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Moldova Climate Adaptation Investment Planning Technical Assistance

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List of Acronyms

AAC	Annual Allowable Cut
ACSA	Agency for Consultancy and Training in Agriculture
BASE	Bottom-up Climate Adaptation Strategies towards a Sustainable Europe
BAU	Business as Usual
BCR	Benefit Cost Ratio
CBA	Cost Benefit Analysis
CIAT	International Center for Tropical Agriculture
CSA	Climate-Smart Agriculture
ECC	Emergency Command Centres
EIB	European Investment Bank
ENPI	European Neighbourhood and Partnership Instrument
ES	Ecosystem Services
ESA	Ecosystem Services Approach
ESMAP	Energy Sector Management Assistance Program
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FES	Forest Ecosystem Services
FIRSM	Forest Institutional Reform Strategy of Moldova
FLEG	Forest Law Enforcement and Governance
FMP	Forest Management Plan
GD	Governmental Decision
GDP	Gross Domestic Product
GIS	Geographical Informational System
Ha	Hectares
HHWS	Heat-Health Warning Systems
IPCC	Intergovernmental Panel on Climate Change
IPSS	Infrastructure Planning Support System
IRR	Internal Rate of Return
LPA	Local Public Authorities
MAFI	Ministry of Agriculture and Food Industry
MDL	Moldavian lei/ currency
MENR	Ministry of Environment and Natural Resources
M&I	Municipal & Industrial
NBS	National Bureau of Statistics of the Republic of Moldova
NFF	National Forest Fund
NFMS	National Forest Monitoring System
NTFP	Non-Timber Forest Products
PESETA	Projection of Economic Impacts of Climate Change in Sectors of the European Union Based on Bottom-up Analysis
PPP	Purchasing Power Parity
RCP	Representative Concentration Pathway
RM	Republic of Moldova
SDES	State Department of Exceptional Situations
SSPs	Shared Socioeconomic Pathways

TA	Technical Assistance
TEV	Total Economic Value
TUB	Transylvania University of Brasov
USD	Unites States Dollars
VOLL	Value of Lost Load
VSL	Value of a Statistical Life
VLYL	Value of a Life Year Lost
WB	World Bank
WEAP	Water Evaluation and Planning System
WRM	Water Resources Management
WSS	Water Supply & Sanitation
WUA	Water Users' Association

Executive Summary

Background & rationale

Moldova ranks as the most climate vulnerable country in Europe, according to the widely used ND-GAIN[1] vulnerability assessment methodology. Temperature and rainfall have increased in Moldova over the last century, and severe floods and droughts have been occurring more regularly in recent times. For example, in the years prior to 2007, average annual losses from climate-related disaster losses were estimated at over USD60m per year, but in the same year, a severe drought occurred which was later assessed to have caused around USD1 billion of damage and losses.

Looking forward, climate models predict further mean temperature rises and more variable rainfall with anything from a slight increase to a significant decline in total precipitation. Even under scenarios with an increase in mean rainfall, however, water availability will decrease due to increased temperatures and rates of evapotranspiration. Rainfall will also become more variable and more concentrated due to the more common extreme events.

In general, climate adaptation issues in Moldova have been well characterized. The National Climate Change Adaptation Strategy identifies 6 sectors at particular risk. **Agricultural productivity** will significantly decrease due to increasing water stress on crops, even without accounting for the increasing impact of extreme weather events (i.e., hailstorms and late frosts, major floods and droughts, or changes in patterns of disease and pests). Total **water availability** will fall below total demand within a couple of decades. **Health** effects of climate change will include increases in heat-related ailments (including cardio-vascular disease), transmission of gastro-intestinal diseases, air pollution and allergies, as well as higher numbers of casualties from natural disasters. The productivity of **forests** will diminish and pathology patterns are expected to change. Peak **energy** consumption patterns will shift from the winter to the summer, energy distribution / transmission infrastructure may also be impacted and the country’s potential to reduce energy imports through development of renewable sources (mainly solar, biomass, wind, and geothermal) could be compromised. **Transport infrastructure** could be disrupted.

The current study extends existing analyses through a quantitative assessment of adaptation investment opportunities and returns across the target sectors. To achieve this, the study evaluated the ***cost of inaction*** in each sector, i.e., the expected annual opportunity cost of not being better adapted to prevailing climate conditions. The cost of inaction was calculated on the basis of both:

- potential **savings** from reducing harmful effects of climate (or from reducing the cost of defending against harmful effects), and
- potential **gains** from enhancing primary production that is directly dependent on climate (i.e., agricultural & forest products & services, water services, and weather-based renewable energy generation).

The cost-of-inaction concept therefore embraces climate-smart development, encompassing both investments from avoided costs and the gains from proactive investment in opportunities[2]. The cost

[1] Notre Dame Global Adaptation Index - http://index.gain.org/

[2] This contrasts with a concept of climate change adaptation based on strict additionality, which would focus on avoiding costs of changes in climate relative to an historical baseline, in order to differentiate climate change adaptation from development investments. However, distinguishing between adaptation and development can be difficult in practice, and always requires comparison against a counterfactual. It is likely to

of inaction was calculated for the present time and 2050, to understand how future climate change may affect investment opportunities. The costs of inaction indicate how *total potential (annualized) savings and gains* are distributed across the target sectors. Cost-benefit analysis was then used to estimate the *economic viability (in net present value terms) of specific investments* that exploit those potentials.

Costs of inaction on climate adaptation

The economy of Moldova already bears significant costs from climate extremes and foregoes potential benefits. These real and opportunity costs will continue to grow with future climate change. Figure 0.1 summarizes the expected annual costs of inaction, at present and in 2050, across the target sectors. Potential **savings** from better protection against current harmful climate impacts are estimated to be substantial, amounting to more than USD100 million per annum in total. These are mostly due to damages caused by flooding and a variety of weather impacts on agriculture, as well as the cost of climate-related health impacts (extreme heat mortality and food-borne disease). Evaluated costs of inaction in infrastructure (other than flood damage) are relatively negligible.

However, the potential **gains** in expanded production due to improved adaptation to climate are even larger. In agriculture, improving performance to the level of neighboring countries could result in around a couple of hundred million USD of increased output per year[3]. Production potentials in the forestry and water sectors (from forest restoration and improving the provision of water supply and sanitation (WSS) services) are smaller but still significant.

In future, the potential savings from protecting against climate damage are expected to increase in all sectors, totalling at least USD600 million per annum by 2050. This is partly related to an increase in the volume and value of assets at risk in line with GDP growth. But particularly in agriculture and health, the frequency and severity of harmful climate events are also expected to increase. In contrast, the potential gains from enhanced production are expected to increase less rapidly. Estimates of unrealized production in forestry, agriculture, and energy in 2050 are not very different from the present. It is only in the water sector that the unrealized potential increases dramatically. In the absence of increased storage capacity, seasonal water constraints are expected to impact industry and irrigation

The present total cost of inaction on climate adaptation is estimated at around USD600 million, equivalent to 6.5% of GDP. This value is expected to more than double in real terms by 2050 to around USD1.3 billion[4]. Given the projected economic growth rates used in the analysis, however, these future costs represent a smaller fraction of future GDP.

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be more efficient to explore all options to increase the net benefits from climate-dependent processes and sectors.

[3] In energy, power production from climate-dependent renewables could potentially be increased by over USD100 million per year, but because the current economic viability of these potentials is still uncertain, these don't feature in the priority recommended investments.

[4] In comparison, the direct costs of climate change by 2050 (i.e., the decrease in production caused by climate change, plus the increase in damage and costs of prevention) are expected to be of a similar magnitude at around USD1 billion, 70% of which are incurred in the agriculture sector.

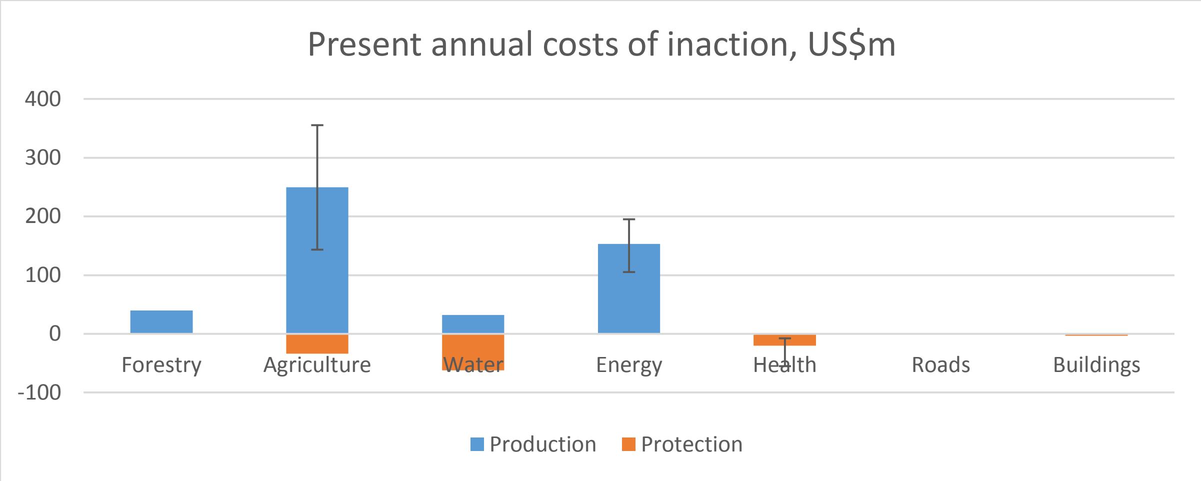
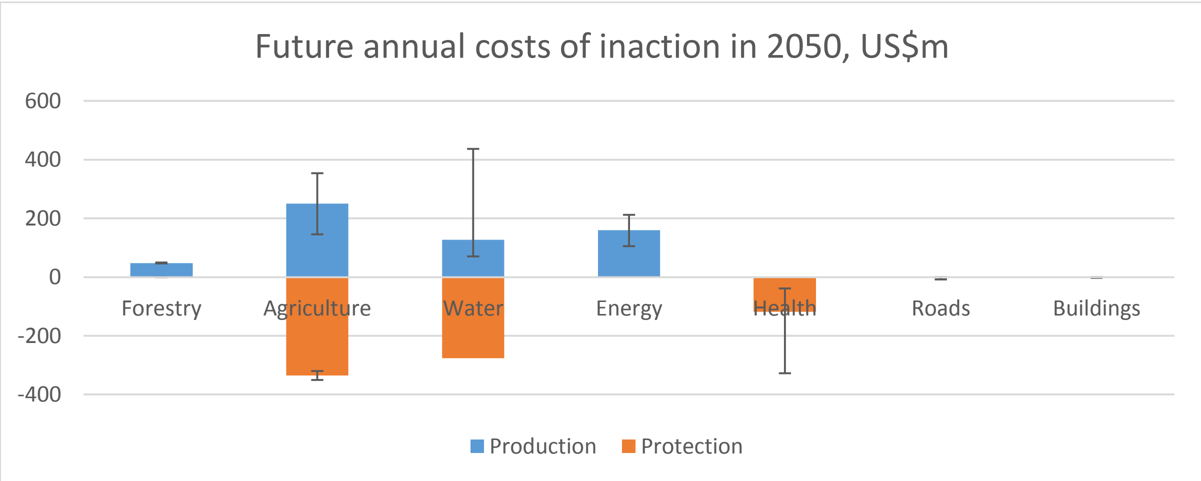


Figure 0.1: Comparison of present (above) and 2050 (below) annual costs of inaction across assessed sectors (both presented in 2015 dollars). Costs of inaction related to potential gains from enhancing climate-dependent production are represented as positive values (blue). Costs of inaction related to potential savings from reducing harmful effects of climate and the costs of protecting against them are represented as negative values (orange). The total cost of inaction in each sector is the sum of the magnitudes of both potential gains and savings (i.e. the combined height of the orange and blue bars). The confidence limits represent the range of values obtained from the climate, price, and shared socioeconomic pathways (SSP) scenarios used in the analysis. They do not encompass all sources of uncertainty.



Much of the current and predicted impacts of climate variability and climate change are concentrated in rural areas, where populations have fewer resources to cope. Agricultural production is very sensitive to weather conditions, but 98% of Moldovan farmers are small-holders (typically of 0.8-10 ha) lacking access to rural finance to improve productivity and resilience. The rural poor also have less access to domestic water supply and sanitation services (WSS) and to other infrastructure, such as roads, that will be put under increasing pressure by climate change. In total, 75.4% of urban populations have sewerage connections, compared to 1.6% in rural areas. Women are also likely to be more vulnerable to unfavorable climate conditions and future climate change, both because they already have fewer resources at their disposal, and because they are likely to be disproportionately impacted by climate. Many impoverished women are farmers, but female-headed farms are a third smaller than male-headed (0.81 vs 1.2 ha) and receive less investment (women own only 12% of existing agricultural machinery), and are more rarely connected to a water supply (55% vs 75%).

Recommended adaptation investments

A set of potential adaptation investments have been identified across the target sectors, which would reduce (although not eliminate) the costs of inaction. A little under half of the total volume of investment (USD1.85 billion of USD4.22 billion) are considered high priority for implementation in the near future (see table 0.1).

Priorities were identified based on estimated economic returns, the size of potential investments, and qualitative assessments of impact on gender and poverty. These consist of:

- Agriculture: The biggest challenges and investment opportunities are in agriculture. Rehabilitation/modernization of centralized irrigation systems and drainage infrastructure will make a major contribution to increasing current productivity and mitigating future climate impacts. These are expected to have good rates of return as long as they can be combined with successful institutional capacity-building for management of irrigation systems. Other options include small-scale on-farm irrigation systems, soil management and climate risk management technologies (e.g., anti-hail nets), and the potential for changes in crop mix towards perennial crops (i.e., grapes and fruit trees), which will be more resilient to climate change.
- Forests: Ecological rehabilitation and expansion of forests and forest belts are expected to have high returns on suitable land, and to have a high poverty and gender impact. Restoration of degraded forests and pasturelands also promotes agricultural productivity through improved watershed function and protection from harsh weather.
- Human Health: Although there is uncertainty around the scale of climate-related health impacts, modest investments in heat warning systems and public health campaigns are expected to have high returns.
- Water: Improvement in municipal supply systems to reduce losses, and building a small-scale storage reservoir on the lower Nistru River, present immediate, modest investment opportunities with high returns. In coming decades, larger-scale storage infrastructure will be needed. The ideal size and timing of these requires more analysis, and the institutional capacity to effectively manage a variety of water investments would also need to be strengthened.
- Flood Control: A substantial set of structural and non-structural measures for flood control is expected to provide substantial economic returns from the reduction of damages and loss, based on the recent work of EIB (2016).
- Disaster risk management: A set of modest investments is expected to provide key gains for public safety as well as substantial economic returns, i.e., improvements to emergency prevention and preparedness, including training facilities, new Emergency Command Centers in the North and South, and improving emergency response capabilities.

The study relied on estimating literature to estimate many of the returns, and was not able to carry out separate cost-benefit analysis under both current and future conditions. Nevertheless, proposed investments are considered robust with respect to future climate changes, i.e. they are adaptive both to current climate conditions and to future climate change. The earlier investments are made, the sooner benefits will be realized.

The only major proposed investments for which immediate implementation is not recommended are the development of larger-scale multi-purpose water storage infrastructure on the lower Nistru and Reut. The viability of these is dependent on predicted future restrictions on overall water availability.

Table 0.1: High Priority Investments - in the near to mid-term

Sector	Description on investment	Period for capital investment	Amount in USD (Mn.)	Indicative economic return (BCR or IRR)[5]	Uncertainty of benefits and costs[6]	Impact on poverty	Impact on gender
Agriculture: Water Management	Rehabilitate/Modernize Centralized Irrigation Systems	2017 to 2040	975.0	IRR: 8% to 15%	Medium	Medium	Medium
	Rehabilitation/Modernization of Drainage infrastructure in irrigated areas	2017 to 2026	120.0	IRR: 8% to 15%	Medium	Medium	Medium
	Institutional Reforms/Capacity Building	2017 to 2024	140.0	n/a	Medium	High	High
Forestry	Ecological reconstruction of forests	2020 to 2029	91.3	IRR: 3% to 14%	Medium	High	High
	Ecological reconstruction of forest belts	2020 to 2029	4.9	IRR: 4% to 15%	Medium	High	High
Health	Heat Health Warning System	2017+	0.4[7]	Current BCR: 3.1 to 170 2050 BCR: 9.9 to 920	High	Medium	Medium
Water Supply	Improving Municipal and Industrial Water System Efficiency by 10% Reduction in Losses	2017+	2.8-5.5	BCR: 61 to 70	Low	Medium	Medium
	Water Storage in Lower Nistru (100MCM)	2030+?	18.4	BCR: 2.6 to 6.4	Low	Medium	Medium
	Water Storage in Reut (1MCM)	2020	0.3	BCR: 20 to 59	Low	Low	Medium
Flood Prevention	Structural Measures	2020-2040	360.8	BCR: 2.1	Medium	Unknown	Unknown
	Non-Structural Measures	2020-2040	136.6	BCR: 5.6	Medium	Unknown	Unknown
WSS	Rehabilitation of existing and construction of new WSS infrastructures	2020-2040	409 [350-439]	BCR: 2.5-3.2	Medium	High	Medium
Disaster Response	Improved training facilities Creation of Emergency Command Centres in	2020	11	BCR: 2.1 to 4.1	Medium	Medium	Medium

[5] In several cases, the benefit-cost analysis relied on values in the literature. Therefore the analysis could not be fully standardized and in some cases the results are reported as benefit-cost ratios, and in others as internal rates of return.

[6] Ratings are given here for the significance of uncertainty of benefits for each investment. Red = high uncertainty, amber = medium uncertainty, and green= low uncertainty. A discussion of the basis of these ratings for each sector is given in the section “Uncertainty in the Analysis and Critical Knowledge Gaps” of this Executive Summary.

[7] Costs incurred in years of a heatwave.

Sector	Description on investment	Period for capital investment	Amount in USD (Mn.)	Indicative economic return (BCR or IRR)[5]	Uncertainty of benefits and costs[6]	Impact on poverty	Impact on gender
Management	North and South Improving emergency response capabilities						

There is a high degree of uncertainty around current climate impacts (i.e., how bio-physical processes respond to variation in climate parameters) and around the pricing of non-market goods. Extrapolating several decades into the future greatly exacerbates the uncertainty in the study, both in terms of future climate projections, but even more profoundly in the uncertainty around future socio-economic conditions, i.e., demand and prices for goods and services, availability of alternate technologies, etc. The most important knowledge gaps, and therefore priorities for investment in additional studies, are summarized as follows, in approximate order of importance:

1. The energy sector analysis lacked data on potential costs savings related to thermal efficiency of buildings. There could be very large opportunities to reduce energy expenditure on heating and cooling of living spaces. Under the *cost of inaction* concept, these would qualify as potential savings in the management of current adverse climate effects, whether or not domestic energy demand will be impacted by future climate change (cursory analysis suggests there perhaps won't be any overall increase).
2. Agriculture potentials have only been approximately characterized, and effects of future climate change on agricultural production remain imprecisely known. Given the importance of the sector for adaptation, additional work is recommended.
3. The optimal scale and timing of water storage investments to address future shortages remains to be determined.
4. Data on damage and losses from extreme weather is generally incomplete. More systematic reporting systems, including impacts of smaller-scale events, such as hailstorms and frosts, would improve understanding of the scale of the losses, and therefore the extent of investment in mitigation, that would be justified.
5. The analysis of maintenance costs for roads and buildings was based on generalized models for international construction standards. These should to be 'ground-truthed' against the actual construction standards and maintenance practices in use in Moldova.

1 Introduction & rationale

1.1 Background

Despite a sharp decline in poverty in the 2000s, Moldova remains one of the poorest countries in Europe. Although landlocked and therefore having no exposure to sea-level rise, Moldova ranks as the most climate vulnerable country in Europe, according to the assessment by a respected climate assessment agency, ND-GAIN[8]. In 2007, the average annual losses from climate-related disaster losses in Moldova were estimated at over USD60m per year. In the same year, a severe drought occurred which was later assessed to have caused around USD1 billion of damage and losses. Severe floods and droughts have been occurring every couple years in recent times.

Temperature and rainfall have increased in Moldova over the last century. Climate models predict further mean temperature rises, but are uncertain with regard to precipitation, which may show either a slight increase or significant decline. Even under scenarios with a slight increase in precipitation, water availability would decrease due to increase temperatures and rates of evapotranspiration. Rainfall will also become more variable and extreme events more common.

A significant body of work has already been carried out on climate impacts and adaptation in Moldova. As a result, the general issues and vulnerabilities are fairly well characterized, although typically not in quantitative terms:

- In 2007, the World Bank collated data on natural disasters, and made a rough calculation of their cost to the national economy. Natural hazards were estimated to cause annual losses of 3.5-7 per cent of Moldova's GDP – losses that were mostly in the agricultural sector.
- UNDP's 2010 Human Development Report focused on climate adaptation, and included a broad review of the vulnerabilities across key sectors, including agriculture and water resources.
- In 2012, the World Bank completed a quantitative analysis of future climate-change impacts in the agriculture sector, including effects on crop productivity and demand for water resources. The cost-benefit analysis of some adaptation options took future climate conditions into account. This study was the precursor to the work presented here on adaptation options in agriculture. The World Bank has also piloted climate resilient agricultural practices through the Agriculture Competitiveness Project.
- In 2014, the Government of Moldova, through the Ministry of Environment and with support of UNDP and the government of Austria, developed and approved a National Climate Change Adaptation Strategy, which re-iterated much of the earlier information on vulnerabilities and needs, and included an initial action plan to 2020. The cost estimate for the action plan was roughly USD155m, but specific investments and costs were not very clearly elaborated, nor the allocations between sectors explained – e.g. two-thirds of the entire budget was for energy investments, 68 times greater than the amount indicated for agriculture sector investments, despite the paramount importance of agriculture to the economy and to rural vulnerability.

[8] Notre Dame Global Adaptation Index - http://index.gain.org/

- The UNDP / Ministry of Environment National Adaptation Planning (NAP) project has also been deeply engaged in assessing institutional and policy aspects of climate change. They have recently conducted an institutional capacity assessment, and are currently preparing adaptation strategies for the forest and health sectors, as well as policy reviews for the energy and transport sectors.
- Some work on irrigation investment needs and integrated water resources management for the two major rivers running through Moldova (the Nistru and the Prut) has recently been conducted, largely by MCC, who have rehabilitated 10 irrigation schemes, as well as conducting feasibility studies for several others. The EIB also has a TA underway to map flood risks and assess infrastructure investment needs for their management.

The National Climate Change Adaptation Strategy identified 6 sectors at particular risk from climate change. Expected climate issues within those sectors are summarized as follows:

Forests
Moldovan forests, the best-preserved ecosystems compared to other natural remnants (e.g. wetlands, steppes), are already fragmented and stressed, and climate-related changes in species composition are being observed. Climate change is expected to have substantial negative impacts on forests, especially in the southern and eastern parts of Moldova. It is expected to reduce the productivity of natural forests and to change pathology patterns. Changes in the vitality of forests has a cross-sectoral impact on agriculture and land management as well.

Agriculture
Climate change could seriously undermine Moldova's food security, as shown by the severe drought of 2007, which worsened both the overall quantity and quality of food available to rural inhabitants. It is expected to significantly reduce the productivity of most current crops in Moldova (although cereals are more severely impacted than tree crops) before even accounting for the impacts of extreme events, which include hailstorms and late frosts (icing), as well as major floods and droughts, or changes in patterns of disease and pests. Climate change with changing rain patterns may also worsen the challenges of land management and increase such erosion events as landslides, etc. Even though climate change can induce some positive changes, the overall balance of the climate change effects projected for the next 100 years is not favourable for Moldovan agriculture.

Water Resources
Utilization of water resources is already much lower in Moldova than during Soviet times, and potable water supply is a problem in many rural areas owing to decreased ground water level and its quality. Despite low levels of current use, water availability is expected to fall below total demand within a couple of decades, and the south of the country could experience a one to two-thirds reduction in resources by the 2080s. The most populated and economically important regions are the most vulnerable to expected climate change. Some of these regions are already facing water shortages. Addressing deficits in these regions will be critical for supporting a sustainable economic recovery. Due to climate change, Moldova is expected to experience increasing frequency of short-term water oversupply, particularly in the form of flash floods, as well as seasonal droughts.

Energy
Climate change is likely to affect the energy distribution infrastructure, patterns of demand and energy production capacities. Infrastructure may suffer as a result of more frequent and more violent extreme weather events, damaging supply grids, while growing demand in the summertime could cause transmission lines to sag. The patterns of demand will change, shifting peak energy consumption from the winter to the summer. Additionally, climate change could potentially affect

the country's abilty to reduce energy imports[9], through reducing the potentials for renewable sources, such as hydropower, solar, biomass and wind.

[9] Moldova currently imports 95% of its non-wood fuel energy

Transport
Climate change will have several effects on the transport sector. First, lasting heat waves can worsen or even destroy the asphalt pavement of national roads. Second, high temperatures during summertime can cause deformation of railroad lines, accelerate the physical wear-out of metal parts in bridges and even cause thermal deformation. Moreover, higher temperatures may require the use of more heat-resistant engines. Still more critical, climate change is set to significantly constrain the development of riverine transport, if water levels are lowered. Besides higher temperatures, extreme weather events can also have a significant impact on transportation, both in urban and rural areas.

Health
The health effects of climate change will include increases in heat-related ailments (including cardio-vascular disease), transmission of gastro-intestinal diseases, air pollution and allergies, as well as higher numbers of casualties from disasters.

1.2 Approach, methodology & terminology

The goal of this study was to apply a consistent and repeatable analytical framework across the 6 target sectors to assess and compare (i) the size of the climate adaptation challenge in economic terms, and (ii) adaptation investment opportunities and returns. For (i), the study assessed the costs of failing to be better adapted to the prevailing climate conditions. These opportunity costs, referred to as the ***cost of inaction***, included both the costs of failing to fully protect against the negative impacts of climate (the cost of inadequate or no protection), as well as the costs of failing to take full advantage of climate-dependent production opportunities (the value of unrealized potential production). The costs of inaction are expressed as expected annual values – i.e., this is a flow rather than a stock concept.

Climate-dependent production is considered to include primary production that relies directly on climate conditions (i.e., ambient temperature, water, sunlight or wind), effectively agriculture & forestry (i.e., production processes depending directly on natural photosynthesis), water services and weather-based renewable energy source (i.e., solar and wind, in addition to hydropower). Unrealized climate-dependent potential production is any incremental production above and beyond current output that is realistically attainable under the prevailing climate conditions.

The cost of inadequate protection is estimated as the sum of (i) the value of physical damages and losses caused by climate-related events (e.g., flood damage, crop losses due to drought or climate-related disease, etc.), and (ii) avoidable defensive expenditures (i.e., expenditures on preventing climate-related damage or harm that could be avoided through adoption of better mitigation strategies). Unavoidable defensive expenditures (e.g., the cost of a flood defence system that represents the most cost-effective option available) are not included within the costs of inaction, because the intention is to assess the opportunity cost of not implementing improved protection or mitigation.

Previous work on the economics of adaptation within the World Bank has tended to evaluate the costs of future climate change, i.e., any losses in production or increases in damage and related costs over future decades, in comparison to a hypothetical no-climate-change scenario. This approach has a number of limitations, however:

- It is based on the concept of *additionality* – i.e., the precept that climate change adaptation should be distinct from and incremental to normal economic development, which is linked to the desire of donors to ensure that funding for climate change adaptation is distinct from and additional to regular development support. In practice, however, the distinction

between adaptation and development is frequently artificial. Irrigation investments, for example, achieve both, and in under-developed countries development is often the best form of adaptation. Practitioners are increasingly aiming to circumvent this distinction by referring to *climate-smart development*.

- It tends to focus attention on a limited set of interventions, i.e., those related to reducing damage or losses, as opposed to those that enhance production, regardless of which is more cost-effective.
- Its assessment for any given point in time is predicated on a past climate baseline and counterfactual no-climate-change scenario. It is not therefore designed to assess whether a sector or system is well adapted to current climate conditions, but rather to limit the disruptions associated with future climate change.

The present study is primarily focused on identifying current climate adaptation opportunities, especially the most cost-effective interventions that will improve performance of climate-dependent or climate-affected sectors, yet it is not constrained by externally imposed additionality requirements. It has therefore elected to assess the costs of inaction as a basis for understanding the adaptation (or climate-smart development) opportunities in the targeted sectors. However:

1. The impacts of ongoing and future climate change remain of interest. Costs of inaction were assessed for the mid-term future (2050) as well as the present, in order to understand how climate challenges will change and their influence on the selection on adaptation investments.
2. As the costs of inaction is a new concept, we have also assessed a more traditional measure of the costs of climate change. This evaluates any decrease in production and increase in damages or defensive expenditures between 2015 and 2050 as a result of climate change. As for the cost of inaction, it is expressed as an expected annual cost.

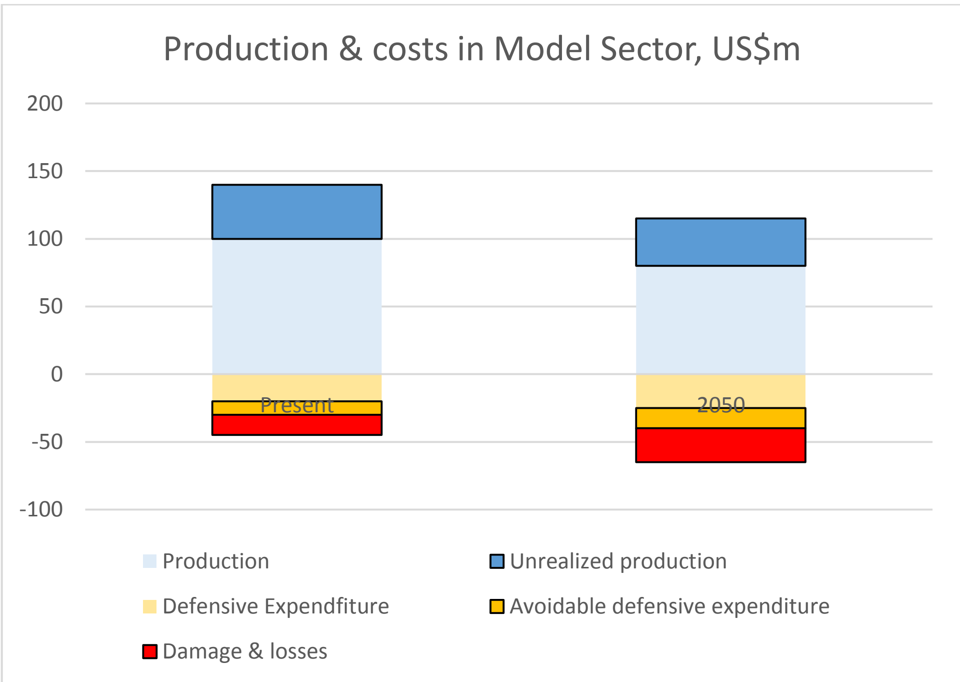


Figure 1.1: Climate-related annual production and impacts illustrated for a hypothetical sector for the present and 2050. Climate-dependent production (actual and potential) are shown as positive values, and

costs associated with climate-related physical damage and losses are shown as negative values. The costs of inaction are defined as the sum of the magnitudes of unrealized potential production, damage & losses, and avoidable defensive expenditures (i.e., the parts of the columns with a black border). In this hypothetical case, the cost of inaction increases by 2050, as although unrealized production is little changed, damage & losses and avoidable defensive expenditures have increased. Note that actual production and non-avoidable defensive expenditures do not contribute to the costs of inaction, but are shown for completeness. They do, however, contribute to the cost of climate change, which is considered to be the sum of the (climate-driven) decrease in actual production and increase in damage & losses and all defensive expenditure up to 2050.

Costs of inaction have been calculated for the present time (nominally 2015) and for 2050 within each of the target sectors: forestry, agriculture, health, energy, water, and infrastructure (roads and buildings). The results for each sector are presented in a standard graphical format, as illustrated in figure 1.1.

There is some overlap between the 6 sectors, and therefore the assignment of specific topics to individual sectors was to some extent arbitrary, although guided by the general principle of allocating to the sector in which the related adaptation investments would lie. For instance, irrigation is included under agriculture, whereas flood damages and mitigation are included under the water sector. General disaster preparedness and response is a cross-cutting theme, but in this study was considered under the health sector due to the common link to emergency services.

The study drew primarily upon existing national and comparable international datasets, but some new modelling of climate impacts and processes was also included. The latter consisted of:

- Modelling the availability of water resources under future climate changes by updating an earlier model with more data on water abstraction points.
- Modelling the costs of maintaining Moldova's road network and building stock in the face of changing climate, and the relative benefits of reactive maintenance (i.e., repairing damage as it happens, using construction standards based on historical climate patterns) versus proactive maintenance (i.e., upgrading design standards based on expected climate change).

Future (i.e., 2050) costs are expressed in terms of 2015 dollars without discounting.

1.3 Climate and socio-economic scenarios used for future projections

In order to undertake climate-related economic analysis for future time-points, both climate and socio-economic scenarios have to be taken into account. To account for socioeconomic development, in this study we have used the so-called Shared Socioeconomic Pathways (SSPs) available at IIASA data base under the label OECD v9_130325[10]. These scenarios are part of the new framework adopted by the climate research community for integrated assessment of future climate impacts. They are based around different storylines of how the world could develop. The storylines[11] are as follows:

- SSP1 – Sustainability – a world making good progress towards sustainability and development goals. In this world there is reduced resource intensity and fossil fuel

[10] https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about#intro

[11] For more information on the storylines see https://tntcat.iiasa.ac.at/SspDb/static/download/ssp_suplementary%20text.pdf

dependency. There is rapid development of low-income economies and reduction in inequality.

- SSP2 – Middle of the Road – a world where current trends continue, with some progress towards development goals. Uneven development of low-income countries. There are weak global institutions and achievement of Millennium Development Goals is delayed by several decades;
- SSP3 – Fragmentation – a world characterized by regionalization, with little progress in addressing sustainability concerns. High population growth globally.
- SSP4 – Inequality – a world with high levels of inequality both between and within countries.
- SSP5 – Conventional development – in this world, conventional development oriented towards economic growth is stressed as the solution to social and economic problems. Under this scenario, there is an energy system dominated by fossil fuels and there are high greenhouse gas emissions.

Quantitative estimates of these pathways include different assumptions regarding population, economic development, land use or energy use. Each SSP has a single population and urbanization scenario while for GDP, three alternative interpretations are provided. In our case we have only focused in OECD GDP estimates. The GDP and population data for each scenario are included in Tables 2-11-1 and 2-11-2 and in figures 1.2 and 1.3 below. All the scenarios involve optimistic projections for GDP, but pessimistic projections of population (i.e., significant population decrease).

Table 1.1: GDP PPP projections under SSP scenarios (billion USD2005/yr)

Scenario	2005	2010	2020	2030	2040	2050
SSP1_v9_130325	8.492	9.951	15.745	27.087	42.874	55.235
SSP2_v9_130325	8.492	9.951	15.611	23.964	33.148	40.618
SSP3_v9_130325	8.492	9.951	15.896	23.508	29.962	34.834
SSP4_v9_130325	8.492	9.951	15.505	23.707	32.801	39.880
SSP5_v9_130325	8.492	9.951	15.529	27.969	45.143	57.002

Table 1.2: Population projections under SSP scenarios (million)

Scenario	2005	2010	2020	2030	2040	2050
SSP1_v9_130325	3.767	3.573	3.187	2.821	2.469	2.123
SSP2_v9_130325	3.767	3.573	3.197	2.850	2.511	2.181
SSP3_v9_130325	3.767	3.573	3.289	3.089	2.877	2.692
SSP4_v9_130325	3.767	3.573	3.178	2.791	2.411	2.045
SSP5_v9_130325	3.767	3.573	3.113	2.634	2.191	1.775

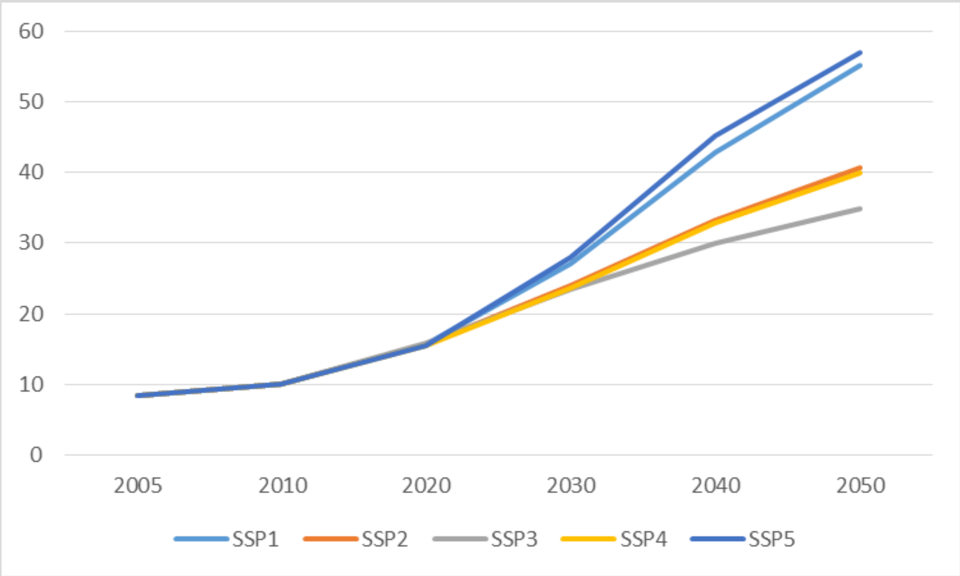


Figure 1.2 Moldovan PPP GDP projections under SSP scenarios (USDbn USD 2005)

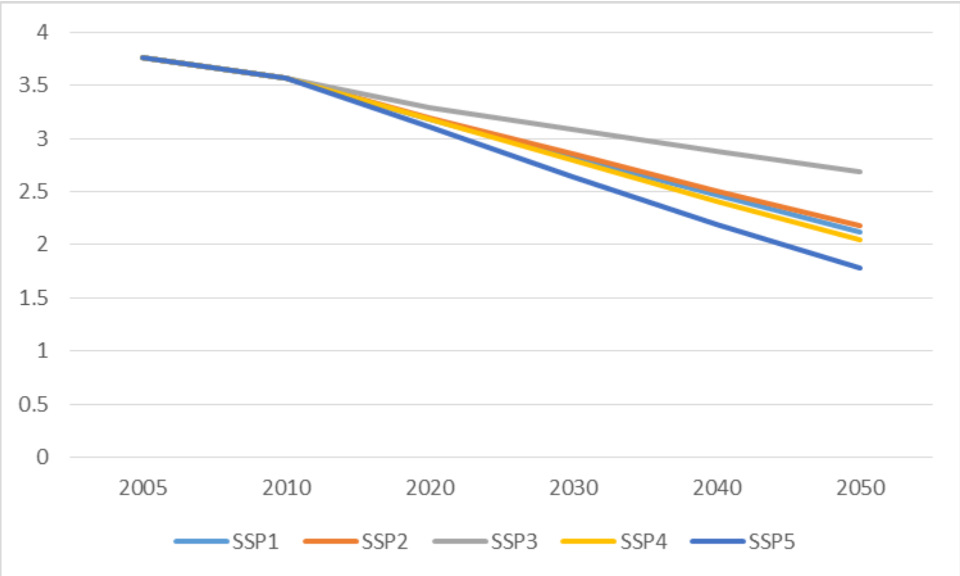


Figure 1.3 Moldovan population under SSP scenarios (million)

To account for different climate scenarios, we have followed the emissions scenarios described in the IPCC SRES, which describe four different storylines of the relationship between the forces driving emissions and their evolution. The main families are described below:

The Emissions Scenarios of the Special Report on Emissions Scenarios (SRES)

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and

social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end-use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1 and B1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Source: IPCC. https://www.ipcc.ch/ipccreports/tar/wg1/029.htm

Data limitations (i.e., frequent use of existing studies, rather than new physical models of climate-related processes) have not allowed us to be fully consistent in the use of these scenarios across all 6 sectors. Table 1.3 below shows the scenarios used for the assessment of different sectors in this report.

Table 1.3: Socio-economic and climatic scenarios used in sector analyses

Sector	SSP Scenarios Used	Emissions Scenarios Used
Forestry	SSP1, SSP3, SSP5	A1B
Agriculture	SSP1, SSP2, SSP3	A2, A1B, B1
Water	SSP1, SSP3, SSP5	A1B, A2, B1
Energy	SSP1, SSP3, SSP5	A1B, A2
Health	SSP1, SSP3, SSP5	A1B, A2, B1

Roads & buildings	--	A1B, A2

For most of the analyses, the actual climate projects under the selected emissions scenarios were based on data from Taranu et al. (2012), who state that "The model simulations for precipitation and temperature used in this study stem from 10 of the global coupled atmosphere ocean general circulation models (AOGCMs) made available by the World Climate Research Program (WCRP) Coupled Models Intercomparison Program Phase 3 (CMIP3) [14]: CSIROMk3 (Australia's Commonwealth Scientific and Industrial Research Organisation, Australia), ECHAM5-OM (Max-Planck-Institute for Meteorology, Germany), HadCM3 (UK Met. Office, UK), BCCR_BCM2.0 (Bjerknes Centre for Climate Research, Norway), CCCma_CGCM3_T63 (Canadian Center for Climate Modeling and Analysis, Canada), NIES_MIROC3.2_medres, NIES_MIROC3.2_hires (National Institute for Environmental Studies; Japan), MRI_CGCM2.3.2 (Meteorological Research Institute, Japan), NCAR_CCSM3 (National Centre for Atmospheric Research, USA), GFDL_CM2.1 (Geophysical Fluid Dynamics Laboratory, USA) model experiments for SRES A2, A1B and B1 were downloaded from: http://www.ipcc-data.org/gcm/monthly/SRES_AR4/index.html.

The new models of water availability and infrastructure were based on climate scenarios as detailed in table 1.4.

Table 1.4: Details of climate scenarios used in modelling of water availability and infrastructure costs.

THIS STUDY'S SCENARIO	GLOBAL GENERAL CIRCULATION MODEL BASIS FOR THE SCENARIO	RELEVANT IPCC SRES SCENARIO
High Impact	Centre National de Recherches Météorologiques, Coupled Model 3 (France)	A1B
Medium Impact	Center for Climate Modeling and Analysis, Coupled GCM 3.1.t63 (Canada)	A1B
Low Impact	Goddard Institute for Space Studies, ModelER (US)	A2

2 Analysis of vulnerable sectors

2.1 Forestry

2.1.1 Overview

Moldova has the lowest forest cover in Europe at 11.4% (c. 446,600 ha). Forests tend to occur in hilly areas with the majority of them located in the central part of Moldova, with slightly less in the north and even fewer in the south. The forests are mainly broadleaved - oak, ash, hornbeam, black locust and poplar being the most significant species (WB 2014, TUB 2015). According to the National General Cadaster Registry, 86.6.1% of the national forest estate is owned by the state (through the public authority, Moldsilva, and its forest units), 12.7% by Local Public Authorities (LPAs), circa 4% are properties of other state institutions (e.g. Botanical Garden, Central Authority for Waters), and private ownership is low at around 0.6%.

Based on the Ecosystem Services Approach (ESA), recent studies have identified a range of important benefits from forests in Moldova, extending beyond the direct provision of goods, such as timber, to ecosystem services, such as carbon sequestration. The forest sector's direct economic contribution is relatively small at just 0.28% to GDP in 2014, while wood products represented only 0.5% of total exports and 1.7% of total imports in 2012. However, analysis completed under the ENPI FLEG Program estimates total consumption of fuelwood in Moldova is nearly 3 times the official harvest, indicating significant volumes of illegal harvesting (WB 2014, Galupa et al. 2011)

Additionally, the forests provide critical habitat for biodiversity (GD 2015) and other essential environmental benefits such as soil protection, water regulation and carbon sequestration. Most sector analyses (WB 2014, Popa 2013, TUB 2015) highlight under-used potential in the forestry sector, especially in terms of water and soil regulation, tourism, household use of forest products and carbon sequestration. Protective forest belts have a long tradition in Moldova, being established post-1947 as shelter belts for agricultural land, riparian buffers and protection of transportation routes and reduction of soil erosion. The total extent of forest belts is 30,300 ha. The main species are black locust (36%) and walnut (38%), but there are 12 other indigenous species and 8 exotic species (Postolache 2008). There are no centralized data regarding the present status of forest belts, however different sources (Clima East 2013) indicate that many areas are affected by illegal logging, abusive and uncontrolled grazing, waste pollution or different degradation factors. Different studies (Turcanu and Platon, 2014) indicate that forest belts contribute to increased agricultural productivity.

2.1.2 Climate impacts & current costs of inaction

Forests provide a range of goods and environmental services. All primary production in the forestry sector is dependent on climatic conditions, and any steps to improve forest productivity enhance climate benefits, represent climate-smart development, and are adaptive in the broad sense defined above.

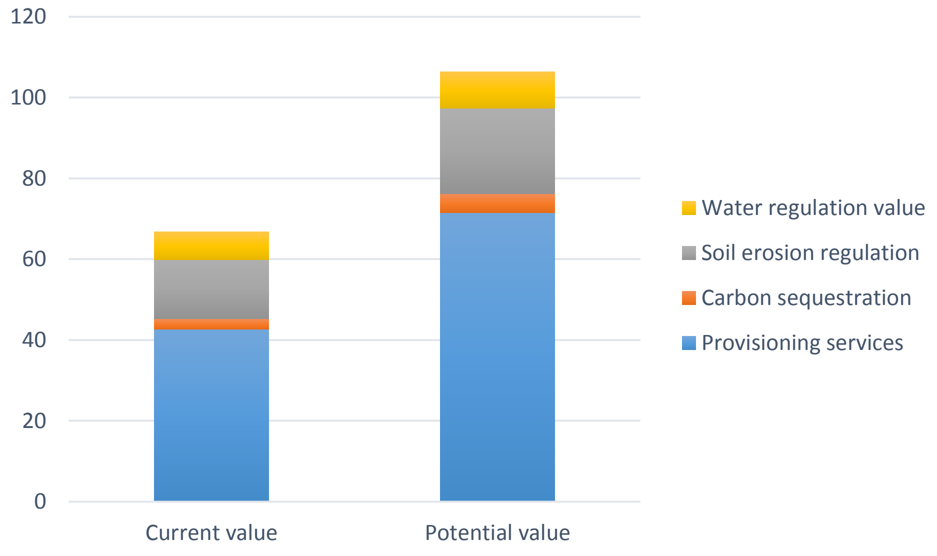
A recent study (TUB, 2015) estimated the total current economic value of Moldova's forests to be USD66.77 million. This figure includes the values of provisioning services (timber, fuelwood, NTFPs, mushrooms and game: USD42.64 million in total) and of environmental services, such as carbon sequestration (USD2.59 million, based on a price of $4.2 per ton of CO_2 eq.), soil protection (USD14.62 million, based on a rule of thumb of a 10% decrease in forest cover providing a 12% increase in soil loss), and hydrological regulation (USD6.92 million, based on a rule of thumb of a 10% increase in forest cover within a given basin leading to a 20% decrease in water treatment costs).

Currently foregone climate-dependent production was estimated on the basis of a potential value for forest services under an optimal forest management scenario consistent with national forest policies and objectives, including the Forest Sector Climate Change Adaptation Strategy (GD 2016c). The following assumptions were involved:

- Ideal forest coverage would be 15% of national territory, based on areas of degraded and unproductive land that could be reforested.
- The annual allowable cut is 40% of total annual woody biomass growth (as at present), but illegal logging is reduced to 25% of the present level.
- The distribution of tree species is optimized to local conditions, meaning a significantly higher percentage of oak stands, and degraded forests are regenerated. This results in a 10% increase in value of NTFPs produced per unit area, and a higher proportion of timber (as opposed to lower-value fuelwood) in the annual harvest (15% rather than 10%).
- Values of water regulation, soil protection, and carbon sequestration increase in accordance with the increased forest area and productivity.

The resulting optimized production is estimated at USD106.41 million, of which provisioning services account for USD71.54 million, carbon sequestration for USD4.61 million, soils protection for USD21.16, and hydrological regulation for USD9.11 million. Thus current foregone production, calculated as the difference between the potential and current value of forest ecosystems, is estimated at USD39.64 million.

Figure 2.1. Actual and potential values of forest services (USD million per annum) under current climate conditions.



Climate-related factors also cause losses in the forestry sector, but the costs are relatively minor in relation to production. Current annual damages are estimated at USD18,000 due to fire, USD177,000 due to pests, and USD219,000 from drying of trees (i.e., drought), making a total of USD414,000. It is estimated that around USD300,000 per year is also spent on pest treatments, representing current defensive expenditure, but that this figure would fall to around USD135,000 under optimal management, and therefore that USD165,000 of the spending on pest management is avoidable defensive expenditure.

2.1.3 Future costs of inaction

Future climate change will affect both the growth of tree species (eventually leading to changes in species' distributions, although this is not expected to be significant by 2050), and the frequency and extent of damages from disease, drought and fire. A range of mostly regional studies were used to assess these expected impacts, which were modelled under only one emissions scenario (A1B – being that used by the key source for tree species growth projections, Taranu 2012), but three SSP scenarios (SSP1, SSP3 & SSP5 – which had only moderate effects on the expected prices of forest services). The key impacts of climate change to 2050 are expected to be as follows:

- A decrease in availability of water resources is expected to limit growth. Different species will react differently, but native oaks should generally fare better than non-native species.
- Temperature increase, changes in precipitation and a reduction in year-round water availability are expected to lead to a 15% increase in area affected by pests, a 25% increase in area of drying, a 30% increase in fire risk, and increased soil erosion.
- The greatest impact is expected to be felt in the South (where there is already the lowest degree of forestation, at 7.7% of land area), followed by the Centre (which has the biggest surface coved with forest, 209.4 thousand ha or about 14.5% of total land area).

Foregone production in the year 2050 is calculated in a similar fashion as before, by comparing the productivity of a business-as-usual scenario (involving the current forest estate and management practices) to the same ideal forest management scenario, under future climate conditions.

Forest production in 2050 is estimated at around USD55 million (range 54.2 – 56.4 million), under business-as-usual. Moving to optimal forest management would increase production by around USD48 million (range 46.7 – 49.7 million). Damage from pests, drought and fire amount to around USD0.45 million, and another USD0.47 million is spent annually on pest control, USD0.2 million of which could be avoided under an optimal management scenario.

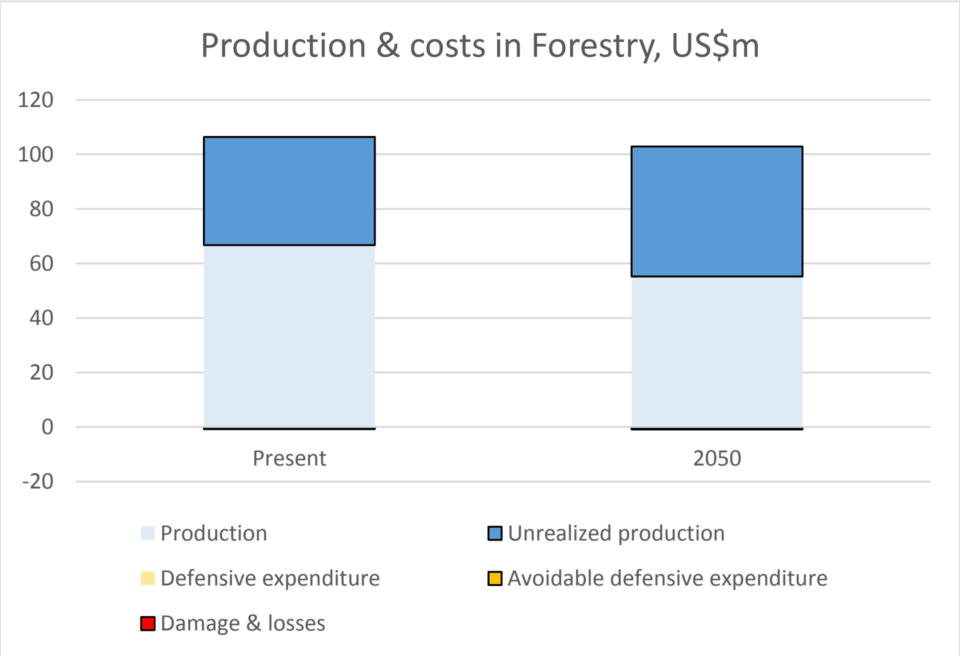


Figure 2.2: Climate-related annual production and impacts in the forestry sector for the present and 2050. Unrealized production increases (representing an increase in the cost of inaction) as actual production falls by 2050. Defensive expenditure and damage & losses also increase, but are too small to be shown clearly.

The impact of future climate change means that future production under the business-as-usual scenario is significantly lower than current production, but the potential benefits of moving to optimal forest management (i.e., the foregone production) are higher, mostly due to the fact that the optimal management scenario involves greater representation of native oaks, which are better adapted to future climate conditions. Nevertheless, total potential production is slightly lower in the future. The annual costs of climate change by 2050 would be represented by the loss of production under business-as-usual, plus the increase in damage and defensive expenditure. This comes to around USD12 million per annum.

2.1.4 Adaptation investments

Potential adaptation investments for the forestry sector are implied in the ideal management scenarios used to calculate the production deficits, and essentially consist of both ecological reconstruction of the present forest resources and the expansion of forest vegetation. Stable complex forests are less sensitive to damages caused by forest fires and pests and are less affected by drought. Their regulating services in terms of water and soil erosion protection, and their productivity, are increased. Included in the options are the rehabilitation and expansion of shelter belts and riparian buffers, which provide elevated environmental services in terms of protecting crops and water sources. There are also needs for research and action to identify and propagate resilient tree varieties, and for improved management of risks from intensifying pests and forest fires.

The cost-benefit analysis (CBA) of investment options was carried out based on the mapping of potential intervention areas and estimates of the multiannual costs by ICAS (2016b). The costs include removal of present forest vegetation (for ecological reconstruction), preparing the land, value of materials and works (human and machines) for planting and maintaining the plantations until they become forest, costs for forest management (thinning, sanitary cuttings, forest management planning, guarding, harvesting, etc.).

A summary of the analysis is given in Table 2.2.3. Uncertainty of benefits has been given a preliminary rating of moderate for all options due to the following:

1. Necessity for successful implementation of the Forest Institutional Reform Strategy of Moldova (FIRSM) as a prerequisite for any significant investment initiatives in the sector - without this institutional reform to increase transparency, effectiveness, and efficiency of forest management, there is an increased risk of benefits not being realized near to their full potential.
2. All the investment effort must be accompanied by strengthening of the research and production capacity in terms of germplasm management and capacities for seedlings production and afforestation, as well as improved management of forest fires and forest pests.
3. Certain limitations imposed by the data used/valuation methodology and the assumptions made for the evaluation (e.g., prices for selling sequestered carbon, growth, productivity, and species distribution predictions).

Table 2.1. Summary of Potential Investments in Forestry

Description on investment	Period for implementation	Amount in USD (Mn.)	Indicative IRR[12]	Uncertainty of Benefits	Impact on poverty	Impact on gender	Overall Priority
Ecological reconstruction of forests	2020 to 2029	91.3	2.9% to 13.5%	Moderate	High	High	High
Ecological reconstruction of forest belts	2020 to 2029	4.9	4.1% to 14.7%	Moderate	High	High	High
New forest belts	2025 to 2034	56.5	5.3% to 10.4%	Moderate	High	High	Medium
Afforestation of degraded land	2030 to 2044	199.7	5.1% to 6.5%	Moderate	High	High	Medium
Afforestation of degraded pastures	2030 to 2044	28.3	3.6% to 9.3%	Moderate	High	High	Medium

Rates of return depend on quality of forest areas and species used (see annexes for further details), and tend to be higher for forest belts (i.e., shelter belts and riparian buffers) due to the enhanced environmental services these provide for crop production and hydrological regulation.

The high ratings for impact on poverty reflect the importance of forest services for rural populations (Popa et al. 2014), including for income and consumption of non-timber forest products and wood resources (pole/logs, timber, fuelwood, and tree branches). In poor rural communities, the lower the household income, the higher the dependence on the forest. Gender impact is also high as all family members are involved in forest product collection, preparation, and selling activities.

2.1.5 Constraints & uncertainty

For the forestry sector, key sources of uncertainty are:

- Estimation of potential ecosystem services values for forest. For the provisioning services the estimates are quite precise, based on the estimated annual allowable cut provided by the forest management plans, with variations raging by 10-15 %. The demand for wood is not expected to decrease, and therefore uncertainty only arises due to price evolution. Regarding the regulating ecosystem services, uncertainty is greater as estimates were based on rules of thumb developed from studies in other countries with more or less similar conditions. Values of carbon sequestration ecosystem services are based on assumptions regarding the C transaction price (USD4.2 per ton CO2 eq.) and the availability of markets for sequestered carbon, but only contribute around 5% of the total value of forest production.
- Climate change impacts on forests. Available studies are limited and only provided a basis to include one emissions scenario, A1B, in the assessment. However, predicted growth rate changes for the period up to 2050 are not very dramatic and the change in species

[12] Inserted here is an indicative IRR range. A range is necessary due to variation between species included in the investment and due to site conditions.

distribution is limited for such a short period (considering the average production cycle for oak-based forests is around 100 years).

- Impacts of pests and forest fires. Available studies are limited so estimates are extrapolated from damages recorded in the last 5 years
- Investment benefits. An important source of uncertainty is how successfully the Forest Institutional Reform Strategy of Moldova (FIRSM) will be implemented. Without institutional reform to increase transparency, effectiveness, and efficiency of forest management, there is an increased risk of benefits not being realized near to their full potential.

2.2 Agriculture

2.2.1 Overview

Agriculture has traditionally played a key role in Moldova's economy, shaping the country's landscape. The prevailing climate and quality of soils have historically determined agricultural specialization, especially in high-value crops such as fruits and vegetables. The sector represented about 13 percent of Moldova's GDP in 2014, with a value of about MDL 14.5 billion (about USD 1.05 billion). About 26 percent of the active population were engaged in some form of agriculture in 2013. In 2013, agricultural land accounted for about 75 percent of total land area, of which 73 percent was arable, 12 percent under permanent crops, and 14 percent pastures.

The nature and practice of agriculture in Moldova have changed greatly since the end of the Soviet era, with land devoted to high-value crops reduced by half, loss of most irrigated areas, and an overall decrease in land productivity. This is in part related to a lack of investment and credit in the sector, resulting in application of low-yield technologies and in reductions of agricultural inputs, especially fertilizers and other agricultural chemicals. The agricultural sector receives only 9.7 percent of capital investments in the country, with foreign investments representing only about 4 percent of the total in 2013 (Moroz et al, 2015).

Crop cultivation made up about 66 percent of the total value of agriculture in 2013. Crop selection has become less diversified in recent years, with cereals and industrial crops occupying about 90 percent of sown areas. The makeup of total crop production has been volatile recently, partly as a result of extreme weather events.

Animal production occupied about a third of agricultural land in 2013, a share that has declined since the 1990s. In recent years, many corporate farms have ceased milk and meat production. Thus households and small-scale farms currently account for a high proportion of livestock holdings and livestock product output. This includes 86 percent of beef production, 70 percent of pork production, 93 percent of sheep and goat meat production, about 50 percent of poultry meat production, about 97 percent of total milk production, and 61 percent of egg production in 2013. The poultry sector retains intensive production, including over 40 industrial enterprises.

Agrofood exports constituted about 45 percent of total exports from Moldova in 2015. The wine industry represented 7 percent of its exports worldwide in 2015, employing more than 200,000 citizens. Exports of wine amounted to more than USD160 million.

Factors contributing to low productivity in the agriculture sector in Moldova can be summarized as follows (Moroz et al 2015; World Bank 2012):

- Water supply. This includes: limited access to large-scale irrigation and small-scale storage reservoirs and to technologies making the most efficient use of irrigation water (e.g., drip irrigation); sub-optimal use of local water sources; and inefficient or limited drainage infrastructure.

- Low rate of adoption of modern agronomic practices and technologies. This includes land management (changes in planting patterns, crop rotation, and inter-cropping), improving varieties, optimizing fertilizer application, introducing alternative crops, and changing the distribution of existing crops.
- Unsustainable land management, which contributes to land degradation and has resulted in significant soil erosion, loss of organic matter, and soil pollution. In 2014 942,422 ha (about 37 percent) of agricultural land was classed as degraded with about 13 percent of that total heavily eroded and about 29 percent moderately eroded. The total has increased by about 7 per cent since 2008. It is estimated that the annual costs of foregone agricultural production due to erosion are USD 40 million USD (from World Bank, 2007), with a range of USD 60 to 70 million per year for financial losses from soil erosion given in World Bank (2012b). The fertile chernozem soil types are among the most vulnerable to certain climate risks (including storms, droughts). Forecasts for changes in soil quality under climate change conditions imply a reduction and limitation of productive potential, including through increased erosion (Moroz et al, 2015).
- High vulnerability to extreme climate events coupled with inadequate use of protective measures, such as: moving vegetable production to greenhouses; applying mulch or other plant protection to soil; using hail nets; and distributing timely meteorological information to farmers.
- Insufficient provision of extension services for a number of technical options, such as cultivation of alternative crop varieties.
- Inadequate provision of agricultural market information to assist farmers in decision-making.
- Institutional and market issues, such as limited access to finance, distortions in agricultural input and output markets, and weak public services.

2.2.2 Climate impacts & current costs of inaction

All primary productivity in agriculture, from both crops and livestock, is dependent on climate, and Moldova is considered to have a production deficit in comparison to countries with similar conditions but significantly higher agricultural productivity.

Current foregone production of crops was assessed by comparing Moldovan yields with those of neighbouring countries based on FAO data. Models of potential agricultural yields undertaken by the International Institute for Applied Systems Analysis (IIASA, 2015) were also reviewed. The FAO data show a consistently lower yield of cereal, vegetables, and fruit for Moldova than for Romania, the European average, and Eastern Europe. FAO livestock productivity figures for Moldova were similarly compared with regional neighbours.

Table 2.2: Comparison of Yield Gaps (IIASA simulations and international comparisons)

Calculated yields based on IIASA simulations[13] (tonnes/hectare)				FAO data on regional yields[14] (tonnes/hectare)			
Crop	**Current yield**	**Potential (no irrig.)**	**Potential w/ irrig.**	**Moldova**	**Romania**	**Europe**	**Eastern Europe**
Barley	1.5	4.6	4.7	1.84	2.79	3.38	2.41
Maize	3.9	8.6	12.9	3.18	4.19	6.26	5.07
Millet	1.2	2.4	3.0	n/a			
Potato	22.2	40.5	44.3	10.39	15.23	19.56	15.13
Rape	1.0	2.3	2.7	1.29	1.88	2.70	2.04
Rye	1.6	4.6	4.7	n/a			
Soya	1.5	2.9	4.3	1.51	2.08	1.82	1.60
Sugar beet	23.0	57.2	122.4	27.09	37.30	53.66	38.51
Sunflower	1.6	4.3	5.5	1.55	1.72	1.60	1.56
Wheat	2.1	6.5	9.3	2.44	3.06	3.74	2.81

Table 2.3: Estimated potential livestock production in Moldova assuming average yields of Romania, Europe and Eastern Europe (1000 tonnes)

	Moldova actual production	Romania yield	Europe yield	Eastern Europe yield
Beef	9.5	11.8	18.0	13.8
Sheep Meat	2.1	1.4	2.0	2.0
Pork	64.5	64.2	68.5	66.6
Chicken meat	38.8	41.6	42.6	44.2
Milk	524.6	429.0	2294.1	2082.8
Eggs (Hens)	34.8	19.2	36.6	33.1

Source: Own calculations based on FAOstat data

Current primary agricultural production is around USD710 million per annum[15], including USD619 million from crops and USD91 million from livestock. Based on the comparisons with international data, current foregone production is around USD250 million (range 145-335 million, based on the broad range amongst international comparators), including USD235 million in crops and USD15 million in livestock.

Extreme weather events have high impacts on agricultural output in Moldova. Figure 2.3 illustrates recent trends in gross agricultural production showing high fluctuations during years of extreme

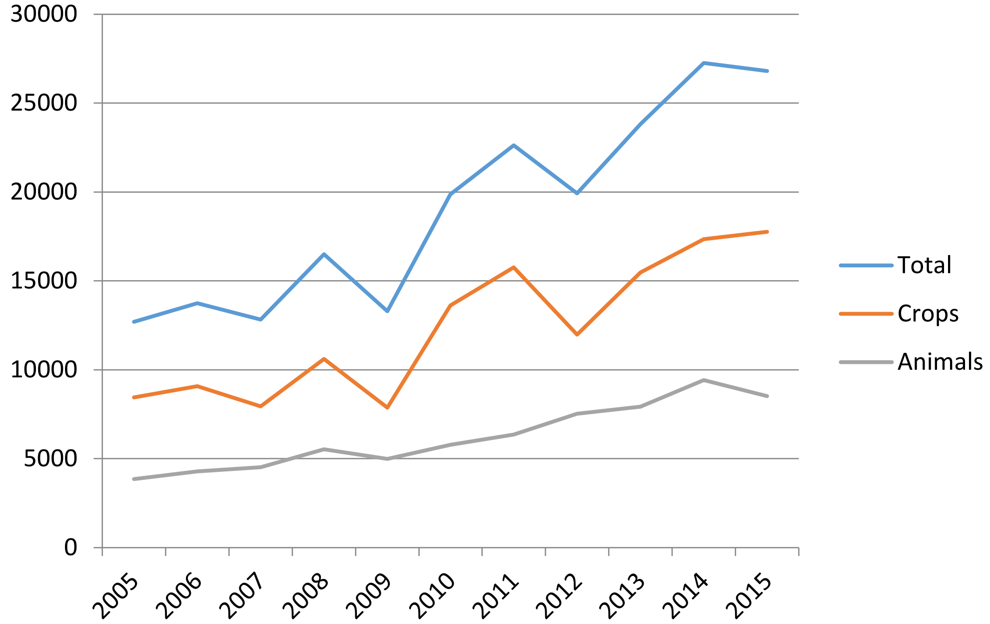
[13] Own calculation of average actual yield simulation, yield potentials, and yield gaps based on data from (IIASA, 2015) for administrative districts.

[14] Own calculations based on FAOstat data.

[15] Based on those crops and livestock for which the climate analysis could be conducted.

weather events, in particular for crop production in the drought years of 2009 and 2012. Livestock production shows much less volatility during this period. The MAFI report for the 2012 drought suggested that the crop failures greatly exceed drought impacts on the livestock sector, but livestock are still affected by events that impact on the availability of feed (particularly fodder for winterisation), and extreme events can also facilitate outbreaks and propagation of diseases.

Figure 2-3: Moldovan agricultural production in recent years: 2015 prices; million lei



Extreme events impacting the agriculture sector include:

- *Droughts* Estimates show droughts as the most significant extreme event in terms of losses to agriculture. Regular droughts have a significant impact on agricultural production and exceptional droughts can be catastrophic. During the period 1990 to 2014, there were ten years with droughts, with severe droughts in 2007 and 2012 (Government of RM, 2015). The drought in 2007 has been estimated as resulting in USD 1.2 billion in losses (UNDP, 2012).
- *Floods* Estimates of agricultural losses from floods are lower than for droughts. Annual losses are estimated at about 5 million USD (World Bank 2007).
- *Other severe weather events* Summer storm events include torrential rains, hail, and heavy winds, sometimes in combination (and available reporting of damages sometimes combines these phenomena). There are limited data on damages caused by frosts, although frost is known to be a common problem for farmers in spring and autumn. For example, a failure in the winter wheat harvest in 2002/3 is attributed to an early frost in the autumn of 2002 combined with a drought (World Bank, 2007).
- *Climate-related diseases* Agricultural plant health issues include cereal and dry bean pests, western corn rootworm threat, and Mediterranean fruit fly. However, there is little quantitative information on losses or their relationship to climate change.

Based on the estimates given in the World Bank (2007) report and estimates using the SDES database, a tentative estimate of average annualised losses due to weather events (drought, flood, hail, rain, wind, frost and landslides) is USD 34 million per year. However, this is likely to be very conservative as the largest drought losses occurred after 2007, and there is little information

available on a range of more frequent, smaller-scale events. Defensive expenditures (i.e., the costs of measures taken to avoid losses from pests and extreme events) were not assessed.

2.2.3 Future costs of inaction

Estimates of the impacts of climate change on yields of key crops in Moldova (wheat, maize, sunflower, sugar beet, and grapes) for the A2, A1B and B2 emissions scenarios (to 2020 and 2050) are from the study by Taranu (2014). These show significant negative impacts on wheat and maize yields in the medium- and long-term, and on sunflower and sugar beet from the medium-term, with positive impacts on grapes in the short- and medium-term (Table 2-3-1). It is assumed that in the absence of climate change there would be an underlying average 1% growth in yields per year. Values of projected harvests were calculated for SSP1, SSP2 and SSP3 (SSP4 and SSP5 were not available), based on estimated crop price changes in Europe[16] (in Frank et al. 2014, from GLOBIOM model). The most significant cumulative losses in comparison to a no-climate change scenario are for maize and wheat, followed by sunflower. Grape is the only crop showing increases in total harvest and value under climate change scenarios.

Table 2.4. Summary of average future yield change projections in Republic of Moldova (%)[17]

	2020s			2050s			2080s		
Crop	**A2**	**A1B**	**B1**	**A2**	**A1B**	**B1**	**A2**	**A1B**	**B1**
Wheat	-9	-13	-12	-34	-41	-27	-71	-56	-38
Maize	-9	-16	-14	-48	-52	-35		-74	-49
Sunflower	4	2	3	-10	-13	-7	-33	-21	-11
Sugar Beet	0	-5	-1	-10	-12	-5	-20	-19	-10
Grapes	17	13	14	6	3	6	-9	-1	4

Source: Taranu (2014)

Estimates of impacts on key livestock products were made under emissions scenarios A2, A1B and B2 from Taranu (2014). Losses are based on increased heat stress and mortality for animals, as well as on impacts to feed crops. Yield changes relative to a no-climate change scenario are summarized in Table 2.5 below. Production values were estimated in the same manner as for crops.

Overall, agricultural production is forecast to grow to USD1.006 billion by 2050 (USD877 million from crops and USD129 million from livestock), as underlying productivity improvements slightly exceed expected losses due to climate change.

[16] Use of Europe-wide price projections can be justified if one assumes greater market integration, so prices tend to converge across countries. However, projections for future population in Moldova show very large reductions, which would imply a reduced domestic demand for agricultural products, which is not reflected in the current price assumptions.

[17] These are projections of future yield changes in the Republic of Moldova (as % over 30 years) relative to 1981-2010, based on an Ensemble from 10 GCMs for SRES A2, A1B, and B1 emission scenarios.

Table 2.5: Summary of yield change projections for livestock products in Republic of Moldova (%)

	2020s			2050s		
	A2	A1B	B1	A2	A1B	B1
Milk	-7	-12	-11	-31	-34	-23
Eggs	-2	-6	-5	-20	-22	-14
Wool	-1	-2	-2	-5	-5	-4
Beef	-12	-21	-18	-56	-61	-42
Pork	-8	-14	-12	-37	-41	-28
Mutton	-3	-6	-6	-17	-18	-12
Poultry	-5	-9	-7	-22	-26	-17

Source: Taranu (2014)

The relative effect of climate change on both the actual and potential production of individual crops is assumed to be the same. Therefore the overall change in foregone production is less than that for actual production, as the crops which are least affected by climate change contribute relatively more to future output. Despite the addition of variation from differing emissions and SSP scenarios, the biggest source of uncertainty for future projections remains the original variation in estimates of production deficits for crops (see Table 2.6 below) and for livestock. Unrealized production is estimated at around USD250 million (range 145-355 million), including USD243 million in crops and USD7 million in livestock.

Table 2.6: Foregone production under Climate Change and SSPs combinations (mil. USD 2014, each cell gives range based on the original high and low estimates of yield deficits for Moldova)

Scenario	SSP1	SSP2	SSP3
A2	137.4 – 342.1	136.5 – 339.9	135.9 – 338.6
A1B	128.7 – 320.5	127.7 – 318.0	127.1 – 316.5
B1	153.8 – 383.1	153.2 – 381.6	152.8 – 380.7

Future damages and losses in the agricultural sector are expected to increase due to both an increased frequency of extreme events and an increased asset base at risk. Increased frequency of events has been estimated recently for European countries in a paper by Fischer and Knutti (2015), while the value of the future asset base is assumed to be proportional to GDP[18], which in turn is based on the three SSP scenarios. The 2050 estimate of expected annual damages and losses is around USD335 million (range 320 – 350 million; see Table 2.7).

Table 2.7: Expected Annual Damages from Climate-Related Extreme Events (USD mil.)

Scenario	Baseline	2020	2030	2040	2050
A2	34.86	81.77	148.39	246.36	334.62
A1B	34.86	84.75	154.16	256.34	350.12
B1	34.86	85.97	151.69	242.83	319.63
As % of GDP	0.7%	1.0%	1.1%	1.2%	1.3%
GDP (USD Bn.)	4.8	8.3	13.83	20.79	25.92

[18] The agricultural proportion of GDP has stayed relatively constant in recent years.

Figure 2.4 summarizes the current and future costs of inaction in the agriculture sector, as described above. The expected annual cost of climate change by 2050 is around USD700 million, calculated from the difference in future production under the climate change and no-climate change scenarios (roughly USD430 million, including USD235 million from crops and USD195 million from livestock) and from the portion of the increase in damages and losses that are attributable to the increased frequency and extent of extreme events (roughly USD270 million).

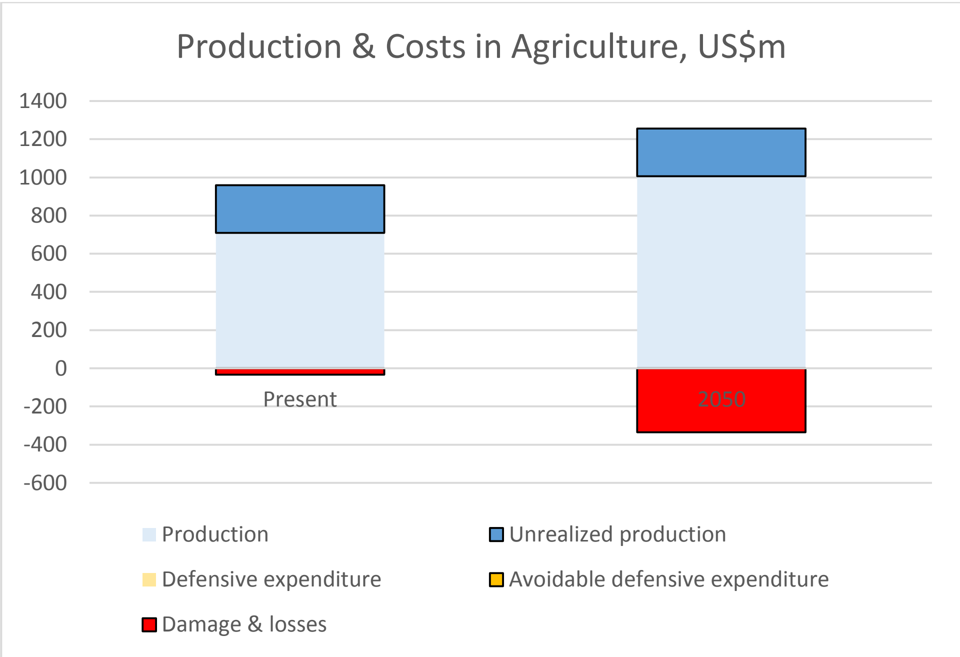


Figure 2.4: Climate-related annual production and impacts in the agriculture sector for the present and 2050. The value of production increases to 2050, with a slight decrease in unrealized production. Damages and losses show a pronounced increase by 2050, driving the overall increase in costs of inaction.

2.2.4 Adaptation investments

Investment in water supply options

A number of priority interventions for irrigation, drainage, and on-farm technologies are summarized in Table 2.8, which shows investment totals per type of investment, including ratings for uncertainty of benefits, poverty, and gender impacts. These investments address the current productivity deficit in Moldovan agriculture but also aim to make the sector more resilient to climate change. The favourable potential for on-farm irrigation technologies (in particular, drip and sprinkler irrigation systems for vegetables and fruits) is underlined by the significant improvements in gross margins compared with BAU practices found in ACSA demonstration projects. An important complementary program, dealing with institutional reforms of Apelei Moldovei, the key agency responsible for water infrastructure, WRM, and WSS, is considered to be a prerequisite for sustainable and viable irrigation investments, due to the need for ongoing management of irrigation and drainage infrastructure. Assessment of water infrastructure options requires further detailed analysis.

Investment in other agronomic options

There are a number of promising options for investment in on-farm climate risk management measures, including: improved varieties; improved soil/land management; alternative crops/changes in distribution; and extreme events risk management (such as hail nets and greenhouses). There are,

however, key knowledge gaps in defining the potential scale of these investments. A number of demonstration plots under the ACSA Climate Risk Management Project show promising results. For example, soil management (Mini Till) shows a change in gross margins (compared with BAU practices) ranging from 18 percent for maize to 30 percent for wheat and sunflower, and 43 percent for soybean, while annual income in the demonstration apple orchard was 4,200 euro/ha higher with an anti-hail net system (calculated from ACSA, 2014). Also, vegetable-producing greenhouses showed significant improvements in gross margins. There have been a small number of replications of these demonstrations, but it is necessary to further assess the market potential, land suitability, and availability aspects to understand the potential for further scaling up of these and other options on existing and newly sown areas.

Potential for expansion of high value crops

Field evidence (from ACSA-funded demonstration plots) and a literature review indicates the potential for expanding high-value crops in Moldova, in particular fruits and vegetables. This can be justified by both current suitability of soil and climate conditions, which give the country a comparative advantage in growing most temperate fruits and (irrigated) vegetables, and suitability under future climate change, given that available research (discussed in Section 2.1) suggests more favourable conditions under future climate scenarios for some fruit crops, including grapes. High-value crops also offer higher potential for increased incomes from domestic sales and exports[19].

Given that existing ACSA demonstration sites for adaptation investments focusing on high value products are likely to be in the most promising conditions and have mainly been set up by experienced commercial farmers, further analysis is needed of the real potential for and constraints to more widespread adoption. Land consolidation and tenure issues may also influence the ability to make longer-term investments, and any shifts from annual to perennial crops will affect subsistence farmers differently than commercial farmers. The impacts for subsistence farmers therefore need to be assessed thoroughly in any investment decisions supporting this expansion.

The Agricultural Support Fund of the Government of Moldova also recognises the need to shift the focus of investment support towards high value products. Any expansion in high value crop production also needs to be linked to development of appropriate post-harvest infrastructure, which has been identified as a weak link in fruit and vegetable supply chains in Moldova (World Bank 2012b) and has high capital requirements.

A climate-smart agriculture analysis, prepared for Moldova by CIAT, also identifies improved pasture and livestock management as one of the adaptation options with the greatest potential. However, this is not included in the table above, as there was insufficient information for Moldova to calculate economic returns.

[19] Profitability for cereals in 2010 ranged from 171 USD per ha for wheat to 348 USD per ha for maize. This compares to 1885 USD per ha for apples, 1993 for table grapes, and 4319 for tomatoes (from ACSA farm budget survey).

Table 2.8: Summary of Potential Investments in Agriculture

Description on investment	Period for implementation	Amount in USDm	Indicative IRR[20]	Uncertainty of Benefits	Impact on poverty	Impact on gender	Overall Priority
Water Management							
Rehabilitate/Modernize Centralized Irrigation Systems[21]	2017 to 2040	975	8% to 15%	Medium	Medium	Medium	High
Investments in on-farm irrigation technologies[22]	2017 to 2040 From 2031 the cost is O&M	130	8% to 15%	Low Medium	High Medium	High Medium	High Medium
Rehabilitation/Modernization of Drainage infrastructure in irrigated areas	2017 to 2040 From 2026 the cost is O&M	120	8% to 15%	Medium	Medium	Medium	High
Investments in Drainage Infrastructure in rainfed areas	2025 to 2040 From 2032 the cost is O&M	118	8% to 15%	Medium	Medium	Medium	Medium
Upscaling of small-scale irrigation systems[23]	2017 to 2040 From 2023 the cost is O&M	13.6	8% to 15%	Low Medium	High	High	Medium
Investments in improved on-farm technologies for rainfed cultivation[24]	2017 to 2040 From 2026 the cost is O&M	65	8% to 15%	Low Medium	High	High	Medium
Institutional Reforms/Capacity Building[25]	2017 to 2024 (Apele Moldovei), 2017 to 2040 (WUAs)	140	n/a	Medium	High	High	High

[20] Benefits of water management options vary depending upon crop mix over the area under consideration. The Benefit Costs Ratios in the World Bank 2012 study shows great variation between different crops and regions within specific water management investments. Inserted here is an indicative IRR range.

[21] Combines investments in Centralized Irrigation Systems for Prut, Nistru and Reut river systems. The cost consists of Operations & Maintenance (O&M) from 2031 onwards for Prut and Nistru, and from 2026 onwards for Reut.

[22] This covers a variety of technologies (such as drip, sprinkler, gated pipes for gravity irrigation in furrows for cereal crops, central pivot systems) for which benefits will vary and assessment is needed on a case-by-case basis. Assessment of medium-to-high poverty and gender impacts reflects this variation in technologies.

[23] This covers using farm ponds, low lift, and groundwater where water quality is not an issue for which benefits will vary and assessment is needed on a case-by-case basis. Assessment of medium poverty and gender impacts reflects the relatively lower level of total investment.

[24] This includes contour bunds, in-field water retention and small watershed management structures. Benefits will vary and assessment is needed on a case-by-case basis. Assessment of medium poverty and gender impacts reflects the relatively lower level of total investment.

[25] Includes restructuring of Apele Moldovei and associated state-owned enterprises (pre-requisite for any large-scale irrigation or drainage investment), and creation of functioning Water Users Associations (WUAs) in each system. Poverty and gender impacts are indirect but potentially high if reforms are successfully implemented.

Other Agronomic Practices			**BCR**				
Improved varieties research investment[26]	2020 to 2029	286	Rainfed Maize: 3 to 23 Irrigated Maize: 11 to 34 Rainfed Wheat: 9 to 34 Irrigated Wheat: 14 to 83	High	Medium	Medium	Medium
Improve agricultural extension services and demonstration for optimized fertilizer application[27]	2020 to 2029	561	Rainfed Maize: 1.7 to 3.3 Irrigated Maize: 1.7 to 5 Rainfed Wheat: 1.7 to 3.3 Irrigated Wheat: 3.3 to 5.8	Low	High	High	Medium
Extension services and demonstration for on farm-practices[28]							
Better Soil management (no till/mini till)			n/a	Case specific	High	High	Medium
Alternative crops/changes in distribution			n/a	Case specific	High	High	Medium
Greenhouses			n/a	Case specific	Medium	Medium	Medium
Anti hail/UV nets			n/a	Case specific	High	High	Medium

[26] Illustrative investment scenarios for improved varieties research are based on benefit cost ratios given in the World Bank 2012 report and have been scaled up to all areas currently sown for those crops.

[27] Illustrative investment scenarios for optimised fertilizer application are based on benefit cost ratios given in the World Bank 2012 report and have been scaled up to all areas currently sown for those crops.

[28] Investment amounts for these options not given due to knowledge gaps in potential for scaling up these options, as discussed in conclusions on knowledge gaps.

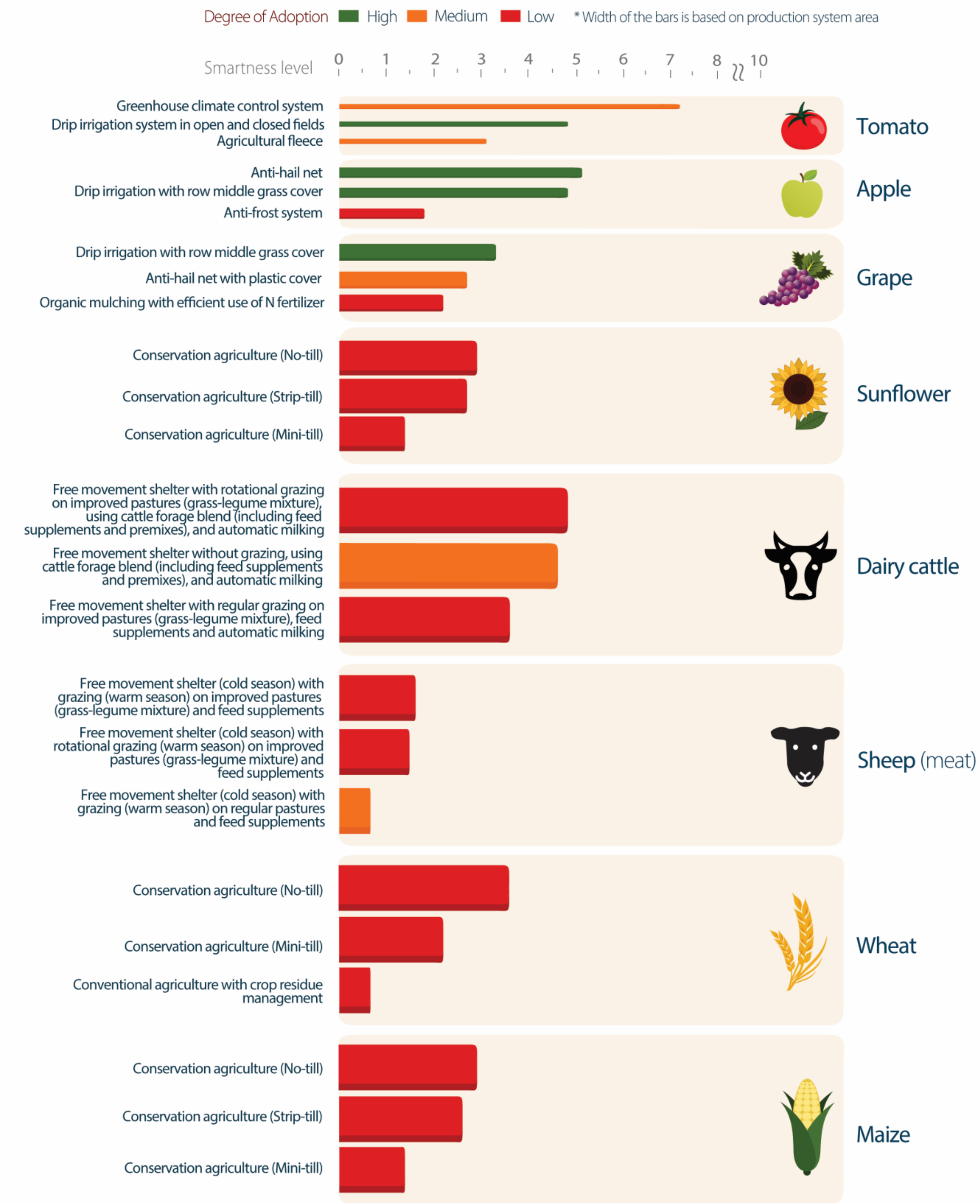


Figure 2.5. Proposed climate-smart agriculture (CSA) practices in Moldova (CIAT, 2016)

2.2.5 Constraints & uncertainty

In the agriculture sector, key sources of uncertainty are:

- Production potential: Estimated potential crop and livestock production is based on international comparisons. There is a large range between the high and low-bound estimates of the gap between actual production and potential production, with the high bound about 2.5 times the lower bound on average, although there is much variation in this range between specific agricultural products. More research is needed to establish the real potential production per crop and per region in Moldova, taking into account local soil and economic conditions.
- Climate change yield impacts: Estimates for long-term changes to yields due to climate change are dependent on the available crop and livestock modelling results, which come with a high degree of variability between models. Using the best available projections of yield impacts in Moldova produces considerable variation between cost of inaction estimates for different emissions scenarios (A2, A1B and B1). For estimates of costs of inaction for crops in 2050 the variation is about 20 percent between the highest and lowest emission scenario for any given SSP. The comparable variation is much higher for livestock, the highest scenarios being about 4 times the lowest, reflecting the high variation in available projections of livestock yield impacts between emission scenarios. In general, the response of crops to climate-related diseases is still not well understood and crop simulation models do not include yield reduction due to weather-induced pest and disease (Taranu, 2014). Also, endogenous adaptation (i.e., adaptation measures adopted by farmers without external intervention, such as changing crop varieties) is not modelled. Detailed discussions with farmers would be necessary to understand the types of adaptation strategies available to them and likely to be adopted in the absence of additional external support.
- Socio economic scenarios: The variation between cost of inaction results for different socio economic scenarios (SSP1, SSP2 and SSP3) for any given emission scenario is much lower than the variation between emission scenarios, although again it is higher for livestock estimates than for crop estimates.
- Extreme event losses: Estimates of total losses in the agricultural sector from extreme events are affected by reporting issues. The lack of comprehensive recent data on losses has resulted in high uncertainties regarding the baseline figures used for estimation of future damages. In addition, this study was not able to assess the level of avoidable and unavoidable defensive expenditures to mitigate the impacts of extreme events or climate-related disease.
- Investment benefits: Benefits from large-scale irrigation investments depend on successful institutional reforms in Apele Moldovei and associated state-owned enterprises. Returns on irrigation investments will also vary significantly depending on where the interventions are made, with an IRR range of 8 to 15 percent estimated. Greater knowledge about the potential scale of both improvements to other agronomic practices and changes in crop mix (especially the potential for expansion of high-value crops) is an important requirement for investment decisions. However, prioritization of institutional reform and of water management investments in general is considered robust.

2.3 Water

This section looks at the cost of inaction and investment needs related to the provision of water supply and sanitation (WSS). The supply side, however, does not deal with irrigation rehabilitation and investment or with drainage issues, which have been covered in the agricultural section.

2.3.1 Overview

Moldova has two main rivers, the Nistru and Prut, which flow south from Ukraine, and a smaller one, the Reut, which originates in Moldova. Water quality in these varies between moderately polluted to clean (KPC, 2013).

Groundwater is abstracted through approximately 120,000 springs and wells and 3,000 functional artesian wells. Groundwater supplies potable water to the majority (65%) of the population. There are significant issues with groundwater quality, including water hardness exceeding national standards (KPC, 2013).

There are 3,500 small- to medium-sized reservoirs, with surface area of at least 300km^2. Two large reservoirs supply the country as well, the Costesti-Stînca on the Prut river (678 million m^3), which is jointly operated with Romania, and the Dubusari on the Nistru river (235 million m^3) (Climate Change Post, undated).

A significant part of the population still needs to be connected to water infrastructure in Moldova. Some estimates suggest there are 100,000 people in urban areas and 189,500 in rural areas who should be connected by 2020. In addition, 227,200 people in urban areas and 432,700 in rural areas require connection to wastewater services. Moldova has also suffered from a number of significant droughts and floods in recent years, including the 2007 drought, which cost approximately USD957 million to the agriculture sector, and the 2010 flood, which cost USD48.3 million across a range of sectors.

2.3.2 Climate impacts & current cost of inaction

Climate determines the availability of freshwater resources, and therefore all primary production that relies on water could be viewed as climate-dependent. This study did not attempt to enumerate all water-dependent production, however. Instead, it assessed unrealized production in terms of (i) deficits in overall water availability in relation to actual demand, and (ii) deficits in the provision of water supply and sanitation (WSS) services.

Overall water availability and demand were assessed using the Water Evaluation and Planning System (WEAP) and other tools (see annexes for details). Demand was assessed for municipal & industrial (M&I), irrigation, hydropower, and cooling for thermal energy plants based on installed infrastructure for abstraction and use, providing an allowance for maintenance of ecological flows. The assessment indicated that, at present, there is little overall shortage of freshwater resources. The only deficit is in the lower Nistru, which has an annual average deficit of 23 million m^3 for thermal energy generation, the cost of which is accounted for under the energy sector.

GTZ (2013) estimated that roughly 290,000 people in Moldova lacked connections to a potable water supply, and an additional 66,000 are in need of sanitation connections. No reliable data exists for Moldavia on the value of these unrealized services, but WHO (2004) estimated the total economic benefits of granting access to improved water and sanitation services in Eastern Europe at USD23.93 per capita. Converting to 2015 dollars and multiplying by the number of additional connections needed gives an estimate of around USD32 million in unrealized WSS services.

Damages and losses within the water sector are assessed as the expected annual value of damages and losses due to flooding. This has been recently estimated to be around USD62.20 million (EIB 2016). Defensive expenditures against flood damage were not evaluated.

2.3.3 Future costs of inaction

The National Climate Change Adaptation Strategy for Moldova identifies a number of key risks for water resources in the country (see Table 2.9).

Table 2.9: Risks and Opportunities of climate change to the Water Sector

Detail of magnitude of risk/opportunity	Location			
	North	Centre	South	Chisinau
Water quality affected by higher water temperatures and variation in runoff	Low	Medium	High	High
Changes in water demand (increase as a result of population growth, economic development and irrigation requirements	Medium	High	High	High
Changes in river flows - both increase and decrease	Medium	High	High	High
Increased risk of drought and water scarcity	Medium	High	High	High
Increased irrigation requirements	Medium	High	High	High
Decreased water availability from surface sources or ground water	Medium	High	High	High
Higher pollution with pesticides and fertilizers to water due to higher runoff	Medium	High	High	High
Flood increase in frequency and intensity	Medium	High	High	Low

Source: National Climate Change Adaptation Strategy of the Republic of Moldova

The WEAP model was used to estimate the impacts of both climate and socioeconomic change on overall water demand and availability by the 2040s. Even in the absence of climate change, the projected growth in demand for water means that significant shortages are expected by the 2040s (see "Base 2040s" scenario in table 2-4-2, which is generally exacerbated under the 3 emissions scenarios used.

The costs associated with future unmet demand were valued on the basis of actual charges for water: USD0.50 per m^3 for M&I use and irrigation costs of 0.15 lei per m^3 in Puhaceni to 0.22 lei per m^3 in Jorile (MCC, 2015). Prices were projected into the future based on expected income growth and an income elasticity of demand for water, which it assumed to be between 0.3 and 1 (based on the literature).

Table 2.10: Unmet water demands by catchment, cubic metres

BASIN	CLIMATE SCENARIO AND DECADE				
	Base 2010s	Base 2040s	Low 2040s	Medium 2040s	High 2040s
Irrigation					
Lower Nistru	0	103,000	202,000	282,000	540,000
Reut	0	303,000	993,000	2,779,000	9,301,000
Upper Nistru	0	58,000	107,000	140,000	281,000
Kogilnic	0	0	0	0	0
Prut	0	0	0	0	0
All	**0**	464,000	1,302,000	3,200,000	10,122,000
Municipal and Industrial					
Lower Nistru	0	63,983,000	53,604,000	47,291,000	106,264,000
Reut	0	2,175,000	2,797,000	2,305,000	3,765,000
Upper Nistru	0	8,485,000	3,888,000	3,207,000	8,731,000
Kogilnic	0	0	0	0	0
Prut	0	0	0	0	0
All	0	74,643,000	60,288,000	52,803,000	118,702,000
Thermal					
Lower Nistru	23,329,000	30,856,000	50,164,000	54,512,000	89,846,000
Reut	0	NA	NA	NA	NA
All	23,329,000	30,856,000	50,164,000	54,512,000	89,846,000

Source: estimates from Industrial Economics

Table 2.11: Value of unmet M&I and irrigation water demands by catchment, USDMn.

	Income elasticity	SSP1				SSP3				SSP5			
		Base	Low	Med	High	Base	Low	Med	High	Base	Low	Med	High
Low water value	0.3	62.2	50.2	44.0	99.1	52.0	42.2	37.5	84.9	66.3	53.8	47.7	108.2
	1	201.7	163.0	142.9	321.5	110.5	89.8	79.9	181.4	248.0	201.6	179.3	407.1
High water value	0.3	1,826.9	1,475.6	1,292.4	2,905.5	1,524.3	1,231.5	1,079.2	2,427.1	1,942.7	1,569.5	1,375.5	3,093.3
	1	5,924.6	4,785.3	4,191.4	9,422.7	3,239.3	2,617.1	2,293.9	5,159.0	7,270.4	5,873.9	5,148.4	11,579.1

The value of unmet demand is dominated by the M&I usage and evaluated at roughly USD95 million [range 38 – 405 million]. The value of the deficit in WSS services is assumed to remain the same without further investment, and therefore the overall estimate for unrealized production by 2050 is around USD127 million [range 70 – 437 million].

The estimate for expected annual damage & losses due to flooding by 2050 is around USD276 million based on the EIB study. Figure 2.6 summarizes the current and future costs of inaction in the water sector, as described above.

The annual expected cost of climate change by 2050 is calculated from: (i) the difference in future unrealized production between the no climate change and climate change scenarios (roughly USD40 million, although there is a lot of variation in terms of M&I unmet demand across the three emissions scenarios); and (ii) the portion of the increase in damages and losses beyond that expected without climate change (roughly USD165 million, adjusting for the increased asset base at risk as before). The total cost of climate change in the water sector is therefore estimated at roughly USD205 million.

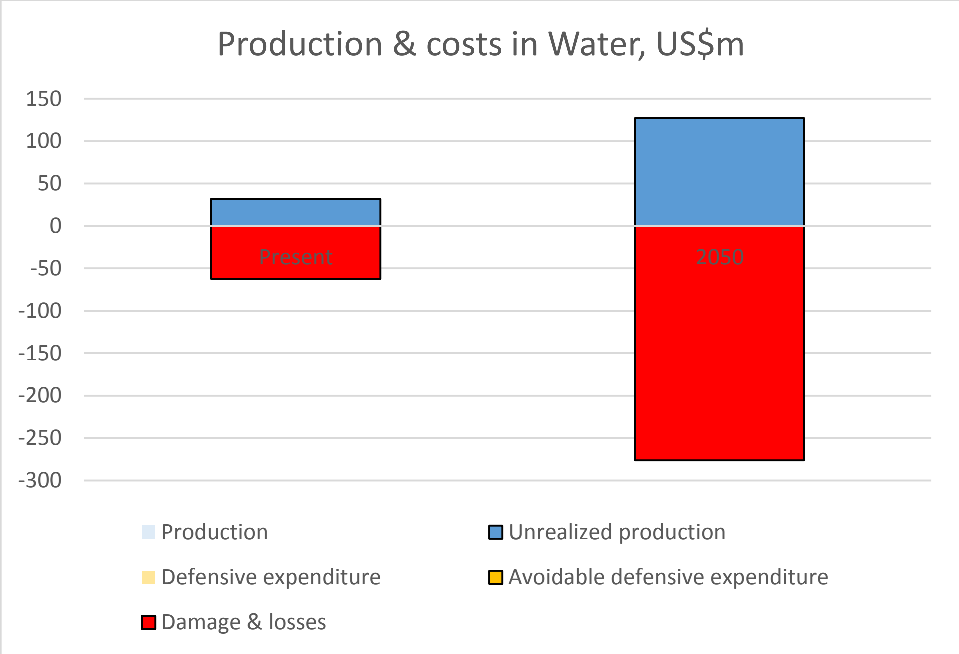


Figure 2.6: Climate-related annual production and impacts in the water sector for the present and 2050. The costs of inaction show a strong increase to 2050 from increases in both unrealized production and damage & losses.

2.3.4 Adaptation investments

Further investment in ***infrastructure for rural water supply*** may be one option for adaptation in terms of increasing water provision for agriculture and rural populations. Cost-benefit analysis of small-scale water supply shows a BCR of 2.5 to 21.3 in the pan-European region (including Moldova) (UNECE and WHO, 2011). A detailed estimate of these investments has not been made, however, as detaled data were not available.

Improvements in the efficiency of municipal and industrial (M&I) supply systems (i.e., reducing losses) appear to be economically favorable across all basins, even at the present time, and with returns increasing in later decades. Calculated BCRs vary between 14 to 69.9 depending on the socioeconomic scenario and whether a 10% or 15% reduction in losses is targeted, based on the following assumptions:

1. Capital costs range from USD0.04 per m3 to USD0.17 per m3. O&M is taken to be 2% of capital costs per annum (Sutherland and Penn, 2000).
2. Water value is USD0.50 per m3 in 2014, and increases with per capita GDP using the conservative 0.3 income elasticity.
3. Efficiency systems are established to meet 2040s deficits.
4. A 6% discount rate is applied.
5. The lifetime of a supply system is 25 years.

Another option to address expected water deficits in Moldova from 2020 onwards is the construction of ***water storage reservoirs***. A cost-benefit analysis was conducted for reservoirs of varying size on each of three basins, using construction costs adapted to Moldova from Ward et al (2010), estimates of the values of water for M&I, irrigation, and thermal energy generation, and the following assumptions:

1. The discount rate was taken as 6%.
2. Construction would start in 2020 and would take 5 years for the smaller reservoirs and 6 years for the largest one).
3. The assessed lifetime was set at 30 years (i.e., to 2050).
4. Water is allocated to meet unmet demand first to the use with the highest value, then to the use with the second highest, and so on.

The following tables present results for the Lower Nistru, Reut and Upper Nistru. In each case the economically optimal size of the reservoir is highlighted in bold. Note, however, that water demand and benefits of additional storage increase in later years, so if the investments were made later, larger reservoirs might be favored.

Table 2.12: Benefit Cost Estimates for Lower Nistru Water Storage (Base Case)

Size of Reservoir (MCM)	PV of Costs USDMn	PV of Benefits USDMn.	BCR	Unmet Demand Satisfied
1	0.3	6.7 to 20.5	19.5-59.4	M&I
25	6.2	168.6 to 383.8	27.1 to 61.8	
100	18.4	413.2 to 937.5	66.5 to 151.0	M&I, Irrigation, Thermal Energy
500	43.2	401.0 to 919.7	64.6 to 148.1	

Table 2.13: Benefit Cost Estimates for Reut Water Storage (Base Case)

Size of Reservoir (MCM)	PV of Costs USDMn	PV of Benefits USDMn.	BCR	Unmet Demand Satisfied
1	0.3	6.7 to 20.5	19.5-59.4	M&I
25	6.2	12.7 to 31.6	2.0 to 5.1	
100	18.4	12.7 to 31.6	0.7 to 1.7	M&I, Irrigation.
500	43.2	12.2 to 31.0	0.3 to 0.7	

Table 2.14: Benefit Cost Estimates for Reut Water Storage (Base Case)

Size of Reservoir (MCM)	PV of Costs USDMn	PV of Benefits USDMn.	BCR	Unmet Demand Satisfied
1	0.3	6.7 to 20.5	19.5-59.4	M&I
25	6.2	47.0 to 117.0	7.6 to 18.8	
100	18.4	47.0 to 117.0	2.6 to 6.4	M&I, Irrigation.
500	43.2	45.6 to 114.6	1.1 to 2.7	

For the case of **water supply and sanitation** (***WSS) services***, calculation of total investment needs to address connection deficits and benefits until 2050 yielded benefit-to-cost ratios from 2.5 to 3.2.

The EIB's (2016) Preliminary Flood Risk Assessment (PFRA) identified ***84 structural and 30 non-structural flood management measures***. For these, a detailed investment plan has been prepared

with a total investment of €325 million for structural measures and €120 million for non-structural measures, including maintenance.

Table 2.15 gives a summary of potential water sector investments, including ratings for uncertainties, impacts on poverty, and impacts on gender.

Table 2.15: Summary of Potential Investments for Water Sector

Description of investment	**Period of implementation**	**Amount in USD (Mn.)**	**BCR**	**Uncertainty of Benefits**	**Impact on poverty**	**Impact on gender**	**Overall Priority**
Improve Municipal and Industrial (M&I) Water System Efficiency Reducing 10% of losses	Capital investment over 1 year, O&M over 25 years	2.78 to 5.48	61.1 to 69.9	Low	Medium	Medium	High
Reducing 15% of losses		10.63 to 23.9	14.0 to 16	Low	Medium	Medium	Medium
Improving Rural Water Supply		Not assessed	2.5 to 21.3	Low	High	High	Medium
100 MCM reservoir in lower Nistru	Construction over 5 years	18.4	66.5 to 151.0	Low	Medium – impacts on farmers	High	High
25 MCM reservoir in upper Nistru	Construction over 5 years	6.2	7.6 to 18.8	Low	Low	High	Medium
1 MCM reservoir in Reut	Construction over 5 years	0.3	19.5 to 59.4	Low	Low	High	High
Water Supply and Sanitation (WSS)	Rehabilitation of existing and construction of new WSS infrastructures	409	[350-439]	2.5-3.2	Medium (20-30%)	High	Medium
Structural flood mitigation measures	2020-2040	360.8	2.12	Medium: Estimated as avoided damages of flooding. Based on hydraulic modelling with all uncertainties mentioned.	Unknown		High
Non-structural flood mitigation measures	2020-2040	136.6	5.60				High

The viability of the above investments is considered to depend on institutional reform of Apele Moldovei, the agency responsible for water resources management in Moldova.

2.3.5 Constraints & uncertainty

For the water sector, key sources of uncertainty are:

- The impact of climate change on water availability in Moldova has been assessed only in summary fashion, using a relatively simple model.
- Economic valuation of water services. There is uncertainty both in the size of costs (e.g., for water used in thermal energy production, reduction in energy generation was simply assumed to be proportional to unmet demand) and in values of water in other sectors, including for the elasticity of demand with growth in future incomes (a range between 0.3 and 1.0 was used). Water values based on existing willingness-to-pay studies were considered unrealistically high, therefore values based on current prices were used, but the latter should be considered as lower-bound estimates.
- The most critical adaptation investment decision affected by high uncertainty is the investment in additional water storage. Modeling indicates that future water shortages are likely to occur and that they will have major economic impacts, but the modeling done for this study did not allow the optimal timing and size of investments to be determined in a robust manner. Given the importance of water storage, further analysis of hydrological projections, adaptive management strategies, and climate triggers is warranted.
- For flood risk management, data used in this report come from the EIB study, "The Management and Technical Assistance Support to Moldova Flood Protection Project." But the EIB report states that its hydrological analysis and calculated flood flows are subject to significant uncertainty, and further quantification was not provided.

2.4 Energy

2.4.1 Overview

The Energy sector in Moldova faces a number of challenges, the main one being its heavy dependence on imports (especially of natural gas), which currently meet about 75% of demand. Domestic heat and electricity are largely produced by old, inefficient, and expensive combined heat-and-power (CHP) generation plants.

Electric energy in Moldova is therefore expensive. Domestic generation from CHP plants has a regulated price of USD115/MWh, compared to a European average of USD60/MWh. The overall average price of electricity is USD80/MWh, once lower-priced imports are taken into account.

A recent ESMAP and World Bank study investigated current energy supply issues in Moldova. Heavy dependence on natural gas imports from Ukraine and the disputed area of Transnistria leads to significant concerns about security of supply. Connection to the Romanian transmission network is recommended to diversify Moldova's outside energy sources. Some estimates suggest that excess supply from Transnitria may be depleted by the end of 2020. If this were the case, then increases in demand beyond that year would need alternative sources to avoid load shedding.

The investments required to implement a recommended scenario in the ESMAP study are estimated to range from USUSD421-441 million over the period 2017 to 2019. Implementation would result in a 20-year levelized tariff of about USUSD 15.5 cents/kWh, which is affordable and acceptable.

2.4.2 Climate impacts & current cost of inaction

Current production from climate-based renewable energy sources is only valued at around USD286,000 per annum—from hydroelectric power.

Moldova has been estimated, however, to have significant unrealized potential from climate-dependent renewable energy:

- Potential wind energy production, according to the Moldova Renewable Energy Strategy, is 372,160 MWh, although significant investment in the Moldovan energy system would be needed before it could absorb such distributed production.
- Hydroelectric power potential is estimated to be 3 billion kWh/year (Ciofu et al, 2014), while actual generation is only 1% of that. But the extent to which this potential could be realized is debatable, given the geopolitical context of the rivers in question. A recent study suggests between 10% and 86% of possible investments in hydropower would be economically viable (IRENA, 2012).

Current unrealized climate-based renewable energy production is accordingly estimated at around USD150 million (range 105 – 195 million) per annum.

Unrealized thermal energy production due to the current deficit in water supply in the Lower Nistru is estimated at USD4.6 million per year, based on the current import price and the assumption that energy production is proportionately impacted by water supply shortage.

Extreme weather events can also cause significant damage to Moldova's energy supply system:

- A severe frost in 2000 damaged 3,402 km of power lines, 42,174 power transmission towers and poles, 6,995 phone lines and 2,715 phone poles. The estimated economic cost was USD31.6 million.
- Flooding in 2010 cost USD0.78mn to the energy sector.

But flood damages have already been accounted for under the Water sector, and severe frost and ice-storm damage is so rare that annual expected costs are uncertain. In comparison to other factors, these numbers are relatively small, and it is not clear whether frost damage would increase under future climate change. Therefore damages and losses from extreme events are not considered further for the energy sector.

Energy use for domestic heating and cooling also represents a defensive expenditure against unfavourable climate conditions, and energy saving from improved efficiency would represent an avoidable defensive expenditure (and therefore a cost of inaction). Improving energy efficiency is a recognized agenda in Moldova, but the study was not able to generate estimates of current energy expenditures on domestic heating and cooling, or on the potential savings from improved efficiency.

2.4.3 Future costs of inaction

Future energy production from hydropower and thermal power is expected to decline in the face of reduced water availability. The use of the WEAP model suggests a decline in water available in rivers by 2040, so that hydropower generation will fall from its current annual level of 299 mWh to between 219 and 272 mWh, depending on the scenario.

For thermal power, there could be unmet demand from 19% to 34% of optimal cooling water use in the lower Nistru Basin by 2040.

The figures below represent the expected losses in hydropower and thermal power generation across three emissions scenarios, and the associated costs based on two price scenarios (substitution cost is based on the current import price, USD0.055 per kWh, or the current production price USD0.102/kWh). Note that the contribution of hydropower losses is essentially negligible in relation to thermal energy, as current hydropower production is very limited.

Figure 2.7: Hydroelectric power losses due to climate change under different climate scenarios (million kWh)

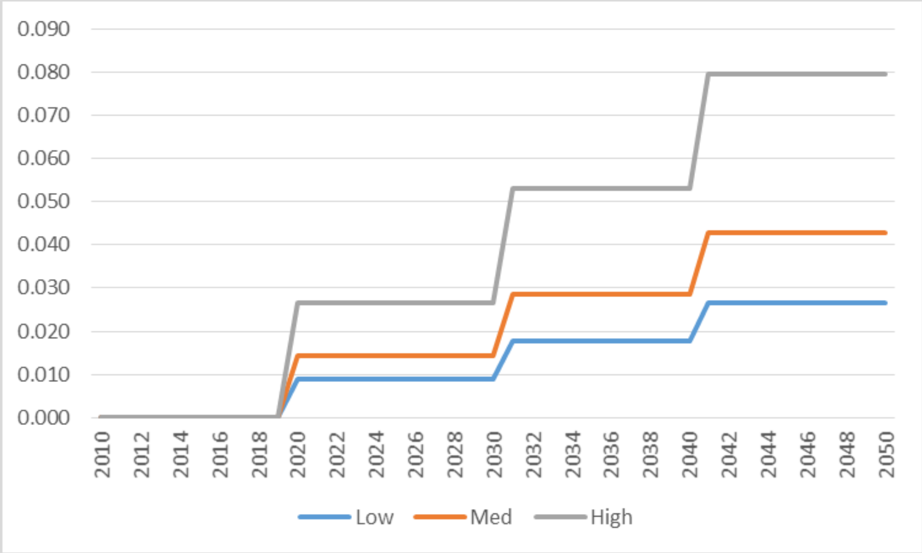


Figure 2.8: Thermal power losses due to climate change under different climate scenarios (million kWh)

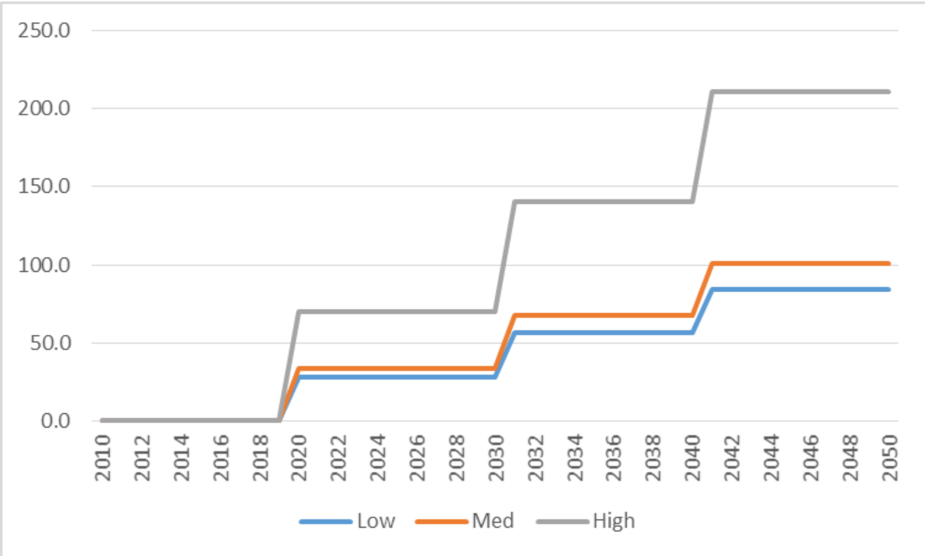
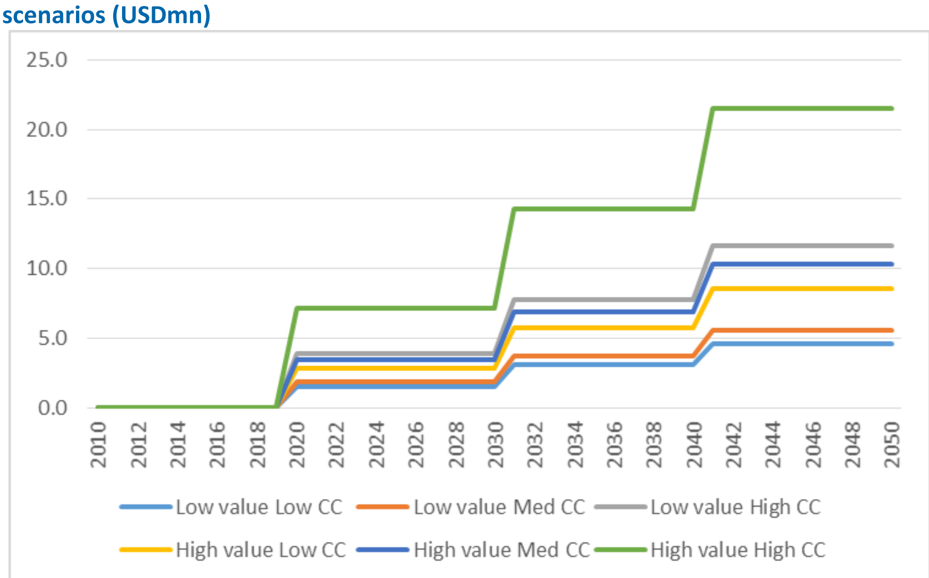


Figure 2.9: Costs of climate change to energy production in Moldova under different climate & price scenarios (USDmn)



The value of this loss of power generation is therefore estimated at around USD10 million (range 4.6 – 21.5 million), which represents unrealized production, and is additional to the earlier estimate of USD150 million of unrealized production from unexploited climate-dependent renewables.

Energy demands for heating and cooling are also likely to change with expected warmer winters and warmer summers in the future. Cooling demand will increase while heating demand will fall. De Cian and Wing (2014) model the demand for energy globally based on econometric relationships between energy demand, climate, and changes in socioeconomic factors through the shared socioeconomic pathways (SSPs). Their analysis suggests, overall, energy demand for Moldova may fall – with the reduction in winter demand outstripping the increase in summer demands. Hence, we do not consider that changing energy demands will lead to an increase in defensive expenditures in Moldova.

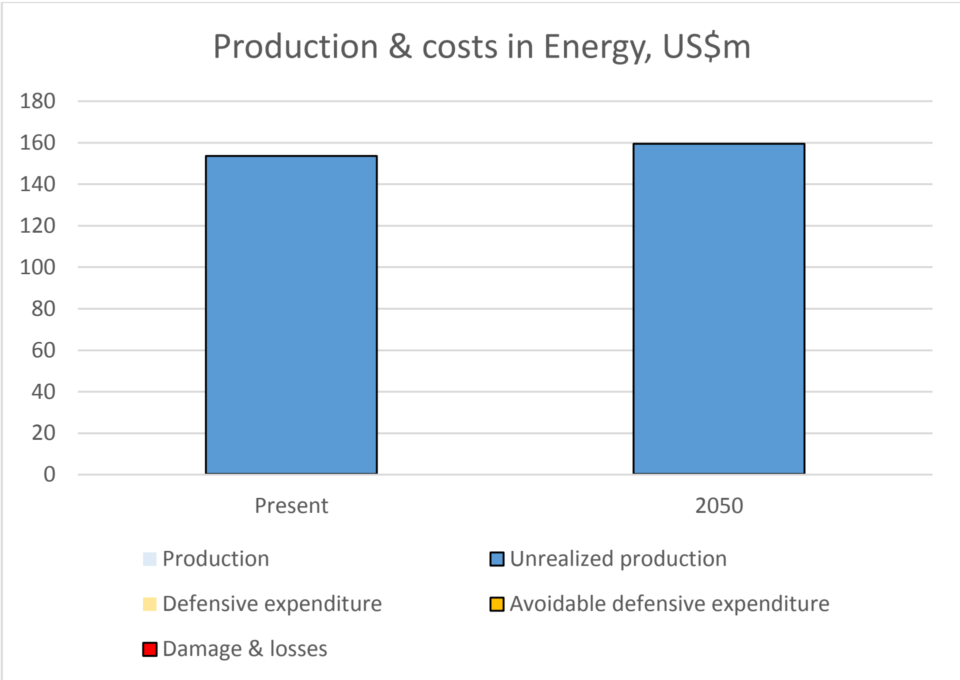


Figure 2.10: Climate-related annual production in the energy sector for the present and 2050. Unrealized production (and therefore the cost of inaction) increases slightly to 2050 due to shortages of water for thermal energy generation.

Figure 2.10 summarizes the current and future costs of inaction in the energy sector, as described above. The annual expected cost of climate change by 2050 is around USD6 million; calculated on the basis of expected losses to thermal and hydropower energy production, above those currently being experienced.

2.4.4 Adaptation investments

The Renewable Energy Strategy of Moldova foresees a significant increase in renewable power generation and UNEP (2014) has suggested wind power could reach up to 27.2% of Moldova's energy generation by 2030 under a green development scenario.

A cost-benefit analysis was carried out for investment in wind power, on the basis of displacing energy imports at USD0.055 per kWh, and under the assumptions in the table below. Costs of wind

technology may fall over time, but even at the present time wind generation may be economically viable. Total investment potential is estimated at USD235 million.

Table 2.16: Key parameters for CBA of wind power options in Moldova

Full load production time	**hrs**	**2500**
Efficiency electricity	hrs	2500
Power per plant	MW	2.3
Cost per plant	USDm	3.63
Cost per MW	USDm/MW	1.57826087
Lifespan	years	20
Expected generation capacity 2020	MWh	372,160
Carbon value	USD/ton	20

Table 2.17: Summary of Potential Investments for Energy Sector

Description of investment	**Period for implementation**	**Amount in USD (Mn.)**	**BCR**	**Uncertainty of Benefits**	**Impact on poverty**	**Impact on gender**	**Overall Priority**
Windpower generation – significant investment in wind power generation	Construction over 1 year, with O&M	234.9	1.25 to 2.43	Low – based on market prices	Medium – some jobs created	Low	Medium

Potential options for improving water storage to protect energy security concerns are addressed in the water section.

Studies by GTZ (2013) and Cohen et al (2016) suggest that the total cost of renovating private and public building stocks in Moldova to improve heating and cooling efficiency could be on the order of hundreds of millions of dollars per year over a couple of decades. Energy efficiency investments often have high returns, and some available estimates based on international experience suggest a benefit/cost ratio of 4.4 for investments in retrofitting to avoid temperature increases of 1.6-2.4ºC (Bengtsson et al., 2007). However, in the absence of more specific data for Moldova on current expenditure for heating and cooling and on potential savings from available energy efficiency measures, the very high investments potentially suggested are considered to require further scrutiny.

2.4.5 Constraints & uncertainty

In the energy sector, key sources of uncertainty are:

- The technical and economic viability of identified potentials for hydropower and other weather-based renewables.
- Extreme events were not considered separately from the general assessment of flood damage, but these are not expected to be very large on average.
- Valuation of future energy. Valuation of lost energy production used a lower-bound estimate based on current market prices (i.e., on the assumption that any deficit could be

substituted through additional generation or purchase, and that these prices would not change significantly in future). The value of lost load, which would be much higher, was not used because of a lack of studies on this in Moldova.

- There is no good national-level modeling of change in energy demand under climate change, and our estimate that the country's overall energy-demand increase in summer will be offset in winter comes from an international econometric study.
- Domestic energy efficiency agenda. Although very large expenditures on renovation of Moldova's building stock to improve energy efficiency have been suggested, robust figures on the potential energy savings and their values were not readily available, and therefore this study was not able to assess the cost of inaction related to the failure to improve energy efficiency or the BCR of the suggested investments. This is a key gap in the current study.

2.5 Infrastructure (roads & buildings)

2.5.1 Overview

This section analyses the vulnerability of roads and buildings in Moldova to climate change by applying the Infrastructure Planning Support System (IPSS) to GIS inventories of infrastructure at risk. Moldova's networks of paved, gravel, and earthen roads were documented from existing sources, and are summarized in Table 2.18.

Table 2.18. Summary of road assets analysed

	Paved (kilometres)			Gravel (kilometres)	Total (kilometres)
Moldova road stock	Primary	Secondary	Tertiary		
	3,796	77	1,225	2,905	8,002

The study also estimated the stock of three different building types for Moldova—houses (both urban and rural), hospitals, and schools—using a variety of techniques. These three building types make up a substantial percentage of the total building stock. Data from the National Bureau of Statistics of the Republic of Moldova provide a base to estimate the number of buildings per district. The area per building type was estimated using census data and, where data were not available, estimates were based on U.S. Department of Energy reference buildings. Rural dwellings are considered to be private dwellings, while the remaining buildings are considered to be public buildings. Table 2.19 shows the building stock in square meters.

Table 2.19. Building stock for Moldova

Rural Dwellings (sq. meters)	Urban Dwellings (sq. meters)	Hospitals (sq. meters)	Primary Schools (sq. meters)	Secondary Schools (sq. meters)	Vocational Schools & Colleges (sq. metres)
49,099,850	32,401,431	1,870,000	1,215,732	3,261,030	417,480

2.5.2 Climate impacts & current cost of inaction

Maintenance costs for external infrastructure tend to be a function of climate and degree of use. This section focuses on the costs of routine wear-and-tear for Moldova's road network and building

stock in relation to climate (damage from extreme events is assessed under flood damage in the Water Sector). The analysis was conducted using the Infrastructure Planning Support System (IPSS) model (see annexes for further details).

IPSS assumes that infrastructure is built according to recommended specifications for historic climate conditions, and then calculates maintenance costs based on the number of times threshold values of climatic stressor variables are exceeded and the related damage incurred. The model therefore assumes that required maintenance is always carried out, however severe the impacts of climate. This is termed reactive adaptation. For historic climate conditions in Moldova, the model estimates expected annual maintenance costs of around USD2.1 million for the road network and around USD8.7 million for buildings.

The model is also able to evaluate the costs of upgrading construction specifications to better resist climate extremes. This is termed proactive adaptation, and in the model occurs through upgrading infrastructure at the time of replacement to resist the most extreme weather parameters it will experience during its economic life (perfect knowledge of future climate is assumed).

Applying the proactive adaptation strategy under historic climate conditions increased overall costs for road repair and maintenance, but reduced the cost of maintaining public buildings by around USD3.3 million per year. This figure therefore represents avoidable defensive expenditure for the building stock.

2.5.3 Future costs of inaction

Applying a range of future climate change scenarios increased the overall expected maintenance costs for both roads and buildings under reactive adaptation to around USD10 million (range 9 – 22 million) and USD36 million (range 23 – 47 million), respectively, by 2050. Maintenance costs for unsealed roads and for non-wooden buildings, both of which are primarily driven by rainfall, were little affected or even decreased under the climate change scenarios, whereas maintenance costs for sealed roads and wooden buildings, which are more strongly affected by temperature, showed marked increases.

Proactive adaptation remained a more costly strategy for roads, except in the high climate change scenario, when it resulted in savings of around USD7.8 million per year on average.

Figure 2.11. Projected cumulative maintenance costs for paved roads under proactive and reactive adaptation strategies

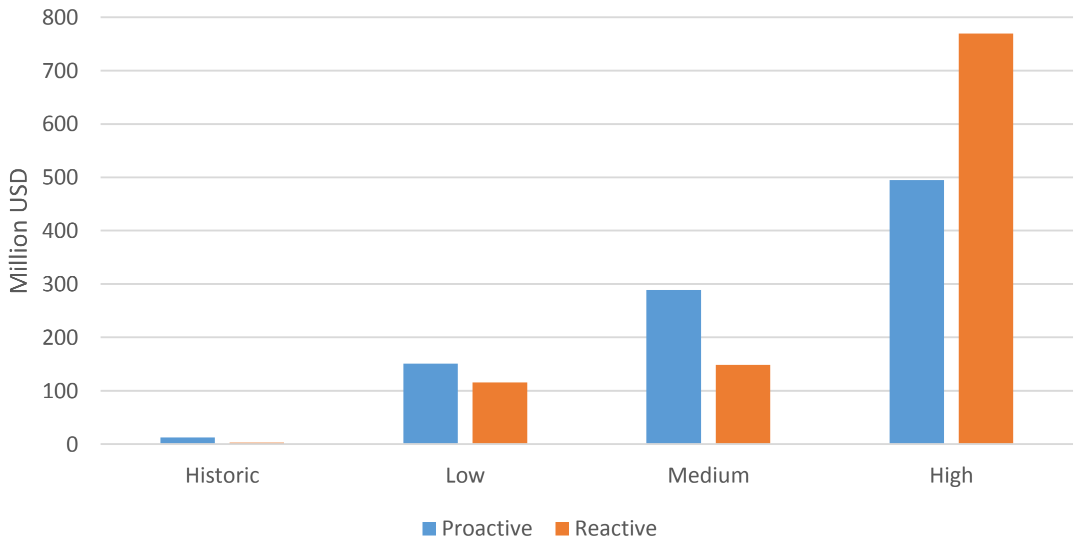


Table 2.20. Additional expected annual maintenance costs for all roads under climate change (USD Mn.)

CC Scenario		2020s	2030s	2040s	2050s
No CC	Paved	0.0	0.1	0.1	0.1
	Gravel	1.3	6.5	6.5	6.5
	Total	1.3	6.6	6.6	6.6
Low	Paved	4.8	4.1	8.0	5.8
	Gravel	0.1	4.4	4.7	2.2
	Total	4.9	8.5	12.7	8.0
Medium	Paved	0.3	5.9	2.9	4.9
	Gravel	1.5	5.2	6.1	3.4
	Total	1.8	11.2	9.0	8.4
High	Paved	15.3	30.2	6.0	4.1
	Gravel	8.6	16.0	6.0	3.8
	Total	23.8	46.2	12.0	8.0

Proactive adaptation for non-wood buildings remained the cheaper strategy under all climate change scenarios, but the expected annual savings fell to USD1.1 million (range 0.9 – 2.6 million) as rain damage became less important.

Table 2.21. Cumulative and decadal average cost impacts of climate change vulnerability 2015-2050 (USD millions/no discounting)

Building Type	**Proactive adaptation**					**Reactive adaptation**				
	2020	**2030**	**2040**	**2050**	**Cum.**	**2020s**	**2030s**	**2040s**	**2050s**	**Cum.**
Public buildings (investments are for drainage and roofing adaptations)										
Historic	USD0.0	USD3.9	USD3.4	USD2.5	USD96.6	USD0.0	USD7.1	USD7.1	USD7.1	USD213.3
Low	USD0.0	USD2.4	USD2.4	USD0.3	USD50.4	USD0.0	USD4.1	USD4.1	USD0.0	USD81.9
Medium	USD0.0	USD2.9	USD2.8	USD0.6	USD61.9	USD0.0	USD4.9	USD4.6	USD0.4	USD99.9
High	USD2.1	USD7.3	USD2.0	USD0.4	USD109.0	USD3.5	USD14.9	USD3.0	USD0.2	USD201.8
Private dwellings (no adaptations available – all costs are reduced lifespan)										
Historic	-	-	-	-	-	USD13.6	USD0.3	USD0.3	USD0.3	USD90.9
Low	-	-	-	-	-	USD9.1	USD27.5	USD28.0	USD11.9	USD728.9
Medium	-	-	-	-	-	USD33.3	USD28.4	USD29.8	USD45.4	USD1,234.9
High	-	-	-	-	-	USD54.4	USD16.7	USD31.9	USD61.7	USD1,428.9

Figures 2.12 & 2.13 summarize the current and future costs of inaction for roads and buildings, as described above. The expected annual cost of climate change for infrastructure in Moldova by 2050 is around USD35 million, which is calculated from the increase in expected annual defensive expenditures (roughly USD8 million and USD27 million for roads and buildings, respectively).

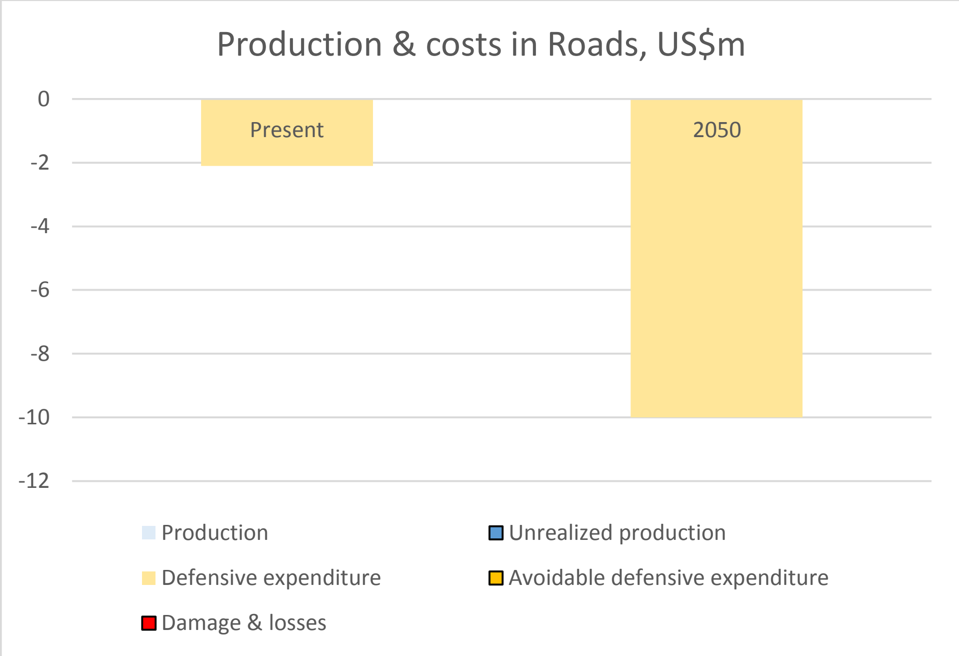


Figure 2.12: Climate-related annual costs in the roads sector for the present and 2050. Defensive expenditure (maintenance costs) increases by 2050.

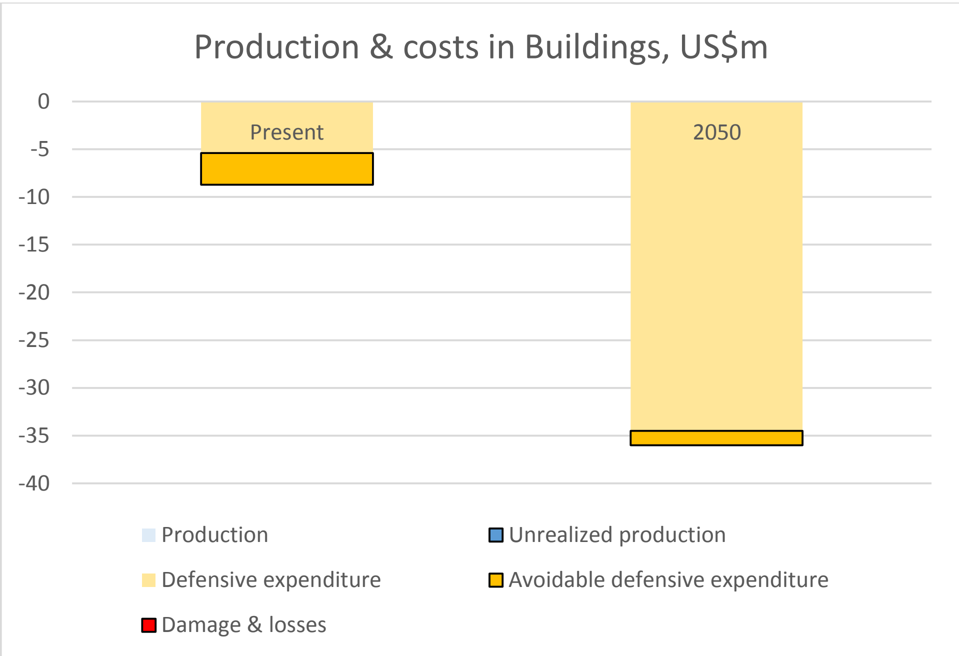


Figure 2.13: Climate-related annual costs in the buildings sector for the present and 2050. Defensive expenditure (maintenance costs) increases by 2050. There is a predicted decrease in avoidable defensive expenditure, representing a decrease in the cost of inaction.

2.5.4 Adaptation investments

Potential adaptation options for infrastructure are implied in the strengthening measures included in the IPSS model. For non-wooden buildings, this essentially involves increasing the specification of roof drainage to handle maximum expected rainfall volumes. The results of the analysis suggest that

this would be an economic investment, regardless of climate change. There are no adaptation measures modelled for wooden housing, which represents the majority of rural residences.

Table 2.22 shows potential adaptation options for paved and gravel roads. For paved roads, the adaptations for temperature focus on changing the design mix as well as changing the design of the seals to protect the road from further damage. For precipitation, the adaptations include both increasing the base depth that is the default adaptation in IPSS, and expanding the width of the road to allow for greater drainage. This is the second adaptation applied as precipitation levels increase across multiple thresholds. Flooding adaptations are focused on culvert design changes.

Gravel roads do not have a temperature adaptation process as temperature increases do not affect these roads. However, precipitation increases require increases in base layer thickness to enable greater carrying-capacity and drainage. However, there is an option to upgrade to a paved road where this may be appropriate. In this project, upgrading to paved is not an automatic adaptation as gravel road projects are focused on upgrading in near-term timeframes. Flooding adaptations also focus on culvert design as seen in paved roads.

The results of the analysis suggest that strengthening measures may become cost-effective for roads by 2050 under higher temperature increases.

2.5.5 Constraints & uncertainty

Results for roads and buildings were based on generalized probabilistic models of maintenance costs for construction standards based on international experience, and on the assumption that maintenance needs are always met. The models were based on the actual infrastructure stocks in Moldova, but would also need to be 'ground-truthed' against the construction standards and maintenance practices in actual use. The models indicate that a switch to higher construction standards for paved roads could possibly be beneficial in the medium term, but more detailed work is needed to define specific standards and climate triggers.

Table 2.22. Adaptation measures for roads

Road type	Climate stressor	Effect	Reactive Measures	Proactive Adaptation measure
Paved roads	Temperature	Increased temperature leads to accelerated aging of binder	Additional sealing required on a more frequent basis due to faster degradation of road quality	Construct dense seals (e.g., Sand Seal, Otta Seal, Chip Seal). These are subject to local practices
		Increased temperature leads to rutting (of asphalt), and bleeding and flushing (of seals)	Additional patching required each year to fill cracks resulting from pavement weakening	Adoption of base asphalt binders with higher softening points (including polymer modification) for surface seals and asphalt. Local mix may be available in addition to standard mix
	Precipitation	Increased precipitation leads to increased average moisture content in subgrade layers and reduced load-carrying capacity	Increase patching to address cracking from surface failure	Add wider paved shoulders to improve surface drainage.
			Fill subbase where erosion has occurred due to water infiltration. Follow with additional patching	Increase base strength (thickness and/or quality) to increase protection of subgrade layers. Should increase an additional 10 cm – 15 cm.
	Flooding (in excess of design flood)	Washouts and overtopping of road	Repair of localized washouts including cleaning culverts, replacing culverts, replacing subbase, and replacing asphalt surface	Increase flood design return period by increasing the size of culverts (in most cases will require raising the road to allow larger culvert to fit). Increase is done in standard increments according to local practice. Generally need to increase one diameter size or approximately 5 cm.
Unpaved roads	Temperature	Not applicable		
	Precipitation	Increased precipitation leads to increased average moisture content in subgrade layers, and reduced load-carrying capacity	Regrade road localized to precipitation, fill subbase and reapply gravel top layer.	Increase gravel wearing course thickness to increase cover and protect subgrade layers. Generally increase by 10 cm - 15 cm to handle increase in moisture
				Upgrade road to paved.
	Flooding (in excess of design flood)	Washouts and overtopping of road	Same as for paved except application of gravel top layer rather than application of asphalt layer.	Increase flood design return period by increasing the size of culverts (in most cases will require raising the road to allow the culvert to fit underneath).

2.6 Health

2.6.1 Overview

Moldova's health outcomes are moderately better than expected for its level of economic development, but not as good as expected for its level of health expenditure (around USD360 per

capita per year). Over the last 20 years, while good progress has been made in reducing death rates in younger age groups, mortality in adult males has increased. Non-communicable diseases (NCDs) have become the major burden of mortality and illness for the population. High blood pressure (hypertension) and smoking are among the leading NCD risks. Around 50 percent of Moldovan adults have high blood pressure. Adult smoking prevalence is 43 percent, compared to the regional average of 31 percent, and half of youth smokers started before they were 10 years old. The NCD burden is associated with a significant annual welfare and economic cost of around USD440 million.

Despite repeated changes in political leadership over the last decade, health has remained a priority of the Moldovan Government. There has been a series of significant reforms to modernize the health sector. A key development was the introduction of national health insurance in 2004 and the establishment of the National Health Insurance Company. Approximately 80 percent of the population is currently covered by health insurance. Primary care has been strengthened through the creation of family medicine. Family medicine providers are paid on a capitation basis to provide primary care for a defined population and to act as gate keepers to specialist care. Citizens have free access to selected primary care services regardless of insurance status.

2.6.2 Climate impacts & current cost of inaction

The transmission and effects of a variety of diseases can be exacerbated by climatic conditions. High and low temperatures impose physiological stress; the abundance of most disease vectors is influenced by climatic conditions; and extreme weather events contribute a range of acute threats to physical and mental health and wellbeing. In an attempt to quantify the current costs of climate-related health risks, this study focused on heat-related mortality and food-borne disease, namely salmonellosis, but this is far from a comprehensive accounting of climate-related health costs.

For extreme heat, the impact on mortality of the heatwave in 2007 was estimated by Corobov et al. (2013). They concluded that 142 additional deaths were caused, and treated it as a 1-in-100 year event. Overcenco et al. (2015) estimated there were 488 additional deaths from the same heat event. We estimate the cost of a death based on EU estimates of the value of a statistical life (VSL) in Moldova of USD240,000. Using these estimates gives an annual expected cost of USD777,070 (range USD354,139 to USD1.2 million).

There were 1,886 reported cases of salmonellosis in Moldova in 2014. The literature suggests a 1% to 5% reporting rate – implying that between 37,720 and 188,600 cases actually occurred. The PESETA project suggests that, in the EU, 35% of cases are climate-related and that the cost per case is between €3,500 to €7,000 (in 2009 prices). Adjusting these figures for inflation and relative PPP GDP per capita between Moldova and the EU, this gives a current value per case in Moldova of USD542 to USD1,085 (2015 prices), and current estimates of annual costs of salmonellosis between USD7.16mn and USD53.91mn.

Thus, the total expected current annual cost of these two climate-related health effects is estimated to be around USD20 million (range USD7.5 million to USD55.1 million).

2.6.3 Future costs of inaction

Climate change in Moldova is expected to have a number of health impacts. Heat stress and related mortality may increase in the summers; cold stress-related mortality may decrease due to warmer winters; vector-borne diseases may increase as the potential ranges of different vectors change; and water- and foodborne disease is likely to increase due to temperature change and increased incidence of extreme events, particularly flooding. A strategy for adaptation to climate change in the

health sector in Moldova exists, which assessed climate risks and benefits to health in different regions of Moldova. A summary is given in **Table 2.23.**

Table 2.23: Summary of climate-health risks in Moldova

Degree of risk/benefit		North	Centre	South	Chisinau
Risks	Increasing number of deaths from heat waves	Low	Medium	High	High
	Increasing number of deaths from air pollution	Medium	Medium	Medium	High
	Changes in plants leading to increased allergies	Medium	Medium	Medium	High
	Emergence of high risk of drought and water scarcity	Low	Medium	High	Low
	Increased frequency and intensity of floods	Medium	High	High	Low
	Increased incidence of water- and food-borne disease	Medium	High	High	Medium
Benefits	Reduced duration of the heating season and fuel consumption in winter	High	Medium	Low	Medium
	Reduced mortality caused by cold				

Source: Republic of Moldova (2015a)

Corobov et al. (2013) found that, with air temperature below optimal values (mean 22 degrees C), each degree of warming was accompanied by a 1.4% decrease in mortality, while with temperature above a mean temperature of 22 degrees C, each degree of warming led to a 2.8% increase in mortality. Taking into account income and population changes, we can estimate the future costs of heat and future benefits of reductions in cold mortality in the 2050s. Table 2.24 shows average results across three SSP scenarios (SSP1, SSP3, and SSP5). On balance in this time period, the benefits outweigh the costs (i.e., the decrease in winter mortality exceeds the increase in summer mortality), but this does not include extreme events. Assuming that the frequency of extreme heatwaves will increase from 1 in 100 to 1 in 75 by 2050, and adjusting for the inflated value of statistical life and population decline, the expected cost of mortality from extreme events would be around USD4.6 million per annum (range 1.5 – 8.3 million).

Table 2.24: Expected annual costs of Heatwaves and Benefits of Warmer Winters by 2050, based on VSL (USDMn.)

Scenario	A2	A1B	B1
Mean	-19.3	-3.1	-26.7
Lower Bound	-13.5	-2.1	-18.6
Upper Bound	-25.2	-4.0	-34.8

Salmonellosis

To estimate the impact of climate change on salmonellosis, an additional 6% of climate-related cases is assumed per degree Celsius increase in daily average temperature. Costs per case and overall population at risk were adjusted in accordance with the three SSP scenarios (SSP1, SSP3, and SSP5) and for the two reporting rates. Under the conservative 5% report rate assumption, the costs of climate-related salmonellosis will rise from USD7.2 million to USD10.8 million at the current time to between USD14.2 million to USD22.0 million in the 2020s and between USD36.5 million to USD56.8 million in the 2050s.

Table 2.25: Costs of climate-related salmonellosis under different climate scenarios and reporting rates USDmn.

	Current	2050s		
		A2	A1B	B1
1% Reporting Rate				
Low Value	35.8	182.5	188.5	177.8
High Value	53.9	274.8	283.8	267.7
5% Reporting Rate				
Low Value	7.2	36.5	37.7	35.6
High Value	10.8	55.0	56.8	53.5

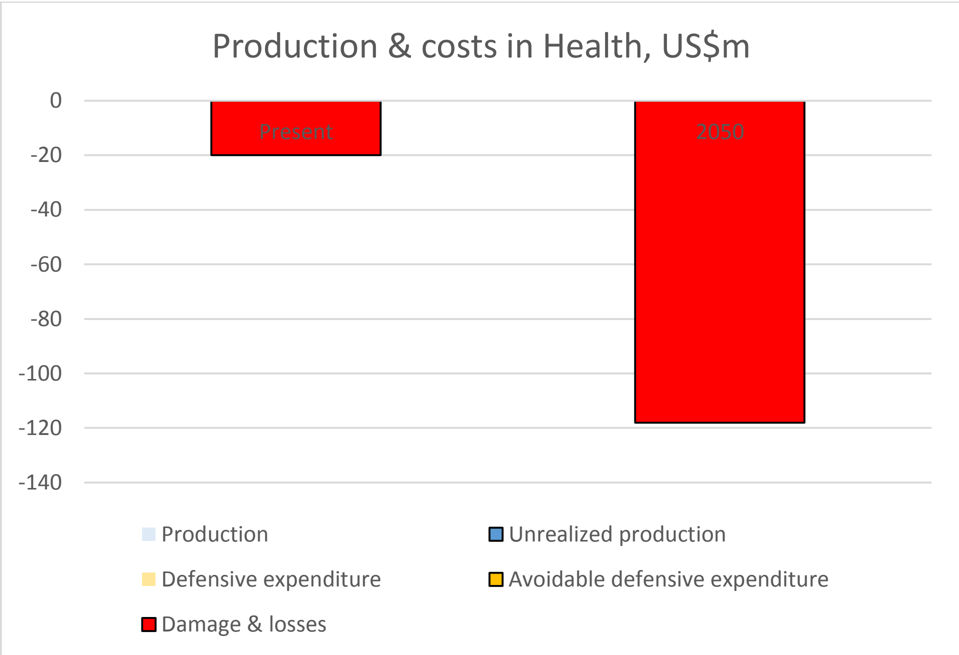


Figure 2.14: Climate-related annual costs in the health sector for the present and 2050. Damage & losses (i.e. costs of climate-related diseases) increase markedly from 2015 to 2050.

Total expected annual costs of climate-related impacts on health (damages & losses) are therefore estimate to rise to around USD118 million (range 39 – 324 million) by 2050. Figure 2.14 summarizes the current and future costs of inaction in the health sector. The annual expected cost of climate change by 2050 is equal to that portion of the increase in expected losses due to increased incidence of disease (as opposed to inflation in the costs of individual cases), or roughly USD60 million.

2.6.4 Adaptation investments

A variety of adaptation strategies for health have been suggested to increase awareness and preparedness, particularly for heat stress and related diseases (see UNDP HDR 2009). Following on from the analysis above, this study focuses on three main measures:

- Heat early warning systems

- Public Health campaigns for Salmonellosis
- Strengthening of general emergency response systems

General strengthening of health care systems would also be expected to improve the management of climate-related health burdens. However, the proportion of the overall health burden that is directly related to climate is relatively small, and therefore the climate aspect will make little difference to the economic assessment of healthcare development in Moldova as a whole.

Heat warning systems

To respond to extreme heat risks, heat-health warning systems (HHWS) have been proposed in a number of countries. A recent study for European Union countries suggested that heat-health warning systems have very favorable benefit-cost ratios, from 710 to 2210 across different member states (BASE, 2016). The costs and benefits of a HHWS in Moldova were assessed under the following assumptions:

- The costs of HHWS are similar to those estimated in other European countries. This includes costs of USD550 for the fixed cost of maintenance of the system and variable costs of USD3,712 per heat day.
- Costs of running a Heatline: USD1,000/day during the week, USD3,000/day during week end.
- Cost of Emergency Medical service: USD4,000/day.
- Future heatwaves last on average 45 days (as in 2007) and have the same expected mortality as 2007, but increase in frequency from 1 in 100 years to 1 in 75 years by 2050.
- A HHWS would reduce mortality by 68% on average (Fouillet et al. 2008).

We take a low value of 142 deaths per 1:100 year event based on Corobov et al., and a high value of 482 deaths for such an event based on Overcenco et al.

We use the estimated value of a statistical life (VSL) adjusted for future increases in GDP per capita under the average of the three SSPs (SSP1, SSP3, and SSP5) to estimate the value of reductions in mortality.

Table 2.26 shows the derived expected benefit-cost ratios (BCRs) based on either a high or low estimate of expected mortality for a typical event, with future VSL averaged over the three SSP scenarios. All estimates greatly exceed 1. The expected annual cost of installing and running such a system is estimated at USD4,728 currently, and USD6,120 in the 2020s and 2050s. Given the high benefit-cost ratios from current investment in a heat-health warning system, this is a recommended action.

Table 2.26: Benefit-Cost Ratio for Heat-Health Warning in Moldova

	Timing of investment		
Estimated extreme heat death assumption in base case	Current	2020s	2050s
Low (Based on Corobov et al. mortality estimate)	49.5	71.5	228.1
High (Based on Overcenco et al. mortality)	170.3	245.6	783.8

Public health campaigns for Salmonellosis

For salmonellosis, the costs of a public health campaign are estimated based on UK values of USD0.03 per person per annum, applied to the population size of Moldova. This gives present costs of a campaign of USD108,901 and future costs of USD70,890 in the 2050s (falling with mean population size decrease under the SSP1, SSP3, and SSP5 scenarios). The effectiveness of public health campaigns is a matter of some debate. We assume a 1% effectiveness rate—i.e., only 1 in 100

cases is reduced through such campaigns. We also consider only the most conservative estimate of incidence of salmonellosis—i.e., that there is a 5% reporting rate. The Benefit-Cost ratios derived from these data are shown in Table 2.27. The BCR is shown to range between 1.88 and 2.82 if enacted currently, rising to 13.20 to 20.14 if enacted in the 2050s. Given the high ratios from current investment in public health campaigns, this is a recommended action.

Table 2.27: Benefit-Cost Ratio for Public Health Campaigns against salmonellosis in Moldova

Value per case Avoided	Current	2020s			2050s		
		A2	A1B	B1	A2	A1B2	B1
Low Value (USD542)	1.88	3.60	3.64	3.63	13.20	13.37	13.05
High Value (USD1,042)	2.83	5.42	5.48	5.47	19.87	20.14	19.65

Strengthening emergency response

The Civil Protection Directorate in Moldova has prioritized future investment needs for emergency and disaster response as follows:

- Improving training:
  - This would involve the construction of a Training Centre aimed at fire and rescue personnel in both the public and private sector;
  - A training curriculum to enhance the capacity of Moldova for emergency prevention and preparedness.
- Operationalisation of Emergency Command Centres (ECC) in North and South:
  - At present there is one ECC in the country located in central Chisinau. This is a modern well-run facility, but there is no back-up facility in other locations;
  - Further ECCs would provide better support for routine and non-routine tactical operations;
  - A technical feasibility study already exists for these investments.
- Improving emergency response:
  - This includes investment in equipment to increase the geographic range of emergency response and to modernize emergency services. Some equipment is outdated, while the country also needs to upgrade facilities; new snow rescue vehicles and more electricity and heat generators would help.

The estimated investment needs are USD11 million. Benefits are not well characterized, but based on the experience under an existing World Bank disaster risk management project, we estimated that an expected amount of around USD15 million in current annual losses (and rising with GDP as per the SSPs) is potentially avoidable through strengthening of emergency response systems, and that between 15% to 25% of this can be saved through the identified investments. Overall, BCRs are estimated between 2.09 and 4.10, even without factoring in the likely increase in extreme events over time.

Table 2.28: Benefit Cost Ratios for proposed emergency response investments

	Low benefit	Medium benefit	High benefit
SSP1	2.38	3.17	3.97
SSP3	2.09	2.79	3.49
SSP5	2.46	3.28	4.10

Table 2.6.9 gives a summary of investments including ratings for uncertainties, impacts on poverty and impacts on gender.

Table 2.29: Summary of Potential Investments for Health

Description on investment	Period for implementation	Amount in USD (Mn.)	BCR	Uncertainty of Benefits	Impact on poverty	Impact on gender	Overall Priority
Heat Health Warning System	Capital investment 1 year, ongoing O and M	Up to 0.42 for a year with a heatwave, 0.0005 otherwise	Current : 3.1 to 170.3 2050: 9.9 to 921.1	High – valuation of statistical life based on value transfer	Medium	Medium – women disproportionately care for those affected	High
Public Health Campaigns	Ongoing O and M	Current cost: 0.1 per annum 2050: 0.05 to 0.9 per annum	Current : 1.88 to 2.83 2050: 7.16 to 27.3	Medium – actual number of salmonella cases unknown, this assumes 1 in 20 cases reported	Medium	Medium - – women disproportionately care for those affected but men worse affected	Medium
Improving emergency response	Four year investment period assumed	11.0 investment PVC including O and M 14.1	2.09 to 4.1	Medium– uncertainty over true benefits, but may be higher under climate change	Medium – some jobs created	Medium	High

2.6.5 Constraints & uncertainty

In the health sector, key sources of uncertainty are:

- Valuation of mortality risk. Both the actual numbers of deaths attributable to extreme heat (different studies provide considerably different figures), and the economic valuation of those deaths (based on adapting figures from European studies) are uncertain.
- Reporting rates for food borne diseases are also very hard to estimate without systematic surveys.
- The actual relationship between these health impacts and climate variables, is still poorly understood.
- Figures used in the BCR calculations only indicative, but tended to be conservative and the very favorable returns indicated suggest that there is considerable margin for error.
- A variety of additional climate-related health impacts are probable. Rising temperatures are expected to exacerbate the impacts of air pollution, and further work is also needed to

consider the impacts of extreme events on psychological wellbeing and the increased risks of vector borne disease. None of these were included in the quantitative analysis.

3 Cross-sector results

3.1 Costs of inaction

Table 3.1 summarizes the analysis of the costs of inaction and costs of climate change across each of the sectors analysed, and figure 3.1 summarize the expected annual costs of inaction at the present time and in 2050, respectively.

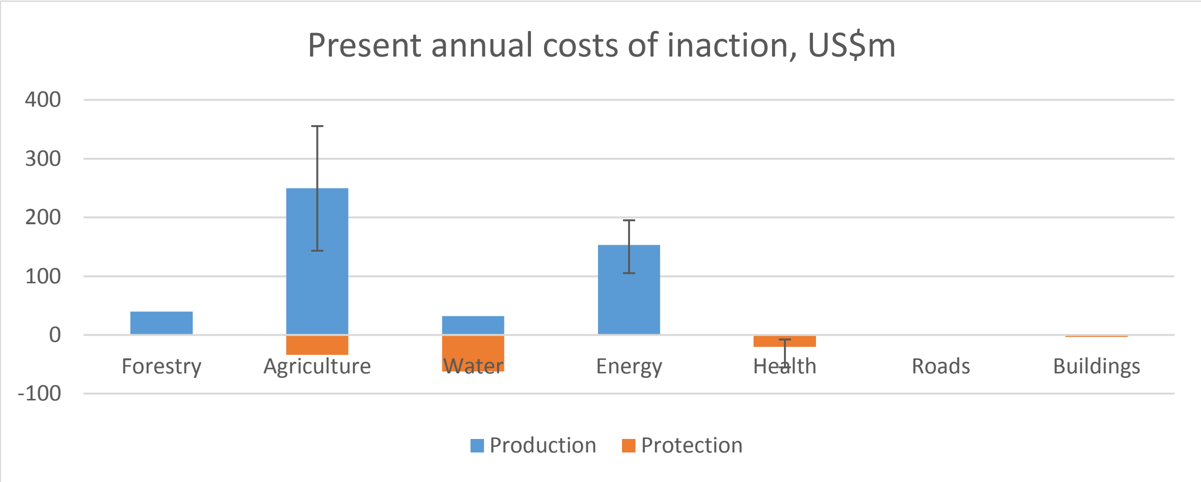
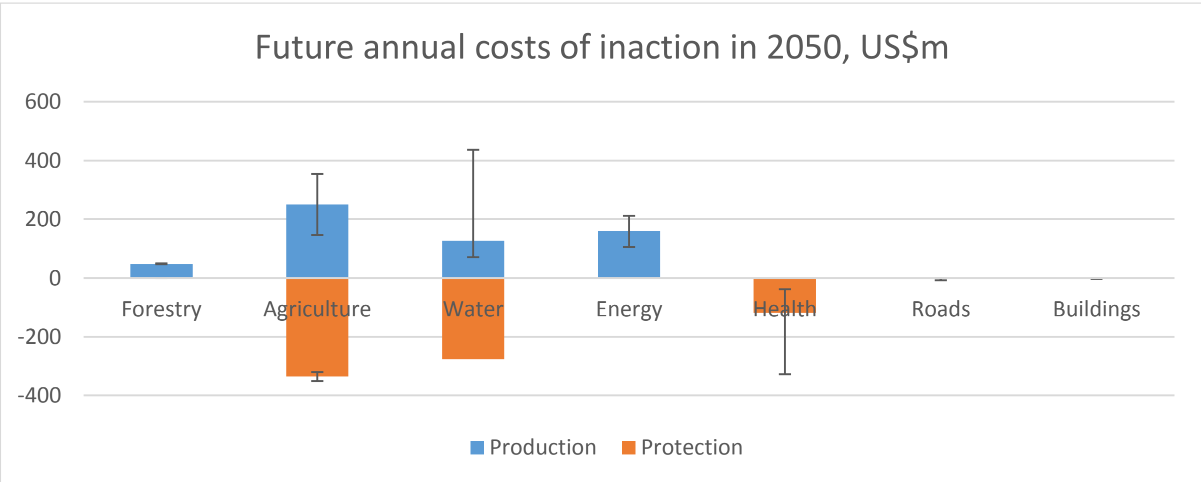


Figure 3.1: Comparison of present (above) and 2050 (below) annual costs of inaction across assessed sectors (both presented in 2015 dollars). Costs of inaction related to potential gains from enhancing climate-dependent production are represented as positive values (blue). Costs of inaction related to potential savings from reducing harmful effects of climate and the costs of protecting against them are represented as negative values (orange). The total cost of inaction in each sector is the sum of the magnitudes of both potential gains and savings (i.e. the combined height of the orange and blue bars). The confidence limits represent the range of values obtained from the climate, price, and shared socioeconomic pathways (SSP) scenarios used in the analysis. They do not encompass all sources of uncertainty.



At present, costs of inaction are dominated by unrealized production potentials in the sectors that depend on climate for their output. The largest opportunity cost is in agriculture, where production could probably increase by a couple of hundred million USD per year if the sector were managed more similarly to neighboring countries. There is also an unrealized production potential of over USD100 million per year in the energy sector through increased exploitation of climate-dependent renewables, although there are questions over the extent to which these are viable. Production

potentials in the forestry and water sectors, from forest restoration and improving the provision of WSS services respectively, are smaller, but still significant.

Table 3.1: Summary of results for costs of inaction

Sector	Key components of costs of inaction	Valuation methods	Annual costs in 2015 dollars, USDm			Uncertainty rating[29]
			Cost of inaction, 2015	Cost of inaction, 2050	Cost of climate change, 2050	
Forestry	Production of forest products and ecosystem services is climate-dependent and could be enhanced through restoration and reforestation with native species. Forests are also negatively impacted by climate-related pests and from drying and fire, but damage is relatively small in comparison to unrealized potential production. In future, forestry production will decrease and damages increase, but unrealized potential production increases slightly because the benefits of restoring (more resilient) native species increase with climate change.	Recent estimates of the total economic value of Moldova's forests were extrapolated to estimate the benefits of an ideal forest management scenario based on national forestry targets. Literature estimates of climate impacts on the productivity of individual tree species and on pests and drought were used to estimate future values under business-as-usual or improved management.	40.2	48.4 [47.4 – 50.4]	12	Potential value of ecosystem services CC impacts Socio economic scenario impacts Pest and fire losses
Agriculture	Moldova's agricultural yields are low compared to neighboring countries, representing unrealized climate-dependent production. Agriculture is also impacted by a range of climate-related extreme events,	Yield data for key agricultural products from Moldova and comparable countries were used to estimate unrealized production.	283.4 [177.6 – 389.2]	584.8 [465.3 – 703.1]	700	Production potential CC yield impacts

[29] Uncertainty ratings reflect the significance of different types of uncertainty in the estimation of cost of inaction for each sector. Red = high uncertainty, amber = medium uncertainty, and green= low uncertainty.

	particularly drought and floods. Future climate is expected to further reduce the yields of many key crops, as well as intensifying damage from extreme weather events.	Crop-specific models of the impacts of climate change, (Europe-wide) price changes for agricultural commodities and estimates of the increase in frequency of extreme events were used to forecast future impacts.				Socio economic scenario impacts Extreme event losses
Water	Deficits in overall water supply and unmet demand for domestic water supply and sanitation services represent unrealized potential climate-dependent production. A recent assessment of the economic impact of flooding provided an estimate of damage and losses in the water sector. There is little shortage of overall water resources at present, but modelling of future climate impacts and demand predicts a significant future shortfall without WRM investments. Flood damage is also predicted to grow significantly over coming decades.	A hydrological model was used to predict current and future overall availability of water resources. Water values were largely based on current market prices and therefore likely to underestimate the full value of future deficits.	94.1	403.1 [347.1 – 713.1]	205	Climate change impact Socio economic scenarios Damage and losses of flooding Valuation of water losses Valuation of benefits of WSS services
Energy	Unrealized production occurs due to the potential for power generation from climate-dependent renewables (i.e. wind and hydropower) that is not currently being exploited, as well as reductions in hydro and thermal power generation due to constraints on water resources. Significant impacts of	Unrealized production was valued at both domestic generation and import prices, but no changes in energy prices were modelled. Potential savings (avoidable defensive expenditures) from	153.4 [105 – 195]	159.2 [105 – 212]	6	Value of energy Economicallly viable hydropower potential

	(non-flood) extreme climate events on energy infrastructure were too rare to infer expected annual costs. Future climate change is expected to have little impacts on the former, and limited impacts on the latter. No appreciable increase in energy demand was forecast with future climate, as increasing summer cooling costs are at least offset by decreasing winter heating costs.	improved energy efficiency of buildings was not assessed.				Climate scenarios Extreme events – not considered Changes in energy demand in future
Roads and Buildings	Maintenance costs in the face climate-related deterioration of roads and buildings represents a defensive expenditure. In the case of buildings, upgrading roof specifications is expected to result in reduced costs, representing an avoidable defensive expenditure. Maintenance costs are expected increase with climate change for both roads and buildings.	Maintenance costs under current vs more climate resilient construction specifications were modelled.	3.3	1.5 [0.4 – 2.1]	35	IPSS engineering-based approach
Health	Losses in the health sector stem from a range of diseases whose severity and transmission are influenced by climate. Increases are predicted in the costs of mortality and disease burden associated with heatwaves and food-borne diseases. Increased mortality from generally higher summer temperatures is expected to be offset by reduced winter mortality, however.	Values of mortality and salmonella costs were adapted from European studies. Future disease trends were projected from a number of local and regional studies.	20 [7.5 – 55.1]	118.1 [39.2 – 327.3]	60	Socioeconomic scenarios Values of mortality risk Climate scenarios Climate-health linkages
Total			594.5 [431.8-779.4	1315 [1,009-2,013]	1,018	
Total as percentage of GDP			6.5%	3.4%	2.6	

	[4.7-8.5]	[2.6 – 5.2]	

Current opportunity costs of failing to protect against the negative impacts of climate are also substantial, amounting to more than USD100 million per annum in total, mostly due to the damages caused by flooding and a variety of weather impacts on agriculture, as well as the cost of climate-related health impacts. Costs of inaction in infrastructure (not including flood damage) are relatively negligible.

By 2050, the pattern of production-related costs of inaction is fairly similar. Estimates of unrealized production in forestry, agriculture and energy are not very different from the present, it is only in the water sector that the unrealized potential increases dramatically, as future water constraints are expected to intensify and limit industrial and irrigation uses.

In contrast, the costs of inaction in protecting against negative climate impacts show strong increases across the board, and are expected to total at least USD600 million per annum by 2050. The growth in expected damage and losses exceeds the GDP-linked growth in assets at risk, particularly in agriculture and health, as unfavourable climate events are expected to become more frequent.

The expected direct costs of climate change are also substantial, reaching around USD1 billion per annum by 2050. The distribution of direct costs of climate change across the sectors is similar to the pattern the costs of inaction on protection, except that the costs to the agriculture sector are even more dominant, accounting for around 70% of the total. At an expected direct cost of USD35 million per year, the direct costs on climate change on roads and buildings is also significant. This figure reflects an increase in maintenance costs predicted under the IPSS model, but is not reflected in the opportunity costs of inaction because the increased expenditure is unavoidable.

Both the present and future costs of inaction, and the direct costs of climate change by 2050 are significant in relation to overall GDP. The present total cost of inaction on climate adaptation is equivalent to 6.5% of GDP. Despite the total cost of inaction more than doubling by 2050 in real terms, this represents a lower fraction of total GDP at 3.4%. The direct costs of climate represent 2.6% of GDP by 2050. However, this reduction in the relative costs as a proportion of GDP is predicated on optimistic predictions of GDP growth (equivalent to 4.2% sustained growth in real terms over 35 years). More modest growth would lead to an increase in the relative costs of inaction and climate change.

3.2 Adaptation investments

The analysis of individual sectors in Section 2 provides details on potential investments in each sector. Table 3.2 and figure 3.2 summarize recommended investments that would exploit the climate adaptation opportunities represented by the costs of inaction. The investments are prioritized on several criteria, including: the benefit-cost ratio (BCR) or internal rate of return (IRR) (when available) and the confidence in those estimates; the size of the potential investment and returns; and qualitative assessment of impacts on gender and poverty. Overall, the biggest challenges and investment opportunities are in agriculture (and a range of related landscape restoration activities) and in water-related infrastructure (including supply networks, irrigation, flood control, and multi-purpose water storage. The two areas overlap through irrigation. The ideal size and timing of water storage investments requires more analysis, and the institutional capacity to effectively manage a variety of water investments would also need to be strengthened. In addition, there are modest investment opportunities in emergency warning and response systems that could have significant benefits for public health and safety.

Table 3.2: High Priority Investments - in the near to mid-term

Sector	Description on investment	Period for capital investment	Amount in USD (Mn.)	Indicative economic return (BCR or IRR)[30]	Uncertainty of benefits and costs[31]	Impact on poverty	Impact on gender
Agriculture: Water Management	Rehabilitate/Modernize Centralized Irrigation Systems	2017 to 2040	975.0	IRR: 8% to 15%	Medium	Medium	Medium
	Rehabilitation/Modernization of Drainage infrastructure in irrigated areas	2017 to 2026	120.0	IRR: 8% to 15%	Medium	Medium	Medium
	Institutional Reforms/Capacity Building	2017 to 2024	140.0	n/a	Medium	High	High
Forestry	Ecological reconstruction of forests	2020 to 2029	91.3	IRR: 3% to 14%	Medium	High	High
	Ecological reconstruction of forest belts	2020 to 2029	4.9	IRR: 4% to 15%	Medium	High	High
Health	Heat Health Warning System	2017+	0.4[32]	Current BCR: 3.1 to 170 2050 BCR: 9.9 to 920	High	Medium	Medium
Water Supply	Improving Municipal and Industrial Water System Efficiency by 10% Reduction in Losses	2017+	2.8-5.5	BCR: 61 to 70	Low	Medium	Medium
	Water Storage in Lower Nistru (100MCM)	2030+?	18.4	BCR: 2.6 to 6.4	Low	Medium	Medium
	Water Storage in Reut (1MCM)	2020	0.3	BCR: 20 to 59	Low	Low	Medium
Flood Prevention	Structural Measures	2020-2040	360.8	BCR: 2.1	Medium	Unknown	Unknown
	Non-Structural Measures	2020-2040	136.6	BCR: 5.6	Medium	Unknown	Unknown
WSS	Rehabilitation of existing and construction of new WSS infrastructures	2020-2040	409 [350-439]	BCR: 2.5-3.2	Medium	High	Medium
Disaster Response	Improved training facilities Creation of Emergency Command Centres in	2020	11	BCR: 2.1 to 4.1	Medium	Medium	Medium

[30] In several cases, the benefit-cost analysis relied on values in the literature. Therefore the analysis could not be fully standardized and in some cases the results are reported as benefit-cost ratios, and in others as internal rates of return.

[31] Ratings are given here for the significance of uncertainty of benefits for each investment. Red = high uncertainty, amber = medium uncertainty, and green= low uncertainty. A discussion of the basis of these ratings for each sector is given in the section "Uncertainty in the Analysis and Critical Knowledge Gaps" of this Executive Summary.

[32] Costs incurred in years of a heatwave.

Sector	Description on investment	Period for capital investment	Amount in USD (Mn.)	Indicative economic return (BCR or IRR)[30]	Uncertainty of benefits and costs[31]	Impact on poverty	Impact on gender
Management	North and South Improving emergency response capabilities						

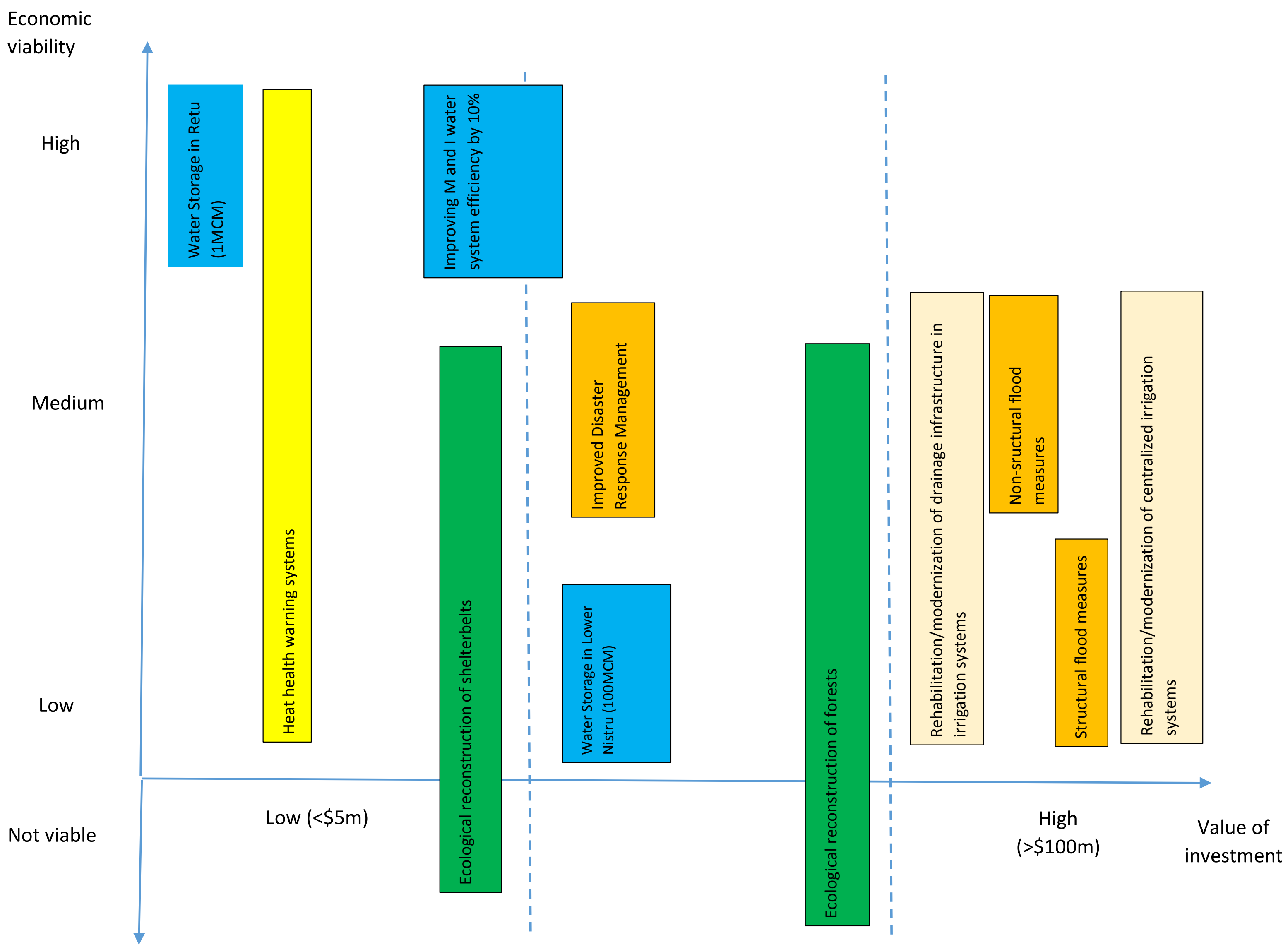


Figure 3.2 Comparison of priority projects: Economic viability compared to value of investment

Ratings of economic viability are based on the following:

- High viability – indicated by a BCR above 5 or an IRR above 20%;
- Medium viability – indicated by a BCR between 2 and 5 or an IRR between 10% and 20%;
- Low viability – indicated by a BCR between 1 and 2 or an IRR between 6 and 10%
- Not viable – indicated by a BCR below 1 or an IRR below 6% – the rationale is that this would indicate that costs outweigh benefits under both measures since the IRR would be below a low discount rate usually applied in a country such as Moldova

Priorities consist of:

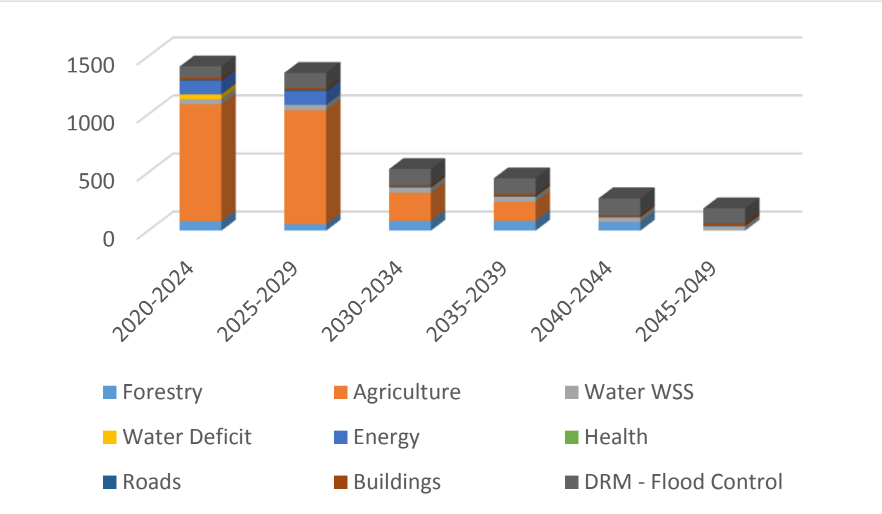
- Agriculture: The largest costs from inaction and future climate change occur in the agriculture sector. Key investments related to expanding irrigation, i.e., rehabilitation and modernization of centralized irrigation systems and of drainage infrastructure in irrigated areas, will make a major contribution to increasing current productivity and to mitigating future climate impacts. These investments are expected to have good rates of return as long as they can be combined with successful institutional capacity-building for management of irrigation systems. Other options include: small-scale on-farm irrigation systems; soil management; climate risk management technologies (e.g., anti-hail nets); and the potential for changes in crop mix towards perennial crops (i.e., grapes and fruit trees) which will be more resilient to climate change.
- Forests: Ecological rehabilitation and expansion of forests and forest belts are expected to have high returns on suitable land, and to have a high poverty and gender impact due to the range of products and services they provide to rural communities. Restoration of degraded forests and pasturelands are also linked to agricultural productivity, as they provide hydrological regulation as well as protection from wind and snowdrifts.
- Health: Although there is uncertainty around the scale of climate-related health impacts, the establishment of early warning systems for heatwaves is likely to enjoy a high benefit-cost ratio and significantly improve public health.
- Water: Improvement in municipal supply systems to reduce losses, and building a small-scale storage reservoir on the lower Nistru, present immediate, modest investment opportunities to improve water supply with strong returns. In the medium-term, larger-scale storage infrastructure on the Reut and lower Nistru are likely to be needed, but the ideal timing and scale of these investments requires further analysis. Rehabilitation of existing and construction of new water supply and sanitation infrastructure would provide valuable services to rural communities, although their financial viability is less certain.
- Flood Control: A substantial set of structural and non-structural measures for flood control is expected to provide significant economic returns from the reduction of damages and loss, according to the recent work of EIB (2016).
- Disaster risk management: A set of modest investments are expected to provide key gains for public safety and substantial economic returns, i.e., improvements to emergency prevention and preparedness, including training facilities, new Emergency Command Centers in the North and South, and improving emergency response capabilities.

In addition to identifying shorter-term investment priorities, a potential investment pathway was prepared to illustrate how total identified investment needs might be spread over the period to 2050 (see Table 3.3 and Figure 3.3). The figures are for five-year intervals, from 2020-2024, to 2045-2050, and averaged over different climate scenarios. Total investment is highest (close to USD280 million per annum on average) in the first 10 years when much of the priority investment needs (amounting to USD1.85 billion, or about 29% of total investment) are delivered. During this period, investment would be equivalent to a couple of percent of total GDP—a large amount, but smaller than the predicted annual costs of inaction. In subsequent years, the investments decline to around USD100 million per annum in the second decade and to less than USD50 million per annum on average in the third decade. The relative value of these investments as a percentage of GDP fall significantly beyond the first decade, given the assumption of sustained, strong GDP growth.

Table 3.3: Investment & Other Expenditures to Address the Cost of Inaction (USD Mn.)

Sector	2020-2024	2025-2029	2030-2034	2035-2039	2040-2044	2045-2049
Forestry	81.2	55.6	84.3	85.3	74.4	0.0
Agriculture	1,005.8	979.8	242.0	163.0	0.00	0.0
Water WSS	44.0	44.0	41.0	41.0	38.5	38.5
Water Deficit	41.5	1.5	1.5	1.5	1.5	0.0
Energy	117.5	117.5	0.0	0.0	0.0	0.0
Health	0.1	0.1	0.1	0.1	0.1	0.1
Roads	4.5	11.0	11.2	6.7	4.9	4.2
Buildings	18.7	17.2	14.4	15.8	15.5	19.1
DRM - Flood Control	99.0	131.4	134.7	136.2	142.4	128.7
Total	1,412.2	1,358.1	529.3	449.8	277.3	190.6
Annual Inv. as % of GDP	3.1%	2.3%	0.7%	0.5%	0.3%	0.2%

Figure 3.3: Investment Needs by Sector, by time period (USDm)



3.3 Uncertainty and further work

This study aims to establish an analytical framework that can be repeated as models and data improve. The results are not intended to be definitive, and identifying key knowledge gaps (i.e., those that have the greatest impact on the conclusions) is a valuable output of the work.

Figure 3.1, Summary of Results for Costs of Inaction, does not represent the full range of uncertainty around the assessment of the costs of inaction. The "confidence intervals" around the results only represent the range of values obtained from the limited set of price, emissions, and SSP scenarios used in each analysis. In most sectors there are significant limitations in physical models that relate the expected values of impacts to climate variables. Once any projection more than a few years into the future is involved, such limitations are amplified by fundamental uncertainty around socio-economic processes, i.e., future populations, technologies, and prices, which typically exceed the uncertainty within climate and physical models.

Relying on available data, rather than developing all estimates from first principles, also precluded a fully standardized approach to the cost-benefit analysis of investment options. Figure 3.2, Comparison of Priority Projects: Economic Viability Compared to Value of Investment, attempts to provide a sense of the relative scale and economic returns from each investment, but a more rigorous approach would have allowed a marginal adaptation cost curve to be plotted, analogous to the marginal abatement cost curves developed for analysis of climate mitigation options.

Nevertheless, the broad patterns observed in terms of the relative magnitudes of the costs of inaction and investment returns are likely to be generally robust for the present and near future. The most consequential knowledge gaps, and therefore priorities for future studies, are summarized, in approximate order of importance, as follows:

1. The analysis of the energy sector suffers from fundamental uncertainty over the scale of viable power generation potential from climate-dependent renewables, and from lack of data on potential cost savings related to thermal energy efficiency of buildings (which would qualify as an avoidable defensive expenditure, given that heating and cooling of living space serves to protect from uncomfortable temperatures). This is probably the biggest gap in the analysis. Additional work on the energy sector could significantly change the assessment of the costs of inaction and investment opportunities in relation to other sectors, although a major change in the expected role of future climate change is less likely.
2. Agriculture potentials have only been approximately characterized, and effects of future climate change on agricultural production remain imprecisely known. Given the importance of the sector for adaptation, additional work is recommended.
3. Modelling indicates that future water shortages are likely to occur and that they will have major economic impacts, but the optimal scale and timing of investments to address these shortages was not reliably determined. Given the importance of expected future impacts on water availability, further analysis of hydrological projections, economics of water-related services, adaptive management strategies, and climate triggers would be warranted.
4. Data on damage and losses from extreme weather are generally incomplete. More systematic reporting systems, including for impacts of smaller-scale events such as hailstorms and frosts, would improve understanding of both the scale of such losses and the extent of investment in mitigation that would be justified. It is possible that there is some overlap between estimates of disaster losses to the agriculture sector and from flooding in general under the water sector, but estimates of agricultural losses are likely to be conservative anyway, given the scale of recent droughts in 2007, 2012, and other years.
5. The analysis for roads and buildings was based on generalized probabilistic models of maintenance costs for construction standards based on international experience, and on the assumption that maintenance needs are always met. The models were based on surveys of infrastructure stocks in Moldova, but would also need to be 'ground-truthed' against the construction standards and maintenance practices in actual use. The models indicate that a switch to higher construction standards for paved roads could possibly be beneficial in the medium-term, but more detailed work is needed to define specific standards and climate triggers.
6. There are many uncertainties in the health sector as to the nature, extent, and value of climate-related impacts, but total effects are still likely to be relatively small in comparison to the overall disease burden in the country. General strengthening of health systems is probably the most effective approach to address climate-related disease, but is unlikely to

be justified on the basis of climate impacts alone. Conversely, the recommendations for small, directed investments in information campaigns and early warning systems are likely to be robust due to their low cost.

7. In the forestry sector, there is a lot of uncertainty over the long-term ecological effects of climate change (i.e., changes in species productivities, distributions, incidence of pests & disease), but these effects will not result in major economic impacts within the timeframe of the analysis in this study (i.e., by 2050).

3.1 Poverty, gender & social dimensions

Despite a sharp decline in poverty in the 2000s, Moldova remains one of the poorest countries in Europe. The country grew on average by 5 percent annually between 2000 and 2014, much more rapidly than other countries in the region, with a concurrent fall in poverty rates from around 68 to 11.4 percent. However, disparities among regions inside the country and between genders persist. Poverty in rural areas is triple that in urban areas, and the rate outside of Chisinau is five times that within (Davalos et al. 2016). Agriculture is a major source of income for local families and the economy. In 2014, it represented 14 percent of the total GDP and employs 30 percent of workers. Almost 80 percent of the poor and 70 percent of lowest 40% of the population by income are employed in the agricultural sector, many of them underemployed (Mollers et al. 2016). Small family farms, many operating on a semi-subsistence basis, produce around 71 percent of total agricultural output.

Much of the current and predicted impacts of climate and climate change are concentrated in rural areas, precisely where poor populations have limited resources to cope with it. Agricultural production in Moldova is very sensitive to weather conditions, particularly staple crops, such as cereals. Yet 98% of Moldovan farms are small holdings of 0.8-10 ha, and there is a lack of access to rural finance for investments to improve productivity and resilience in the sector.

Recent studies (Popa et al. 2014) reveal the importance of forests to poor rural communities, and that the lower the household income, the higher the dependence on the forest. Fuelwood, poles and timber, and a variety of NTFPs (particularly walnuts) comprise the third most important source of income for villages with access to forest resources (11% of the total income, ranging from 18.2% in villages with higher forest coverage to 7.3% in villages with lower forest coverage). Nuts, primarily walnuts, represent the most valuable forest product (53% share in terms of value) as well as the most frequently collected product (17% in terms of frequency of total collection). Fuelwood is also the main source of fuel for heating and cooking in rural areas. Officially, the quantity of fuelwood sold by forest administrators represents only a small portion of total wood consumed for heating, which suggests a high dependence on illegal sources. The issue of illegal logging brings attention to the scarcity of the forest resources in Moldova and raises questions of their sustainability.

The rural poor also have less access to household water supply and sanitation services, and other infrastructure, such as roads, that will be put under increasing pressure by climate change. In total, 75.4% of urban populations have connections to sewerage, compared to 1.6% in rural areas.

Women are also likely to be more vulnerable to unfavorable climate conditions and future climate change, both because they already have fewer resources at their disposal (UNDP 2009: in 2007 – 2008, women's wages were on average 70 percent of men's, up from 64 percent in 2006), and because they are likely to be disproportionately impacted by climate:

- Many impoverished women are farmers and depend on agriculture and natural resources for subsistence and income. Women comprise 36% of agricultural landholders, but only own

19% of land. Female-headed farms are a third smaller (0.81 vs 1.2 ha) and receive less investment (women own only 12% of existing agricultural machinery).

- There are substantial differences in access to piped water supply for female-led compared to male-led households. In rural areas, 55% of female-headed households are connected, compared to 75% of male-headed households. (Solidarity Water Europe, 2014). Women are most often the users, providers, and managers of water in rural households and are the guardians of household hygiene. If a water system breaks down, women will most likely be more affected, as they may have to travel further for water or use other means to meet the household's water and sanitation needs. Investment in WSS will contribute both to climate change adaptation and to gender equality.
- Although Moldova-specific data are lacking, women are expected to be more severely impacted by a number of climate-related health effects (see Table 3.4) below.

Table 3.4: Health impacts of climate change and gender-specific factors

Health impact	Gender factors
Temperature-related morbidity and mortality	In general, women's mortality is more strongly impacted by extreme heat than men's mortality (Röhr et al, 2004)
Extreme events	Women more impacted due to taking burden of increased care. There can be adverse reproductive outcomes following a disaster. Other biological differences and social risk factors may also impact on differential health impacts based on gender (WHO, 2002).
Air pollution-related health effects	Indoor air pollution exposures may differ by gender.
Waterborne and foodborne diseases	Some studies suggest differential symptoms between genders – with women clearing the symptoms of salmonella more rapidly than men, but with a longer diarrheal phase. Treatments may also have a different impact on people of different genders (Lonnemark et al, 2015)
Vector-borne and zoonotic diseases	Potential impacts on pregnant mothers (e.g. Zika).
Exposure to UV	Higher mortality rates from malignant melanoma in men than women, due to both biological and behavioural reasons

Source: Based on WECF (2004)

Broader economic impacts are possible from climate-related effects to agriculture and water resources. Climate-induced yield losses for key crops could be on the order of 33-52% (compared to a no-climate change scenario) by 2050, even before accounting for the impact of intensifying extreme events. This would represent a major blow to the economy, in which agricultural output accounts for 14% of GDP and 50% of exports, and would give rise to problems of food security,

which would disproportionately affect the urban poor. In recent years, the prices of food have risen much more than the prices of services. These changes in food prices are affecting the poor much more, potentially squeezing out spending on other needs, including health care and education, that are important for long-term well-being (Davalos et al. 2016).

Economic growth prospects could also be affected by intensifying water deficits if the latter are not addressed through adaptation measures. Recent estimates suggest that average run-off of surface water, including to the rivers Prut and Dniester, will decrease on average by 13 percent by 2020 (depending on the modelling scenarios), while peak flows will increase, thus increasing the risks of floods and droughts. Decreasing annual surface water runoff and reduced groundwater recharge combined with the ambitious target of national economic development will lead to significant water scarcity by the 2030s (OECD, 2013). This will likely have a disproportionate impact on water availability for irrigation, as municipal and industrial use is likely to be prioritized.

Maintenance costs in infrastructure (for roads and buildings) are also projected to increase, and if these are not met, there will also be an impact on economic growth, particularly from the transport sector.

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