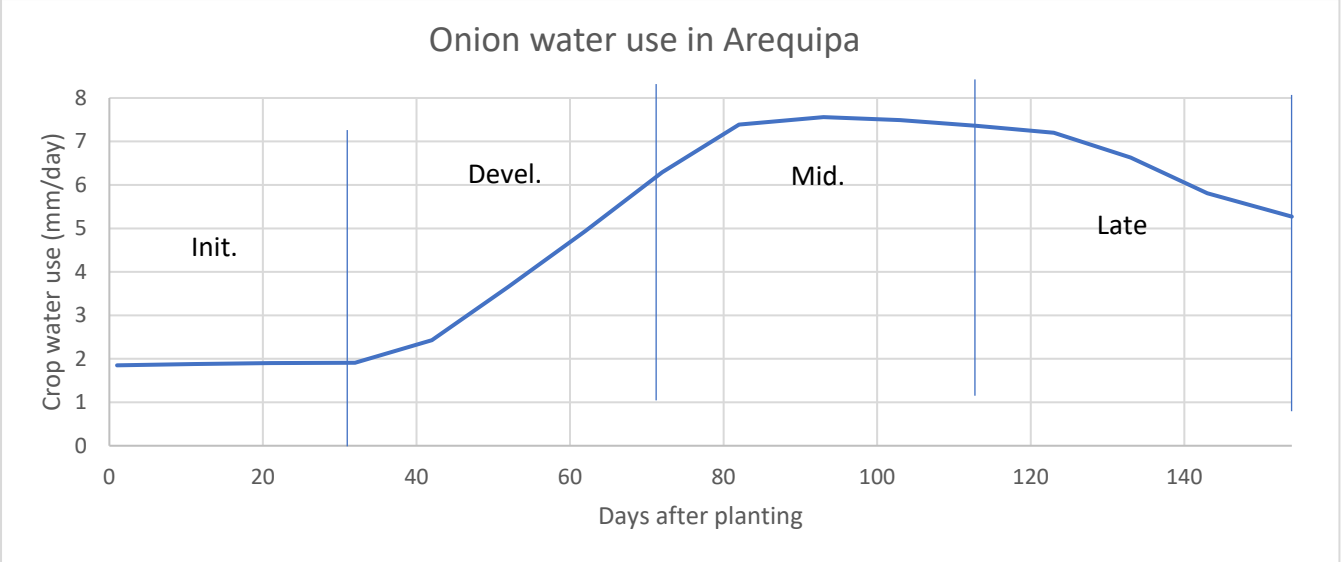

Figure 17. Onion water use reaches a maximum of 7.5 mm/day in the city of Arequipa

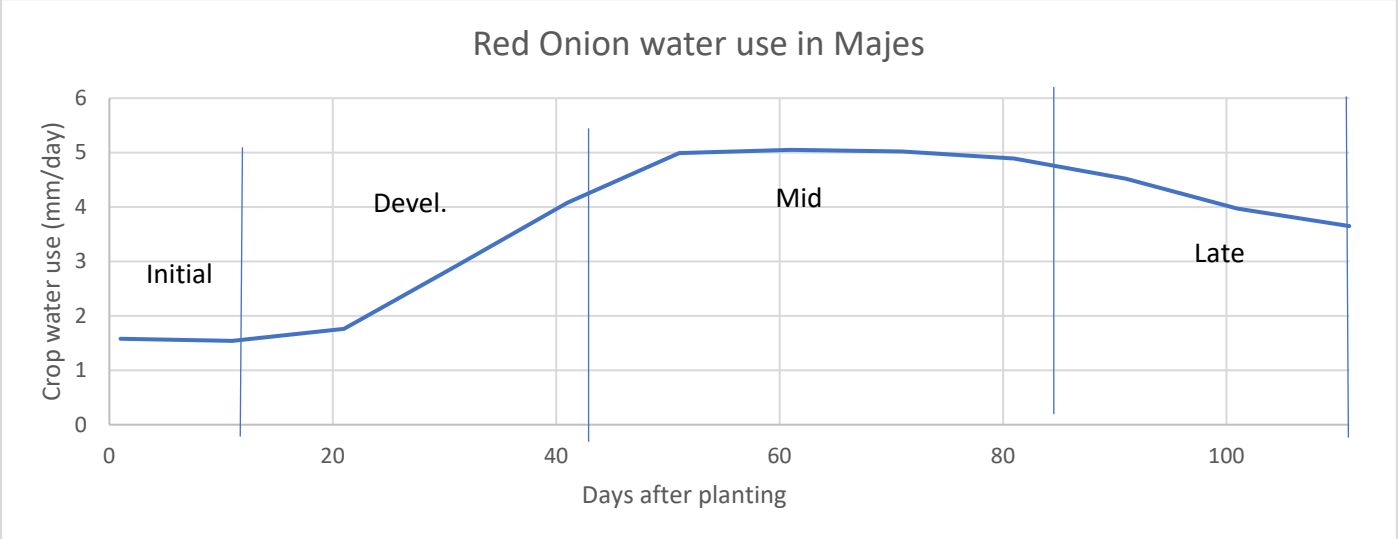

Figure 18. Red onion water use reaches a maximum of 5.0 mm/day at the Majes Irrigation

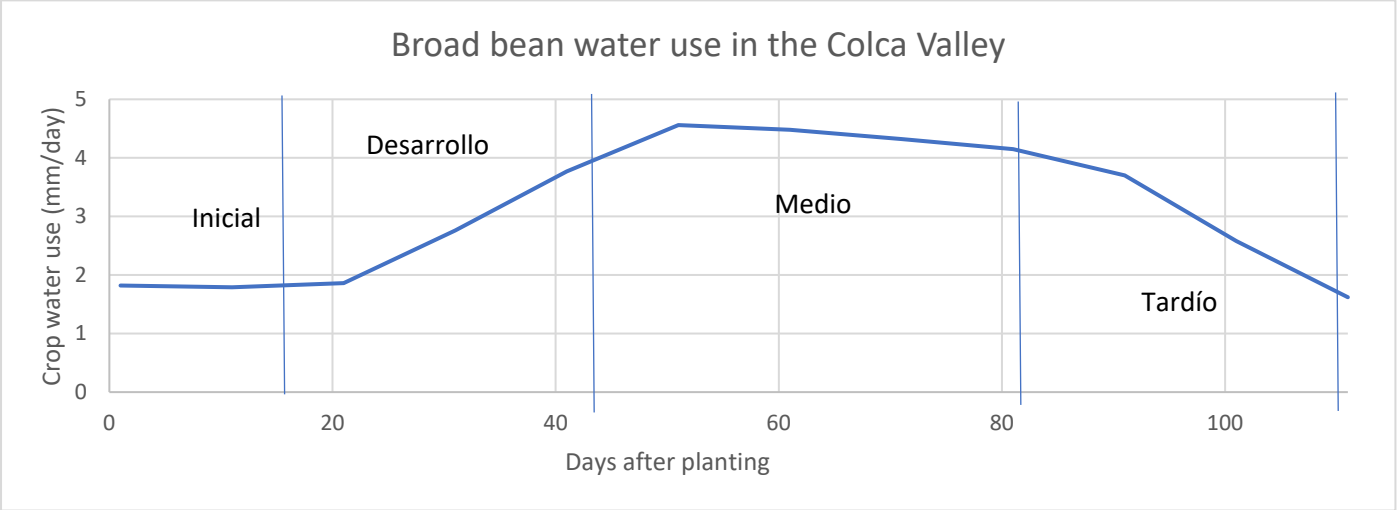

Figure 19. Broad beans water use reaches a maximum of 4.56 mm/day in the Colca Valley

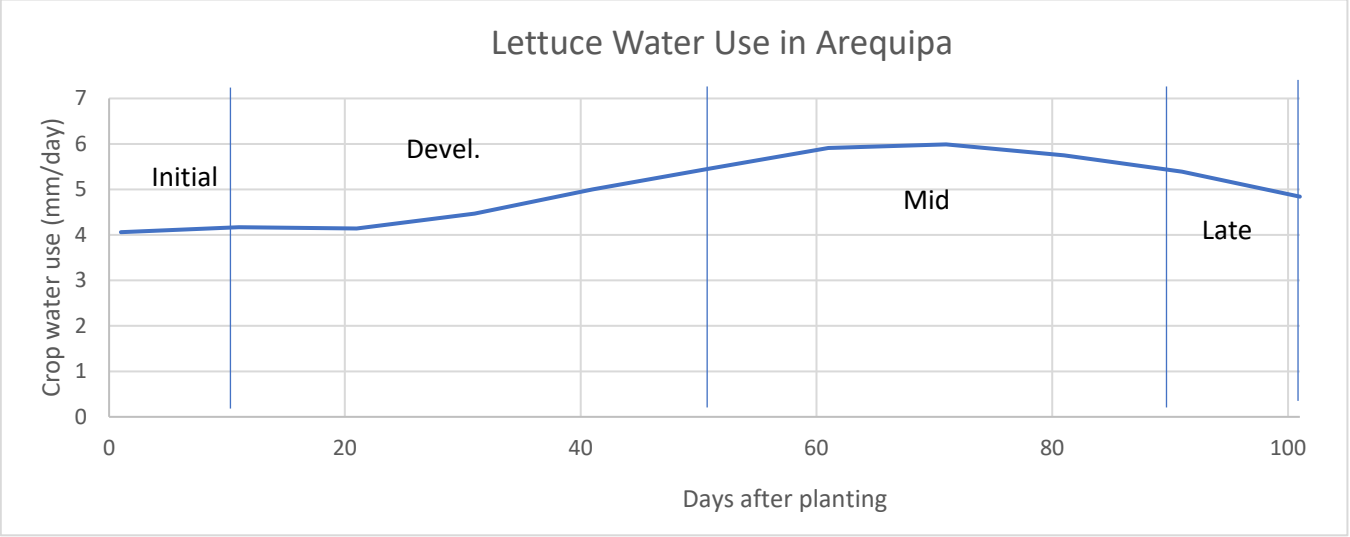

Figure 20. Lettuce water use reaches a maximum of 5.9 mm/day in the city of Arequipa

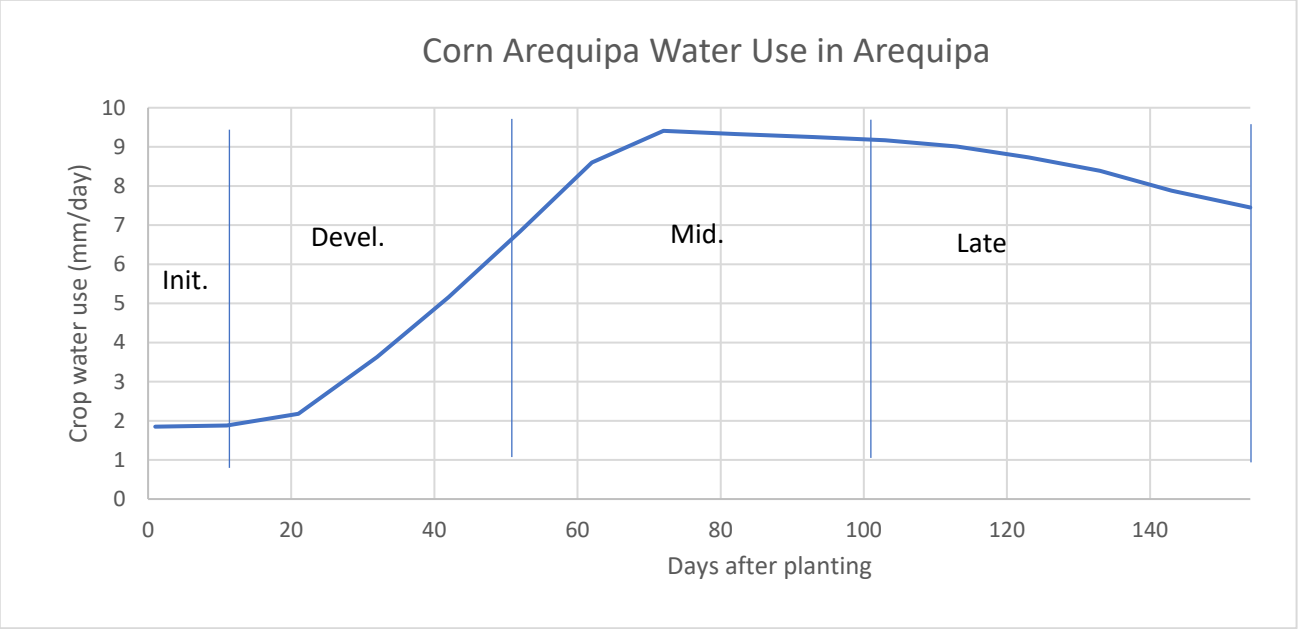

Figure 21. Corn water use reaches a maximum of 9.4 mm/day in the city of Arequipa

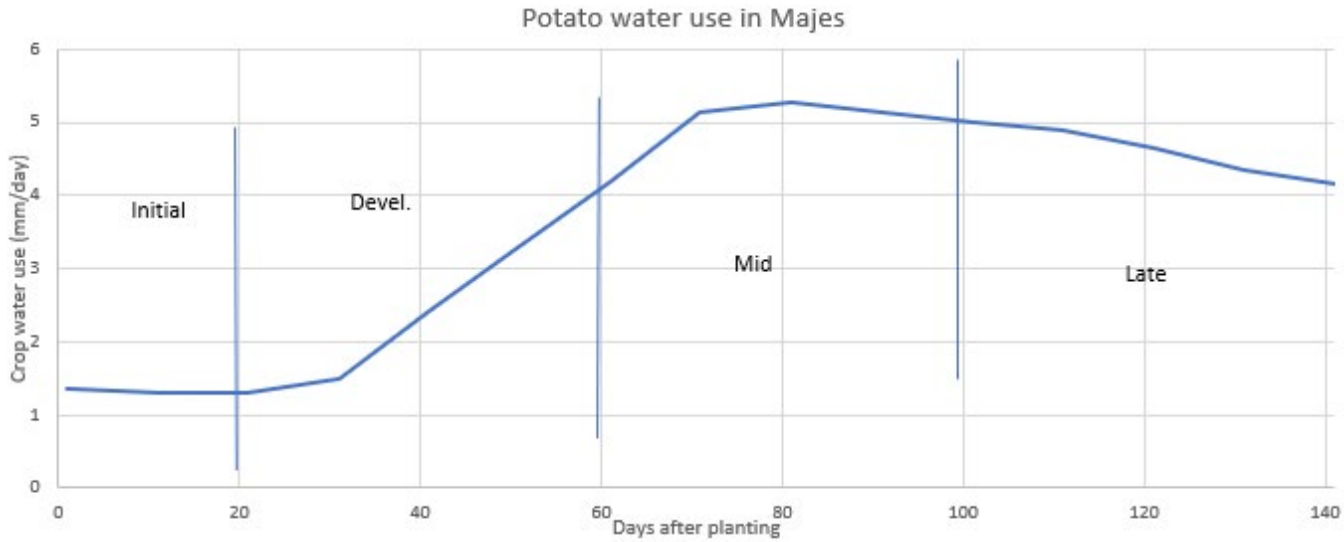

Figure 22, Potato water use reaches a maximum of 5.2 mm/day at the Majes Irrigation

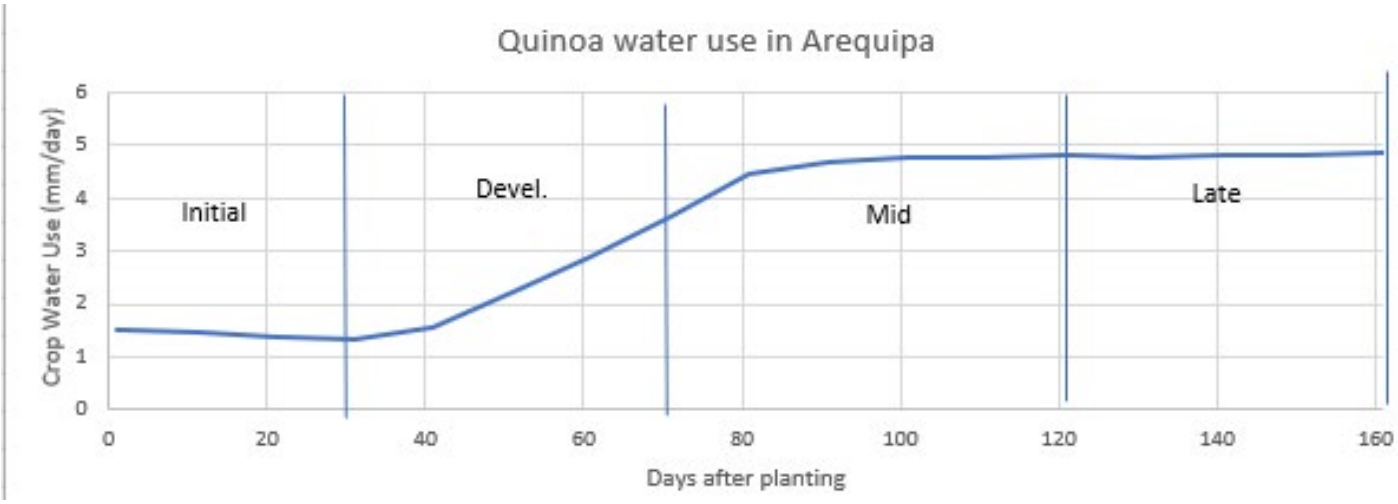

Figure 23. Quinoa water use reaches a maximum of 4.8 mm/day in the city of Arequipa

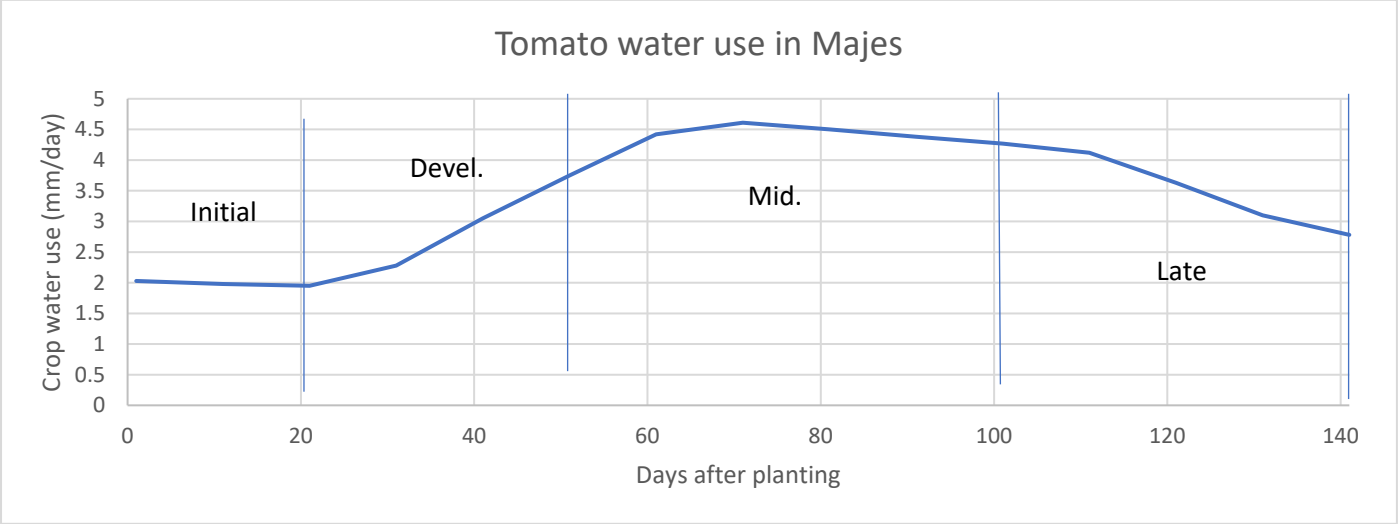

Figure 24. Tomato water use reaches a maximum of 4.6 mm/day at the Majes Irrigation

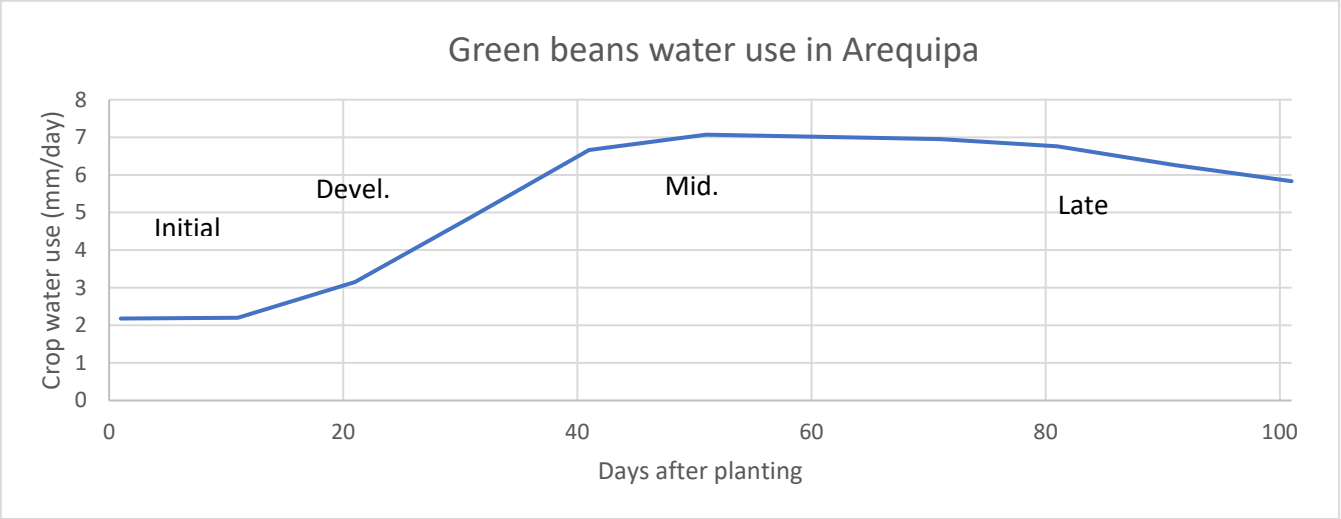

Figure 25. Green beans water use reaches a maximum of 7.0 mm/day in the city of Arequipa

Table 12. Average daily water need and maximum daily water need for crops in different locations

Location	**Crop Name**	**Maximum water use**	**Ratio of maximum consumption to average consumption**	**Day at maximum**
		mm/day	*mm/day*	
Arequipa	Alfalfa	6.10	1.8	280
	Broccoli	6.54	1.3	70
	Corn	9.41	1.4	70
	Garlic	7.92	1.3	80
	Green Beans	7.07	1.3	50
	Lettuce	5.99	1.2	70
	Onion	7.56	1.5	95
	Peas	5.23	1.1	70
	Quinoa	4.85	1.2	120
Majes	Artichoke	5.97	1.6	110

	Potato	5.28	1.5	80
	Pumpkin	4.03	1.4	60
	Red Onion	5.05	1.6	60
	Tomato	4.61	1.3	70
Colca	Alfalfa	4.69	1.9	310
	Barley	4.32	3.8	70
	Broad Beans	4.56	2.0	50
	Corn	4.71	2.5	60
	Peas	4.56	2.0	50
	Potato	4.37	1.3	70
	Quinoa	3.85	2.8	80

APPLICATIONS

AguaRiego provides a general overview of the water demand for different crops, depending on location, soil type and irrigation method. Farmers can use this information to determine which among their crops of interest require more water, or if they have access to sufficient water to support their irrigation needs.

Estimating available irrigation water volume and total irrigation volume needed

Worksheet 1 shows how to estimate flow rate in an irrigation canal, and estimate total daily volume available based on time, frequency of access and flow rate. Worksheet 2 can be used to estimate if you should have enough water on average to support the proposed mixture of crops.

Imagine that a farmer in Majes has three fields to plant, and he wants to figure out if he has access to enough irrigation water to grow maize, peas and quinoa at the same time. Worksheet 2 can help to answer this question. In the example Worksheet 2 shown below, the farmer should have plenty of water overall, because the daily water available is less than the total needed for his crops each day, on average. However, it might be necessary to stagger planting times to make sure that they do not experience water use peaks at the same time.

Worksheet 1: Available Irrigation Water

How do I calculate my irrigation water available for a month or season?

1. In your irrigation canal, measure a length (distance) like 5 meters.
    a. Length: ___ meters
2. Measure the depth and width of this canal in meters. Multiply these together to get area.
    a. _____ meters wide x ___ meters deep = ____ m^2
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.
4. Combine all measurements into the below equation:
    a. 1000 x Length x Width x Depth / time recorded
    b. 1000 x ___ meters x ___ meters x ___ meters / ___ s = **___ L/s is your flowrate**
    c. **OR ___** L/s / 1000 L/m^3 = **____ m^3/s**
5. Multiply by time to get total daily, monthly or seasonal water need
    a. Every time you have access to water, how many hours is it available for?
        i. *Flowrate* x 60 s/min x 60 min/hr x *Hours* available in a single day
        ii. ____ m^3/s x 60 s/min x 60 min/hr x ___ hr/day = **___ m^3/day**
    b. Write down how many days a month water is available
        i. *Daily water* x *# of Days*
        ii. ___ m^3/day x ___ days/month = **____ m^3/month**
    c. How many months long is the growing season for this crop? That is, for how many months do you want to irrigate this crop?
        i. *Monthly water* x *Months to irrigate*
        ii. ____ m^3/month x ____ = **_____ m^3/season**
6. Divide this by area you plan to irrigate to get water needs per hectare
    a. How many hectares do you want to irrigate?
        i. *Seasonal water* / *area*
            1. Hectares: ____ m^3/season / _____ ha = _____ m^3/ha/season
            2. Topos: _____ m^3/season / _____ topos = ____ m^3/topo/season
        ii. *Monthly water* / *area*
            1. Hectares: _____ m^3/month / _____ ha = _____ m^3/ha/month
            2. Topos: _____ m^3/month / _____ topos = _____ m^3/topos/month

Worksheet 1: *Example* of Available Irrigation Water

How do I calculate my irrigation water available for a month or season?

7. In your irrigation canal, measure a length (distance) like 5 meters.
    a. Length: _5_ meters
8. Measure the depth and width of this canal in meters. Multiply these together to get area.
    a. _0.25_ meters wide x _0.5_ meters deep = _0.125_ m^2
9. 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.
10. Combine all measurements into the below equation:
    a. 1000 x Length x Width x Depth / time recorded
    b. 1000 x _5_ meters x _0.25_ meters x _0.5_ meters / _50_ s = _12.5_ **L/s is your flowrate**
    c. **OR** _12.5_ L/s / 1000 L/m^3 = _0.0125_ **m^3/s**
11. Multiply by time to get total daily, monthly or seasonal water need
    a. Every time you have access to water, how many hours is it available for?
        i. *Flowrate* x 60 s/min x 60 min/hr x *Hours* available in a single day
        ii. _0.0125_ m^3/s x 60 s/min x 60 min/hr x _8_ hr/day = _360_ **m^3/day**
    b. Write down how many days a month water is available
        i. *Daily water* x *# of Days*
        ii. _360_ m^3/day x _15_ days/month = _5400_ **m^3/month**
    c. How many months long is the growing season for this crop? That is, for how many months do you want to irrigate this crop?
        i. *Monthly water* x *Months to irrigate*
        ii. 5400_ m^3/month x _4.5_ = _24300_ **m^3/season**
12. Divide this by area you plan to irrigate to get water needs per hectare
    a. How many hectares do you want to irrigate?
        i. *Seasonal water* / *area*
            1. Hectares: _24300_ m^3/season / _5_ ha = _4860_ m^3/ha/season
            2. Topos: _24300_ m^3/season / _15_ topos = 1620 m^3/topo/season
        ii. *Monthly water* / *area*
            1. Hectares: _5400_ m^3/month / _5_ ha = _1080_ m^3/ha/month
            2. Topos: _5400_ m^3/month / _15_ topos = _360_ m^3/topos/month

Worksheet 2: Verify Available Water

Water available per day (from Worksheet 1): _____

(1) Field	(2) Area (ha)	(3) Soil texture	(4) Irrigation method	(5) Efficiency of irrigation method	(6) Crop	(7) Avg. water need (m^3/month)	(8) Peak water need (m^3/day)

Average monthly irrigation requirement (9):

$(Area_1 \times AvgWater_1 / Efficiency_1) + (Area_2 \times AvgWater_2 / Efficiency_2) + \ldots$etc.

Peak irrigation water requirement per day (9):

$(Area_1 \times MaxWater_1 / Efficiency_1) + (Area_2 \times MaxWater_2 / Efficiency_2) + \ldots$etc.

Instructions:

(1) Enter the field location or description of the field

(2) Enter the estimated area of the field

(3) Enter the dominant soil texture for this field

(4) Enter the irrigation method possible for this field

(5) Enter the efficiency of the method of irrigation used, which can be found in Table 4

(6) Enter the crop you would like to plant for the next rotation

(7) Choose the Table 5 - 12 (depending on your location), read across for the desired crop, and then move to the row for the correct soil texture. Then find the column associated with the average water use for your area units. Record the monthly water need here.

(8) From Table 12, you can find the maximum daily water use for each crop in the three regions examined in this tool. Enter the value for the right region and crop for the peak water need.

(9) To find the monthy irrigation water requirement: For each crop multiply the cropped area (2) by the average water need (7) and divide these by the efficiency of the irrigation method (5). If you have several fields, add these calculated values for each field

(10) To find the maximum daily irrigation water requirement: For each crop, multiply the cropped area (2) by the maximum water need (8) and divide these by the efficiency of the irrigation method (5). If you have various crops or fields, add each of these calculated value for each field.

(11) If your daily water available exceeds your daily maximum water need AND your monthly available water exceeds the average monthly water need, you should have sufficient water to irrigate these crops for the whole season.

Worksheet 2 example: Check on Available Water

Water available per day (from Worksheet 1): 1600 m^3/day

(1) Field	(2) Area (ha)	(3) Soil texture	(4) Irrigation method	(5) Efficiency of irrigation method	(6) Crop	(7) Avg. water need (m^3/month)	(8) Peak water need (m^3/day)
1	0.5	Silt loam	Sprikler	75%	Green beans	1580	7.07
2	0.75	Silt loam	Gravity	60%	Garlic	1790	7.92
3	1	Silt loam	Gravity	60%	Quinoa	1259	4.85

Monthly irrigation water need (9): ($Area_1$ x $AvgWater_1$ / $Efficiency_1$) + ($Area_2$ x $AvgWater_2$ / $Efficiency_2$) + ….. etc.

(0.5 x 1580/0.75) + (0.75 x 1790/0.6) + (1 x 1259/0.60) = 5389 m^3/month → less than 5400 m^3/month

Maximum daily irrigation water need (10): (0.5 x 7.07 / 0.75) + (0.75 x 7.92 / 0.6) + (1 x 4.85 / 0.6) = 22.7 m^3/day → less than 360 m^3/day

The monthly water need is less that the monthly available water, and the maximum daily is less than the daily available water, so this plan works for the quantity of water available.

Sizing a reservoir in the Colca Valley

In some places, reservoirs are allowed and necessary for having access to water in the dry season, especially on the north side of the Colca River where there is no canal to draw from. The storage volume of water needed depends on which crop is chosen and how much water is needed for the entire growing season. Figure 11 below compares reservoir area needed if the reservoir is built 3 meters deep based on area of crops planted and irrigated. For example, the size of a reservoir would need to be much bigger if growing corn or alfalfa than if growing barley. For irrigating 2 hectares, a reservoir to store enough water to irrigate barley throughout the growing season would only need to be 0.2 ha. On the other hand, the same area of alfalfa would need a 1 ha reservoir to store all necessary water, which is 5 times larger than what is needed for barley.

It should be noted that this sizing does not consider inputs like stream or spring inflow during the growing season. If there is streamflow during the same time irrigation is needed, reservoir size can be reduced. Also, crops grown during the rainy season will need less irrigation, so these reservoirs can be reduced to account for any rain.

Figure 11. Area needed for a 3-meter-deep reservoir based on irrigated area for alfalfa, barley, corn, and potato.

Worksheet 3: Sizing a reservoir

Total water needed per month (9 from Worksheet 2): _____ m^3/month

Average monthly water available (from Worksheet 1): _____ m^3/month

Number of months plants grown: ____ months

Number of months water available to fill reservoir in a year: _____ months

Total water needed monthly	
Number of months plants grown	
(1) Total seasonal water need	

Average monthly water available	
Number of months water available	
(2) Total water available to store	

If your total water available to store (2), exceeds total seasonal water need (1), there will be enough water through the season to provide proper irrigation. If not, there will be an insufficient amount, but a reservoir can be sized to store as much water as possible.

Proceed with sizing a reservoir based on the smaller of the two quantities between (1) and (2).

Decide on average reservoir depth desired or that is possible based on limitations (in meters).

Divide total water (1) or (2) by average depth to get reservoir area needed in m^2.

Convert m^2 to hectares by dividing by 10,000.

Average depth of reservoir required:	
Average depth of reservoir desired/possible (in meters)	
Reservoir area (m^2)	
Area of the reservoir (ha)	

Worksheet 3: Sizing a reservoir

Total water needed per month (9 from Worksheet 2): 5389 m^3/month

Average monthly water available (from Worksheet 1): 5400 m^3/month

Number of months plants grown: 6 months

Number of months water available to fill reservoir in a year: 8 months

Total water needed monthly	5389 m^3/month
Number of months plants grown	6 meses
(3) Total seasonal water need	32,334 m^3

Average monthly water available	5400 m^3/month
Number of months water available	8
(4) Total water available to store	43,112 m^3

If your total water available to store (2), exceeds total seasonal water need (1), there will be enough water through the season to provide proper irrigation. If not, there will be an insufficient amount, but a reservoir can be sized to store as much water as possible.

Proceed with sizing a reservoir based on the smaller of the two quantities between (1) and (2).

Decide on average reservoir depth desired or that is possible based on limitations (in meters).

Divide total water (1) or (2) by average depth to get reservoir area needed in m^2.

Convert m^2 to hectares by dividing by 10,000.

Average depth of reservoir required:	32334 m^3
Average depth of reservoir desired/possible (in meters)	4
Reservoir area (m^2)	32,334 m^3/4 m = 8,083.5 m^2
Area of the reservoir (ha)	8,083.5 / 10,000 m^2/ha = **0.81 ha**

ABOUT THE TEAM

Development team

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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.

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References

Daneshvar, F., J.R. Frankenberger, L.C. Bowling, K.A. Cherkauer, and M.J.C. Villalta Soto. 2020. Estimated soil physical properties for hydrologic modeling in Arequipa, Peru. Purdue University Research Repository. doi:10.4231/N5MX-9W30

FAO (Food and Agriculture Organization of the United Nations) CropWat. https://www.fao.org/landwater/databases-and-software/cropwat/en/, accessed in 2019.

Moraes, A.G.L., L.C. Bowling, C.R. Zeballos-Velarde, F. Daneshvar, A.H. Watkins, and K.A. Cherkauer. 2022. Terrain Sensitive Climate Mapping for Arequipa Department in Peru. *International Journal of Climatology*: 1-23. https://doi.org/10.1002/joc.7730

CFSR (Climate Forecast System Reanalysis). https://climatedataguide.ucar.edu/climate-data/climate-forecastsystem-reanalysis-cfsr, accessed in 2019.

MINAGRI (Ministerio de Desarrollo Agrario y Riego). 2010. Sistema de Información de Abastecimiento y Precios (SISAP) Versión 2.0. Lima, Peru. http://sistemas.midagri.gob.pe/sisap/portal2/ciudades/#