Interventions Impact Analysis: Irrigation Season 2021

APSAN-Vale project

CLIENT Agência de Desenvolvimento do Vale Zambeze (ADVZ)

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Summary

APSAN-Vale is a project with the aim to pilot innovative practices that improve productivity and water productivity. The analysis on the impact that the piloted interventions have, is central to determining the effectiveness of the practices. The lessons learned on the adoption of practices, the achieved increases in productivity, and the relation between adoption of practices and production are valuable key findings for this project and assist follow-up activities. The analysis of this report therefore contributes to the overall assessment of the piloted practices.

In summary, the report presents findings from 107 project beneficiaries and 15 control group farmers in Báruè, Nhamatanda and Moatize for the 2021 irrigation season. The main crop types in this impact assessment are cabbage, onion, and tomato. Data is presented on crop yield, water productivity, adoption and knowledge of practices. This data is presented in a synthesized version in this report, with full details presented in accompanying reports.

Analyzing the observations of the comparison between adoption of practices in 2020 and 2021, we come to the following conclusions:

- A key development is the increase of control group farmers who use a pump to irrigate (from about 5% to 22%) (and consequentially use furrows in their fields which has an increase from about 22% to 36%). A decrease of bucket irrigation by the control group strengthens this observation. This is major because this is a major difference jump into commercialization of the production system. Farmers have the incentive to start to produce more intensively which could possibly be an indirect spill-over effect of APSAN-Vale project. Explanations are: farmers see the potential or irrigated agriculture around them, better access to input and output markets (incentivizing farmers to produce commercially), or increased availability of pumps in the region that can be hired.
- The high and even increased rate of both APSAN-Vale farmers as control group farmers that plough by hand and the high and even increased rate of APSAN-Vale farmers that use local seeds is not desired as it is considered a “low tech” or “original" practice.
- Water field management practices are highly adopted amongst APSAN-Vale farmers, very limited by control group: thus a practice to promote among new farmers.
- There is an increase in all kinds of ploughing. This is a positive observation for mechanized and animal traction. However, it is remarkable that manual also increased, as one would expect that if the others increase, manual decreases as it would be substituted. There are less APSAN farmers who do it manually (and this have a more advanced technological alternative) compared to the control group. Especially if we want to promote horticultural production during the hot season, special attention should be paid to animal and mechanical ploughing to reduce labour requirements.
- Business plans: this practice needs more attention in the future, as farmers are willing to adapt (see comparison with control group).

In this report, the impact of interventions was analyzed using a theoretical approach with AquaCrop simulations and observed impact using case studies from selected PPCs (small commercial farmers). The comparison of results with the practices applied gives some key messages, namely:

- The adoption of practices for the group of APSAN-Vale project beneficiaries was high with on average 10 practices adopted. The control group adopted on average 2 practices.
- Comparing adoption of practices of 2020 and 2021, low-cost practices that require knowledge are adopted most, especially water management practices. Drainage and soil humidity sensors show an increase showing potential to be further promoted.
- Increased pumped irrigated agriculture, even among the control group, is a proof that APSAN-Vale is catalysing farmer-led development processes.

- Runoff management practices had limited impact on the water balance components or yield results for this study, because it is more relevant as a practice in the rainfed season.
- The results of mulching and improved seeds interventions show that improvements in water productivity can be achieved by adopting these interventions. The practical implementation of these practices should be evaluated with case studies and interview questions.
- The irrigation methods showed that furrow irrigation in combination with soil sensors gave good results in water productivity and yield. However, if furrow irrigation is practiced without proper monitoring of the irrigation schedule, there is a tendency of over-irrigation.

Overall, the findings from the theoretical analysis gave some interesting linkages with the observed impact as reported in the case studies. In upcoming seasons, the preliminary findings can be further verified and used to convince growers about the benefits that can be achieved with interventions.

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1 Introduction

1.1 APSAN-Vale project

The APSAN-Vale project commenced end of 2018 and is a 4.5 year project with the objective to: 'Pilot innovations to increase the Water Productivity and Food security for Climate Resilient smallholder agriculture in the Zambezi valley of Mozambique'. Water productivity is used as an indicator to quantify the impact of the innovations on smallholder agriculture. These innovations are presented as technical packages that include improved practices and technologies. Information on water productivity incorporates both temporal and spatial aspects. The temporal changes in water productivity indicate if an intervention resulted in an increase of water productivity. The spatial patterns in water productivity indicate if the knowledge is being adopted in the region and increased the overall water productivity of the locality, and district. Project activities take place in three districts namely: Báruè, Moatize, and Nhamatanda. Within each district, localities are selected for piloting innovations. The location of the districts are shown in Figure 1.

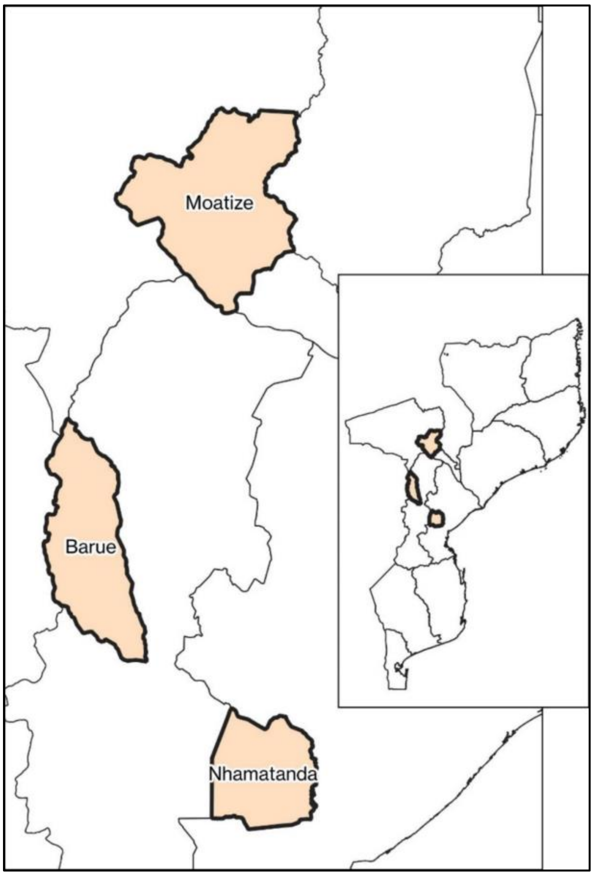

Figure 1. Location districts of APSAN-Vale project activities

1.2 Aim

This report evaluates the impact of the different field interventions that were introduced and promoted through the APSAN-Vale project in Mozambique. This was done by comparing the trained and adopted interventions by farmers against the yield and water productivity data. Goal of this analysis is to gain insight in successfulness of different interventions on the crop- and water productivity of the farmers. The results can be used to select the most successful interventions and gain insight in interventions that are most likely to be adopted. This information is valuable when scaling up to new areas.

1.3 Reading guide

Chapter 2 elaborates on the different field interventions that took place as part of the APSAN-Vale project during the 2021 irrigation season and provides a description of the methodology for the data collection and the interventions impact analysis. Chapter 3 presents the results from data collection activities namely the adoption of practices and the crop yield and water productivity results. Chapter 4 presents the results from the impact interventions analysis from theoretical AquaCrop simulations of selected interventions and the observed impact using case studies as examples. Chapter 5 provides a discussion on the results and some concluding remarks.

1.4 Accompanying reports

Several results have been published in other accompanying project reports namely:

- Van Opstal, J.D., M. de Klerk, V.R. Hollander. 2022. APSAN-Vale Water Productivity Analysis: Irrigation Season 2021. FutureWater Report 236[1]
- Van Krieken, K.W., Van den Akker, J. 2020 Analysis of adoption of practices in APSAN-Vale: Adoption and knowledge sharing of APSAN training topics. Resilience Report
- Massop, E. Mufanequisso. O, van Krieken, K.W., Van den Akker J. 2021 APSAN-Vale In-depth comparison 2020-2021. Resilience Report

[1] Available at https://www.futurewater.nl/wp-content/uploads/2022/04/APSAN-Vale_Irrigation2021_WaterProductivity_Final.pdf

2 Methodology

2.1 Overall approach

The approach of this analysis can be divided into three steps, as shown in Table 1. Details of each step are provided in the sections below.

Table 1. Overall approach of analyzing the impact of interventions.

Step	Description
1	Categorization of practices
2	Collection of information on: - Adoption of practices and knowledge sharing - Crop yield and water productivity data
3	Impact of interventions: - Theoretical: AquaCrop simulations - Observed: comparison of practices and crop yield data - Case study analysis of selected farmers

2.2 Step 1: Categorization of practices

This interventions impact analysis combines various types of data based on implemented practices. The data from these practices are aligned with the crop growth model, data from the monitoring survey, from the training lists, and observations from the field. A categorization of practices is introduced to facilitate the analysis of these different datasets.

The data on adoption of practices was collected through the monitoring survey of July 2021. In total 107 beneficiaries being PPE (smallholder farmers) and PPC (small commercial farmers) and 15 other community members serving as the control group have been interviewed using semi-structured interviews to map out the uptake of training topics. Participants are first asked if they know a certain practice, whether a certain practice has been implemented in their field and if so, who has introduced him/her to this new practice.
The various practices definitions come from the following data:

- The project monitors 38 irrigation season practices related to water management and irrigation, good agricultural practices and market linkages.
- These 38 practices are then grouped in the specific categories mentioned in the logframe (water management practices, crop rotation, mulching, integrated pest management, improved access to input/output markets).

Early 2020, FutureWater developed an intervention framework as part of a project for the FAO, intended to serve as a clear and practical guideline on how to implement "real" water savings in agriculture by selecting suitable interventions for enhancing crop water productivity. The final report states that, to deal with the challenge of developing a structured framework where broader options can be derived into smaller ones, "no universal categorization in options [practices] exist" (FAO and FutureWater, 2020[2]). As there is no universal categorization, we focus on the logframe indicators as the basis for the current intervention analysis.
As a result, all the practices were divided in to three main groups: irrigation and water management practices, good agricultural practices, and market-oriented activities. The list below presents all practices introduced for irrigation crops (in *italics*) and how they are grouped. An overview of all practices and a

[2] Van Opstal, J., Droogers, P., Kaune, A., Steduto, P. and Perry, C. 2020. Guidance on realizing real water savings with crop water productivity interventions. Wageningen, FAO and FutureWater.

description of how the programme trains on specific practices related to irrigation and water management are presented in Annex 1.

1. Irrigation and Water Management Practices

1.1 Land preparation for water management and irrigation

1.1.1 Land preparation for irrigated fields

-Furrows, basins, in lines (e.g. for drip irrigation)

1.1.2 Land preparation for water management

-Bunds, terrasses, dikes, drainage, heaping

1.2 Irrigation methods

-Motor pump, solar pump, foot pump, furrows, tubes, buckets, sprinklers, drip

1.3 Overall water management practices

-Water management practices

1.4 Use of soil sensor

-Soil sensor

2. Good agricultural practices

2.1 Land preparation methodologies

-Mechanical ploughing, animal tractions, manual ploughing

2.2 Use of inputs

2.2.1 Seeds

-Local seeds, improved seeds, seed beds

2.1.2 Pesticides and herbicides

-Use of herbicides, use of pesticides, sustainable handling of pesticides

2.1.3 Fertilizer

-Organic fertilizer, chemical fertilizer, organic and chemical fertilizer

2.2 GAP (planning and spacing)

-Crop spacing, Intercropping, Crop rotation, Staggering and planning

2.3 Soil cover

-Incorporating plant rests, complete mulch, partial mulch

3. Market oriented activities

-Business plan

2.3 Step 2: Data collection on adoption of practices and knowledge sharing

This data collection round focusses on the implementation of training topics by farmers and has been carried out to capture farm performance (economic and yield), household demographics, access to input/output markets and to measure the implementation of APSAN-Vale training topics.

Interviews have been conducted in the three project districts: Báruè, Nhamatanda and Moatize (Figure 2). The districts already differ without project intervention, therefore, caution should be taken once averaging and comparing the results of the three districts.

Over three weeks, 107 project beneficiaries and 15 non-project farmers (control group) were interviewed. Data collection tools were designed and reviewed by the consortium, according to the following criteria;

1. use simple quick-to-understand language for respondents
2. use a mix of qualitative and quantitative data
3. create a comprehensive and simple tool that at the same time provides answers to the logframe indicators.

The analysis focuses on three groups of farmers: PPC farmers, or impact analysis farmers, project beneficiaries in general and the control group. The PPC farmers are the farmers that are monitored closely throughout the production season. Crop growth modeling and water productivity data is available for a selection of fields of these PPCs through FutureWater's flying sensor data. The project beneficiaries are a representative group of overall APSAN-Vale beneficiaries. They include PPCs and PPEs who are active in the localities where APSAN-Vale operates and who have interacted with the project (i.e. attended trainings, received technical assistance, benefited from market linkages, were present at market days). The control group farmers are farmers who were surveyed during the monitoring exercise and the results of this group serve as an in-season comparison to validate the results of project evaluation. These farmers have a comparable socio economic and agro-ecological environment to farmers in the project target group but have no interference by the project.

Figure 2. The interviews were conducted in Báruè, Nhamatanda and Moatize.

The outcomes of the interviews have been analyzed using descriptive statistics. Data is predominantly expressed in percentages to express how a (group of) producer(s) relates to the total group respondents. In addition, the adoption data of specific farmers is used for the impact analysis of this report.

All results from the monitoring survey can be found in the APSAN-Vale M&E Analysis Report no. 5.[3]

2.4 Step 3: Data collection on crop yield

Crop yield values are collected from the water productivity report of the Irrigation season 2021[4]. These results are based on an analysis integrating flying sensor (drone) data, satellite (Sentinel 2) data, and crop growth modelling (AquaCrop). AquaCrop is a crop simulation model developed the FAO to simulate soil-water-plant interactions, and giving results in crop yield and water productivity depending on the management decisions and environmental conditions. The AquaCrop model input files are calibrated to local conditions (soil, climate, crop varieties) and data collected by drones. Flying sensor imagery throughout the growing season, at regular intervals, was used to provide a good estimate of the canopy cover, from which an estimation of the crop yield and water productivity can be derived. Data is generated specifically for the 'Intervention impact analysis' farmers. Details of the methodology with AquaCrop is described in the water productivity report, either in the baseline[5] (for the calibration parameters) or subsequent seasonal water productivity reports.

2.5 Step 4: Theoretical crop growth modeling

The theoretical impact of the interventions is modeled using the crop simulation model AquaCrop. The AquaCrop model was selected for simulating crop growth and water consumption, which is based on FAO principles as reported in FAO Irrigation and Drainage Papers #56 and #66. It simulates both crop development and the water balance, resulting in crop water productivity results. Selected interventions are simulated that coincide with the categories as described in section 2.2 and Annex 1. The AquaCrop parameters used to simulate the interventions are listed below:

[3] Marula, N. Massop, E., van Krieken, K.W., Mufanequisso, O., van den Akker,J.. 2021. M&E Analysis APSAN-VALE Report no.5. Resilience for APSAN-Vale.
[4] Van Opstal, J.D., M. de Klerk, V.R. Hollander. 2022. APSAN-Vale Water Productivity Analysis: Irrigation Season 2021. FutureWater Report 236
[5] Van Opstal, J.D., A. Kaune. 2020. Water Productivity Technical Report - Baseline assessment for APSAN-Vale project. FutureWater Report 195.

- For land preparation: WRM practices (category 1.1.3) a runoff management practice is simulated to mimic the practice of 'bunds' or 'heaping'
  - Run 0: Original scenario without runoff management
  - Run 1: Runoff management by introducing 0.25m soil bunds

- For soil cover (category 2.4) mulching was introduced as a management intervention
  - Run 0: Original scenario without mulching
  - Run 1: Partial mulching is implemented with 40% cover and 50% reduction in soil evaporation
  - Run 2: Complete mulching is implemented with 85% cover and 50% reduction in soil evaporation

- For introducing improved seeds (category 2.1.1) the crop growth parameters (CGC[6] and CDC[7]) are adjusted in AquaCrop to mimic the impact of improved (or hybrid) seed varieties
  - Run 0: Original crop growth parameters from water productivity analysis as calibrated in the baseline report[5] similar to the crop growth of local seed varieties
  - Run 1: Crop growth parameters increased by 20% to mimic improved seed varieties
  - Run 2: Crop growth parameters increased by 50% to mimic improved seed varieties

- For irrigation methods (category 1.2) the different irrigation methods are simulated in AquaCrop
  - Run 0: Furrow irrigation with 80% of soil surface wetted by irrigation (default value in AquaCrop model)
  - Run 1: Sprinkler irrigation with 100% of soil surface wetted by irrigation (default value in AquaCrop model)
  - Run 2: Drip irrigation with 30% of soil surface wetted by irrigation (default value in AquaCrop model)

These simulation runs were performed for two PPCs per district:

- Bárùe: Ananias and Joelmo both cultivating cabbage
- Moatize: Zeca and Alberto L both cultivating tomato
- Nhamatanda: Flora and Lucas B, both cultivating onion

2.6 Step 5: Case study analysis

For an increased understanding of the relation between data collected and practice, a few case studies are selected and presented in this report. The selected farmers are:

- Bárùe: Ananias and Joelmo both cultivating cabbage
- Moatize: Zeca and Alberto L both cultivating tomato
- Nhamatanda: Flora and Lucas B, both cultivating onion

For these farmers the theoretical impact of interventions is compared to the observed data for the adoption of practices, crop yield, and water productivity. Conclusions can be made on the effective implementation of practices and the profitability of the interventions for the farmer.

[6] Canopy growth coefficient (CGC)
[7] Canopy decline coefficient (CDC)

3 Results

3.1 Adoption of practices

3.1.1 Number of practices applied

Figure 3 shows the average number of practices applied, comparing the project beneficiaries and control group in all districts. The figure shows that the project beneficiaries have included a higher number of practices than the control group farmers.

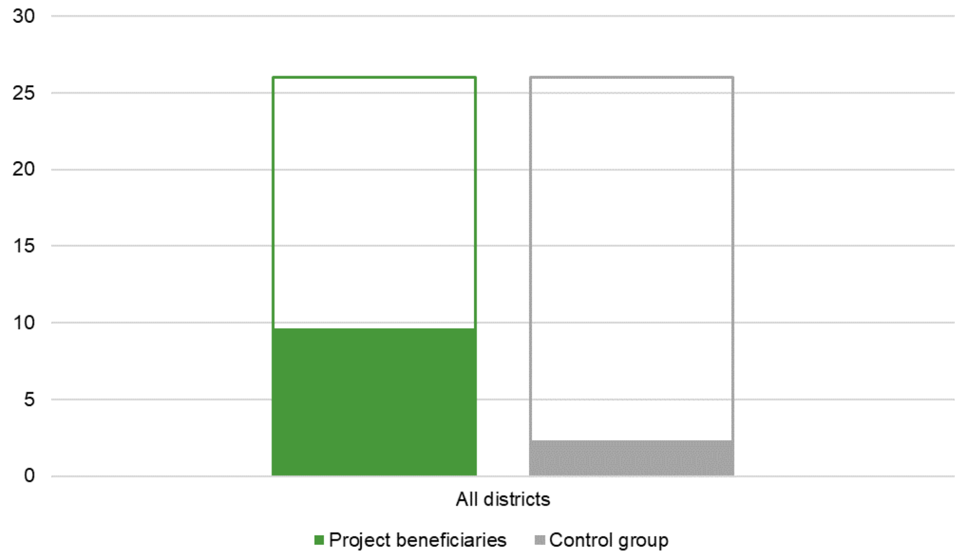

Figure 3. Average number of practices applied for impact analysis farmers, project beneficiaries and control group in all districts

Figure 4 shows the average number of grouped practices (or logframe practices) applied for the project beneficiaries and the control group in all districts. Afresh, the control group shows less practices adopted compared to the project beneficiaries.

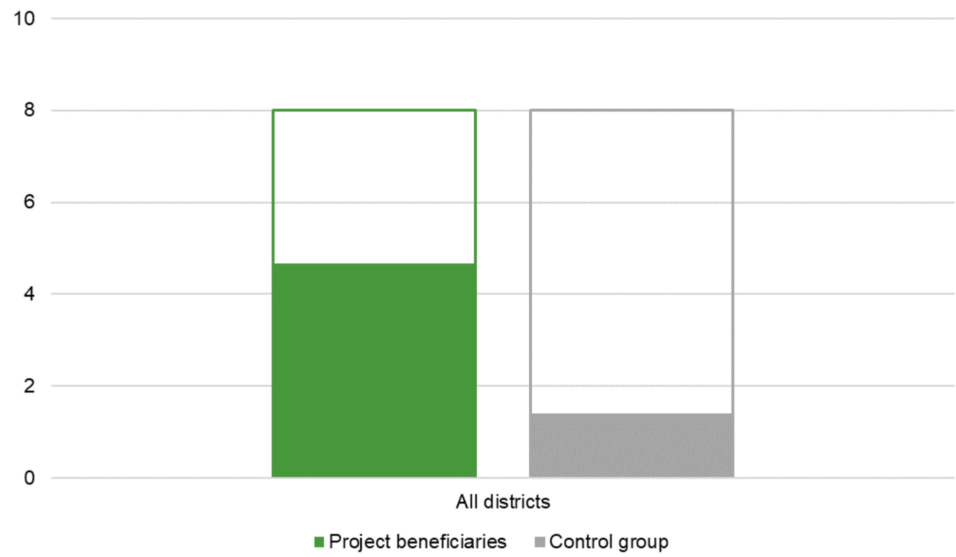

Figure 4. Average number of logframe practices applied for impact analysis farmers, project beneficiaries and control group in all districts

Figure 5 presents the adoption of practices by farmers. This allows to compare the adoption of APSAN-Vale PPC farmers (39), PPE farmers (68) and control group (15). On average PPC farmers adopted 40% of all practices this season, PPE farmers 14% and control group farmers only 8%.

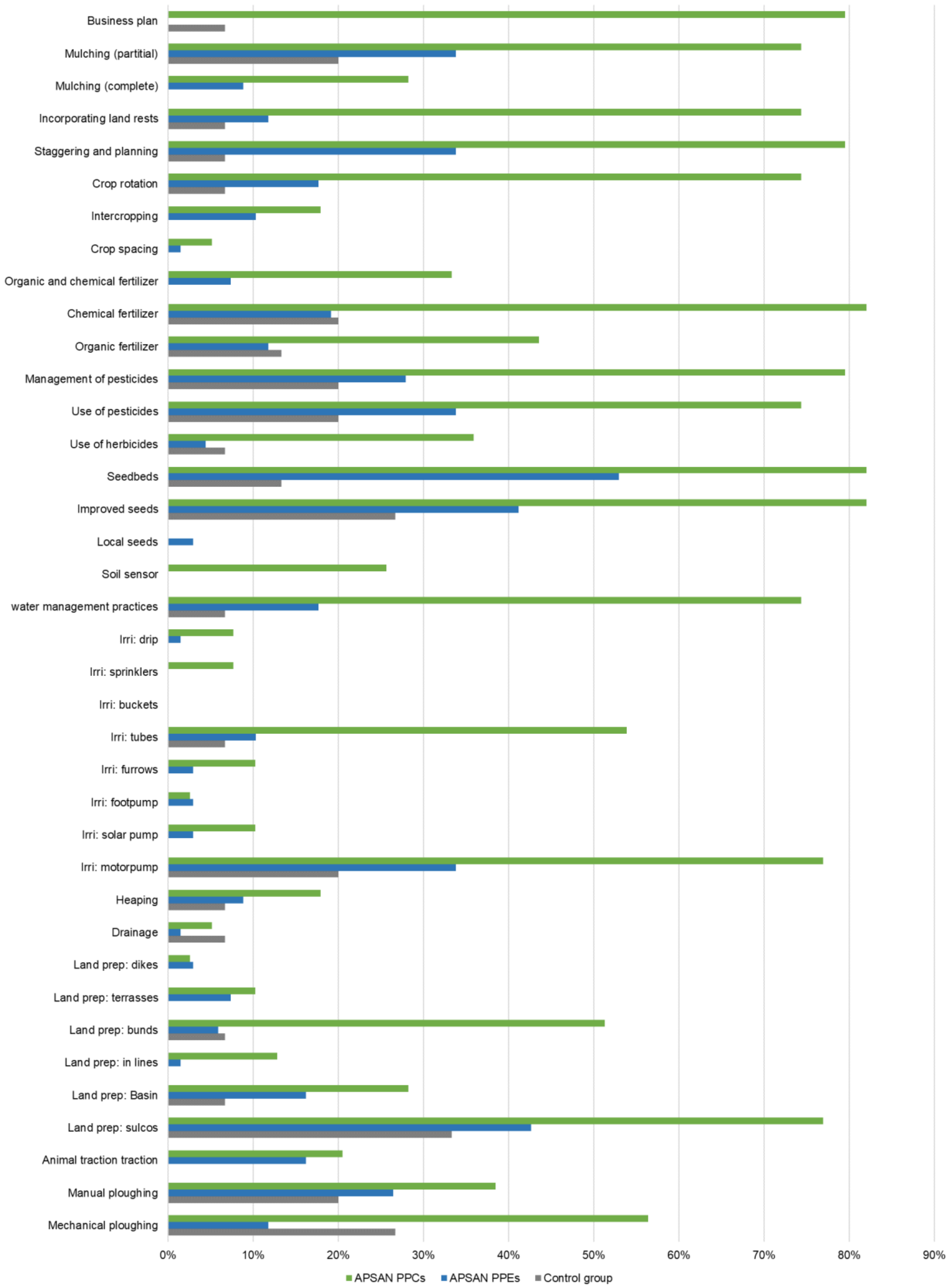

Figure 5. Adoption of practices by the APSAN-Vale PPC and PPE farmers and control group.

3.1.2 Comparison between adoption of practices 2020-2021

Table 2 shows the percentage of adoption of each practice for the year 2020 and 2021 for APSAN-Vale project beneficiaries, compared to control group farmers.

Table 2. Percentage of adoption of each practice for the year 2020 and 2021 for APSAN project beneficiaries and the control group farmers

Practices	APSAN 2020	APSAN 2021	Difference	Control 2020	Control 2021	Difference
Heaping	61	74	13	16	11	-5
Complete soil cover	38	19	-19	5	3	-2
Partial soil cover	38	19	-19	0	0	0
Correct spacing between crops	87	93	6	57	43	-14
Intercropping	63	62	-1	35	23	-12
Drainage	17	36	19	5	3	-2
Staggering	80	88	8	3	9	6
Management and handling of pesticides	89	73	-7	30	14	-16
Sprinkler irrigation	3	4	1	0	0	0
Bucket irrigation	24	20	-4	27	20	-7
Drip irrigation	4	4	0	0	0	0
Ploughing through animal traction	35	42	7	41	34	-7
Manual land preparation	57	68	11	54	83	29
Mechanized ploughing	37	40	3	8	31	23
Business plan	31	33	2	0	3	3
Land preparation incorporating plant rests	73	66	-7	32	9	-23
Nurseries	70	65	-5	30	31	1
Land preparation: basins	23	21	2	0	3	0
Land preparation: bunds	48	38	-10	3	3	0
Land preparation: protection dikes	3	4	1	0	0	0
Land preparation: furrows	63	60	-3	22	34	12
Land preparation: terrasses	14	9	-5	0	0	0
Land preparation: in lines (for drip irrigation)	2	5	3	0	0	0
Crop rotation	91	78	-13	30	6	-24
Water management practices	72	75	3	0	3	3
Irrigation conveyance: open canal	12	6	6	0	0	0
Irrigation conveyance: tube	12	29	17	0	20	20
Irrigation: foot pump	8	3	-5	0	0	0
Irrigation: solar pump	4	6	2	0	0	0
Soil humidity sensor	6	15	9	0	3	3
Fertilizer: organic and chemicals (mix)	25	20	-5	0	0	0
Fertilizer: organic	50	30	-20	16	11	-5
Fertilizer: chemical	40	52	12	11	26	15
Herbicides use	18	26	8	16	31	15
Irrigation: fuel pump	48	49	1	3	23	20
Use of pesticides	94	86	-8	57	40	-17
Seeds: local seeds	67	94	27	81	57	-24
Seeds: improved seeds	97	51	-46	78	74	-4

The findings of the analysis comparing adoption of practices 2020 and 2021 (Massop et al, 2021[8]) allow to deepen the observation about impact and adoption of practices. Some key observations from this publication are summarized in the points below referring also to information from Table 2:

- Most practices with a relatively high implementation rate in 2020, still have a relatively high implementation rate in 2021 (Table 2). An exception is use of improved seeds, which decreased substantially (97% in 2020 to 51% in 2021).
- For some of the practices with a high adoption rate, the adoption in 2021 even further increased: spacing and sowing density, production scheduling, water management practices, heaping,

[8] Massop, E. Mufanequisso. O, van Krieken, K.W., Van den Akker J. 2021 APSAN-Vale In-depth comparison 2020-2021. Resilience Report

manual tillage, and especially the use of local seeds has a large increase (67% in 2020 to 94% in 2021). For manual tillage and the use of local seeds, this is not considered positive, as these are low technology practices.

- For some of these practices there was a low decrease of adoption, but stayed high: the use of pesticides, crop rotation, pesticide management, land preparation with crop residues, and nursery preparation.
- Scattering production had increased adoption for both the APSAN farmers (80-88%) and control group, but the latter at very low levels (3-9%).
- The APSAN-Vale beneficiaries increased use of chemical fertilizers and herbicides (which was very little done but went from 18-26%) has increased adoption for both but remains low.
- Most of the practices with a low adoption rate in 2020, have not been adopted (much) more in 2021.
- Drainage adoption doubled from 17 to 34% and almost not done by the control group. Similarly, use of soil humidity sensors still has a low adoption rate but more than doubled in 2021. This is considered a positive outcome as these practices are more intensive practices requiring costs, labour and/or markets.
- Alarmingly, the use of local seed has increased between the years 2020 and 2021 from 67 to 94% for APSAN farmers and decreased for the control group and improved seed use decreased by 4% (control group) and APSAN farmers reduced from 97% to 51%

3.2 Crop yield

This section discusses the crop yield of the analyzed farmers, analyzed using AquaCrop runs in combination with flying sensor and satellite data as described in chapter 2. In all three districts, the crops that are accounted for in this analysis are potato, cabbage, tomato, onion, maize, and beans. The results are presented in tables 3, 4, and 5. Details of the results from this analysis and explanation of the differences were reported in the accompanying water productivity report[9].

Table 3. Results of AquaCrop water productivity and dry crop yield, and percent change of water productivity compared to baseline (75th percentile) for Moatize farmers

PPC code	Name	Crop type	Water Productivity [kg/m^3]	Normalized Water Produc-tivity [kg/m^3]	% change with baseline*	Dry crop yield [ton/ha]
MO-MA-AC-01-01	Alberto	Tomato	1.79	1.89	+5%	2.73
MO-MA-GM-01-01	Girio	Tomato	2.59	2.73	+52%	7.44
MO-MA-GM-01-01	Girio	Tomato	2.72	2.87	+60%	8.08
MO-SA-ZM-01-01	Zeca	Tomato	2.96	3.13	+75%	8.29
MO-SA-CA-01-01	Cezario	Tomato	2.03	2.14	+19%	3.96
MO-CA-AB-01-01	Albino	Tomato	2.53	2.67	+49%	4.72
MO-MA-JC-01-02	Joao	Tomato	2.62	2.76	+54%	5.05
MO-CA-XT-01-03	Xavier	Tomato	2.68	2.83	+58%	4.98
MO-BE-SJ-01-01	Staben	Tomato	1.80	1.89	+6%	2.58
MO-BE-SJ-01-02	Staben	Tomato	2.02	2.13	+19%	5.15
MO-BE-T-01-02	Teofilo	Tomato	2.29	2.42	+35%	3.98
MO-SA-MC-01-01	ManuelC	Beans	0.82	0.87	NA	1.32
MO-SA-CA-01-08	Cezario	Beans	1.22	1.29	NA	2.17
MO-CA-XT-01-01	Xavier	Beans	1.10	1.16	NA	1.77
MO-SA-CA-01-06	Cezario	Beans	1.18	1.25	NA	2.02
MO-SA-CA-01-02	Cezario	Onion	0.91	0.96	+18%	1.15
MO-SA-CA-01-07	Cezario	Cabbage	1.36	1.44	+7%	2.54

* Note: NA indicates when irrigation season baseline values are not available for these crop types

[9] Van Opstal, J.D., M. de Klerk, V.R. Hollander. 2022. APSAN-Vale Water Productivity Analysis: Irrigation Season 2021. FutureWater Report 236

Table 4. Results of AquaCrop water productivity and dry crop yield, and percent change of water productivity compared to baseline (75th percentile) for Báruè farmers

PPC code	Name	Crop type	Water Productivity [kg/m^3]	Normalized Water Productivity [kg/m^3]	% change with baseline*	Dry crop yield [ton/ha]
AP_BA_ACI-01-03	Ananias	Potato	3.51	3.95	+66%	5.36
AP_BA_MA-01-01	Margarida	Potato	3.85	4.34	+82%	5.70
AP_BA_ACI-01-04	Ananias	Cabbage	2.05	2.31	+37%	3.41
AP_BA_ACI-01-07	Ananias	Cabbage	2.20	2.47	+47%	3.47
AP-BA-CF-01-02	Chuva	Cabbage	2.45	2.76	+65%	3.48
AP-BA-BV-01-02	Bernardo	Cabbage	1.53	1.73	+33%	2.74
AP_BA_JDR-01-02	Joelmo	Cabbage	2.42	2.73	+62%	3.55
AP-BA-LJ-01-01	LucasJ	Cabbage	1.91	2.16	+28%	3.51
AP_BA_ML-01-02	ManuelL	Cabbage	2.34	2.63	+57%	3.47
AP_BA_MD-01-02	Modesto	Cabbage	1.99	2.25	+34%	3.19
AP-BA-CF-01-01	Chuva	Beans	1.12	1.26	NA	2.33
AP-BA-CF-01-03	Chuva	Beans	1.17	1.31	NA	2.33
AP-BA-CF-01-04	Chuva	Beans	1.07	1.20	NA	2.13
AP-BA-CF-01-05	Chuva	Beans	1.13	1.28	NA	2.33
AP_BA_ACI-01-05	Ananias	Beans	1.17	1.32	NA	2.41
AP_BA_ACI-01-06	Ananias	Beans	1.21	1.36	NA	2.51
AP-BA-BV-01-01	Bernardo	Beans	0.91	1.02	NA	2.12
AP-BA-PGM-01-01	Paulo	Beans	0.78	0.88	NA	2.10
AP_BA_JDR-01-03	Joelmo	Beans	1.30	1.47	NA	2.88
AP_BA_MD-01-03	Modesto	Maize	1.40	1.58	NA	3.56
AP-BA-AB-01-01	Anita	Maize	1.14	1.28	NA	3.29
AP_BA_ACI-01-08	Ananias	Tomato	1.57	1.77	+65%	2.49
AP-BA-PGM-01-02	Paulo	Tomato	2.95	3.33	+211%	8.19
AP_BA_MD-01-04	Modesto	Tomato	2.82	3.17	+196%	6.31

* Note: NA indicates when irrigation season baseline values are not available for these crop types

Table 5. Results of AquaCrop water productivity and dry crop yield, and percent change of water productivity compared to baseline (75th percentile) for Nhamatanda farmers

PPC code	Name	Crop type	Water Productivity [kg/m^3]	Normalized Water Productivity [kg/m^3]	% change with baseline*	Dry crop yield [ton/ha]
AP_NH_AS_01_02	Associacao	Tomato	1.99	2.03	+60%	4.54
AP_NH_JA_01_01	Jose	Beans	0.64	0.65	NA	1.04
AP_NH_FM_01_01	Flora 1	Beans	0.81	0.83	NA	1.56
AP_NH_AM_01_01	Antonio	Beans	0.97	0.99	NA	2.01
AP_NH_LB_01_03	LucasB	Beans	0.81	0.83	NA	1.54
AP_NH_LB_01_02	LucasB	Cabbage	1.91	1.95	+42%	3.32
AP_NH_FMA_01_05	Filipe	Cabbage	1.71	1.74	+27%	3.21
AP_NH_DP_01_03	Domingos	Cabbage	1.83	1.87	+36%	2.79
AP_NH_FM_02_01	Flora 2	Cabbage	1.82	1.86	+35%	3.55
AP_NH_MD_01_01	ManuelD	Cabbage	1.63	1.66	+21%	3.06
AP_NH_FM_02_02	Flora 2	Onion	0.79	0.80	+93%	1.12
AP_NH_MD_01_01	ManuelD	Onion	0.60	0.62	+48%	0.90
AP_NH_LB_01_04	LucasB	Onion	0.78	0.80	+92%	1.16
AP_NH_FMA_01_01	Filipe	Maize	1.20	1.23	NA	2.62

* Note: NA indicates when irrigation season baseline values are not available for these crop types

3.3 Theoretical crop growth modeling

Different AquaCrop runs were performed to evaluate for selected farmers the theoretical change in yield, water productivity, and water balance components that can be expected following certain interventions. The interventions simulated with AquaCrop were runoff management, irrigation method, improved seed varieties, and mulching. Details on the different scenarios are listed in section 2.4.1.

The results of each scenario are explained in the sections below with detailed results presented in Annex 2. As this is a theoretical impact analysis, based on simulations, the conclusions should take note that observed (or practical) impact can be different from the theoretical due to changing conditions or factors playing a role that are not incorporated in simulations.

3.3.1 Runoff management

The results for the runoff management intervention showed negligible changes in water balance components and yield. This is due to the limited effect runoff has during the irrigation season, whereas in the rainfed season it is a worthwhile intervention for capturing more water, as was found in a previous report[10].

3.3.2 Mulching and improved seeds

Mulching is one of the key practices introduced by APSAN-Vale. The impact of mulching is compared with simulations without mulching. Separately, the intervention of improved seeds is compared to local seed varieties simulating differences in crop growth parameters in the AquaCrop model. Results are presented in Figure 6,Figure 7, and Figure 8. Simulations were performed for the three districts with three different crop types, namely cabbage, tomato and onion. The detailed results from the simulations are added in Annex 2: Results AquaCrop simulations.

The evapotranspiration (ET) decreased in all three situations of the mulching scenarios (district and crop types) with an average decrease of 5% as shown in Figure 6. The largest decrease is found in Bárùe for cabbage with a decrease in ET of 8%. Reductions in ET is mainly a result of a decrease in soil evaporation due to the covering of the soil with organic or plastic material. Overall, gains can be found in reducing ET and thus water consumption by introducing mulching practices.

On the other hand, the ET increased for the scenarios with improved seeds with an average increase of 8% as shown in Figure 6. An increase in ET is expected because the plants are growing larger and yield more harvestable product. Increased crop growth will result in higher quantities of transpiration. The results of increased ET were similar for cabbage and tomato crop. Results for onion crop (in Nhamatanda) were unsuccessful due to issues with the crop growth parameters not calibrating properly for the onion crop under changed conditions.

The results for yield from both the mulching scenarios and improved seeds scenarios are presented in Figure 7. The scenarios of mulching showed limited impact on yield with the onion crop (from Nhamatanda) having the most impact in increasing yield up to 5% and on average an impact of 1.7%. The scenarios of improved seeds show a larger increase of on average just over 15%. This is expected as the aim of improved seeds is to increase yields substantially.

The results for water productivity are presented in Figure 8 for the scenarios on improved seeds and mulching practices. On average both the improved seeds and the mulching scenarios show a similar increase in water productivity of around 7%. For each crop type and district, the interventions have a positive impact thereby increasing water productivity from 4% to 10% maximum. These results show that

[10] Van Opstal, J., M. de Klerk, K. van Krieken, D. Chale. 2020. Interventions Impact Analysis: Rainfed Season 2019-2020 (in Portuguese). Technical report.

the mulching practices are most effective for onion and cabbage fields. However, it should be noted that the simulations are theoretical and should be verified with field examples. Overall, the similar increase in water productivity for both interventions indicates that farmers can increase water productivity by either opting for increasing yield by using improved seeds, or reducing water consumption (i.e. ET) by using mulching.

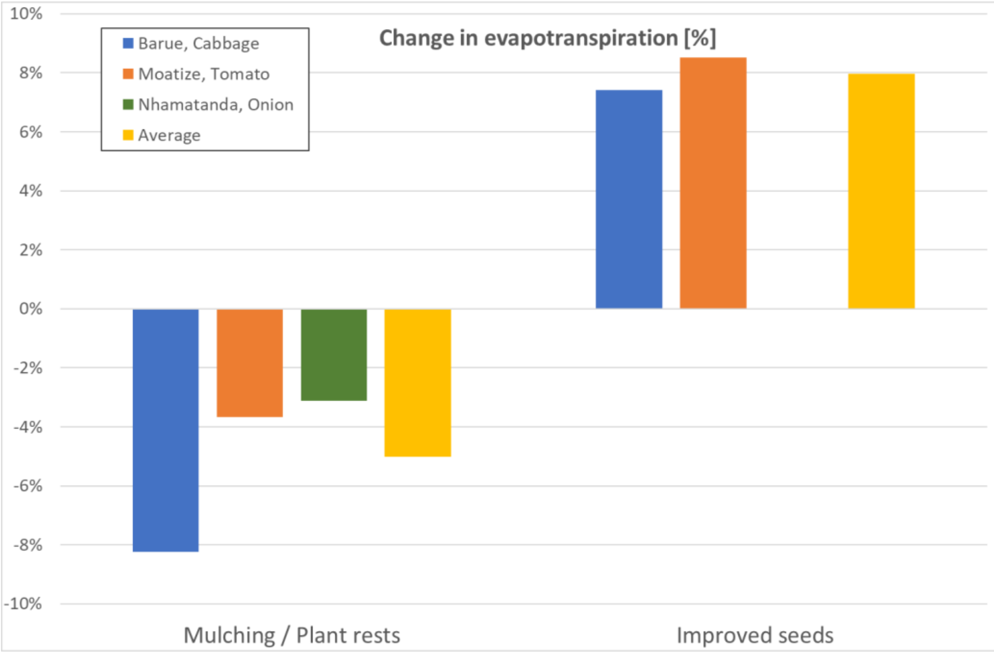

Figure 6. Results from simulations for each district in change of evapotranspiration (ET) as percentage of original scenario without the intervention

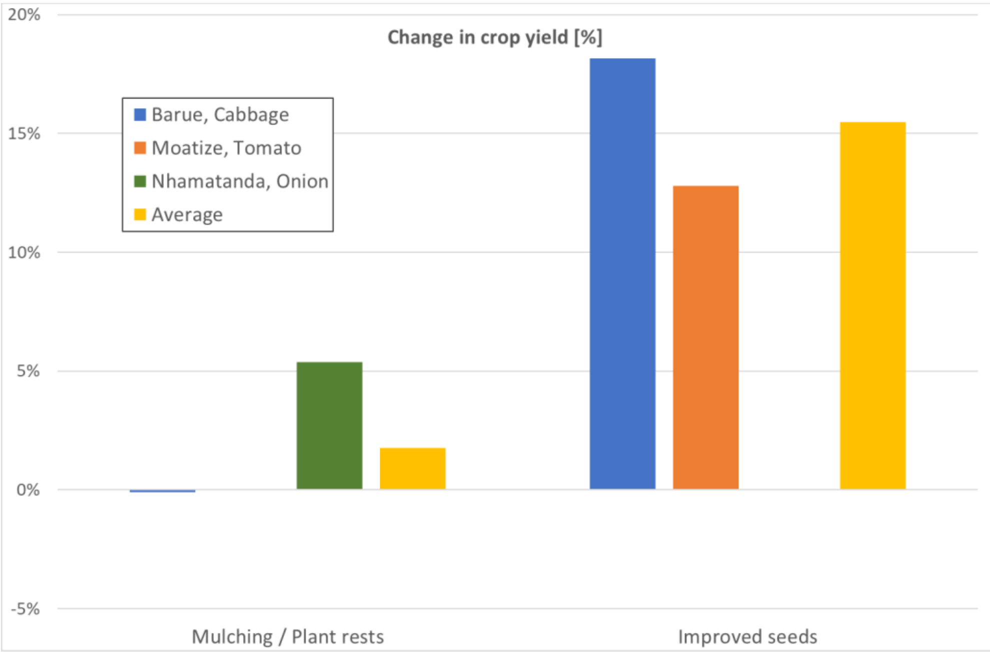

Figure 7. Results from simulations for each district in change of yield as percentage of original scenario without the intervention

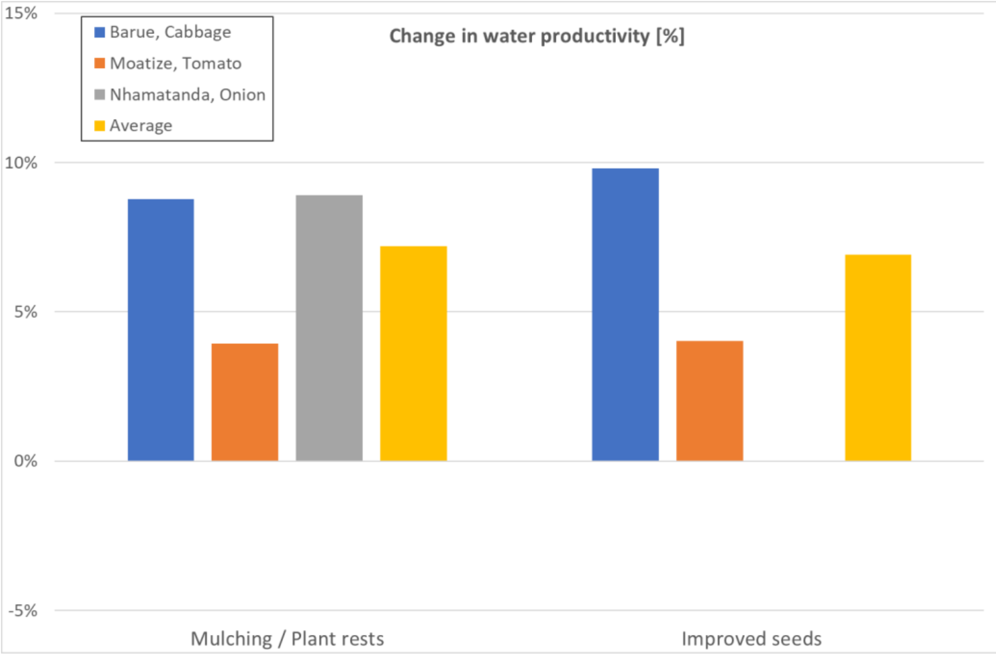

Figure 8. Results from simulations for each district in change of water productivity as percentage of original scenario without the intervention

3.3.3 Irrigation method

Different irrigation methods were simulated for all three districts and three crop types. The results for the simulations of drip, furrow, and sprinkler irrigation are presented in Figure 9. The irrigation scheduling is for all scenarios the same, namely irrigation occurs at a certain level (25%) of maximum allowable depletion of the rootzone soil moisture. In practice, it is commonly found that farmers using furrow irrigation overirrigate, thus applying water more frequently than is currently simulated in these scenarios. Farmers making use of soil sensors for deciding when to irrigate, will assumably have a similar irrigation schedule as is currently simulated with these scenarios.

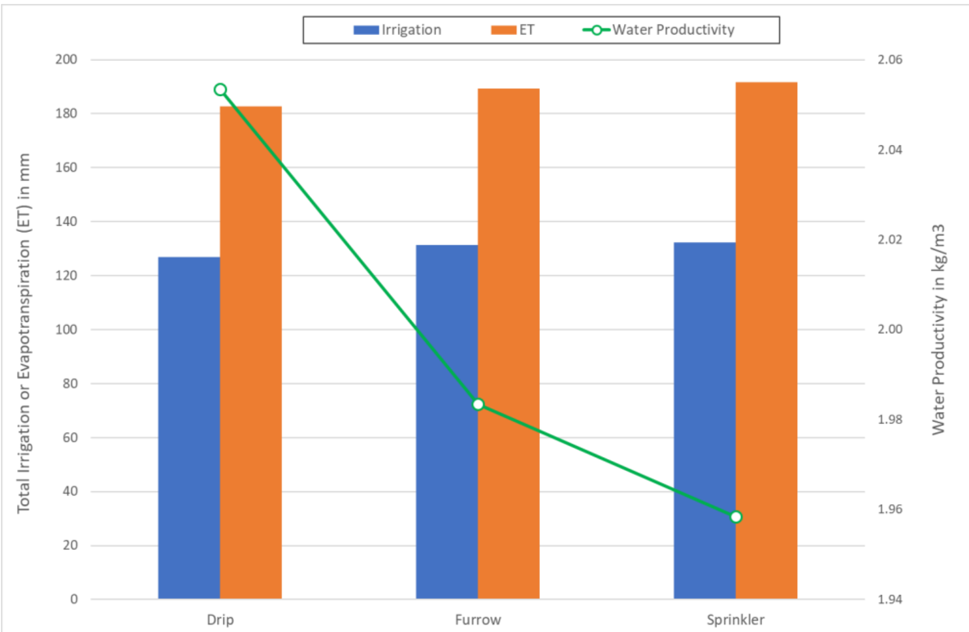

Figure 9. Results of total volume of irrigation, evapotranspiration (ET), and seasonal water productivity for drip, furrow, and sprinkler irrigation scenarios

The results in Figure 9 show that the total volume of irrigation water applied and the evapotranspiration (ET) is lowest for drip irrigation and highest for sprinkler irrigation. This is explained by the percentage of wetted surface which is low for drip irrigation (30%) and high for sprinkler irrigation (100%). A higher percentage of wetted surface will cause higher values in soil evaporation. Furrow irrigation is set at 80% wetted surface, which is the default of AquaCrop. However, discussion of these results with the field technicians led to conclude that the approximation of wetted surface can be improved by making some field measurements but is likely closer to 60% (Figure 10. The wetted surface of furrow irrigation), thus reducing soil evaporation further.

Figure 10. The wetted surface of furrow irrigation. APSAN-Vale 2022

The water productivity is highest for drip irrigation and lowest for sprinkler irrigation. The higher water productivity values for drip irrigation is also similar to trends found in other studies as reported in a summarizing literature review on water productivity interventions[11]. In practice, the drip irrigation systems used in APSAN-Vale project and frequently also connected with a solar pump. This gives the added value of saving fuel costs, but flow rate is lower than diesel pumps.

The water productivity is lower for furrow irrigation and sprinkler irrigation. However, these results need to be verified in further detail with the field observations. It was already noted that common practice for furrow irrigation is that the farmers over-irrigate. The amount of over-irrigation can be noted and implemented in future analysis to further improve the quality of the impact analysis results. Moreover, water losses can take place during the transport from the pump to the field, which could stimulate promotion of increase investment in transportation pipes.

3.4 Case studies

Several interventions were implemented successfully during the APSAN-Vale project and monitored for selected PPCs. The practical aspects of implementing interventions and the observed impact can be most effectively explained with some case study examples. For each district a combination of two PPCs are selected that grow the same crop but have different practices implemented.

[11] Van Opstal, J., Droogers, P., Kaune, A., Steduto, P. and Perry, C. . 2021. Guidance on realizing real water savings with crop water productivity interventions. Wageningen, FAO and FutureWater. https://doi.org/10.4060/cb3844en

3.4.1 Bárùe (Cabbage)

Figure 11 shows the case study profiles for cabbage fields of PPC Ananias and Joelmo in Báruè.

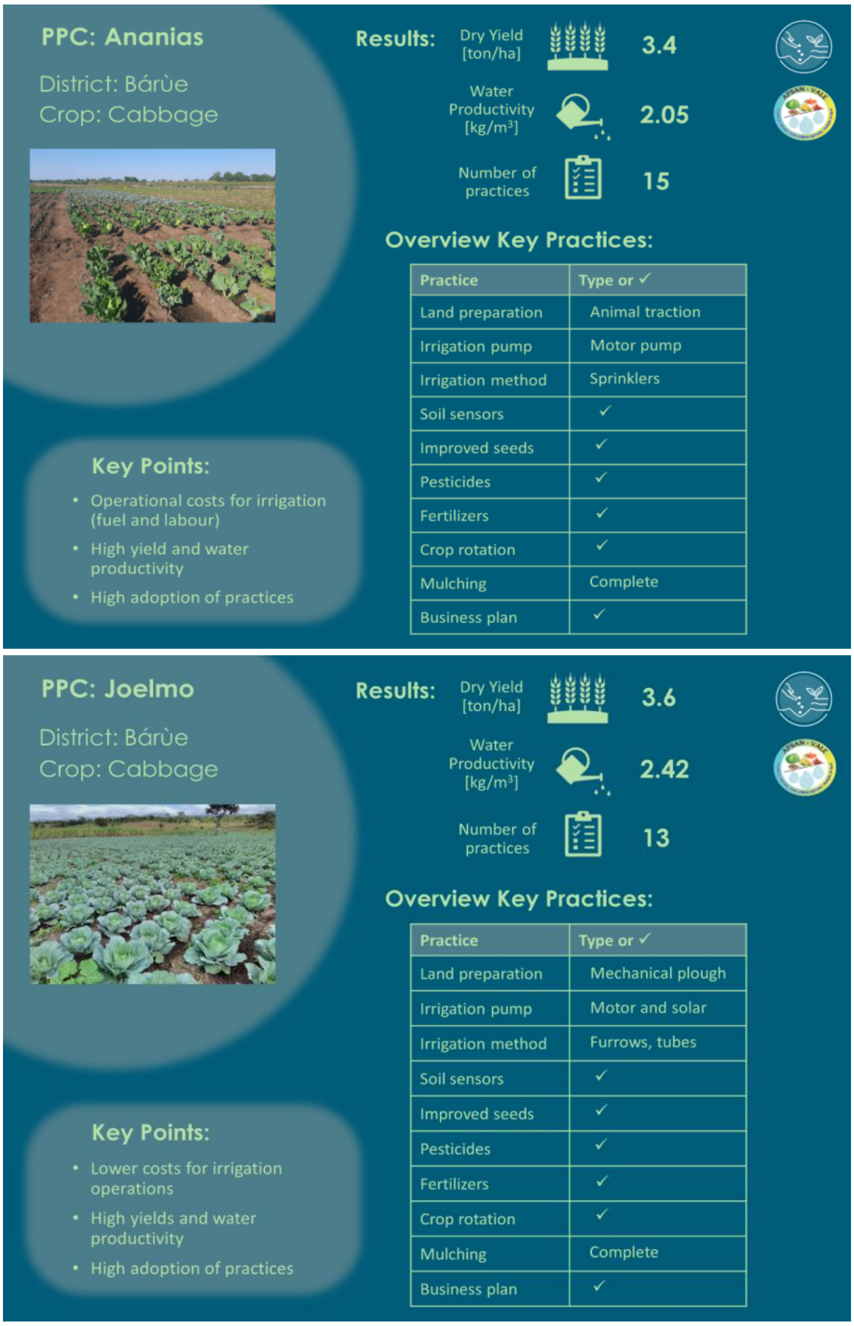

Figure 11. Case study profiles for Bárùe cabbage fields of PPC Ananias and Joelmo

The following observations were made:

- The crop yield results found for these PPCs (Ananias and Joelmo) are very similar, whilst the water productivity of Joelmo is higher than Ananias. Both PPCs adopted a high number of practices.
- Joelmo practices furrow irrigation, which in combination with soil sensors (thereby preventing over-irrigation) is an effective water management strategy for achieving higher water productivity results. This conclusion can be verified using other examples from other PPCs in upcoming seasons.

3.4.2 Moatize (Tomato)

Figure 12 shows the case study profiles for tomato fields of PPC AlbertoL and Zeca in Moatize.

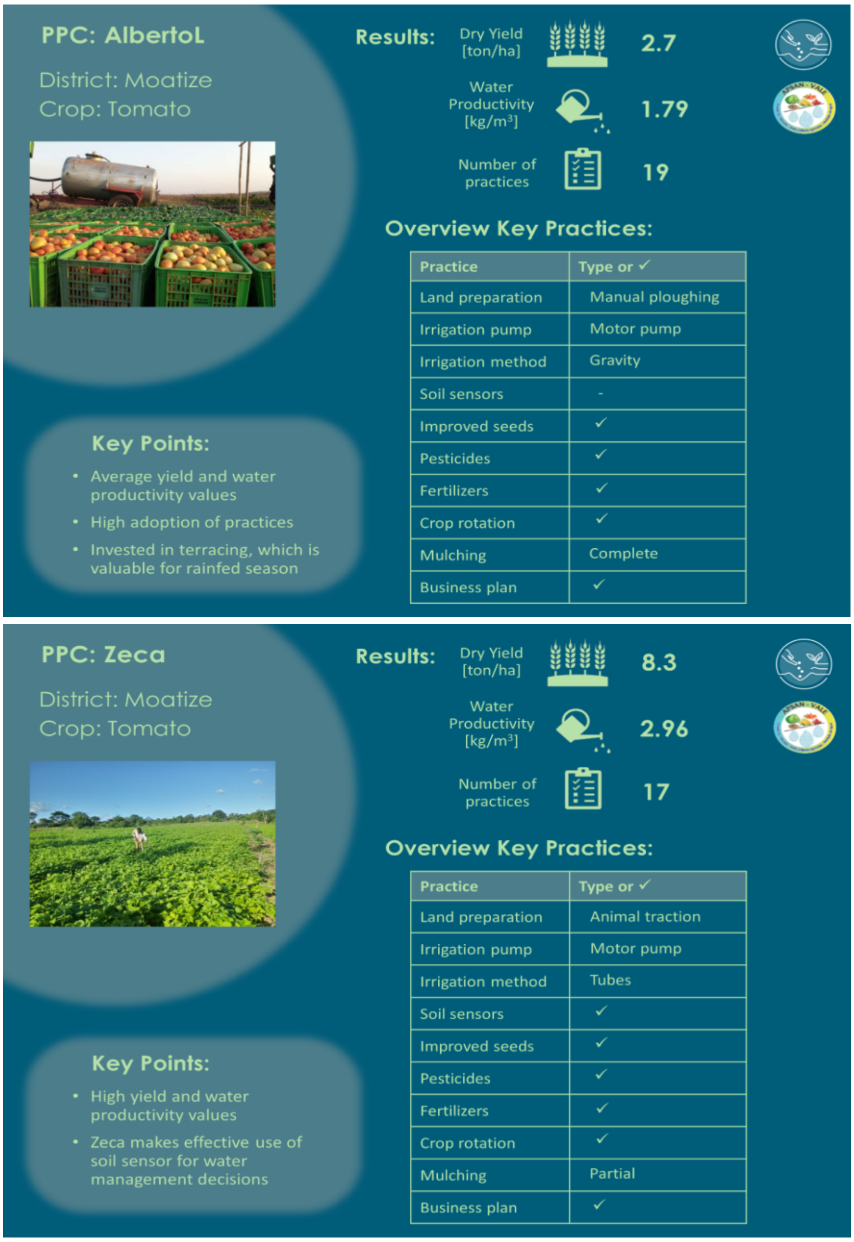

Figure 12. Case study profiles for Moatize tomato fields of PPC AlbertoL and Zeca

The following observations were made:

- The crop yield and water productivity results for Zeca is much higher than Alberto L. Both PPCs adopted a high number of practices.
- Both implemented gravity irrigation (tubes or furrows), however Zeca also made use of soil sensors for determining the timing of the irrigation. This can be the reason that yield and water productivity results were found to be higher for Zeca. This conclusion can be verified in upcoming seasons using other examples from PPCs.
- The adoption of practices survey noted that Alberto L invested in land preparation (terrasse and dikes) interventions, which will be beneficial for the rain season when runoff management is an effective management strategy for improving water productivity and crop yield.

3.4.3 Nhamatanda (Onion)

Figure 13 shows the case study profiles for onion fields of PPC Flora and Lucas in Nhamatanda.

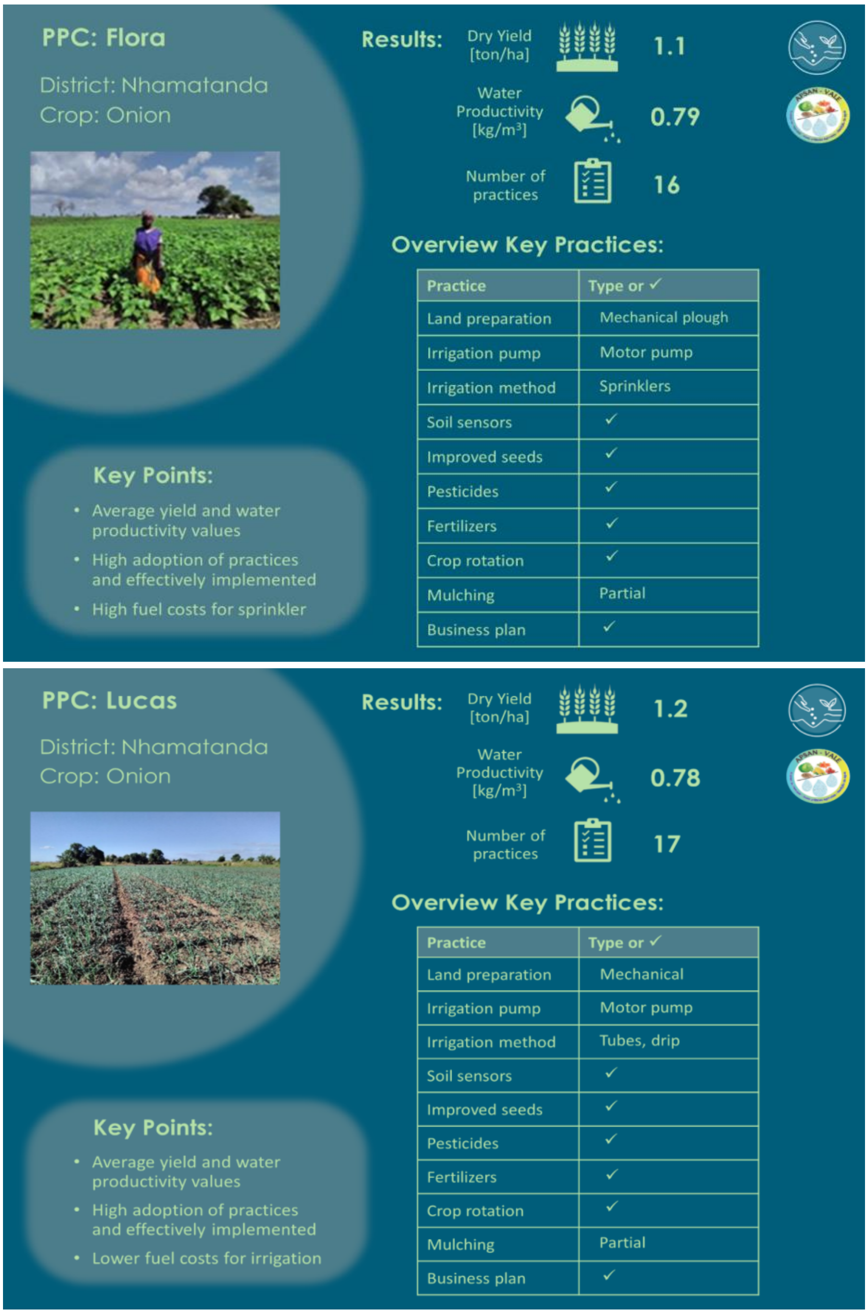

Figure 13. Case study profiles for Nhamatanda onion fields of PPC Flora and Lucas

The following observations were made:

- The crop yield and water productivity results found for these PPCs (Flora and Lucas) are very similar. Both PPCs adopted a high number of practices.
- The sole difference in practices between these two PPCs is the irrigation method, which is sprinkler irrigation for Flora and both tubes and drip irrigation for Lucas. The theoretical higher water productivity found in simulations (section 3.3.3) for furrow and drip irrigation is not observed in this case study.

4 Concluding remarks

Analyzing the observations of the comparison between adoption of practices in 2020 and 2021, we come to the following conclusions:

- A key development is the increase of control group farmers who use a pump to irrigate (from about 5% to 22%) (and consequentially use furrows in their fields which has an increase from about 22% to 36%). A decrease of bucket irrigation by the control group strengthens this observation. This is major because this is a major difference jump into commercialization of the production system. Farmers have the incentive to start to produce more intensively which could possibly be an indirect spill-over effect of APSAN-Vale project. Explanations are: farmers see the potential or irrigated agriculture around them, better access to input and output markets (incentivizing farmers to produce commercially), or increased availability of pumps in the region that can be hired.
- The high and even increased rate of both APSAN-Vale farmers as control group farmers that plough by hand and the high and even increased rate of APSAN-Vale farmers that use local seeds is not desired as it is considered a "low tech" or "original" practice.
- Water field management practices are highly adopted amongst APSAN-Vale farmers, very limited by control group: thus a practice to promote among new farmers.
- There is an increase in all kinds of ploughing. This is a positive observation for mechanized and animal traction. However, it is remarkable that manual also increased, as one would expect that if the others increase, manual decreases as it would be substituted. There are less APSAN farmers who do it manually (and this have a more advanced technological alternative) compared to the control group. Especially if we want to promote horticultural production during the hot season, special attention should be paid to animal and mechanical ploughing to reduce labour requirements.
- Business plans: this practice needs more attention in the future, as farmers are willing to adapt (see comparison with control group).

The comparison of results with the practices applied gives some key messages, namely:

- The adoption of practices for the group of APSAN-Vale project beneficiaries was high with on average 10 practices adopted. The control group adopted on average 2 practices.
- Comparing adoption of practices of 2020 and 2021, low-cost practices that require knowledge are adopted most, especially water management practices. Drainage and soil humidity sensors show an increase showing potential to be further promoted.
- Increased pumped irrigated agriculture, even among the control group, is a proof that APSAN-Vale is catalysing farmer-led development processes.
- Runoff management practices had limited impact on the water balance components or yield results for this study, because it is more relevant as a practice in the rainfed season.
- The results of mulching and improved seeds interventions show that improvements in water productivity can be achieved by adopting these interventions. The practical implementation of these practices should be evaluated with case studies and interview questions.
- The irrigation methods showed that furrow irrigation in combination with soil sensors gave good results in water productivity and yield. However, if furrow irrigation is practiced without proper monitoring of the irrigation schedule, there is a tendency of over-irrigation.

Overall, the findings from the theoretical analysis gave some interesting linkages with the observed impact as reported in the case studies. In upcoming seasons, the preliminary findings can be further verified and used to convince growers about the benefits that can be achieved with interventions.

Annex 1: Grouped practices

1. Water management practices							
1.1 Land preparation							
1.1.2 Land preparation: irrigation			1.1.3 Land preparation: WRM				
Land prep: sulcos	Land prep: Basin	Land prep: in lines	Land prep: bunds	Land prep: terrasses	Land prep: dikes	Drainage	Heaping

1. Water management practices									
1.2 Irrigation methods								1.3 overall water man practices	1.4 use of soil sensor
Irri: motor pump	Irri: solar pump	Irri: footpump	Irri: furrows	Irri: tubes	Irri: buckets	Irri: sprinklers	Irri: drip	Water management practices	Soil sensor

2. Good agricultural practices											
2.1 Land preparation methods			2.2 Use of inputs								
			2.1.1 Seeds			2.1.2 Use of inputs (pesticides and herbicides)			2.1.3 Fertilizer use		
Mechanical ploughing	Animal traction	Manual ploughing	Local seeds	Improved seeds	Seedbeds	Use of herbicides	Use of pesticides	Management of pesticides	Organic fertilizer	Chemical fertilizer	Organic and chemical fertilizer

2. Good agricultural practices							**3. Market**
2.3 GAP (planning and spacing)				2.4 Soil cover			
Crop spacing	Intercropping	Crop rotation	Staggering and planning	Incorporating plant rests	Mulching (complete)	Mulching (partitial)	Business planning

Overview of training topics, content of the topic and implication for the production process for irrigation specific trainings and support on: 1.2 irrigation methods, overall water management practices 1.3, good agricultural practice (2.3), 2.4 (soil cover)

Training topic	Content of the training	Benefits and implications for the production system
Irrigation calendar	Apsan-Vale Project provide tailor-made irrigation calendars to inform about irrigation frequency and quantity, based on the production system of the farmer. The calendars are personalised and the producers are trained in their use.	– More efficient use of irrigation materials, decreasing labour time and operational costs. – Better understanding of water requirements, allowing farmer to plan irrigation turns. – Better growth of plants, increasing quantity and quality of production, leading to higher income.
Staggering	Staggered rainfed crop production means that farmers plant their crops in periods to reduce labour and to reduce the risk of irregular rainfall.Staggered production of horticultural crops is planting the crops in different phases. This technique helps to secure and ensure better market management.	– Reduction of risks of climate variability (unpredictable rains) – Spread of labour, allowing for expansion of production area – Opportunity to produce during higher market prices, increasing income
Water and soil management	Water management techniques on how to maintain soil moisture: runoff management, ways of drainage and how to save water, and heaping. For the irrigation season, farmers learn about soil moisture test to know soil humidity and the need for irrigation to decrease the frequency of watering and soil water management practices to avoid water losses during irrigation irrigation.	– Increase of water availabilty to plant, increasing production – Reduction of irrigation requirements, which is a reduction of labour and operational costs – Less water losses, leading to increase of water productivity
Mulching or soil coverage	Mulching is the placing of dry organic material (grass, straws, leaves and others) over the soil. This technique helps to retain soil moisture, reduces weed growth, improves soil structure and ensures nutrient supply to crops. We teach different techniques of mulching and its advantages.	– Increase of water availability and nutritiens in the soil, increasing production – Reduction of irrigation requirements, which is a reduction of labour and operational costs – Less water losses, leading to increase of water productivity
Operation of irrigation materials	Together with farmers, irrigation systems are designed, co-financed based on the characteristics of the farm, the intend crops to produce, availability of money through a business plan. Farmers are trained on how they should istall and operate the pump.	– Understanding of design process, facilitating farmer’s understanding of materials on production system – Increase farmer’s independence in future irrigation material purchases. – Efficient use of materials, leading to sustainability of the system and reduction of operational costs.
Maintenace of irrigation equipment	The participants are trained on how to use the irrigation materials in a sustainable way and how and when they should do basic maintenance of the irrigation systems.	– Increase of sustainability and durability of system
Irrigation techniques	Based on understanding of the soil-water-plant relationship, farmers better understand required irrigation quantity and frequency per crop and growing stage.	– Reduction of irrigation frequency, leading to less operational costs and labour requirements. – Increase of water use efficiency, increasing water productivity
Irrigation practices	We discuss the different water application forms, water quantities (crop water requirements), recommended watering frequency (watering intervals) and make decisions for the best management of the different irrigation systems.	– Reduction of irrigation frequency, leading to less operational costs and labour requirements. – Increase of water use efficiency, increasing water productivity

Annex 2: Results AquaCrop simulations

ID	District	PPC	Croptype	Simulation	Intervention	Irri	Infilt	Runoff	Drain	E	Tr	ET	Yield	WPet	Wpir	Change ET	Change in Irri	Change Yield	Change WP_Ir	Change WP_ET
Irri_AP_BA_ACI-01-04	Barue, Cabbage	Ananias	Cabbage	Sprinkler	Original	128	180	1	4	97	100	197	3.40	1.95	2.66	1%	0%	0%	-1%	0%
Irri_AP_BA_ACI-01-04	Barue, Cabbage	Ananias	Cabbage	Furrow	Irrigation type	129	181	1	4	95	100	195	3.40	1.97	2.64					
Irri_AP_BA_ACI-01-04	Barue, Cabbage	Ananias	Cabbage	Drip	Irrigation type	103	155	1	5	80	100	180	3.40	2.05	3.30	-8%	-20%	0%	4%	4%
Irri_AP_BA_ACI-01-04	Barue, Cabbage	Ananias	Cabbage	Mulch_no_orig	Original	128	180	1	4	97	100	197	3.40	1.95	2.66					
Irri_AP_BA_ACI-01-04	Barue, Cabbage	Ananias	Cabbage	Mulch_partial	Mulching / Plant rests	103	155	1	5	75	100	175	3.40	2.12	3.31	-11%	-20%	0%	9%	9%
Irri_AP_BA_ACI-01-04	Barue, Cabbage	Ananias	Cabbage	Mulch_full	Mulching / Plant rests	104	153	3	9	65	100	165	3.40	2.30	3.29	-16%	-19%	0%	18%	18%
Irri_AP_BA_ACI-01-04	Barue, Cabbage	Ananias	Cabbage	Runoff_no_orig	Original	128	180	1	4	97	100	197	3.40	1.95	2.66					
Irri_AP_BA_ACI-01-04	Barue, Cabbage	Ananias	Cabbage	Runoff_yes_orig	Runoff management	128	181	0	4	97	100	197	3.40	1.95	2.66	0%	0%	0%	0%	0%
Irri_AP_BA_ACI-01-04	Barue, Cabbage	Ananias	Cabbage	Seeds_orig	Original	128	180	1	4	97	100	197	3.40	1.95	2.66					
Irri_AP_BA_ACI-01-04	Barue, Cabbage	Ananias	Cabbage	Seeds_improv	Improved seeds	129	179	2	5	83	113	195	3.84	2.14	2.98	-1%	1%	13%	10%	10%
Irri_AP_BA_ACI-01-04	Barue, Cabbage	Ananias	Cabbage	Seeds_improv_more	Improved seeds	131	182	2	4	77	123	200	4.19	2.26	3.18	2%	2%	23%	16%	16%
Irri_AP_BA_JDR-01-02	Barue, Cabbage	Joelmo	Cabbage	Furrow	Original	81	124	0	0	66	103	169	3.60	2.50	4.45					
Irri_AP_BA_JDR-01-02	Barue, Cabbage	Joelmo	Cabbage	Sprinkler	Irrigation type	81	124	0	0	66	103	169	3.60	2.50	4.45	0%	0%	0%	0%	0%
Irri_AP_BA_JDR-01-02	Barue, Cabbage	Joelmo	Cabbage	Drip	Irrigation type	81	124	0	0	66	103	169	3.60	2.50	4.45	0%	0%	0%	0%	0%
Irri_AP_BA_JDR-01-02	Barue, Cabbage	Joelmo	Cabbage	Mulch_no_orig	Original	81	124	0	0	66	103	169	3.60	2.50	4.45					
Irri_AP_BA_JDR-01-02	Barue, Cabbage	Joelmo	Cabbage	Mulch_partial	Mulching / Plant rests	81	124	0	0	63	103	166	3.59	2.56	4.46	-2%	0%	0%	2%	2%
Irri_AP_BA_JDR-01-02	Barue, Cabbage	Joelmo	Cabbage	Mulch_full	Mulching / Plant rests	81	123	1	0	59	103	162	3.60	2.65	4.46	-4%	0%	0%	6%	6%
Irri_AP_BA_JDR-01-02	Barue, Cabbage	Joelmo	Cabbage	Runoff_no_orig	Original	81	124	0	0	66	103	169	3.60	2.50	4.45					
Irri_AP_BA_JDR-01-02	Barue, Cabbage	Joelmo	Cabbage	Runoff_yes_orig	Runoff management	81	124	0	0	66	103	169	3.60	2.50	4.45	0%	0%	0%	0%	0%
Irri_AP_BA_JDR-01-02	Barue, Cabbage	Joelmo	Cabbage	Seeds_orig	Original	81	124	0	0	66	103	169	3.60	2.50	4.45					
Irri_AP_BA_JDR-01-02	Barue, Cabbage	Joelmo	Cabbage	Seeds_improv	Improved seeds	123	166	0	0	76	117	192	4.06	2.62	3.31	14%	52%	13%	5%	5%
Irri_AP_BA_JDR-01-02	Barue, Cabbage	Joelmo	Cabbage	Seeds_improv_more	Improved seeds	123	166	0	0	65	129	194	4.46	2.72	3.64	15%	52%	24%	9%	9%
Irri_AP_MO_AC-01-01	Moatize, Tomato	Alberto	Tomato	Furrow	Original	124	134	0	0	39	108	146	2.78	1.90	2.24					
Irri_AP_MO_AC-01-01	Moatize, Tomato	Alberto	Tomato	sprinkler	Irrigation type	126	136	0	0	41	108	149	2.78	1.87	2.21	2%	2%	0%	-2%	-2%
Irri_AP_MO_AC-01-01	Moatize, Tomato	Alberto	Tomato	Drip	Irrigation type	123	133	0	0	32	108	139	2.78	2.00	2.26	-5%	-1%	0%	5%	5%
Irri_AP_MO_AC-01-01	Moatize, Tomato	Alberto	Tomato	Mulch_no_orig	Original	124	134	0	0	39	108	146	2.78	1.90	2.24					
Irri_AP_MO_AC-01-01	Moatize, Tomato	Alberto	Tomato	Mulch_partial	Mulching / Plant rests	123	133	0	0	35	108	143	2.78	1.95	2.26	-3%	-1%	0%	3%	3%
Irri_AP_MO_AC-01-01	Moatize, Tomato	Alberto	Tomato	Mulch_full	Mulching / Plant rests	122	132	0	0	29	108	136	2.78	2.04	2.28	-7%	-2%	0%	7%	7%
Irri_AP_MO_AC-01-01	Moatize, Tomato	Alberto	Tomato	Runoff_no_orig	Original	124	134	0	0	39	108	146	2.78	1.90	2.24					
Irri_AP_MO_AC-01-01	Moatize, Tomato	Alberto	Tomato	Runoff_yes_orig	Runoff management	124	134	0	0	39	108	146	2.78	1.90	2.24	0%	0%	0%	0%	0%
Irri_AP_MO_AC-01-01	Moatize, Tomato	Alberto	Tomato	Seeds_orig	Original	124	134	0	0	39	108	146	2.78	1.90	2.24					
Irri_AP_MO_AC-01-01	Moatize, Tomato	Alberto	Tomato	Seeds_improv	Improved seeds	123	133	0	2	37	122	158	3.12	1.97	2.54	8%	-1%	12%	4%	4%
Irri_AP_MO_AC-01-01	Moatize, Tomato	Alberto	Tomato	Seeds_improv_more	Improved seeds	124	134	0	0	35	137	172	3.46	2.02	2.80	17%	0%	24%	6%	6%
Irri_AP_MO_ZM-01-01	Moatize, Tomato	Zeca	Tomato	Furrow	Original	245	254	0	0	42	225	267	8.31	3.11	3.40					
Irri_AP_MO_ZM-01-01	Moatize, Tomato	Zeca	Tomato	sprinkler	Irrigation type	247	257	0	0	49	225	274	8.31	3.04	3.36	3%	1%	0%	-2%	-2%
Irri_AP_MO_ZM-01-01	Moatize, Tomato	Zeca	Tomato	Drip	Irrigation type	247	256	0	0	32	225	256	8.31	3.25	3.37	-4%	1%	0%	5%	5%
Irri_AP_MO_ZM-01-01	Moatize, Tomato	Zeca	Tomato	Mulch_no_orig	Original	245	254	0	0	42	225	267	8.31	3.11	3.40					
Irri_AP_MO_ZM-01-01	Moatize, Tomato	Zeca	Tomato	Mulch_partial	Mulching / Plant rests	247	257	0	0	39	225	264	8.31	3.16	3.36	-1%	1%	0%	2%	2%
Irri_AP_MO_ZM-01-01	Moatize, Tomato	Zeca	Tomato	Mulch_full	Mulching / Plant rests	247	256	0	0	32	225	256	8.31	3.24	3.37	-4%	1%	0%	4%	4%
Irri_AP_MO_ZM-01-01	Moatize, Tomato	Zeca	Tomato	Runoff_no_orig	Original	245	254	0	0	42	225	267	8.31	3.11	3.40					
Irri_AP_MO_ZM-01-01	Moatize, Tomato	Zeca	Tomato	Runoff_yes_orig	Runoff management	245	254	0	0	42	225	267	8.31	3.11	3.40	0%	0%	0%	0%	0%
Irri_AP_MO_ZM-01-01	Moatize, Tomato	Zeca	Tomato	Seeds_orig	Original	245	254	0	0	42	225	267	8.31	3.11	3.40					
Irri_AP_MO_ZM-01-01	Moatize, Tomato	Zeca	Tomato	Seeds_improv	Improved seeds	249	258	0	0	41	235	276	8.77	3.18	3.53	3%	2%	5%	2%	2%
Irri_AP_MO_ZM-01-01	Moatize, Tomato	Zeca	Tomato	Seeds_improv_more	Improved seeds	248	257	0	2	40	242	281	9.08	3.23	3.67	5%	1%	9%	4%	4%
Irri_AP_NH_LB-01-04	Nhamatanda, Onion	LucasB	Onion	Furrow	Original	105	181	17	10	64	114	178	1.96	1.16	1.88					
Irri_AP_NH_LB-01-04	Nhamatanda, Onion	LucasB	Onion	sprinkler	Irrigation type	105	182	17	10	66	114	179	1.95	1.15	1.86	1%	1%	0%	-1%	-1%
Irri_AP_NH_LB-01-04	Nhamatanda, Onion	LucasB	Onion	Drip	Irrigation type	105	181	18	10	60	115	174	1.97	1.22	1.88	-2%	0%	0%	5%	5%
Irri_AP_NH_LB-01-04	Nhamatanda, Onion	LucasB	Onion	Mulch_no_orig	Original	105	181	17	10	64	114	178	1.96	1.16	1.88					
Irri_AP_NH_LB-01-04	Nhamatanda, Onion	LucasB	Onion	Mulch_partial	Mulching / Plant rests	103	180	17	12	57	116	173	2.00	1.21	1.94	-3%	-1%	2%	4%	4%
Irri_AP_NH_LB-01-04	Nhamatanda, Onion	LucasB	Onion	Mulch_full	Mulching / Plant rests	105	181	18	14	42	129	171	2.19	1.33	2.09	-4%	0%	12%	15%	15%
Irri_AP_NH_LB-01-04	Nhamatanda, Onion	LucasB	Onion	Runoff_no_orig	Original	105	181	17	10	64	114	178	1.96	1.16	1.88					
Irri_AP_NH_LB-01-04	Nhamatanda, Onion	LucasB	Onion	Runoff_yes_orig	Runoff management	103	194	0	25	64	115	179	1.98	1.17	1.91	0%	-1%	1%	1%	1%
Irri_AP_NH_FM-01-02	Nhamatanda, Onion	Flora	Onion	Furrow	Original	105	154	1	1	65	116	181	2.03	1.26	1.93					
Irri_AP_NH_FM-01-02	Nhamatanda, Onion	Flora	Onion	sprinkler	Irrigation type	106	155	1	1	67	116	182	2.02	1.24	1.91	1%	1%	0%	-2%	-2%
Irri_AP_NH_FM-01-02	Nhamatanda, Onion	Flora	Onion	Drip	Irrigation type	103	152	1	1	62	116	178	2.02	1.30	1.96	-2%	-2%	0%	3%	3%
Irri_AP_NH_FM-01-02	Nhamatanda, Onion	Flora	Onion	Mulch_no_orig	Original	105	154	1	1	65	116	181	2.03	1.26	1.93					
Irri_AP_NH_FM-01-02	Nhamatanda, Onion	Flora	Onion	Mulch_partial	Mulching / Plant rests	102	151	1	2	58	119	177	2.08	1.32	2.03	-2%	-3%	2%	5%	5%
Irri_AP_NH_FM-01-02	Nhamatanda, Onion	Flora	Onion	Mulch_full	Mulching / Plant rests	104	153	1	3	52	122	175	2.15	1.41	2.07	-3%	-1%	6%	12%	12%
Irri_AP_NH_FM-01-02	Nhamatanda, Onion	Flora	Onion	Runoff_no_orig	Original	105	154	1	1	65	116	181	2.03	1.26	1.93					
Irri_AP_NH_FM-01-02	Nhamatanda, Onion	Flora	Onion	Runoff_yes_orig	Runoff management	105	155	0	1	65	117	181	2.05	1.26	1.95	0%	0%	1%	0%	0%