Application of the Volumetric Water Benefit Accounting (VWBA) Withdrawal Method to Incorporate Precipitation Variability for Agricultural Activities that Reduce Water Applied to Crops

A guidance document prepared by Bluerisk[1] and Kilimo[2]

JENNA STEWART[1], JON RADTKE[1], TIANYI LUO[1], JAIRO TRAD[2], ANDREA RAMOS[2], ROSARIO GUMUCIO[2], GUADALUPE AVILA[2], SOFIA DELLA COSTANZA CROXATTO[2], PAOLA FLORES[2], JUSTINA SERRANO[2], AND DIEGO REYES[2]

Summary

Building on the principles, steps, and methods outlined in Volumetric Water Benefit Accounting (VWBA) 2.0, this guidance document provides an example application of the withdrawal method to explicitly account for precipitation in Volumetric Water Benefit (VWB) estimates to isolate the additionality of activities and reduce the risk of overclaiming VWBs. This application of the withdrawal method reduces variability by considering average historical precipitation trends to improve consistency in VWB estimates year to year.

Intended for activities that reduce the volume of water applied to crops (e.g., irrigation efficiency, irrigation conversion, and crop or crop system interventions), this guidance document includes information on the example application of the withdrawal method, best practice guidance for data collection and use, example case studies for applying the method, and an example data collection survey for farmers.

Contents

Acknowledgments

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1. Introduction

Agriculture accounts for roughly 70 percent of freshwater withdrawals globally (UNESCO 2025). With approximately half of the world's population exposed to water scarcity for at least one month of the year (IPCC 2022), implementing interventions to reduce agricultural water demand can have significant benefits on water supplies. In highly regulated or water-scarce areas, these shifts in agricultural practices can become critical to relieving pressure on limited water resources. By implementing activities such as irrigation efficiency, irrigation conversion, or crop conversion, farmers have the potential to reduce water withdrawals, water consumption, or both, which can positively affect surrounding communities and ecosystems.

1.1 Problem statement

To quantify the reduced water demand resulting from irrigation and crop system changes, corporate water stewardship practitioners and project implementers can estimate volumetric water benefits (VWBs) following the interim guidance from Volumetric Water Benefit Accounting 2.0 (VWBA 2.0) (VWBA 2.0 Interim Installment 4 Guidance on Updated VWB Calculation Methods). The VWBA 2.0 methods are presented at a high level so that they can be used for multiple activities, and do not necessarily provide detailed recommendations for all potential applications. For example, for the withdrawal method, VWBA 2.0 does not specify how to incorporate the effect of precipitation to account for the role of weather in agricultural scenarios, or how to balance interannual fluctuations in precipitation to help address potential high variabilities in VWBs year to year. Depending on the local context, the method of balancing precipitation fluctuations presented in this document may be applicable to some agricultural interventions.

1.2 Objectives

Building on the VWBA 2.0 principles, steps, and methods, this document provides guidance for applying the water withdrawal method for activities that reduce the volume of water applied to crops, including irrigation efficiency, irrigation conversion, and crop or crop system interventions. The objective of this guidance is to provide a specific application of the withdrawal method for practitioners who wish to account for variability in precipitation and reduce precipitation-driven VWB variability. This guide describes an application of the withdrawal method that:

- **Explicitly accounts for precipitation in VWB estimates to isolate the additionality of the activity and reduce the risk of overclaiming VWBs** by providing justification that precipitation variability was considered when calculating VWBs from agricultural water demand reduction activities; and
- **Reduces variability by improving consistency in VWB estimates year to year** by considering average historical precipitation trends rather than directly comparing annual precipitation volumes, which can fluctuate significantly from year to year.

Key aspects of this withdrawal method application include:

- **Accounting for variability in precipitation** between years and seasons to better isolate the changes that occur in the volume of irrigation water applied from agricultural activities rather than from climate variability, because precipitation can affect how much irrigation water is applied each year to meet crop water requirements;

- **Estimating effective precipitation** to consider only the portion of precipitation that is available to crops to avoid over- or underestimating VWBs; and
- **Recommending applicable spatial and temporal boundaries and data requirements** for quantifying and claiming VWBs from agricultural activities.

Although VWBA 2.0 includes both the withdrawal and consumption methods for estimating water demand reduction from agricultural activities, this guidance focuses on a specific application of the withdrawal method. Additional considerations are needed when explicitly accounting for precipitation in the consumption method; they are not covered here.

This guidance is intended to stimulate timely discussion and critical feedback and to influence ongoing discussions regarding VWBA. We recognize that other methods exist to account for precipitation, to reduce variability, and to reduce the risk of overclaiming VWBs, and therefore the content of this guidance may be revised over time.

1.3 Applicability

Although the approach presented in this document describes a specific application of the withdrawal method, users are encouraged to consider the local project context when determining whether to use the approach described here. This method is applicable to:

- **Calculation of annual or seasonal VWBs from agricultural water withdrawal reduction activities** that explicitly account for climate data for that year or season; and
- **Agricultural activities that impact how water is applied to crops at the field level**, such as irrigation efficiency or irrigation conversion techniques that reduce the amount of water applied to crops.

A specific application of the withdrawal method is presented in this document. The original VWBA 2.0 withdrawal method is recommended for users seeking to quantify VWBs where precipitation and additionality of the activity are implicitly considered. There may be other methods to incorporate precipitation and climate variability explicitly into the withdrawal method other than what is proposed in this document.

What this method is:

- A specific application of the withdrawal method to account explicitly for the additionality of activities by reducing variability in resulting VWBs driven by changes in precipitation
- Applicable to agricultural activities that impact how water is applied to crops at the field level

What this method is not:

- Broadly applicable to all agricultural water demand reduction activities
- A required modification of the VWBA withdrawal method
- A new requirement to estimate VWBs resulting from irrigation activities
- An application of the consumption method

2. Method

2.1 VWBA 2.0 objectives and indicators

This guidance enables the estimation of VWBs of activities that reduce water withdrawal.

VWBA 2.0 Objectives	VWBA 2.0 Output indicator	Activities
Reduced water demand	Reduced withdrawal	Activities that change how water is applied to crops at the field level (e.g., irrigation efficiency, irrigation conversion, or crop or crop system interventions)

The calculation guidelines given here are for agricultural activities that affect how water is applied to crops at the field level. These include:

- Irrigation efficiency (e.g., reducing water applied to crops by deploying technology to improve the efficiency of crop irrigation plans, or by implementing agricultural best management practices);
- Irrigation conversion (e.g., reducing water applied to crops by converting from conventional irrigation to an irrigation method that uses less water); and
- Crop or crop system interventions (e.g., reducing water applied to crops by converting to less water-intensive crops).

In addition to VWBs from reduced withdrawal, these activities have the potential to contribute to reduced runoff, reduced erosion, increased water availability for other stakeholders in the basin, and reduced carbon emissions.

2.2 Methodology description

Per the VWBA 2.0 withdrawal method, the VWB from agricultural activities can be estimated as the difference in withdrawal volume for the with-project condition compared with the volume for the without-project condition (1).

$$\mathbf{VWB = Withdrawal}_{\text{Without-project}} - \mathbf{Withdrawal}_{\text{With-project}} \quad (1)$$

Precipitation is implicitly considered in the VWB equation above (i.e., withdrawal amounts are dependent on precipitation) and can impact the magnitude of annual VWBs when precipitation varies significantly. In this guidance, precipitation is explicitly considered in the equation to remove variability in resulting VWBs driven by changes in precipitation (2). For more details on the data requirements and calculations, see Appendix A, and for example case studies, see Appendix B.

$$\mathbf{VWB} = \mathbf{Irr}_{\text{Without-project}} - \mathbf{Irr}_{\text{With-project}} + \mathbf{Diff\ in\ P} \quad (2)$$

$$\mathbf{Diff\ in\ P} = \mathbf{Avg\ P}_{\text{Before project year}} - \mathbf{Avg\ P}_{\text{Including project year}} \quad (3)$$

Where

Irr is the annual irrigation water applied

Diff in P is the difference in annual precipitation

Avg P is the average historic annual precipitation

The difference in precipitation is calculated by comparing a historic average precipitation with an updated historic average precipitation that also considers the project year (3). The historic average precipitation is calculated as an average precipitation over a representative historic period of at least 5 years with a recommendation (and a suggested maximum) of 10 years prior to project implementation, where N is the number of years (4).

$$\text{Avg P}_{\text{Before project year}} = \frac{P_1 + P_2 + \ldots + P_N}{N} \quad (4)$$

Where

Avg P is the average historic annual precipitation

P is the precipitation per year

N is the number of years

For the project year, precipitation is calculated as the average precipitation over the same historic period plus the precipitation from the project year (5).

$$\text{Avg P}_{\text{Including project year}} = \frac{P_1 + P_2 + \ldots + P_N + P_{\text{Project year}}}{N + 1} \quad (5)$$

When calculating the difference in precipitation, it is recommended to consider only the portion of precipitation that is made available to crops (i.e., the effective precipitation), which is governed by the timing and intensity of precipitation, crop type, growing cycles, soil types, and other climatic factors.

To calculate effective precipitation, practitioners are encouraged to find equations that are applicable to the local context of the project (see Dastane 1978 for examples). If data are unavailable to calculate effective precipitation, practitioners can use simplified equations that apply to the location of interest, such as an example for South America that represents a practical application (Box 1). Precipitation for each year is the sum of daily effective precipitation for the crop season/s of interest (6).

$$P = \sum \text{Effective P}_{\text{Daily}} \quad (6)$$

Where

P is the precipitation per year

Effective P is the daily effective precipitation

Box 1. Example calculation of effective precipitation in South America using a simplified equation

For each day:

- If $P_{\text{Daily}} < 15$ mm, then:

  $$\text{Effective P}_{\text{Daily}} = P_{\text{Daily}}$$

- If $P_{\text{Daily}} > 15$ mm, then:

  $$\text{Effective P}_{\text{Daily}} = 2.43 * (P_{\text{Daily}}^{0.67})$$

Required Inputs

Variable	Input
$Irr_{\text{Without-project}}$	Annual measured or reported irrigation water applied during the without-project condition from data spanning at least one year, with a recommendation of three years or more, prior to project implementation.
$Irr_{\text{With-project}}$	Annual measured or reported irrigation water applied during the with-project condition for the project year.
Diff in P	The difference between the average historic annual precipitation before the project year and a new average for historic annual precipitation that includes the project year.
$Avg\ P_{\text{Before project year}}$	Average annual precipitation over a representative historic period of at least 5 years with a recommendation (and a suggested maximum) of 10 years prior to project implementation. Precipitation for each year or season is calculated as the sum of daily effective precipitation.
$Avg\ P_{\text{Including project year}}$	Average annual precipitation over the same historic period including the precipitation from the project year. Precipitation for each year or season is calculated as the sum of daily effective precipitation.
P_{Daily}	Daily precipitation from a nearby representative station spanning a historical period of at least 5 years with a recommendation (and a suggested maximum) of 10 years. The timeframe should be selected to reflect the local context and conditions.
$Effective\ P_{\text{Daily}}$	The amount of daily precipitation available to crops based on a representative threshold and/or formula for the local context.

For more information on data requirements and an example data collection survey for farmers, see **Appendix A** and **Appendix C**.

2.3 Spatial and temporal boundaries

Considerations of spatial and temporal boundaries for the application of this specific method are provided below.

2.3.1 Spatial boundaries

The project area should be defined by the irrigated lot or lots where the improvements are expected to take place. Spatial boundaries for the project area should be provided by the farmer or by satellite image, defining the basin of interest and the area to be included in the project as part of the irrigated crop area where the VWBs will be generated.

2.3.2 Temporal boundaries

- **Irrigation data:** Irrigation data for the without-project condition should span at least one year, with a recommendation of three years of data or more, before project implementation. To ensure that the VWBs still represent efficiency gains and continuous improvement over time, this application of the withdrawal method recalculates the without-project condition with a new average every few years according to an appropriate timeframe for the local project context. For the with-project condition, irrigation amounts should be the irrigated water applied after project implementation.

- **Precipitation data:** Precipitation data should be from a representative historical period and should span at least 5 years with a recommendation (and a suggested maximum) of 10 years. Although a 30-year average is standard for a climatological normal average, a 5- to 10-year precipitation record is proposed here because it allows capturing enough data to smooth out year-to-year variability while still reflecting recent climatic conditions; this can help to avoid overestimating VWBs. Although including more years in the average historic precipitation calculation will reduce the effect of the project year's precipitation, the recommendation of 10 years provides a balanced approach and is based on practical project experience (see Appendix C). Additionally:
  - A minimum of five years captures at least one full El Niño–Southern Oscillation, which is one of the main drivers of precipitation.
  - A maximum of 10 years helps avoid including outdated rainfall patterns that no longer reflect current trends, which is important in rapidly evolving climate change scenarios.
  - High-quality long-term data (beyond 10 years) are often hard to obtain or may involve inconsistencies because of changes in measurement techniques or station relocations.
  - Although the 5- to 10-year window provides a practical compromise, it should be used alongside an understanding of longer-term extremes to ensure that rare but impactful events (such as multiyear droughts or intense storms) are not overlooked.

- **Annual claims:** VWBs may be quantified at the end of each crop season and should reflect the appropriate growing season for the crop. To make annual claims, VWBs from each season of interest should be summed to an annual VWB.

3. Limitations

- **Extreme events:** While the VWBA 2.0 withdrawal method implicitly considers climate variability, this application of the withdrawal method can better isolate the changes in irrigation water derived from agricultural activities rather than from climate variability. However, its use is limited in project years with extreme events, such as prolonged flooding during the crop season (i.e., no or significantly reduced irrigation was required, so that VWBs are artificially high), or droughts (i.e., significantly increased irrigation was required, so that VWBs are artificially low). In situations where no irrigation was applied during that crop season or year (i.e., during prolonged extreme floods), or the calculated VWB is negative (i.e., for extreme droughts) it is recommended not to claim a VWB for that project year.
- **Time frame:** Three years (or less) of irrigation data for the without-project condition can lead to a false baseline if the climate in those years is abnormal. Practitioners are encouraged to consider the historical climate and irrigation trends for the region to justify the irrigation volumes for the without-project condition.

Appendix A. Best practice guidance for data collection and use

Appendix A1. Checklist for data collection and use

☐ Relevance	Ensure that the use of data and calculations is appropriate for the intended purpose.
☐ Completeness	Consider all relevant information that may affect the without-project and with-project calculations.
☐ Consistency	Use data and calculations that allow meaningful and valid comparisons.
☐ Transparency	Provide clear and sufficient information for reviewers to assess the credibility and reliability of the calculations.
☐ Accuracy	Reduce uncertainties as much as is practical or feasible.
☐ Conservative approach	Use conservative assumptions, values, and procedures when uncertainty is high in the calculations.
☐ Additionality	The project must demonstrate that the improvements result in reduced withdrawal. This is important because it indicates a net benefit.

Appendix A2. Ranking for sources of irrigation and precipitation data

Ranking	Irrigation data	Precipitation data
Good	Reference irrigation amount for the crop and basin if obtained from a credible local or national research institution	Modeled estimates from a credible local, national, or global model, with documentation justifying the model selection and its applicability in the local context (for small farms or those in mountainous areas, satellite-based precipitation estimates might not be as accurate as they are elsewhere)
Better	Calculations from a fixed irrigation schedule (i.e., farmers usually irrigate a fixed amount every week during the crop season)	Not applicable
Best	Irrigation records (i.e., measurements) for the project year and for at least 1 year (with a recommendation of three years or more) prior to project implementation	Measurements for the project year and for at least 5 years prior to project implementation with a recommendation (and suggested maximum) of 10 years from a nearby representative station, accounting for any changes in topography that could impact precipitation amounts compared with the project location

Appendix B: Case studies

Appendix B1. Case Study: Irrigation efficiency in the Bravo San Juan Basin for a high-precipitation year

<table>
<tr><th colspan="4">Project overview</th></tr>
<tr><td>Activity</td><td colspan="3">Irrigation efficiency</td></tr>
<tr><td>Shared water challenges addressed</td><td colspan="3">The Bravo San Juan basin is located within Monterrey's metropolitan area, where more than 90% of the state's population dwells. Over time, population growth has led to a significant decrease in available water per person (Cantú Ayala, et al. 2018). Research has demonstrated that “improving sustainable management practices could make it possible to meet current conventional water demands for agriculture, population, industry, [and] riparian environments and ease social tension” (Návar Cháidez 2017). The shared water challenges addressed by this project are water scarcity and the need for effective water resource management.</td></tr>
<tr><td>Project description</td><td colspan="3">In this project, Kilimo is working with five farmers and a total of 59 hectares within the basin. The project improves irrigation efficiency using Kilimo's technology of artificial intelligence (AI), big data, meteorological data, and historical irrigation data to help farmers design precise irrigation plans, reducing water waste.</td></tr>
<tr><td>Location</td><td colspan="3">Bravo San Juan Basin, Monterrey, Mexico</td></tr>
<tr><td>Project start date</td><td colspan="3">October 2023</td></tr>
<tr><td>Project end date</td><td colspan="3">October 2026</td></tr>
<tr><td rowspan="5">Project changes</td><td>Condition</td><td>Without-project</td><td>With-project</td></tr>
<tr><td>Irrigation system:</td><td>Drip irrigation</td><td>Drip irrigation</td></tr>
<tr><td>Crop:</td><td>Oranges</td><td>Oranges</td></tr>
<tr><td>Irrigation management:</td><td>Irrigation decisions were made based on “calicatas” (soil pits or trenches dug in a specific point of the field to examine soil humidity)</td><td>Irrigation decisions are being made based on real climate, soil and crop data, following Kilimo’s platform recommendations</td></tr>
<tr><td>Annual precipitation:</td><td>Average historic precipitation from the past 10 years:
551 mm/year</td><td>Precipitation for the project year:
660 mm/year</td></tr>
</table>

<table>
<tr><th colspan="3">VWB calculations</th></tr>
<tr><td>VWB indicator</td><td colspan="2">Reduced withdrawal</td></tr>
<tr><td rowspan="8">VWB calculations</td><td colspan="2">Effective precipitation was calculated daily using the equations in Box 1.</td></tr>
<tr><td>Key characteristics</td><td>Volume (m^3/year)</td></tr>
<tr><td>Avg $P_{\text{Before project year}}$</td><td>253,182</td></tr>
<tr><td>Avg $P_{\text{Including project year}}$</td><td>263,947</td></tr>
<tr><td>Diff in P</td><td>−10,765</td></tr>
<tr><td>$Irr_{\text{Without-project}}$</td><td>753,726</td></tr>
<tr><td>$Irr_{\text{With-project}}$</td><td>551,823</td></tr>
<tr><td>VWB</td><td>191,137</td></tr>
<tr><td>Co-benefits</td><td colspan="2">▪ Education: Agronomic training was provided to help farmers adopt the technology.
▪ Reduction in electricity use for farmers: When irrigation equipment operates more efficiently, its usage decreases, leading to lower electricity consumption and, consequently, a reduced electricity bill.
▪ Increased economic income: Through its ecosystem services payment program, Kilimo provides cash payments to farmers for the positive externalities they generate in the watershed.</td></tr>
<tr><td>Comments</td><td colspan="2">Precipitation data were obtained from weather stations located in the field or within a ~10 km radius and irrigation data were obtained from irrigation controllers of irrigation equipment or farmers' daily irrigation input on the Kilimo platform, depending on the case.</td></tr>
<tr><td>Other considerations</td><td colspan="2">Precipitation was high for the project year in comparison with the historical average (i.e., 109 mm/year higher). The increased precipitation was accounted for in the method to be more conservative and avoid overestimating the VWB.</td></tr>
</table>

Appendix B2. Case Study: Irrigation efficiency in the Lago Bustillos Basin for a low-precipitation year

<table>
<tr><th colspan="4">Project overview</th></tr>
<tr><td>Activity</td><td colspan="3">Irrigation efficiency</td></tr>
<tr><td>Shared water challenges addressed</td><td colspan="3">The Lago Bustillos Basin, situated between the Sierra Madre Occidental and the Mexican plateau in the central region of Chihuahua, Mexico, experiences a semiarid climate with minimal precipitation (Amado Álvarez et al., 2016). Challenges such as competition among diverse land uses, the scarcity of surface water, and the overexploitation of aquifers are critical issues in regions like this, marked by arid and semiarid agroecological conditions (Alatorre et al., 2019). The shared water challenges addressed by this project are water scarcity and the need for effective water resource management.</td></tr>
<tr><td>Project description</td><td colspan="3">In this project, Kilimo is working with four farmers and a total of 106 hectares within the basin. The project improves irrigation efficiency using Kilimo's technology of AI, big data, meteorological data, and historical irrigation data to help farmers design precise irrigation plans, reducing water waste.</td></tr>
<tr><td>Location</td><td colspan="3">Lago Bustillos Basin, Chihuahua, Mexico</td></tr>
<tr><td>Project start date</td><td colspan="3">October 2023</td></tr>
<tr><td>Project end date</td><td colspan="3">October 2026</td></tr>
<tr><td rowspan="5">Project changes</td><th>Condition</th><th>Without-project</th><th>With-project</th></tr>
<tr><td>Irrigation system:</td><td>Drip irrigation</td><td>Drip irrigation</td></tr>
<tr><td>Crop:</td><td>Apples</td><td>Apples</td></tr>
<tr><td>Irrigation management:</td><td>Irrigation decisions were made based on "calicatas" (soil pits or trenches dug in a specific point of the field to examine soil humidity)</td><td>Irrigation decisions are being made based on real climate, soil, and crop data, following Kilimo's platform recommendations</td></tr>
<tr><td>Annual precipitation:</td><td>Average historic precipitation from the past 10 years:
440 mm/year</td><td>Precipitation for the project year:
252 mm/year</td></tr>
</table>

VWB calculations		
VWB indicator	Reduced withdrawal	
VWB calculations	Effective precipitation was calculated daily using the equations in Box 1.	
	Key characteristics	**Volume (m^3/year)**
	Avg $P_{\text{Before project year}}$	408,907
	Avg $P_{\text{Including project year}}$	393,347
	Diff in P	15,560
	$Irr_{\text{Without-project}}$	2,335,207
	$Irr_{\text{With-project}}$	2,465,757
	VWB	**–114,990**
Co-benefits	▪ **Education:** Agronomic training was provided to help farmers adopt the technology. ▪ **Reduction in electricity use for farmers:** When irrigation equipment operates more efficiently, its usage decreases, leading to lower electricity consumption and, consequently, a reduced electricity bill. ▪ **Increased economic income:** Through its ecosystem services payment program, Kilimo provides cash payments to farmers for the positive externalities they generate in the watershed.	
Comments	Precipitation data were obtained from weather stations located in the field or within a ~10 km radius and irrigation data were obtained from irrigation controllers of irrigation equipment or farmers' daily irrigation input on the Kilimo platform, depending on the case.	
Other considerations	Precipitation was low for the project year in comparison with the historical average (i.e., 188 mm/year lower). The decreased precipitation was accounted for in the method to avoid underestimating the VWB. However, because the VWB resulted in a negative amount (i.e., the irrigation amount was higher under the with-project condition, even when considering the difference in precipitation), it is recommended not to claim a VWB for the selected project year.	

Appendix B3. Case Study: Irrigation efficiency in the Arroyo Tijuana Basin for an average precipitation year

<table>
<tr><th colspan="4">Project overview</th></tr>
<tr><td>Activity</td><td colspan="3">Irrigation efficiency</td></tr>
<tr><td>Shared water challenges addressed</td><td colspan="3">The Tijuana River Watershed, a binational basin of 4,532 km2 (73% in Baja California, 27% in California), faces pressing challenges. These include a rapidly growing population, the need for effective water resource management, flood control, water quality concerns (heavy metals and sewage), and the loss of significant plant and animal species (San Diego State University, 2013). Furthermore, climate change forecasts anticipate temperatures to rise and precipitation to decline in the next 20 years, impacting urban water availability (Rodríguez Esteves, 2020). The shared water challenge addressed by this project is water scarcity and the need for effective water resource management.</td></tr>
<tr><td>Project description</td><td colspan="3">In this project, Kilimo is working with five farmers and a total of 31 hectares within the basin. The project improves irrigation efficiency using Kilimo’s technology of AI, big data, meteorological data, and historical irrigation data to help farmers design precise irrigation plans, reducing water waste.</td></tr>
<tr><td>Location</td><td colspan="3">Arroyo Tijuana Basin, Tijuana, Mexico</td></tr>
<tr><td>Project start date</td><td colspan="3">October 2023</td></tr>
<tr><td>Project end date</td><td colspan="3">October 2026</td></tr>
<tr><td rowspan="5">Project changes</td><td>Condition</td><td>Without-project</td><td>With-project</td></tr>
<tr><td>Irrigation system:</td><td>Drip irrigation</td><td>Drip irrigation</td></tr>
<tr><td>Crop:</td><td>Wine grapes</td><td>Wine grapes</td></tr>
<tr><td>Irrigation management:</td><td>Irrigation decisions were made based on the advisory's “historical experience” (human-based) and “calicatas” (soil pit or trench dug in a specific point of the field to examine soil humidity)</td><td>Irrigation decisions are being made based on real climate, soil, and crop data, following Kilimo’s platform recommendations</td></tr>
<tr><td>Precipitation:</td><td>Average historic precipitation from the past 10 years:
150 mm/year</td><td>Precipitation for the project year:
147 mm/year</td></tr>
</table>

<table>
<tr><th colspan="3">VWB calculations</th></tr>
<tr><td>VWB indicator</td><td colspan="2">Reduced withdrawal</td></tr>
<tr><td rowspan="8">VWB calculations</td><td colspan="2">Effective precipitation was calculated daily using the equations in Box 1.</td></tr>
<tr><td>Key characteristics</td><td>Volume (m³/year)</td></tr>
<tr><td>$\text{Avg P}_{\text{Before project year}}$</td><td>46,507</td></tr>
<tr><td>$\text{Avg P}_{\text{Including project year}}$</td><td>46,422</td></tr>
<tr><td>Diff in P</td><td>85</td></tr>
<tr><td>$\text{Irr}_{\text{Without-project}}$</td><td>136,919</td></tr>
<tr><td>$\text{Irr}_{\text{With-project}}$</td><td>115,866</td></tr>
<tr><td>VWB</td><td>21,137</td></tr>
<tr><td>Co-benefits</td><td colspan="2">▪ Education: Agronomic training was provided to help farmers adopt the technology.
▪ Reduction in electricity use for farmers: When irrigation equipment operates more efficiently, its usage decreases, leading to lower electricity consumption and, consequently, a reduced electricity bill.
▪ Increased economic income: Through its ecosystem services payment program, Kilimo provides cash payments to farmers for the positive externalities they generate in the watershed.</td></tr>
<tr><td>Comments</td><td colspan="2">Precipitation data were obtained from weather stations located in the field or within a ~10 km radius and irrigation data were obtained from irrigation controllers of irrigation equipment or farmers’ daily irrigation input on the Kilimo platform, depending on the case.</td></tr>
<tr><td>Other considerations</td><td colspan="2">Because precipitation for the project year was comparable to the historical average (i.e., 3 mm/year lower), the calculated VWB was similar to the difference in irrigation amounts between the without- and with-project conditions.</td></tr>
</table>

Appendix C: Example data collection survey for farmers

Objective

This is an example survey for how to collect farm-level irrigation and precipitation information from farmers to establish the baseline (i.e., without-project condition) for VWB calculations as well as other helpful project information. For the purposes of this survey, a farm is made up of fields, which are then divided into plots by crop and/or irrigation schemes.

Note: This survey is intended to help collect contextual project information. However, not all the information listed is required to calculate VWBs.

The objectives of each section are as follows:

- Section 1. General farm information: Obtain the geolocation of the fields and the hectares involved in the project and validate the farm's location within the selected basin.
- Section 2. Crops and soil: Obtain information on the crops produced in previous years, the crops that will be produced in the coming seasons, and the soil characteristics of the fields involved in the project.
- Section 3. Irrigation: Verify the plots and irrigation schemes within the fields and collect irrigation records by plot for previous years. Information from field logs, a fixed sheet strategy, automatic irrigation controller spreadsheets, or energy consumption (converted into water withdrawals) per year can be used.
- Section 4. Precipitation: Collect precipitation data for the previous 5 to 10 years, using field records from nearby meteorological stations and reliable public institutions as a source of information. If there is heterogeneity of precipitation between the plots, it must be addressed (see Section 3).

Section 1: General farm information	
1.1	**Company financing the project**
1.2	**Farmer details**
	▫ First and last name
	▫ E-mail
	▫ Phone number
	▫ Other people involved and their roles
1.3	**Location of the field/s**
	▫ Country
	▫ Region or locality
	▫ Hydrological basin
	▫ Field name/s
	▫ Field coordinates (i.e., latitude and longitude of the center point)
	▫ Link to or PDF of a map with the location of the fields in the basin
	▫ Total hectares participating in the project

Section 2: Crops and soil	
2.1	**Crop cultivation**
	▪ Crop details – *perennial crops* ▫ Does the farm produce perennial crops? Which crop or crops? ▫ Did each plot have the same perennial crop during the years that will be included in this assessment? ▫ What is the crop rotation for each plot for the years that will be included in this assessment? *See **Example - 2.1 Crop cultivation records**.* ***Note:** the number of years to be included in the assessment should reflect the period that is most representative of the crop system.*
	▪ Crop details – *annual crops* ▫ Does the farm produce annual crops? Which crop or crops? ▫ How many annual crop cycles did each plot have during the years that will be included in this assessment? ▫ What is the crop rotation, and cycle duration, for each plot for the years that will be included in this assessment? *See **Example - 2.1 Crop cultivation records**.* ***Note:** the number of years to be included in the assessment should reflect the period that is most representative of the crop system.*
	▪ Has any plot remained uncultivated for a period in the years that will be included in this assessment (i.e., bare or fallow soil)?
	▪ Has any of the following ever been used: anti-hail mesh, anti-frost fabric and rain cover, or plastic mulch? For how long and in which plots?

- Do any plots have a problem that affects the crop annually (e.g., lowlands affected by frost, stands with soil diseases, etc.)?
- Are there any pests or diseases that typically affect the crops?
- What is the destination of the crop production?
- What are key times of year for the crops (i.e., pruning, harvesting)?

2.2 Soil

- What types of soil do the plots have?
  Note: *indicate textural classes, clarifying the percentage of sand, the percentage of clay, and the percentage of silt of each plot.*
- Are soil analyses available?
- What is the soil depth (according to soil retentive capacity, physical impediments, and root exploration)?
  Note*: indicate if there is any physical impediment that could limit the depth (i.e., presence of nappe, coarseness, bedrock, salinity).*
- Is there variability within the field or within the irrigation plots?
  Note: *this will be used to define whether it is necessary to carry out an assessment and soil sampling per plot that accounts for the heterogeneity.*

EXAMPLE – 2.1 Crop cultivation records

Irrigation plot	Crop year 1	Crop year 2	Crop year 3	Current crop year
Plot 1	Lettuce (Jan-Apr) Corn (Apr-Nov)	Strawberry (Jan-Jun) Corn (Jun-Dec)	Lettuce (Jan-Apr) Corn (Apr-Nov)	
Plot 2	Avocado	Avocado	Avocado	

Section 3: Irrigation	
3.1	**Irrigation plots or schemes**
	▪ How many plots or irrigation schemes is the field/s divided into?
	▪ How many hectares are in each plot or scheme and what names are assigned to them? *See **Example 3.1 – Irrigation plots or schemes.***
	▪ What were the criteria for the formation of the plots? Were the plots laid out because of soil, surface, the location of a well or valves, installer design, or other factors?
	▪ Are irrigation schemes modified throughout the cycle or year?
	▪ Has the same plot design been maintained for the years that will be included in this assessment?
	▪ For horticultural producers with irrigation tapes, are the irrigation tapes changed every year? If not, how many more years will they be used? Note: this data is important to calculate irrigation efficiency over years of reuse.
	▪ Link to the map with location and polygons of the plots.
3.2	**Irrigation strategy**
	▪ How is each plot typically irrigated? Please describe. ▫ Fixed flow ▫ Variable flow
	▪ How is irrigation managed? Please describe. ▫ Manual ▫ Automated (which irrigation controller and for how long has it been in operation?)
	▪ How frequently are the plots irrigated?
	▪ Does any differential irrigation management occur throughout the cycle? How long does it last? How is it done (e.g., deficit irrigation, water restriction, saturation, profile filling)?
	▪ How deep do the irrigations go?
3.3	**Technical aspects of irrigation**
	▪ What is the flow rate of the drippers (in mm/h or l/h)?
	▪ What is the distance between drippers, the distance between laterals and number of laterals per row?
	▪ What type of drippers are used (e.g., pressure-compensating (PC), anti-drain (ND), turbulent-flow emitters)?
	▪ Are any measurements made on the uniformity coefficient and real flow rate of the drippers?
	▪ Are the irrigation hoses cleaned and maintained? How often?
	▪ What is the irrigation water source? Is there a quantity limitation at any time of the year? How often and for how many hours is water available?
	▪ Are there any water quality concerns with the irrigation water source (e.g., pollutants or salinity)?
	▪ List any literature references.

3.4	Irrigation records from previous years
	▪ Are there irrigation records by plot for the past three years (or at least the previous year)?
	▪ *If **yes**:* ▫ Are they written down in field notebooks or Microsoft Excel spreadsheets? Can they be extracted from an automated irrigation controller database?
	▪ *If **no**:* ▫ In the case of perennial crops, is there a fixed irrigation strategy that is followed each year that can be applied to all plots equally? For horticultural crops, what is the strategy for each crop? ▫ Have there been any periods when the strategy changed? If so, for which years, plots and crops? ▫ Is there information on electricity consumption in the field (e.g., invoices, tickets, bills) that can be used as a source of information to calculate monthly or annual irrigation? **Note:** with information on the total kilowatts used per month or per crop cycle and the power of the pump, it is possible to calculate the hours that the pump was operating, after which the expenditure or flow rate can be defined based on the pump model. ▫ What model of pump is used? ▫ If irrigation amounts are estimated rather than measured from previous years, the amount should be confirmed with the farmer to corroborate whether the monthly and annual values are logical. ▫ **Note:** Literature from credible project implementers (e.g., Kilimo) can also be used to define valid irrigation parameters. As a last resort, if irrigation data cannot be obtained through any of the previous steps, data references from credible institutions on irrigation of similar crops in the area can be used.

EXAMPLE – 3.1 Irrigation plots or schemes

Irrigation plot	Hectares	Location[1]
Plot 1		
Plot 2		

Notes: [1] For example, coordinates (i.e., latitude and longitude) or link to geospatial file (e.g., KML/KMZ or shapefile)

Section 4: Precipitation	
4.1	**Precipitation records from previous years**
	▪ Does the farm have precipitation records from the past 10 years (or at least the past 5 years)?
	▪ *If **yes**:* ▫ Are they written down in field notebooks or Microsoft Excel spreadsheets? ▫ Are the records kept per day or accumulated per month? ▫ Is the same precipitation recorded for all plots together or separately? ▫ Is effective precipitation calculated, or is the data recorded from a rain gauge or weather station?
	▪ *If **no**:* ▫ Is there a weather station within the farm to access precipitation data? When was it installed? ▫ Are there any meteorological stations near the farm to access precipitation data from previous years? ▫ Are there any precipitation records from credible institutions in the area? If so, which institutions? ▫ Is it possible to access the precipitation records of a neighboring farm?

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