CHAPTER 3

Armenia: Risks, Impacts, and Adaptation Menu

This chapter summarizes the results of efforts to develop a menu of adaptation options for the agricultural sector in Armenia. It is organized into four sections: (1) climate risk, (2) climate impacts, (3) adaptation assessment, and (4) evaluation and prioritization of adaptation options.

Climate Risk

Historical Climate Trends

The South Caucasus region has seen a variety of changes in climate, including increasing temperatures, shrinking glaciers, sea level rise, reduction and redistribution of river flows, decreasing snowfall, and an upward shift of the snowline. In the past 10 years, the region has also experienced more extreme weather events—flooding, landslides, forest fires, and coastal erosion—resulting in economic losses and human casualties (WWF 2009).

Figures 3.1 and 3.2 present historical temperature and precipitation data for Armenia. Figure 3.1 shows annual temperatures and growing season temperatures, 1900–2012. During 1980–2012, average annual temperature and average growing season temperature both increased by approximately 1°C.

Figure 3.2 presents average monthly precipitation over the year and average growing season precipitation, 1900–2012. During 1980–2012, the average monthly precipitation increased approximately 11.5 mm, while average growing season precipitation increased approximately 19.3 mm.

In addition to the temperature and precipitation changes, the glaciers are melting rapidly in the region, as they are globally. The volume of glaciers in the South Caucasus has been reduced by 50 percent over the last century, and 94 percent of the glaciers have retreated 38 meters per year (Stokes et al. 2006). Changes in glacier composition can potentially reduce long-term river flow in Armenia.

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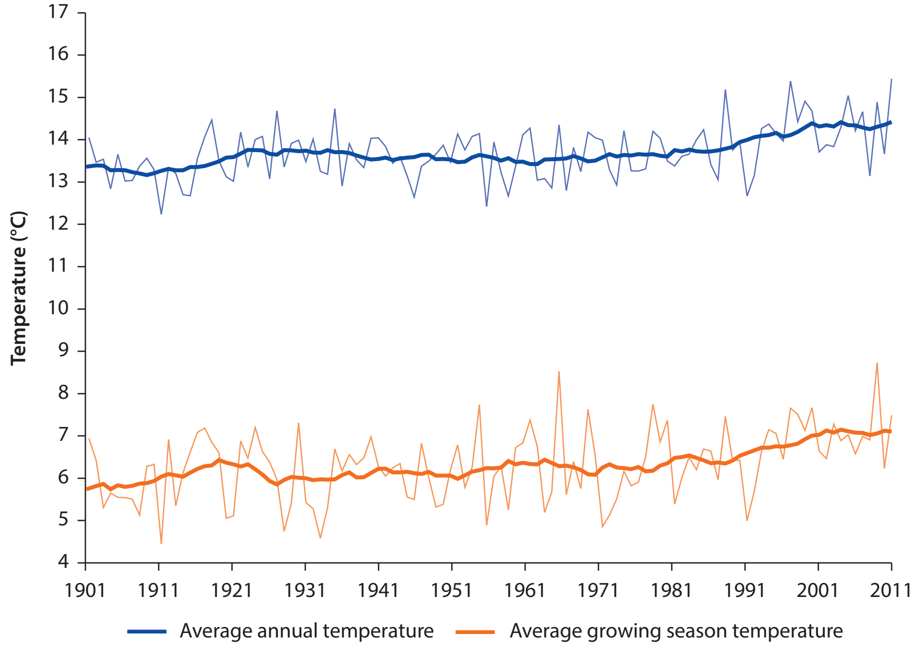
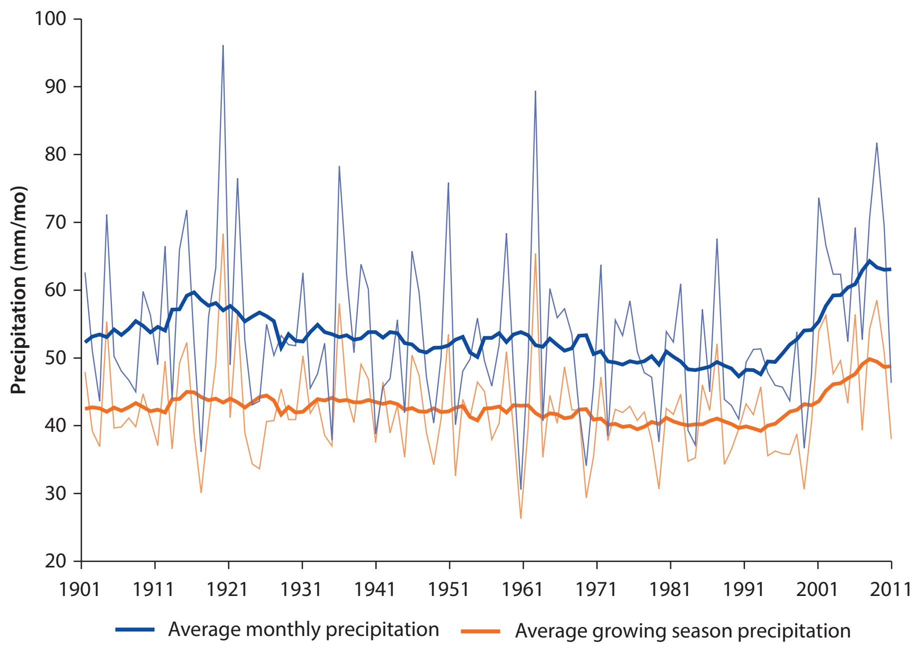
Figure 3.1 Average Annual and Growing Season Temperatures in Armenia, 1900–2012



Source: University of East Anglia Climatic Research Unit, Norwich, UK.

Figure 3.2 Average Monthly and Growing Season Precipitation in Armenia, 1900–2012



Source: University of East Anglia Climatic Research Unit, Norwich, UK.
Note: mm/mo = millimeters per month.

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Forecasted Changes in Temperature and Precipitation

Analyses of recent climate data and information gathered from the study's farmer workshops support the study finding of a trend of increasing temperature in Armenia, and also reveal that the frequency of extreme temperature events is also increasing in the country. The results of this study indicate that this warming trend will accelerate in Armenia in coming decades, as shown on map 3.1. Although the degree of warming that will occur in Armenia remains uncertain, the overall warming trend is clear and evident in all three of Armenia's agricultural regions—mountainous, intermediate, and lowlands—with average warming over the next 50 years for the Medium Impact Scenario estimated at about 2.6°C, much greater than the increase of less than 0.85°C observed over the last 80 years (UNFCCC 2010). Warming could be more modest, but average temperature changes for the Low Impact Scenario nonetheless represent an increase of about 1.2°C, compared to current conditions.

Changes in precipitation are harder to predict, and estimates of how precipitation will change in Armenia are uncertain, as shown on map 3.2. Under the Medium Impact Scenario, nationwide precipitation decreases approximately 52 millimeters (mm) per year on average by the 2040s. However, the range of precipitation outcomes across the Low and High Impact alternatives is large, ranging from a modest increase under the Low Impact Scenario to a 19–28 percent decline under the High Impact Scenario. Uncertainty at the regional level is even higher, and annual precipitation declines in the highest elevation agricultural region could be as large as 144 mm per year.

Climate change may also increase the frequency and magnitude of droughts, frosts, and floods in Armenia. While precipitation is expected to increase only under the Low Impact Scenario by the 2040s (map 3.2), rainfall events are predicted to become more variable, with a high probability of daily to multi-day events becoming larger and less frequent. Such flood events pose a particular threat to the agriculture sector in Armenia in the spring, when flooding can delay or prevent planting of summer crops, and during late summer, when flooding can destroy an entire year's growth and prevent timely harvesting. Even small flood events can reduce productivity, since prolonged water-logging is detrimental to many crops.

Finally, the yearly averages of temperature and precipitation are less important for agricultural production than are the seasonal distribution of temperature and precipitation. Under climate change, temperature increases are predicted to be highest in the period July–October relative to current conditions. This summer temperature increase can be as much as 5°C in the intermediate agricultural region of Armenia. In addition, forecasted precipitation declines are greatest in the key July–August period, when precipitation is already near its lowest. Figure 3.3 presents the monthly baseline and forecasted temperatures and precipitation changes for the intermediate agricultural region.

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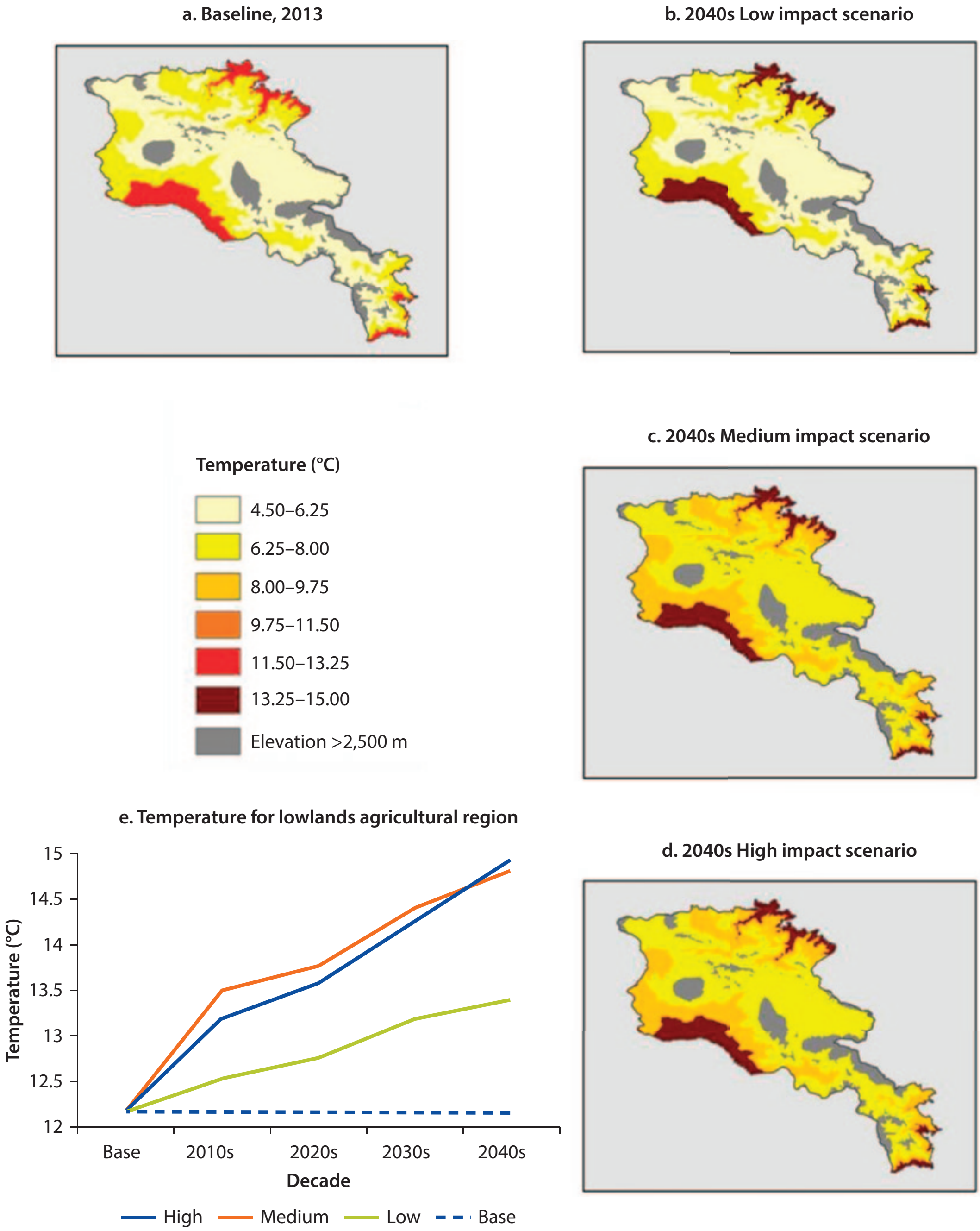
Map 3.1 Armenia: Predicted Effect of Climate Change on Average Annual Temperature in the 2040s



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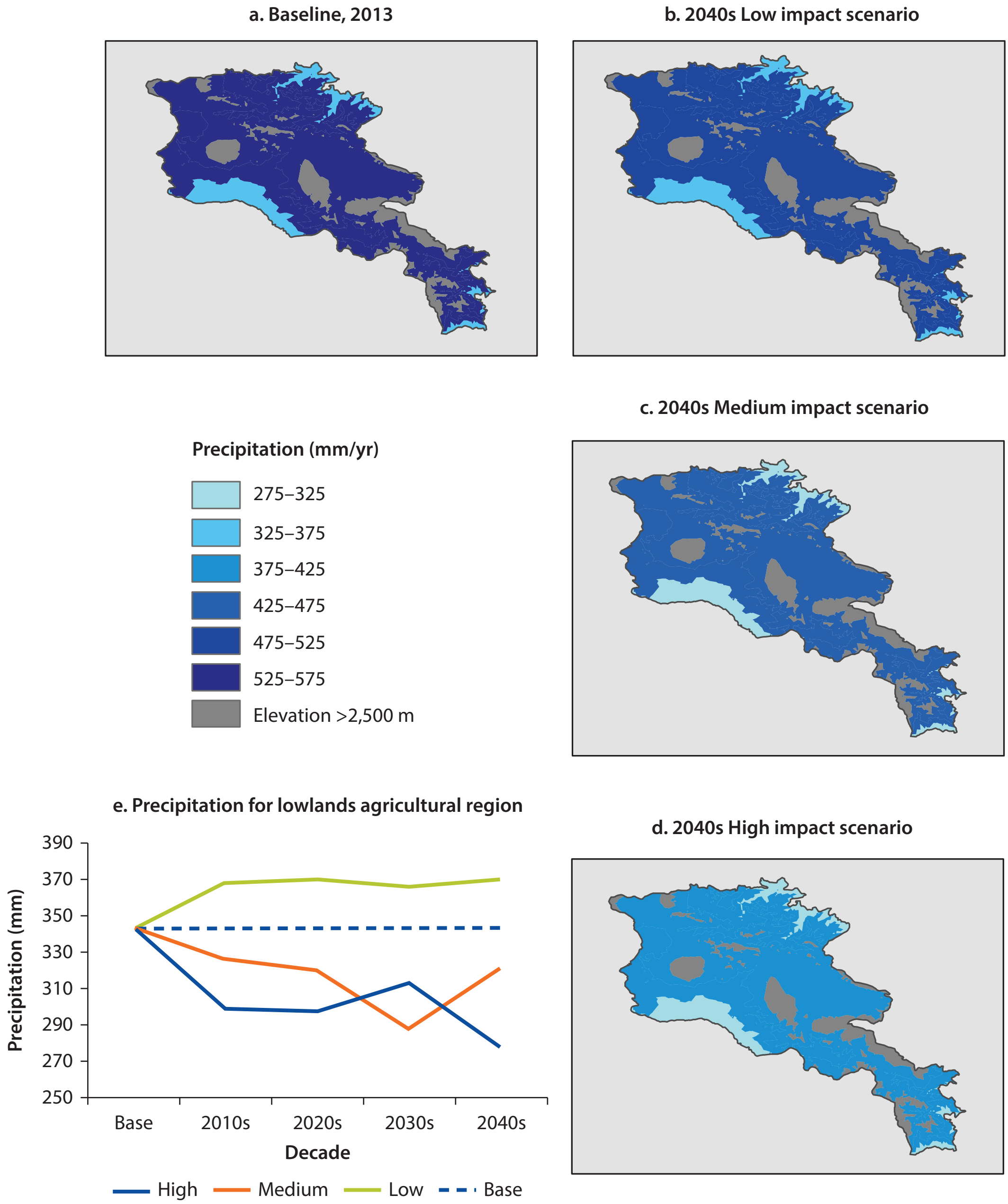
Map 3.2 Armenia: Predicted Effect of Climate Change on Average Annual Precipitation in the 2040s



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Note: mm = millimeters.

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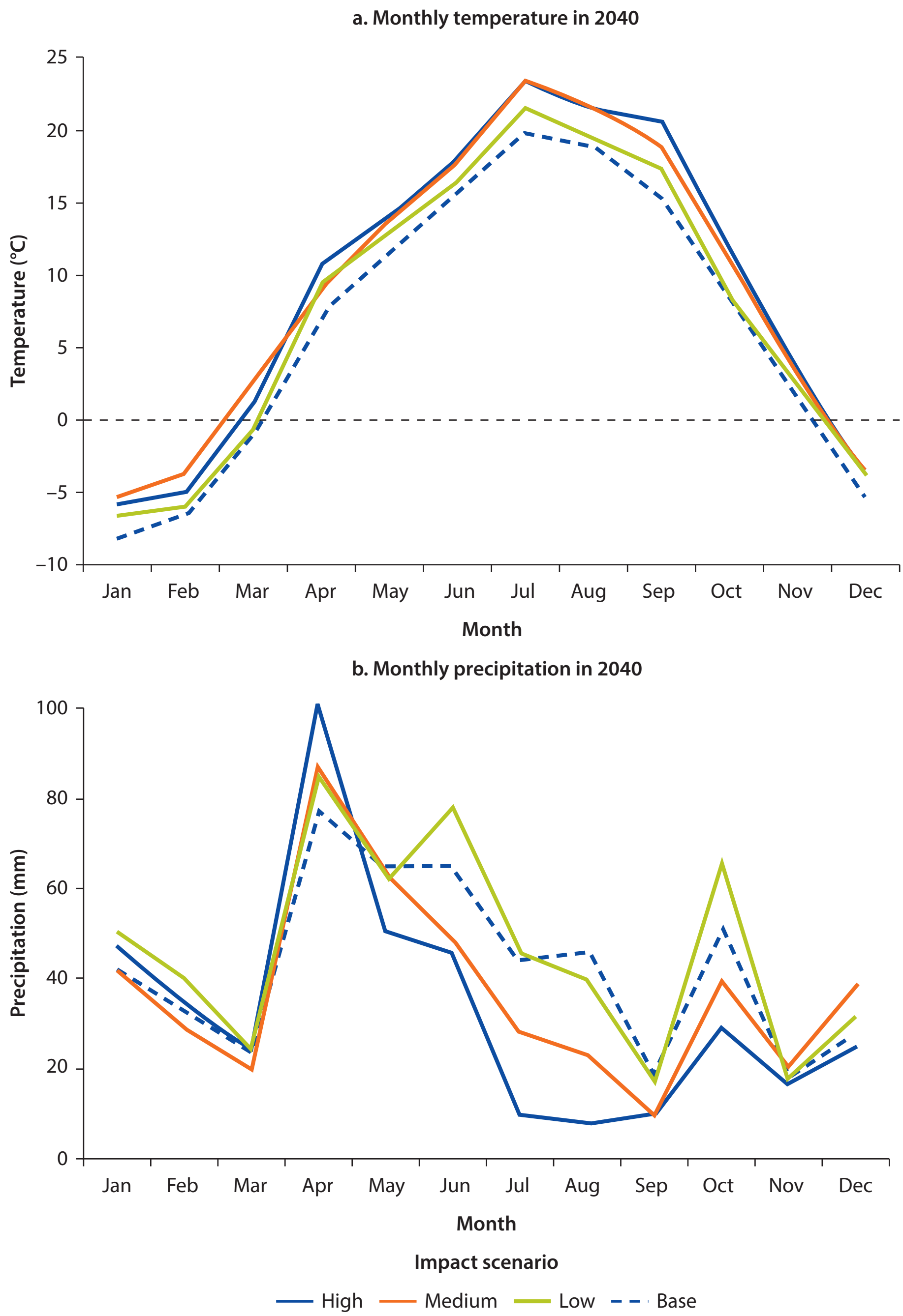
Figure 3.3 Armenia: Effect of Climate Change on Monthly Temperature and Precipitation Patterns for the Intermediate Agricultural Region in the 2040s



Source: World Bank data.
Note: mm = millimeters.

Climate Impacts

In order to assess the impact of climate change on the agricultural sector in Armenia, the monthly projections of temperature and precipitation were translated to daily projections for use in crop models, as described in chapter 2, box 2.2. The crop models examined the potential effect of climate change on crop yields in Armenia under the "no adaptation" scenario (that is, if no adaptation measures are taken). The crop yield impacts presented in table 3.1 represent the potential outcome under the Medium Impact Scenario and do not take into account irrigation water constraints.

Decline in Crop Yields

As shown in table 3.1, yields of alfalfa, apricot, grape, and potato are expected to decline across all agricultural regions in the 2040s under the Medium Impact Scenario. Yields of wheat, Armenia's key cereal crop, are expected to increase in the mountainous and intermediate regions, but decrease in the lowlands region due to rising temperatures and water stress. Tomato yields are also expected to increase in the mountainous and intermediate agricultural regions, and irrigated watermelon yields are expected to increase in the intermediate region.

Although table 3.1 reflects the assumption that irrigation water will not be constrained, changes in temperature and precipitation resulting from climate change are expected to impact water resources in Armenia. As a result, a more detailed water resource analysis is also needed to determine the extent of

Table 3.1 Effect of Climate Change on Crop Yields in the 2040s under the Medium Impact Scenario, No Adaptation and No Irrigation Water Constraints

		Change in yield (%)		
Irrigated/rainfed	*Crop*	*Lowlands*	*Intermediate*	*Mountainous*
Irrigated	Alfalfa	−5	−7	−2
	Apricot	−5	−5	−5
	Grape	−7	−5	−5
	Potato	−12	−9	−5
	Tomato	−16	6	50
	Watermelon	−12	10	n.a.
	Wheat	−6	1	38
Rainfed	Alfalfa	−3	−8	−1
	Apricot	−28	−7	−5
	Grape	−24	−12	−1
	Potato	−14	−14	−8
	Tomato	−19	−8	34
	Watermelon	−18	0	n.a.
	Wheat	−8	1	38

Source: World Bank data.
Note: Results are average changes in crop yield, assuming no effect of carbon dioxide fertilization, under Medium Impact Scenario (no adaptation and no irrigation water constraints). Declines in yield are shown in shades of orange, with darkest representing biggest declines; increases are shaded green, with darkest representing the biggest increases.
n.a. = not applicable (indicates that the crop was not analyzed in that country).

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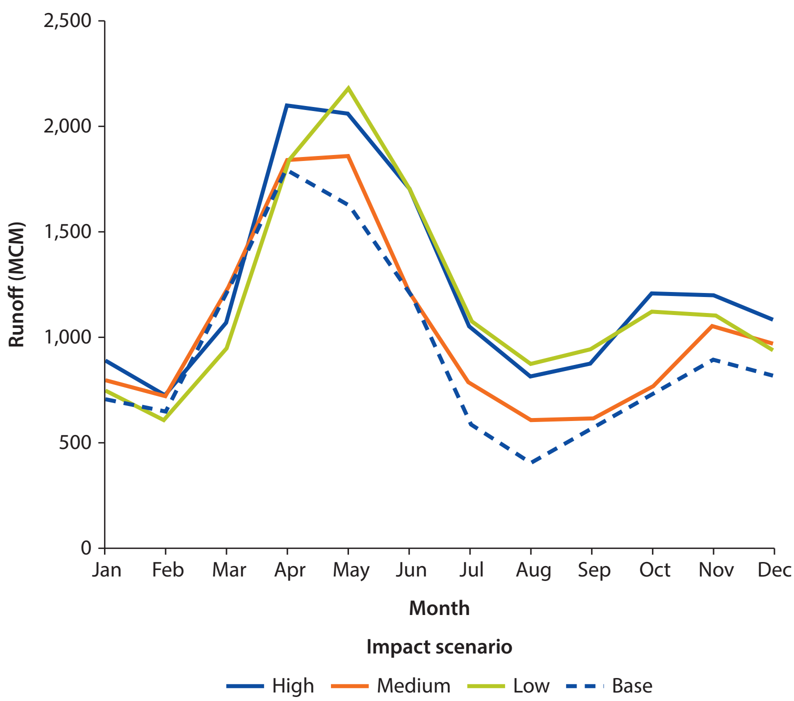
climate change impacts. The study team conducted a water availability analysis for Armenia using the Water Evaluation and Planning System (WEAP) and the Climate and Runoff Hydrologic Model (CLIRUN) model. Next, water supply estimates were matched with forecasts of water demand for all sectors, including agriculture, to determine water availability. Agricultural water demand was estimated using the AquaCrop model (see chapter 2, box 2.2 for more information).

Water Supply Declines, Demand Increases

Figure 3.4 presents the estimated effect of climate change on mean monthly runoff in Armenia in the 2040s. The runoff indicator is directly relevant to agriculture systems and provides insight into the risk of climate change for agricultural water availability, as well as the implications of climate change for water resource management. As shown in figure 3.4, under the High Impact Scenario, overall water supply is expected to decline by an average of 30–40 percent by the 2040s. At the same time, irrigation water demand during the summer months is expected to increase by up to 20 percent relative to historic demands. The net effect of the predicted rising demands and falling supply is a significant reduction in water available for irrigation. Irrigation water shortages by the 2040s are predicted to occur in the Upper Araks basin, while no shortage of irrigation water is forecasted for the other Armenian basins.

Figure 3.4 Estimated Effect of Climate Change on Mean Monthly Runoff in the 2040s for All Armenian Basins



Source: World Bank data.
Note: MCM = million cubic meters.

Negative Net Climate Effects

Therefore three climate change stressors combine to yield an overall negative impact on crop yields in Armenia:

- The direct effect of temperature and precipitation changes on crops
- Increased irrigation demand required to maintain yields
- Decline in water supply associated with higher evaporation and lower rainfall

All of these effects have a more pronounced impact during the summer growing season. For example, even though annual runoff is forecasted to increase under the Low Impact Scenario, it is expected to decline during the late spring and late summer months under all three scenarios relative to baseline conditions, which is exactly when irrigation water demand is highest. The net effect of these three factors on irrigated agriculture is illustrated in table 3.2.

The study analysis reveals that in Armenia the main effect of climate change on availability of agricultural water (which results from the combined effect of temperature and precipitation changes and decline in water supply) will be on

Table 3.2 Effect of Climate Change on Irrigated Crop Yields Adjusted for Estimated Irrigation Water Deficits in the Upper Araks Basin in the 2040s

a. Crop yield impacts due to temperature and precipitation changes without considering irrigation water constraints

	Change in yield (%)		
Crop	*Lowlands*	*Intermediate*	*Mountainous*
Alfalfa	−5	−7	−2
Apricot	−5	−5	−5
Grape	−7	−5	−5
Potato	−12	−9	−5
Tomato	−16	6	50
Watermelon	−12	10	50
Wheat	−6	1	38

b. Crop yield impacts due to temperature and precipitation changes as well as forecasted irrigation water constraints

	Change in yield (%)		
Crop	*Lowlands*	*Intermediate*	*Mountainous*
Alfalfa	−48	−49	−46
Apricot	−48	−47	−47
Grape	−42	−41	−41
Potato	−51	−49	−47
Tomato	−53	−41	−17
Watermelon	−51	−39	−17
Wheat	−48	−44	−24

Source: World Bank data.
Note: Results are average changes in crop yield, assuming no effect of carbon dioxide fertilization. Declines in yield are shown in shades of orange, with darkest representing biggest declines; increases are shaded green, with darkest representing the biggest increases.

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the Upper Araks basin, which feeds the Ararat Valley. The net effect of the three factors on irrigated agriculture in the Upper Araks basin is illustrated in table 3.2. Table 3.2a shows the effect of temperature and precipitation changes alone on irrigated agriculture if there are no irrigation water constraints. Table 3.2b shows the combined effect of all three factors mentioned above, including the forecasted irrigation water shortages for the Upper Araks basin. The net effect of these factors on crop yields is dramatic, and provides an important focus for adaptation efforts to mitigate potential losses. While the water resources modeling does not indicate water shortages for the Lower Araks basin, changes in transboundary water withdrawal rates could alter that finding and lead to shortages in that part of the Araks basin as well.

The direct effects of climate change on livestock production in Armenia could also be severe, but the methods available for quantitatively assessing effects on livestock are relatively untested. There is a robust literature establishing that increases in temperature decrease livestock productivity (Thornton et al. 2009), but suitable modeling tools for quantifying the effect in the Armenian context are not available. According to the analysis in this study, the indirect effect of climate change on livestock feedstocks including pasture would be positive, thus providing a counterbalance to the negative direct heat stress effects cited in the literature.

Adaptation Assessment

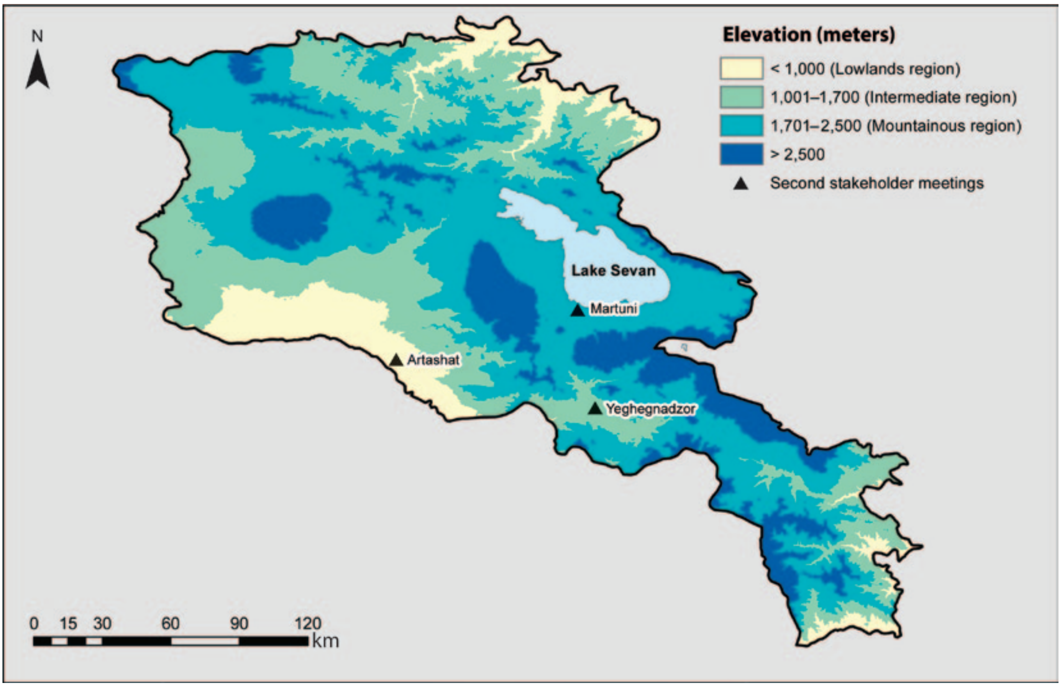
After examining the local climate risk and likely impacts of climate change on Armenia's agricultural sector, the study team conducted an adaptation assessment of the sector, both at the national and regional levels. This involved stakeholder outreach to elicit information about current farming practices, observed impacts of climate change thus far, and how farmers are currently adapting to these impacts. In addition, the stakeholder outreach sessions allowed the study team to compile an initial list of priority adaptation options based on input from farmers as well as government officials and other local experts. This section describes the findings of the adaptation assessment and the recommended adaptation options from the stakeholder consultations.

Current Regional Adaptive Capacity

To assess Armenia's current regional adaptive capacity, it was essential that the study team inform and consult with a variety of local stakeholders—farmers and farmers' associations, local government officials, students studying agriculture, and other local experts—on the predicted impacts of climate change on agriculture and water resources. The team first met with farmers for a one-day stakeholder workshop in Yeghegnadzor in April 2012. A second set of farmer consultations was conducted in October 2012 at three locations (Martuni, Artashat, and Yeghegnadzor), representing the different agricultural regions of Armenia (map 3.3).

At the initial workshop, participants were given an overview of the study and the potential impacts of climate change on crop yields and water

Map 3.3 Locations of Stakeholder Consultations in Armenia



Note: km = kilometers.

availability in Armenia. They were then asked if they had witnessed climate change impacts and what they have done, or would do, to mitigate their effects. All confirmed that several of the impacts have been felt on local farms. The stakeholders at the workshop made it clear that, although farmers are becoming more flexible in their response to climate events, their adaptive capacity is still quite limited due to poorly maintained irrigation and drainage systems, limited financial resources, and inadequate support from and access to extension services.

At the subsequent farmer consultations, participants were provided with a list of potential climate adaptations. They were asked to remove any irrelevant adaptations and add any additional adaptations that they believed would be effective. Participants then provided rankings for both national-level and regional-level adaptation options. Rankings of regional-level options varied among the regions, reflecting differences in current climates, topography, and other location-specific factors. The ranked recommendations of adaptation options for each of Armenia's three agricultural regions are as follows.

Lowlands Agricultural Region: Artashat

The agricultural sector in this region produces a variety of crops, including wheat, vegetables, watermelons, grapes, and orchard fruits, as well as livestock.

Table 3.3 Ranked Recommendations from the Artashat Consultation

Adaptation option	*Points*
Rehabilitation of water reservoirs	26
Rehabilitation of irrigation	25
Optimize application of water	20
Reduce erosion and soil conservation	15
Improve livestock nutrition and shelter	9
Optimize agronomic practices (fertilizer)	9
Improve crop varieties, particularly those tolerant to droughts	9
Restoration of pastures by improved agronomic practices	7
Adjust type of crops based on elevation	6
Hail rockets	4

The region's climate is sufficiently mild that two crops a year can be grown, but farmers find it necessary to use irrigation rather than rely on rainfall. Farmers reported noticing an increase in temperature in this already warm climate, in addition to a greater frequency of extreme events such as drought, hail, and heat waves, resulting in negative impacts on crops.

The importance of irrigation to support agricultural production is apparent in the adaptation rankings (table 3.3). Farmers stressed the need for adequate irrigation water to ensure both quantity and quality of orchard and vineyard production. In addition, the rankings support the fact that livestock are an important part of the agricultural economy as they can beneficially use field crop aftermath (second growth) as well as rainfed rangeland. Improved livestock husbandry and health and optimizing the production and storage of livestock forage were aggregated as a single measure and ranked fifth, tied with improved crop production practices and improved crop/livestock genetics.

Local orchardists reported some innovative attempts to reduce climatic risk by interplanting crops with different climate sensitivities. Examples are an apricot orchard with a peach tree planted as every other tree to hedge against early spring frosts that might damage apricots but not the later-flowering peaches, and a vineyard with tomato planted in between the rows of vines for the same reason.

Intermediate Agricultural Region: Yeghegnadzor

Farmers in this region reported that the climate was becoming warmer and that extreme weather events were more frequent. They noted that the most important weather-related impact is drought, which is especially burdensome due to its variability and extremes. Changes in the cropping season, hail, winter frost, warming, and increasing water demand also negatively affect crop production in this region of Armenia. With the crop seasons shifting, farmers plant earlier, but spring freezing can harm crops. Hail has also worsened recently, especially in the spring when it hits early vegetation. Winter frost was noted, especially during the winter of 2002 when trees were completely frozen. Increasing temperatures have resulted in increased incidences of diseases, pests, and weeds, as well as

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Table 3.4 Ranked Recommendations from the Yeghegnadzor Consultation

Adaptation option	*Points*
Rehabilitation of irrigation	26
Adjust type of crops based on elevation	23
Optimize agronomic practices (fertilizer)	15
Improve crop varieties, particularly those tolerant to droughts	13
Reduce erosion and soil conservation	12
Improve livestock nutrition and shelter	11
Hail rockets	8
Optimize application of water	8
Restoration of pastures by improved agronomic practices	6
Rehabilitation of water reservoirs	3

the emergence of new types of pests and diseases. Finally, crop water demand continues to increase, which can become problematic socially as people have to pay more for water.

Generally, farmers have observed the changing climate and have already begun responding. Many are planting crops earlier to respond to higher temperatures earlier in the season, moving their crops to higher elevation areas, changing crop rotations, and changing the timing of irrigation. Highly ranked adaptation options (table 3.4) include rehabilitation of aging irrigation systems and relocating orchards to less frost-prone sites, as well as application of a variety of other basic improved practices dealing with crop and livestock production.

Mountainous Agricultural Region: Martuni

Farmers in this region rely on irrigation for crop production, with non-irrigated land often used as unimproved pasture. Major crops include wheat, potato, and cabbage. The major climatic changes noted were increased temperatures, more frequent heat waves, and droughts. Farmers reported that disease and pest problems were also increasing, perhaps as a byproduct of climate change, and that these have resulted in crop damage. The high rankings given to irrigation-related adaptations (table 3.5) clearly reflect the importance of irrigation to crop and fruit production in this region. Farmers raise livestock but have limited pasture to support them and are aware of the need to improve basic animal husbandry practices.

Current National-Level Adaptive Capacity and Responses

Participants in all three regions generally agreed about the need for low-interest, long-term loans for farmers to help them implement adaptation measures. This recommendation, along with crop insurance, was by far the highest-ranked item of the adaptation options (table 3.6). Currently it is difficult for farmers to obtain loans, and those available are most often short-term and high-interest. Farmers reported that although crop insurance was sometimes available from the private market, it is often too expensive. They were very interested in securing insurance against losses such as hail and frost. The second tier of adaptation options reflects

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Table 3.5 Ranked Recommendations from the Martuni Consultation

Adaptation option	*Points*
Rehabilitate irrigation systems	24
Construct small volume reservoirs	19
Provision of agricultural equipment	19
Improve crop varieties	9
Improve livestock nutrition and shelter	7
Optimize application of irrigation water	5
Optimize agronomic practices	4
Change cropping patterns, especially by altitude	4
More modern irrigation technologies	3

Table 3.6 Stakeholder-Ranked National-Level Climate Adaptations

Adaptation option	*Points*
Provide low interest, long-term loans to farmers	81
Create crop insurance program	71
Establish local markets	39
Improve farmer access to agronomic technology and information	34
Improve extension services	33
Improve hydrometeorological capacity	24
Produce local seeds within region	8
More direct linkage between government and farmers	4
Obtain more modern irrigation technologies	3

the need to expand farmer support services such as hydrometeorological, market access, and extension services.

In general, the stakeholder consultations revealed that farmers in Armenia have observed the changing climate and have begun responding in a variety of ways. Many have begun planting crops earlier, moving their crops to higher elevation areas, changing crop rotations, and changing the timing of irrigation for their fields. Climate change clearly challenges Armenian farmers' adaptive capacity. The combination of droughts, frost, hail, and temperature increase is especially disruptive. While the current on-farm adaptation responses have been partially successful, new programs, policies, and infrastructure investments are needed. These include crop insurance, improved hydrometeorological forecasts, improved water storage, and irrigation systems, as well as farmer training and information access about weather-related farming practices.

Evaluation and Prioritization of Adaptation Options

The menu of adaptation options to improve the resilience of Armenia's agricultural sector to climate change is derived from the results of the stakeholder consultations described in the previous section, in addition to the quantitative modeling, qualitative analysis, and expert input from international and local teams. The results reflect the following set of five criteria for prioritizing from among a

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larger menu of farm-level, infrastructure, programmatic, and indirect adaptation options: (1) net economic benefits (benefits minus costs); (2) qualitative expert assessment; (3) potential to aid farmers with or without climate change, referred to as "win-win" potential; (4) greenhouse gas (GHG) emissions mitigation potential; and (5) evaluation by stakeholders. Some of the options identified may also yield benefits in the form of reduced GHG mitigation potential, helping contribute to climate change mitigation as well as agricultural adaptation.

Benefit-Cost Analysis

The study conducted quantitative benefit-cost (B-C) analyses for the following eight adaptation options: (1) improving irrigation capacity and efficiency by new investments or rehabilitation to optimize application of irrigation water, (2) shifting to new crop varieties, (3) optimizing fertilizer application, (4) improving hydrometeorological services, (5) improving extension services, (6) optimizing basin-level application of irrigation water, (7) adding water storage capacity, and (8) installing hail nets for selected crops.

The results of the B-C analysis for rehabilitating irrigation infrastructure are presented in table 3.7 as an illustration of economic analyses conducted for the above options in all four agricultural regions. The table shows the B-C ratios for each crop assessed under the baseline and each climate scenario, using average price assumptions. B-C ratios above one (green shading) are favorable (that is, benefits outweigh costs), while B-C ratios below one (no shading) are not favorable (that is, costs outweigh benefits). The higher the B-C ratio (darkest green shading), the better the option is from a B-C standpoint. For example, for rainfed apricots in the intermediate agricultural region, the costs of rehabilitating irrigation infrastructure outweigh the benefits under all climate scenarios, and therefore this option is not favorable. On the other hand, for rainfed tomato in the intermediate agricultural region, the benefits of rehabilitating infrastructure far outweigh the costs under all climate scenarios, and therefore this option is favorable.

Table 3.7 Benefit-Cost Ratios for Rehabilitating Irrigation Infrastructure in Armenia's Intermediate Agricultural Region

		Climate impact scenarios			
Irrigated/rainfed	*Crop*	*Base*	*Low*	*Medium*	*High*
Rainfed	Alfalfa	0.60	0.60	0.60	0.60
	Apricot	0.02	0.02	0.10	0.30
	Grape	0.50	0.70	3.00	4.00
	Potato	5.00	5.00	6.00	6.00
	Tomato	21.00	23.00	27.00	27.00
	Watermelon	8.00	8.00	11.00	11.00
	Wheat	0.02	0.02	0.02	0.02

Source: World Bank data.
Note: Results are the estimated benefit-cost (B-C) ratios associated with the rehabilitation of irrigation infrastructure, by crop and climate scenario. B-C ratios greater than 1 (shaded in green) indicate that the benefits of the adaptation measure exceed the costs, while benefit-cost ratios less than 1 (not shaded) indicate that the costs exceed the benefits. Values shaded darker represent the biggest increases.

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Assessment of GHG Mitigation Potential of Adaptation Options

Many of the potential adaptive measures also yield co-benefits in the form of climate change mitigation. For example, some adaptive practices can significantly reduce nitrous oxide and methane emissions. Nitrous oxide emissions are largely driven by fertilizer overuse, which increases soil nitrogen content and generates nitrous oxide. By improving fertilizer application techniques, nitrous oxide emissions can be reduced while maintaining crop yields, specifically through more efficient allocation, timing, and placement of fertilizers. Mitigation of methane emissions, on the other hand, is largely enabled by increasing the efficiency of livestock production. Optimizing breed choices, for example, serves to increase productivity, thereby reducing overall methane emissions. Alternative uses of animal manure (for example, biogas production) and improved feed quality quickens digestive processes, resulting in reduced methane emissions. Finally, adaptive measures, such as conservation agriculture and manual weeding, may also reduce the emissions associated with agricultural production and by heavy machinery use. Similarly, increased irrigation efficiency reduces the energy required to pump groundwater.

The potential for adaptive agricultural practices to simultaneously mitigate climate change has already garnered attention in Armenia. Armenia, as a transition country (United Nations Framework Convention on Climate Change [UNFCCC] Non-Annex 1, that is, not obligated by GHG emissions caps), has submitted two National Communications to the United Nations Framework Convention on Climate Change (UNFCCC 2010), and some of the Armenian Government's current agricultural policies address adaptation and mitigation priorities in the agricultural sector. Some mitigation projects in Armenia are already under way.

One World Bank project that addresses mitigation is the Natural Resources Management and Poverty Reduction Project in Armenia, which promotes the adoption of sustainable natural resource management practices and the alleviation of rural poverty in places where severe environmental degradation has occurred. The global environmental objective is to preserve the mountain, forest, and grassland ecosystems in the South Caucasus through enhanced protection and sustainable management. Specifically, to mitigate climate change, the project proposes demonstrations of biogas production installations that would reduce methane emissions while reducing the use of timber. In addition, Armenia has several projects funded through the Clean Development Mechanism, which allows Annex I countries to implement mitigation projects in non-Annex I countries (UNFCCC 2010).

National Conference

The National Dissemination and Consensus-Building Conference, held in Yerevan in October 2012, provided another opportunity to consult with Armenia's experts to identify the highest priority adaptation and mitigation options at both the national and agricultural region levels. The overall program included a detailed presentation of the technical and farmer consultation

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findings (outlined in the last section), and a half-day consensus-building exercise among participants, with region-focused groups providing rankings and information for the multi-criteria assessment calculations.

The small groups were presented with tables that summarized the results of the completed B-C analysis, expert assessment, win-win assessment, and mitigation assessment. The agenda for the process was in three parts: (1) rank the actions/policies for the focus region from the provided table in order of importance, including crossing off any options that are not relevant, identifying other actions or policies that should be considered, and ranking the resulting overall set of options; (2) rate the importance of three technical criteria by allocating 100 total points across: (a) B-C analysis (net economic benefit), (b) potential to help with or without climate change (win-win potential), and (c) GHG mitigation potential, to reflect the relative importance the group places on achieving each objective; and (3) report back on findings to the full conference in plenary session.

Rankings of the groups, as reported from the conference, are presented in table 3.8. The national group focused on national-scale policies, and as a result

Table 3.8 Ranking of Adaptation Measures for Armenia's Agricultural Regions

		Ranking of measure by group			
Adaptation measure	*Specific focus area*	*National*	*Lowlands*	*Intermediate*	*Mountainous*
Improve farmer access to agronomic technology and information	Crop varieties; more efficient use of water	1			
Create crop insurance program	Promote investments in agricultural crops susceptible to drought and hail	2			
Increase the quality, capacity, and reach of extension services	Demonstration plots	3			
Improve farmer access to hydro-meteorological capacity	Develop short-term temperature and precipitation forecasts	4			
Improve irrigation water availability	Rehabilitate irrigation capacity		1		2
Optimize agronomic practices	Increase and improve fertilizer application		4	No group formed, no ratings	
Improve crop varieties	Introduce drought-tolerant varieties		2		3
Research and improve livestock nutrition, management, and health	Include research on sheltering techniques				4
Optimize and/or improve irrigation techniques	Sprinkler, drip irrigation				2
Construct small volume reservoirs for water storage			3		5
Improve agricultural practices	Increase capacity, knowledge, and pasture management skill				1

Note: Items without entries were not ranked by those groups.

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presented an entirely different focus from the region-focused groups. The region-focused groups provided additional measures for consideration unique to their regions. Across the regions, there was broad support for improving irrigation water availability, optimizing irrigation practices, and building small-scale reservoirs. No group was formed to consider the intermediate region.

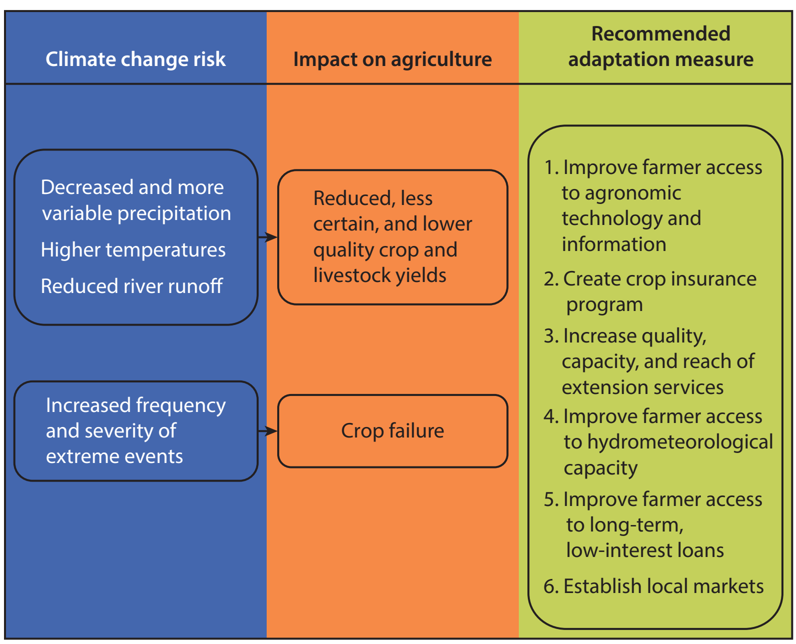
Final Menu of Recommended Adaptation Options

The final menu of recommended adaptation options for Armenia reflects multiple lines of quantitative and qualitative analysis of potential net benefits, including evaluations and recommendations from farmers, stakeholders, and other experts. These measures were identified as important both at the national conference and at the farmer workshops. The six national-level measures (figure 3.5) focused on the following areas:

- ***Improve farmer access to agronomic technology and information.*** Through improved extension services, farmers could access technologies to improve crop yields—for example, obtaining new seed varieties or investing in drip irrigation. More targeted and practical trainings, such as demonstration plots, could lead to the use of better technologies and agronomic practices.

- ***Investigate options for crop insurance, particularly for drought.*** Crop insurance is not viable for the vast majority of agricultural producers due to its

Figure 3.5 National-Level Priority Adaptation Measures for Armenia



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high cost, but farmers remain eager to explore insurance options. One possible way to expand coverage might be piloting a privately run weather index-based insurance program. This approach has many potential advantages over traditional multiple-peril crop insurance, including simplification of the product, standardized claim payments to farmers in a district based on the index, avoidance of individual farmer field assessment, lower administrative costs, timelier claim payments after loss, and easier accommodation of small farmers within the program. The drawback of an index-based approach may be the inability to readily insure coverage of damage from pests. In addition, pilot insurance schemes based on weather indices have encountered low demand in many locations, partly because poor farmers are cash and credit constrained; therefore they cannot afford premiums to buy insurance that pays out only after the harvest (Binswanger-Mkhize 2012). Poorly designed insurance schemes may also slow autonomous adaptation by insulating farmers from climate-induced risks. In general, countries may need to first consider improving market access and reducing credit constraints in order to better create enabling conditions suitable for crop insurance to be effective.

- ***Improve the quality, capacity, and reach of the extension service, both generally and for adapting to climate change.*** There was broad agreement among those surveyed that the capacity of the existing extension and research agencies must be improved to support agronomic practices at the farm level, including implementation of more widespread demonstration plots and increased access to better information on the availability and best management practices of high-yield crop varieties. The study's economic analysis suggests that expansion of extension services is very likely to yield benefits in excess of estimated costs.

- ***Improve capacity of hydrometeorological institutions.*** Farmers noted the need for better local capabilities for hydrometeorological data, particularly for short-term temperature and precipitation forecasts. Those capabilities are acutely needed in the short term to support better farm-level decision-making. The economic analysis of the costs and benefits of a relatively modest hydrometeorological investment, which includes training and annual operating costs, suggests that benefits of such a program are very likely to exceed costs.

- ***Improve farmers' access to rural finance to enable them to access new technologies.*** Farmers could acquire technologies through well-targeted and affordable credits to improve crop and livestock yields. However, the current rural finance system, with its relatively high interest rate combined with stringent collateral requirements and limited outreach, prohibits access to credit for many rural households despite the demand. The commercial banks and non-bank financial institutions (NBFI) need to tailor their loan products to the specificities of rural investments: reduce periodicity of cash-flow, provide longer maturity to match the specific crop and livestock production cycles,

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and pay non-monthly payments. The need for tailoring techniques to shifting climatic conditions without harming ecosystems of the country is pressing and urgent.

- ***Improve access to local markets.*** Specific recommendations to improve the marketability of produce and livestock in rural areas of Armenia include the following:
  - Change farmers' perception of marketing: Train them to focus on quality of products that they produce. Poor quality is not marketable, or if marketed, a low price for poor quality is inevitable.
  - Invest in market information gathering and dissemination, including mass media, fax, telephone, and real-time computer access systems.
  - Create, train, and support producer associations (cooperatives) and small and medium scale enterprises to improve the bargaining power of small farmers.
  - Provide storage facilities including cold storage that enable farmers to inventory their products for periods when the market is not saturated.

As indicated in figure 3.5, these measures address the climate change risks and corresponding impacts on agriculture. In addition, they are responsive to a key policy focus area for Armenia that was established early in the stakeholder process: Specifically, as described in box 3.1, many farms in Armenia's mountainous agricultural region operate small-scale cereal/fodder/livestock production systems, and a key policy objective for poverty relief in the country is to support these systems. Providing improved extension services and access to local markets—both measures identified above as priorities at the national level—can potentially contribute to this goal.

Box 3.1 Policy Focus Area for Armenia: Smallholder Cereal and Livestock Production

The Armenian agricultural sector is dominated by production of irrigated fruits and vegetables, particularly in the productive Ararat Valley region. A key policy objective for poverty relief, however, is support for rural subsistence farmers in the more mountainous areas, where many farms operate small-scale cereal/fodder/livestock production systems. In the early part of the 21st century livestock made up more than half of total agricultural production, but since then, crop production has grown faster than livestock production, and currently livestock is less than 40 percent of total production. Most of the crop production increases have occurred in lowland and intermediate areas, while livestock production in higher elevation areas has remained strong, with a recent focus on increases in sheep and goat production (mainly for the growing Iranian export market) (ArmStat 2013; Welton, Asatryan, and Jijelava 2013).

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Box 3.1 Policy Focus Area for Armenia: Smallholder Cereal and Livestock Production *(continued)*

Climate change may be good news for farmers focusing on livestock and cereal production in high elevation areas, but only if market access can be improved. For example, crop modeling for this study found that alfalfa yields would decline by a very small amount through 2050 under the Medium Impact Scenario (1 percent rainfed, 2 percent irrigated), and wheat yields would likely increase by more than 33 percent over the same period. Although pasture was not modeled in the Armenia study, in the high elevation areas of Georgia and Azerbaijan that border Armenia, climate change was forecasted to increase pasture yields by 11 percent (western areas of Azerbaijan) to 87 percent (eastern areas of Georgia). Increases in both wheat and pasture productivity could provide a boost to smallholder cereal/livestock producers.

Farmers in these high elevation areas, however, have the greatest difficulties bringing goods to market in Armenia, not only mostly because of poor road conditions, but also because of lack of storage facilities and market knowledge, as well as the fact that export markets for landlocked Armenia have been limited in recent years. Furthermore, this study's farmer consultations in highland regions suggested that most smallholders have limited knowledge of modern livestock production techniques. Enhanced extension in these areas, coupled with greater market access, could be critical factors in unlocking the potential for higher livestock productivity in these smallholder systems.

Recommended Adaptation Options by Agricultural Region

Recommendations for each agricultural region to improve the resilience of Armenia's agricultural sector to climate change—presented in figures 3.6 through 3.8—include the following focus areas:

- ***Irrigation.*** All regions identified irrigation as a key focus area for improving resilience to climate changes and extremes, now and in the future. Specific measures discussed include: (1) improving existing irrigation schemes, (2) improving water use efficiency by investing in drip and sprinkler irrigation, (3) rehabilitating water reservoirs (mainly in lowland and intermediate regions), and (4) increasing national water storage capacity, in part through building small-scale reservoirs in vulnerable higher elevation regions.

- ***Hydrometeorological forecasts.*** Farmers currently use forecasts made available by television, but these are aimed at too broad a geographic area and do not provide information specific for agriculture (for example, information that would allow them to know when to apply pesticides, when to irrigate, or when to plant). Today, many farmers still plant when the snow is at a certain level on Mount Ararat.

- ***Extension services.*** The extension service run by the Armenian Government is active and well-funded, but few farmers seem to use the training or other

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Figure 3.6 Lowlands Agricultural Region Priority Adaptation Measures for Armenia

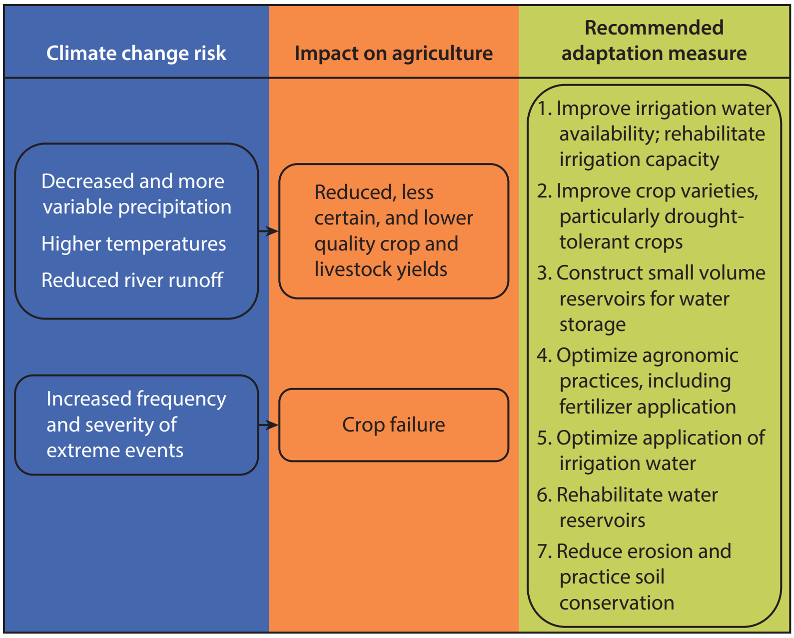


Figure 3.7 Intermediate Agricultural Region Priority Adaptation Measures for Armenia

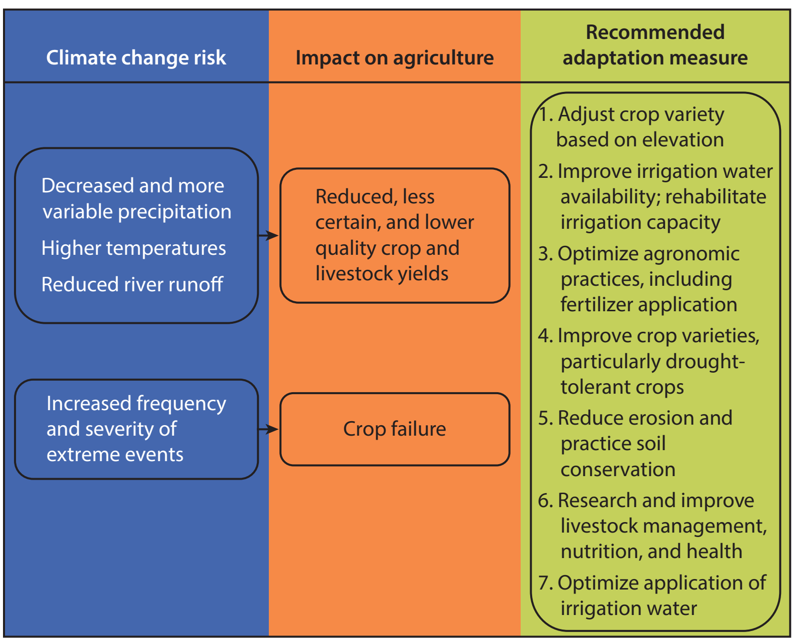
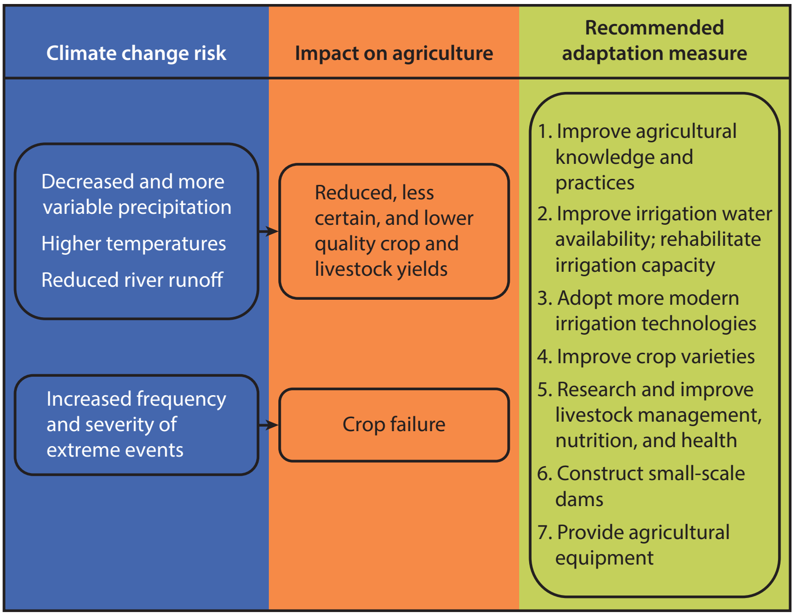


Figure 3.8 Mountainous Agricultural Region Priority Adaptation Measures for Armenia



educational opportunities offered by the service. The farmers indicated that they would be interested in more practical and targeted training, such as demonstration plots.

- ***Seed selection.*** Some farmers indicated that their seedlings and plants are tolerant to weather changes, but most said they were not tolerant. Generally, farmers prefer to produce and use their own seeds, and they will clean and replant seeds from season to season. Sometimes they use seeds from the extension service, but these are often not tailored to the specific climate and soil conditions of their region. Ideally, the service would provide seeds for heat and drought tolerant crops to address anticipated warmer and drier conditions.

- ***Crop insurance.*** While insurance does exist, it is currently too expensive for most farmers. Both hail and spring frost are major issues for farmers in the region, with estimates of annual losses on the order of 10 percent of annual production for some crops, which may account for as much as US$100–150 million in annual losses nationwide. Subsidized programs for crop insurance would greatly stabilize their incomes and improve their capacity to reinvest in farming, but insurance schemes must be carefully designed for affordability, and they must recognize cash and credit constraints if there is to be sufficient uptake of insurance among poor smallholder farmers.

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- ***Bank loans.*** Most farmers indicated they have access to high-interest, short-term bank loans for agricultural development, but it is difficult to obtain low-interest, long-term bank loans for agricultural development.

- ***Infrastructure.*** To moderate temperatures and improve yields, some farmers have constructed greenhouses. Few farmers attending the stakeholder meeting had greenhouses, however, as most of these farmers were smallholders.

Limitations of the Study

Finally, due to its broad scope, this study necessarily involves significant limitations. These include the need to make simplifying assumptions about many important aspects of agricultural and livestock production in Armenia, and the limitations of simulation modeling techniques for forecasting crop yields and water resources. As a result, certain recommendations may require a more detailed examination and analysis than could be accomplished here in order to ensure that specific adaptation measures are implemented in a manner that maximizes their value to Armenian agriculture. However, the authors hope that the awareness of climate risks and the analytic capacities built over the course of this study provide not only a greater understanding among Armenian agricultural institutions of the basis of the recommendations presented here, but also an enhanced capability to conduct the required more detailed assessment that will be needed to further pursue the recommended actions.

In addition, it is desirable that the countries of the South Caucasus address climate change through collaboration on issues such as climate-related data sharing and crisis response. There are many challenges to achieving these objectives, but fortunately there are a wide range of existing models of regional-scale institutional arrangements throughout the world, encompassing the scope of regional cooperation for water resources planning, agricultural research and extension, and enhanced hydrometeorological service development and data provision.

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