Assistance in using Modeling Tools for Climate Change Vulnerability and Impact Assessment, Armenia

Final summary report

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FutureWater Report 162

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Preface

This final report summarizes the work carried out for Phase B of the assignment "Assistance in using modeling tool(s) for climate change vulnerability and impact assessment", providing expert input and training to specialists in Armenia on these subjects. The project took place between September and December 2016. A report on Phase A of this assignment wherein the training model was selected through stakeholder consultation is separately available.

Two International Experts from FutureWater carried out this project out as subcontractor of DAI Europe for the "Clima East: Support to Climate Change Mitigation and Adaptation in Russia and ENP East Countries" programme funded by the European Commission. The project was financed through the Clima East Expert Facility with reference CEEF2014-025-AM.

The report summarizes the activities, training materials and outcomes of the workshop. It also provides a few recommendations for follow-up work and training in the country. The authors of this report would like to thank the experts of the Clima East programme, and in particular Medea Inashvili, Armine Astsatryan and Taron Aleksanyan.

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1 Introduction

1.1 Country background

Armenia is considered especially vulnerable to the adverse impacts of climate change, as recognized by the UNFCC Convention. The Ministry of Nature Protection of Armenia is the main organization responsible for climate-change-related issues and the fulfilment of the commitments under the UNFCC Convention. As required by the Convention Armenia prepares regularly National Communications that describe the country´s efforts in implementing climate mitigation and adaptation measures.

So far, Armenia has submitted three National Communications, the latest was published in 2015. These documents contain chapters for adaptation and vulnerability assessment of different sectors and areas, based on present capacities in the country. The Third Communication confirmed that multiple, often interrelated impacts of climate change, conditioned by the complexity of the region (geographical, geological, economic and political), the diversity of ecosystems, are causing more and more losses in practically all economic sectors and are leading to a security challenge (food scarcity, human livelihoods, resource depletion).

Given the complexity of the drivers and impacts, assessment studies and tools are required that allow informed decision making on CC adaptation planning and policy development. Therefore, the national capacity needs to be strengthened to undertake these types of studies and to use the adequate modelling tools to predict climate change impacts on vulnerable ecosystems and sectors of the economy. This should enable the dedicated institutions to evaluate and prioritize adequate adaptation planning measures and develop a robust National Adaptation Plan.

Several projects under various donor activities have been carried out and or are ongoing that focus on capacity building on climate change adaptation in order to enhance resilience to climate change. Various international and bilateral donor funds and agencies such as UNDP, USAID, World Bank, WWF, German GIZ, have realized or are implementing CC-adaptation-related projects in Armenia. However, they were not specifically targeting capacity building of technical staff of the relevant country´s institutes in the use and application of modeling tools for climate change vulnerability assessments.

1.2 The Clima East programme

Clima East is a European Union funded project package assisting the Eastern Neighbourhood Partnership Countries in approaches to climate change mitigation and adaptation. The project has a Policy component that seeks to foster improved climate change policies, strategies and market mechanisms in the partner countries by supporting regional cooperation and improving information access to EU climate change policies, laws and expertise. This component is implemented by an HTSPE led consortium, and has a budget of EUR 8.2 million over 4 years.

The Clima East programme includes a so-called Expert Facility that enables to provide flexible, demand driven support to Clima East Partner Country stakeholders through the provision of EU and local experts for short term inputs to address arising needs. The Clima East Expert Facility

(CEEF) is open for applications for support from eligible organizations involved with climate actions, targeting both mitigation and adaptation in Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine. Applications to the Expert Facility must correspond to one or more of Clima East’s targeted result areas and should be able to demonstrate direct relevance to Climate Policy and its implementation.

Armenia requested assistance from the Clima East Expert Facility (EF) to increase its capacity in using modeling tools to assess water-related and climate change-induced impacts on agriculture. The overall objective is to have its national experts better prepared for assessing climate change adaptation strategies and developing a National Adaptation Plan.

2 Description of the assignment

2.1 Objectives

The objective of this assignment was to increase the capacity in Armenia in using models for qualified assessment of vulnerability and planning of adaptation measures, with emphasis on water and agriculture. For this a group of national specialists was trained that are working or attached to the relevant institutes and organizations in the country.

From this, the following specific objectives were identified:

1) Selection of the most appropriate modelling tool, given the priority areas (agriculture, water, disasters/extreme weather events), technical specifications, accessibility, and suitability for the conditions in Armenia;
2) Assistance in the development, interpretation and analysis of future scenarios for climate change projections and;
3) Enhancing the staffs' capacity in data collection process for the selected modelling tool;
4) Support in the access, installation and use of to the modeling tool and other related software needed for the assessment;
5) Hands-on training of the specialists in the model use, both theoretical as well as practical data, using local data if available

2.2 Target group

The target group of the capacity building assignment were specialists from the national hydro-meteorological office, the Ministry of Agriculture, the Ministry of Nature Protection and academic experts working in related matters. Only experts were selected with good technical knowledge and experience in working with climate and agricultural data, and a reasonable understanding of the agricultural sector.

In total, 9 specialists were trained. They included:

- Chief Specialist of the Division of International Project Management and Monitoring / RA Ministry of Nature Protection (MNP)
- Chief Specialist of the Climate Change and Atmosphere Protection Policy Division / RA MNP
- Leading Specialist of the Water Resource Cadastre and Monitoring Division / Water Resources Management Agency, RA MNP
- Leading Specialist of the Melioration Department / RA Ministry of Agriculture
- Chief Specialist of the Meteorology Division / Meteorological Centre, Armstatehydromet, RA Ministry of Emergency Situations
- First Class Specialist of the Agrometeorology Division / Meteorological Centre, Armstatehydromet, RA Ministry of Emergency Situations
- Leading Specialist of the Agrometeorological Forecasting Division / Armstatehydromet, RA Ministry of Emergency Situations

2.3 Activities

The project was divided in two phases. In **Phase A** the proper vulnerability assessment modelling tool was selected together with the local experts, based on coverage of the priority areas (agriculture, water, disasters/extreme weather events) and technical specifications. This phase was carried out in preparation of the work that is summarized in this report and was reported previously by the respective international expert that carried out this phase.

Phase A concluded with the selection of the crop water productivity model developed by the FAO: AquaCrop. See the next section for more details.

Then, **Phase B** consisted of the following main activities

A. Assistance in selection of proper scenario(s) together with the national expert for projections and how to interpret them within adaptation decision-making frameworks, as well as assistance in using and accessing the tool.
B. Enhancing the staffs' capacity in the data collection process (improving access to data, methods for estimation for missing data) for the selected modelling tool(s);
C. Hands-on training of the staffs in the model use (including the conduction of impact assessment for agriculture and the analysis of the results. This training was consisted of a 1-week theoretical and practical training, and a 4-day workshop in which local data were used obtained together with the local experts and institutes.

For the first and second workshop, tailored training materials were prepared. The training programme started in September and ended the beginning of December. Figure 1 shows the Gantt chart of the activities (as in Terms of Reference) as they were actually carried out.

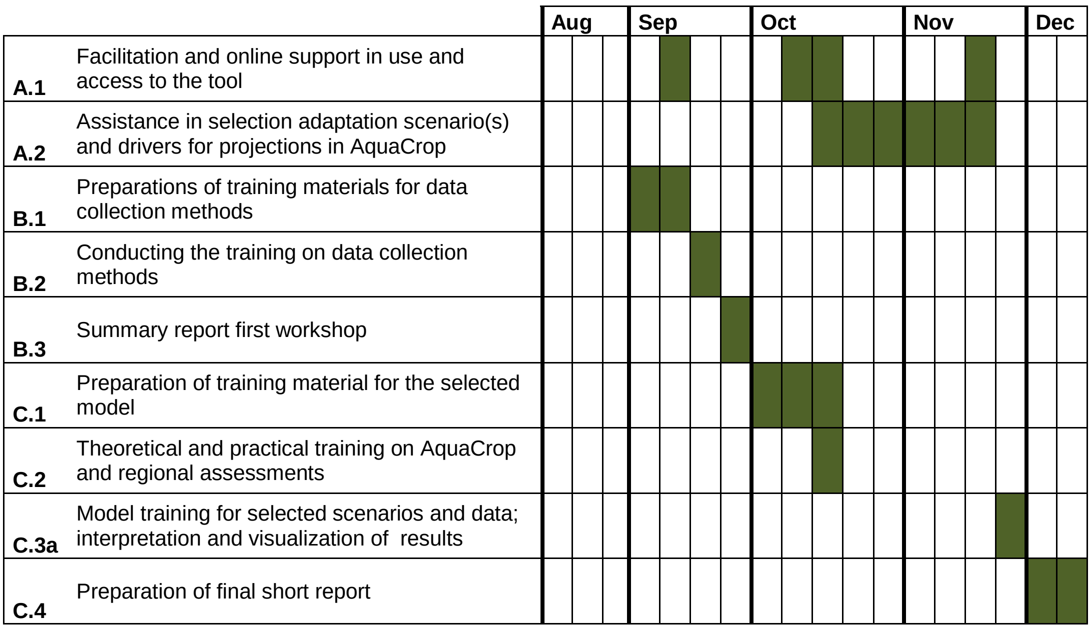


Figure 1. Gantt chart of activities of Phase B as they were carried out

2.4 Modeling tools

The selected modeling tool was the crop water productivity model developed by the FAO: AquaCrop. AquaCrop is typically used a planning tool or to assist in management decisions for both irrigated and rainfed agriculture. AquaCrop is particularly useful for (Figure 2):

- understanding the crop response to environmental changes (educational tool);
- to compare attainable and actual yields in a field, farm, or a region;
- to identify constraints limiting crop production and water productivity (benchmarking tool);
- to develop strategies under water deficit conditions to maximise water productivity through;
- irrigation strategies: e.g. deficit irrigation;
- crop and management practices: e.g. adjusting planting date, cultivar selection, fertilization management, use of mulches, rain water harvesting;
- to study the effect of climate change on food production, by running AquaCrop with both historical and future weather conditions;
- for planning purposes, by analyzing scenarios useful for water administrators and managers, economists, policy analysts and scientists.

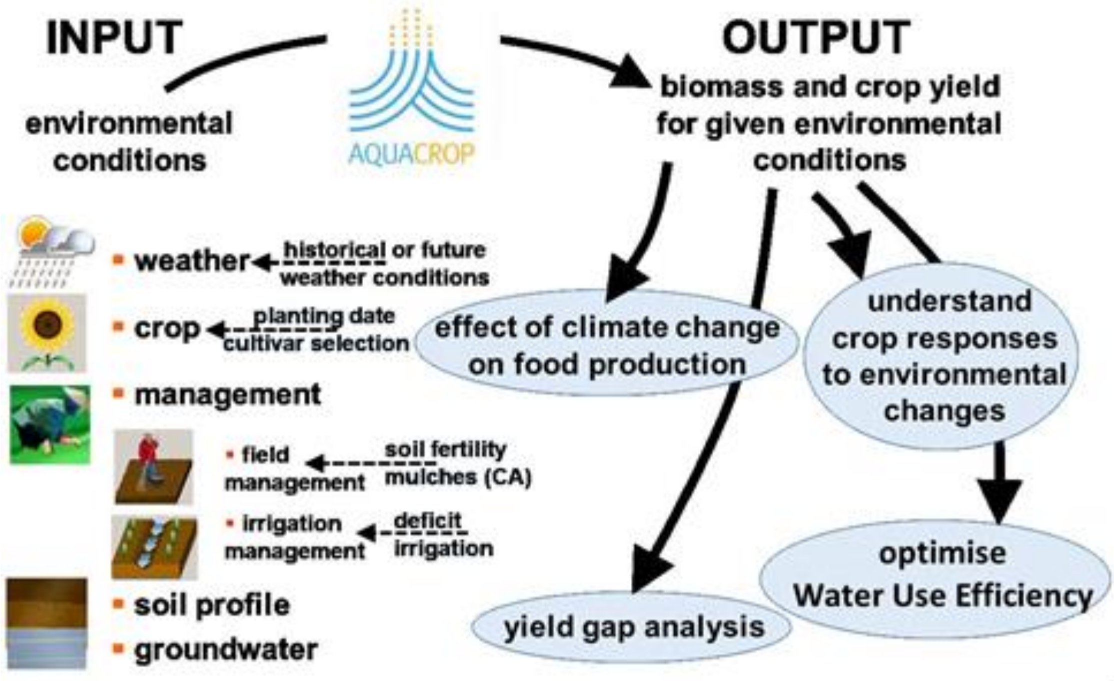


Figure 2. Typical applications of AquaCrop

AquaCrop uses a relatively small number of explicit parameters and largely intuitive input variables. Those are either widely available or require just simple methods for their determination. Input consists of weather data, crop and soil characteristics, and management practices that define the environment in which the crop will develop. Soil characteristics are divided into soil profile and groundwater characteristics and Management practices into field management and irrigation management practices.

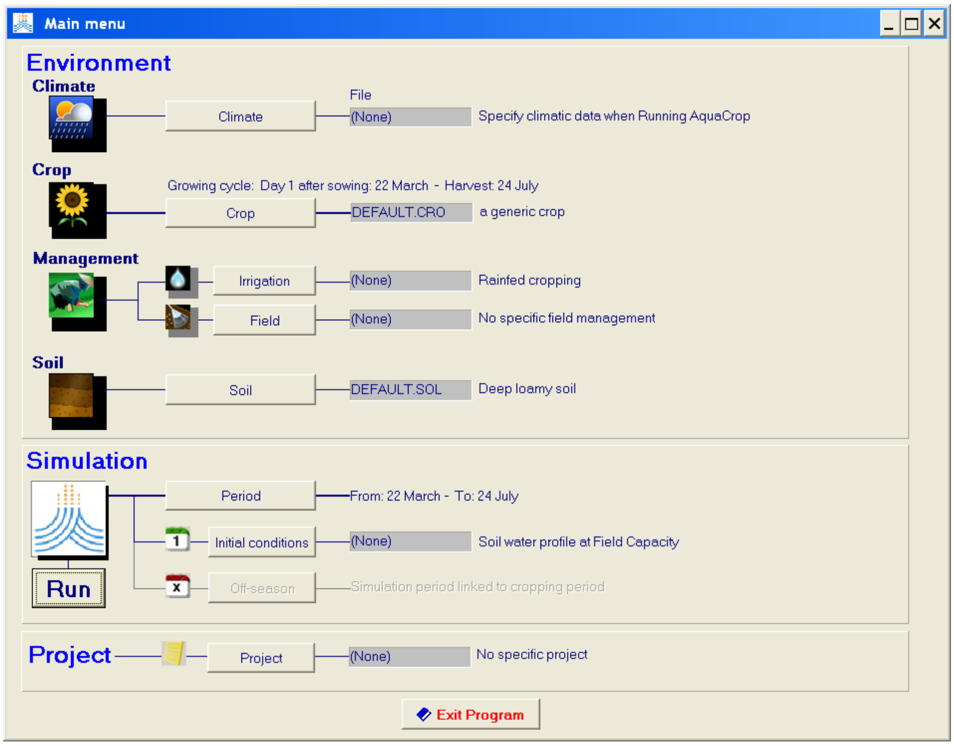


Figure 3. The main menu of the AquaCrop user interface

AquaCrop is designed to predict crop yield (only of herbaceous crops) at the single field scale (point simulations). However, it is often used for regional assessments but then other tools need to be employed in combination with AquaCrop. These tools are:

- Geographic Information System (GIS) software, as for example Quantum GIS (QGIS)
- Water allocation and modeling tools, as for example the Water Evaluation And Planning System (WEAP) software
- Downscaling and upscaling algorithms for climate data and model outputs

For climate change impact assessments at the national level, a good understanding of these complementary tools is desirable.

More details on AquaCrop can be found in the manuals, the AquaCrop website (http://www.fao.org/nr/water/aquacrop.html), and the training material of the workshops of this technical assistance.

3 Outcomes of the workshops

3.1 Workshop 1: Data Collection and Data Preparation for Climate Vulnerability Assessments using AquaCrop

Dates: 22-23 September 2016
Number of participants: 9
Program: See Annex A

Short summary of the workshop:
The participants first presented themselves and exposed their expectations. Then, the trainer gave a presentation on "Data and tools for climate change vulnerability assessments" related to agriculture and water. Special emphasis was given to:

- The need to match the question with the right modeling approach.
- Need for an integrated approach, including water users elsewhere in the watershed that either affect the potential for adaptation measures in a certain location, or are affected positivity or negatively by climate adaptation measures
- Climate change vulnerability analysis in agriculture requires often the need to upscale outcomes to provincial or national level. Thus capacity to use spatial data is essential.

This presentation was followed by practical exercises using GIS software (QGIS) in which the participants worked with the extraction of climate data from spatial climate datasets, established watersheds and visualized spatial data. After a quick tutorial was provided on using the WEAP software to collect the data in an integrated framework, and establish a simple water balance.

Figure 4. Presentation on data analysis tools

The second day started with a presentation with an introduction to AquaCrop, the interface and the main components of the model, in order to make the participants familiar with the main data requirements and start a discussion on these data needs. The outcome of this discussion was that several participants committed themselves in exploring over the next weeks the data availability in their institute.

After the presentation and discussion, the participants carried out exercises on model inputs and water balances, and started exploring future scenarios and their impact on water availability and the water gap for users in a watershed.

Relevant follow-up conclusions

From the feedback received during the first data-training, the following conclusions were drawn, that were useful to inform and tailor the design of the rest of the training program:

- A combination of theory with practice is optimal as this allows the participants to apply the theory directly. The modular setup of AquaCrop allows a training in which theory and practice are combined, and in which step-by-step an additional component will be taught by means of a lecture and a corresponding hands-on exercises.
- A discussion with the participants on data availability for climate vulnerability assessments was held and apparently quite some data are available on climate, crops and management in Hydromet, as they have currently a crop monitoring tool operational. The participants from this institute will explore the possibility of accessing these data or a small subset of it, for use in the training. Also in the Ministry of Agriculture, possibly some data are available on irrigation applications. Also data from other local sources (university) were discussed.
- It was agreed, that possibly the group will be extended with 2 participants more. The group will be relatively large (originally planned in the ToR to be between 6-8). To make sure that this does not negatively affect the quality of the workshop, a requirement for these two additional participants is that they possess a relatively high level of experience in using similar tools.

Training materials

A training tutorial was provided to the participants (digitally and as hand-out) that included explanation of the exercises. Besides, the required software and input data for the analysis was provided to the participants.

3.2 Workshop 2: Theoretical and Practical Training on the Use of AquaCrop

Dates: *17-21 October 2016*
Number of participants: 11
Program: See Annex A

During the first workshop, it was decided to enlarge the ambition of the training programme slightly compared to what initially envisioned in the ToR. Given the good response of the local experts (motivation and technical capabilities) it was considered feasible to dedicate the second training to a combination of theory and practical exercises, and then have the the third workshop fully for building applications of the modeling tool using local data.

Figure 5. One of the theoretical sessions during the workshop

Each day started with a theoretical session, in which the governing processes, model concepts, equations and user-interface were explained. Each day was dedicated to a specific sub-component of the model:

- Day 1: Introduction, user interface and database management
- Day 2: Climate data and reference evapotranspiration
- Day 3: Soil water balance, crop parameters and canopy development
- Day 4: Yield response to water, water stresses, rainfed farming and initial conditions
- Day 5: Irrigation scheduling, climate change analysis.

Training materials

Training materials provided to the participants consisted of:

- Powerpoints for each session
- Manuals of AquaCrop
- Training manuals with exercises
- Background literature

3.3 Workshop 3: Assessing Current and Future Climate Impacts on Crop Yields using AquaCrop

Dates: *28 November – 1 December, 2016*
Number of participants: 11
Program: See Annex A

This training was prepared together with a local expert (Taron Aleksanyan) who collected a complete dataset for 3 pilot sites and coordinated the data collection process with the local authorities. An overview of the data gathered is given in Annex B.

Given the good level and motivation of the participants, it was decided to apply the modeling tool to local data and assess climate change impacts on crop yields for 3 sites and 3 typical crops and management practices in Armenia. The participants were divided in 3 groups, each one responsible for one site. Each group prepared a Powerpoint presentation with the study setup (goal, input data, model outcomes, recommendations).

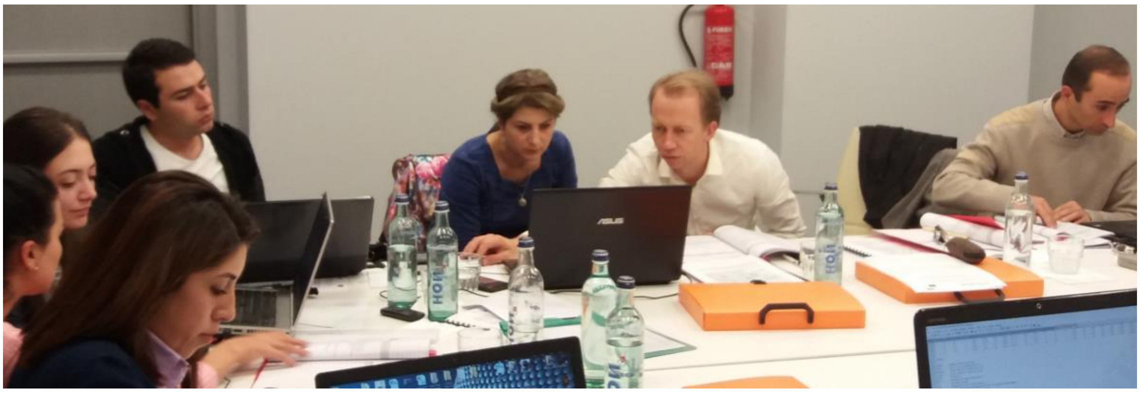


Figure 6. Participants working on the practical exercises

The training was finalized with the presentations of the 3 groups followed by a discussion on future works and recommendations. A chief national representative (Mr. Aram Gabrielyan, the National Focal Point of the UNFCCC) attended this final session and participated in the discussion. The main messages of this discussion are included in the following section.

Figure 7. Participants with the certificates of successful completion of the workshop

4 Conclusions and Recommendations

This technical assistance targeted technical experts of the relevant institutions of Armenia and provided a training programme that had the overall aim to increase the country´s ability to prepare and adapt to climate change impacts in the agricultural sector. The local experts were trained in using a crop water productivity model, preparing and collecting data for the tool and analyzing the results. The specialists were coming from a mix of organizations: ministries, academic environment and the national hydrometeorological office. The training enabled the specialists to use the selected tool independently.

Key recommendations:

1. Several participants concluded that the AquaCrop tool could be a promising tool to be used in Armenia for agricultural planning: estimation of seasonal water requirements, irrigation planning, crop selection, evaluation of irrigation practices, evaluation of agricultural conservation practices were mentioned among others.
2. It was mentioned that it could also potentially be used to provide recommendations in the National Agricultural Bulletin that comes out on a regular basis and has a large group of users in the agricultural sector
3. Combining this process-based model with more standard data-based approaches for which already decades of experience exists in the country was also put forward as an important recommendation. These methods are currently used by the national hydrometeorologial office for agrometeorological forecasting.
4. This training focused on the usability of AquaCrop to be used for climate change impact assessments (long-term). But most of the experts agreed that it could also be very useful for today´s issues and more medium-term agricultural planning.
5. More advanced-level training is recommended on spatial analysis in order to prepare the experts for nation-wide analysis – taking into account the wide diversity and heterogeneity in crops, farmers´ practices, and biophysical conditions. GIS techniques are critical for this type of analysis. The specialists have received beginners´ level training of GIS but more advanced techniques were out of scope of this assignment.
6. Also, for irrigation water availability and allocation, the use of Water Allocation Models is highly recommended. The specialists received a beginner´s level training in the use of the WEAP tool (a state-of-the-art water allocation tool), but more advanced training is recommended to be able to carry out basin-level or nation-wide integrated assessments of water demand and supply for irrigation, considering competing water uses.

Annex A. Workshop programs

Program of workshop 1

Training on Input Data Preparation and Analysis for Climate Vulnerability Assessments using AquaCrop

Dates: *22-23 September 2016*
Venue: *Ani Plaza Hotel,Yerevan, Armenia*
Trainers: *On-site: Johannes Hunink, FutureWater (j.hunink@futurewater.es)*
Online: Peter Droogers, FutureWater (p.droogers@futurewater.nl)

Program		**Manual**
Thursday 22-Sep-2016:		
8:30:	Registration	
9:00:	Welcome and objectives of project and training	
9:15:	"Tour de table" by the participants	
9:45:	Presentation *"Data and tools for climate change vulnerability assessments"*	
10:45:	*Coffee Break*	
11:00:	Practical: *"Data preparation and GIS"*	Chapter 2
13:00:	*Lunch break*	
14:00:	Practical: *"Quick tutorial water balance analysis"*	Chapter 3
16:30:	*Coffee Break*	
16:45:	Practical work: "*Building your own model"*	Chapter 4.1 and 4.2
18:00:	Closure	

Friday 23-Sep-2016:		
9:00:	Welcome and summary of previous day	
9:30:	Practical work: *"Explore model inputs"*	Chapter 4.3
11:00:	*Coffee Break*	
11:15:	Practical work: *"Water balance analysis of a baseline scenario"*	Chapter 4.4
13:00:	*Lunch break*	
14:00:	Practical work: *"Future scenario analysis"*	Chapter 5
17:45:	Wrap-up	
18:00:	Closure	

Program of workshop 2

Theoretical and Practical Training on use of AquaCrop for Climate Vulnerability Assessments

Dates: *17-21 October 2016*

Venue: *DoubleTree by Hilton Hotel Yerevan City Centre, Grigor Lusavorich Street,4/2, Yerevan,0015, Armenia*

Trainers: *On-site: Johannes Hunink, FutureWater (j.hunink@futurewater.es)*
Online: Peter Droogers, FutureWater (p.droogers@futurewater.nl)

Program		**Theory/ Practical**
Monday 17-Oct:		
14:00:	Registration	
14:15:	Introduction to the course and AquaCrop, presentation of user interface	T
16:00:	*Coffee Break*	
16:15:	Installation of AquaCrop, database management	P
18:00:	Closure	
Tuesday 18-Oct:		
9:00:	Climate: evapotranspiration, weather data	T
11:00:	*Coffee Break*	
11:15:	Exercises with importing climate data	P
13:00:	*Lunch break*	
14:00:	Climate: crop water requirements	T
16:00:	*Coffee Break*	
16:15:	Exercises with reference evapotranspiration	P
18:00:	Closure	
Wednesday 19-Oct:		
9:00:	Soil: soil water balance, soil physical characteristics	T
11:00:	*Coffee Break*	
11:15:	Exercises with soil data, creating projects	P
13:00:	*Lunch break*	
14:00:	Crop: transpiration, canopy development	T
16:00:	*Coffee Break*	
16:15:	Exercises with crop data	P
18:00:	Closure	
Thursday 20-Oct:		
9:00:	Yield response to water	T
11:00:	*Coffee Break*	
11:15:	Exercises with crop data, responses to water stress	P
13:00:	*Lunch break*	
14:00:	Initial conditions, rainfed farming, calibration	T
16:00:	*Coffee Break*	
16:15:	Exercises with initial conditions, calibration/validation	P
18:00:	Closure	
Friday 21-Oct:		
9:00:	Irrigation and management practices	T
11:00:	*Coffee Break*	
11:15:	Exercises with irrigation, irrigation scheduling, deficit irrigation	P
13:00:	*Lunch break*	
14:00:	Climate change analysis in AquaCrop	T

16:00:	*Coffee Break*	
16:15:	Feedback and follow-up by the participants	P
17:30:	Closure	

Program of workshop 3

Training on assessing Current and Future Climate Impacts on Crop Yields using AquaCrop

Dates: *28 November – 1 December, 2016*
Venue: *Ani Plaza Hotel, Hall Garni, 19 Sayat-Nova Ave, Yerevan, Armenia*
Trainers: *On-site: Johannes Hunink, FutureWater (j.hunink@futurewater.es)*
Online: Peter Droogers, FutureWater (p.droogers@futurewater.nl)

Program		**Theory/ Practical**
Monday 28-Nov:		
9:00:	Registration	
9:30:	Introduction to the training and summary of previous trainings	T
10:30:	Gap-filling, quality check and preparation climate data	P
11:00:	*Coffee Break*	
11:20:	Gap-filling, quality check and preparation climate data	P
13:00:	*Lunch break*	
14:00:	Gap-filling, quality check and preparation climate data	P
16:00:	*Coffee Break*	
16:20:	Local soil files and field management	P
18:00:	Closure	
Tuesday 29-Nov:		
9:00:	Climate characterization of the selected pilot sites	T
9:30:	Adjustment of crop files to local conditions	P
11:00:	*Coffee Break*	
11:20:	Adjustment of crop files to local conditions	P
13:00:	*Lunch break*	
14:00:	Create project files and simulations	P
16:00:	*Coffee Break*	
16:20:	Analysis of soil water balance and crop yield	P
18:00:	Closure	
Wednesday 30-Nov:		
9:00:	Summary of first simulation outputs	T
9:30:	Calibration and validation, soil fertility	P
11:00:	*Coffee Break*	
11:20:	Calibration and validation, soil fertility	P
13:00:	*Lunch break*	
14:00:	Preparation of climate files for future climate projections	P
16:00:	*Coffee Break*	

16:20:	Simulations of future projections	P
18:00:	Closure	

Thursday 1-Dec:

9:00:	Summary of first simulations with future climate	T
9:30:	Analysis of soil water balance, crop yield under future climate	P
11:00:	*Coffee Break*	
11:20:	Yield gap analysis	P
13:00:	*Lunch break*	
14:00:	Summarizing and reporting the work	P
15:30:	*Coffee Break*	
15:50:	Brainstorm on future work, recommendations for improvements	P
17:30:	Closure	

Annex B: Climate change impacts on yields for selected pilot sites

This annex gives an overview of the modeling work carried out during the third workshop with the title “Current and Future Climate Impacts on Crop Yields using AquaCrop”, held in November 2016, Yerevan, incorporating data collected by the national expert for this assignment: Taron Aleksanyan.

After consultations with several experts, three sites were selected. This appendix summarizes the collected model input data and the results obtained by the participants, coordinated by FutureWater.

Figure 8. Location of the three pilot sites

Overview of input data

The following table shows the collected model input data, collected by the national expert. Climate data were available for a 20-year period, from 1996-2015. The following climate variables were available:

- Daily minimum temperature
- Daily maximum temperature
- Daily rainfall

Table 1. Data collected for the model inputs. The national expert collected the local data.

Site	**Gavar**	**Ashtarak**	**Talin**	**Source**
Crop	**Potato**	**Wheat**	**Barley**	**Local**
Mean daily minimum temperature January (ºC)	-12.0	-6.2	-9.4	Local
Mean daily maximum temperature August (ºC)	24.2	33.5	28.9	Local
Soil texture - Sand	40% - 50%	35% - 40%	30%-40%	Local
Soil texture – Silt	50% - 60%	20% - 25%	35%-45%	Local
Soil texture - Clay	20% - 25%	35%-45%	30%-35%	Local
Soil fertility	Mild	Moderate	Moderate	Local
Mean annual rainfall (mm)	515	385	370	Local
Dry matter content crop (%)	25	95	90	Literature

Site	Gavar	Ashtarak	Talin	Source
Sowing date	April 25 - May 5	Sept 15 – Sept 25	March 20 - April 1	Local
Max Canopy cover	August 5 – August 15	Jun 10 – Jun 20	June 10 - June 20	Local
Senescence	August 25 – September 5	(same as maturity)	July 15 - July 25	Local
Maturity	September 25 – Oct 5	Jul 25 – August 5	July 15 - July 25	Local
Mean fresh yield (ton/ha)	17.5	2.1	2.3	Local

No yield data were available for these sites. Instead, aggregated yield data for the administrative unit was available, as a reference (see mean values in previous table).

To build the future climate inputs, the assumption was that the climate variability in the future is similar to the variability in the current climate. A so-called delta change approach [*Diaz-Nieto and Wilby*, 2005; *Immerzeel et al.*, 2008] was applied that uses the difference between the mean values under the current climate (based on observations) and under the future climate (based on climate model outputs), to generate future climate inputs. For precipitation, the percentual (or ratio) change is used, while for the temperature the difference in ºC is used. The delta-change factors were based on the tables and maps in the Third National Communication of Armenia (CCSM4 model for several emission scenarios), and were established in collaboration with the national expert.

For the purpose of the workshop, two scenarios were prepared (see also the following table):

- A wet scenario for the 2050s – with moderate increase in temperatures and an increase in precipitation
- A dry scenario for the 2050s with high increase in temperatures and decrease in precipitation

Table 2. Delta change factors used to built future climate inputs

Site	Scenario	Tmax (ºC)	Tmin (ºC)	Prec (%)
Ashtarak	Wet	1.8	1.8	107
	Dry	3	3	93
Gavar	Wet	1.4	1.4	102
	Dry	3	3	93
Talin	Wet	2.1	2.1	107
	Dry	3	3	93

Characterization of climate

A summary of the climate data is represented in the following figures. It is based on daily data available for the 20-year period (1996-2015).

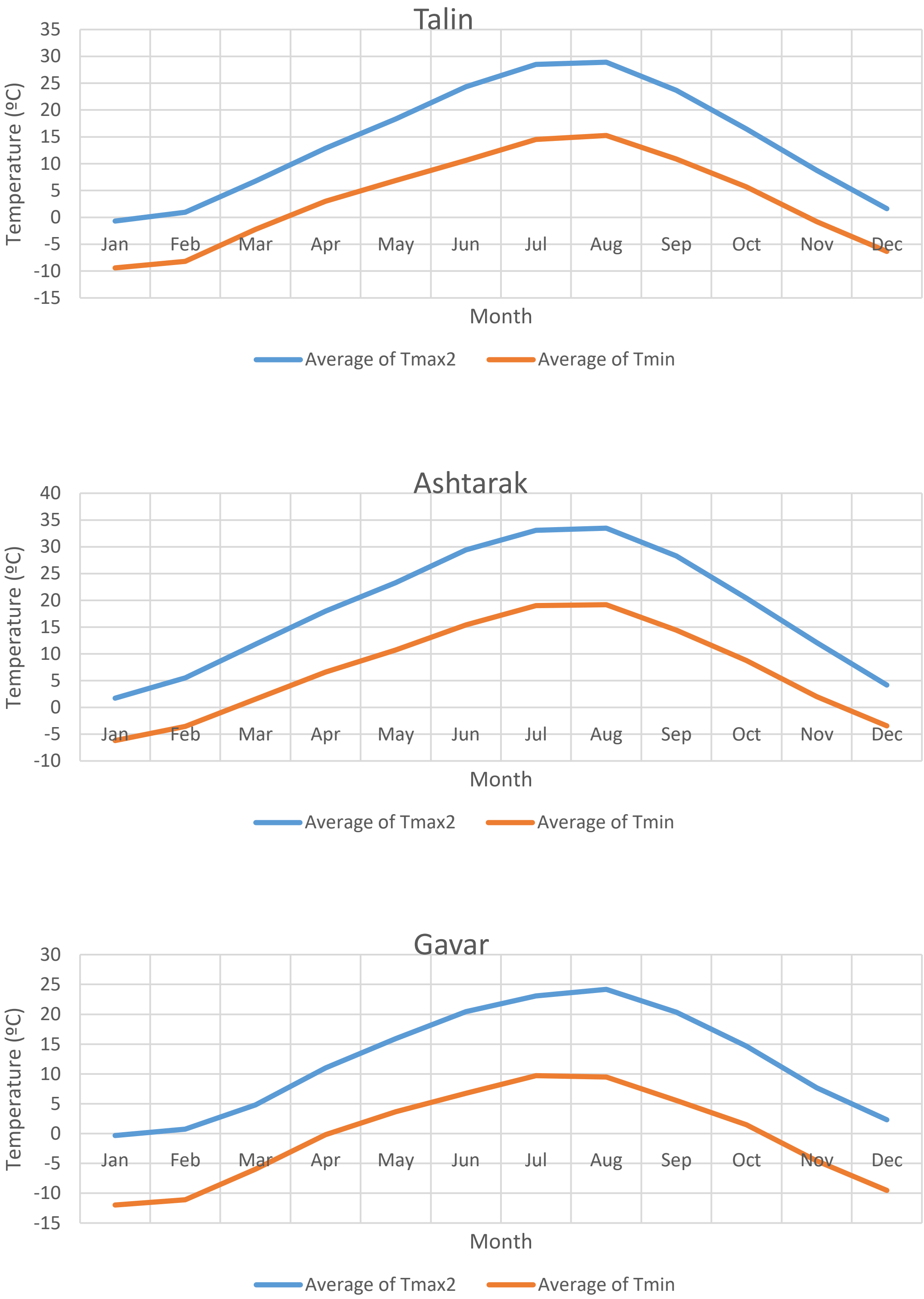
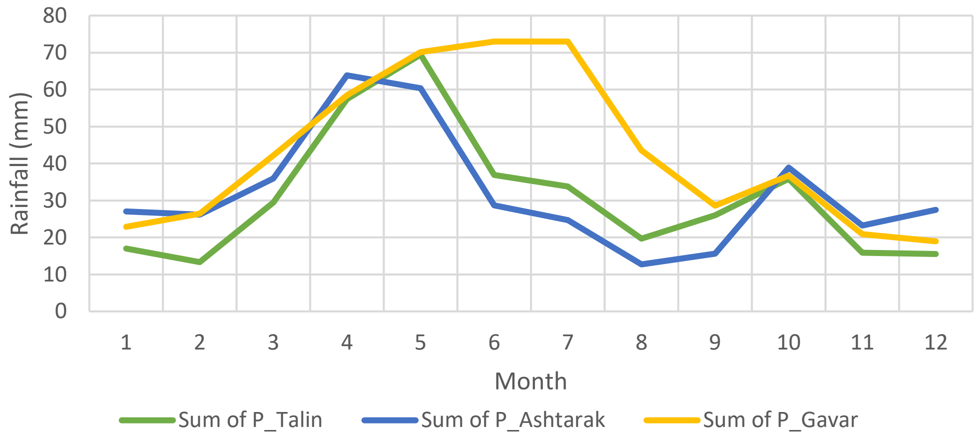


Figure 9. Minimum and maximum temperature for the 3 sites



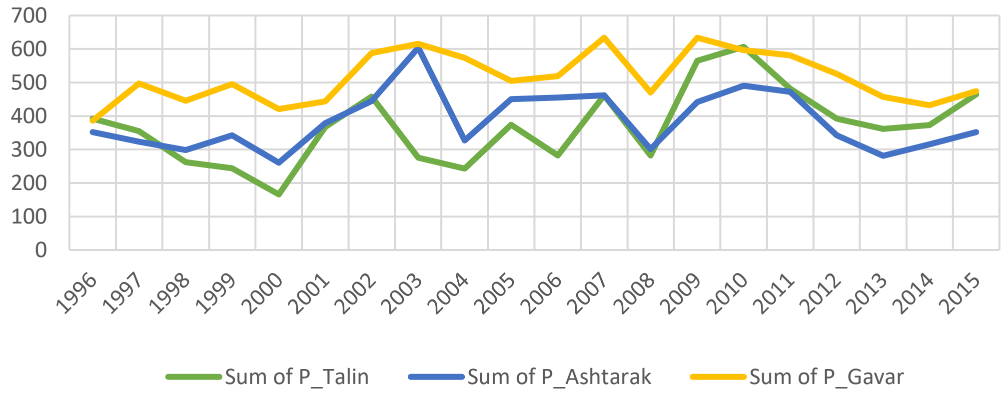


Figure 10. Annual and monthly rainfall for the 3 sites

Current and future yield predictions

Potato (Gavar)

The following table and figures show the results from the AquaCrop simulations, for potato at Gavar. Yields in the wet scenario are 14% higher, and in the dry scenario 17% lower.

Table 3 Yield predictions potato

	Current	**Future - Wet**	**Future - Dry**
Mean yield	21.5	24.5	17.9
Standard deviation	7.1	8.3	6.4
Coefficient of variation	0.3	0.3	0.4

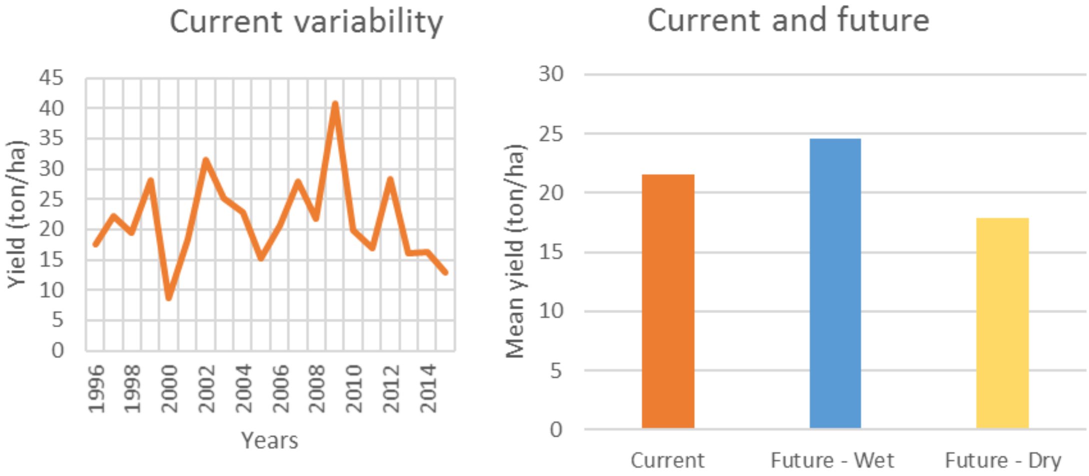


Figure 11. Potato yield variability under the current climate (left) and mean yield for the two future scenarios vs current.

The participants studied effects of different stress levels on crops (Figure 12). Fertility stress was assumed to be moderate under current conditions, and mild under future conditions (adaptation scenario supporting farmers in soil conservation, erosion reduction, fertilizers, etc). As can be seen, due to limited water availability, reduced fertility stress causes a higher water stress: not enough water is available for the crop to grow at its potential rate. Temperature stress is very low in the current scenario, and non-existent in the future scenario according to the simulations.

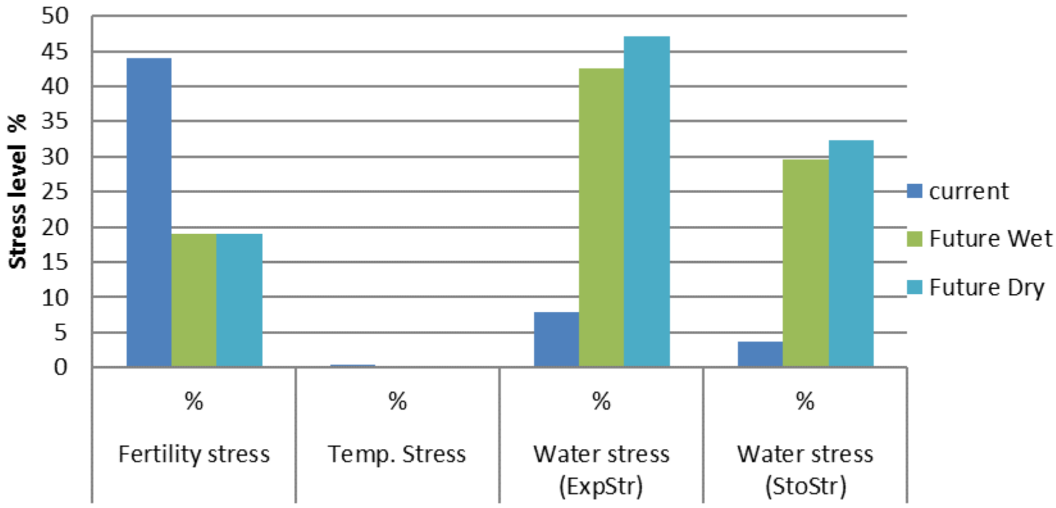


Figure 12. Stress levels (fertility, temperature and water) under current and future scenarios

Wheat (Ashtarak)

The following table and figures show the results from the AquaCrop simulations, for wheat at Ashtarak.

Table 4 Yield predictions Wheat

	Current	**Future - Wet**

Mean yield	3.7	4.0
Standard deviation	1.6	1.8
Coefficient of variation	0.4	0.5

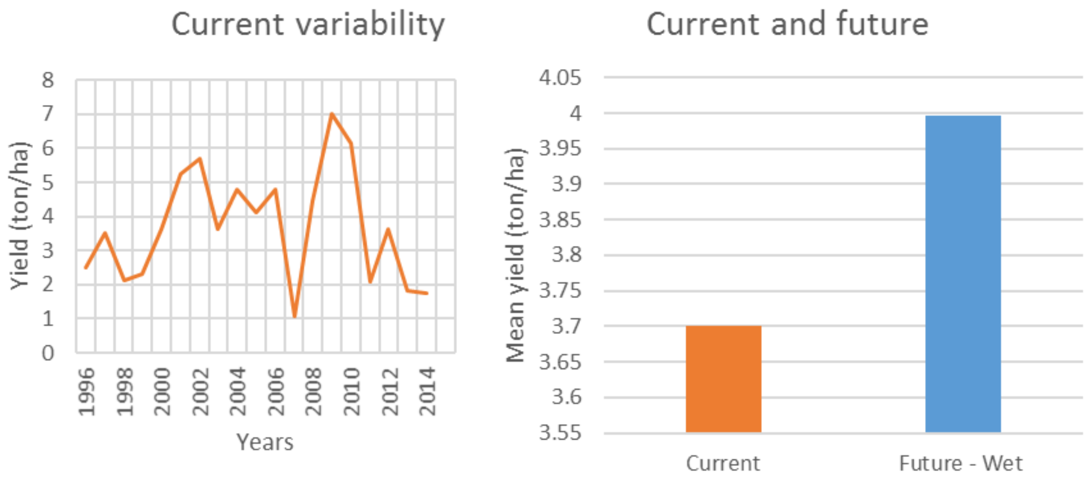


Figure 13. Wheat yield variability under the current climate (left) and mean yield for the Wet future scenario vs current.

The following figure shows the fertility stress and water stress (for leaf expansion) that were simulated for the wheat crop at this site. The stresses are expressed in %, indicating the impact the stress has on the potential yield (actual yield/potential yield).

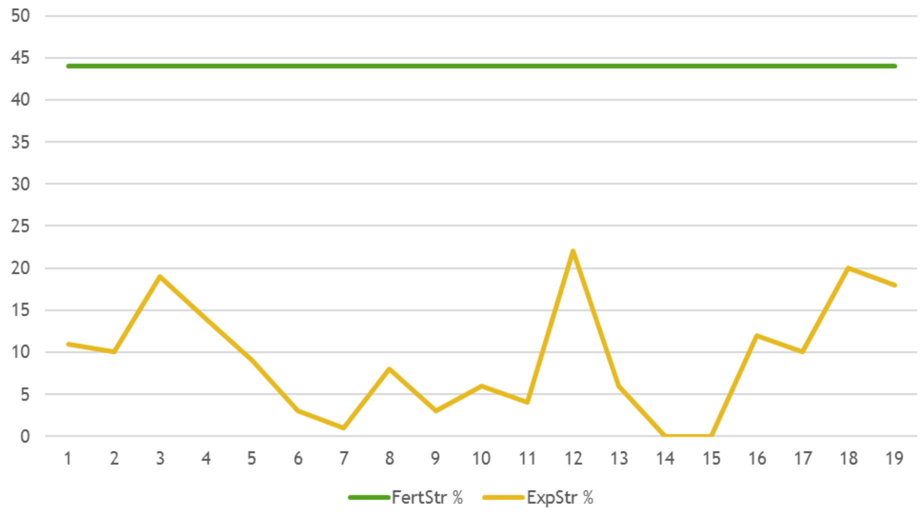


Figure 14. Fertility stress and water stress (ExpStr) for the 19 cropping seasons of the future scenario.

Based on the model simulations, Figure 15 shows the relationship between the rainfall that the crop receives and the final harvested yield.

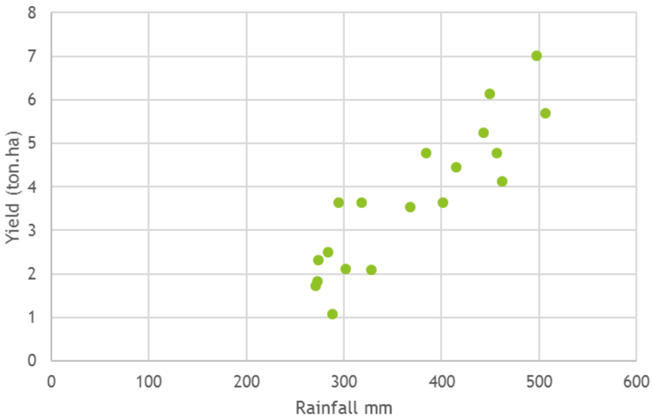


Figure 15. The relationship between rainfall received during the cropping period and yield.

Barley (Talin)

The following table and figures show the results from the AquaCrop simulations, for barley at Talin. Yields in the wet scenario are 5% higher, and in the dry scenario 12% lower.

Table 5 Yield predictions Barley

	Current	Future - Wet	Future - Dry
Mean yield	2.3	2.4	2.0
Standard deviation	0.5	0.6	0.2
Coefficient of variation	0.2	0.3	0.1

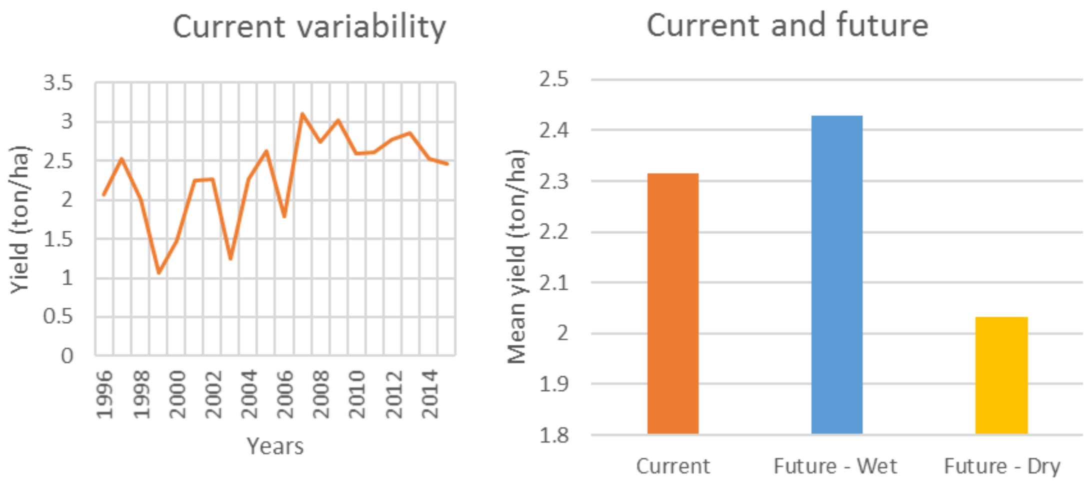


Figure 16. Barley yield variability under the current climate (left) and mean yield for the two future scenarios vs current.

As can be seen in the table below, the simulations showed that temperature stress decreased in the future climate (less lower extremes), water stress decreases in the wet scenario, but increases in the dry scenario.

Table 6 Temperature and water stress for current and future climate (barley)

Scenario	Temperature stress %	Water stress ExpStr %	Water stress StoStr %
Current	15	14	12
Wet	8	10	14
Dry	8	12	16

Annex B: List of workshop participants

No	Name, Surname	Position/Institution
1.	Kristine Khachatryan	Chief Specialist of the Division of International Project Management and Monitoring / RA Ministry of Nature Protection (MNP)
2.	Lara Sargsyan	Chief Specialist of the Climate Change and Atmosphere Protection Policy Division / RA MNP
3.	Davit Mejlumyan	Leading Specialist of the Water Resource Cadastre and Monitoring Division / Water Resources Management Agency, RA MNP
4.	Kristina Khanoyan	Leading Specialist of the Melioration Department / RA Ministry of Agriculture
5.	Hasmik Kocharyan	Chief Specialist of the Meteorology Division / Meteorological Centre, Armstatehydromet, RA Ministry of Emergency Situations
6.	Gohar Guloyan	First Class Specialist of the Agrometeorology Division / Meteorological Centre, Armstatehydromet, RA Ministry of Emergency Situations
7.	Sona Grigoryan	Leading Specialist of the Agrometeorological Forecasting Division / Armstatehydromet, RA Ministry of Emergency Situations
8.	Artur Gevorgyan	Climate Change and Forest Expert
9.	Medea Inashvili	Key Expert, Regional Coordinator for Armenia, Azerbaijan and Georgia / Clima East Policy project
10.	Johannes Hunink	International Expert for AM 025 Assignment/ Clima East Policy project
11.	Armine Astsatryan	National Coordinator / Clima East Policy project
12.	Taron Aleksanyan	Local Expert for AM 025 Assignment / Clima East Policy project
13.	Armine Ivanyan	Volunteer
14.	Shushanik Avagyan	Interpreter