Adaptation to Climate Change in Europe and Central Asia Agriculture

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To ensure the viability and competitiveness of agriculture and forestry and sustain rural livelihoods, it is critical to take stock of the impacts of climate change on rural sectors in Europe and Central Asia (ECA) countries and implement appropriate adaptive measures. The interactions between the weather-sensitive agriculture and forestry sectors, climate change, and the natural resource base are highly complex and deserve special attention. Globally, the increased frequency of heat stress, droughts and flooding events caused by climate change threaten to reduce crop yields and livestock productivity in many areas, while increased risks of fires and pest outbreaks will have negative consequences for forests.[2] For ECA the story is even more complex, with projections suggesting losses in some areas and at the same time potential gains in others.

At the same time, the agriculture and forestry sectors are important for mitigation of climate change. Together, agricultural production and deforestation account for up to 30 percent of greenhouse gas emissions worldwide, second only to the energy sector.[3] The sectors also offer important opportunities for carbon sequestration, such as through aforestation or minimum tillage agriculture. But while aggressive mitigation of greenhouse gas emissions should continue to be a priority, most experts now agree that climate change is already happening.[4] For example, the severe losses incurred by Moldova's agricultural sector and the devastating forest fires in Greece as a result of the 2007 drought and heatwave have been attributed to global warming. And mitigation today does not protect against the climate change impacts in the pipeline from past greenhouse gas emissions – impacts that will continue to unfold for decades to come. As a result, both the IPCC and the EU recommend that countries already make serious efforts to reduce their vulnerability by identifying and implementing adaptation measures.

Although agriculture and forestry constitute decreasing shares of the economies of ECA countries, they continue to be critical for rural poverty reduction, employment, economic growth and food security. ECA is somewhat unique among World Bank regions in that some areas are projected to potentially benefit from climate change, at least for moderate temperature increases (1-3°C). As a result, ECA's agriculture is gaining global prominence as one of the most promising prospects for providing the supply response needed to feed the world's increasing appetite, both today and in the future.

However, the positive projections for ECA's agriculture, which have led to a sanguine attitude toward climate change and agriculture among some people, mask a great deal of

[1] This report was prepared as part of the 2008 ECA regional umbrella study on climate change adaptation, *Managing Uncertainty: Adapting to Climate Change in ECA Countries*, led by Marianne Fay. The team leader for the Agriculture Report is William R. Sutton (ECSSD). The agriculture team is comprised of Rachel I. Block and Jitendra Srivastava. Contributions were also provided by Brian Bedard, Lucy Hancock, Robert Kirmse, and Michael Westphal.
[2] Easterling et al., 2007
[3] WDR 2007, the World Bank
[4] IPCC, 2007. The EU White paper, 2009.

uncertainty, assumptions, and variation across the region. While higher latitude countries have the potential to benefit, southern regions of ECA, where the most productive lands are located today, will suffer significant losses. In the northern countries, the potential benefits from climate change will only be realized through significant adaptation, and even then there will be costs, including significant investments in public services and new infrastructure, and the possibility of social dislocations and environmental damage. The high food prices experienced over recent years are due in part to extreme weather.[5] Since extreme weather events are expected to become more frequent with climate change, the food price crisis experienced in ECA countries and around the world in 2007-2008 could in many ways be viewed as a preview of what is to come if nothing is done to adapt.

Thus, both potential winners and losers will have to undertake proactive adaptation programs in order to reduce the damage to their rural sectors from climate change, and to maximize the benefits from any opportunities that may be presented. The good news is that many of the recommended adaptation measures are also generally good development practice that would yield benefits regardless of climate change – though currently most ECA countries have not taken the steps needed in order to reap these benefits. Indeed, more detailed country-level and regional analysis has shown that the gains to be made today by closing the productivity gap with the West in both agriculture and forestry far outweigh any potential future gains or losses from climate change.[6]

Unfortunately, the fact that these productivity gaps persist is evidence of fundamental weaknesses in ECA's agriculture and forestry sectors, and does not bode well for their capacity to adapt to climate change. To reduce these vulnerabilities, much needs to be done to increase the capacity of institutions in the sector and improve public services, invest in production and market infrastructure, and develop the skills and knowledge of farmers and foresters. In many cases, acting sooner rather than later will increase the effectiveness and reduce the costs of such interventions.

There is an important role for governments to play in adapting to climate change due to the potential for market failure. It is also important for governments to get the policy environment right to avoid counterproductive distortions, such as the food export restrictions many countries adopted during the food price crisis, which reduce incentives to invest in agriculture. A number of global challenges that converge around issues of climate change and agriculture are also currently high on the international agenda: rising energy prices; rising food prices; mitigating emissions and improving energy security with biofuels; and adapting to the unavoidable impacts of climate change.

While these challenges have fundamentally international dimensions, national policies will be key to shaping and implementing the solutions. Technical, financial, and political support from research bodies and multilateral financial institutions (MFIs), as well as their advocacy in advancing international policy regimes (e.g. trade liberalization in agriculture, carbon credits for reduced deforestation), will also be essential to establish a framework and provide tools for national policymakers. This foundation can aid policymakers to effectively

[5] FAO (2007). FAO & EBRD (2008)
[6] Olesen and Bindi (2002)

adapt to climate change impacts on agriculture and forestry while managing the competing pressures of food and energy security and keeping in sight the goal of rural poverty reduction. But despite the clear importance of investing in agriculture and the potential win-win benefits such investments promise, global investment in agriculture has been declining over recent decades.

In this paper, we examine the **exposure**, **sensitivity**, and **adaptive capacity** of ECA agriculture to climate change, and provide recommendations for addressing the challenges of climate through adaptation. We have made use of the best available climate change projections to categorize countries in the region by likely agricultural sector impacts. We have also attempted to synthesize information from the literature on climate change adaptation in agriculture in order to identify the most relevant points for ECA countries, including options for technical, institutional and policy measures. Based on this initial assessment, there are plans to support World Bank clients in carrying out assessments and developing strategies at the country level in the near future.

I. The agricultural sector is highly sensitive to climate change, and ECA will be impacted.

Agriculture is highly sensitive to climate. This is the true across countries and environments, from labor-intensive farming in the tropics to capital-intensive farming in temperate zones. The extent and nature of changes in climate vary, as do the capacities of governments and agricultural communities to respond to new challenges. A substantial body of research indicates that the economic impacts of climate change on agriculture may ultimately be a small share of GDP at a global scale, but potentially very large at the country and local level,[7] and large relative to the impacts in less weather-sensitive sectors.[8] The transition countries of Europe and Central Asia (ECA) face significant risks to their agricultural systems, food supply networks, and rural livelihoods as a result of climate change. It is possible to reduce the vulnerability of ECA agriculture to climate change, as well as take advantage of some opportunities that may be presented. However, this can only be achieved with better ECA-specific analysis of rural livelihoods and the challenges presented by climate change, followed by proactive planning, policy-formation, investment design, and implementation from the local to the national and regional level. (Annex Figure A1 illustrates the boundaries of the sub-regions of ECA used for this paper's analysis.)

The climate impact information and analysis for agriculture in ECA is not comprehensive, but is sufficiently advanced to illustrate the reality of existing climate shifts and future changes and a range of potential impacts on food production and national economies. Much attention to damages in the agricultural sector from climate change has focused on Sub-Saharan Africa, given the region's many environmental and socioeconomic vulnerabilities, while the smaller discussion of potential gains has mostly concerned high-latitude, high-capacity areas in Northwestern Europe and North America.[9] But there is also already evidence of changes in climate in ECA and resulting changes in output. In addition, current impacts of climate phenomena, whether related to long-term global change or not, demonstrate the sensitivity of ECA countries' rural sectors to an even more challenging climate projected for the coming decades.

A range of changes in weather linked to climate change have been observed. In some cases, associated impacts on agricultural systems and rural economies are also already evident. In Europe, over the 20th century, average temperature has increased by +1˚C, with an acceleration in the last three decades and particularly acute increases in Central Europe and Northeastern Europe.[10] As a result, a longer than normal growing season has been observed in

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[7] Representative examples of multi-country studies on the global agronomic and economic impacts of climate change in the agricultural sector include the work of Robert Mendelsohn and colleagues (Mendelsohn et al 2000, Kurukulasuriya and Mendelsohn 2006, Seo and Mendelsohn 2007); Cynthia Rosenzweig, Martin Parry, Francesco Tubiello, and colleagues (various); Guenther Fischer and colleagues (Fischer et al 2002, 2005); and the synthetic analysis of William Cline (2007). Section III provides more discussion of these models and estimates.

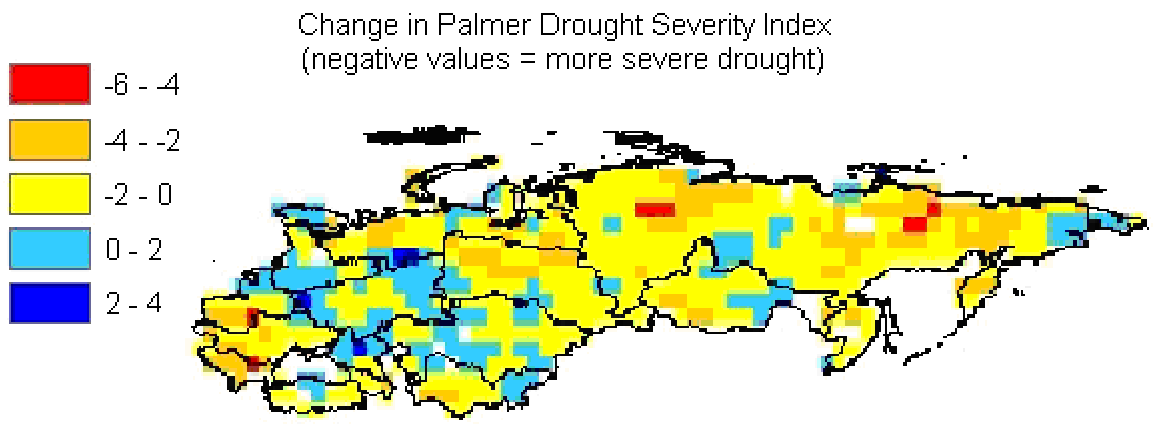
[8] Researchers working with multi-sectoral, so-called integrated assessment models, such as Nordhaus and Boyer (2000), Mendelsohn and other economists including Sir Nicholas Stern, have contended that agriculture is "the most climate-sensitive of all economic sectors (Stern Review, p vii)." How the economic damages are ultimately experienced and distributed remains to be seen and will of course vary across countries, but a consensus about the sensitivity and importance of agriculture has emerged in the discipline.

[9] Kurukulasuriya et al 2006, the Up in Smoke Africa report, a not *too* old ag impact study for the US perhaps.

[10] Böhm et al 2001, Klein Tank 2004, as cited in IPCC Ch 12, p545.

locations from Germany to European Russia.[11] Extreme events have occurred with greater frequency and intensity in Europe, most recently in the 2003 summer heatwave over much of the continent, the 2007 drought in southeastern Europe, and more intense flooding in Central and Southeastern Europe in the past few years. A decline in precipitation along the northeastern coast of the Mediterranean has caused significant drought-related damages in the agricultural economies of Southeastern Europe (Figure 1).[12] Economic losses in all sectors due to drought have been estimated in the range from $25 million (Albania, 1989-1991) to $500 million (Romania, 2000).[13] Drought has caused major economic disruptions in Moldova in 2007, when its resilience was already weakened by storms and droughts of recent years (see Box 1).

Figure 1. Observed Increases in Drought Severity in ECA from 1961-1980 to 1981-2005



Source: Team

Box 1. Moldova: drought of 2007.

With almost 60% of the population living in rural areas and over 40% of the population employed in agriculture, Moldova is highly vulnerable to adverse climate events[14]. Moldova has always been impacted by drought on a regular basis, however the frequency and severity of such events has increased significantly in recent decades[15]. The 2007 event was the most severe

[11] Maracchi Sirotenko Bindi 2005 p119.
[12] Norrant and Douguédroit 2006, as cited in IPCC Ch 12, p545.
[13] Albania (1989-1991: $25m), Macedonia (1993: $10m), Moldova (2000: $170m, 2007: $1 billion), Romania (2000: $500m), Croatia (2003: $330m), Bosnia Herzegovina (2003: $410m). Reproduced from EM-DAT database in World Bank 2007, South Eastern Europe Disaster Risk Management Initiative: Desk Study Review Risk Assessment in South Eastern Europe.
[14] World Development Indicators, 2009, The World Bank.
[15] Prepelita N. 2007 drought in the Republic of Moldova. Regional scientific and technical conference on the role of the NMHSs in prevention and mitigation of natural hazards impact impact, 9-10 October 2008, Chisinau, Republic of Moldova (see: http://www.un.org/esa/sustdev/sdissues/desertification/beijing2008/presentations/prepelita.pdf)

drought in living memory, with 80% of the country's territory affected, resulting in a devastating impact on agricultural production, rural livelihoods and the national economy[16]. Losses from this event in the agriculture sector were estimated at close to US $1 billion[17]. The greatest losses were experienced by fruit and vegetable growers (US $550 million), livestock producers (US $305 million) and cereal growers (US $132 million). When compared to 2006 production figures, the harvest of all major crops was reduced significantly in 2007, with production of wheat, maize and sunflower declining by 55.5%, 72.4% and 71.4%, respectively[18]. For the livestock sector the impact of the 2007 drought still lingers. With limited pasture and forage availability, many farmers were forced to sell livestock, including cattle, pigs and sheep. However, selling pressure was also exacerbated by the widespread failure of home gardens, which are often used to supply rural households with fruits and vegetables. With increased food expenses, farmers were also forced to sell additional livestock to fund these essential purchases. De-stocking rates across the country for the drought were estimate at over 30%[19]. To this day, many farmers are still re-building their livestock numbers, which has been made all the more difficult by another drought, albeit less severe in 2009. This highlights the important point that extreme events, like drought, can impact vulnerable communities for many years after the event has passed, which ultimately makes these communities more vulnerable to future events. To reduce vulnerability, a focus on bridging the adaptation deficit and building adaptive capacity is essential.

In the eastern parts of ECA (Central Asia (especially Kazakhstan), Asian Russia, and the Arctic), particularly large increases in temperature over the 20th century have been observed, from +1 to +3˚C (see Figure 2).[20,21] There is evidence that the frequency and intensity of extreme events has increased, including heatwaves, extreme cold days and winter storms, heavy rains and floods, and droughts.[22] In the mountainous South Caucasus, observed changes have exhibited geographic variation in both direction and magnitude, so while average temperature has increased slightly and average precipitation declined slightly, localized impacts have been larger.[23] Severe droughts have become increasingly common in the North and South Caucasus and Central Asia, worsened by local climate feedback loops of poor land management, soil degradation, and reduced rain or river runoff (see Figure 1).[24]

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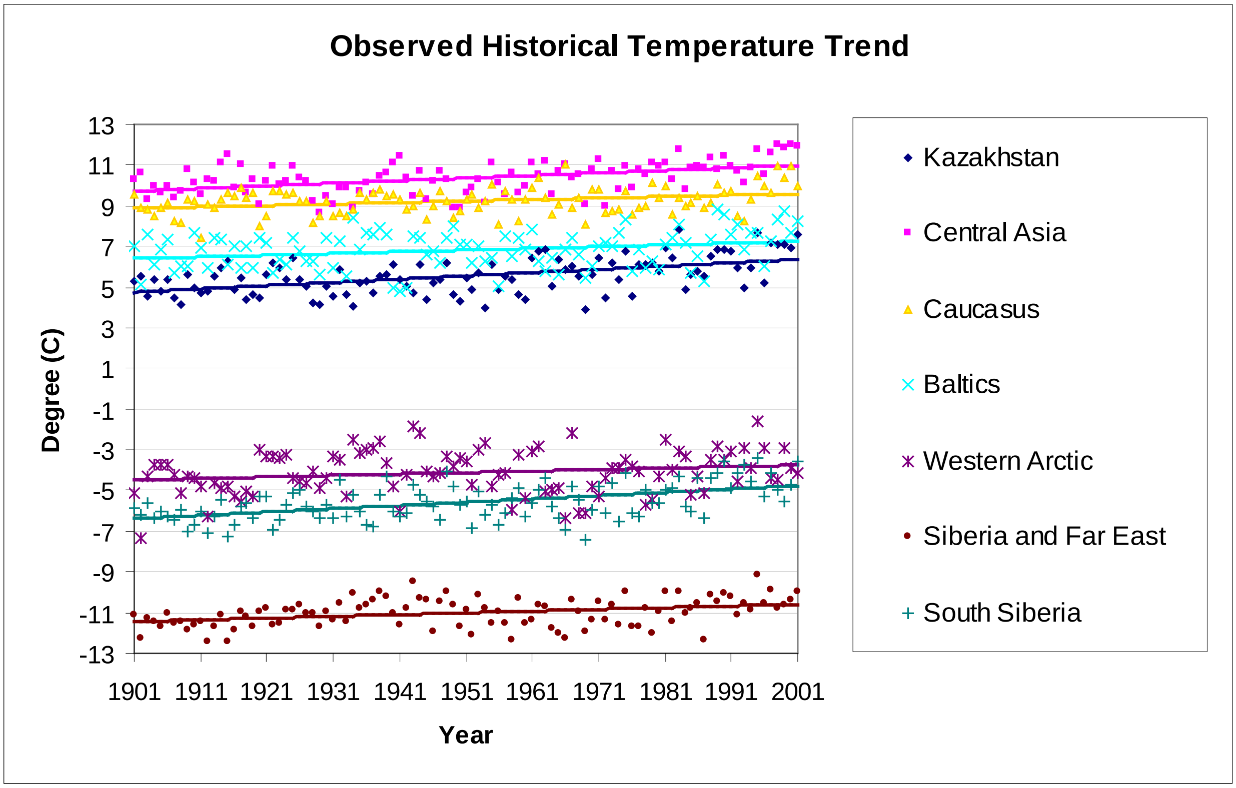
16 http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=19186
17 Prepelita N. 2007 drought in the Republic of Moldova. Regional scientific and technical conference on the role of the NMHSs in prevention and mitigation of natural hazards impact impact, 9-10 October 2008, Chisinau, Republic of Moldova (see: http://www.un.org/esa/sustdev/sdissues/desertification/beijing2008/presentations/prepelita.pdf)
18 http://siteresources.worldbank.org/INTMOLDOVA/Resources/FAO_assessment.pdf
19 http://www.worldbank.org.md/WBSITE/EXTERNAL/COUNTRIES/ECAEXT/MOLDOVAEXTN/0,,contentMDK:21452985~pagePK:141137~piPK:141127~theSitePK:302251,00.html
20 IPCC Ch 10 Asia p475.
21 Kattsov p8.
22 IPCC Ch 12 and Ch 10.
23 Hovsepyan and Melkonyan (draft, late 2007).
24 Drought report 2005.

Figure 2. Observed Mean Annual Historical Temperature Trend for Regions in ECA with Significant Warming, 1901-2001



Source: Team

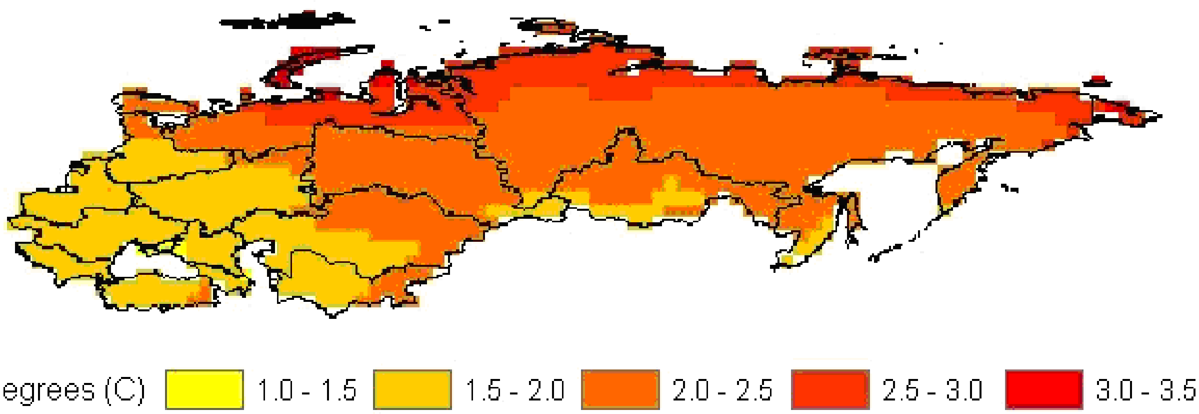
Environmental issues independent of climate change have also presented substantial challenges to rural livelihoods as a result of poor policy and resource management. A recent assessment of environmental issues more generally in the agriculture and forestry sectors of ECA found that significant improvements in management were required to ensure the sustainable management of the natural resource base upon which these sectors depend.[25] Issues of concern highlighted by the assessment include soils, water, and pest management, nutrient conservation, forest health, and illegal logging. At the same time, agriculture and forestry can also be significant providers of environmental services, including carbon sequestration, biodiversity preservation, and management of watersheds and rural landscapes. These issues will only become more important as climate risks, variability, damages, and uncertainties increase.

Climate projections through the middle of the century indicate the exposure of ECA's regions to different regimes of temperature and precipitation levels, changes, and variability. The projections tell a story of agronomically significant changes in temperature and precipitation averages (see Figures 3 and 4), with distinct trends in the north (much of Russia, the Baltics, northern Kazakhstan) and in the south (Central and Southeastern Europe, Turkey, the Caucasus, Central Asia).

[25] Sutton, W. et al. (2008), *Integrating Environment into Agriculture and Forestry: Progress and Prospects in Eastern Europe and Central Asia*, the World Bank: http://www.worldbank.org/eca/environmentintegration

The northern areas will experience particularly large increases in mean annual temperature (+1.5 to +3˚C), with much of the increase in the winter (+2 to +4˚C). The north will see increases in precipitation of +5 to +30% in autumn and winter, with the greatest increases in the Arctic, while more moderate increases of +0 to +10% are projected in the summer months. The southern areas, starting from much higher baseline temperatures, are projected to experience warming of +1.0 to +2˚C in the winter and more extreme increases of +1.5 to +3˚C in the already hot summer months. Precipitation is projected to decrease by as much as 20% in the southernmost and western areas from autumn through spring, with annual average changes of +5% to -15% across southern ECA.[26]

Figure 3. Projected Changes in Mean Annual Temperature, 2030-2049 vs. 1980-1999



Notes: Scenario A1B. Average of eight global circulation models (GCMs). Source: Team

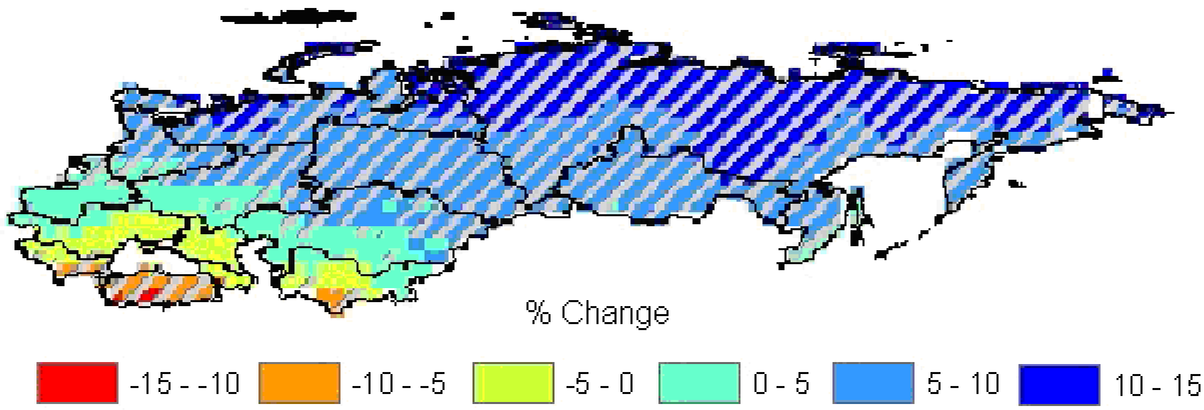
In addition to these changes in mean temperature and precipitation, all parts of ECA will experience fewer frost days and an increase the frequency and/or intensity of extreme weather events such as droughts, floods, and storms. Even in areas projected to have less precipitation overall, rainfall is more likely to come in concentrated storm events, rather than being distributed more evenly over many days, increasing the risk of nutrient leaching, soil erosion, flooding, crop damage, and interference with planting and harvesting activities. As rainfall becomes more clustered in fewer events, the span of dry days without precipitation, and thus propensity for drought, will increase in many areas, including Kazakhstan and Central Asia, the Caucasus, most of European Russia, Central and Southeastern Europe, and Turkey.[27]

The nonlinearities of climate change impacts include not only increased climate variability and incidence of extreme events, but also tipping-point effects on ecosystems and water resources. One such case is the climate change impact on the glaciers of the Tien Shan

[26] See Michael Westphal 2008.
[27] See Michael Westphal 2008.

Mountains of Northern China and Kyrgyzstan and resulting impact on water resources for agriculture throughout Central Asia. Agriculture in arid Central Asia is almost entirely dependent on irrigation, with the Syr Darya and Amu Darya rivers providing much of the water before eventually draining into the Aral Sea in western Kazakhstan and Uzbekistan. These rivers are fed by mountain snowmelt in the spring and early summer, and glacial melt in the late summer – the crucial periods of water demand for crop growth.

Figure 4. Projected Changes in Mean Annual Rainfall, 2030-2049 vs. 1980-1999



Notes: Scenario A1B. The GCM ensemble median (20 GCMs) for the change in mean annual precipitation. The hatching indicates where at least 2/3 of the models agree with the sign of the change.
Source: Team

Because of higher temperatures, mountain snowpack and thus the volume of the Tien Shan glaciers has declined sharply in the past fifty years, with that decline accelerating in the past two decades.[28] As warming continues and winter snowfall is replaced by rainfall, river flow will increase in the winter but decline in the spring and summer when it is most needed because there will be little accumulated snow. This will cause winter floods and summer droughts.[29] In the short-term, total annual glacial water supply from the mountains will be concentrated earlier in the spring and will at first be much greater, increasing by one third[30] or as much as threefold[31] by 2050, as the existing glaciers melt rapidly. However, once the glaciers are diminished, water supply throughout the year will decline markedly in the subsequent decades. There will likely be insufficient water for extensive irrigation of agriculture, and the challenge of sustaining water levels in the Aral Sea will worsen, possibly threatening recent successes in restoring the Sea's environmentally and economically important ecosystems.[32]

[28] Niederer et al 2007.
[29] IPCC Regional Impacts Ch 10 Temperate Asia.
[30] Agaltseva 2008.
[31] IPCC Regional Impacts Ch 10 Temperate Asia.
[32] Coping with Climate Change, Savoskul.

Estimated agricultural impacts vary according to baseline climates as well as the magnitude and type of changes in average climate trends and specific weather phenomena. Further, the economic, social, and political characteristics of diverse ECA countries and communities determine their capacity to adapt to climate shocks, and therefore are also fundamental determinants of realized outcomes for the agricultural economy.[33, 34] In general terms, climate change will likely cause agricultural losses in the drier, warmer southern areas where much of ECA's population and poverty is concentrated. However, the projected changes suggest the potential for gains in the cooler, rainier north and mid-latitude areas.

In the ideal case with smooth and unhindered adaptation, cereal cultivation could shift northward in Russia and Kazakhstan, and longer growing seasons could allow for increased diversification into higher-yield or higher-value crops in the cool, temperate areas of Central Europe and European Russia. Increased summer temperatures and declining precipitation will likely cause more frequent, intense droughts in Southeastern Europe and Turkey, the North and South Caucasus, and Central Asia, perhaps significantly limiting output and requiring proactive adaptation measures in order to sustain or fundamentally alter existing agricultural systems. Greater variability in crop yields from year to year is estimated for much of the region.

The projected increase in extreme events presents challenges for agriculture across all parts of ECA, including excess precipitation in Russia and the Baltics interrupting sowing and harvesting of cereals, storms in Central and Southeastern Europe destroying tree crops, alternating drought and intense rain and snowmelt causing landslides in the densely cultivated low slopes of the Caucasus, and drought combined with scarcity of irrigation water leading to soil degradation and a local climate change feedback process of accelerating aridity in Central Asia and the Southern Caucasus.[35]

Climate change is also expected to have a significant impact on sustainable livestock production. The anticipated variations in temperatures, changing rainfall patterns, uncertain water access and reduced crop yields would create biological stress on animals, alter daily growth and reproductive patterns and undermine the essential sources of feed, fodder and available grazing. Higher temperatures and milder winters contribute to altered livestock reproductive patterns and the spread of infectious diseases in livestock which may be already immuno-compromised through biological stress and poor nutrition. This could lead to a further increase in the zoonotic diseases in the region including brucellosis, rabies, etc.

The risks associated with increased temperatures, erratic weather patterns, drought, heavier snowfalls, depleted water sources and reduced feed availability have been traditionally compensated by increased livestock numbers, which can result in overgrazing, grassland and pasture degradation and erosion of watershed catchments.[36] This climate change feedback scenario may be particularly relevant to the ECA region and especially Central Asia where traditional agro-pastoral grazing systems predominate. The livestock sector and related activities

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[33] Rural Institutions and Climate Change: Proposed Framework on the Role of Local Institutions in Adaptation to Climate Change. World Bank 2007. http://go.worldbank.org/YNVS8PUTB0
[34] Antle et al 2004.
[35] IPCC Ch 5, Ch 10, Ch 12. Olesen Bindi 2002. Maracchi, Sirotenko, Bindi 2004. van der Celen & Lampietti / World Bank, forthcoming. Hovsepyan and Melkonyan, draft.
[36] Kokorin, A. (2008) Expected impact of the changing climate on Russia and Central Asia countries.

also aggravate the situation through emissions of methane, and competition for natural resources such as grassland and forests which are needed for carbon sequestration. Livestock production contributes nearly 80% of the anthropogenic greenhouse gas emissions from agriculture worldwide.[37]

Forestry will also be affected by climate change. In the ECA region, the main impact of climate change on forests is an increase in extreme weather events, which can directly or indirectly cause tree loss and forest degradation. Regional droughts and shifting wind patterns have already been seen to have caused increased frequency and intensity of wildfires, most notably in Greece in 2007, Portugal in 2003 (where some 400,000 ha were lost), and Russia in 2003 (where over 20 million ha were lost to fires in a single year).

Changes in temperatures and rainfall can also favor outbreaks of insect infestations with devastating consequences, as seen in the northern march of pests in Boreal forests around the world. Likewise, a changed climate also opens the way for the invasion of non-native, harmful plant species into already disturbed forest ecosystems, which can cause further forest degradation. Moreover, changing climates can cause the realignment in the distribution of tree species. Generally tree species tend to shift to both higher latitudes and higher altitudes in response to global warming, a trend already observed in the northward expansion of birch (*Betula pubescens*) into the tundra of Sweden over the last half of the 20th century.

Parallel and interrelated impacts and responses will occur in related sectors dependent on climate and natural resources such as land and freshwater supplies, with possible environmental and economic feedbacks. Shifting climate will stimulate competition between forestry and agriculture for land in northern areas. The relative feasibility of field crops, tree crops, and livestock may further alter land-use patterns. As seen in the case of the Aral Sea, overexploitation of water resources for irrigation, as well as overuse and resulting runoff of polluting fertilizers, can have devastating consequences on fisheries and other water-dependent activities. Changes in climate and associated changes in production activities will have unpredictable consequences on local and national economies. The complexity of the market, financial, and policy environment at the local, national, and international levels increases the challenge of uncertainty that characterizes climate change risk.

However, unpredictability and uncertainty do not mean that policy-makers must give up, nor choose to act in the future after a delay to "wait and see". Rather, uncertainty itself is an integral aspect of the climate change challenge, alongside current and future climate risks and economic and social challenges, that decision-makers at all levels of society, from farmers to government ministers, can and should be equipped to engage with now.

As an example, the threat of a feedback loop in the Tundra and Boreal Forests is a major concern. Together, these forests contain more than half of the carbon that exists on land. The theory and observations are that global warming causes the melting of permafrost, which brings about the decomposition of peat, deadwood and buried pine needles, thus freeing the vast amounts of carbon that they contain. This, together with an increase in wildfires that send wood (and the carbon that it contains) up in smoke, and insect infestations that girdle trees, sending

[37] FAO (2006). Livestock's Long Shadow. Environmental Issues and Options.

them to rot on the forest floor, could push the world's climate towards an even greater heat spiral (i.e., feedback loop), and all the believed consequences on sea levels and farming, not to mention the loss of forest resources.

Such a case has already been observed in Canada, where an unprecedented outbreak of mountain pine beetle infestation has resulted in an accelerated dynamic of "widespread tree mortality [which] reduces forest carbon uptake and increases future emissions from the decay of killed trees."[38] This has converted the pine forests of British Columbia from an important carbon sinks to a large net carbon source even after the outbreak, resulting in emissions that rival those from a few decades worth of forest fires and which further the spiral of warming and insect infestations.

There is an important role for governments to play in adapting to climate change due to the potential for market failure resulting from the long-term strategic planning required, the lack of and inability to process climate information in the private sector, the potential for externalities from investments in goods such as crop variety research, and the scale of the problem. It is also important for governments to get the policy environment right to avoid counterproductive distortions, such as the food export restrictions that many countries adopted during the food price crisis, which reduce incentives to invest in agriculture. Establishing the right incentives will help countries harness the power of the private sector.

[38] Kurz et al. A large net carbon source both during and immediately after the outbreak. Nature 452, 987-990 (24 April 2008).

II. Agriculture is important for poverty reduction and growth in ECA

Agriculture and non-farm rural employment remain an important source of income in many ECA countries. As Table 1 indicates, agriculture is a particularly important part of GDP in Central Asia (27.0%), the South Caucasus (12.0%), and Southeastern Europe (12.3%). Across ECA, roughly one third to one half of people live in rural areas with the figure approaching two thirds in Central Asia. Even in places where agriculture accounts for a lower share of output, such as Central and Eastern Europe (8.7% of GDP) and Kazakhstan (6.7% of GDP), rural populations still represent a significant share of the total (36.1% and 42.2%, respectively), indicating that there are many people whose livelihoods continue to be linked to agricultural production, processing, and related services.

Table 1. Agriculture Matters: Poverty and the Rural Economy in ECA[39]

Region	Agriculture as share of GDP (%)	Rural population (%)	Rural extreme poverty rate (%)	Rural poverty rate (%)	Of the extremely poor, share found in rural areas (%)	Of the poor, share found in rural areas (%)
Southeastern Europe	12.3	35.4	20 (9 without Turkey)	61 (44 without Turkey)	46	45
Central & Eastern Europe	8.7	36.1	10	44	54	48
Baltics	5.3	35.2	3	33	39	42
Russia	5.6	27.1	14	53	42	34
South Caucasus	12.0	45.9	30	80	49	48
Kazakhstan	6.7	42.2	31	79	64	52
Central Asia	27.0	64.1	62	94	73	69

Sources: World Development Indicators (2005, or 2006 where available); *Growth, Poverty, and Inequality: Eastern Europe and the Former Soviet Union* (Alam, A. et al., World Bank 2005). The extreme poverty line is $2.15 per person per day and the poverty line, $4.30. Note that poverty lines are expressed in purchasing-power parity dollars, which means that the income data have been adjusted take account of the benefit of lower prices in lower-income areas.

[39] For all poverty statistics in table: 2003, except 2002 for Albania, Belarus, Poland, Russia, Serbia and Montenegro, and Turkey, and 2004 for Bosnia and Herzegovina. For rural poverty rates, Southeastern Europe is Bulgaria, Serbia and Montenegro, Albania, FYR Macedonia, Bosnia and Herzegovina, and Turkey. Central & Eastern Europe is only Ukraine, Romania, and Moldova, and Central Asia is only Kyrgyzstan, Tajikistan, and Uzbekistan, because of data availability. Agriculture and rural population include all countries for each region.

Rural poverty rates in ECA are significant and generally higher than national averages. The share of rural people in poverty varies from a low of 33% in the Baltic countries and 44% in Central and Southeastern Europe (not including Turkey) up to 80% in the South Caucasus and Kazakhstan and a staggering 94% in the rest of Central Asia. Indeed, 62% of the Central Asian rural population is below the even lower, extreme poverty line. Throughout ECA, about half of the poor are found in rural areas, with a few exceptions; about two thirds of the poor in Russia are urban, while over two thirds of the poor in Central Asia are rural. And despite a perception that ECA is an urbanized region, 35 percent of the population still resides in rural areas, and agriculture and forestry are the main sources of income for these people.[40]

Therefore, prospects and outcomes for the agricultural sector are a primary determinant of rural and thus national poverty rates. This is true for ECA countries despite the limited share of agriculture in GDP in some economies because agricultural growth is particularly effective in combating poverty. As discussed in the World Development Report 2008, whether considering agriculture-based, transforming, or already-urbanized countries, "…agricultural growth has special powers in reducing poverty across all country types. Cross-country estimates show that GDP growth originating in agriculture is at least twice as effective in reducing poverty as GDP growth originating outside agriculture." The inverse of this relationship between agricultural growth and poverty alleviation suggests that setbacks in agriculture – whether losses or missed opportunities – will be disproportionately damaging to the rural poor.

Through agriculture, climate change is also anticipated to have a significant impact on human health and nutrition.[41] The delicate balance of grain allocation as a staple food or as animal feed and the complex dynamic between livestock husbandry, family health and nutrition, livelihoods, and poverty reduction will become more difficult to maintain, potentially exacerbating global food and feed supply challenges.[42] Livestock are important for the livelihoods of many vulnerable groups in the ECA region and the demand for meat, eggs and dairy products is expected to increase as incomes increase in the transitional and less developed regions. How changing regional and global demand for livestock products evolves, in addition to the supply-side impacts of climate change, will strongly influence rural livelihood outcomes in ECA in the coming years.

An understanding of the characteristics and vulnerabilities of rural livelihoods, combined with attention to and investment in the agricultural sector, are essential components of poverty reduction and mitigation of the potential damage caused by climate change. The regional distribution of agricultural land, along with other land uses including forests and barren desert, are illustrated in Figure 5. The diversity of agricultural systems, practices, and products among these agricultural lands is significant. The basic features of ECA's agriculture are summarized in Annex Table A1, which addresses topics including land ownership and farm structure, major crops and livestock, and the source and scarcity of agricultural water resources.

[40] Alam, A. et al., 2005
[41] Randolph, T.F. et al. Invited review : Role of livestock in human nutrition and health for poverty reduction in developing countries. J. Anim Sci 2007. 85:2788-2800
[42] Sirohi, S. Sufferer and cause: Indian livestock and climate change.

Figure 5. Current Agricultural and Other Land Use in ECA

Source: European Commission – Joint Research Center. Notes: from GLC Landuse Classification 2000. Based on spot vegetation data collected at 1km intervals.

Agricultural institutions play an important role in the rural economy, and their current state in ECA (with the exception of Turkey) can only be understood in the context of the post-Communist transition. During the Communist era, the Agricultural Knowledge and Information Systems in ECA countries were designed to assist large, public-sector, collective farms in meeting pre-determined production targets for individual crops and livestock commodities. Under the command economy, collective farms, sub-national regions, and even entire countries specialized in an often small number of products that may or may not have been most appropriate to the local natural and human resource endowments (e.g., overexploitation of water for irrigation of cotton in semi-arid Central Asia).

In the first decade of the transition, agriculture like most sectors experienced major upheavals, with declines in agricultural output (quite severe in some cases), and the drying up of government investment in support institutions. The shift from a command economy to a market-based economy introduced a distinct set of problems for new private farmers, who had little experience with farm management or operating in a market economy, and who could not rely for training or support on diminished institutions that remained geared towards the old system. Agricultural institutions largely collapsed in Central Asia, only faring a little better in Russia and the Eastern European states of the USSR, and with somewhat less decline in Central Europe. Ill-equipped farmers faced challenges including the collapse of input and output markets; cash constraints and limited or no access to credit; outmoded agronomic and farm management practices poorly suited to meet the new market needs; poor quality inputs, particularly the lack of good seeds or animal breeds; obsolete agricultural machinery and a shortage of spare parts; lack of advisory and training services; and overall inadequate rural infrastructure, including roads, communications, energy, and facilities for storage and marketing.

Recovery in the agricultural economies of ECA has been observed in the second decade of the transition, with harvests and livestock herd sizes increasing toward 1990 levels. Considerable reform and privatization of farms has been achieved in Central Europe and Russia, but often still lags behind other sectors. Private agriculture based on market principles is now predominant (though market distortions still exist). However, the national research, education, training and technology-transfer systems by and large continue to suffer from a policy of benign neglect and therefore are unable to contribute effectively to continued productivity growth, particularly in the face of climate change. Though the agricultural system is gradually adjusting to *policy* reforms, serious problems persist in the *institutional foundations* of the sector. It remains for governments to reorient and restructure these institutions, both public and private, in order to respond to problems and opportunities today and in the future.

The situation in Turkey is distinct from that in the rest of ECA, as it did not undergo decades of transformation according to a Communist model. Rather, farming in Turkey has always been in the hands of private farmers, and so Turkey has not experienced the same upheavals and challenges in recent decades. However, farms in Turkey remain small and fragmented, limiting the labor-productivity and income-generating potential offered by larger operations. There is diversity in farm production within the country, and generally agriculture in western Turkey has been more progressive and export-oriented as compared to eastern Turkey. The research, extension, training, information and technology transfer institutions, as well as other rural institutions, have been reasonably supported by the government, although their quality varies by region.

As in agriculture, *forest institutional capacity* has largely broken down in Russia and other ECA countries. This undermines the countries' ability to adapt to and monitor the impacts of climate change. In Georgia, for example, prior to the collapse of the Soviet system, there had been an effective forest pest monitoring system. That infrastructure and technical capacity is now completely lost, as this has not been an investment priority of the post-Soviet governments. This lost capacity is evident throughout the ECA region, both for pest monitoring and for wildfire monitoring and control. More recently, there has been some progress on wildfire management in the thinking and technology of Commonwealth of Independent States (CIS) countries of the former Soviet Union, where fire management rather than control is now the preferred and more cost-effective approach.

Another important institutional and technological capacity that is important for agriculture and climate change adaptation is hydrometeorological (hydromet) services, which are the subject of a recent World Bank study in the ECA Region.[43] Agriculture could be expected to benefit greatly from good weather and climate forecasts because it is highly dependent on weather conditions. In the past, weather forecasting and hydromet services were state of the art in many ECA countries. But the status of most such services deteriorated significantly during the last two decades due to under-funding. For example, in Russia's system, the percentage of hazardous weather phenomena that were unforecast increased from 6 percent at the beginning of the 1990s to 23 percent ten years later. Many data collection stations have closed, and those that remain open often operate with outdated equipment and collect more limited information. The means to convey this information to national weather offices are further constrained. In many cases, the skills of staff have also degraded. Most critically, systems for disseminating weather information to farmers in a timely manner are often completely lacking or, where limited services are available, they cost more than most farmers can afford. The ability of hydromet services in the region to provide seasonal forecasts is even rarer. Without substantial investment in modernization, hydromet systems in some countries could soon become completely inoperative. The lack of good weather forecasting significantly reduces the adaptive capacity of ECA farmers.

In addition to agricultural institutions, farm type and structure are important determinants of the resilience of agriculture to climate change. One feature common across the ECA Region is the importance of a new class of small, family farmers who work marginal, fragmented plots and make up a large share of the rural poor. Agricultural output, farmers' livelihoods, and the broader rural economy are highly sensitive to climate change, and these small farmers will be particularly sensitive because of their limited resources. This **sensitivity** is not only a function of physical resource endowments, such as poor soils, and shifting climatic variables, such as more frequent storms or heatwaves, but also of social, institutional, technological, and financial factors.

In general, the ability of farmers and rural economies to adapt to changing climate, regardless of what form such changes take, will be determined by their access to the following: timely climate information and weather forecasts, and the skills needed for their interpretation; locally-relevant agricultural research in techniques and crop varieties; training in new technologies and knowledge-based farming practices; private enterprises and public or cooperative organizations for inputs including seeds and machinery; finance for such inputs; infrastructure for water storage and irrigation; physical infrastructure and logistical support for storing, transporting, and distributing farm outputs; and strong linkages with local, national, and international markets for agricultural goods.

Within the rural economy, vulnerability will largely be determined by access to these informational, institutional, and financial resources, which varies across the four predominant farm types in ECA. These types, whose distribution varies across ECA countries, are corporate farms, cooperative farms, commercially-oriented family farms, and subsistence farms (the latter two sometimes being referred to locally as "peasant farms"). In some ECA countries, access to key resources is uniformly scarce among nearly all types of agricultural producers, while in others, small farmers struggle to compete with larger enterprises with the know-how and finance to take advantage of new information and technologies, public support for irrigation

[43] Hancock and Tsirkunov (2008).

infrastructure and extension services, access to machinery, and links to evolving distribution channels. Though family farmers are the norm in the West and can be very productive in ECA with the limited land that they have, their small plots often limit their scope for investing in machinery and infrastructure and for expanding their production to a level that would allow for greater commercialization and income.[44]

Corporate farms, found mostly in Bulgaria, Romania, Hungary, Russia, and northern Kazakhstan, are the largest type of farm and have the greatest physical and human capital resources, and therefore are best positioned to cope with climate risks and exploit possible gains. Next are the cooperative or group farms that are generally managed by a few individuals using the pooled land of many smallholders who may also be hired to provide farm labor. While these farms can exploit economies of scale, their managers lack the technological know-how and financing of the corporate farms. Thus these farms will be vulnerable to climate risk and in need of assistance in developing and implementing adaptation strategies.

The largest and fastest growing group is the family farm, which is the predominant farm type in the West. As mentioned above, family farms in the ECA Region generally fall into one of two types: commercially oriented family farms that are similar to those in the West, often have entrepreneurial owners who want to be professional farmers, and produce for the commercial market but at a small scale; and small, low-productivity subsistence farms often run by aging proprietors that farm because they have no other option. Family farms constitute the bulk of agricultural income and output in the Balkans, Turkey, the Caucasus, and Central Asia, and remain important in Central and Eastern Europe and Russia. Family farms will likely continue to serve as the engine of the rural economy in the coming decades, but may be highly vulnerable to climate change.

Small farmers face both stressors experienced by all farms as well as unique pressures, including the following identified in the IPCC impacts report and observed in ECA as well: fragmented holdings, marginal land, limited technical knowledge, poor access to public and private informational and financial services, poor environmental management because of ill-defined property rights, increasing demand for standardized and safety-controlled products, declining health and vitality of the rural poor (in ECA, due to aging and outmigration of the young), protectionist food policies abroad, and unpredictable world food prices.[45] This is particularly true for the subsistence farms, which have little resilience to shocks. For these farmers, the investments required to adapt to climate change will in some cases be too large to justify in light of the low returns, requiring diversification into non-farm income sources or exit from farming altogether. Given this differential vulnerability, increasing climate risk may exacerbate not only poverty but also inequality. The successful acceleration of poverty reduction, and in some cases, stemming of recent rural poverty increases,[46] will require the expansion and strengthening of farmers' access to a whole range of resources, from the technological to the financial.

[44] Lerman, Z. and W. Sutton (2008).
[45] IPCC Ch 5 p279.
[46] E.g. Georgia, Armenia, Uzbekistan, Lithuania. A number of countries are also only partly recovered from a surge in poverty in 2000/01. Growth, Poverty, and Inequality book.

Weaknesses in the institutional, policy, and infrastructure foundations of the rural economy will constitute important entry points for government action to reduce vulnerability to climate change and safeguard the livelihoods of those most at risk. The ECA countries vary widely in the current state of, and capacity for improvement in, the functioning and reach of their public agricultural and forestry institutions, as well as the design and implementation of relevant market policies and provision of essential infrastructure.

A recent assessment found that while progress has been made since the transition, agriculture and forestry institutions were still plagued by low capacity, particularly in CIS countries.[47] This includes low levels of funding, lack of skilled staff, and outdated equipment. This is especially true of advisory and research services, and of environmental management capacities, which are critical for adaptation. It was also found that while many good agri-environmental laws and policies were in the books, implementation was sorely lacking. Weaknesses in these areas reduce the **adaptive capacity** of ECA countries. The types of agricultural institutions, their importance for adaptation, and their status in ECA are covered in more detail in Section IV.

[47] Sutton et al., 2008.

III. Potential Winners and Losers: Realizing opportunities and safeguarding livelihoods.

There are potential climate change winners and losers in ECA, both across and within countries, and each group will need to act on tailor-made adaptation strategies to seize opportunities and limit damages. ECA as a whole, and even individual countries such as Russia and Kazakhstan, is distinguished from other World Bank regions by encompassing both warm, dry areas where agriculture and forests are projected to experience significant damage from climate change, as well as colder areas where agriculture and forestry stand to potentially benefit from warmer temperatures and increased precipitation (see Table 2 for a summary of changes in agricultural potential). For example, irrigation-dependent smallholder farms in Albania may be hard hit by droughts and heatwaves, while a longer growing season and warmer winters may allow greater crop diversity and productivity in Poland. Further, agronomic outcomes will vary within individual ECA countries, such as Kazakhstan, which spans areas that will likely experience increasing rainfall and expanding opportunities for rain-fed, high-yielding winter wheat, as well as areas that will likely face drought, reduced water availability, and thus lower yields for irrigation-dependent cotton cultivation.

Table 2. Crop Potential in the ECA Region Today and Possible Shifts by 2100

General Climate Class	Average Temperature of Warmest Months (°C)	Crop-Growing Period (Days)*	Crop Potential	ECA Regions in 2008	ECA Regions in 2080
Very Cold	8.5 - 11	<90	Quick maturing green root vegetables e.g. lettuce & radishes.	Parts of Arctic Region, Siberia & Far East (Russia).	
Cold	10.5 - 16	<100	Early varieties of vegetables, e.g. cabbage, spinach, turnips, early varieties of barley, oats, buckwheat, flax, hardiest local varieties of apples & pears	Northern parts of Urals, Western Siberia & Far East.	
Moderately Cold	15 - 20	100 - 150	Winter wheat, spring wheat, rye, barley, oats, legumes, flax, potatoes, cabbage, beets, locally adapted winter-hardy varieties of apples, pears, plums.	Baltics, Northern parts of Central Russia & Volga Region & Southern Siberia, Northern Kazakhstan.	
Moderate	18 - 25	150 - 180	Grain, corn, sunflower, soybeans, rice, wheat, melons, early cotton vegetables, walnuts, peaches, apricots, apples, grapes, cherries, plum.	Ukraine, Southern parts of Central Russia & Volga Region, Northern Caucasus, Central Europe.	Compare to South Mediterranean & Middle East in 2008

Warm	>25	>180	Cotton, citrus, figs, olive, wheat, rice, vegetables during winter, subtropical perennials e.g. tea, corn, nuts and a variety of fruit crops.	Central Asia, Caucasus, South Eastern Europe, Turkey, Southern Kazakhstan.	

Countries are likely to have losers as well as winners within the agricultural sector, and this has important distributional implications. This section will briefly cover the projected impacts of climate change on agriculture and forestry in the ECA region, demonstrating six key aspects of the projections and their implications: geographic diversity of baseline and future climate, uncertainty about both climate and yields, the importance of climate variability as well as means, the scale of potential damages in the absence of adaptation, the need for adaptation in order to realize potential benefits, and the implications for world food markets.

Summaries of the potential impacts of climate change for ECA sub-regions, based on current agricultural land use patterns and our analysis of projected climate change, are presented in Annex Table A2. Based on our analysis and estimates available in global synthesis studies, we have also attempted to identify potential winners and losers. The results show that roughly speaking, there is potential for net losses in Southeastern Europe and Turkey, the North and South Caucasus, and most of Central Asia; gains in the Baltics and the Siberia, Urals, Far East, and Baltic & Western Arctic regions of Russia; and mixed or uncertain net outcomes in Central and Eastern Europe, Kazakhstan, and the Central and Volga regions of Russia (see Table 3).

Table 3. ECA's Potential Winners and Losers in Agriculture from Climate Change

Region	Based on Annex Table A2, climate projections, authors' analysis	Yield Impacts 2080s without CO2 fertilization (%)	Yield Impacts 2080s with CO2 fertilization (%)
Southeastern Europe and Turkey	Likely loser	Eur: -8.6 Turk: -16.2	Eur: +5.1 Turk: -3.6
Central & Eastern Europe	Mixed/ indeterminate	-5	+8.5
Baltics	Potential winner	-5 to +5	+9.5 to +27.9
South Caucasus	Likely loser	-17	-5
Kazakhstan	Mixed/ indeterminate	+11.4	+28.1
Central Asia	Likely loser	-9	+4.6
Russia:Baltics	Potential winner		

Russia: West Arctic	Potential winner	-7.7	+6.2
Russia:Central and Volga	Mixed/ indeterminate		
Russia:North Caucasus	Likely loser		
Russia:South Siberia	Potential winner		
Russia:Urals&W.Sib,E. Sib&FarEast	Potential winner		

Source: Cline 2007, authors. Notes: Relative to the other parts of ECA, Kazakhstan's yield increases could be an overestimate (see Cline 2007 for more details). More details are in the text.

The sub-regional summaries are not meant to be definitive because uncertainties and unknowns remain, but they can serve as a guide for identifying potential conditions that farmers and policymakers can shape and respond to based on current climate change knowledge. For some sub-regions, it is not possible at this time to project the net impact because there will be both winners and losers. But a pattern does begin to emerge, whereby southern countries and southern parts of large countries, particularly those that are already water-stressed, will generally be negatively affected by higher temperatures and lower precipitation. In contrast, higher latitudes will have more favorable climatic conditions for agriculture.

Potential losers can develop strategies to mitigate the impacts of climate change and reduce net losses. The measures discussed below in Section IV can help these countries to prepare for climate change by supporting their farmers to address constraints such as reduced water availability and increased heat stress. They also suggest ways to more effectively take advantage of any opportunities that may appear as a result of climate change. In some place, agriculture may no longer be viable, and the sustainable adaptation option will be a transition to different economic activities altogether. In these cases, there is a role today for governments in developing alternative livelihood strategies for their rural residents. Many of these measures, whether for the expansion, adjustment, or exit from agriculture, take time to implement, and being proactive in integrating them into sector plans will increase their effectiveness.

Potential winners will not benefit automatically or costlessly. They must take significant actions if they are to reap the potential benefits of climate change for their agricultural sectors. Many people in northern latitudes have seen press reports that predict that their agricultural sectors will benefit from climate change. But there is a risk that this will breed a dangerous complacency. What they may not realize is that the studies that predict benefits in these areas make many assumptions. Chief among them is the assumption that all actors will adapt, including those who become winners only by adapting, as well as those who remain net losers despite their adaptation efforts.[48] Without adaptation, potential benefits may not be realized, resulting in significant opportunity costs and even financial losses for projected winners. The potential winners therefore also need to be aware of the specific changes that are projected to

[48] See for example Parry et al., 2005.

take place and how best to take advantage of them, and need to develop and implement strategies to do so. They will also likely have potential losers within their countries, and should take actions to mitigate the risks to them.

There remains much uncertainty surrounding the agricultural impact models, and this presents risks for all concerned. The potential yield impacts and shifts of crop suitability summarized in Table 4 imply distinct economic and development outcomes for different countries and different groups within countries. However, identifying the economic implications of the agronomic impacts described in the table is neither simple nor direct. To date, very little analytical work has been done at the country level in ECA to estimate the economic costs and benefits of climate change impacts and agricultural adaptation, and even less to address the intra-country distributional implications of climate change.

Several approaches exist for analyzing the economic impacts of climate change on agriculture, but each has its limitations and requires certain assumptions to be made, making deterministic interpretations of climate change impacts based on the models very risky. It is therefore important for policymakers to be aware of the limitations of the models (see Box 2). One limitation common to all the major tools of climate change impact analysis is that they are based on climate *averages*, though climate variability and extreme events will likely be more important determinants of agricultural outcomes. Another weakness is that the agronomic-based models are strictly concerned with potential yields subject to the physical constraints of climate, soil, and terrain, but ignore other constraints, such as the availability of knowledgeable farmers, suitable land, appropriate machinery, storage and processing facilities, roads, and markets. These latter constraints are however very relevant in ECA countries.

The outlook for livestock also varies, with gains possible in the wetter, cooler, more northern regions due to increased forage production, lower feed requirements, and less threat of extreme cold. In the drier, hotter, more southern regions, risks include heat stress, resulting lower milk production, aridity and degradation of pastureland, and shortage of drinking water in vast, otherwise-suitable grasslands. The expansion of the range of warm-weather diseases such as the Bluetongue virus, already in evidence, will be a challenge in all parts of ECA.[49]

[49] Purse, Bethan V.; Mellor, Philip S.; Rogers, David J.; Samuel, Alan R.; Mertens, Peter P. C.; and Baylis, Matthew (February 2005). "Climate change and the recent emergence of bluetongue in Europe". Nature Reviews Microbiology 3 (2): 171–181.

Box 2. Review of Models of Impacts of Climate Change on Agriculture

One limitation common to all the major tools of climate change impact analysis is that they are based on climate *averages*, though climate variability and extreme events will likely be more important determinants of agricultural outcomes. Another caveat involves the uncertainty of the climate projections which becomes amplified in the subsequent step of estimating agronomic responses. The biological benefits of higher ambient carbon dioxide concentrations in the atmosphere, known as the “carbon fertilization” effect, are still controversial. The first global impact estimates were probably overly optimistic because they over-estimated this effect. Further uncertainty is introduced into global economic impact models by our lack of knowledge about non-climate trajectories including land use, international trade regimes, commodity prices, and income growth, which are a challenge to estimate five years, let alone five decades, into the future. Perhaps the most important limitation of the economic impact models is the lack of comprehensive and detailed treatment of adaptation, from evaluation of marginal or combined benefits of specific adaptation measures, to direct costs of adaptation, and, even more, the informational, institutional, and financial barriers to adaptation.

The quantitative impact models fall into three basic categories: agronomic, agroecological zone, and Ricardian models.

- The **agronomic models** are perhaps the most intuitive, predicting changes in yield given changes in average climate variables according to biological models of crop growth. This sort of model forms the basis of both small-scale single-crop studies (e.g. “Modelling the impact of future climate scenarios on yield and yield variability of grapevine,” Bindi et al, 2000; “Comparison of two potato simulation models under climate change,” Wolf, 2000) as well as some elaborate global models covering many crops and which include trade and other economic dynamics (e.g. “Effects of climate change on global food production under SRES emissions and socio-economic scenarios,” M. Parry, C. Rosenzweig, et al, 2004; “Climate change, global food supply and risk of hunger,” M. Parry, C. Rosenzweig, M. Livermore, 2005). These latter broad agronomic studies which link to economic models explicitly include a limited set of farmer adaptations, including changed planting dates and different crop variety selection. There is scope for improving the accuracy of the projections in ECA through collection of additional climate and yield data from the region to aid model calibration. The large-scale agronomic models are unique in providing yield estimates based on relatively detailed climate information, but can’t account for gaps between potential and actual yield, which are already large in ECA today.
- The related **agroecological zone (AEZ) model** (described in Fischer et al 2002) incorporates information about land resources and land use, along with climate variables, to examine changes in the suitability of land for crop production based on projected climate and soil variables, and thus is compatible with greater focus on land-use, but relies on a relatively simplified underlying biological model of crop yields. While including some physical barriers to shifting crop production in the form of soil type and steep terrain, not all physical barriers are captured and lack of other requirements such as settlements, infrastructure, and markets are not addressed. There are few climate change AEZ studies so far (Fischer et al 2005), but the model is currently being applied in more detailed climate change impact analysis. It is particularly useful for examining the changing frontiers of current and future crop production and possible conflict with commercial forestry and carbon-absorbing forest conservation.
- The **Ricardian models** popularized by Robert Mendelsohn start from the economic foundation of land values, using extensive observations on land values (which are the market mechanism for representing yield potentials) under diverse current climate conditions in order to estimate a formal quantitative relationship between temperature, precipitation, and yield (e.g. Mendelsohn, Morrison, Schlesinger, and Andronova, 2004). This relationship is then used to predict yields under future temperature and precipitation regimes, implicitly assuming that optimal adaptation has occurred in the transition from the baseline climate to the changed climate. The advantage of these studies is that they give a sense for future economic potentials, given rational adaptation, but they do not shed light on the agronomic details, economic costs, or physical and institutional barriers in getting from point A to point B, and use extremely simplified inputs of a few annual or seasonal climate

The question of whether ECA's potential winners can realize the benefits of favorable climatic conditions has important implications not just for the countries themselves, but for world food markets in general. In particular, Kazakhstan, Russia and Ukraine (KRU) are often cited as countries with the most unrealized grain production potential, as well as countries that could benefit from climate change (at least in their northern regions). A recent report notes that since the breakup of the Soviet Union, these three countries combined have removed 23 million hectares of arable land from production, the largest such withdrawal in recent world history.[50] Almost 90% of this land had been used to produce grain. It has been suggested that bringing large parts of this land back into production could increase world grain supplies and help mitigate global food price shocks such as the one experienced in 2007-2008. Meanwhile, a number of global studies such as Cline's project a substantial increase in agricultural output for the KRU countries as a result of climate change (see Table 3 above).[51] These projected increases contribute to the relatively sanguine attitude of many towards climate change's impact on world food supplies.

There are reasons to seriously question whether the potential ECA winners will be able to provide the supply response that many expect of them. There are two possibilities for increasing production in the KRU countries: (i) raise yields on currently cultivated agricultural land; or (ii) expand the area under cultivation. The first possibility is preferable, because expanding the area under cultivation will be costly. It will require new investments in production, marketing and transport infrastructure, clearing of land, and expansion of support services to new areas, and will likely cause damage to the environment. It may also entail bringing marginal lands with low yield potential into production. The formerly cultivated abandoned lands may be easier to bring back into cultivation, but even there experts estimate that only 11-13 million hectares of the 23 million would be viable.[52] Raising yields on existing farmland would therefore be a better solution. There is significant potential for increasing yields in the KRU countries given current and future climatic and soil conditions, and current levels of productivity. But this would also entail challenges. Although world grain yields have been rising on average by about 1.5% per year since 1991, yields in Ukraine and Kazakhstan have fallen during that period, and Russia's yields have increased only slightly. Yields in all three countries are far lower than those in Western Europe or the US, and are even lower than the world average. This has important implications for climate change adaptation, and in particular for the ability of the KRU countries to benefit from a warmer climate.

Agricultural production in the future will depend not only on the climate conditions, but also on technology, policy, investment, support services and crop management. Analysis has shown that the current gap between potential and actual yields in Central and Eastern Europe and the European parts of the former Soviet Union are significantly higher than any potential gains from climate change.[53] In particular, the current yield gap for the former Soviet countries in Europe (including Ukraine and European Russia) is 4.5 times higher than the potential increase in production from climate change by 2050. The fact that the KRU countries and other ECA

[50] FAO & EBRD, "Fighting food inflation through sustainable investment", 2008.
[51] Cline (2007). Includes carbon fertilization effects.
[52] Ibid.
[53] Olesen and Bindi (2002)

countries have not been able to take advantage of this potential for productivity gains suggests fundamental weaknesses in the agricultural sectors of these countries, which does not bode well for the capacity to adapt to climate change. This is also referred to as the “adaptation deficit”. Recall that estimates of climate change impacts demonstrating potential benefits typically assume that adaptation will take place to varying degrees. Without adaptation, those results would likely no longer be valid.

With regard to forests, some models have also shown potential for increased timber production, particularly in northern Europe, with potential decreases in southern Europe.[54] The losses in southern Europe will largely be due to the effects of higher temperatures and water limitations. The potential gains in the north are through location changes of forests and higher growth rates due largely to CO_2 fertilization effects. However, as discussed in Section 1, there are also a number of threats to forests even in northern Europe, including potential vulnerability to fire and pests, extreme weather events, and the inability of tree species and infrastructure to adapt. Forest models do not adequately reflect these types of threats. Finally, in a finding similar to that for agriculture described above, it has been estimated that the largest share of potential forest stock increases in Europe would be due to improved management (60-80%) rather than climate change (10-30%).[55] Improved management requires strong forest institutions, which are often lacking in the transition countries.[56]

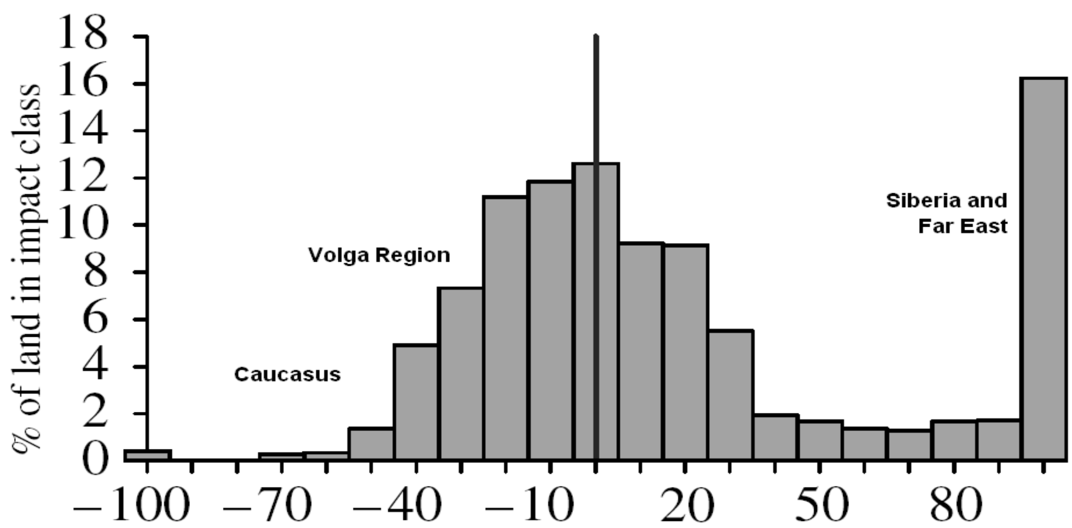
The case of Russia provides a good example of the opportunities and challenges ECA countries could face in taking advantage of the opportunities presented by climate change. In absolute terms, a number of global studies such as Cline’s estimate that Russia’s agricultural output will increase as a result of climate change more than any other ECA country’s, to the tune of over $1.3 billion per year by the 2080s.[57] This projected increase is mostly thanks to a longer growing season and the northward expansion of crops into newly suitable lands (see Table 4). However, as discussed above, the availability of land is not currently a constraint on Russian agricultural production—low productivity is. In addition, due to the large size of the country and diversity of conditions, climate change will not have the same impact on all regions. Intensive, commercial Russian agriculture is primarily concentrated in a relatively small area of South European (western) Russia with the best soils (Central & Volga, North Caucasus, and to some extent South Siberia). Recent country-specific work on Russia projects that due to the possibility of reduced precipitation with warming, these prime production regions will suffer significant decreases in yields by the 2020s.[58]

Upon closer examination, there would appear to be many challenges that could prevent Russia from benefiting from climate change’s impacts on the country. The aggregate, country-wide analysis of Russian agriculture under climate change obscure important sub-national differences that illustrate the implausibility of the most optimistic projections. Figure X, taken from Fischer et al’s 2005 AEZ study, shows the distribution of land in Russia over categories of decreased (<0) and increased (>0) suitability for cereal production in 2080 relative to the

[54] IPCC Working Group II, Fourth Assessment, Chapters 5 and 12 (2007).
[55] IPCC Working Group II (2007), Fourth Assessment, Chapter 5.
[56] See Sutton et al. (2007).
[57] Cline (2007). Includes carbon fertilization effects.
[58] Kokorin (2008).

present.[59] Those regions where agriculture is projected to have the possibility of expanding (Baltic and Western Arctic, Siberia, Urals, Far East) are the boreal forest zones of northern Russia. These areas are characterized by poorer soils, which global models do not take into account. In addition, the boreal areas lack transport, marketing, and storage infrastructure, essential services like extension and research, and perhaps most importantly able farmers. Thus, it is unlikely that agriculture in these northern areas will ever compensate for decreasing productivity in the south.[60] The impacts of climate change will also have important distributional implications for Russia. For the country as a whole to benefit from the geographic shifting of agriculture, markets must function properly to allow food production to reach population centers, which are mostly in the south and west. However, there are currently significant regulations imposed on grain trade between regions of Russia (not to mention external trade), which constrain the country's possibility to redistribute any climate change benefits. Finally, opening up the boreal areas to agriculture will require extensive deforestation and plowing of formerly uncultivated lands, which will release substantial amounts of greenhouse gasses into the atmosphere and exacerbate the effects of global warming.

Figure X. Distribution of Land Area in Russia by Categories of Decreased or Increased Suitability for Crop Cultivation as a Result of Climate Change by 2080, Showing that Most Increases Are Expected in Siberia and the Far East



Source: Adapted from Fischer et al 2005. Notes: AEZ-simulated distribution of climate impacts on cereal productivity in the 2080s, under the scenario A1FI and HadCM3 climate model. The diagrams show the distribution of land with respect to cereal suitability changes under climate change. Bars shown to the right of the vertical line indicate land pixels where suitability increased; bars to the left denote negative changes. SI = suitability index for potential cereal-production computed by AEZ. *Likely regions represented by different parts of the distribution not in original figure; added by authors of present paper.*

[59] Fischer et al. (2005).
[60] Dronin and Kirilenko (forthcoming).

There are also significant threats to the forestry sector in Russia posed by climate change. Current projections are that over the next 10 years the number of high-risk fire days will increase by 5-7, which will have a large impact on Russia's vulnerable forests, and the people who depend on them. The huge areas of spruce die-back in Arkhangelsk Oblast, Russia, are but one example of the increased threat from pests moving northward. Another rarely mentioned impact of global warming in the northern forests is the melting of winter roads, which are used for transporting logs. Because these roads pass through marshes and wetlands, and therefore cannot be economically improved, this will seriously impede good forest management and economic benefits from these forests, thus placing them at even higher risk of uncontrollable wildfires and degradation. These impacts are believed to be taking place faster than nature or man can adjust and cope. For some species, for example, climate change might outpace their ability to adapt to the shifting weather patterns, thus raising the specter of large-scale species and forest die-offs.

Adaptation in ECA and the impacts of climate change will influence and will be influenced by world food markets and the degree of countries' integration in those markets. The high food prices experienced over recent years are due in part to extreme weather. Since extreme weather events are expected to become more frequent with climate change, the food price crisis experienced in ECA countries and around the world in 2007-2008 could in many ways be viewed as a preview of what is to come if steps are not taken to adapt. Wheat was the first commodity to experience a run-up in prices, and this was blamed largely on poor harvests in Australia as a result of a series of severe droughts linked to climate change.[61] The droughts experienced in southeastern Europe in 2007 added to the supply problems, especially in ECA.[62] Later, the price of corn was pushed up dramatically, and this was attributed largely to the increased demand for corn-based ethanol, which had been promoted in the west as an alternative to greenhouse-gas emitting fossil fuels[63]. Increased demand for agricultural products in key emerging markets (especially China and India) has also been a key factor. Concurrently, the price boom has been accompanied by a significant increase in price volatility.[64] While prices have since come down somewhat, to the extent that these factors—including extreme weather events—are the result of longer-term structural changes, higher prices and price volatility are likely to continue to characterize global food markets.

While the high prices for grains represent a threat to consumers, they present an opportunity for producers and for sending the signals farmers need to encourage investment and expanded production. In the recent past, the trend has been the opposite: the higher profitability of oilseed crops (sunflower seed, soybean, rapeseed) had caused a shift away from cereals in the CIS countries. The rise in global prices for cereals presents an opportunity to reverse this trend. However, due mostly to counterproductive policies such as export taxes and restrictions, and domestic price caps on bread and flour, the higher world market prices for cereals are not fully

[61] FAO (2007)
[62] FAO & EBRD (2008)
[63] Though more recent evidence suggests that ethanol production from grains can contribute at least as much to global warming as the fossil fuels they have been slated to replace.
[64] FAO (2007).

passed through to farmers and profit margins for wheat and barley continue to be much lower than those for oilseeds in places like Russia.[65] Other constraints such as a lack of access to quality research and extension services, training, credit, irrigation, market infrastructure and coordination, credit, and efficient land markets limit the potential for a positive supply response even if cereal prices were allowed to rise in these countries.

There is much that must be done to prepare ECA countries for climate change, and it is in the interests of the countries' populations and the world community that action be taken starting now to adapt. As explained in this section, it is important for both potential winners and losers in the ECA region to prepare for the impacts of climate change by achieving adequate adaptation in their agricultural sectors. For the potential losers, it is a matter of reducing the exposure and sensitivity of their sectors. For the potential losers as well as the potential winners, it is a matter of increasing the adaptive capacity of their agricultural sectors. The existing weaknesses, or adaptation deficit, in the agricultural sectors of the KRU countries revealed by very low yields indicate that much should be done now to invest in the development of agriculture in these countries and across the region. Declining attention to agriculture among multi-lateral financial institutions, bilateral donors, including in ECA, has coincided with years of domestic underinvestment in the sector.[66] A reversal of both trends will be necessary for safeguarding the most vulnerable, realizing much-touted potential gains, and minimizing damage to agriculture from climate change in ECA countries. The following chapters provide recommendations on which adaptation options are available for the agricultural sector, what the priorities should be for the ECA region, and how the Bank and its clients can achieve them.

[65] FAO & EBRD (2008).
[66] WDR, The World Bank (2007).

IV. Many adaptation options for agriculture are good development practice.

The IPCC[67] considers climate adaptation practices to be "actual adjustments, or changes in decision environments, which might ultimately enhance resilience or reduce vulnerability to observed or expected changes in climate." Enhancing resilience of communities and economies to adverse shocks and evolving risks clearly constitute aims of more broadly defined economic development. Thus, sustainable, appropriately chosen adaptation measures and initiatives are also good development practice. In particular, "win-win" adaptations are defined as those measures that would yield a positive rate of return, even without the additional potential benefit of avoiding climate-induced losses, because they further a country's development goals by reducing current vulnerability to weather risks or generating growth. There are myriad examples of good practices in agricultural production and policymaking that make good economic sense even in the absence of climate change. Policies and technologies for more efficient distribution and on-farm use of water, for example, make economic sense by lowering costs to government in the form of water subsidies, and makes adaptation sense by equipping farmers to cope with persistent reduced water availability as well as drought events.

Adaptation encompasses activities and investments in multiple realms, and not only at the farm-level: adaptations can be technological, institutional, and policy-based. As expressed by the authors of UNDP's Adaptation Policy Framework, "Adaptation in a narrow sense refers only to those measures that are taken at the farm level. But in fact adaptation is a much wider concept involving choices at national and international levels as well as local. Adaptation involves more than measures, it is also a matter for national agricultural and development policy (Burton and Lim 2005, p195)." Considering the example of increased water-use efficiency, there are technologies that may be employed by farmers such as irrigating field crops planted in furrows rather than flooding an entire flat field, thereby reducing water demand without reducing yields. There is also an institutional component to this effort, as water-user associations may be created in order to share knowledge about and minimize negative externalities from farmers' and other sectors' use of local water resources, and agricultural advisory services can instruct farmers in techniques for reducing unnecessary waste. Finally, there is a policy aspect to this adaptation, as governments can choose to invest resources in advisory services and in public awareness campaigns, and have the power to reform water pricing schemes to better relay the costs of water usage to end users, giving them an incentive to reduce waste and lowering government spending on subsidies.

Annex table A3 provides a menu of technological adaptation options for agriculture, from small-scale measures (e.g. changed timing of planting and harvesting) to the large-scale systematic efforts (e.g. installation of new drip or sprinkler irrigation facilities). More in-depth discussions of these techniques are widely available in compendia of adaptation options and the agricultural literature more generally (Kurukulasuriya and Rosenthal 2004, Padgham 2008, Olesen and Bindi 2002). The adaptations specifically for crop cultivation in Annex Table A3 include conservation tillage, a plowing technique minimizing the turning of the soil, thus conserving moisture, reducing fossil fuel usage from field operations, and reducing CO_2

[67] 2007, WGII, Ch 18, p720.

emissions from the soil. Use of organic matter to protect field surfaces also helps preserve soil moisture. A number of measures concerning the capture and efficient usage of water will be extremely important in currently rain-fed areas and areas where scaled-up irrigation is environmentally unsustainable or economically infeasible, while techniques for drainage and watershed management will be particularly important in areas with increasing precipitation. Given the predicted decrease in precipitation and water availability in many of the current agricultural regions of ECA, better-managed and expanded irrigation will be a very important part of adaptation. More efficient use of irrigation water can be achieved with properly timed applications and drip irrigation, among other methods.

Another key adaptation is diversification of crops and of agricultural activities (Olesen and Bindi 2002, p252; Padgham 2008), which small farms are better positioned to do than large monocultures. Even if the direction and scale of changes in climate are unknown, diversification can decrease farmers' vulnerability to climate shocks and gradual shifts. The greater the number of distinct crops and varieties on a farm, the greater the chance that some of the harvest will survive a severe storm, a drought, or an early arrival of spring. The more diverse the types of production on one farm (e.g. tree crops, livestock, and cheese-making), the greater the chance that at least one of these endeavors will yield income after a climate or market shock. The efficiency gains from specialization may be less important relative to the risk-reduction achieved through diversification as climate change results in much greater uncertainty about climate means and variability, and the timing and intensity of weather events. Given the greater resilience of diversified farms to climate and economic shocks, small but commercially-oriented family farms tend to be highly diversified, in contrast to large-scale mono-cropped commercial farms. Therefore, small farms may come to play an increasingly important role in the agricultural economy, as models of flexibility and resourcefulness in the face of climate risk. The potential resilience as well as the particular needs of such farms should inform choices about investments in technological measures, the emphasis given to reforming and improving various institutions, and the development of policies that affect small farms, particularly land and price policies.

In addition to diversifying across crops or types of production, farmers may select different cultivars or crops more suitable for changing means and increasing threats from weather extremes and pests. As temperatures increase and patterns of precipitation shift, areas of suitability for growing staples such as wheat as well as horticultural field crops and tree crops will shift, and appropriate crop choice can limit losses or even result in gains. Adoption of drought-, flood-, heat-, and pest-resistant varieties will also help minimize losses.

Planting techniques, from rotating of crops to timing of planting and harvesting, can maintain soil nutrients and allow for a sufficiently long grain-filling period before excess heat or drought sets in. Adopting particular cropping patterns and constructing contours and barriers can serve to protect plants and soils from erosion and storm damage and to conserve soil moisture. A suite of techniques called integrated pest management (IPM), in conjunction with similarly knowledge-based weed control strategies, can help counter increased threats from pests, disease, and weeds. Pests and disease-carrying insects are less likely to survive the milder winters and flourish, as will weeds which will benefit from CO_2 fertilization. IPM and related techniques help to minimize overuse of biodiversity-threatening and resistance-inducing pesticides and herbicides.

Choosing the correct timing and most appropriate crops will require short-term and seasonal forecasts, while crop selection will require a longer-term view of changing climate trends. Many of these adaptations entail a shift from physical inputs such as deep ploughing, flood irrigation, and high doses of fertilizer to knowledge inputs. Knowledge-based farming might include, for example, identification of the stages during crop development when irrigation is most needed, reducing unnecessary use of irrigation water at other times. Another example is the use of timely information about regional incidence of particular pests and crop or animal diseases, allowing for the application of pesticides or administration of costly medicines only when needed. A transition to knowledge-based farming will be challenging but potentially very beneficial for increasing efficiency even in the absence of climate change, and some ECA countries are already pursuing this change.

In addition, development of capacity for knowledge-based farming facilitates the adoption of response farming, a related strategy that entails actively using weather forecasts at the seasonal and short-term scale to inform decisions such as crop selection and timing of planting and harvesting. This approach could be very helpful under all possible future climates regimes throughout ECA. For example, cereal farmers in the north could time their harvests to avoid instances of intense rainfall in early autumn that would otherwise damage the unharvested grains. Just-in-time application of water on tree crops in irrigated systems can prevent frost damage during crucial flowering periods. By reducing uncertainty as well as enabling more sparing, efficient use of scarce inputs, response farming has significant potential to reduce agriculture's vulnerability to climate risks.

For the livestock sub-sector, there are a number of adaptation strategies that can be considered in the ECA region on a short and long term basis and incorporated into country agricultural programs. Some of these will also be "win-win" by mitigating greenhouse gas emissions. The most obvious intervention with the greatest impact would be improved grassland management (including reduced stocking rates, rotational grazing, pasture management plans, etc) and incorporating reformation of land tenure and community-based organizations or pasture user associations. This can contribute to a reduction in the degradation patterns, increased biomass on the grasslands and more sustainable livelihoods for herders. Changes in feeds and feeding management can also have direct benefits in terms of both mitigation and adaptation. Improved grass and legume varieties, yield improvements, and strategic harvesting and storage of forages for ruminants can have direct impacts on production and reduce grazing pressure on the grassland. More efficient use of grain-based feeds and feeding through least-cost ration formulation, diversification of species distribution, selective breeding for improved feed conversion efficiency and incorporation of crop residues and processing byproducts are some of the approaches that can be incorporated into agricultural and livestock projects. Improvements in manure management would include the promotion of anaerobic digestion and biogas production to reduce CH_4 (methane), and fine-tuning livestock waste application to land to be harmonized with the most optimal timing for crop physiology and climate. Improvement in livestock production and feed crop efficiencies should be combined with pro-active programs to reduce de-forestation. Many of these strategies will have to be accompanied by legislative and policy reforms (land tenure, forest protection) combined with incentives (subsidies, safety nets, insurance, financial services, etc) or penalties to ensure compliance with and support enforcement of regulations. All of these approaches will require fundamental behavioral changes and adjustments to traditional practices through more effective communication tools, knowledge sharing, participatory extension and training all supported by international and local trainers and technical advisors.

With respect to forestry, fire management rather than control should be promoted as the preferred and more cost-effective approach. With the World Bank's assistance, the Russian government is attempting to instill this new thinking in the forest sector through the Sustainable Forest Pilot Project. In other countries (for example, Bosnia, Romania, Georgia) Bank-financed projects have helped improve forest monitoring and information management systems. In Kazakhstan, the Forest Protection and Reforestation Project aims to, inter alia, establish a fire management information system. These are good starts, but much more is needed to be done to help ensure effective monitoring and control of the effects on forests of climate change, and in particular on wildfire events and pest and invasive species infestations. Efforts are also needed to ensure the best possible management of forests as a way to ensure sustainable economic returns from these valuable resources, while also striving to avoid the onset of the vicious feedback cycle described in Section 1, which would also generate significant increases in greenhouse gasses.

The recommended technologies and practices reflect the findings of extensive past research, as well as rely on continued research into new crop varieties, technologies for combating extreme events and pests, and other challenges. As in the past, while climate risks increase and research focuses on the resulting challenges, scientists can be most effective when taking into account knowledge and needs at the farm level, as well as ensuring that the products of their work reach all the way to farmers and on-the-ground decision-makers. Given the inputs of time and financing required for research, it is usually better to adapt the findings of others to local conditions whenever possible.

ECA countries, especially those in Europe, can take advantage of the extensive climate-change related research carried out in other countries of similar latitudes, including publicly-funded activities in the European Union. Relevant projects already underway include developing annual food crops with improved tolerance to multiple abiotic stresses; improving animal health, product quality, and performance of organic and low-input livestock systems through integration of breeding and innovative management techniques; and improving understanding, tracking, and emergency management of emerging vector-borne poultry and livestock diseases, particularly West-Nile fever, Rift Valley fever, and Crimean-Congo hemorrhagic fever.[68]

Many adaptations are available for improving the resilience of livestock and pasture systems. Changes in management practices, including rotational grazing of grasslands – and installation of dispersed watering points to make this possible – prevent overgrazing, soil degradation, and eventual desertification. Storage of fodder and use of supplemental feed minimize the impact of drought damage to grasslands on herd health. As with crops, so too certain breeds and varieties of livestock will be best suited and most hardy to the weather and disease environments of different regions.

Adaptation and diversification will need to occur not only within given agricultural production systems but also via substitutions among different land uses. For example, areas of

[68] van der Celen 2008.

Central Asia and Kazakhstan that are currently used for cereal cultivation that become too arid may become more sustainably used for pasture. Land that is now unproductive and which becomes suitable for cereals may come under cultivation in Russia. Field crops in Southeastern Europe may increasingly be replaced by agroforestry, the cultivation of perennial tree crops.

Land use management decisions will constitute an integral part of the adaptation process, with the potential for sustainable and adaptive choices, as well as unsustainable outcomes driven by poorly evaluated trade-offs. For example, deforestation in order to expand crop cultivation northward is in one sense an adaptive response to warming climate; however, widespread deforestation is ill-advised for a host of reasons, from disruption of ecosystem services to release of sequestered carbon dioxide.[69] Examples such as this point to a very simple adaptation concept – do no harm – which in practice can be very difficult to adhere to when trade-offs are not well understood or quantified. Decisions about land use at the most basic, local level can have surprisingly large impacts through feedback effects in markets, in the policy arena, and in ecological processes. Decision-makers at all levels must be informed of the impacts of their choices in order to ensure sound management of land resources.

Diversification may also take another form, in addition to crop diversification and diversification across agricultural production systems. Given the likely increased interannual variability of yields, rural populations with non-farm income in addition to agricultural income will be best equipped to absorb adverse shocks due to extreme events or other damages to crops and livestock. Income diversification also better cushions people from market-based shocks. Thus, the adaptive response of diversifying livelihood strategies is also desirable based strictly on poverty-reduction criteria.

However, there are some respects in which encouraging the adaptations in Annex Table A3 will be somewhat different from business-as-usual development policy. In particular, timing and priority-setting in choosing technologies to promote and investments to make if it were not for climate change, some of the measures would not be necessary in order to increase efficiency or mitigate vulnerability to current climate risk, such as introduction of irrigation facilities in places that currently have sufficient rainfall, or the construction of barriers and windbreaks to protect fields in mild areas expected in the future to experienced increased storms and winds. For the most part, though, the recommended technologies and practices are already understood to be efficiency-enhancing and vulnerability-reducing, and thus in line with good development policy and investments.

Some measures are not just "win-win," but are also "win-win-win," that is, they advance the three goals of economic development, adaptation, and mitigation of greenhouse gas emissions. These adaptations which may also reduce emissions, indicated in the last column of Annex Table A3 as contributing to mitigation, include practices that allow for carbon sequestration in the soil from reduced plowing, switching from field to perennial tree crops, better management of run-off, and maintenance of pasture. In cases where there are no financial incentives for farmers and planners to achieve mitigation, the added mitigation benefit of a measure will not be internalized and not increase the likelihood of adoption. Opportunities for simultaneous adaptation and mitigation should be pursued where possible – and where efficient –

[69] IPCC WGII Ch18 p757.

particularly if the mitigation activity can be externally verified and thus generate income by earning tradeable carbon permits.

A case of effective policy design and implementation which has improved economic outcomes and increased resilience to heat and drought, while also sequestering carbon, is the conversion of low-productivity lands used for cereal cultivation into more water-efficient perennial grasses for the raising of livestock in southern Kazakhstan through a World Bank/GEF project. As this case illustrates, an adaptation that reduces emissions in one way – no plowing allows the soil to trap and store carbon – may contribute in another, as livestock produce methane which is a greenhouse gas. Careful consideration is needed to effectively assess the emissions increases, decreases, or neutrality of adaptations, and to set standards for acceptable levels of emissions from an adaptive activity in cases where there is no potential for mitigation.[70]

While much early adaptation research and policy planning focused on technological adaptations, institutional aspects of adaptation have garnered more attention as the role of institutions in facilitating – or hindering – adaptation has become evident. Under the United Nations Framework Convention on Climate Change (UNFCCC), many countries including a number in ECA produced national communications addressing adaptation issues. These documents, some written as many as ten years ago, compile relevant technological adaptations for different sectors at the country level, yet in many cases thus far have not resulted in significant adoption of adaptive practices in agriculture.[71] A more operational perspective, necessarily identifying individual and institutional actors, has characterized the subsequent National Adaptation Programs of Action (NAPAs), but these have only been prepared by a selection of least developed countries (LDCs) and no countries in ECA.[72] Any contribution to agricultural adaptation research and planning in ECA must investigate and support the role of institutions in promoting adaptation at each step from agricultural research to on-farm adoption.

Given the importance of institutional development for broader economic development and growth goals, adaptation actions that involve investment in and support for institutions offer countries win-win opportunities for reducing vulnerability to climate risk and promoting development. The institutions critical for effective and sustained adaptation are described in Annex Table A4. Many of the key institutions are part of national or local government, or entail coordination between national, or even international, and local bodies. For example, hydrometeorological centers (or simply "hydromet"), which perform extensive data collection and analysis, and forecasting centers require frequent information from data collections sites and weather stations scattered across sometimes vast territory (e.g. Russia, Kazakhstan), requiring local participation in the maintenance and operation of these facilities. Further, there is scope for international cooperation, particularly for smaller countries whose climate and weather phenomena will be closely related to their neighbors' and for whom large investments in centralized hydromet capacity would be too burdensome (e.g. the South Caucasus).

While hydromet services may be useful across a number of sectors, agriculture stands to benefit most because it is most dependent on weather conditions. In an environment of increased

[70] IPCC WGII Ch18.
[71] Burton and Lim 2005, p195.
[72] http://unfccc.int/national_reports/napa/items/2719.php. Accessed 4/22/08.

climate variability and uncertain trends, forecasts will have an important role to play in facilitating adaptation to climate uncertainty and risk, and in supporting knowledge-based response farming. In-depth country studies of national meteorological services in ECA illuminated the myriad ways that forecasts and other hydromet services are essential for the sorts of technological adaptations described in Annex Table A3. There are a number of prerequisites for realizing the benefits of hydromet, starting with renewed investment in national capacity and fostering of international cooperation. The capacity requirements for producing and applying weather information include basic forecasting skills, agrometeorological (agromet) extension, and drought monitoring. To produce short-term forecasts (3-5 days) of temperature, precipitation, and wind conditions, local networks of sensors would need to be improved, while medium-term forecasts would require integration and cooperation with multinational networks (e.g. ECMWF, EUMestat, WMO), as well as improvements in the infrastructure for data gathering and communication. In order for these forecasts to benefit small farmers, they should not be restricted to paying clients, but rather provided as a public service. Forecasts are most effective when accompanied by agromet extension, which is attuned to the informational needs of farmers, and which can include mechanisms for drought monitoring. The frequency and impact of droughts in the Caucasus, Central Asia, and Moldova point to the importance of "instruments to measure soil temperature and moisture and micro-climates, satellite data to facilitate agromet analyses and support drought monitoring, and models to draw out the implications of soil moisture, temperature and solar radiation data."[73]

Gaps in capacity, reach, depth, and overall effectiveness are common among ECA's public agricultural institutions, and the importance that these institutions will play in agricultural adaptation argues for concerted and sustained investments in order to fill those gaps. One of the major public institutions that will play a role in climate adaptation is agricultural advisory services, which encompass traditional agricultural extension concerning farming practices, technologies, and inputs types; advice on obtaining financing to support farm operations including adaptation measures; and information about price trajectories and channels of access in local, national, and international markets. These services are essential for communicating to farmers existing and evolving information about climate change, including guidance in the interpretation and use of probabilistic climate forecasts. The lack of understanding of weather events in the context of climate change, as well as the lack of understanding of the probabilistic nature of weather forecasts, have constituted barriers to application of forecasting information in agricultural adaptations.[74] For hydromet to help farmers adapt, extension services must be functioning effectively at the local level, country by country and oblast by oblast.

Advisory services also play a complementary role to agricultural research by encouraging the adoption of locally-appropriate adaptations based on existing off-the-shelf practices and crops but also resulting from the innovations developed in the research sector. Agricultural research institutes will be important in creating new knowledge relevant to the challenges of increased climate uncertainty. Cooperation among international and domestic researchers will facilitate the inclusion of local concerns and knowledge into the global research agenda, and likewise will encourage the diffusion of new knowledge from the global level down to the farm via local research institutes and agricultural advisory services. Research capacity is high in some

[73] Hancock and Tsirkunov 2008.
[74] Padgham 2008.

parts of ECA, but very limited in others. However, countries have the opportunity to share in the outcomes of international research.

V. Act sooner rather than later to reduce damages and maximize potential benefits

We are reaching the point where information about climate risks and adaptation, from evidence of current climate change and its economic impacts to projections of future climate and associated agricultural market outcomes, such that decision-makers can recognize the reality of increasing climate risk as well as draw on existing best practices to develop an integrated adaptation strategy. It is in the interest of actors from the farm up to the ministries to begin investing in adaptations that will reduce the agricultural economy's vulnerability to climate risk because as disaster management projects have demonstrated, ex ante adaptations are more cost effective than responding to crises once they have occurred. Early identification of market opportunities, such as increasing global food prices, demand for biofuels, and greater meat consumption in Asia, as well as awareness of projected expansion of suitable cropping area is some parts of ECA, are essential in order for producers to make timely investments to realize any potential gains from climate change.

The availability of win-win, or no regrets, and win-win-win adaptation measures, which further development goals no matter how climate change and world food market dynamics unfold, offer justification and concrete entry points for undertaking the work of agricultural adaptation, despite the uncertainty characterizing the temporal and spatial distribution of future manifestations of climate change and the non-climate trajectories of domestic and global markets. In fact, this very uncertainty further underscores the urgency and importance of developing a strategy to inform decision-making at all levels of the agricultural sector. Policymakers and producers of course make decisions without complete information about the present, let alone the future, all the time. But as the risks of unpredictable weather increase, decision-makers will need a new strategy to support their evaluation of and response to problems and opportunities: a set of tools for understanding the problems, evaluating vulnerabilities, setting priorities, assessing adaptations' feasibility and robustness to an uncertain future, and measuring successes and remaining gaps.

The next step for policymakers and development partners is to assess the situation at a country level and make a plan for action. The usual tool for analyzing investments and projects, cost-benefit analysis, has its weaknesses in the area of climate change adaptation, as discussed below. Therefore the planning and implementation framework for climate change adaptation adopted by many high-income, high-capacity countries is the best model for ECA countries to follow in building resilience to climate change.

Cost-benefit analysis of adaptation measures ideally begins with the quantification of the benefit, that is, the cost of *not* acting, and of the costs of implementing an adaptive measure. The benefits might be narrowly defined as avoided yield losses from increased climate stress, but even in this case the no-adaptation counterfactual of economic damages from climate change is poorly understood, and if benefits are expanded to include the contribution of an adaptation to the sustainability of rural livelihoods, the challenge is still greater. There is no agreed upon way to estimate the damages from climate change because of the difficulty of accounting for adaptation.

Estimating the costs of various adaptations is no different than the usual analysis of investments and projects and is therefore a more manageable exercise. The costs of an adaptation might include easily estimated measures such as the price of machinery for conservation tillage, or costs that are more complex but still possible to model such as the investments required to fund research hoped to result in a new drought-resistant crop variety, to enhance agricultural extension services to disseminate the information, to foster private sector engagement ensuring seed provision by distribution enterprises, and so on. But given the uncertainties of estimating the avoided damages, as well as the difficulty in estimating marginal impacts of individual measures or combined impacts of synergistic technological, institutional, and policy interventions, and it is no surprise that the economics of adaptation, currently in its infancy, is not alone a sufficient tool for guiding policymaking.

The more qualitative approaches to adaptation planning created and implemented in developed economies including the UK, Australia, and Finland, as well as approaches designed by United Nations and other researchers for developing countries, can serve as models for ECA governments. The process outlined here will need to be undertaken on a country-by-country basis, as the informational inputs depend on detailed knowledge of social and economic capacities and constraints. The steps, integrated from a number of broadly consistent sources, are as follows:

1. Define the problem and associated risks.

2. Complete a vulnerability assessment based on *existing* as much as future climate and economic risks and prioritize areas for action.

3. Identify appropriate adaptation options to reduce vulnerability and manage risk.

4. Appraise options given findings of vulnerability assessment, chosen priorities, and current climate experience.

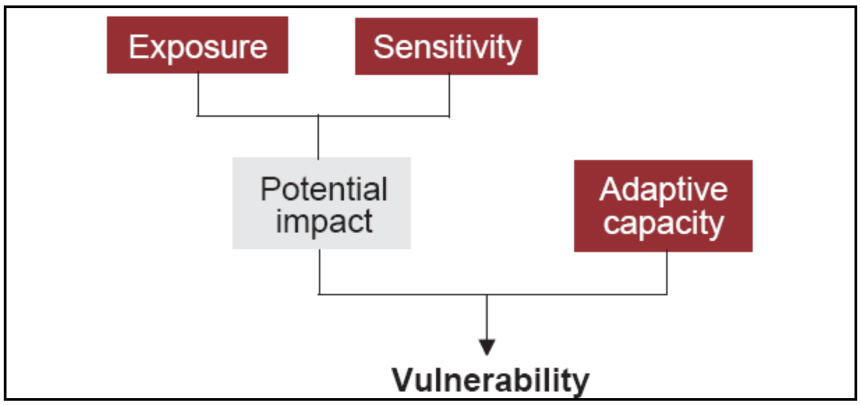
5. Evaluate and address congruence or conflict with current policies and practices, and barriers to implementation and adoption.

6. Design a project and implementation plan and secure financing.

7. Take adaptation action and gather lessons for continued rounds of planning and action.

The first step entails defining the scope of the problem to be addressed in the planning process and characterizing the basic threats to agricultural livelihoods. The vulnerability assessment, modeled on the approach developed by the Australian Government (2005) is the larger process of gauging the climate change vulnerability of various groups, which can be classified by regions, cropping systems, social or ethnic groups, farm types, or other communities and systems. The *potential impact* of climate change is understood to be the product of *exposure*: the particular climate phenomena of changing means and extreme events the community will face; and *sensitivity*: the extent to which the system is at baseline affected by current weather (see Figure 7). *Vulnerability* is determined by this combined potential impact and by *adaptive capacity*: the ability of systems or communities to cope with current and future climate and economic challenges.

Figure 7. Vulnerability Assessment Framework



Source: Australian Government 2005.

The vulnerability approach to identifying and managing risks has important advantages over a narrower, deterministic, hazards-based model of projections → impacts → adaptation → vulnerability reduction → development. If decision-makers focus on all aspects of vulnerability rather than just an estimate of a particular future climate, they are more likely to pursue adaptations i) that address equally-important non-climate aspects of vulnerability, ii) that include uncertainty itself as part of the challenge, as far as some groups are more able to cope with uncertainty than others, and iii) that are relevant to local concerns. Vulnerable production systems and communities face multiple stressors. Climate change is only one driver of among many, so adaptation solutions must be understood in the context of other challenges and trajectories.[75] It remains a difficult task for policymakers and development partners to judge how much emphasis to put on climate risk among all other risks, and what share of resources to direct toward adaptation as compared to existing development programs.

One of the values of the vulnerability approach is that the assessment process induces policymakers to conduct a fine-grained analysis attentive to distinct communities' unique challenges and sources of resilience at the local level. This local perspective is needed to guide eventual choices of adaptation measures and ensure sustained adoption, which will require that adaptations be appropriate to local agricultural needs, social processes and values, and economic

[75] Kandlikar and Ribsey 2000, p536.

resources, as well as effective in cutting through local barriers to change. Further, the relative importance of climate-related stressors in magnifying risks and determining economic outcomes will vary across regions, within countries, and even within villages. An understanding of local priorities can guide policymakers in their assessment of the scope of investment in adaptation measures that will be needed.

Arguably the most important source of information about overall vulnerability to climate change will not be the magnitude of projected changes in temperature and precipitation (i.e. exposure), but rather observations about sensitivity to and adaptive capacity for managing current climate stressors. For example, a community farming or grazing the most marginal land, which has already experienced droughts because of weather conditions combined with poor resource management, and which has the least effective institutions and social safety nets, will be extremely vulnerable to climate change, even if climate projections only indicate a 15% decrease in rainfall, because this small change might push the local economy beyond the threshold of sustainability. The importance of beginning with current climate vulnerability has been stressed both by researchers advocating adaptation in developing countries and by policymakers and planners in high-capacity countries such as the UK.[76]

Planners must resist the instinct to appraise vulnerability by looking at color-coded maps of mean seasonal summer temperature or precipitation changes, that is, by solely looking at exposure. Only an overlay of exposure with current areas of high poverty incidence, poor governance and institutional support, and a record of damages from current weather phenomena can highlight those regions or communities that are the highest priority for intervention. The questions that arise in a current-climate oriented vulnerability assessment might include: What have been recent experiences with climate challenges? How have people responded? Who has been least able to cope, and who most? What has been the difference between instances of successful management of challenges and failure? At what stage do problems arise, and what strategies, institutions, and practices can be improved? What efforts at improvement have not gone far?

In addition to supporting the application of the holistic vulnerability approach, attention to current climate also facilitates participatory planning and decision-making, which increases the likelihood of adoption of adaptation measures. Investigating current weather vulnerabilities requires that development experts and governments engage with farmers in discussions of problems that are real and tangible to them, opening the way for education of farmers about climate change as a real and current matter, rather than an abstract concern relevant only in a distant future if at all.[77] Efforts by national governments to facilitate the dissemination and adoption of adaptation practices, such as the use of probabilistic seasonal forecasts, have so far and will in the future generate little response from farming communities if it the messages are not connected to the short-term economic considerations and short-term climate variability that actually concern farmers.[78] The challenge of even the relatively more concrete process of

[76] UKCIP 2003, Burton and Lim 2005.
[77] Burton and Lim 2005.
[78] For a discussion of challenges in communicating forecasts in terms of probabilities rather than in deterministic terms, and the resulting dissappointment of farmers in the “failure” of the forecasts to predict the rains, see Jon Padgham 2008 forthcoming.

technological adaptation is not just technology transfer or dissemination, but also facilitation of adoption.[79]

The next steps after the vulnerability assessment are to identify relevant adaptations, producing a menu of options, and to evaluate and choose among them. The tables of technological, institutional, and policy adaptations in this paper are general models that could be expanded to include more detailed information relevant at the country level. After a country's exposure and sensitivity have been characterized in the vulnerability assessment, the technological adaptations can be tailored to address specific potential impacts such as field drainage and grain storage practices to limit damage from increasing rainfall during sowing or harvesting periods. Further, institutional and policy adaptation menus can be tailored to the individual country, as the current state and capacity for improvement of the institutional and policy environment varies across countries, and some areas are stronger than others within countries.

As mentioned in the discussion of the technological adaptations, in section IV, there are many lists of adaptation options, of varying usefulness for different regions and different challenges, which ECA countries can draw from. However, choosing from such lists is not simple, and existing classifications of adaptations can be misleading about the appropriate timing of implementation and about the relationship between measures taken by farmers and those taken by other actors such as national policymakers or managers of local institutions and enterprises. Unlike many existing lists, this paper has presented adaptations as distinctly technological, institutional, and policy-based in order to highlight the multi-faceted aspect of a single technological adaptation and to suggest areas for government action and investment to promote adaptation among actors who participate in the agricultural economy in diverse ways. This presentation of adaptation also intentionally omits classification of measures along two dimensions often used in adaptation studies: autonomous versus planned, and short-term versus long-term.

Much of the agricultural adaptation literature identifies autonomous adaptations as those measures taken at the farm-level in response to observed or understood changes in climate and which do not entail major changes in farming systems. These adaptations are also often called short-term; for example, "Short-term adaptations to climate change include efforts to optimize production without major system changes. They are autonomous in the sense that no other sectors (e.g. policy, research, etc) are needed in their development and implementation (Olesen and Bindi 2002, p252)." Yet most studies fail to indicate what short-term means. Is it an adaptation that is quick to implement under ideal conditions? Or one that is quick to implement even giving existing barriers? Or one that yields returns soon after implementation has started? Or is it one that should be begun immediately because returns are slow to accrue? Is a short-term adaptation always short-term, in all countries and contexts?

Further, the notion that farm-level adaptations can occur without the support of institutions and policies seems optimistic even in the context of high-income countries, and naïve in the context of ECA client countries where knowledge about changing climate and access to physical, informational, and financial inputs to adaptation measures are currently not adequately

[79] Burton and Lim 2005.

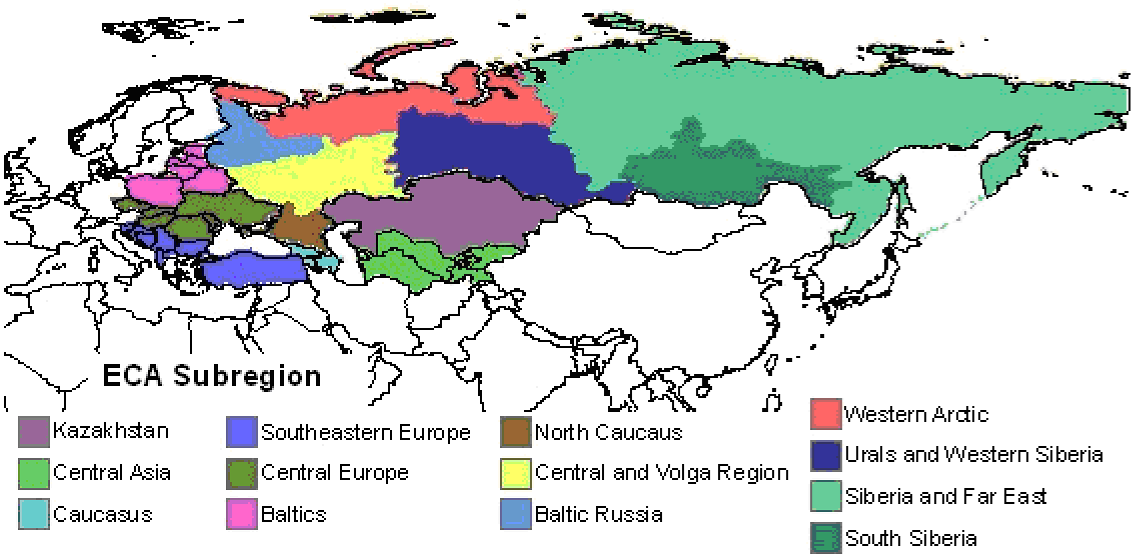
provided by markets or governments. Adaptation is a political process, not something that happens in isolation on the farm. For a small farmer to adapt, there need to be resources in place than can only result from adaptation-oriented policies and functioning supporting institutions.[80] Institutional and policy-based adaptations, including research, are often labeled as long-term in the adaptation literature, which may be intended to indicate that change in these areas can be slow and the investments have a long response time. Also included in the category of long-term, however, may be adaptations that are somewhat fast to implement but which need not be pursued until climate has changed more, e.g. switching from field crops to heat- and drought-tolerant grapevine and fruit trees. But investments in institutional capacity for producing, interpreting, and disseminating climate forecasts, for example, will need to be made now in order to increase future, long-term climate resilience.

Therefore, this paper suggests that assessment and selection of adaptations should be guided by a process of prioritizing adaptation measure that explicitly incorporates and distinguishes among response time, duration of implementation, appropriateness for current versus future climate, win-win(-win) or cost-benefit characteristics, and the vulnerability of those helped by the measure.[81] Each option on a menu of adaptations can be characterized according to these five criteria, but this must be done at the country level. Evaluation of adaptations within the current policy context must also be done at the country level. In choosing investments and measures, planners should consider the interaction of adaptations with current policies, the extent to which existing policies enhance or undermine adaptive capacity and adaptation opportunities, and the feasibility and effectiveness of adaptation options in light of experience with existing measures' successes and failures in addressing current climate challenges. This is not an easy process; making the right choices and pursuing the right measures *at the right time* cannot be taken as a given, as some economic impact models do.[82] But it is not impossible.

Some general recommendations about timing adaptations can assist decision-makers in designing an effective, efficient, and feasible plan for adaptation implementation. One set of measures that should be implemented early on are those that will be beneficial under current climate conditions as well as future climate, especially if the gains are not reliant on a narrow set of potential future climate conditions, such as reforming water pricing policies. Another set of measures that require early action are those with a long response time from the initial investment or policy change to the adaptive outcome, such as research into new crop varieties which may take 10 to 15 years to reach the market. Some adaptations will fit both of these descriptions, e.g. strengthening and supporting agricultural advisory services and vocational training. Educating farmers and disseminating practical information will increase resilience to current climate and market shocks in addition to building capacity for farm-level adaptations and resilience to climate change impacts. Expanding and better equipping these institutions will take time, because generating the political will and securing financing must be considered, in addition to the activities of better training extension agents, developing curricula for vocational schools, and so on.

[80] Kandlikar and Ribsey.
[81] See Table 1 in Kandlikar and Ribsey for an early example of separately classifying adaptations by time to generate an adaptive response and time to realize gains from the response.
[82] Hanneman 2000, p 547.

Annex Figure A1. Europe and Central-Asia Sub-Regions



The regional groupings of the ECA countries were chosen based on current climate, projected climate, and general economic and agricultural characteristics.

The multi-country regions and individual country region are: Southeastern Europe (Albania, Bosnia, Bulgaria, Croatia, FYR Macedonia, Serbia, Slovenia, Montenegro, Turkey); Central and Eastern Europe (Czech Rep., Hungary, Moldova, Romania, Slovakia, Ukraine); the Baltics (Belarus, Poland, Estonia, Latvia, Lithuania); the South Caucasus (Armenia, Azerbaijan, Georgia); Central Asia (Tajikistan, Uzbekistan, Turkmenistan, Kyrgyzstan); and Kazakhstan.

Because of its vast and varied territory, Russia has been divided into six subregions based on climate and the geographic distribution of agricultural activity. The oblasts, republics, and districts contained in each are: Baltic and Western Arctic (Arkhangelsk, Kaliningrad, Karelia, Komi, Kostroma, Leningrad, Murmansk, Nenetsk, Novgorod, Pskov, St Petersburg, Taymyr, Tver, Vologda, Yamalo-Nenetsk, Yaroslavl, Arctic Islands); Central and Volga (Bashkortostan, Belgorod, Bryansk, Chuvashia, Ivanovo, Kaluga, Kirov, Komi-Permyak, Kursk, Lipetsk, Mari El, Mordovia, Moscow, Nizhniy Novgorod, Orel, Orenburg, Penza, Perm, Ryazan, Samara, Saratov, Smolensk, Tambov, Tatarstan, Tula, Udmurtia, Ulyanovsk, Vladimir, Volgograd, Voronezh); North Caucasus (Adygea, Astrakhan, Chechnya, Dagestan, Ingush, Kabardino-Balkaria, Kalmykia - Khalmg Tan, Karachay-Cherkessia, Krasnodar, North Ossetia - Alani, Rostov, Stavropol); Urals and Western Siberia (Altay, Chelyabinsk, Kemerovo, Khakassia, Khant-Mansiysk, Kurgan, Novosibirsk, Omsk, Sverdlovsk, Tomsk, Tyumen, Tyva); South Siberia (Aga Buryatia, Amur, Buryatia, Chita, Irkutsk, Ust-Orda Buryat); East Siberia and the

Far East (Chukotka, Evenk, Jewish, Kamchatka, Khabarovsk, Koryak, Krasnoyarsk, Magadan, Primorskiy, Sakha-Yakutia, Sakhalin, Taymyr, Arctic Islands).

Annex Table A1. Characteristics of Current Agricultural Production in ECA

Region	Distribution, Ownership, and Productivity of Agricultural Land[83]	Major Crops & Products[84]	Cropland Irrigation[85] and Water Supply	Livestock in Agricult. Output[86]
South-eastern Europe and Turkey	Farms of Bulgaria now privatized, Croatian and Macedonian farms privately owned. Albania, Serbia & Montenegro mostly private but unclear ownership rights, and some inefficient collectives remain. Excessive fragmentation of holdings throughout region limits efficiency. In Turkey, farms are small and privately owned.	Highly diversified. Cereals, fruits, vegetables, orchards, vineyards, oilseeds, nuts, sugarbeets. Dairy, pork, sheep, poultry. In Turkey; cotton, olives, figs in addition to above.	Northwestern part of Balkans entirely rainfed. Albania: 50% irrigated. Macedonia, Bulgaria: 15%. Turkey: 20%. Drought-prone, hot dessicating winds, intense rain, soil erosion.	30 to 50%
Central & Eastern Europe[87]	Current yields low relative to potential. Moldova especially poor and agriculture-based; moderate privatization but highly fragmented private holdings and some remaining inefficient collectives. Privatization also incomplete in Ukraine. Privatization largely complete in Romania, mix of small family and commercial farms.	Moderately diversified. Wheat, barley, fodder, fruit & vegetables, orchards, potatoes, oilseeds, sugarbeets. Livestock, poultry.	Mostly rainfed, around 10% irrigated, except in Romania 30%. Moderately drought-prone, Moldova more drought-prone.	25 to 35%
Baltics	In Poland and in Belarus the 3 small Baltic states farms are privately owned.	Little diversification. Barley, rye, wheat, potatoes (especially Belarus). Livestock, pork and poultry. Oilseed in Poland. Limited fruits and vegetables.	Entirely rainfed, abundant precipitation.	40 to 60%
Russia	Farms mostly in Central & Volga, N Caucasus, some in Baltic, and in southern Urals and South Siberia. About one third of agricultural land in private hands, the rest public. Few subsistence farms. Family, joint stock company farms and public owned farms; low yields, poorly run.	Little diversification except in N. Caucasus. Barley, rye, potatoes, fodder in north & west. Spring wheat in north & east, some winter wheat in south. Diverse fruits, vegetables, vineyards in Volga & N. Caucasus. Some rice in N. Caucasus. Livestock.	Mostly rainfed. Some irrigation in N Caucasus, southernmost part of Urals and Siberia, small amount in Central & Volga. Moderately drought prone in south.	45%
South	Most productive arable land now under private ownership,	Highly diversified. Fruits & vegetables, orchards	Armenia, Azerbaijan: 20-30% of	40 to 50%

[83] ECSSD Working Paper 46.
[84] FAO, ECSSD Working Paper 46.
[85] Approximate values. From FAO Statistical Yearbook.
[86] ECSSD Working Paper 46.
[87] Text refers to Ukraine, Moldova, and Romania, excluding Czech Republic, Slovak Republic, and Hungary.

Caucasus	but pasture still communal in places. Small, fragmented holdings. Subsistence and family farms w/ low productivity.	including apple, pears, cherries and some citrus, vineyards, dairy, sheep. Cereals, forage, corn, tea.	cropland irrigated. Georgia: 40%. Highly drought-prone, but rainfall more abundant in Black Sea coastal area of Georgia.	
Kazakhstan [88]	Privatization progressing but incomplete. Small family farms in irrigated south but large farms in the north are better-run, private joint stock companies growing wheat.	Moderate diversification. Cotton, rice, wheat, fruits & vegetables. Forage, livestock, poultry in south. In the north monoculture of wheat, some oil crops, pasture.	Rainfed pasture. Just 10% irrigated. Highly drought-prone.	45%
Central Asia[89]	Little privatization, with land ownership and distribution policies distortionary, except in Kyrgyzstan which is implementing privatization. Subsistence/family farms, inefficient low-productivity collective farms.	Cotton, rice, wheat, corn, large number of fruits, vegetables, livestock, poultry, sheep, pasture.	Kyrgyz, Turkmen, Uzbek mostly rainfed pasture. 75-90% of rergion's cropland irrigated. Extremely drought-prone, water-stressed.	40 to 60%

Sources: World Development Indicators. Growth, Poverty, and Inequality: Eastern Europe and the Former Soviet Union. FAO Statistical Yearbook Country Profiles. ECSSD Working Paper 46 The Agrarian Economies of Central-Eastern Europe and the Commonwealth of Independent States: An Update on Status and Progress in 2005. Drought: Management and Mitigation Assessment for Central Asia and the Caucasus.

[88] Drought Management and Mitigation.
[89] Drought Management and Mitigation.

Annex Table A2. Estimated Agronomic Impacts of Climate Change in ECA without Adaptation, to 2050

SOUTHEASTERN EUROPE including Turkey Decreased precipitation in all seasons, yet more storms, floods • soil erosion from wind, storms, and floods[90] • increased evapo-transpiration, soil salinization • increased irrigation demand, stress on water supply • especially severe water stress in southern Turkey. Higher average temperature, very hot summers, heatwaves, and droughts • faster maturation, shorter development period, with water shortage and heat stress, grain sterility, lowers yield of many cereals, oilseeds, and pulses (i.e. determinant crops)[91] • decreased yield or quality of onions[92], cool-weather vegetables[93] • longer season for warm-weather vegetables • possilbe shifts to higher altitude of some crops (esp. mountainous Turkey) • increased variabilty of grape quality, quantity, and vulnerabilitly to pests, but potential benefit from CO_2 fertilization • expansion of drought-tolerant olive, citrus, fig[94] • but tree crops highly vulnerable to storms, pests[95] • winter survival and subsequent proliferation of pests.[96] Increased variability in yields of cereals, other crops.[97] Livestock Heat stress and both indigenous and non-indigenous disease in livestock threaten milk and meat production.[98] Heat, water scarcity decrease forage production leading to shortage in late summer.[99]
CENTRAL & EASTERN EUROPE Right on line between north (wetter, milder winter) and south (drier, hotter), so not yet clear if climate and thus impacts will be similar to the neighbors to the north or to the south. Potential yield increases mostly shown in Alps, Carpathians[100], where significant agriculture not actually feasible. Disagreement among sources, including range from benefits to large losses around Black Sea (E. Romania, Moldova, S. Ukraine – hot and dry), little agreement for all of Ukraine.[101] Increased storms, but ambiguous magnitude and direction of precipitation change • tree crops vulnerable to storms • even if no change in region overall, possible yield decline if too wet in the north (see Baltics) or even slightly drier in the south (see Southeastern Europe). Same amount of warming in winter and summer • faster maturation, shorter development period, may lower yield of many cereals, oilseeds, and pulses (i.e. determinant crops)[102] • potential for northward expansion of warm weather crops like oilseeds, pulses, vegetables[103] • potatoes more variable, possibly limited by low soil moisture[104] • winter survival and subsequent proliferation of pests • too warm, dry for rain-fed cereals in parts, but suitable for more tree crops including fruit, nuts and more natural pasture biomass for animals; possible increase in area of winter wheat and rye.

[90] Olesen and Bindi 2002, p247.
[91] Olesen and Bindi 2002, p246.
[92] Maracchi et al p126.
[93] Olesen and Bindi 2002, p250.
[94] Olesen and Bindi 2002, p250. van der Celen 2008, p6.
[95] Maracchi et al p123.
[96] IPCC Ch 12.
[97] Olesen and Bindi, 2002. van der Celen, 2008.
[98] Maracchi et al p128. van der Celen 2008, p6.
[99] van der Celen p7.
[100] Peseta yield map.
[101] Compare Peseta to Maracchi et al, for example.
[102] Olesen and Bindi 2002, p246.
[103] Maracchi et al p125.
[104] Olesen and Bind 2002. p 249.

BALTICS Increased precipitation, floods • risk of soil erosion • excess soil moisture limits days suitable for machinery use[105] • spring planting disrupted by April/May rains • harvest disrupted, damage from water-logging, or molding of harvested grain if excess rain in autumn.[106] Milder winters and higher average temperature • faster maturation, shorter grain-filling period, lower yield of winter wheat[107], but now possible to use higher-yielding spring-wheat • potential for northward expansion of warm weather crops like oilseeds, pulses, vegetables[108] • either no or favorable changes in potato, sugar-beet yields, but increased variability[109] • winter survival and subsequent proliferation of pests[110], more varieties of apples, plums, pears. Increased variability in yields of cereals, other crops.[111] Potential yield gains require more fertilizer and pesticides.[112] No consensus on strongly positive nor strongly negative yield projections overall; generally small, positive for initial moderate warming, becoming unpredictable and possibly negative as mean temperature increases further.[113] Livestock Increased survival, reduced winter feed requirements for livestock.[114] Forage, grassland may benefit but only with proper drainage.[115]
RUSSIA: Baltic & Western Arctic Marked increase of precipitation, especially in winter, and of surface water • risk of soil erosion and nutrient leaching from excess rain • excess soil moisture limits days suitable for machinery use[116] • spring planting disrupted by April/May rains • harvest disrupted, damage from water-logging, or molding of harvested grain if excess rain in autumn.[117] Much milder winters and higher average temperature • potential for northward expansion of temperate cereals, vegetables, pulses in Baltic, and of hardiest crops into uncultivated land[118] • longer growing season[119] • potato yields more variable, though with average increase[120] Large change, especially in Arctic, and thus large uncertainty. Expansion of leaf-bearing and steppe range into current tundra, taiga.[121] Change in composition of forests, and possible increase in value for timber production. Livestock Increased survival, reduced winter feed requirements for livestock.[122] Forage, grassland may benefit but only with proper drainage.[123]

[105] Olesen and Bindi 2002, p247.
[106] Olesen and Bindi 2002.
[107] Olesen and Bindi 2002.
[108] Maracchi et al p125.
[109] Olesen and Bind 2002. p 249.
[110] IPCC Ch 12.
[111] Alexandrov 1997. Sirotenko, Abashina, Pavlova 1997.
[112] Maracchi et al p129.
[113] IPCC Ch 12. Peseta – EU Green Paper.
[114] Maracchi et al p128.
[115] Olesen and Bindi 2002, IPCC Ch 5 p285.
[116] Olesen and Bindi 2002, p247.
[117] Olesen and Bindi 2002.
[118] Maracchi et al p125.
[119] Sirotenko et al 1997.
[120] Maracchi et al p127.
[121] Maracchi et al p128.
[122] Maracchi et al p128.

RUSSIA: Central & Volga

Small increase of precipitation, mostly in winter, and of surface water • given small change, unclear if there will be sufficient moisture, given temperature increases, in some months • extreme low run-off events threaten output[124] due to drought.

Much milder winters and hotter summers, higher average temperature • potential for northward expansion of winter cereals and crops like oilseeds, pulses, vegetables, as well as fruit crops currently grown in N Caucasus[125] • longer growing season • winter survival and subsequent proliferation of pests.[126]

Increased variability in yields of cereals, other crops.[127]

Livestock Increased survival and reduced feed requirements for livestock in winter.[128] Possible heat stress, drying up of grassland in summer.[129] Possible expansion, intensification of indigenous and non-indigenous disease.[130] In southern part, productivity of grassland to decline, will need to shift northward. Lower grass production, heat stress, dry summers lead to reduced milk, vulnerability to disease.[131]

RUSSIA: North Caucasus

Decreased precipitation in all seasons, yet more storms, floods and soil erosion.

Higher average temperature, very hot summers, heatwaves, and droughts.

Very similar changes, on average, to South Caucasus, though even higher heatwave risk. See agronomic impacts information for South Caucasus. The area with the greatest potential damages within Russia, given current agricultural importance and nature of projected changes. Plant and animal diseases to become more recurrent.

RUSSIA: Urals & W. Siberia, S. Siberia, E. Siberia & Far East

Marked increase of precipitation, especially in winter, and of surface water, high flood risk • excess precipitation may limit expansion of cereals otherwise possible from temperature increase alone • risk of soil erosion • excess soil moisture limits days suitable for machinery use[132] • spring planting disrupted by April/May rains • harvest disrupted, damage from water-logging, or molding of harvested grain if excess rain in autumn.[133]

Much milder winters and higher average temperature • shift of agro-ecological zones on a diagonal gradient towards the northeast, so currently forested or uncultivated land warm enough for winter cereals, short season vegetables, • expansion of cereals would entail major changes in land-use over time.

Livestock Increased survival, reduced winter feed requirements for livestock.[134] Forage, grassland may benefit but only with proper drainage.[135]

Expansion of leaf-bearing and steppe range into current tundra, taiga.[136] Change in composition of forests, and possible increase in value for

[123] Olesen and Bindi 2002, IPCC Ch 5 p285.
[124] IPCC Ch 10 p483.
[125] Maracchi et al p125.
[126] IPCC Ch 12.
[127] Alexandrov 1997. Sirotenko, Abashina, Pavlova 1997.
[128] Maracchi et al p128.
[129] Olesen and Bindi 2002, IPCC Ch 5 p285, Sirotenko et al 1997.
[130] IPCC Ch 5.
[131] IPCC Ch 10 p481.
[132] Olesen and Bindi 2002, p247.
[133] Olesen and Bindi 2002.
[134] Maracchi et al p128.
[135] Olesen and Bindi 2002, IPCC Ch 5 p285.

timber production. South Siberia has a different climatic and agricultural baseline, though projected climate *changes* are similar to the rest of Asian Russia.
SOUTH CAUCASUS Decrease in surface water; droughts and floods; decline in spring and summer precipitation, small increase on sea coasts in winter • high risk of summer droughts • salinization, desertification, and soil degradation[137] • yield declines for cereals, vegetables, potatoes from water shortage and excess heat in many areas • widespread crop failures during droughts • strain on water supply for irrigated agriculture.[138] Especially hotter in summer, also milder winters • despite milder winters, more crop-destroying frosts (tree crops, fruits) because of absence of heat-retaining humidity[139] • longer growing season may allow multiple harvests[140] • expanded area for cultivation of warm-weather treecrops (fig, nuts) in plains, and expanded area for vegetables (tomato, peppers) and cool-weather treecrops (apples) at high altitudes, but limited by steepness and risk of increased erosion[141] • potential yield increase and geographic expansion for hot-weather perennials like grapevine, olive, citrus, but with risk of high variability[142] • tree crops vulnerable to storms, pests[143] • winter survival and subsequent proliferation of pests.[144] Livestock Increased heat stress and disease, but less stress from cold in winter.[145] Outcomes for forage, grassland not clear.[146] Increased plant pest infestation.
KAZAKHSTAN More rainfall, suraface water yearround in north, with very dry summers in south • despite CO_2 fertilization, increased heat and water shortage cause decline in cotton, rice, fodder, vegetable and fruit crop production in irrigated south yields in south.[147] • potential expansion of grazing land northeards and in formerly virgin marginal lands, ploughed for wheat cultivation. Much warmer throughout year, slightly more in summer • potential increase in cereal, legume and oil crop production in cooler, wetter north • increased fodder production • increased water demand of plants and drying of soils in warmer months because of higher tempertures, causing drought risk and water scarcity to persist or worsen. Livestock Initial warming good for livestock, provided sufficient water availability, but after first few degrees, increased heat stress and disease.[148] . Note, greater water demand for rice production with higher temperatures.[149] See impacts in Kazakhstan for more relevant agronomic impacts.
CENTRAL ASIA Unchanged or increased winter rainfall, decrease in rainfall and suraface water in spring, summer, fall, with droughts • major stress on water resources for irrigation • decline in cereal yield from water shortage from spring to fall, and from thermal stress[150] • drought, desertification, soil erosion, salinization • widespread crop failures during droughts • increased suitability for drought-resistant tree crops.

[136] Maracchi et al p128.
[137] Hovsepyan and Melkonyan, p9.
[138] Hovsepyan and Melkonyan, p10.
[139] Hovsepyan and Melkonyan, p9.
[140] Hovsepyan and Melkonyan, p9.
[141] Hovsepyan and Melkonyan, p12.
[142] Hovsepyan and Melkonyan, p9. Maracchi et al.
[143] Maracchi et al p123.
[144] IPCC Ch 12.
[145] Maracchi et al p128.
[146] Hovsepyan and Melkonyan, p12.
[147] IPCC Ch 5 p288.
[148] IPCC Ch 5 p 287.
[149] IPCC Ch 10 p480.
[150] IPCC Ch 10.

Hotter summer, milder winter • greater water demand for rice production with higher temperatures.[151] • despite CO_2 fertilization, increased heat and significant water shortage cause decline in cotton yields.[152] Livestock Marginal grasslands at risk for aridization, desertification. Heat stress reduces milk production. Note, greater water demand for rice production with higher temperatures.[153] See impacts in Kazakhstan for more relevant agronomic impacts.

[151] IPCC Ch 10 p480.
[152] IPCC Ch 5 p288.
[153] IPCC Ch 10 p480.

Annex Table A3. Technological adaptation practices and investments for various climate, weather and agricultural phenomena

Technological adaptation measures and investments	Drought	Need for soil moisture conservation (rain-fed)	Need for water use efficiency (irrigated)	Land degradation, soil infertility, erosion	Heat stress	Pest and disease control	Excess rain, flooding, storms	Milder winters, longer growing season	Emissions mitigation, carbon sequestration
Land use management	x	x	x	x	x	x	x	x	x
Mixed farming systems (crops, livestock, and trees)	x	x	x	x	x	x	x	x	x
Conservation tillage	x	x	x	x					x
Nutrient management and use of organic matter	x	x		x					x
Watershed management	x	x		x			x		x
Water harvesting techniques, storage, reduction of run-off	x	x	x	x	x			x	
Drainage systems				x		x	x	x	
Rehabilitation and modernization of irrigation infrastructure, canals	x		x		x		x		
Develop new irrigation facilities	x				x			x	
Use of marginal water	x		x						
Dams for water storage, flood control	x	x		x	x		x		

Supplemental irrigation	x		x		x				
Irrigation at critical stages of crop growth	x		x		x				
Sprinkler irrigation	x		x						
Drip irrigation	x		x						
Furrow and flat-bed irrigation	x		x						
Crop diversification	x	x	x	x		x		x	
Use water-efficient crops, varieties	x		x	x				x	
Heat- and drought-resistant crops/varieties/hybrids	x	x	x		x			x	
Switch to crops, varieties appropriate to temp, precipitation	x		x	x	x	x	x	x	
Crop rotation (sequencing)	x	x				x			
Switch from field to tree crops (agro-forestry)	x	x	x	x	x	x	x		x
Timing of operations (planting, inputs, irrigation, harvest)	x	x	x		x	x	x	x	
Strip cropping, contour bunding and farming	x	x		x			x		
Vegetative barriers, snow fences, windbreaks	x	x	x	x	x	x			x

Rangeland rehabilitation and management	x	x		x	x	x	x	x	x
Pasture management (rotational grazing, etc) and improvement	x	x		x	x	x	x	x	x
Supplemental feed	x			x					
Fodder banks	x			x					
Watering points	x			x	x			x	x
Livestock management (including animal breed choice)				x	x	x	x	x	
Fire management for forest and brush fires				x					x
Response farming (using seasonal forecasts)	x		x	x	x	x		x	
Integrated Pest Management	x					x		x	

Annex Table A6. Institutions Critical for Adaptation

Institution	Importance for Adaptation	Status in ECA
NATIONAL AND LOCAL GOVERNMENTS		
Hydromet & Forecasting Centers	Essential information for planning, understanding changing climate, providing farmers with long-term, seasonal, and daily weather forecasting for knowledge-based response farming.	USSR was served well, has since crumbled. Improving in European Russia but still unsatisfactory in Central Asia and the rest of ECA. Poor capacity for local monitoring, local data interpretation, and forecasting.
Advisory Services (incl. Agricultural Extension) i. Agronomic Info ii. Financial Advice iii. Market Info	i. Interpret hydromet output for practical advice to farmers; convey information on trends of climate change and risk; recommend and train in new and off-the-shelf technologies and in new/different locally-adapted crops and varieties; demonstrate new farming practices. ii. Provide information on sources of finance for adaptive investments. iii. Provide information on market prices and channels of distribution for crops and livestock. Key to ensure that services reach small small and medium family farms.	Generally poor state of both public and private sector advisory services. Challenge to reach small farmers. Lack of capacity for interpretation of climate forecasts, interpretation of probabilistic climate data, and thus communication of probablistic and not deterministic forecasts. In Turkey, advisory services are better developed but lack capacity to effectively advise farmers in an evironment of increased challenges.
Irrigation Directorates	Maintain, rehabilitate, expand, and replace old and new irrigation facilities, which will be more important in water-stressed areas. Intermediary between managers of water resources and farm users.	
Forestry Deparments / Agencies	Maintain health of forests and respond to pests and risks of fire. Observe changes in forest ecosystems in response to changing climate. Participate in planning related to forest-agriculture land trade-offs.	In much of ECA, often among the best-functioning of those institutions that will be relevant for climate adaptation.
Agricultural Research Institutes	Bring knowledge of locally-relevant needs to research networks from local to international level, develop varieties and technologies suitable for changing climate and local endowments.	After the disintegration of the Soviet Union, research systems collapsed and are not effecttive in meeting the current demands. In Turkey, the situation is better.
Agricultural Education at Vocational Schools, Technical Colleges	Important conduit for information about implications of climate change for farmers and managers, including adaptation measures and technologies and guidance on how and when to implement them. Key in move towards more knowledge-based rather than input-based farming.	
Quality Control, Phytosanitary, & Veterinary Services	Provide standards information and enforcement consistent with national and international regulation, monitor and control livestock health and provide timely information on disease risks.	Strong in some countries, in others not up to challenge of global food market.
CIVIL SOCIETY		
Producer Associations &	Share information about outcomes and challenges of adaptation, serve as locus for absorbing new information from	Producer associations and farmer organizations are starting to grow and their effectiveness varies across

Farmer Organizations	and communicating farmer concerns to government bodies and private enterprises, allow shared investment in new machinery by small farmers.	countries. There is potential for further expansion to more areas and for deepening of activities.
Water User Associations		Relatively recent institution, not fully developed, just beginning to function.
NGOs	Provide information, funding, and institutional support at small scale for pilot adaptation efforts by farmers, offer microcredit to enable adoption, share knowledge of local experiences, advocate farmers' concerns.	Moderate presence, increasing in ECA client countries. Face the usual challenges, e.g. interventions not sustained after projects end, struggle to reach the neediest, lack of coordination with other institutions.
PRIVATE ENTERPISES		
Private & Public Seed Companies & Nurseries	Ensure production and availability of seeds/seedlings of appropriate varieties, e.g., with improved drought- and pest-resistance, to take advantage of agricultural research and development and facilitate adoption.	In Europe, available but currently inadequate. Limited presence, efficacy in Caucasus, Cental Asia. Good in Turkey.
Grain Storage and Drying Facilities	Will be needed in currently un-served newly cultivated areas, and areas with intense rainfall or heat which cause rot, spoilage.	Not present or inadequate in areas that will need them as cropping, livestock zones shift, and as rainfall increases during ceral harvesting time in the Baltics, Central Europe, Russia, northern Kazakhstan.
Agroprocessing Facilities	Offer processing of livestock products in expanded pasture areas, processing of horticulture crops in new areas.	Not present or inadequate in areas that will need them as cropping, livestock zones shift northwards.
Marketing Enterprises	Exploit economies of scale by buying produce of family farms and selling at market, mitigates risk to farmers of adopting unfamiliar crops or varieties with uncertain demand locally.	Variable and with scope for improvement. Generally stronger in Turkey and Europe than the Caucasus, Central Asia.
Financial Services i. Banks ii. Microloans iii. Agricultural Insurance	i. Provide necessary finance for implementation of adaptations. ii. Reach out to small farmers with limited access to formal banks. iii. Mitigate risks of crop failure from unpredictable weather, unproven adaptations, market uncertainties.	Poor access of small farmers to banks. Limited presence, effectiveness of microcredit organizations. Weather-indexed insurance does not exist in most of ECA client countries.

Annex Table A7. Policies Critical for Adaptation

POLICY	IMPORTANCE FOR CLIMATE CHANGE ADAPTATION & IMPLEMENTATION CHALLENGES	Response Time
Non-Distortionary Water Pricing	Reduce subsidies to increase incentives for better management of water resources, the allocation of water, and the efficiency of its use. Difficult b/c removing subsidies often meets with political resistance.	short term
Non-Distortionary Commodity Market Policies	Reduce distortions in markets for cereals and oilseeds, including setting price caps, or taxing or otherwise restricting exports. Letting prices pass through will increase incentives for producers to invest and expand production of these crops over time. Export restrictions become contagious, significantly reducing ag. trade and the ability of world food markets to respond to climate change. Also, manage state grain reserves transparently and effectively to ensure supply during short-term shocks, not to keep prices low.	short term
Financial Incentives for Adoption of Technological Adaptations	Provide tax incentives for, e.g., farmers' purchase of machinery required for conservation tillage, planting of drought-resistant seedlings. Provide financing, coordination for hiring of machines and labor for reforestation projects.	medium term
Access to Modern Inputs	Remove restrictions on imports of modern seeds and seedlings to allow farmers access to modern varieties (e.g., with increased drought resistance or longer maturation).	short term
Invest in Support Institutions (identified in separate table)	Those institutions have been underfunded for a long time, some governments pay attention to it and some don't, some have the resources to invest there and some don't.	short term
Reform Farm Subsidies	Subsidies targeted at production of specific crops may be counterproductive as comparative advantages change. Avoid trying to "pick winners". e.g., subsidies often for cereals rather than fruits and vegetables, which may become more appropriate due to warming. Recurrent production subsidies also reduce scope for investments in public services and farm investment subsidies.	short term
Promote Private Investments	Promote investments by the private sector in new technologies by providing tax incentives, matching grants, technical assistance, etc. Not only for primary production, but also for inputs, processing, logistics, warehousing, and other related sectors.	short term
Risk Insurance	Explore opportunities for developing system of weather index insurance (as opposed to traditional multi-peril crop insurance). For smaller countries especially, spread risk across countries.	medium term
Improve Land Markets	Ensure land tenure security, improve land registration and cadastre systems, and reduce market transaction costs. This will help to increase the flexibility of farmers, reduce fragmentation, increase access to finance, and encourage investment	short term
Calculate Economic Costs and Benefits	Calculate the economic costs and benefits of policy changes and investments decisions as rigorously as possible to ensure the most efficient and effective use of public resources. This will often require capacity building.	

Encourage Livelihood Diversification	In some areas, and for some rural residents, agriculture and forestry may become unviable. Provide training and financial support to encourage the development of non-farm rural employment or skills for urban employment.	
Strengthen Social Safety Nets	Provide targeted income support for poor and vulnerable segments of the population that may have difficulty affording food, may be in areas where agriculture becomes unviable, may not be able to easily change livelihoods (elderly, sick)	

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