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Moldova

Water Security Diagnostic and Future Outlook

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Moldova

Water Security Diagnostic and Future Outlook

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Abbreviations

AIPA	Agency for Interventions and Payments in Agriculture	NEF	National Ecological Fund
AMAC	Asociatia Moldova Apa-Canal	NRDF	National Regional Development Fund
BAU	business as usual	RBMP	River Basin Management Plan
BCR	benefit cost ratio	RDA	regional development authority
CBA	cost-benefit analysis	SDA	Sustainable Development Account
CHP	combined heat and power plant	SE	state enterprise
DALY	disability-adjusted life years	SEI	Stockholm Environment Institute
FAO	Food and Agriculture Organization	SHS	State Hydrometreological Services
GCM	general circulation model	UNDP	United Nations Development Programme
GDP	gross domestic product	UNFPA	United Nations Population Fund
ICPDR	International Commission for the Protection of the Danube River	UNECE	United Nations Economic Commission for Europe
IPCC	Intergovernmental Panel on Climate Change	VSL	value of statistical life
JMP	Joint Monitoring Programme	WEAP	Water Evaluation and Allocation Planning
LPAs	local public authorities	WHO	World Health Organization
MARDE	Ministry of Agriculture, Regional Development and Environment	WIS	water information system
NARDF	National Agriculture and Rural Development Fund	WMS	water management system
MCC	Millennium Challenge Corporation	WRM	water resource management
NBS	National Bureau of Statistics	WSS	water supply and sanitation
		WUA	water user association
		WUPI	Water Utility Performance Index



Executive Summary

Setting the Scene for a Water Security Diagnostic

Why a Water Security Diagnostic and Future Outlook?

Water security underpins development outcomes by delivering benefits for people, the economy, and the environment, and mitigates water risks that will be amplified by climate change. Moldova requires significant investments across a range of water-dependent sectors if its growth ambitions are to be realized, but until now, a detailed assessment of the country's water balance has not been undertaken. Hence, a holistic water security diagnostic is critical for future policy making, strategic investment planning, and adequate financing. This report aims to assess the performance of Moldova's current water sector, identifying areas that require remedial actions to enhance the country's water security. The diagnostic investigates critical questions relevant for decision-makers about Moldova's water security, specifically (1) are water resources reliably available to meet future development needs, now and under future development trajectories; (2) how can Moldova best leverage its water resources to achieve its economic and social development goals in a sustainable manner; and (3) what are the key risks to water security, what are barriers that hinder performance, and what interventions and policy actions need to be prioritized

to realize a water secure future? A water balance assessment tool was developed to help Moldova answer some of these questions.

Development Challenges and Water Security

Moldova is a landlocked country bordered by Romania and Ukraine in Eastern Europe, with a population of approximately 3 million and 60 percent of its population residing in rural areas. It is faced with a challenging development path, exacerbated by the current COVID-19 pandemic and economic recession. The country needs to sustain macroeconomic stability and revive private sector growth and job creation, but its growth model is unsustainable and losing strength. A reliance on remittances, weather-dependent agricultural products, and high exposure to internal and external shocks pose exacerbating pressures on the country, further stressed by declining population numbers.

These developmental challenges are intertwined with water-related sectors. Moldova's water resource endowments need to be harnessed to leverage the productive dimensions of water for the economy, such as agriculture and agribusiness development that can help diversify the economy and increase exports. Water security also means that citizens—both urban and rural—can live productive lives, in a clean environment, with reliable water services, and based on livelihoods

that are resilient to floods and droughts, pollution, or environmental degradation. Moldova's future climate is uncertain and diverging climate projections exist. Most climate models predict a warming and drying effect with lower average runoff and with more frequent and intense droughts and floods, which in turn will pose additional risks to water security.

To achieve the aspirations of Moldova's citizens for higher incomes and lifestyles like those in neighboring middle- and high-income countries, a three-pronged strategy from government is needed that entails (1) boosting productivity and private sector growth, (2) strengthening human capital and social inclusion, and (3) promoting sustainable resource management.

Current Water Resource Endowments and Demand

Moldova's physical water endowments are not a binding constraint for its development and can reliably fulfill demand for drinking water, industry, thermal cooling, and irrigation. Moldova has ample total renewable water resources estimated at 15.6 billion cubic meters annually. On average, unmet demand is 3.5 million cubic meters per year, a fraction of total water demand, which is 725 million cubic meters per year.

It derives 86 percent of total renewable water resources from external territories, through the transboundary Prut and Dniester rivers, and has substantial internal surface water resources (1.9 billion cubic meters per year) and deep groundwater resources (0.3 billion cubic meters per year). Moldova's total water resource endowments (4,952 cubic meters per capita per year) are largely enough for the current modest levels of water withdrawals (231 cubic meters per capita per year).

Thermal cooling for combined heat and power plants, although largely nonconsumptive, forms the largest share of Moldova's water withdrawals (77 percent), followed by drinking water (19 percent), industry (4 percent), and irrigation (1 percent).¹ Because of the collapse of large-scale irrigation systems built in Soviet times, Moldova's agriculture is now largely rainfed. Irrigation is used as a supplemental source to precipitation and only a modest area is irrigated (6,640 hectares), explaining the low demand for water for irrigation. Deep groundwater, despite efforts to increase utilization of surface water because of groundwater quality concerns, remains important as a source of drinking water, and comprises a third of total demand.² Although quantitatively this amount is within sustainable yields, naturally occurring hardness and mineralization limit groundwater use in parts of the country without further expensive treatment.

Water Security Outcomes: For the Economy, People, and Environment

Moldova derives significant economic, social, and environment benefits from its water. However, there are barriers to water security that limit the scale and efficiency of these benefits, and increase the opportunity costs of efforts in the sector.

Water Security Outcomes for the Economy

Agriculture remains an important pillar of the economy, representing 10 percent of gross domestic product (GDP) in 2019. Its value for jobs is significant, employing a third of Moldova's labor force. Agricultural produce and food products account for 45 percent of exports, and most exports still comprise commodity crops, such as oil seeds and cereals. Moldova's largely rainfed agriculture remains vulnerable to droughts, with volatile outputs that expose the economy and affect rural livelihoods. Despite challenges, Moldova's agricultural sector can be a motor for diversification and growth in the future. Since 2010, the area cropped, and the harvests of fruits and vegetables have increased. Although Moldova is transitioning toward a more diversified economy, opportunities from a higher-value agriculture are not fully realized. This is partly the result of underinvestment and poor management of state-owned irrigation schemes, most of which are now dysfunctional. Irrigation systems rehabilitated since 2010 with the support of the Millennium Challenge Corporation (MCC) have not fully delivered the intended benefits yet, requiring additional attention to enhance enabling conditions, such as market linkages, land consolidation, and access to knowledge and finance for farmers. A two-pronged approach is required to realize the full benefit of outcomes from water in agriculture: first, to accelerate the transition toward irrigated high-value agriculture focused on export markets, and second, to increase the adaptive capacity of rainfed agriculture to droughts to ensure resilient livelihoods and food security.

Water also contributes to heat and energy production through thermal cooling and supports an array of industries, such as textiles, metals, food processing, and machinery. However, firm productivity is compromised by the lack of reliable water supply services in towns, with disruptions affecting business processes and manufacturing.

Moldova has both high riverine flood risk and drought risk because of the interannual and intra-annual variability of its precipitation patterns and its mostly rainfed agriculture sector. Climate extremes, channeled through the hydrological cycle, impose large economic costs on the country. The average annual economic impact of floods is estimated at US\$100 million annually (0.1–0.2 percent of GDP), directly or indirectly affecting 70,000 Moldovans.

Water Security Outcomes for the People

Stark disparities continue to exist in access and quality of water and sanitation services between urban and rural areas. Only one in three people in rural areas have a piped water connection to a public network and only one in eight have flush toilets. The low level of sanitation access and lack of adequate treatment directly impose a cost on public and environmental health. Almost a million Moldovans are estimated to rely on shallow polluted wells for their drinking water, and 80 percent of wells are not compliant with drinking water norms (for example, nitrates and microbiological contamination). Reliable water and sanitation services are vital for businesses, including tourism, to flourish and for people to live healthy, dignified, and productive lives. Delivering on the aspirations of citizens for better water, sanitation, and hygiene conditions is critical for social stability and resilience to pandemics.

Water Security Outcomes for the Environment

Moldova's environment has suffered from neglect, specifically under Soviet times, when economic growth was prioritized over environmental goals. This has resulted in polluted waters and an overall poor ecological status of many water bodies in the Prut–Danube–Black Sea and Dniester basin. Approximately 40 percent of water produced for municipal and industrial use is collected but effective treatment is much lower, although not exactly known. Untreated wastewater and industrial and diffuse pollution from agriculture have severely deteriorated the quality status of surface water, limiting the use of these resources for many purposes without costly treatment. High levels of river canalization and deteriorated watersheds and wetlands across the country have compromised ecosystem services. Their restoration is necessary to preserve natural capital and help mitigate the effects of floods and create value through nature-based tourism, a small niche in the economy.

Future Outlook: Endowments, Water Security Risk, and Benefits

Can Water Endowments Reliably Meet Water Demand under Future Development Scenarios?

Using the Water Evaluation and Planning System tool (WEAP), this diagnostic assesses whether there are sufficient water resources reliably available to support water demands for different development scenarios. So-called water futures³ were developed, based on social, economic, and demographic drivers, that reflect

investments and increasing demands for drinking, industrial, and irrigation water by 2030.

Modeled results suggest that, across all water futures, including the Holistic Regional Development scenario that sees a tenfold expansion in irrigated area (from 6,640 hectares to 62,000 hectares), water resources themselves do not pose a constraint for Moldova's development. Total unmet demand remains low at 14 million cubic meters per year, less than 4 percent of total water demand.⁴ Shortages, in the limited instances that they occur, are expected to mostly occur in the irrigation sector. Under the Holistic Regional Development scenario, across all years, including the driest ones, at least 89 percent of the total demand and 75 percent of irrigation water demand can still be realized. Although shortages are expected to be modest at a national scale, more severe effects are found in hotspot catchments, along the north and middle Prut, and in the southwest of the country. Hotspots require careful resilience planning and additional support for vulnerable farmers. This means that irrigation development requires a well-targeted and climate-informed expansion of schemes both for central publicly owned systems and small-scale privately run irrigation systems. A combination of efficiency measures and market-driven allocative decisions is needed to mitigate the effects of shortages on economic output. Other measures such as seasonal storage options should be further investigated. Mitigating the effects of droughts could also be pursued in the future by allowing restricted and controlled use of groundwater for supplemental irrigation, if quality allows and only when informed by adequate risk assessments.

What Are the Most Critical External Risks and Uncertainties for Water Security?

As part of this diagnostic, the water futures have been stress tested for external risks and uncertainties. These include uncertainties surrounding environmental flow requirements, the effects of different climate change projections, and increased irrigation water demand upstream in Ukraine. The diagnostic did not assess specific effects of the hydropower complex at the Ukraine border, or for future upstream hydropower development in Ukraine. Studies are ongoing to analyze environmental risks associated with the hydropower daily peak flow releases (UNDP/OSCE/UNECE 2019).

Climate change remains the most important external risk to Moldova's water security. Modeling results indicate that a future climate that is drier and warmer has a modest effect on water availability and reliability for municipal and industrial use, and risks can be mitigated through efficiency, recycling, and demand

management measures. However, a drier climate is expected to affect irrigation water shortages, seen through the expansion of hotspot catchments, and already vulnerable rainfed farming. A range of measures such as adaptive irrigation and climate resilient agronomical practices, allocative measures that favor high-value uses and seasonal storage can be harnessed to manage water insecurity risks to livelihoods and the economy. Unsurprisingly, trade-offs between environmental flow requirements and irrigation water demand occur in drier years in hotspot catchments. A better understanding and enforcement of environmental flows is thus required to protect ecosystems.

Modeled results indicate that an increase of water use for irrigation, representing a sevenfold irrigated area upstream in Ukraine, does not pose a significant water security risk to Moldova. The large cross-border inflow is marginally affected and additional annual shortages in Moldova are in the order of magnitude of 0.5 million cubic meters.⁵

What Are the Costs and Benefits of Water Futures?

Each “water future” scenario is associated with a range of costs and benefits across sectoral investment components: municipal water supply, irrigation development, and flood protection. An economic assessment undertaken in this report demonstrates that large benefits compared with costs will flow to the economy, the people, and the environment for the different water futures. Because of the large financing envelope, prioritization is needed. Within the irrigated agriculture sector, a first priority is to focus on economic usage of the already rehabilitated irrigation systems, with second and third priorities to support the expansion of private small-scale high-value irrigation schemes, and public investments in rehabilitation of central irrigation systems, respectively. Complementary policy measures are necessary to ensure that irrigation services are fully used and intended economic outcomes are achieved. Investments in irrigation systems will have knock-on effects for the agrobusiness industry, strengthen Moldova’s export position, and support food security, jobs, and local supply chains, especially relevant in post-COVID-19 times. Investments in flood protection and water supply and sanitation (WSS) show economic benefits, but these investments also have many benefits that are not easily quantifiable in terms of social inclusion, quality of life, and environmental protection of the resource. The COVID-19 pandemic illustrates the knock-on economic and public health benefits that come with water supply and hand hygiene to curb outbreaks and prevent infection.

Sector Performance and Barriers for Water Security

The performance analysis of the sector at large illustrates that governance, institutions, infrastructure, information, and finance are all barriers to achieving water security outcomes in Moldova.

Governance and Architecture

Although Moldova has a comprehensive legal framework that is largely aligned with the European Union Water Framework Directive, limited oversight in the sector, weak water abstraction and allocation management, underdeveloped policy mixes, and a slow operationalization of legal frameworks limit the effectiveness of the sector’s performance. Ambiguities and shortcomings in the legislative framework continue to exist, particularly affecting river basin management, transboundary governance, and WSS. Although reform efforts across the sector have progressed, this process is incomplete for several subordinate agencies under the Ministry of Agriculture, Regional Development, and Environment (MARDE). Even in a context of ample water resources endowments, water resource management (WRM) functions are needed to plan, allocate, manage trade-offs, protect resources, and manage risks in the face of climate change. Negative consequences of Apele Moldovei’s⁶ stalled reform are limited basin-level operational planning and allocation management, incomplete water permit registration, inefficient use of scarce financial resources, limited action on flood protection, and a lack of leadership on the *de jure* WSS mandate. Several functions are missing or underdeveloped at the national level, such as national investment planning, project preparation, quality assurance, innovation, sustainability monitoring, and technical and institutional support and incentives to service providers in urban and rural areas to facilitate aggregation.

Financing for Water Security

Current levels of financing for water security are inadequate. On-budget expenditures are far below the required needs to meet the Sustainable Development Goals (SDGs) and were 0.5 percent of GDP in 2017 or 1.4 percent of government expenditures, far below Organisation for Economic Co-operation and Development (OECD) and international benchmarks of 5 percent of government expenditures. Two-thirds of all sector expenditures (both on and off budget) came from development partner resources in 2017, indicating a heavy reliance on external sources and the need to increase domestic allocations. Investments in irrigation, WRM, and flood protection have been extremely modest—15 percent of all water-related expenditures. To increase funds for WRM, the financing mechanism for water management

and environmental protection needs to be reviewed and improved, with future earmarking of water-related fees and levies to secure allocations for WRM and flood protection. Financing for irrigation is a priority given the untapped potential and poor performance of the irrigation sector, but an irrigation development strategy and investment plan are missing. State irrigation enterprises operating partly functional schemes pose a significant burden to Apele Moldovei's budget and their liquidation will reduce the burden of unsustainable subsidies. Functional-rehabilitated schemes could be managed by water user associations (WUAs), a nascent model that has seen some initial success, gradually increasing financial performance, but which still remains fragile and requires support.

Although there are urban-rural service gaps, there is a sustained bias for capital investments for WSS in urban areas. This is rooted in various issues, such as limited national planning and management capacities for rural service delivery, unfunded decentralization of mandates, lack of political voice of declining rural populations, and lower affordability to sustain cost recovery and support debt servicing. Domestic funding for WSS remains fragmented and has not yet been consolidated in a coherent national program and streamlined delivery mechanism. The National Ecological Fund (NEF) and National Regional Development Fund (NRFD) are the two primary sources of domestic funds in the sector, with the NEF being the most important source of funds for rural communes. Although the NRFD has a good implementation track record, lack of result orientation, and major transparency issues hamper the effectiveness of the NEF. Given the large financing gaps, a financing framework could help to mobilize more resources from tariffs, government taxes, and partner transfers, and capital subsidies to rural areas, with relatively better-off population segments gradually shouldering investments through tariff increases. Such a financing framework would ideally build on a consolidated national program and WSS investment plan.

Recommendations and Pathways to Water Security

Derived from the analysis in this diagnostic, a possible roadmap is presented for Moldova's decision-makers to continue on the path toward building water security. The roadmap seeks to support decision-makers in phasing the implementation of recommendations: foundational measures, short- and medium-term actions, and ongoing measures. Foundational measures underpin the critical barriers to performance and should be addressed as a matter of priority. Actions required in the short and medium term, although important, will likely require sequencing. Ongoing

actions, such as the expansion or rehabilitation of infrastructure, should be done programmatically and in a phased approach in line with available finances and capacities. Recommendations are organized around three critical pillars of Moldova's water sector performance that, if barriers are addressed, can help deliver economic, social, and environmental benefits:

- Water resource management and resilience
- Water supply and sanitation services
- Irrigated and climate-resilient agriculture

Water Resource Management and Resilience

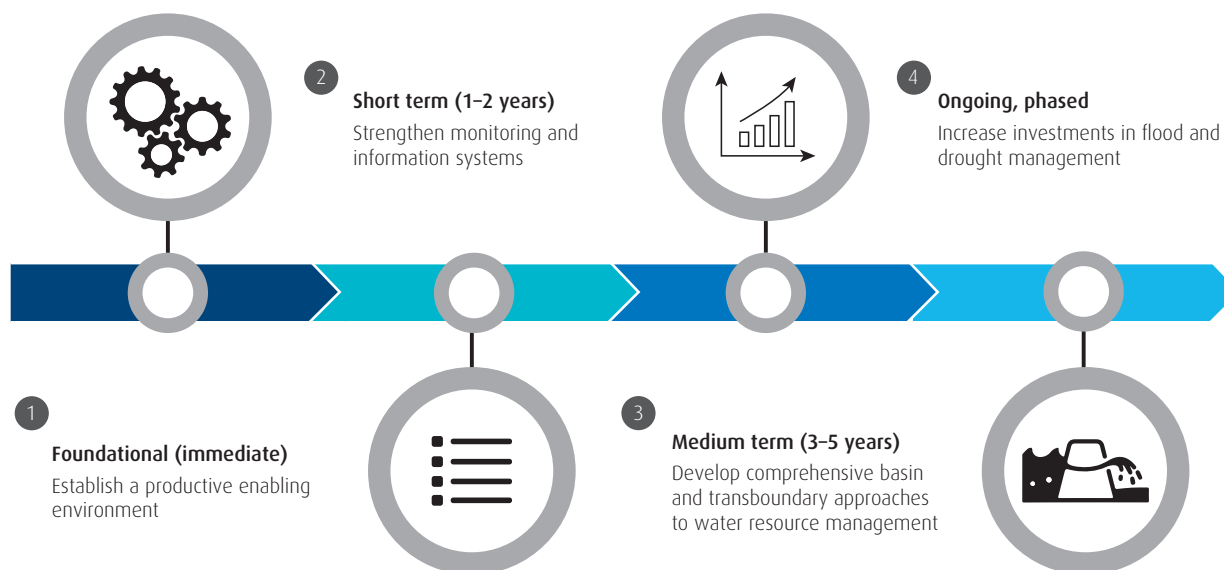
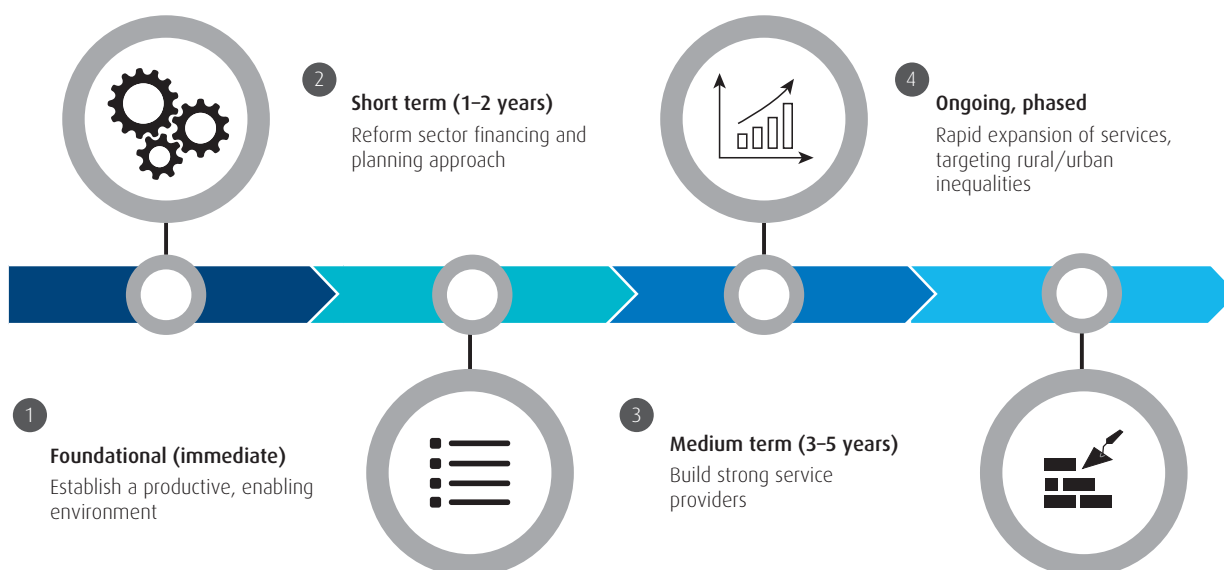
Policy makers are aware of the challenges facing the country's WRM and resilience, specifically the clarification of the institutional framework for water resources management and the need to expedite the long-anticipated reform of Apele Moldovei. An integrated approach at the basin level, informed by River Basin Management Plans (RBMPs) and aligned with national and regional development plans is needed to prioritize investments and to manage water across users and to mitigate water-related risks.

The following recommendations are made that are part of a broader roadmap, as in figure ES.1:

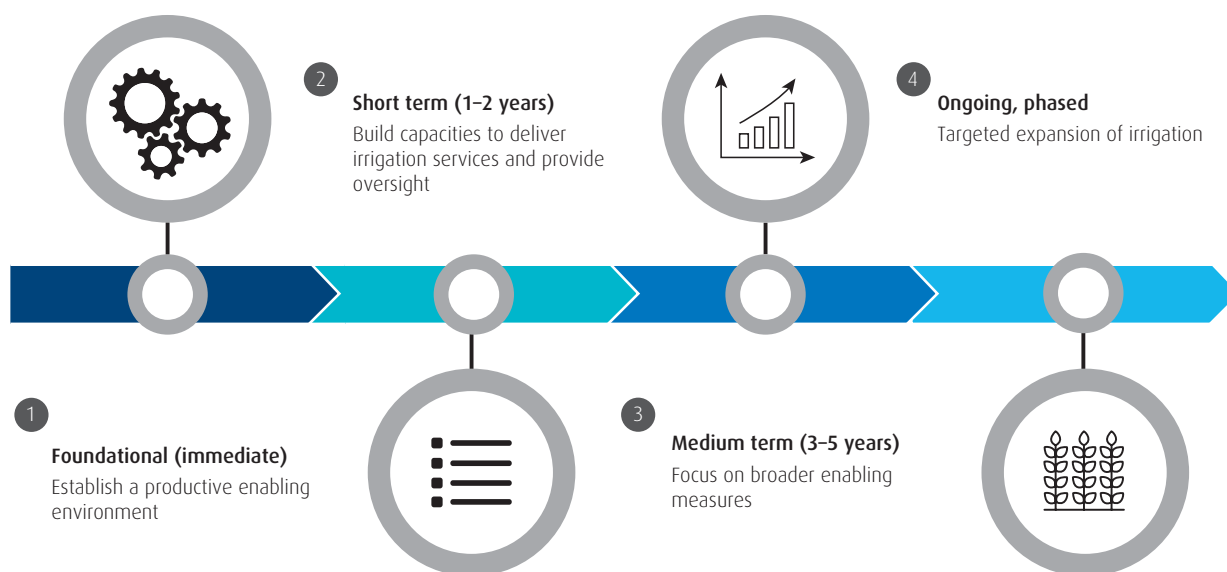
- Finalize institutional reform of Apele Moldovei, clarifying its mandate and organizing its implementation structure at the basin level; secure resources for its operation.
- Strengthen information and management systems, for example, on water quality monitoring, groundwater assessment, hydrotechnical constructions, and flood and drought forecasting.
- Operationalize allocation planning and management; rollout and fully operationalize the State Water Cadastre combined with enforcement measures.
- Strengthen financing mechanisms for holistic WRM and restructure water-related fees and levies to fund RBMPs and increase budget allocations.
- Increase investments in flood and water management, focusing on infrastructure, nature-based solutions, and preparedness measures.

Water Supply and Sanitation Services

Performance in WSS is constrained by large coverage gaps in rural areas, critically low levels of safe sanitation and wastewater treatment, and shortcomings in operators' performance to deliver and sustain services efficiently. Institutional weaknesses underpin many of the infrastructure, information, and finance gaps in the WSS sector. The following recommendations are made as part of a roadmap as illustrated in figure ES.2.

Figure ES.1 Roadmap for Water Resources Management and Resilience**Figure ES.2 Roadmap for Water Supply and Sanitation Services**

- Strengthen national WSS sector development functions, with a focus on investment planning, implementation support, quality assurance, results monitoring, support to service providers, and aggregation processes.
- Develop a national investment plan, and financing framework, and consolidate funds into a national WSS program, led by a future WSS lead entity, while leveraging regional development authority (RDA) capacities in implementation.
- Establish a performance and efficiency improvement program for utilities linked to delivery of result-based grants, and access to financing for utilities to make efficiency gains.
- Focus on inclusion by adopting a so-called portfolio approach for investments and service delivery solutions:
 - Regionalization: expanding services by licensed district and regional operators
 - Oversight and support to local municipal operators in the interim
 - Individual self-supply solutions (not networked) in remote villages
- Develop mandatory connection policies, combined with social support mechanisms to address affordability concerns.

Figure ES.3 Roadmap for Modernizing Irrigated and Climate Resilient Agriculture

Irrigated and Climate Resilient Agriculture

Moldova's irrigation potential remains untapped. Performance is poor because of the lack of an integrated vision of irrigation and agricultural development, weak institutions, and limited investments. State irrigation enterprises, which are largely dysfunctional, pose a significant burden to Apele Moldovei's financial health. Key recommendations are summarized as part of the roadmap depicted in figure ES.3:

- Prepare a comprehensive irrigation development strategy and prioritized investment plan, aligned with RBMPs and embedded in a broader agricultural modernization agenda.
- Pursue liquidation of state irrigation enterprises, with retrenchment costs from the state budget.
- Increase investments for rehabilitation and expansion of central systems and replicate the WUA model: transfer management, operation, and maintenance of functional schemes.
- Develop capacity of WUAs as managers of state-owned irrigation assets and of Apele Moldovei for monitoring, oversight, and technical support to WUAs.
- Focus on broader enabling measures provided by entities beyond the water sector to leverage private investments. A range of measures is needed for the following:
 - Creating favorable access to finance and subsidies for on-farm investments

- Facilitating access to markets and postharvest infrastructure
- Measures to address land fragmentation or long-term land leases
- Advisory services to WUAs and farmers

In addition to modernizing irrigated agriculture, the development of climate-resilient rainfed agriculture is equally, if not more, important for Moldova. This will require the large-scale adoption of climate-smart agronomical management practices, the use of risk mitigation instruments, such as weather-based insurances, and associated incentive and extension programs.

Notes

1. Including a large combined heat and power plant (CHP) on the Transnistria side with a nonconsumptive water diversion from the Kuchurgan lake of 500 million cubic meters per year.
2. Excluding the 500 million cubic meters nonconsumptive diversion at Kuchurgan CHP.
3. These are referred to as Business-as-Usual, Urban and Industrial Development (scenario 1), and Holistic Regional Development (scenario 2) and represent investments and increased water demand by 2030.
4. Excluding the 500 million cubic meters per year nonconsumptive demand at Kuchurgan CHP.
5. Limitations of the model because of data granularity and assumptions may introduce an error margin; however, with an annual cross-border inflow of over 13 billion per year for the Dniester, the effect will remain low.
6. Moldova's Water Agency under MARDE.



CHAPTER 1

Introduction

Key Messages

- Water underpins much of Moldova's ability to rekindle dynamism in its economy and to provide outcomes for the health and well-being of its people and environment. Yet large gaps remain in understanding the country's water resources endowments.
- A holistic water security assessment is a precondition for future policy making, strategic investment planning, and adequate financing. Important to a holistic assessment is a detailed understanding of the country's water balance, which to date has not been undertaken.
- This diagnostic report aims to assess the performance of Moldova's water sector, identifying areas that require remedial action to enhance water security.
- The diagnostic considers the following critical water security questions:
 - Are physical water resources, now and under future climate and development trajectories, sufficient?
 - How can Moldova best leverage its water resources to sustainably achieve its economic and social development goals?
 - What are the risks to Moldova's water security and what interventions and policy actions should the government prioritize to realize a more water secure future?
 - Are appropriate information systems used and appropriate planning tools and approaches adopted?
 - Is the water sector adequately financed and if not, how can financing gaps be closed?
 - What institutional weaknesses constrain water security and what policy reforms are needed?

Background and Objectives

Over the past two decades Moldova has achieved major development results: poverty more than halved between 2007 and 2014, and shared prosperity for the poorest households rose sharply. Yet Moldova's growth model is volatile, unsustainable, and is losing strength. Water underpins much of Moldova's ability to rekindle dynamism in its economy and to provide outcomes for the health and well-being of its people and environment. Yet gaps remain in understanding the country's water resources endowments.

This diagnostic suggests that in 2018 water availability is not a binding constraint to development. Even in the presence of future changes in demand, there are limited or manageable physical constraints to water security. Going beyond a focus on the water balance, this report assesses Moldova's water security and identifies important water-related challenges that may hinder progress in economic and human development. Moldova's water security is threatened by poor infrastructure and suboptimal institutional performance. Through an assessment of service delivery, water resources management and risk mitigation, and an analysis of institutional arrangements and sector expenditure data, this diagnostic establishes a set of policy recommendations on how water should be sustained and leveraged to support Moldova's development.

Water security challenges are intertwined with the unprecedented social, economic, and health effects resulting from the COVID-19 pandemic, that will be felt for several years to come. For example, Moldova's access gaps in water and sanitation hinder critical hand hygiene practices, required for infection control and to prevent future outbreaks. The economy's vulnerability to droughts is even more pronounced during the recession resulting from the COVID-19 pandemic. Hence, a more-climate-resilient agriculture sector is critical to support economic recovery and growth.

Water security is a complex multisectoral concept that describes the social, economic, and environmental outcomes derived from how water is managed and used. The overarching goal of water security is, on the one hand, to harness its productive benefits to promote human well-being, livelihoods, and economic development together with environmental sustainability and, on the other hand, to manage its destructive effects, such as pollution, water-borne diseases, floods, and droughts. Water security matters even more so in the future, because climate

change will be experienced predominantly through the hydrological cycle. This brings about increased vulnerabilities that through risks of droughts, floods, and deteriorating water quality will affect citizens, businesses, and natural habitats.

This report provides a new, comprehensive, and balanced view of water security in Moldova, highlighting the complex water issues that Moldova must tackle to improve its water security. It seeks to elevate water security as an issue critical for national development by providing stakeholders with a stocktaking and outlook on water-related risks, and opportunities in which water can contribute to economic growth and poverty reduction.

The report aims to answer critical questions about the role of water in Moldova's future socioeconomic development, including the following:

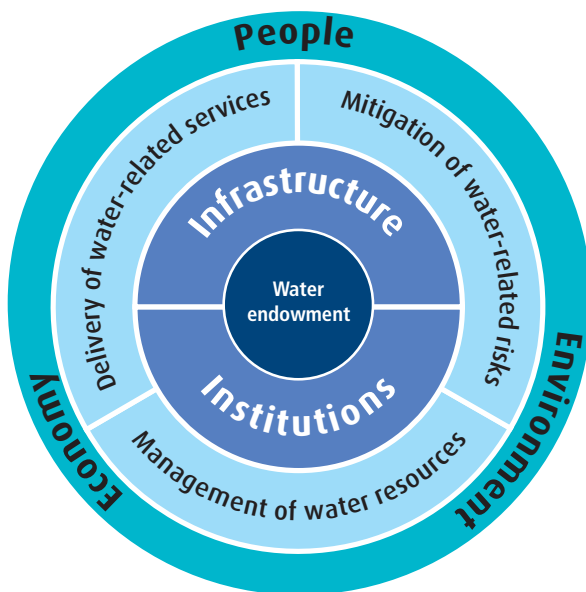
- Are physical water resources, now and under future climate and development trajectories, sufficient?
- How can Moldova best leverage its water resources to sustainably achieve its economic and social development goals?
- What are the risks to Moldova's water security and what interventions and policy actions should the government prioritize to realize a more water secure future?
- Are appropriate information systems used and appropriate planning tools and approaches adopted?
- Is the water sector adequately financed and if not, how can financing gaps be closed?
- What institutional weaknesses constrain water security and what policy reforms are needed?

Framework and Approach

This report adopts a conceptual framework that highlights how water security benefits or poses a cost to Moldova's economy, citizens, and natural ecosystems as depicted in figure 1.1.

Outcomes for people, the economy, and the environment are driven by the delivery of water services, management of water resources, and mitigation of water-related risks. Delivery of water services involves the adequacy of the delivery of water-related services, spanning from drinking water supply and sanitation to irrigation and hydropower services. Management of water resources relates to the sustainable management of water resources, allocation mechanisms, and the optimization and protection of surface and groundwater resources, among others. Finally, the mitigation of water-related risks refers to the extent to which water-related risks are managed, for example, due to flooding or

Figure 1.1 Water Security Assessment Framework



droughts. The robustness of performance across all three pillars is shaped by the country's infrastructure and institutions, including its governance and enabling environment, information systems, and financing. Water endowments are shown at the core of the framework. Understanding water security starts with establishing a clear picture of water resource endowments. That is an assessment of how much water there is, when and where it is available, and its quality, information areas which were severely lacking in Moldova. A water balance model¹ was used to characterize Moldova's water endowments in terms of available water supply and demand for major categories of water use, namely municipal use, industrial use, water demand for thermo-electric cooling, irrigation water use, and water requirements for environmental flows. This water balance model has been established for the baseline situation, representing the year 2018 under current climatic conditions.²

Future water demand depends on a multitude of factors, including shifts in the drivers of the economy and population and demographic changes, and policy choices and investments. To analyze future water resources endowments, scenarios were modeled, including a business-as-usual projection until 2030, along with alternatives or water futures, representing increasing investments and water demand, namely, Scenario 1: Urban and Industrial Development and Scenario 2: Regional Holistic Development. The diagnostic also stress-tested a range of external risks and uncertainties for Moldova's water security, including environmental flow requirements, effects

of climate change on water availability and demand in the future, and increased irrigation water use upstream in Ukraine. In support of the water futures, an economic assessment was carried out to aid the prioritization of strategic investment and policy actions. The focus of the assessment is on the incremental costs and benefits of the suite of investment measures in each scenario through cost-benefit analyses. It illustrates how various sectoral investments, and estimated capital costs, for the water futures will have a net positive effect on society.

The diagnostic includes a comprehensive assessment of water security, building on the water security assessment framework illustrated in figure 1.1. This comprises institutional and performance-related aspects of the water sector, examining sector governance, institutions, information systems, and performance. The diagnostic builds on existing analysis, both from the World Bank³ and data and analysis collected by others, to understand Moldova's water balance, and how its infrastructure and institutions deliver outcomes to the people, the economy, and the environment. Throughout the elaboration of the diagnostic, roundtable meetings were organized under the guidance and facilitation of the Ministry of Agriculture, Regional Development and Environment (MARDE), providing feedback throughout the process. Training to Moldovan experts on the Water Evaluation and Planning System (WEAP) model was delivered to ensure that the water balance tool can be used and refined in the future by Moldovan institutions.⁴

Limitations of the diagnostic relate to data limitations, inherent assumptions made in future water demand projections, and areas that require further in-depth research. The water balance model in WEAP is the first country-level instrument with high complexity and granularity. However, data limitations remain in terms of the spatial allocation of water demand, sourcing of water use from surface water versus deep groundwater, and other aspects. The WEAP model has been instrumental in understanding water supply, demand, and allocations, and in assessing whether, where, and when risks to water shortages and reliability of supply might arise. Appendix A provides details on the model, the water future scenarios, and data, assumptions, and limitations of the cost-benefit analysis. Although this diagnostic uses 2030 scenarios for its outlook, the WEAP model is meant to be used in the future to investigate specific policy and investment choices to inform planning. Further analysis is also needed to better understand the water quality dimensions of Moldova's water resources.

The diagnostic is structured as follows:

- Chapter 2 sets the scene for Moldova's development path, its water resources endowments, and its overall water security trajectory.
- Chapter 3 describes the positive and negative outcomes of water for Moldova's economy, people, and society, and the environment.
- Chapter 4 assesses Moldova's water futures, in terms of physical water security and reliability, mitigating measures, external risks, and economic implications.
- Chapter 5 analyzes water sector performance, financing, and institutional barriers for water security and suggests various policy actions and interventions to address bottlenecks.
- Chapter 6 concludes with prioritizing recommendations in three domains: water management and resilience, water supply and sanitation, and modernization of irrigated agriculture.

Notes

1. Using the Water Evaluation and Allocation Planning tool (WEAP): <https://www.weap21.org/>. Appendix A provides a detailed account of the assumptions and approach in building the WEAP model and its scenarios for Moldova.
2. Current climatic conditions are based on historic climate and hydrology reflecting a long-term average runoff in the period 1950–2016.
3. World Bank (2013) used a water allocation model for Moldova at a very broad scale, which has been refined in this analysis.
4. Training for the Moldova Water Allocation and Evaluation and Planning tool was delivered to Moldovan stakeholders in January 2020.

Reference

World Bank. 2013. *Reducing the Vulnerability of Moldova's Agricultural Systems to Climate Change: Impact Assessment and Adaptation Options*. Washington, DC: World Bank.

CHAPTER 2

Setting the Scene for Moldova's Water Security

Key Messages

- Moldova needs to change its growth model to secure a sustainable development trajectory. This entails boosting productivity, sustainable resource management, and strengthening human capital and social inclusion. These developmental challenges are intertwined with water-related sectors.
- Water security underpins development achievements on many fronts. Water writ large needs to deliver benefits for people, the economy, and the environment and mitigate water risks.
- Moldova's water resource endowments should be harnessed to help diversify the economy and increase exports, support citizens' productive lives, and build resilience to destructive floods, droughts, and pollution.
- Understanding Moldova's water resource endowments is necessary in the context of its development goals. A water allocation and planning tool was used to develop a water balance model for the country.
- Moldova has ample total renewable water resources, mostly derived from its transboundary rivers, the Prut and Dniester, and substantial internal surface and groundwater resources.
- Total water resources endowments (4,952 cubic meters per capita per year) are largely enough for the current modest levels of water withdrawals (231 cubic meters per capita per year).
- Water endowments are not a constraint for development and reliably fulfil demand for drinking water, industry, thermal cooling, and irrigation.
- Thermal cooling, although largely nonconsumptive, forms the largest share of Moldova's water withdrawals, followed by drinking water, industry, and irrigation. Because Moldova's agriculture is largely rainfed, current irrigation water demand from surface water is low.
- Deep groundwater is important for drinking water use and abstraction levels are modest and deemed sustainable, but naturally occurring water quality conditions, although not fully understood, limit its use.
- Moldova's future climate is uncertain but likely to be warmer, with more frequent and intense droughts and floods.

Moldova's Development Challenges

Moldova is a landlocked country, bordered by Ukraine in the north, east, and south, and Romania in the west (map 2.1). It has a rapidly declining population of approximately 3 million as of 2018, of which about 60 percent continue to reside in rural areas.¹ With average annual gross domestic product (GDP) growth of 4.6 percent since 2000, national poverty rates declined from 26 percent in 2007 to 9.6 percent in 2015² and growth benefited more citizens, decreasing inequality. Macroeconomic stability has been maintained despite the country's 2014 banking crisis, whereas the political environment has been in flux over the past years.

Moldova is committed to implementing the Association Agreement³ with the European Union and has benefited from its strategic European location and growing global integration. Moldova has been able to reform its business environment, stimulating foreign investments in manufacturing and reorienting exports toward technology-intensive products and private sector-led growth, resulting in a stronger contribution of exports to growth, employment generation, and more equitable access to economic opportunities and services across the country. There were also efforts to improve Moldova's human capital, notably through education reform and skill development (Kahkonen, Akhalkatsi, and Vincelette 2019).

Map 2.1 Position of Moldova



Yet Moldova has not been successful in converging toward European income levels and remains the poorest country in Europe, with a GDP per capita of US\$7,168 in 2018. Moldova's growth model is volatile, unsustainable, and is losing strength. This results from its economic reliance on remittances, weather-dependent agricultural commodity products, and foreign capital inflows, as well as from exposure to both external and internal shocks. The country needs alternative growth engines fueled by exports and investment (World Bank 2019). Structural challenges, especially population aging, emigration, and stagnant productivity, are holding the economy back (World Bank 2016). The rise in public debt, loss in investor confidence, along with several large loss-making state-owned companies, have narrowed its fiscal space, which is likely to be further affected by the COVID-19 pandemic.

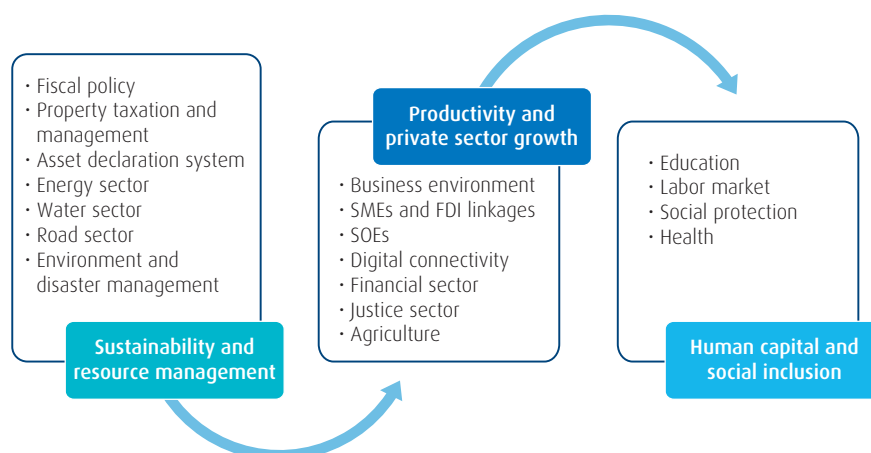
Moldova's current demographic trends exert additional stress on its development: an overall declining and aging population, with the younger population emigrating. Based on population projections, approximately 3 million people (UNFPA Moldova 2016)⁴ were estimated to reside in Moldova in 2018. In the latest census of 2014, more than 17 percent of the population was over the age of 60 and approximately 30 percent of the labor force had already emigrated in search of better opportunities. If these trends continue, Moldova is set to lose a fifth of its current population by 2050. Overall labor participation rates are low, with 53 percent of the working-age population employed or actively seeking employment as of 2017. Employment in the large state-owned enterprise sector, including those in the irrigation sector, shows low productivity and poses a burden on fiscal resources.

Given the small size of the local market, Moldova's exports are essential—exports made up 18 percent of GDP in 2017. Despite several initiatives in Moldova to promote investment, low exports and the limited value added of the export basket constrains Moldova's growth. Although there has been a shift in the past decade to higher-value exports, such as vegetables and foods, there are opportunities to increase value, especially if EU standards can be adhered to, such as on food safety and quality.

Moldova's citizens aspire to rising income levels and convergence with the consumption patterns and lifestyles of neighboring middle- and high-income countries. To achieve this, the government will be confronted with two overarching challenges: sustaining macroeconomic stability and reviving growth. Moldova's Country Economic Memorandum suggests a three-pronged strategy to tackle economic challenges: (1) boosting productivity and private sector growth, (2) increasing sustainability and improving resource management, and (3) strengthening human capital and social inclusion (figure 2.1).

These development challenges undermine water security, such as through inequalities and gaps in service delivery, continued pollution of the environment, and a drought-vulnerable economy because of collapsed irrigation infrastructure. Moldova's water resource endowments should be harnessed to leverage the productive dimensions of water for the economy, that is, in agriculture and business development to help diversify the economy and increase exports. Water security also means that citizens—both urban and rural—can live productive lives, resulting from a clean environment, reliable water and sanitation services, and based

Figure 2.1 Three Pillars of a Sustainable Growth Strategy for Moldova



Source: World Bank 2019.

Note: FDI = foreign direct investment; SOEs = state-owned enterprises; SMEs = small and medium enterprises.

on livelihoods that are resilient to destructive effects, such as floods and droughts, pollution, and environmental degradation. While chapter 3 explores what Moldova gets out of its water, this chapter outlines its current water resources endowments.

Moldova's Water Resources Endowments

Context

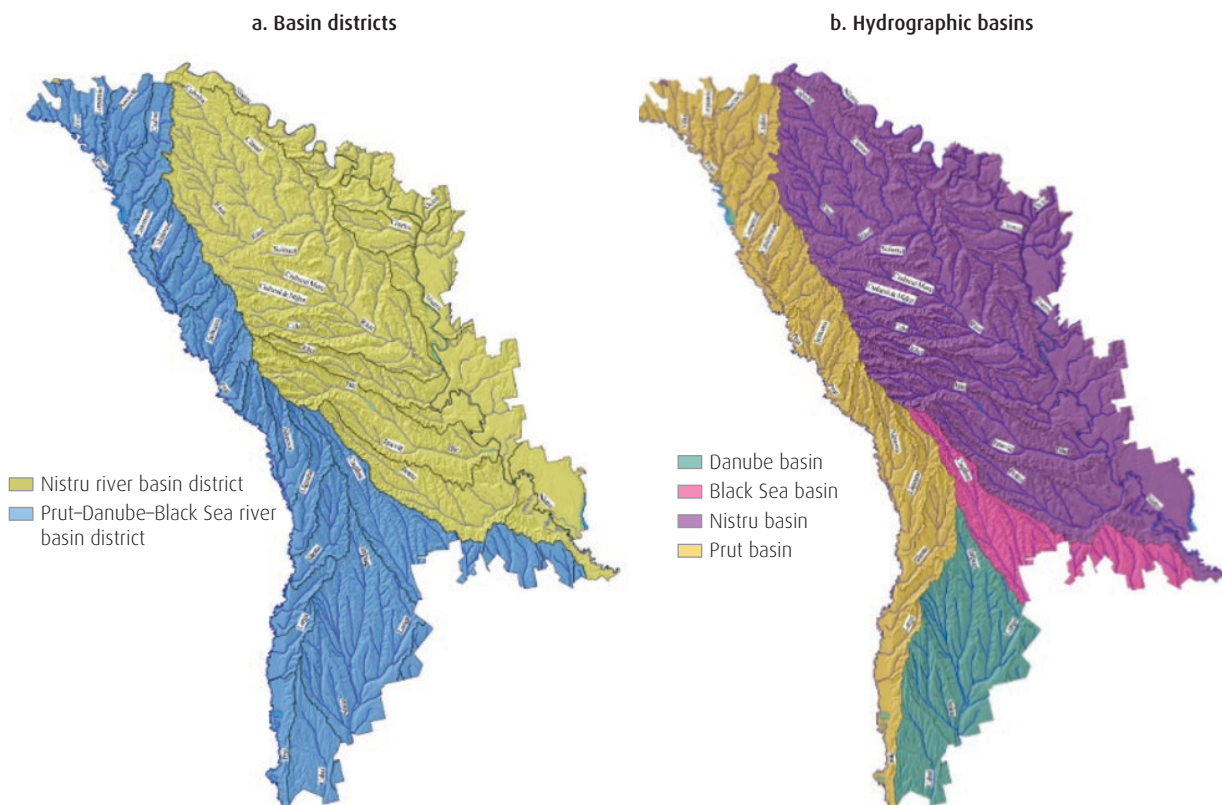
Moldova largely depends on surface water from the inflow of its two large transboundary rivers, the Dniester and the Prut. Therefore, Moldova is rich in total water resource endowments. The country has two river basin districts: the Dniester district and the Danube–Prut–Black Sea⁵ basin district. The Dniester river district covers about 57 percent of the country, or 19,200 km², of which 18 percent is located on the left-bank territories⁶ (Republic of Moldova 2017).⁷ The Prut–Danube–Black Sea basin district covers about 43 percent of the country, or approximately 14,770 km² (Republic of Moldova 2018),⁸ and includes the three hydrographic basins of the Prut, Danube, and Black Sea (map 2.2).

The basin characteristics are extensively described in the two River Basin Management Plans for 2017–22. For the analysis of the water balance, the country can be divided into 28 catchments, that are formally used by Apele Moldovei (map 2.3).

Moldova's main rivers are characterized by a high degree of human alteration, dating back decades. This includes canalization and embankments, limiting natural floodplains, and thousands of small reservoirs, combined with degradation of its upstream internal watersheds. Less than one-tenth of Moldova's territory is estimated to be covered with forest and the area is declining (Global Forest Watch 2019). Protecting and restoring its watersheds is important to preserve water quality and retain precipitation, thus moderating flood effects.

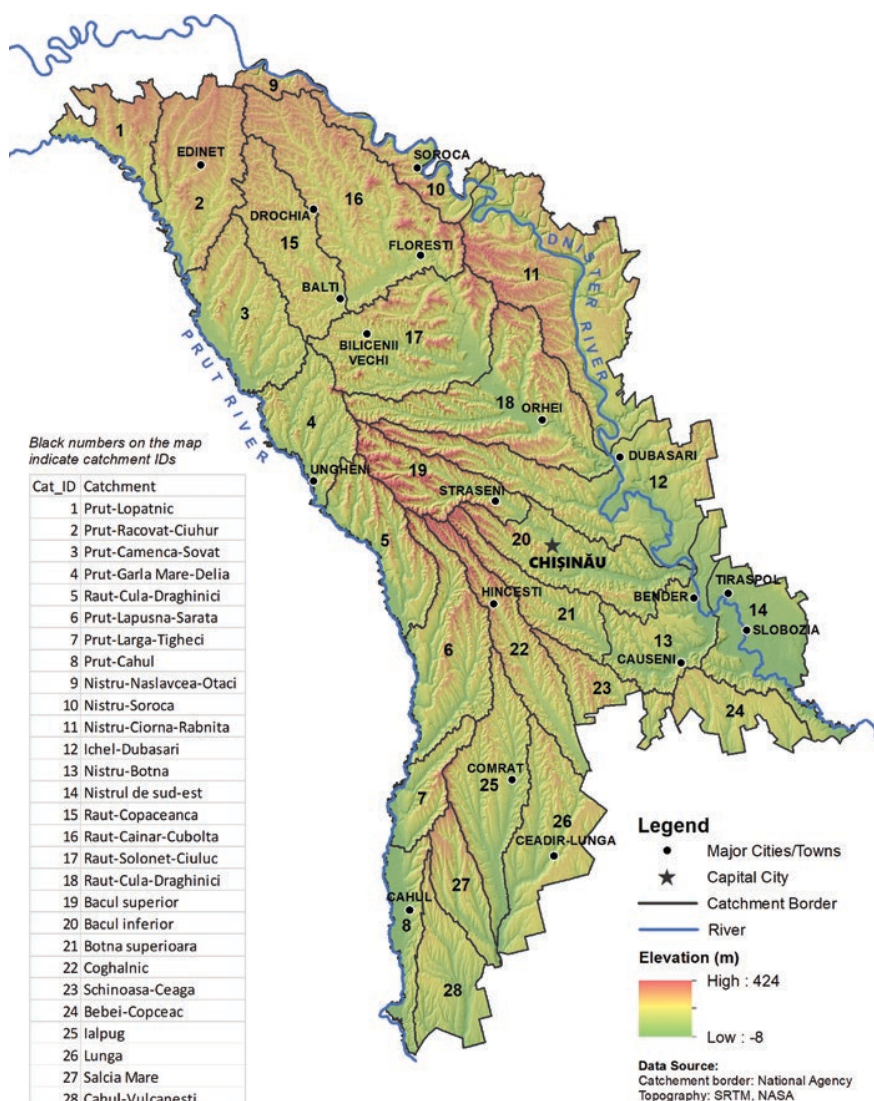
In addition to a few large reservoirs used for both hydropower and thermal cooling, there are more than 5,000 small dams used for irrigation, fish farming, and local drinking water supply. These accumulation ponds and check dams are negatively affecting water quality due to siltation and a high-nutrient load because of fish farming and alteration of the natural runoff regime of Moldova's internal rivers. Overall storage capacity is estimated at 738 cubic meters per capita, although the

Map 2.2 Basin Districts and Hydrographic Basins of Moldova



Source: Republic of Moldova 2017, 2018.

Map 2.3 Moldova and Its Catchments



status and level of the siltation of reservoirs is not well known.

Moldova's climate is moderately continental with warm and long summers (average 20°C) and relatively mild and dry winters (January averages of -4°C). Three agroecological zones can be distinguished, defined by similar characteristics in terms of terrain, climate, soils, and water availability.² Moldova's current climate shows annual precipitation that varies from 370 to 560 millimeters per year (FAO 2019), with precipitation higher in the north and a declining gradient toward the south. Because of the higher temperature and lower rainfall, the south only has marginal productive rainfed agriculture. In the south, there are natural wetlands along the Prut and naturally occurring high salinity levels that require drainage to ensure productivity.

Moldova's Water Balance and Water Use

In this diagnostic Moldova's current water balance was estimated through the development of the Water Evaluation and Allocation Planning tool (WEAP) at the level of the 28 catchments for the country (map 2.3). The water balance assessment confirms that Moldova has large endowments, compared with its modest use.

Appendix A provides a detailed description of the development of the water balance model for Moldova, and key assumptions are summarized in box 2.1. The development and capacity building of the WEAP tool provides opportunities for refining analysis and future application. The WEAP model used hydrographic data provided by the State Hydrometereological Services (SHS) and is based on runoff models used by Apele Moldovei, and detailed assessment of water withdrawals

Box 2.1 Key Assumptions for the Water Balance Model in Moldova

The baseline situation for 2018 in WEAP has used the following key assumptions:

- Climatic conditions represent the current climate based on meteorological data from the period 1950–2016.
- Current hydrology is derived from runoff data from hydrometeorological stations over a similar period, as well as runoff models. Storage data were included in the water balance model representing reservoirs and ponds by location across the 28 catchments.
- Environmental flows are included in the baseline situation and are set at the ten percentile low flow for each of the 28 catchments and for the Prut outflow of the country; a five percentile low flow is set for the Dniester outflow of the country, based on OSCE and UNECE (2005).
- Water demands in the baseline situation represent different withdrawals for municipal and domestic drinking water use, water use for industrial and manufacturing services, withdrawals for agriculture (irrigation), and withdrawal for thermal cooling.
- Water withdrawals are sourced from (1) surface water, including from rivers or streams or from shallow groundwater; or (2) deep groundwater resources. Thermal and irrigation water use is only sourced from surface water, whereas municipal and industrial use is sourced partly from surface and deep ground water; intercatchment transfers are modeled as well.
- After securing the environmental flows, the priority of water uses follows the water law, whereby first drinking water needs are met, then irrigation, followed by industrial use.
- No unmet demands will occur for deep groundwater, and withdrawal levels are assumed to be within the sustainable yields of the deep aquifers.

and consumption. It has undergone comprehensive calibration and quality assurance checks. Therefore, to characterize Moldova's water endowments, the WEAP model is used rather than the Food and Agriculture Organization's (FAO's) AQUASTAT estimates.¹⁰

Moldova's total renewable water resources are estimated at 15.5 billion cubic meters per year, of which 2.2 billion cubic meters per year are internally generated and 86 percent, or 13.4 billion cubic meters per year, are from external surface water inflows of the Prut and Dniester. Table 2.1 illustrates key water endowment indicators for Moldova for the 2018 baseline. Total water resources endowments are estimated to be 4,952 cubic meters per capita per year,¹¹ and internal water resources endowment at 694 cubic meters per capita per year, large enough for the current levels of water withdrawals at 231 cubic meters per capita per year. A large share of withdrawals is nonconsumptive, including 500 million cubic meters per year diverted cooling water for the Kuchurgan Combined Heat and Power Plant on the left bank of the Dniester at the Dubassary reservoir. This leaves the levels of *consumptive use* per capita to be modest at 35 cubic meters per capita per year. Only 5 percent of total renewable water resources are

withdrawn annually, and only 33 percent of total internal renewable resources. Compared with Romania, Ukraine, and regional comparators, Moldova has a high dependency ratio of 86 percent, illustrating the importance of external inflow from the Dniester and Prut (figure 2.2).

To put the water balance assessment in context, it is important to recognize that Moldova's agriculture sector is heavily reliant on rainfall. Agricultural land is mostly planted with rainfed cereals (wheat, barley), industrial crops (sugarbeet, sunflower, oil seeds), followed by potatoes and field vegetables, and perennial fruit orchards and vineyards.¹² The water balance assessment refers to irrigation water demand, which is supplemental to crop water use from precipitation. Under the current climate, this share represents just 42 percent of average crop water demand across agroecological zones.¹³

Another important aspect of the water balance are groundwater resources. As Soviet-time studies indicate, significant amounts of groundwater are available in the country although quality may not be meeting existing standards for current uses. The internal deep groundwater resources are estimated at 1.3 billion cubic meters per year, of which 300 million cubic meters per year is assumed to

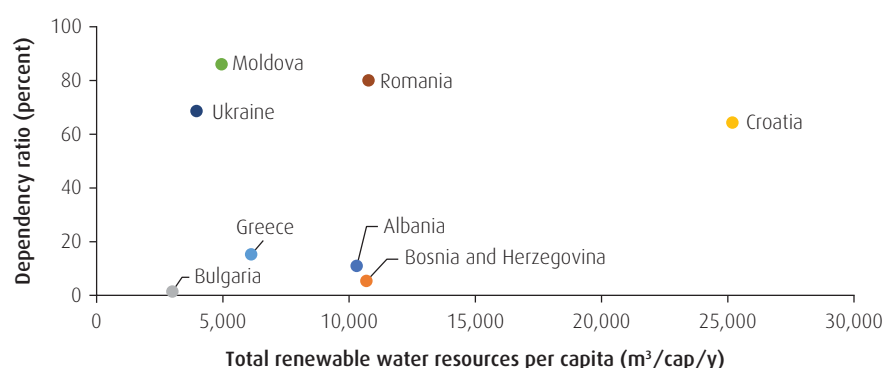
Table 2.1 Water Endowment Indicators Based on WEAP Baseline 2018 under Current Climatic Conditions

Key water resource endowment indicators	Unit	2018
Population (including Transnistria)	million	3.14
Total internal renewable surface water resources	MCM/y	1,878
Total internal renewable groundwater resources	MCM/y	300
Total internal renewable water resources	MCM/y	2,178
Total internal renewable water resources available per capita	m ³ /cap/y	694
Total renewable water resources	MCM/y	15,548
Total renewable water resources available per capita	m ³ /cap/y	4,952
External out of total renewable water resources (dependency)	%	86
Withdrawal out of total renewable water resources (incl. Kuchurgan ^a)	%	5
Withdrawal out of total internal water resources (incl. Kuchurgan)	%	33
Consumption out of total internal renewable water resources	%	5
Withdrawal per capita (incl. Kuchurgan)	m ³ /cap/y	231
Consumption per capita	m ³ /cap/y	35

Source: WEAP Moldova data.

Note: MCM = million cubic meter.

a. Kuchurgan is a large combined heat and power plant on the left bank of the Dniester.

Figure 2.2 Total Water Resources Availability and Dependence Ratio of Moldova (Based on WEAP Model) and Regional Comparators

Source: FAO 2019.

be deep groundwater and 1 billion cubic meters per year shallow groundwater, interacting with and feeding the surface water.¹⁴ It is assumed that current levels of deep groundwater withdrawal of 78 million cubic meters per year are within sustainable yields of the aquifers, because this represents a quarter of the total internal renewable deep groundwater resources. River basin management plans indicate several productive aquifers with good water quality, as well as aquifers with low yield and poor water quality, mostly found in the center and especially in the south (GIZ 2013). Sampling in deep wells across seven districts in the south illustrated

high levels of naturally occurring pollutants, such as boron, fluoride, and iron, as well as high dissolved salt contents, sulphates, and hardness (Czech Development Cooperation 2016). A comprehensive assessment of Moldova's groundwater resources, both in terms of quantity and quality, did not exist at the time of writing this report.

Table 2.2 shows key elements of the water balance generated by the WEAP model, and table 2.3 includes the withdrawals and consumptive use shares. Table 2.2 illustrates that existing water demand is nearly fully met, with an average annual

Table 2.2 Water Balance Elements from WEAP Baseline 2018 under Current Climatic Conditions

	Unit	2018
Inflow across borders upstream (surface water)	MCM/y	13,370
Internally produced water (surface water)	MCM/y	1,878
Outflow across borders downstream (surface water)	MCM/y	15,224
Total surface water consumption	MCM/y	86
Total groundwater consumption	MCM/y	25
Total water consumption from groundwater and surface water	MCM/y	110
Return flow from deep groundwater withdrawal available for use	MCM/y	53
Return flow from surface water withdrawal available for use or reuse	MCM/y	5.5
Unmet water demand	MCM/y	3.5
Environmental flow requirements internally	MCM/y	336
Environmental flow requirements downstream outflow Prut and Dniester	MCM/y	3,846

Source: WEAP Moldova data.

Note: FAO AQUASTAT reports lower cross-boundary inflows (namely 10.6 billion cubic meters per year) as compared to WEAP (13.37 billion cubic meters per year). AQUASTAT uses higher population numbers (namely 4.1 million) than those used in WEAP (3.1 million). Hence the renewable water resources per capita reported in AQUASTAT are much lower at 3,029 cubic meters per capita than through the WEAP water balance assessment (4,592 cubic meters per capita per year). MCM = million cubic meter.

Table 2.3 Water Withdrawals and Consumption from WEAP Baseline 2018 under Current Climatic Conditions

Key data on withdrawals and consumption	Unit	2018
Irrigation water withdrawal: surface	MCM/y	9
Irrigation water withdrawal: groundwater	MCM/y	—
Industrial water withdrawal: surface	MCM/y	21
Industrial water withdrawal: groundwater	MCM/y	9
Municipal water withdrawal: surface	MCM/y	60
Municipal water withdrawal: groundwater	MCM/y	69
Thermal water withdrawal: surface (excl. Kuchurgan)	MCM/y	57
Thermal water withdrawal: groundwater	MCM/y	0
Total water withdrawal (excl. Kuchurgan)	MCM/y	225
Total water withdrawal (incl. Kuchurgan)	MCM/y	725
Total ground water withdrawal	MCM/y	78
Total surface water withdrawal (excl. Kuchurgan)	MCM/y	147
Irrigation water consumption	MCM/y	6
Industrial water consumption	MCM/y	4
Municipal water consumption	MCM/y	43
Thermal water consumption	MCM/y	56

Source: WEAP Moldova data.

Note: At the Kuchurgan Combined Heat and Power Plant an estimated 550 MCM per year is diverted from the Dniester, of which 500 MCM is not consumed and discharged again, that is, nonconsumptive withdrawal. MCM = million cubic meter.

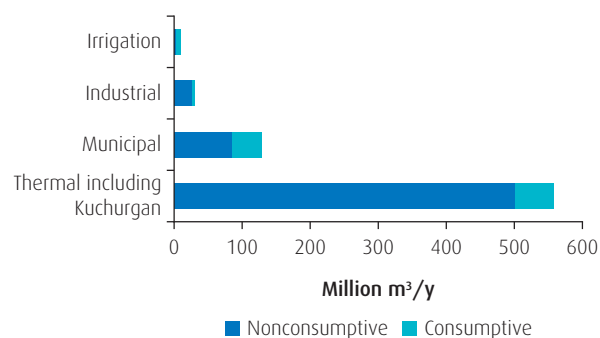
unmet demand¹⁵ of approximately 3.5 million cubic meters per year. This is just 0.5 percent of total water withdrawals, including withdrawals at Kuchurgan, estimated at 725 million cubic meters per year and a negligible fraction (0.02 percent) of total renewable water resources of 15,248 million cubic meters per year.

As can be seen in figure 2.3, the largest sectoral water use is for thermal cooling, followed by municipal drinking water, and water for irrigation and industries.

Table 2.3 provides the water withdrawals and consumptive uses per sector, as modeled in the 2018 baseline. For thermal cooling, the largest water withdrawal by far is for the cooling lake at the Kuchurgan Combined Heat and Power Plant (CHP), estimated at 555 million cubic meters per year, of which 50 million cubic meters per year evaporates.¹⁶ Municipal withdrawals are estimated at 139 million cubic meters per year based on population forecasts and levels of connectivity to centralized systems.¹⁷ Approximately 96 million cubic meters per year is returned to the water system because of physical losses and disposal in on-site or networked wastewater systems. Water withdrawal for industry is estimated at 30 million cubic meters per year, linked to population and GDP growth. Irrigation water withdrawal is low at 9 million cubic meters per year because of the collapse in irrigation systems after the Soviet era. The total *actual* irrigated area is estimated at 6,640 hectares across (1) small-scale private irrigation systems (2,605 hectares), (2) actual area irrigated in centralized fully pressurized systems managed by water user associations (2,270 hectares), and (3) functional centralized systems with mixed service levels (1,765 hectares).¹⁸ Map 2.4 shows the spatial distribution of irrigated areas over the various catchments.¹⁹

Groundwater withdrawals are estimated to form a third of total withdrawals, mostly because of lack of infrastructure for transporting surface water for the main rivers and because of high reliance on groundwater for rural water supply. Thus, groundwater remains strategically important, because these resources are important for drinking water provision, even though quality without treatment may be compromised, especially in the rural drinking water systems. As can be seen from table 2.3, 78 million cubic meters per year are withdrawn for groundwater out of 225 million cubic meters per year (excluding Kuchurgan). Because there is a ban on use of deep groundwater for irrigation, irrigation water use is entirely sourced from surface water and thus more vulnerable to shortages.

Figure 2.3 Overview of Annual Water Withdrawal and Consumptive Use in Moldova Baseline 2018



Source: WEAP Moldova data.

Water Availability and Reliability Assessment

In 2018, physical water resource availability could almost entirely meet all existing water demands, with unmet demand being 1.6 percent of total average demand excluding Kuchurgan withdrawals. Minor spatial and temporal shortages occur in some catchments. This is mostly because part of industrial, rural drinking water, and irrigation water demand is modeled from local shallow water sources, because of a lack of infrastructure for surface water transfers and deep groundwater use. The unmet demand is mostly expressed in the industry sector,²⁰ as well as in the irrigation sector, following the model's allocation rules, in which water is first reserved for environmental flows, and is then allocated as per the water law's priorities. Map 2.5 (panel a) illustrates the average annual unmet demand across the 28 catchments, indicating hotspots of modest shortages in orange. Such shortages can be tackled by augmenting surface water transfer capacity, shifting to use of deeper wells (if quality allows), as well as reuse and efficiency measures. Map 2.5 (panel b) illustrates the reliability of water availability, expressed in the years that at least 95 percent of total demand is being met. Darker orange catchments show that small deficits (5 percent) in demand occur in drier years, specifically once every 10 years. These occur in several catchments along the upper and middle part of the Prut and along the upper Dniester. The extent and intensity of these hotspots in the baseline is modest. Chapter 4 presents a reliability assessment of supply for future climate conditions and alternative development trajectories with growing water demand.

Figure 2.4 illustrates the reliability curves for the various water demand levels underscoring that

reliability issues are not severe overall. In all years at least 92 percent of industrial demand can be supplied. The irrigated agriculture sector is the most vulnerable to surface water shortages, although these remain modest. Under current climatic conditions, 80 percent of irrigation demand is guaranteed in all years, also the drier years. Although at the national level, reliability may not pose a serious issue, adequate reliability assessments need to be conducted for hotspot catchments, where demand may not be met in drier years, such as along the Prut.

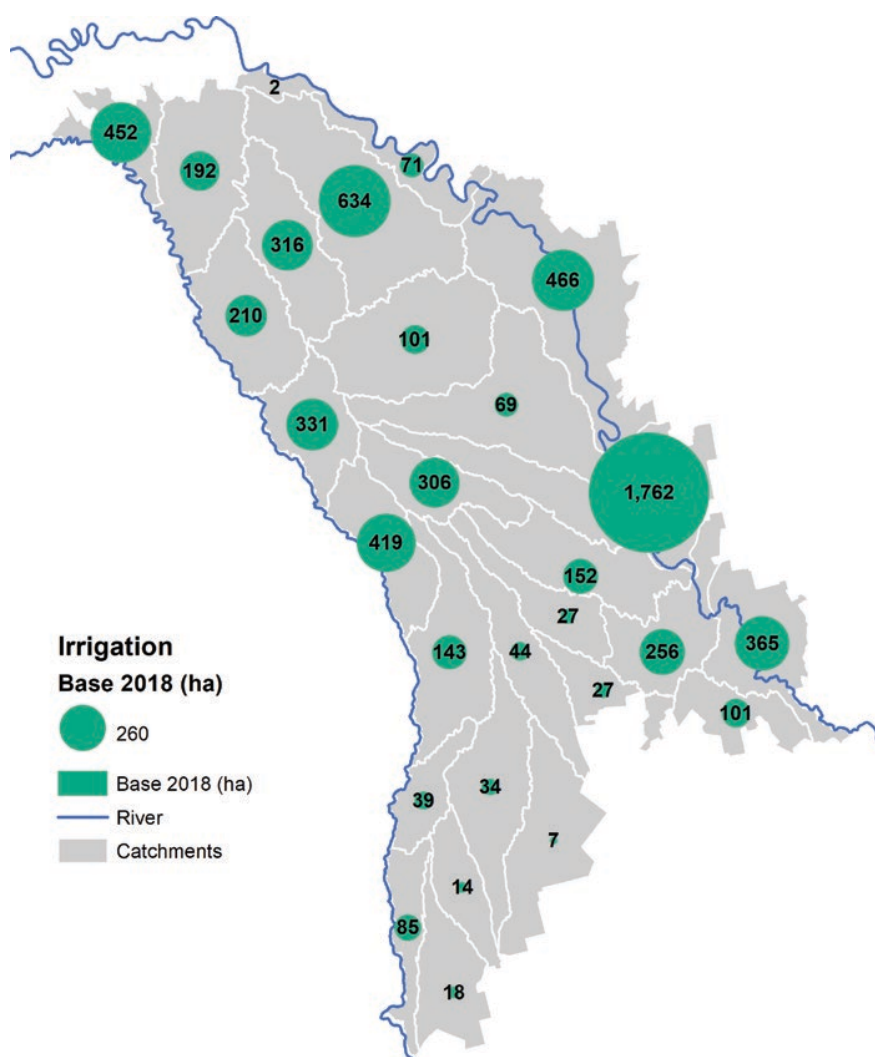
Figure 2.5 illustrates reliability curves for irrigation demand for several of these vulnerable catchments. For example, for the Prut-Lopatnic basin, where the Prut enters Moldova, once every four years, 50 percent or less of total irrigation water demand

can be realized. Irrigation has the lowest allocative priority and environmental flow requirements²¹ and all other water uses are met first. To adapt to shortages, modern irrigation systems allowing deficit irrigation in drier years can help mitigate the effect on yield. Sensitivity analysis for environmental flows is presented in chapter 4.

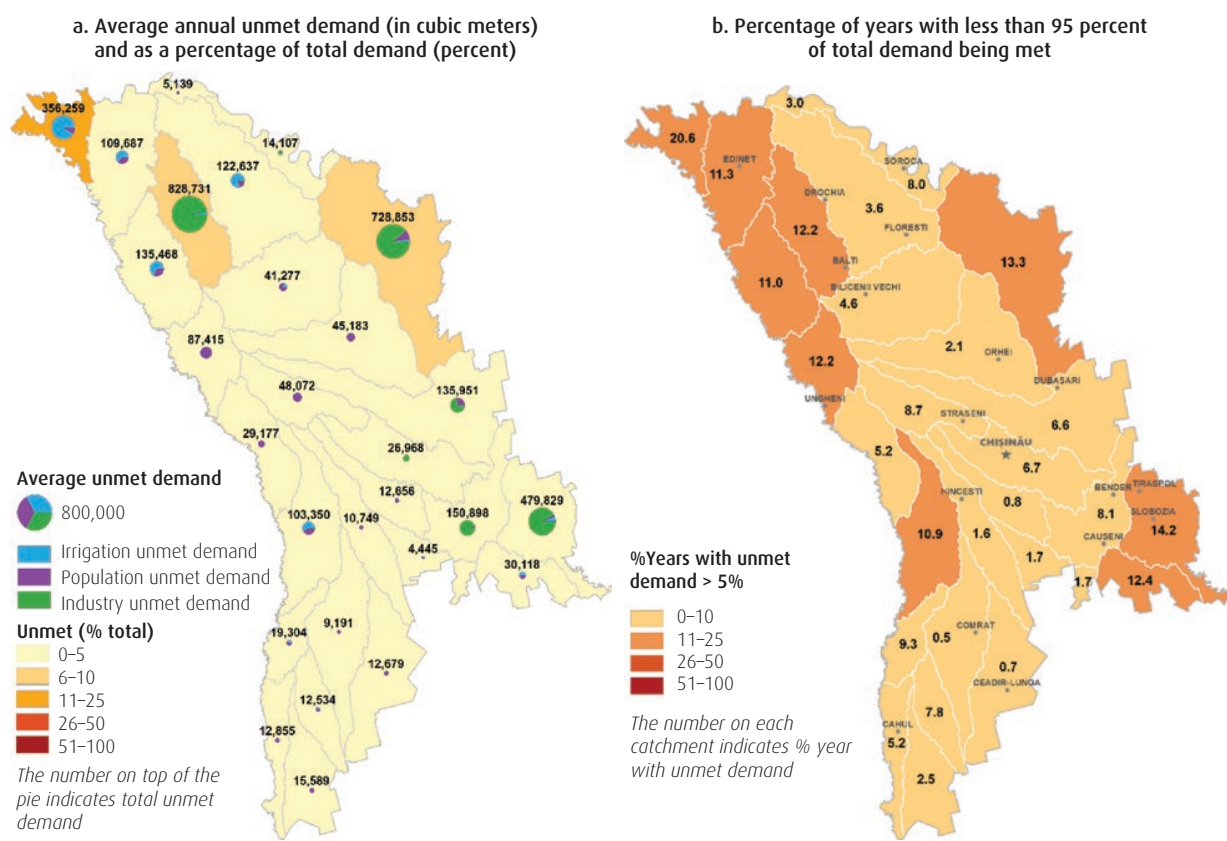
Moldova's Water and Climate Related Risks

Although the outcomes of various climate models generate different effects on temperature and rainfall patterns, the overall direction is that temperatures will rise, and precipitation will become more variable, likely with a drying effect in the growing season. Maps 2.6 and 2.7 illustrate the projected 2050

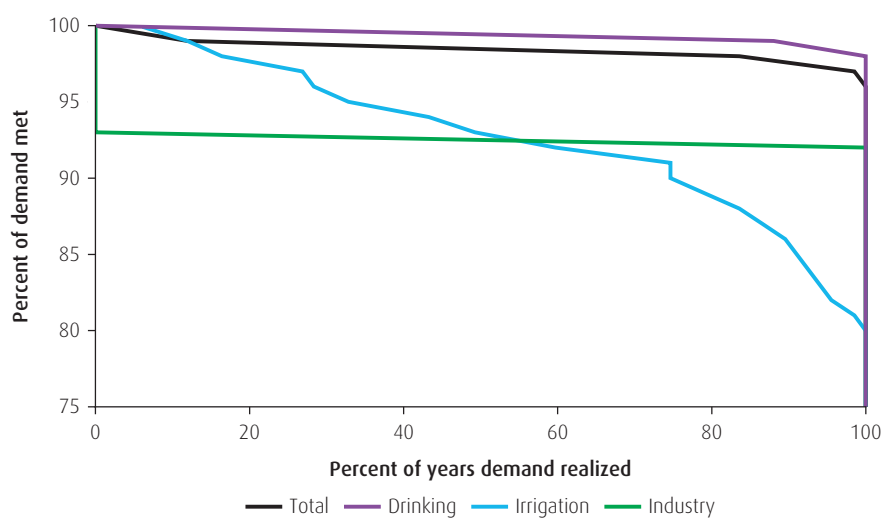
Map 2.4 Distribution of Irrigated Area in the 2018 Baseline



Source: WEAP Moldova data.

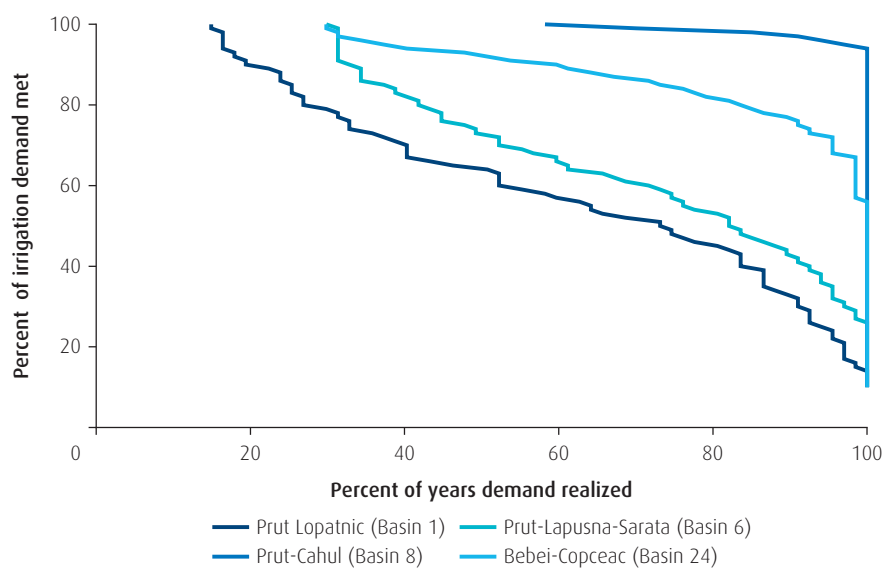
Map 2.5 Baseline 2018

Source: WEAP Moldova data.

Figure 2.4 Baseline 2018: Reliability Curves for Total, Drinking Water, Industry, and Irrigation Demand

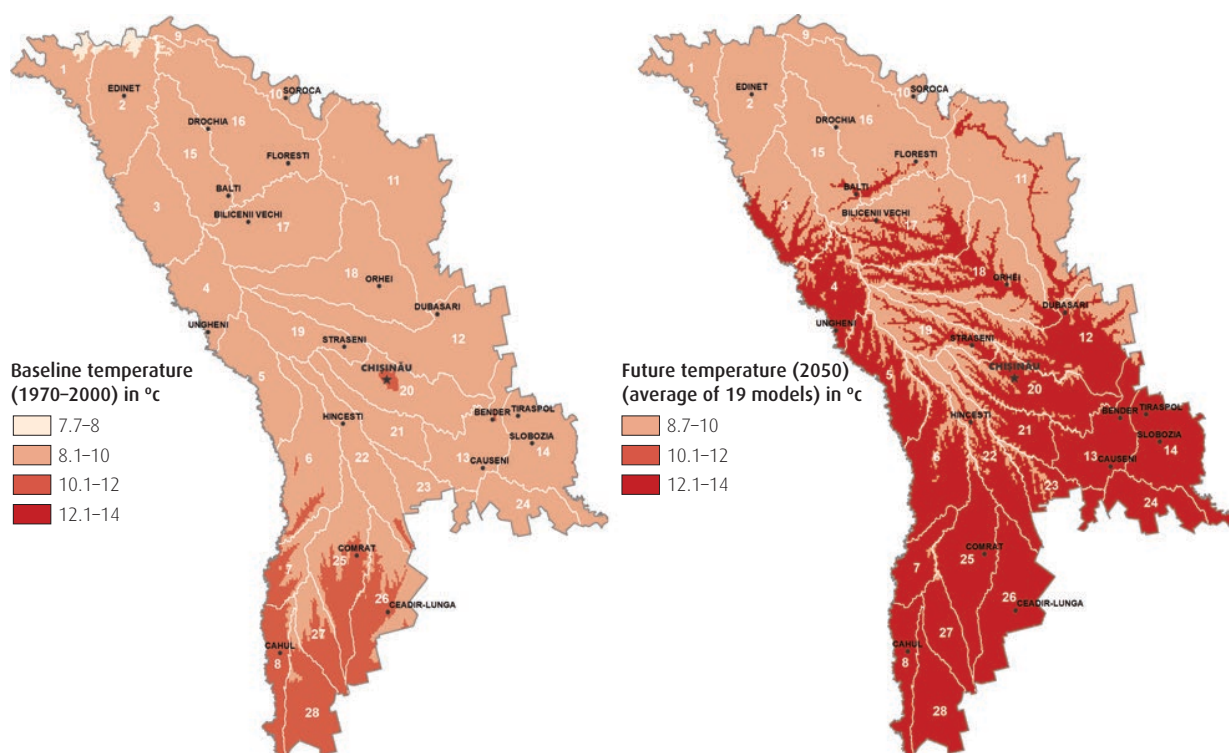
Source: WEAP Moldova data.

Figure 2.5 Baseline 2018: Reliability Curves for Irrigation in Vulnerable Subcatchments in Prut–Danube–Black Sea Basin



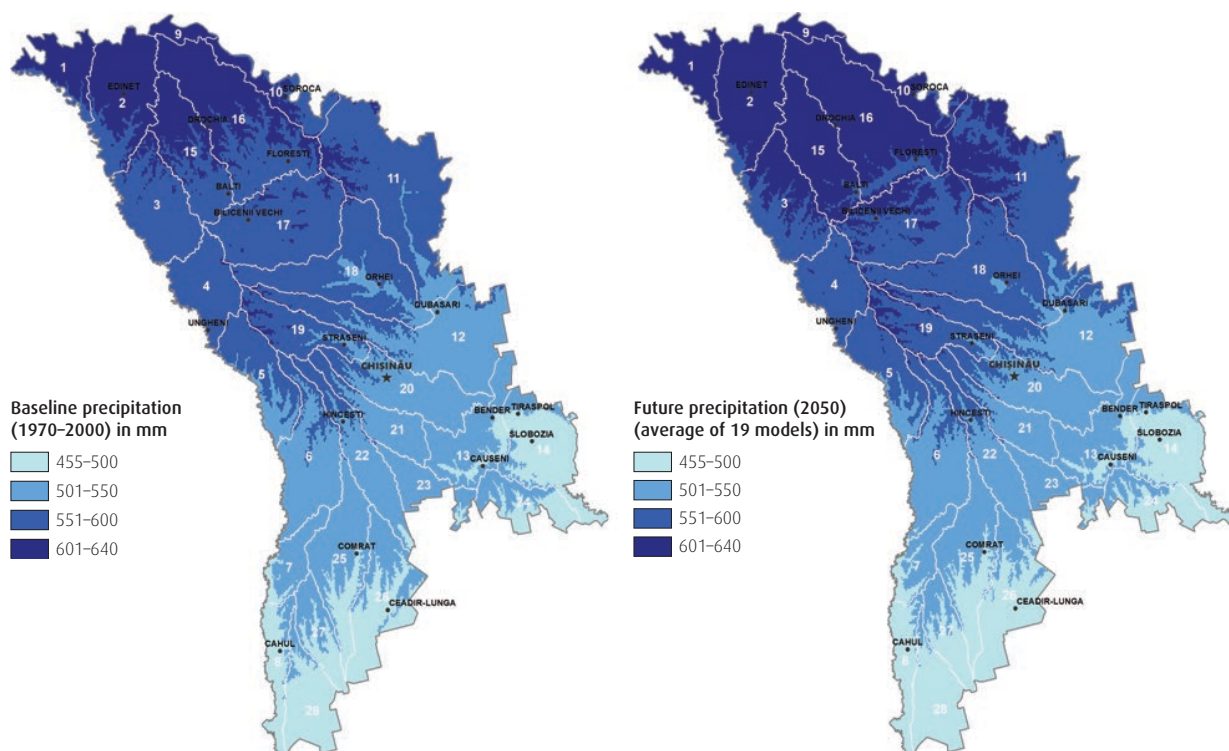
Source: WEAP Moldova data.

Map 2.6 Projections in Average Annual Temperature from 2000 to 2050



Source: WorldClim data, 2020: <https://www.worldclim.org/>.

Map 2.7 Projections of Average Annual Precipitation between 2000 and 2050



Source: WorldClim data, 2020: <https://www.worldclim.org/>.

changes on temperature and on rainfall (WorldClim 2019). Moldova has both high riverine flood risks, as well as drought risks, because of its interannual and intra-annual variability of precipitation and river flow patterns and its mostly rainfed agriculture sector. The drought risks in Moldova are highest in the center of the country, away from the main rivers, as well as in the downstream catchments along the Prut and Dniester (Water Resources Institute 2019a). Although there may be uncertainty on the exact magnitude of the effects of climate change, without doubt Moldova will see an increase in extreme hydrological events, such as floods and prolonged droughts, but also some more favorable warmer temperatures for crop growth in the northern zone.

Notes

1. This includes population estimates on the left bank of the Dniester. Population estimate based on Census data and population and migration trends (UNFPA Moldova 2016).
2. Based on national poverty line estimates from the National Statistical Office; estimates are expected to be revised upward later in 2020 because of the use of a new methodology. The poverty rate at the lower-middle-income country threshold of US\$3.2 a day (2011 PPP)
3. The Association Agreement was signed in 2014 and Moldova started to harmonize legislation with the European Union (EU), and develop instruments required under the EU Water Framework Directive.
4. Population estimates used in the Water Diagnostics for the baseline situation in 2018 assume a population of 3.0 million, of which approximately 0.45 million is assumed to be on the left side of the Dniester.
5. This basin district consists of three hydrographic basins: the Danube, Prut, and Black Sea basins.
6. Left bank territories of the Dniester river or otherwise known as Transnistria.
7. The River Basin Management Plan 2017–22 for the Dniester was approved by the cabinet of ministers on August 30, 2017.
8. The River Basin Management Plan for the Prut-Danube-Black Sea 2017–22 was approved by the cabinet of ministers on October 3, 2018.
9. Full description of the north, center, and south agroecological zones can be found in World Bank (2013).
10. It should be noted that WEAP estimates differ from those by FAO AQUASTAT, specifically with respect to the declined from 69 percent in 2000 to just over 1 percent in 2016. This increases to 15 percent when using the middle-income threshold of US\$5.5 a day (2011 PPP).

inflow across the borders through the Prut and Dniester. However, WEAP is based on the most accurate locally provided data.

11. This is well above international benchmarks for water stress at 1,000 cubic meters per cap per year (FAO 2017).
12. The NBS (2020) states that 0.97 million hectares are under annual crops of which 0.51 million hectares are cereals and legumes, 0.46 million hectares are industrial crops, and 53,000 hectares are potatoes, vegetables, and forage crops. Approximately 47,000 hectares have orchards for fruits and nuts, and 25,000 hectares have vineyards.
13. For an average crop basket, the total crop water demand is 214 millimeters per hectare, of which 124 millimeters per hectare on average is supplied through rainfall and 90 millimeters per hectare through irrigation.
14. The shallow groundwater aquifers are thus not included in the water balance to avoid double counting. Groundwater estimates derived from FAO AQUASTAT (2019).
15. Unmet demand is calculated as follows: inflow across the borders + internally produced surface water runoff + return flows to surface water from deep groundwater withdrawal + return flow from surface water available for (re)use – surface water consumptive use – outflows from Moldova across borders.
16. For the much smaller CHP in Chisinau and Balti, it is assumed that 60 percent of water withdrawals are consumed or lost in the cooling process because of their different outlay.
17. Estimates are informed by the 2013 Census data and forecasts for rural and urban areas, using different growth factors and levels of connectivity to centralized piped water services (per local public administration). The total population is assumed to be 3.1 million (0.45 million on the Transnistrian side), with 40 percent in urban areas and the remaining in rural areas (UNFPA 2018). The rate of connectivity is on average 90 percent for urban areas and 37 percent for rural areas.
18. Private small-scale systems are assumed to source water from local streams, ponds, or reservoirs with high investments from private farmers into high-value crops (intensive and superintensive fruit orchards, vegetables, etc.). The fully pressurized schemes refer to 10 schemes that were recently rehabilitated by the MCC with a high level of service, now under the management of water user associations. The third category are existing centralized pumped systems, currently managed by state irrigation companies under Apele Moldovei, with a limited service.
19. For each catchment, irrigation demands are calculated for each of these three categories, based on assumptions for water source, conveyance losses, irrigation efficiency, cropping mix, and crop water requirements.
20. The unmet industrial demand in the catchment where Balti town is located occurs as part of the industrial demand modeled from local water sources and not through the transfer of surface water from the Dniester through the transfer scheme managed by Acva Nord Company.
21. Modeled as a Q10 flow for downstream outflow of the catchment. The Q10 flow represents the 90 percent probability that the flow would be exceeded (on a monthly basis), in other words, the low-flow condition. It is calculated for the 1950–2016 period and used as a requirement for all internal basins to deliver this flow to the downstream basin.

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CHAPTER 3

Moldova's Water Security Outcomes

Key Messages

- Moldova derives significant economic, social, and environment benefits from its water. However, there are barriers to achieving adequate water security across all three outcomes.
- Agriculture remains an important pillar of the economy. Its value for jobs is significant, employing a third of the labor force and 70 percent of the bottom 40 of the population. Although a motor for diversification and growth, it now remains largely rainfed, focused on commodity crops and vulnerable to shocks and droughts.
- Missed economic benefits from high-value cultivation are resulting from underinvestment and poor management of state-owned irrigation schemes, most of which are now dysfunctional. Insufficient attention to market linkages, land fragmentation, and access to knowledge and finance for farmers has hindered the realization of benefits from investments in irrigation over the past decade.
- To revitalize Moldova's agricultural sector, a two-pronged approach is required: (1) accelerate the transition toward irrigated high-value agriculture for export markets and (2) adopt climate-smart rainfed agricultural practices to ensure resilient livelihoods and food security.
- Stark disparities continue to exist in the access to and quality of water and sanitation services between urban and rural areas. Reliable services are vital for industry and businesses, including tourism, and for people to live productive lives. Almost a million Moldovans rely on shallow, often polluted, wells for drinking.
- Delivering on the aspirations of citizens for better water, sanitation, and hygiene conditions is critical for social stability, human capital development, and prevention of future infectious outbreaks.
- Across the country, sanitation access is low and adequate treatment is lacking, polluting surface water resources and shallow groundwater. This poses a high burden on public and environmental health.
- The ecological status of many water bodies is poor. Untreated wastewater, and industrial and diffuse pollution have severely deteriorated surface water quality, limiting its use without costly treatment.
- High levels of river canalization and deteriorated watersheds and wetlands across the country have compromised ecosystem services. Their restoration is necessary to preserve natural capital and help mitigate flood effects.
- In the absence of flood protection measures and better warning systems, Moldova's flood events will likely increase damage to Moldova's economy as climate change progresses.

Water security outcomes are the observed positive and negative outcomes for people, the economy, and the environment that are influenced by diverse aspects of water management. Social outcomes may include the people affected by water-related disasters, children affected by waterborne diseases, or the well-being that people derive from the environment and ecosystem services. Economic outcomes may include economic losses from floods and droughts, or benefits that flow from the economic use of water for energy production or agriculture. Environmental outcomes relate to whether water resources are sufficiently protected from overexploitation and pollution and whether ecosystems, such as wetlands, rivers, and their watersheds are in good status, such as their water quality and aquatic biodiversity. This chapter discusses the status and trends in water-related outcomes for the economy, the people, and the environment, identifying shortcomings.

Economic Outcomes

Economic water security is an important but often overlooked dimension of water security, which traditionally focuses on physical endowments and withdrawals. Instead, economic water security measures the productive use of water as a driver of economic growth and as a key input to many industries, including food production, manufacturing, energy generation, as well as nonconsumptive sectors, such as tourism. Although physical water scarcity might undermine economic growth, so too does economic water insecurity, in which limited investments in the sustainable management and utilization of water endowments prevent water needs from being met.

There is potential to advance the sustainable use of Moldova's water resources for better economic outcomes. As a percentage of total renewable resources, Moldova's water withdrawals are low, less than 5 percent.¹ Water use has declined during the past two decades as a result of decreasing irrigation water use and other economic changes. However, water is central to the economy, driving higher-value agricultural productivity, powering industry, and contributing to the country's energy production through thermal cooling and small-scale hydropower. With further industrialization, water security will be key to its economic success, whereas inefficient water management can be costly, directly, as well as through foregone economic development gains.

Reliable and good quality municipal water services are critical for Moldova's growing agrifood

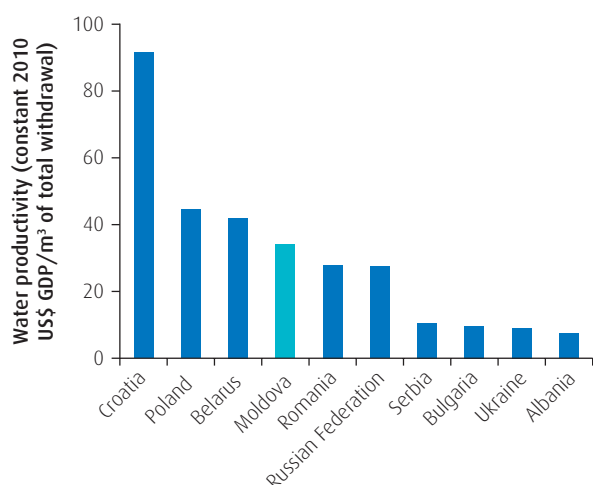
businesses, light manufacturing, and also its services and tourism sector. There remains room for improvement, both in terms of connectivity as well as reliability of supply. In a survey carried out in 2017, 5 percent of firms reported experiencing disruption in production because of water supply outages over 72 hours in length (World Bank 2017). Expanding water supply and wastewater treatment services to people and businesses—specifically to economic and industrial zones—will increase productivity and protect the environment from pollution, avoiding downstream costs.²

In line with historic trends, most water is withdrawn for thermal cooling, currently 76 percent of total withdrawals,³ whereas 22 percent is used for municipal supply to households and industry. With the decline of large areas under functional centralized irrigation systems, and a reliance on rainfed commodity cropping, withdrawals for irrigation have declined to under 1 percent of total withdrawals. This share was estimated to be approximately 10 percent in the early 1990s⁴ (FAO 2019). The low level of total water withdrawals as a percentage of renewable resources (5 percent) indicates that Moldova can use its water resources for development.

This is especially the case for Moldova's agricultural sector, because the lack of irrigation services poses a risk to the resilience of farmers, limits opportunities to produce high-value crops for export, and exposes climate-related economic vulnerabilities. Irrigation development should follow strategic and holistic planning, ensuring that investments are resilient and efficient, and that expanding water use does not threaten ecological demands (see also chapter 4). Groundwater remains an important resource for the country despite concerns over its quality and associated risks for usage in agriculture. A comprehensive groundwater assessment on quality and interaction with soil types is necessary to inform decisions to potentially relax the current ban on groundwater use for supplemental irrigation (see also chapter 5).

Moldova's economic outcomes from water are characterized by a moderate total water productivity, an indication of the total value that the country derives in GDP compared with the amount of total water withdrawn in agriculture, industry, and other services. Moldova's water productivity in 2015, as displayed in figure 3.1, excludes the water diversion at the Kuchurgan CHP, which is under management of Transnistria and does not contribute to Moldova's GDP. When including this withdrawal, productivity drops to a third of this value.⁵

Figure 3.1 Water Productivity per Cubic Meter of Water Withdrawal (2015; constant 2010 US\$ GDP)



Source: World Bank data.

Note: GDP = gross domestic product.

Benefits and Missed Opportunities in Agriculture

Moldova was a key producer of crops during the Soviet era. The country specialized in agriculture, taking advantage of its productive fertile black soils. Although smaller than Ukraine, Moldova was part of the Soviets' breadbasket, and produced a significant share of fruits and vegetables for the Soviet Union. However, since independence, Moldova's agricultural production has fallen dramatically because of a reduction in the markets and profitability of irrigated agriculture. In 1996, about 310,000 hectares were estimated to be equipped with large-scale irrigation systems (World Bank and CIAT 2016). The assessment undertaken during this diagnostic suggests that the area that is actually irrigated today is closer to 6,640 hectares,⁶ of which approximately two-thirds is in central schemes and a third under small-scale privately invested irrigation systems. This presents 2 percent of the equipped area of the 1990s (World Bank 2004). This dramatic decline is largely a result of inadequate investments, operation, and maintenance of state-owned schemes, most of which are either totally ruined or only partially functional (Intexnauca 2018). Rainfed agriculture remains thus an important pillar of the economy, but it is highly vulnerable to rainfall variability.

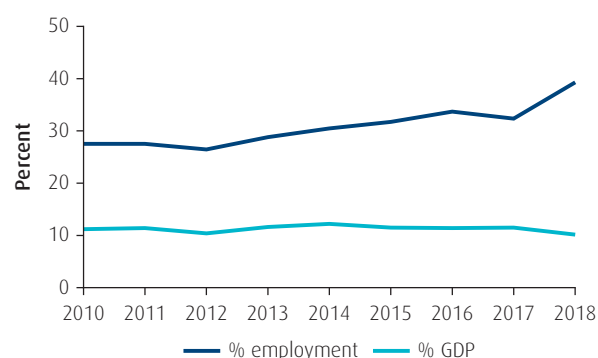
Agriculture's contribution to GDP, although limited by low-value crops and a lack of sector modernization, was 10 percent in 2019 and not inconsequential (figure 3.2). Together with the

agroprocessing sector, it generates nearly 20 percent of GDP. Agricultural produce and food products account for 45 percent of exports, but most exports are still low-value crops, such as oil seeds and cereals. On the positive side, the area cropped, and the harvests of fruits and vegetables have gone up significantly since 2010 (NBS 2020). Because of its export opportunities, the Government of Moldova identifies agriculture as one of the key drivers of growth in its 2030 National Development Strategy (Republic of Moldova 2019).

Moreover, agriculture provides jobs to over one-third of the labor force and its share has been increasing since 2017 (figure 3.3) and will continue to be a backbone for rural livelihoods. It employs 70 percent of the people in the bottom 40 population segment and is critical for poverty reduction efforts, especially with a surge in the return of migrant workers to Moldova's villages because of the COVID-19 pandemic. In the face of the economic recession, resilient rural livelihoods will increasingly be important for the poorest and most vulnerable in society. Although Moldova's economy requires further efforts to diversify, a modernized agriculture sector will be a critical pillar for the economy.

Modernization will be critical to move the country to higher-value crops, ensure better income for farmers, and provide sustainable job opportunities in rural areas. There is room for improvement especially when it comes to agricultural water productivity. This is due to the low levels of irrigation modernization,⁷ limited orientation toward high-value crop production, suboptimal usage of irrigation services in which systems have been rehabilitated, and overall a high reliance on rainfed farming. This means Moldova's agriculture remains highly vulnerable to weather extremes with particularly low

Figure 3.2 Share of Agriculture in GDP and Employment, 2010–18



Source: NBS 2019.

Note: GDP = gross domestic product.

crop outputs during the drought years 2007, 2012, 2015, and 2020.

Although water security and thus irrigation access is a necessary condition for growing high-value crops, complementary efforts have been undertaken to improve competitiveness and market integration. Subsidy schemes are in place to stimulate the production of high-value crops and facilitate investments through matching grants. Over the past decade, intensive and superintensive orchards have been set up, along with vegetable greenhouses, which benefit from drip irrigation, protective nets, as well as improved agronomic practices, and have yields comparable to other developed EU countries. Given the opportunities to increase agricultural exports to the European Union, as well as to markets in the Commonwealth of Independent States, high-value agricultural exports provide a real opportunity. However, to unlock these, a comprehensive set of policy and investment measures are required to overcome barriers both within and outside of the water and agriculture domains that are discussed in chapter 5.

Overall, there is significant potential for the agriculture sector to enable future sustainable development. This would require a transition to efficiently irrigated high-value agriculture that supports exports, while increasing the climate-adaptive capacity of rainfed agriculture to sustain livelihoods, ensure employment, contribute to the country's food security, and help manage risks to the economy.

Benefits from Energy Generation and Navigation

Moldova derives modest economic value from the use of water for energy generation from hydropower, which in turn does not significantly affect its consumptive water usage.⁸ Approximately 5 percent of Moldova's domestic power demand is derived from hydropower, whereas the remaining energy is derived from fossil fuel or fossil-fuel-generated imports. There are two existing hydropower facilities, one at Dubasarry² in the Upper Dniester basin and the other at Costești-Stânca¹⁰ in the Prut basin on the border with Romania, with a combined generation capacity of 64 MW (Republic of Moldova 2013).

Water withdrawals for thermal cooling purposes of CHPs are substantial, specifically for the CHP at Kuchurgan (2,520 MW), which is operated by the Transnistrian authorities on the left bank of the Dniester¹¹ and supplies approximately three-quarters of Moldova's energy. Surface water is

used for cooling at the Chisinau CHPs (240 MW capacity), as well as the CHP in Balti (24 MW capacity) and remains important for domestic energy generation.¹² With only 20 percent of energy demand generated locally, Moldova's Energy Strategy 2030 (Republic of Moldova 2013) is centered on integration and purchase of power from regional networks and ensures continued import of gas and liquid fuels. Moldova's topography, as underscored in the Energy Strategy 2030, does not support large-scale hydropower, and only 1 MW of annual capacity is identified for small-scale hydropower development (Liu et al. 2019).¹³

Transportation by inland waterways is a small contributor to Moldova's economic development with modest potential for growth. Moldova's transport strategy focuses on road and rail transport driving future connectivity. There are navigable stretches on the Dniester and Prut rivers used for cargo transport and limited recreational use. Giurgiulesti is the only international free port on the maritime part of the Danube and, although increasing, only modest volumes of cargo pass through it, mostly comprising agricultural produce, such as grain, vegetable oil, and wine (Giurgiulesti International Free Ports 2018). On the inland waterways there are floating crafts with capacities of 600 tons for the Prut, and 1,000 tons for the Dniester River, owned by state enterprises along with some private vessels. Navigation can be further developed, although risks and up-front investments are large, commercial demand needs to be secured, and environmental effects would need to be carefully assessed.

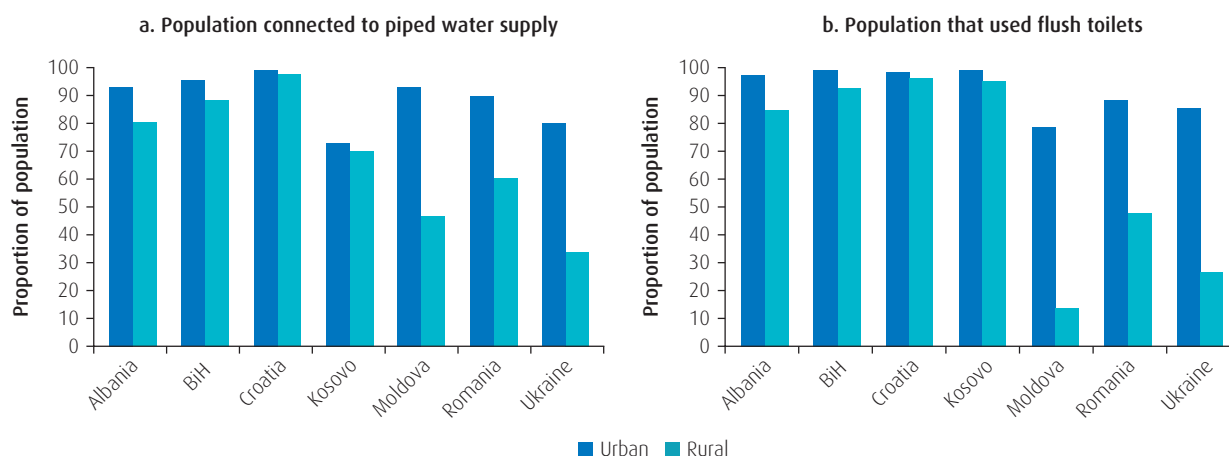
Social Outcomes

Missed Opportunities from Inequalities in Water and Sanitation Services

Compared with other countries in the Danube region, the share of population with access to basic water and sanitation services in Moldova is low. The gap between urban and rural areas remains one of the largest in Europe and is one of the key water security issues the country is facing (figure 3.3).

The level of service is mostly defined by location—urban versus rural—and less so by income levels, recognizing that most of Moldova's poor people live in rural areas. Approximately 90 percent of urban households have access to piped water, whereas in rural areas, only 44 percent of households have piped access and one in three households is served by a publicly managed, centralized drinking water supply company (Household Budget Survey 2015) (figure 3.4). Even starker inequalities

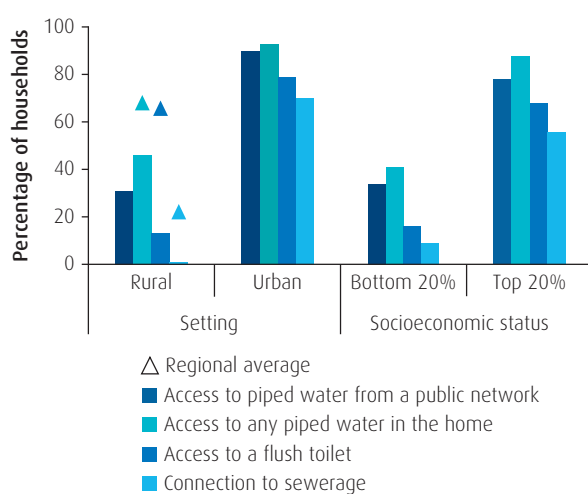
Figure 3.3 Access to Piped Water Supply in the Home and Flush Toilets for Moldova and Regional Comparators



Source: World Bank 2018.

Note: Piped access includes both centralized systems and piped connections to private wells. BiH = Bosnia and Herzegovina.

Figure 3.4 Inequalities in Access to Water Supply and Sanitation in Moldova



Source: Based on World Bank 2018.

are present in Moldova's sanitation outcomes. Supply in rural areas is characterized by fragmented delivery, with more than 900 individual service providers, and a large share of rural households depending on self-supply through the use of wells, putting people at risk because of unregulated, unmonitored, and often inadequate quality of water.

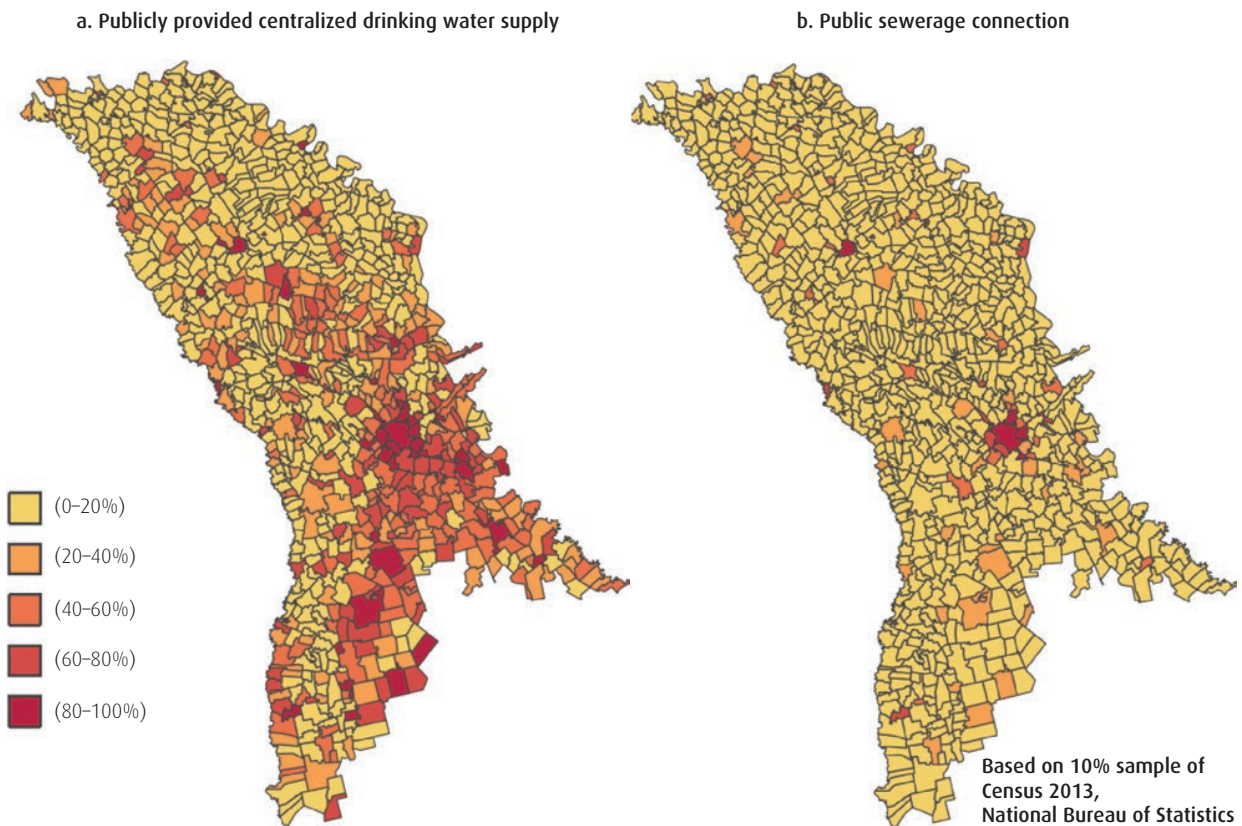
Despite efforts of the government, such as through the investments of the National Environmental Fund, the National Regional Development Fund, the National Fund for Agriculture and Rural Development, and

projects of development partners, overall investment levels remain low. The geographic disparities in the level of access to drinking water services on premises and access to sewerage connections are illustrated in map 3.1.¹⁴ Across much of the country, access is low, but better outcomes can be found in Chisinau, its surrounding areas, and larger urban centers around Chisinau.

Social and Economic Burden from Flood and Droughts

The human face of Moldova's climate-related hazards is visible in loss of life, jobs, livelihoods, health, and well-being and increased stress. Droughts, early onset of frost, floods, and hailstorms are recurring phenomena. Sixty percent of the Moldovan population is rural and largely dependent on rainfed agriculture for their livelihood and thus exposed to droughts. Yearly flooding affects about 70,000 Moldovans and on average costs US\$100 million in GDP (GFDRR 2019).¹⁵ At the same time, in the years with extreme disasters these figures are higher. Moldova's river flood hazard is classified as high based on modeled flood information, indicating that potentially damaging and life-threatening floods are expected to occur at least once in a 10-year period (GFDRR 2019). Climate change projections indicate that the hazard level will increase because of more frequent and intense precipitation in the winter. This underscores the importance of ensuring that planning and design of construction projects is based on long-term flood risk assessments.

Map 3.1 Public Access per Local Government Administration (Percentage of Households Connected)



Source: Based on a 10 percent sample of the Moldova Census 2013 data (National Bureau of Statistics).

More than 1,200 km of flood defenses protect 90,000 hectares of mostly agricultural land, although their condition is not guaranteed because of lack of maintenance and safety monitoring. More than 5,000 small ponds—mostly for irrigation and fishery use—along main rivers and internal tributaries pose additional flood risks, as dam and reservoir conditions are poorly maintained and hardly monitored. This increases risks for local flash flooding resulting from breaches or overflow. The Dniester River Basin Management Plan suggests that the frequency of flash floods on small internal rivers is high, on average once every 6 years over the past 70 years (Republic of Moldova 2017). A lack of investments in flood mitigation and protection—for structural, nonstructural, and nature-based solutions—is hindering water security outcomes.

Droughts already occur frequently and are expected to increase in frequency and intensity because of

climate change. On average, northern Moldova experiences a drought once every 10 years, central Moldova once every 5–6 years, and southern Moldova once every 3–4 years (World Bank 2016a). From 2000 to 2015 the country experienced 4 years with severe droughts (2000, 2003, 2007, and 2012), each seeing an immediate drop in agricultural output. Because of its dependence on rainfed farming, the severe drought in 1994 resulted in a decline of 26 percent in agricultural output (World Bank 2016b), whereas the drought of 2007 resulted in estimated losses for the agricultural sector of about US\$1 billion (World Bank 2016b). Limited access to irrigation, limited knowledge and application of climate-resilient adaptive agricultural practices, as well as the lack of weather-based insurance instruments contribute to these water security risks (World Bank and CIAT 2016). The onset of a drought in 2020 has highlighted again the urgency to reinvest in better irrigation services.

Environmental Outcomes

The Degradation and Loss of Ecosystem Services

Moldova's sustainable development is adversely affected by natural hazards, land and biodiversity degradation, as well as high levels of water and air pollution in major cities of the country. All these directly and indirectly affect living conditions and the health of the population, as well as economic development, contributing to poverty, especially in rural areas (World Bank 2016a). Moldova's environment has suffered from neglect, particularly under Soviet policies when economic growth was prioritized over environmental objectives. Excessive use of pesticides in agriculture and industrial pollution resulted in soil, surface, and groundwater pollution.

Moldova's widespread land degradation is the result of poor land management, with erosion and other soil degradation reducing agricultural productivity. More than 2 million hectares—more than half the country—are prone to degradation, of which 350,000 hectares are heavily eroded (World Bank 2016a). Land privatization and parceling, lack of crop rotation and anti-erosion measures, as well as slow uptake of best practices for soil conservation have all played a role. Soil erosion may reduce agricultural yields by 40 percent and average annual losses because of land degradation are estimated at US\$40 million in foregone agricultural production. Extreme degradation can lead to land abandonment and deteriorating rural livelihoods, especially for poor smallholder farmers (World Bank 2016a).

Biodiversity degradation, particularly of the country's forests and wetlands, is problematic. Moldova's low level of afforested area (approximately 12 percent)¹⁶ contributes to soil erosion, flash floods, landslides, and a lack of water retention and infiltration in its watersheds to feed its water resource base. Although the forestry sector's direct economic contribution to GDP is small, this may increase as the value of direct and indirect forest ecosystems services develops (wood, nontimber products, carbon sequestration, water retention, soil erosion regulation, and tourism, for example).

Moldova lists floodplains and wetlands among its most affected landscapes. Moldova's few wetlands have been significantly degraded because of a long tradition of drainage for agricultural use, particularly along the Prut. River Basin Management Plans highlight the need for restoration and preservation of the country's natural flood plains to restore their ability to act as natural storage systems and provide protection from floods. Currently, protected areas cover

only 6 percent of the country's territory (map 3.2), including wetlands, protected forests, and floodplains, with a total area of almost 67,000 hectares. In the Middle Prut area, some 330 hectares of flood plain forests and wetlands of regional significance¹⁷ have undergone successful restoration. Further restoration efforts along the Prut and Dniester are needed. A poorly understood risk to the ecological status and flow regime of the Dniester is that of the hydropower complex Novodnestrovsk at the border with Ukraine. A recent study claims that the hydropower complex results in high peaks and low flows throughout the day, as well as high temperature variations from the water that is released from the deep reservoir (UNDP, OSCE, and UNECE 2019). This reportedly resulted in changes to the hydrological, hydrochemical, and hydrobiological characteristics of the Dniester River, affecting aquatic and terrestrial ecosystems, although the extent of this impact is not yet fully understood. Ukraine has expressed considerations for further expansion of the Novodnestrovsk complex and the Moldovan government, supported by Swedish-funded technical assistance, is conducting an environmental impact assessment of the hydropower complex.¹⁸

Biodiversity in the Prut basin has been subject to significant changes in the past decades because of human activities. This includes the construction of the Costești-Stânca hydropower plant; the construction of dykes, ponds and reservoirs; as well as the exploitation of floodplains, all of which affect the hydrological regime. Because of siltation and lack of maintenance, many of these structures are not able to achieve their full potential or benefits yet they negatively alter Moldova's natural flow regimes. Alteration and canalization of rivers, mainly in the 1960s and 1970s, occurred to meet the increasing water needs and to regulate flows, allowing the development of ponds for fish farming, industry, and irrigation. An inventory exercise is now in progress.

Water Pollution and Water Quality Risks

Pollution of water bodies presents a major threat to Moldova's development outcomes. The poor quality of water sources—both surface and groundwater—seriously compromises the provision of safe drinking water, affecting human health and economic productivity. The situation is especially unfavorable in rural areas, where two out of three rural Moldovans rely on shallow polluted groundwater as their main source of drinking water and access to piped drinking water systems with adequate treatment is low.

High pollution stems from point sources of untreated wastewater, unsanitary waste landfills, industry, as well as from diffuse sources such as agriculture,

Map 3.2 State-Protected Nature Areas

Source: Institute for Ecology and Geography 2019a: http://ieg.asm.md/en/protected_areas.

livestock, and poor sanitation in rural areas. With collection rates of wastewater in urban areas already being low, the treatment rate is even lower. Out of 1,214 water systems in the country, only 141 have a functional sewerage system, and only 91 have some form of treatment (NBS 2017). Most water treatment plants have deteriorated and discharge untreated wastewater directly into rivers, leading to deteriorating water quality parameters from upstream to downstream in the basins. It is estimated that approximately 65 million cubic meters of wastewater flows yearly into treatment facilities, serving approximately 1 million people (World Bank 2019b). Approximately 40 percent of water produced for municipal and industrial use is collected, but effective treatment is lower.¹⁹ The volume of wastewater managed by Chisinau Apacanal is more than 50 million cubic meters per year serving more than 700,000 people.²⁰ Sewerage networks and treatment facilities in a few larger secondary cities have been upgraded with adequate functionality (Balti, Orhei) and some are under construction or planned for upgrading (Unghen, Cantemir, Cahul, among others). Soroca town remains a priority as it is a major polluter upstream on the Dniester.

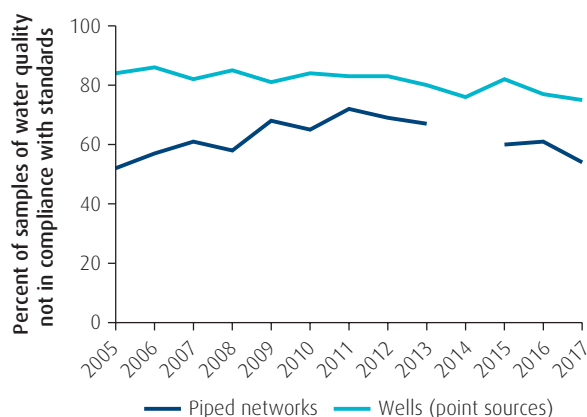
The food industry is a driver of point source pollution, with pressures from the sugar, alcohol and beverage, dairy, meat processing, and canning industries. Old industrial sites significantly contribute to the deteriorated groundwater quality, such as coal-burning plants (Hannigan Bogdevich, and Izmailova 2006) or through contaminants, such as pesticides (Nastasiuc et al. 2016).

Due to efforts of the Environmental Inspectorate, larger enterprises and wineries have been installing wastewater treatment plants or other forms of pretreatment. However, discharges in the municipal sewerage without adequate treatment remain common, compromising the functioning of existing treatment plants. Waste management is also a growing concern as many waste disposal sites have reached their capacity and need to be closed. The great majority of disposal sites do not meet sanitary standards, operate quite often without licensing from sanitary and environmental authorities, and do not always have adequate groundwater protection measures in place (World Bank 2016).

Because of this situation, across Moldova, most water bodies are at risk of not achieving good ecological status and many are classified as polluted.²¹ In the Prut and Danube–Black Sea basins, all water bodies were recorded as at risk, and 95 percent of these were categorized as high risk. The Prut river tributaries and small rivers, as well as the Black Sea and Danube tributaries, are characterized as polluted, indicated by high levels of chemical and biological oxygen demand, mineralization, sulphate, sodium and potassium, total iron, oil products, as well as the presence of heavy metals.²² In the Dniester river, water quality is somewhat better, being classified as good to moderately polluted. However, the pollution situation is more challenging along the tributaries on the right bank of the Dniester river, which are classified as polluted (Republic of Moldova 2017). Water is deemed only suitable for generating electricity and transportation, because surface water contains large amounts of minerals, ammonium, nitrites, oil products, and detergents, compromising its use for drinking water purposes unless undergoing advanced treatment. Reports from the Public Health Agency in Moldova indicate that surface water quality has been deteriorating since 2018.²³

Diffuse pollution from fertilizers, manure disposal, and lack of rural sanitation has affected nitrate levels and microbiological contamination of shallow groundwater. Approximately 80 percent of sampled Moldovan wells do not comply with national drinking water standards. (figure 3.5). Shallow

Figure 3.5 Noncompliance of Water Sources with National Standards



Sources: National Bureau of Statistics and National Public Health Agency data.

wells show high levels of ammonium, nitrates, and microbiological pollutants, with the highest levels of nitrates occurring in the north and posing a public health risk, especially for infants because of blue-baby syndrome.

The status and human effects on deep groundwater bodies have not been comprehensively inventoried. Given the importance of groundwater for Moldova's drinking water provision, such assessment is critical for future water source planning and understanding the trade-offs between costly surface water transfer schemes and advanced treatment methods.²⁴ A preliminary assessment of groundwater bodies in the Dniester showed that most aquifers were of good status, with no observed effects of human-induced salinization, and stable water levels. In the Prut-Black Sea basin, all nine groundwater bodies are of good status, although with high natural mineralization. Shallow aquifers, especially in the floodplains of the Dniester and Prut, have seen declining levels pointing at declining net recharge (Republic of Moldova 2018).

The government follows a prudent approach by not allowing groundwater for irrigation purposes, because of the risk of irreversible soil damage due to high salt contents.²⁵ This approach is perhaps rather conservative, with evidence showing that 10–50 percent of the groundwater resources could potentially be used for irrigation, depending on soil salinization risk indices (Jalalite, Jelepov, and Nicoara 2017; Sandu et al. 2013). Surface waters in lakes and ponds also have high salinity and mineralization, compromising their use for irrigation for the same reasons. In the absence of better risk management

strategies and regulations, a precautionary approach with enforcement seems reasonable in the medium term.

Notes

1. Estimated based on the WEAP model with withdrawals of 725 million cubic meters per year (including thermal cooling). Total renewable resources to be 15.34 billion cubic meters per year. AQUASTAT data estimate this higher at 10 percent, because of high irrigation withdrawal estimates reflecting older data. http://www.fao.org/nr/water/aquastat/countries_regions/MDA/.
2. A political driver related to the Association Agreement with the European Union is to align and advance on implementation of the Drinking Water Directive and the Urban Wastewater Treatment Directive.
3. Including withdrawals at the Kuchurgan CHP.
4. Chapter 5 provides updated estimates for the water balance in the 2018 Baseline situation based on the WEAP model.
5. For Moldova, withdrawal data from the WEAP baseline scenario are used instead of withdrawal data from FAO AQUASTAT.
6. Recent rehabilitation of 10 centralized systems covered around 13,500 hectares, whereas monitoring data suggest that approximately 20 percent is actually irrigated. Constraints relate to lack of access to finance, knowledge, and land ownership structures. In addition, irrigation takes place under nonrehabilitated state schemes that are in the process of being transferred to water user associations, as well as in small-scale private schemes where farmers have invested in water diversion, and irrigation equipment.
7. Water use productivity in irrigated agriculture is estimated at US\$0.5 per cubic meters water withdrawal, with an estimated 3 percent contribution to GDP from irrigated agriculture; based on 2005 data from FAO (2018). Rainfed agriculture is not included in this indicator.
8. Because of the design features of the CHPs most water is diverted to reservoirs and returned back into the system or the CHPs are directly located on the rivers or streams (see appendix A).
9. Built between 1954 and 1966 with a capacity of 48 MW.
10. Built in 1978 with a capacity of 16 MW.
11. Although withdrawals are estimated at 550 million cubic meters annually, the system is operated through a cooling pond, recirculating an estimated 500 million cubic meters back to the surface water, with an estimated 10 percent being lost to evaporation.
12. Of which approximately 20 percent is from hydropower and 80 percent from fossil-fuel-powered CHPs.

13. Currently, licenses for small-scale hydropower developments are not being issued because of environmental concerns and the application of the precautionary principle.
14. This map is derived from a 10 percent sample of the Census data 2013 (National Bureau of Statistics).
15. This represents almost 1 percent of GDP and approximately 2 percent of the population.
16. Compared with the European average of 30 percent.
17. Estimated to be the oldest in Europe and part of the Padurea Domneasca nature reserve.
18. Through the United Nations Development Programme with support of the Swedish Government.
19. Total water withdrawals for municipal and industrial use are estimated at 160 million cubic meters per year in 2018 (chapter 2). Data based on an unpublished survey in 2016 supported by the World Health Organization.
20. Supported by funds from EBRD, EIB, and EU.
21. The River Basin Management Plans for the Prut and Dniester include a first assessment of ecological status of water bodies, using classifications introduced by the EU Water Framework Directive; for details on water quality status, reference is made to both plans. Because of incomplete data, the second cycle of the River Basin Management Plans will include a more comprehensive assessment.
22. The Costești-Stânca lake in the north is moderately polluted and the southern lakes at Beleu and Manta are polluted.
23. <https://ansp.md/index.php/rezultatele-investigatiilor-de-laborator-ale-calitatii-apei-din-sursele-acvatice-de-suprafata-destinate-populatiei/>.
24. Depending on the chemical quality, this would require ion-exchange separation.
25. Loamy and clay soils are specifically vulnerable to sodification, resulting in low water holding and infiltration capacity that is difficult to reverse.

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CHAPTER 4

Water Futures and Risks

Water Endowments and Future Developments

Approach

Chapter 2 showed that Moldova's water resources endowments are sufficient and reliably available to largely meet today's various demands under current climate conditions. However, chapter 3 illustrated that Moldova's water security outcomes, for its people, the economy, and the environment, leave significant room for improvement. Rather than constrained by physical water endowments, water security outcomes are limited by a lack of infrastructure, investments, financing, management capabilities, and enabling policies within and beyond the water sector (discussed in chapter 5). Moreover, against a backdrop of changing social, economic, and demographic trends, other effects such as a changing climate may negatively affect Moldova's water security in the future.

Moldova's development will have a bearing on its future water demand, whereas climate change will affect both water availability and demand. Given the uncertainties related to climate change effects and potential transboundary water risks, it is important to stress test whether water resource endowments will be sufficient and reliably available to meet water demands in the future.

This chapter presents an analysis of water futures that represent stylized scenarios of development and water demand to understand the risks to physical

water security under uncertainty with a 2030 time horizon. It uses the WEAP model, introduced in chapter 2 and elaborated in the appendix, to evaluate water shortages and supply reliability under different scenarios. It also illustrates future resilience and risks to development outcomes through stress testing climate change, environmental water needs, and demand changes upstream in Ukraine.

Moldova's Water Futures

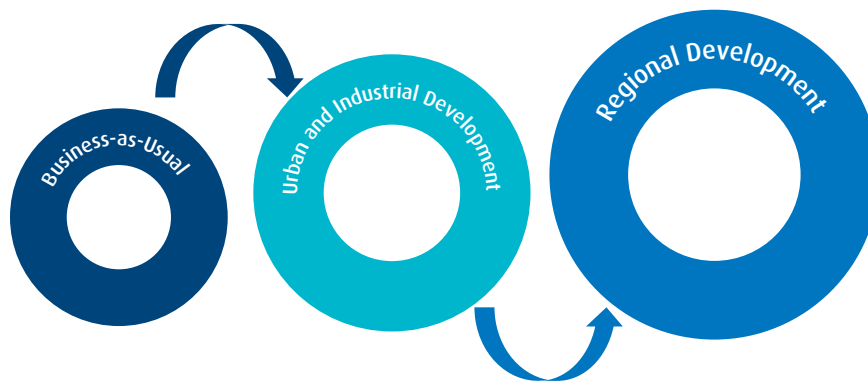
Future water demand depends on multiple factors, including shifts in the drivers of the economy, population and demographic changes, policy choices and investment, as well as climate change. In designing plausible water futures, this diagnostic has considered several important drivers for change needed to put Moldova on a more sustainable development path. Key drivers for this development outlook include, among others: (1) transitioning to export-oriented, high-value, and climate-resilient agriculture; (2) encouraging regional development in growth centers and secondary towns for the manufacturing and service industry; (3) delivering to meet citizen's aspirations for living conditions in rural areas, such as water and sanitation; and (4) protecting people, assets, and livelihoods from flood risks and developing ecosystem services.

With the need to develop alternative growth engines, resilient agriculture and agribusinesses can help to increase exports, maintain food security, reduce

Key Messages on Endowments and Future Developments

- Rather than constrained by physical water endowments, water security outcomes are limited by infrastructure, investments, financing, management capabilities, and enabling policies.
- Moldova's development will change future water demand and climate change will affect water availability and demand. Therefore, it is critical to understand whether water resource endowments may become a constraint or a compounding risk for achieving development outcomes.
- Through the water balance evaluation tool (WEAP), the diagnostic assesses whether there are sufficient water resources reliably available to support social, economic and environmental demands across different development scenarios to 2030.
- Different water futures were developed—based on social, economic, and demographic drivers—that reflect increasing demands and investments for drinking water, industrial and irrigation. They have been informed by existing regional and national plans and reflect different costs, as well as benefits to society.

Figure 4.1 Moldova's Water Futures



weather-related vulnerability, and create jobs and livelihoods. This is even more important in the situation of reduced remittances caused by migrant workers returning during the pandemic and the associated global economic recession. A wider adoption of climate smart agriculture and increased private and public investments in irrigation is necessary, accompanied by incentives and business development to help farmers take risks and invest in modernization measures.¹ Over a 100 larger farms already have the ability to compete in high-value markets with yields nearly 1.5 times those of small farmer or peasant households (World Bank 2019). Moldova has been successfully competing in some markets, such as walnuts, apples, organic produce, and wines.

The development of a diverse economy will require cities, towns, and industrial zones to have resilient water supply and sanitation services and to be

protected from disruptions and damages because of flooding and other water-related risks. With the potential for rural and agrotourism, restoring and protecting watersheds, wetlands, and forests, and improving soil and water quality can serve both economic and environmental outcomes. Moldovans expect higher levels of prosperity, and the need to improve basic living standards and services in small towns and rural areas is pertinent. This will be a condition for businesses and people to flourish, for rural livelihoods to develop, and to sustain regional growth beyond urban centers. Based on the preceding drivers, three stylized water futures for 2030 have been developed and analyzed, each with a different development trajectory and an increasing future water demand (see figure 4.1).² The water futures are summarized with key data in table 4.1 and a brief description in boxes 4.1–4.3 (see also appendix A).

Table 4.1 Summary of the 2018 Baseline and 2030 Water Futures in Figures

	Unit	Baseline 2018	BAU	Scenario 1	Scenario 2
Year		2018	2030	2030	2030
Population^a: total urban-rural	million	3.1 1.2–1.9	2.9 1.3–1.6	2.9 1.3–1.6	3.0 1.4–1.6
Connectivity rates for municipal and industrial demand: urban-rural	%	90–37	93–41	96–63	100–80
Irrigated area total	ha	6,640	13,726	20,476	62,225
<i>Small-scale private-led^b</i>		2,605	5,211	5,211	20,844
<i>Rehabilitated schemes^c</i>		2,270	6,750	13,500	13,500
<i>Centralized large schemes^d</i>		1,765	1,765	1,765	27,883

Note: BAU = business as usual.

a. Population on the left bank is assumed constant at 0.5 million of which 0.3 million are urban and 0.2 million are rural.

b. Small systems using local streams or sources, investments through the private sector.

c. Rehabilitated by MCC/SDA; fully pressurized on-demand systems, now managed by water user associations (WUAs).

d. Large irrigation system managed under state companies; systems could be managed by WUAs and/or by Apele Moldovei in the future.

Box 4.1 Summary of Moldova's Water Futures: Business as Usual 2030 (BAU 2030)

Future: Moldova continues to build on its economic successes of the last decade; however, younger citizens continue to seek work elsewhere. Productivity and exports continue to be limited and below their potential, and challenges remain in terms of diversification and other structural aspects of the economy.

Demographic trends: Overall decline while population remains predominantly rural; there is growth in urban population and decline in rural areas.

Water supply: Some progress is realized in the expansion of coverage of water supply networks in urban and rural areas, although it is still slow.

Agriculture: Sector remains important; partial uptake of area under rehabilitated irrigation systems (under water user association management); transition to higher-value crop mix remains slow; doubling of private-led small-scale schemes with higher-value crop mix; no new public investment in rehabilitation of centralized schemes.

Flood risk: Only extremely high-priority investment measures plus flood warning systems.

Box 4.2 Summary of Moldova's Water Futures: Urban and Industrial Development (Scenario 1)

Future: Moldova successfully develops its designated free economic zones, through light industry, and expansion of agribusiness and services (digital, IT). Towns develop rapidly, becoming hubs of education and economic activities, retaining more younger citizens in the country.

Demographic trends: Population in urban and around free economic zones increases, whereas rural areas continue to depopulate to some extent; overall population declines.

Water supply: Progress is realized by prioritizing expansion of coverage in urban areas, as well as small towns and rural areas close to economic development regions.

Agriculture: Higher-value crop transition and full uptake of the existing rehabilitated systems under WUA management; doubling of private-led decentralized irrigation systems; no public investment in rehabilitation of centralized irrigation schemes.

Floods: High-impact flood mitigation measures, focused on protection of urban areas and industrial zones.

Box 4.3 Summary of Moldova's Water Futures: Holistic Regional Development (Scenario 2)

Future: Rekindled economic dynamism across Moldova, with an inclusive approach toward rural areas, fostering urban and industrial development and large incentives for agricultural investment and investments in modernization. Augmented focus on improving services and developing irrigated agriculture in rural areas, as a cornerstone for broader resilient rural development and job creation.

Demographic trends: Population decline has slowed slightly, because of availability of economic opportunities for the young population and better services in rural areas.

Water supply: Universal expansion in urban cities, plus rapid acceleration of coverage in rural areas.

Agriculture: Dramatic expansion in high-value, private-led, and small-scale irrigation systems (quadrupling); full uptake of the rehabilitated systems under WUA management; and large-scale public investment in the rehabilitation of centralized irrigation systems (managed by either public irrigation companies or future WUAs).

Floods: All priority measures of the short-term (5-year) flood master plan are implemented, as well as nonstructural measures.

Water Resources Constraints and Risks for Development

Water Availability and Reliability

The analysis of the three water futures for 2030 illustrates that, on average, under current climatic conditions, total annual unmet demand at the national level remains modest. Average annual water availability does not pose significant constraints to meet future demand, based on the increasingly progressive investment under all three scenarios. Table 4.2 illustrates key data for the baseline 2018, as well as the three 2030 scenarios (details in the appendix). As can be seen, total withdrawals (including for Kuchurgan) are changing from 725 million cubic meters per year to 855 million cubic meters per year for the Holistic Regional Development future (scenario 2), presenting the most aggressive water demand scenario. In this future, irrigated areas are increased tenfold compared with the baseline, and connectivity of people and businesses to water systems is universal for urban areas and 80 percent for rural areas. Not including the water diversion at Kuchurgan, unmet demand as a percentage of total demand (excluding Kuchurgan) remains small at 4 percent. Groundwater withdrawals increase in this scenario to 111 million cubic meters per year,

or 31 percent of total demand, and remain well within the estimated annual renewable deep groundwater resources of 300 million cubic meters.

Although average annual water shortages may be low, the spatial and temporal distribution of water shortages matters a great deal for prioritization and location of investments in the various sectors. Map 4.1 illustrates the average annual unmet demand at the catchment level as a percentage of the total demand in the catchment,³ as well as the sector in which this shortage is occurring. This gives a first order impression of the spatial distribution of hotspots across the country, indicated by the catchments with a darker orange color.

As water demand increases along the scenarios with increased investments, several more hotspots occur, specifically in scenario 2 with aggressive development of irrigated agriculture.⁴ In this scenario, hotspots intensify in the northern part of the country, as well as in southern catchments of the Prut-Danube and Black Sea catchment. Shortages mostly occur in the irrigation sector, linked to the expansion of irrigation systems, as well as modest shortages in the industry sector, for example, in the subcatchment where Balti is located. Overall, the shortages in the industry sector remain extremely small and no shortages occur for drinking water use, because of its first ranked priority in the allocation order.

Key Messages about Water Resources Risks

- Across all water futures there are no binding water resources constraints for development, not even for the Holistic Regional Development future with the highest water demand because of a tenfold expansion of irrigated area.
- Under the Holistic Regional Development scenario, across all years, including the driest ones, at least 89 percent of the total demand and 75 percent of irrigation water demand can be realized. Although shortages are modest at a national scale, these mask local effects in hotspot catchments, along the north and middle Prut, and in the southeast and southwest of the country.
- Thus, irrigation development requires a well-managed expansion of subsidy schemes for small-scale private irrigation systems, and additional catchment-level analysis before investing in the rehabilitation of large centralized systems. Both efficiency measures and allocative decisions can help to mitigate the effect of shortages in hotspots, as well as small-scale storage to bridge seasonal shortages.
- Water futures have been stress tested for external risks and uncertainties, such as environmental flow requirements, the effect of different climate change projections, as well as increased irrigation water demand in upstream Ukraine.
- Climate change remains the most important external risk to Moldova's water security. A future drier and warmer climate for Moldova has a modest effect on municipal water supply and risks can be mitigated through efficiency, recycling, and demand management measures.
- However, a future drier climate does result in an expansion of hotspot catchments across large parts of the country, reducing the reliability of supply for the irrigated agriculture sector, as well as already vulnerable rainfed farming. Risks to livelihoods can be mitigated through economic allocation, adaptive irrigation and agronomical practices, small-scale storage, and insurance mechanisms.
- Increased irrigation water use in upstream Ukraine, assuming a sevenfold increase in irrigated area in the Dniester basin, does not pose a significant water security risk. Risks and effects related to the management of the hydropower complex (daily flow releases) require further assessments.
- The reliability of irrigation water supply in hotspot catchments is sensitive to the magnitude of environmental flow requirements. Thus, allocations for environmental flows will need to be informed by a better understanding of ecosystem needs in hotspot catchments where trade-offs with irrigation water demand occur.

Table 4.2 Key Data and Ratios for the Baseline 2018 and Water Futures 2030

Description	Unit	Base 2018	BAU 2030	Scen 1 2030	Scen 2 2030
Population (including Transnistria)	million	3.14	2.96	2.97	3.04
Internal renewable water resources	m ³ /cap/y	694	735	734	717
Total renewable water resources (internal and external)	m ³ /cap/y	4,952	5,246	5,242	5,122
Withdrawal per capita (incl. Kuchurgan)	m ³ /cap/y	231	250	256	282
Consumption per capita	m ³ /cap/y	35	39	41	54
Withdrawal out of internal water resources (incl. Kuchurgan)	%	33	34	35	39
Withdrawal out of total water resources (incl. Kuchurgan)	%	5	5	5	6
Consumption out of total renewable water resources	%	0.7	0.7	0.8	1.1
Total water withdrawal (excl. Kuchurgan)	MCM/y	225	240	260	355
Total water withdrawal (incl. Kuchurgan)	MCM/y	725	740	760	855
Total ground water withdrawal	MCM/y	78	75	86	111
Total surface water withdrawal (excl. Kuchurgan)	MCM/y	147	165	174	245

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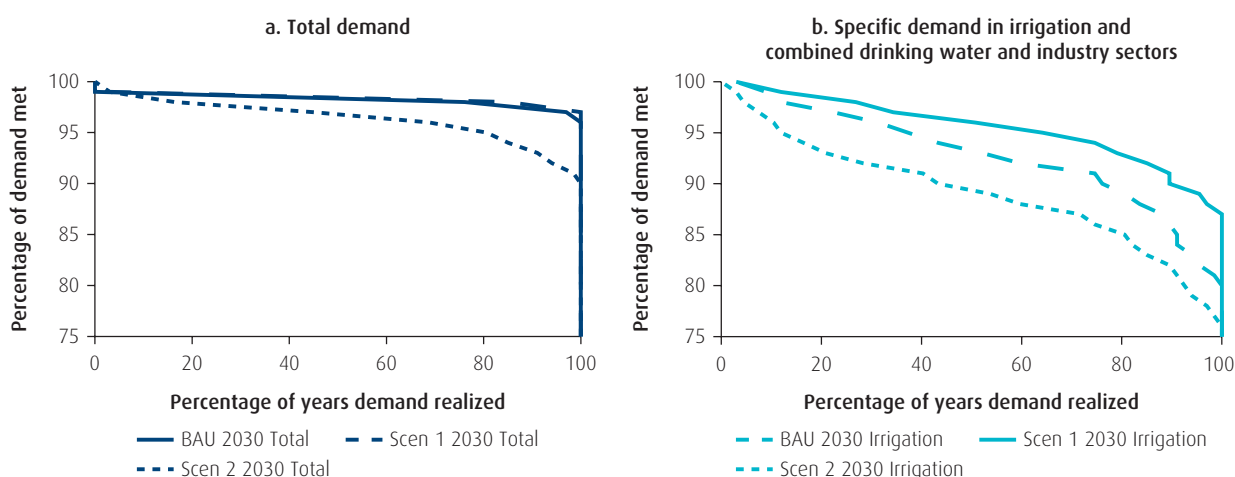
Table 4.2 continued

Description	Unit	Base 2018	BAU 2030	Scen 1 2030	Scen 2 2030
Total irrigation water withdrawal (surface water)	MCM/y	9	17	24	94
Total industry water withdrawal (surface and groundwater)	MCM/y	30	36	41	59
Total municipal water withdrawal (surface and groundwater)	MCM/y	129	131	137	145
Total thermal withdrawal (surface water) (excl. Kuchurgan)	MCM/y	57	57	57	57
Total water consumption (surface and groundwater)	MCM/y	110	114	121	165
Total surface water consumption	MCM/y	86	93	98	137
Total groundwater consumption	MCM/y	25	21	23	28
Unmet water demand	MCM/y	-3.5	-4.5	-4.3	-14

Source: Moldova WEAP data.

Note: The appendix provides elements of the water balance; environmental flow requirements are the same as in baseline 2018.

MCM = million cubic meters.

Figure 4.2 Reliability Curves for Three Scenarios

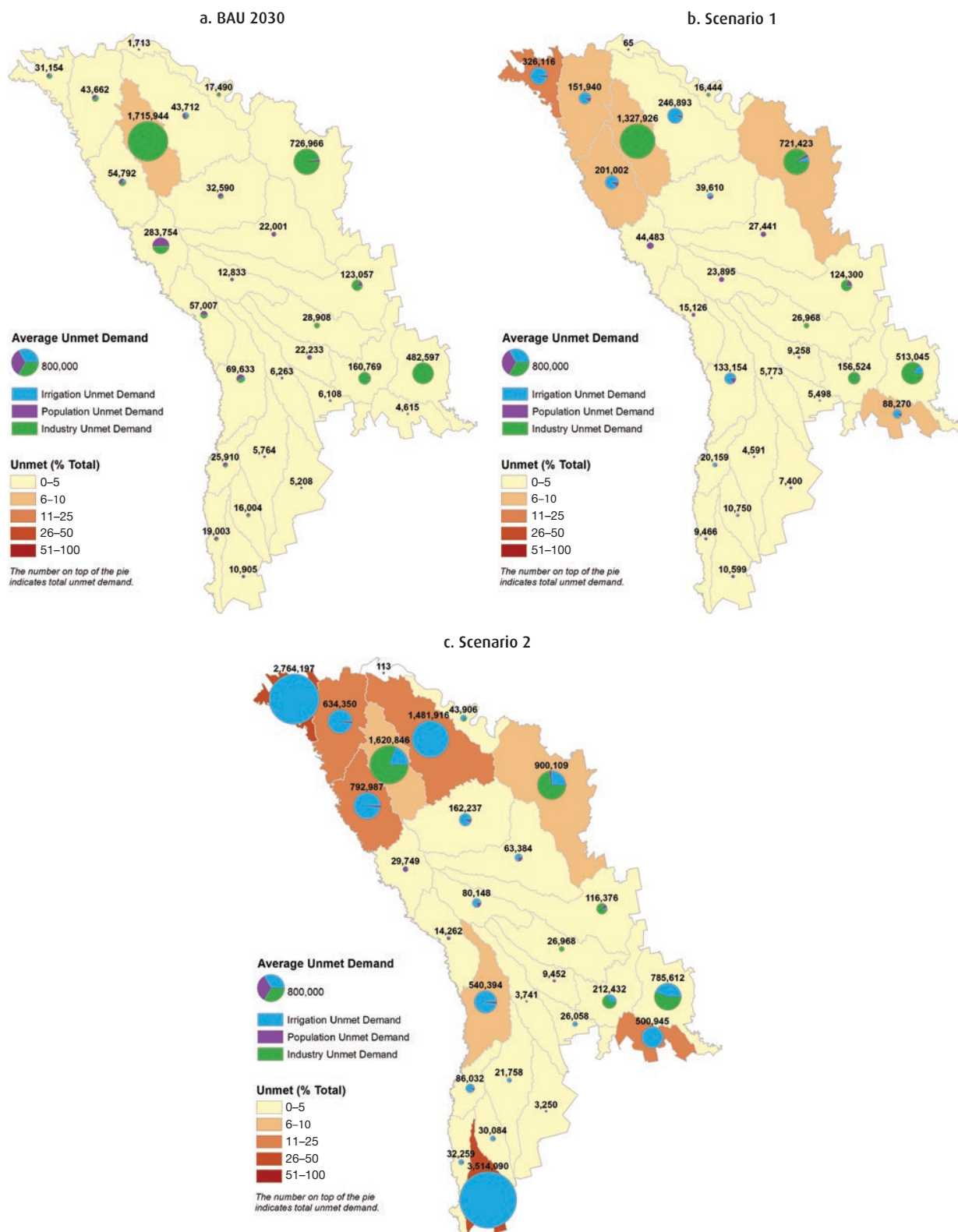
Source: Moldova WEAP data.

Note: BAU = business as usual.

The temporal aspects of shortages can be examined by looking at the reliability of the available water to meet demands. Temporal shortages may occur because of interannual and intra-annual variability in precipitation and temperature and can be illustrated by so-called reliability curves. Figure 4.2 (panel a) illustrates which share of the total demand at the national level is realized for which share of the simulated years⁵ and also include the same curves for irrigation demand.⁶ The Business-as-Usual (BAU) and the Urban and Industrial Development future (scenario 1) show similar patterns, with total demand realized for at least 96 percent in all modeled years, including in years with droughts. Under the Holistic Regional Development future (scenario 2), across all years, including the drier ones, at least 89 percent of the total demand can be realized.

Figure 4.2 (panel b) unpacks these results and shows that the decline in water reliability can largely be attributed to irrigation water shortages that are occurring in the growing season, with increasing severity for scenario 2 due to the large expansion of irrigated area. At the national level, in *all* years, including the drier ones, at least 75 percent of irrigation water demand can be met. Such an average masks the spatial dimensions of vulnerable hotspots as illustrated in map 4.1. For a 1-in-5-year drought,⁷ 93 percent of irrigation water demand can be met in the BAU scenario, and 85 percent of irrigation water demand can be met in scenario 2. Considering that irrigation in Moldova is supplemental,⁸ the effect of shortages is somewhat moderated. A further analysis at the catchment level is needed to understand the severity of irrigation water shortages, especially in scenario 2.

Map 4.1 Average Annual Unmet Demand per Catchment in Absolute and Relative Terms as of Total Demand



Source: Moldova WEAP data.

Note: Average unmet demand in cubic meters.

Moldova's water resources can largely meet developmental demands in all scenarios. In the Business-as-Usual and Urban and Industrial Development future, with modest irrigation

expansion of 13,726 and 20,476 hectares, respectively, shortages are limited. However, water scarcity hotspots intensify under the Holistic Regional Development future with an irrigation expansion to 62,235 hectares. Although shortages in drinking water and industry are negligible, demand could be optimized by curbing consumption, circular use activities, and leveraging rainwater for specific uses. Loss reduction measures in networks can reduce withdrawal although the net effect is limited because of the consequent reduction in return flows. Shortages in irrigation, although modest at a national scale, may have significant local effects in hotspots. This requires a targeted and well-managed expansion of subsidy schemes for small-scale private systems and further climate-proofing before investing in the rehabilitation of large, centralized systems. Efficiency measures, such as drip and sprinkler irrigation, and loss reduction for open conveyance channels, can help to reduce irrigation water demand locally and, to some extent, consumption by curbing nonproductive evaporation losses. Further analysis is needed to understand the effect of these measures, as well as seasonal storage options, at the catchment level.

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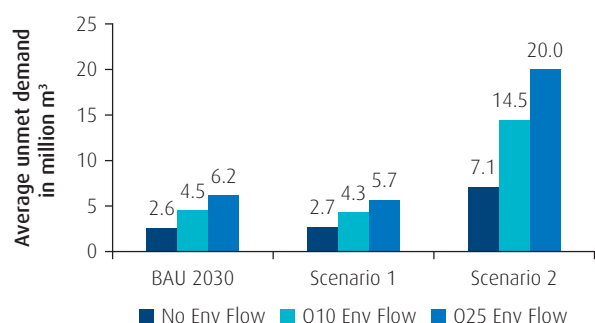
Stress Testing for Risks and Uncertainties

Water demand, availability, and the reliability of supply is influenced by various external risks, as well as uncertainties in the assumptions underpinning the water futures. Better understanding of the magnitude and potential effects of such risks and assumptions is key to inform robust decision making under uncertainty. This diagnostic uses a straightforward stress-testing approach for the following aspects that may affect water demand shortages, as well as reliability of supply, using two extreme scenarios, namely, the Business-as-Usual and the the Holistic Regional Development futures.

Environmental Flows

Figure 4.3 shows the magnitude of average unmet demand at the national level for three situations of assumed environmental flow, as described in the appendix. Although keeping the downstream outflow for the Dniester at a minimum flow of 80 cubic meters per second¹⁰ in all cases, the environmental flow requirements for internal catchments and the outflow of the Prut are changed as follows: (1) no environmental flow requirements, (2) a Q10 environmental flow requirements (the regular model), and (3) an increase to the Q25 environmental flow requirement. In the latter

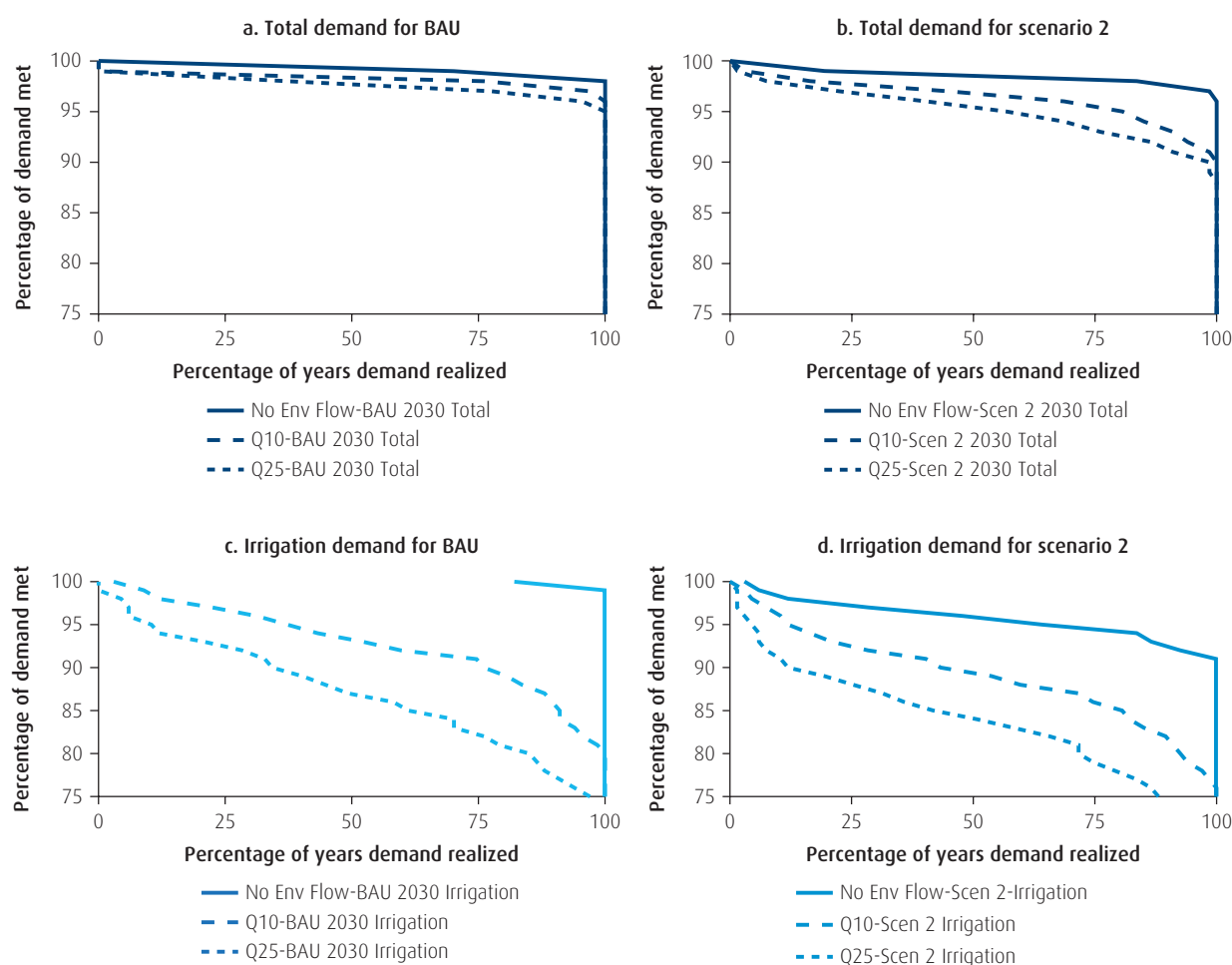
Figure 4.3 Average Annual Unmet Demand for Different Water Futures and for Different Levels of Environmental Flow



Source: Moldova WEAP data.
Note: BAU = Business as Usual.

scenario, the total water resources that are reserved for environmental flow increase from 4.2 billion cubic meters annually to 5.7 billion cubic meters annually, over a third of Moldova's total renewable water resources. Although technical assessments are lacking to determine environmental flow requirements at the catchment level or for ecologically important stretches on the rivers, figure 4.4 illustrates that the magnitude of the overall water shortage is sensitive to the level of environmental flow. Specifically, the trade-offs in reserving water for irrigation or for the environment become apparent in scenario 2 because of the large irrigation expansion. The reliability curves for the BAU and scenario 2 for total and for irrigation water demand illustrates this trade-off (figure 4.4).

Figure 4.4 Sensitivity Analysis for Environmental Flows: Reliability of Water Supply



Source: Moldova WEAP data.
Note: BAU = business as usual.

For the Q25 environmental flow requirements, the reliability to meet total water demand only slightly decreases, and even in scenario 2, at least 88 percent of total demand can be met in all years (figure 4.4, panels a and b). The reliability curves for irrigation demand show higher sensitivity. Under scenario 2, for a 1-in-5-year drought,¹¹ only approximately three-quarters of irrigation water demand can be realized with a Q25 environmental flow allocation, but if this requirement is fully relaxed, 95 percent of demand can be realized. For the Business-as-Usual scenario, irrigation water shortages occurring during a 1-in-5-year drought are approximately 20 percent of total irrigation demand while ensuring a Q25 environmental flow. Hence, further research and assessments are recommended to establish more accurate estimates of environmental flow requirements across Moldova's catchments.

Climate Change Effect

To explore uncertainties surrounding the effects of climate change on demand, supply, and resulting water shortages and reliability, additional climate change scenarios were explored. Although there are many climate models and scenarios available, two extremes for a possible climate in 2050 are chosen. These two future climatic conditions represent the range of uncertainty¹² that Moldova faces in terms of annual run-off patterns within the country and its upstream basins (figure 4.5).

Moderate-impact wet: This scenario, based on the EC-EARTH model, represents a slightly lower annual runoff, 92 percent compared with the current climate, and a wetter growing season (120 percent runoff compared with current climate).

High-impact dry: This scenario, based on the GFDL-CM3 model, represents an overall drier future, with 54 percent of the average annual runoff compared with the current climate, and only 59 percent of the runoff in the growing season.

The climate scenarios not only affect supply but also demand.¹³ Total crop water requirements are higher under a warming climate and the extent by which crop water requirements can be met through rainfall will also be lower on average for a drier climate. Under current climatic conditions, approximately 42-44 percent of crop water requirements relies on irrigation, whereas under the dry climate scenario, this share increases to 55-57 percent.¹⁴ For each of the water futures, a different future climate has a substantial effect on the total irrigation water demand,¹⁵ as can be seen in figure 4.6.

The total irrigation demand under a moderate climate impact does not change significantly compared with the irrigation water demand under the current climate. However, under a drier future climate, irrigation demand under the Holistic Regional Development future will increase from 99 to 142 million cubic meters per year, or a 50 percent increase.

Figure 4.7 illustrates how at the national level the various climate change projections are affecting the average annual water shortages for total demand and irrigation water demand (in relative terms).¹⁶ As expected, the irrigation sector is most vulnerable to shortages with a warmer and drier climate.

Under the Holistic Regional Development scenario, an average annual shortage of 18 percent occurs under

Figure 4.5 Change in Average Runoff for Different Climate Scenarios Compared with Current Climate

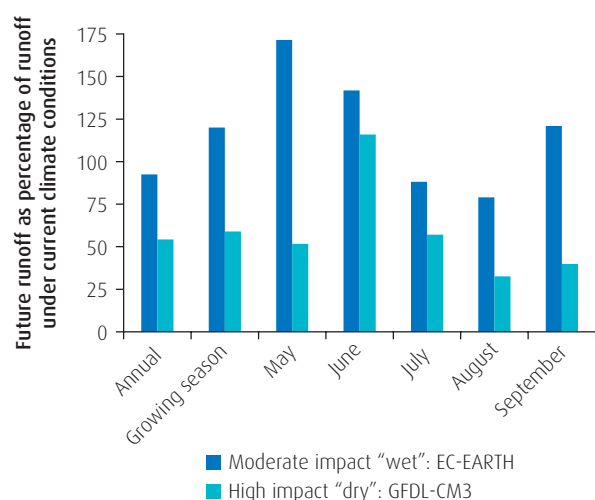
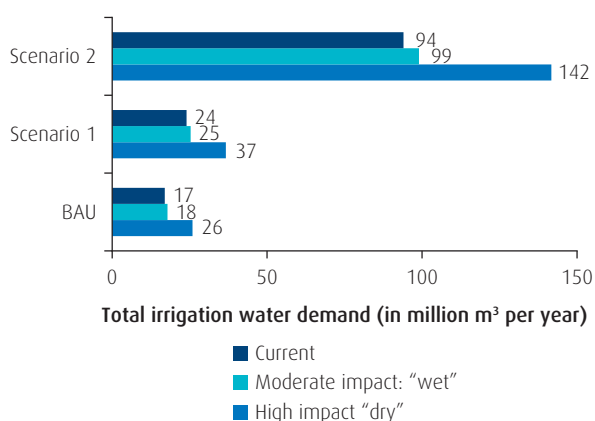
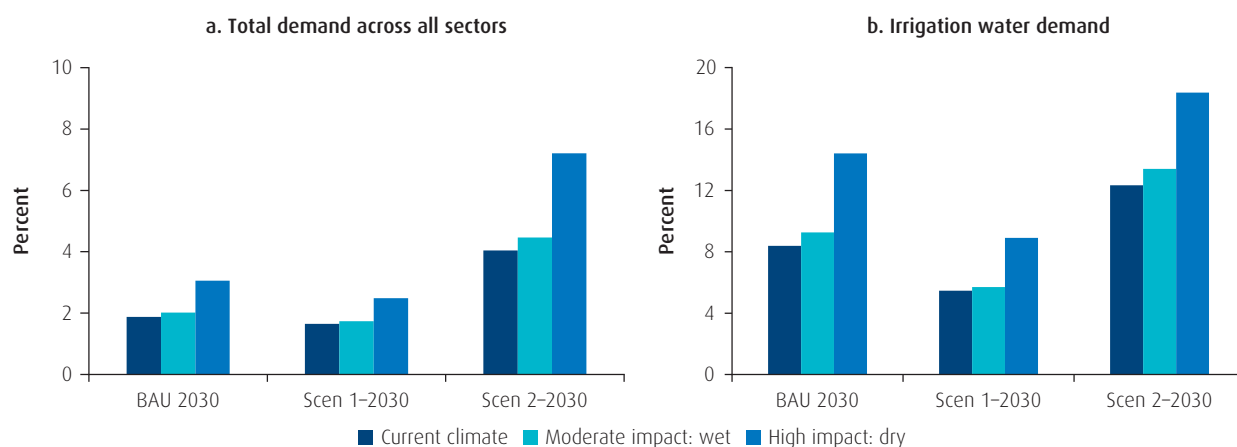


Figure 4.6 Change in irrigation Water Demand for Different Climate Scenarios Compared with Current Climate



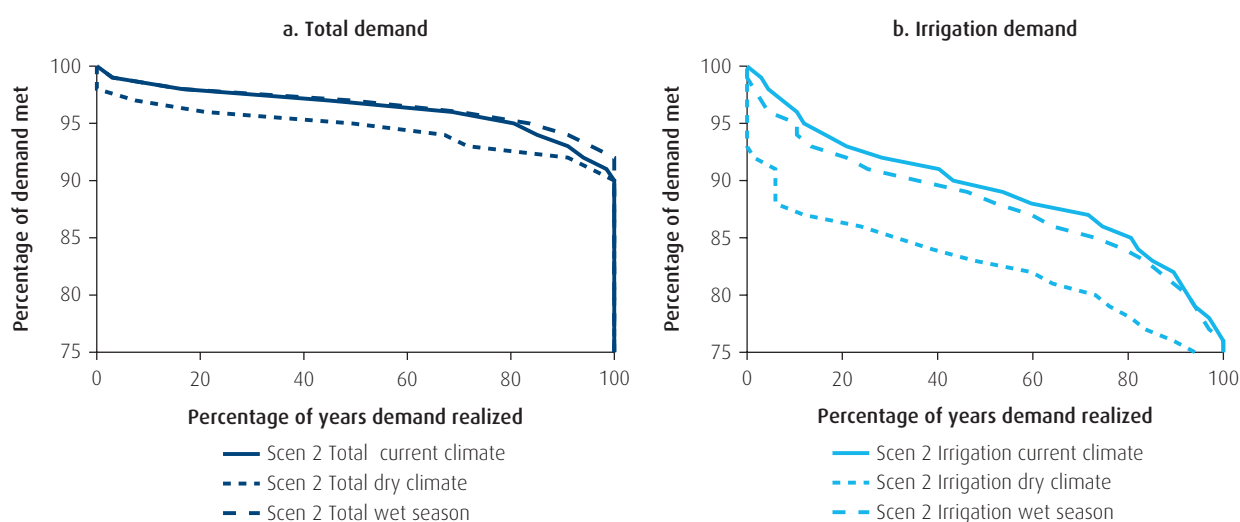
Source: Moldova WEAP data.
Note: BAU = business as usual.

Figure 4.7 Average Annual Unmet Demand as a Share of Total Demand under Different Climate Projections



Source: Moldova WEAP data.

Figure 4.8 Sensitivity Analysis for Holistic Regional Development for Possible Climate Futures



Source: Moldova WEAP data.

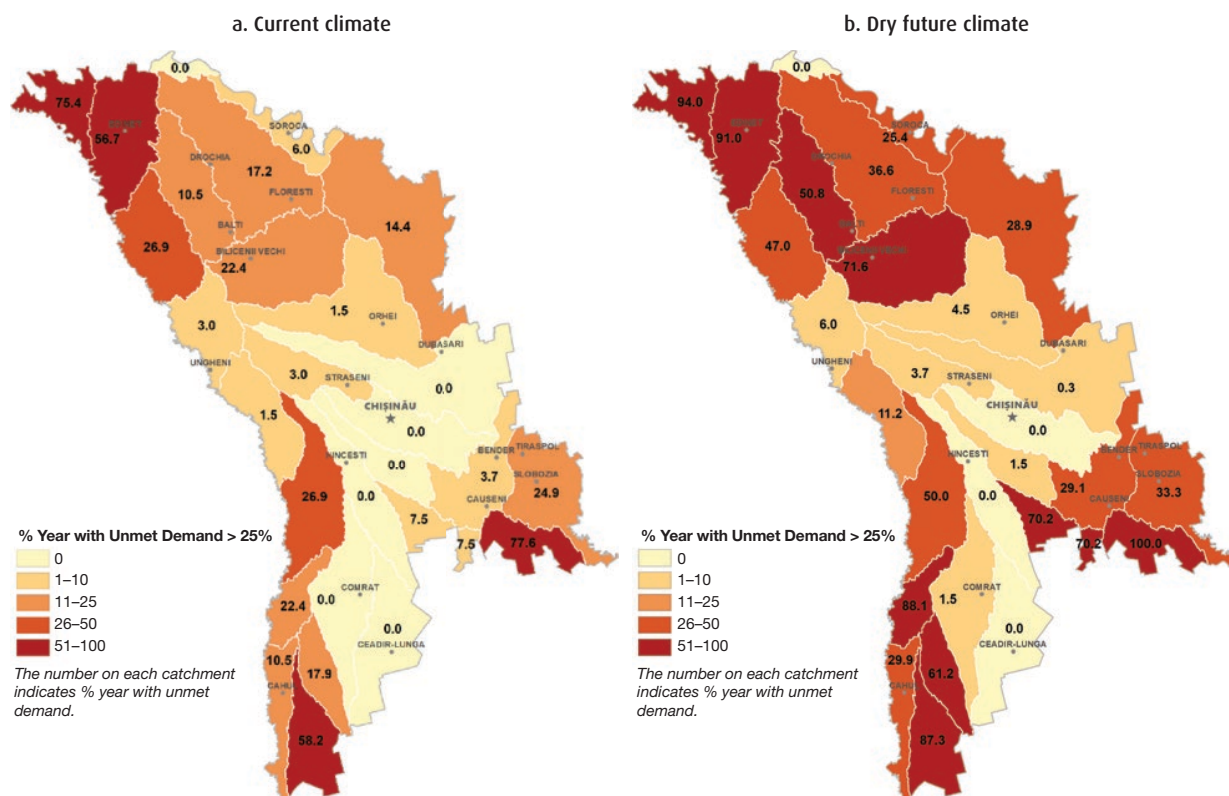
the high-impact dry climate, a 50 percent increase compared with the 12 percent under the current climate.

Figure 4.8 zooms in on the Holistic Regional Development future because this is the most challenged in terms of the reliability of supply for total and irrigation water demand under different climate scenarios. The reliability of the total water demand remains acceptable even under the dry climate future, with more than 90 percent of total demand met in a 1-in-5-year drought. However, when unpacking the total demand, severe constraints arise for the reliability to meet irrigation water demand due to reduced rainfall in the growing season. There are no

years in which 100 percent of irrigation demand is met and in a 1-in-5-year drought only 77 percent of irrigation water demand is met, compared with 85 percent under current climate conditions. This effect is amplified in more extreme drought years.

In terms of spatial variability, it is expected that water shortages will be more pronounced under a future drier climate in the already vulnerable catchments or hotspots. Map 4.3 illustrates this increased vulnerability of irrigated agriculture for the Holistic Regional Development scenario, visually comparing the reliability of supply under current climate conditions (panel a) with a drier future climate under the high-impact

Map 4.3 Scenario 2: Reliability of Irrigation Water Supply across Catchments (Expressed as Percentage of Years with Less Than 75 Percent of Irrigation Demand Met)



Source: Moldova WEAP data.

climate model (panel b).¹⁷ The number of hotspot catchments in red has increased, illustrating those basins in which a shortage of at least 25 percent of irrigation water demand will occur at least once every other year. Similar levels of shortages in irrigation water will now occur in most parts of the country at least once every 10 years.

This analysis again emphasizes the importance to further climate-proof investments, so that expansion of schemes will be prioritized in those catchments for which expected shortages remain manageable. This holds for both the rehabilitation of large centralized irrigation systems, as well as programs that stimulate private investments in small-scale systems. Such analysis would need to consider effects on yields and economic outcomes and consider the economics of developing small-scale storage to mitigate drought risks.

It should be emphasized that unmet demand is a typical phenomenon in irrigation systems. Addressing this through infrastructure investments, for example, through complementary storage or conveyance solutions may be appropriate. However, this requires further modeling and cost-benefit analysis to establish

the business case, which will also depend on the extent of high-value cultivation versus commodity crops under irrigation. Although infrastructure can improve resilience, so can markets and other economic instruments. What matters equally is to equip water managers and farmers with the necessary knowledge, information systems, incentives (e.g., water use fees) and tools to allocate water to the usage and crops with the highest value. Farmers also need to gain the capabilities to use adaptive agronomical and irrigation practices to optimize yield under water constraint conditions. Flanking this with complementary economic mitigation strategies will be necessary to reduce shocks to rural livelihoods and thus for the economy at large. At the same time, the envisaged accelerated stimulation of private sector investments in small-scale irrigation needs to be accompanied with state-of-the-art water management practices to mitigate water security risks.

Because a future drier climate will disproportionately affect rainfed farming, adaptive strategies will be even more important for resilient rural livelihoods. This could among others entail implementing weather-indexed insurance

mechanisms and conservation agriculture, as well as allowing supplemental irrigation from deeper groundwater. The latter would need to be accompanied with strong water permitting and enforcement systems, combined with water quality and soil risk analysis to avoid permanent degradation of agricultural land.

Increased Water Demand in Ukraine and Transnistria

To stress test to what extent external demands, resulting from economic development may affect water shortages within the country, two simple stress tests were carried under current climatic conditions, namely: (1) increasing upstream irrigation water use in Ukraine in the Dniester basin, and (2) increasing demand in Transnistria (the left bank of Dniester). Because of data limitations these stress tests provide an indicative level of effect on downstream water availability in Moldova.¹⁸

For Ukraine, the irrigated area is expanded from the current estimated 14,200 to 106,800 hectares in 2030¹⁹ in the upstream basin. Given the large volume of the Dniester flow, this has marginally reduced the average annual surface water inflow into the country, resulting in a negligible increase of the level of unmet demand (from 3.9 to 4 percent in scenario 2, or only 0.4 million cubic meters per year). This underscores how low withdrawals are relative to the large water availability stemming from the Dniester inflow. For Transnistria, water withdrawal is increased by 30 percent across all sectors,²⁰ increasing total water demand with 5 percent. Figure 4.9 illustrates that the simulated development trajectories in Ukraine and Transnistria have no

significant effect on unmet demand in Moldova and will not likely pose a water security risk.

There may be other water security risks in Ukraine that have not been explored in this diagnostic, such as deforestation in watersheds or hydropower development that could potentially affect flow regime. An assessment of the potential effects of the hydropower complex development in Ukraine could not be simulated using the monthly timescales of the WEAP model and is conducted under a separate study by UNDP, as well as available from UNDP, OSCE, and UNECE (2019).

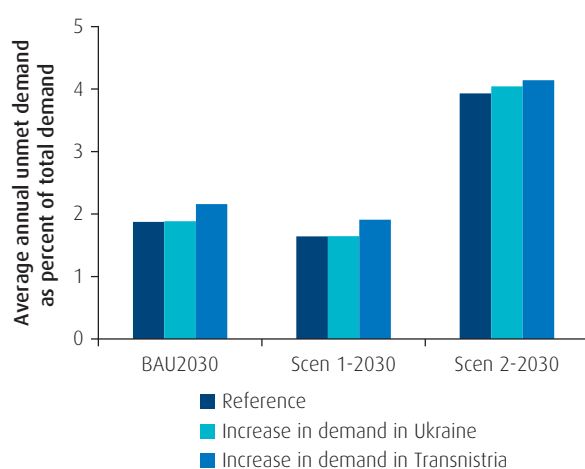
Summary

Concluding, the three analyzed water futures present development trajectories, with alternative socioeconomic and demographic changes, investment measures and policy choices, and increasing water demand. The water balance assessment shows that on average physical water constraints remain modest, even for the most aspirational Holistic Regional Development scenario. Water security risks occur during 1-in-5-year droughts, with compromised reliability of supply, specifically in the growing season, in several hotspot catchments along the upper and middle Prut, the upper Dniester, and in the south of the country.

Climate change remains the most important external risk to Moldova's water security. A future drier and warmer climate for Moldova, under an expanded irrigation development scenario, will result in an expansion of hotspot basins covering large parts of the country along the Prut and Dniester. Although climate change will reduce the reliability of supply for the irrigated agriculture sector, the economic benefits of well-targeted irrigation investments can deliver positive economic outcomes under high-value cultivation. A range of measures should be pursued, such as economic allocations to higher-value uses, adaptive irrigation and agronomical practices, water reuse, and demand management measures in municipal, industrial, and irrigation sectors. Complementary risk mitigation strategies, such as seasonal storage, could also be harnessed to manage risks to livelihoods and the economy.

In the future, requirements for environmental flows will need to be determined based on ecosystems needs, starting with the hotspot catchments in which irrigation expansion is foreseen and trade-offs between environmental and irrigation water demand occur, such as along the upper and middle Prut, the upper Dniester, and the southeastern and southwestern tip of the country.

Figure 4.9 Changes in Unmet Demand Resulting from External Demand Changes in Ukraine and Transnistria under Current Climate



Source: Moldova WEAP data.

Economic Outlook of Water Futures

Unlocking benefits for the different water futures requires strategic planning and financing as benefits largely result from the government's ability to invest in infrastructure for water security. To understand the kinds of benefits and costs associated with the three water futures, and across the sectoral investment components, a cost-benefit analysis (CBA)²¹ was performed. The analysis sheds light on the financing and support required from the government to unlock the benefits, highlights the need for investment prioritization, and discusses key challenges. Three

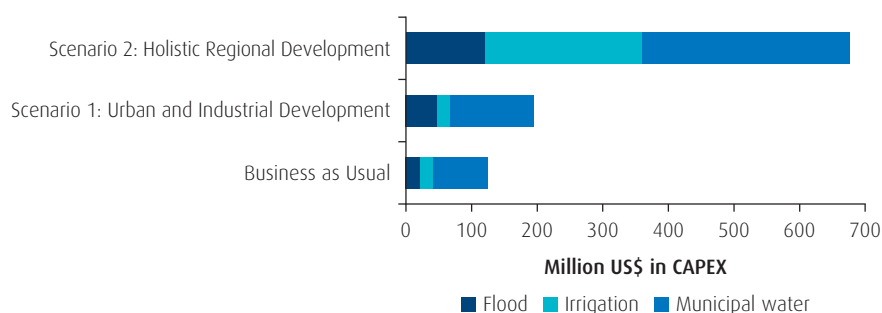
sectoral investment streams are considered, namely, for irrigated agriculture, for municipal water supply²² serving households and industry, and for increasing flood resilience.²³

Key findings from the economic assessment indicate that investing in water security yields high benefit-cost ratios across scenarios, but requires increasingly demanding up-front costs. The total investments for each of the stylized water futures range from US\$125 million for BAU 2030 to US\$676 million in the Holistic Regional Development future (figure 4.10).²⁴ This excludes equally necessary and very costly

Key Messages on Future Economic Outlook

- Physical water resources endowments are not a binding constraint. Unlocking benefits for the water futures requires strategic planning and financing as benefits largely result from the government's ability to invest in a range of water-related infrastructure measures.
- Investing in water security yields high benefit-cost ratios across scenarios and sectoral investments (urban and rural water supply, irrigation, floods). With high upfront financing needs, prioritization remains political and shaped by external developments.
- The COVID-19 pandemic, economic recession, and another drought in 2020 highlight the necessity to invest in water supply services, as well as irrigated agriculture to support future jobs, economic recovery, food security, and health outcomes.
- In a business-as-usual future with low levels of investments in all sectors, only marginal net positive outcomes are delivered. Benefits to society and the economy increase if more financing is made available for rural water supply expansion, irrigation development, and flood protection.
- Within the irrigated agriculture sector, the analysis shows that a first-order priority is to focus on economic usage of the already rehabilitated irrigation systems. Second and third priorities are enabling the expansion of private small-scale, high-value irrigation schemes, and, respectively, public investments in rehabilitating larger central irrigation systems in a cost-effective manner.
- To unlock benefits from investments in irrigation, complementary policy measures are necessary to ensure that irrigation services are fully used and intended economic outcomes are achieved. These include facilitating land consolidation, access to finance, and advisory services.

Figure 4.10 Investments under the Three Water Futures



investments in sanitation and wastewater that were not included.

Moldova is constrained by its financial ability to drive these investments, indicating that the choice of investments should be prioritized based on expected costs and benefits realized. As such, the CBA investigates whether there is economic justification across the proposed water futures. Economic benefits have been quantified to the extent possible for water supply, but likely bring an array of more difficult to quantify social benefits.²⁵ Irrigation benefits are derived from a complex analysis considering different irrigation typologies, changes in cropping patterns, yield differences in rainfed and irrigated yields, and marginal benefits from switching from low- to high-value crops.

With high up-front financing needs, this prioritization is also shaped by a political process and external developments. The COVID-19 pandemic, economic recession, and the drought in 2020 highlight the necessity to invest in water supply services for infection prevention and control and to ensure productivity of people and businesses. Investments in modernization of irrigated agriculture will be able to support future jobs, economic recovery, food security, and livelihoods.

Figure 4.11 illustrates that in the Business-as-Usual future only marginal net positive outcomes are delivered, because investment levels remain low in agriculture, flood protection, and municipal water supply. In this situation, Moldova remains in a low-level equilibrium in which investments are insufficient to unlock benefits to people, businesses, and the economy. As Moldova moves to more ambitious water futures with higher investments, the economic benefits increase. However, the annualized costs for the Holistic Regional Development

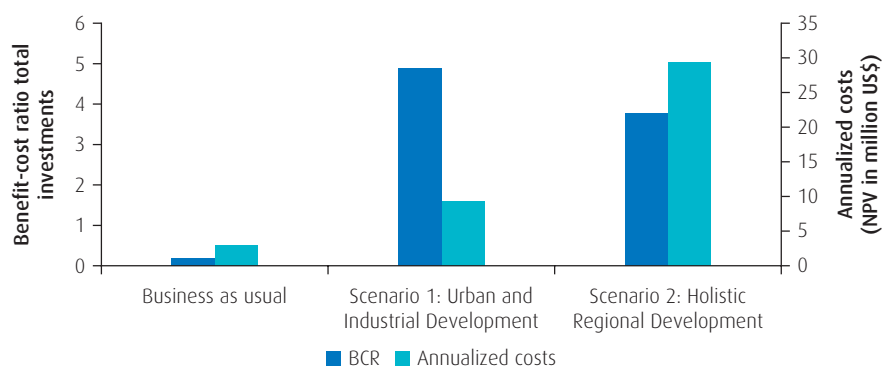
future require significantly larger flows of capital per year, driven by the combination of significant water supply investments in rural areas and aggressive investments in rehabilitation and expansion of centralized irrigation schemes. In the face of the fiscal impacts of the COVID-19 crisis, the need to prioritize investments is even more pressing. Therefore, a mix of scenario 1 and 2 may be a good place for Moldova to reap water security benefits, social benefits, and generate jobs within a more realistic financial framework.

Zooming in on net benefits from water supply investments, annualized costs are the highest when connecting the unconnected under the Holistic Regional Development scenario, albeit with a slightly lower benefit-cost ratio (BCR). Nevertheless, these investments are well justified by social benefits, arising from better living conditions in rural areas, stabilizing the rural hinterland and addressing long-standing inequalities that undermine social cohesion (figure 4.12).

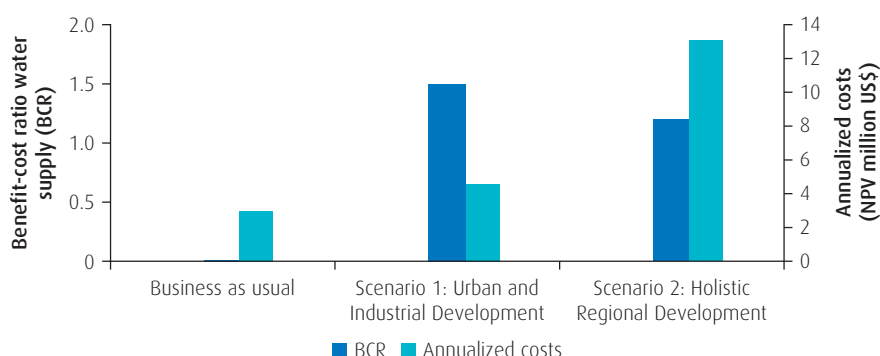
Zooming in on irrigated agriculture, the CBA analysis shows that the expected benefits from irrigation do not accrue evenly across the different typologies of irrigation schemes that have been modeled, for a low- and high-price scenario (see the appendix). Figure 4.13 illustrates that a first-order priority is to focus on an optimal economic usage of the already rehabilitated irrigation systems (a sunk investment cost).²⁶

Although WUA membership and irrigated area is gradually expanding, continued measures are needed to expand areas under drip and sprinkler systems and to shift to higher-value cultivation. Enabling conditions, such as facilitating land consolidation, access to finance, and advisory services also need to be put in place.

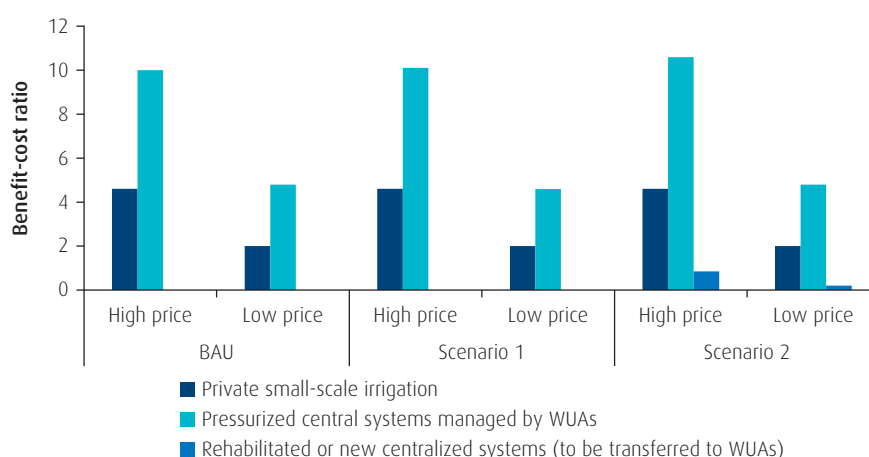
Figure 4.11 Benefit-Cost Ratio and Annualized Costs for Water Futures



Note: BCR = benefit-cost ratio; NPV = net present value.

Figure 4.12 Benefit-Cost Ratio and Annualized Costs for Drinking Water Supply Investments

Note: BCR = benefit-cost ratio.

Figure 4.13 Benefit-Cost Ratio for Irrigation Investments under Three Typologies for Different Price Assumptions

Note: BAU = business as usual; BCR = benefit-cost ratio; WUA = water user associations.

Figure 4.13 also shows that second and third priorities are enabling the expansion of private small-scale, high-value irrigation schemes and public investments in rehabilitating larger central irrigation systems in a cost-effective manner. Across all water futures private, small-scale irrigation is expected to expand, with significant benefits due the focus on high-value crops in such farmer-led systems (orchards, vegetables). Benefits to private farms outweigh cost by over four times in a high-price scenario, and are double in a low-cost scenario; they also provide resilience benefits because of the ability of drip systems to deliver precision agriculture.

Moreover, with the increasing effect of climate change on water reliability and yields, the indirect economic and social benefits from expanding central irrigation systems on food security and the resilience of rural livelihoods need to be considered. To ensure that irrigation services are fully used by farmers and that intended economic benefits are achieved, complementary policy measures are needed.

Chapter 5 elaborates these dimensions and provides recommendations in this regard.

Notes

- Such as improving farming practices during growing season and harvest; improving postharvest handling and infrastructure; improving the flow of market information and improving ability of producers and processors to meet export standards.
- Such as Regional Development Plans, Flood Master Plans, data on irrigated areas from Apele Moldovei, data on irrigation subsidies from the Agency for Interventions and Payments in Agriculture (AIPA), as well as data provided by the Sustainable Development Account. Stakeholder consultation took place to inform the futures.
- Excluding Kuchurgan nonconsumptive demand.
- This assumes that all existing central schemes assessed as feasible for rehabilitation are brought back in function, as per Intexnauta (2018). Appendix A provides the overview of the area brought back under irrigation for the various scenarios.

5. Modeled period 1950–2016, with monthly timesteps.
6. Thermal cooling demand does not show any shortages across all scenarios (largely nonconsumptive) and reliability of combined drinking water and industrial demand is also high.
7. A one-in-five year drought means that in 20 percent of simulated years demand is not met and in 80 percent of years demand is met.
8. Under current climatic conditions, on average crop water requirements per hectare of crop mix are met for 44 percent through supplemental irrigation water and for 56 percent through precipitation. To assess the effect on crop yield, more detailed crop-water modeling is needed to assess the yield effect in dry years.
9. Appendix A provides details of crop water requirements and irrigation areas per catchment for all scenarios.
10. The minimum flow for the downstream outflow for the Dniester is characterized as a monthly Q5 of 80 cubic meters per second, based on reporting in OSCE and UNECE (2005). No comparable value is available for the Prut. Appendix A provides further details.
11. Meaning in less than 20 percent of the simulated years.
12. Both climate models are based on the Representative Concentration Pathway 8.5 scenarios over the decade 2046–55. RCP 8.5 is characterized by high greenhouse gas concentration levels.
13. Although a warming climate may affect demand for thermal cooling, as well as evaporation rates from cooling reservoirs, such assessment was beyond the scope of the diagnostics. Except for irrigation, all other demands were kept constant.
14. Under the moderate-impact wet climate scenario, there is no significant change and the relative share of irrigation to meet all crop water requirements remains 42–44 percent on average.
15. Total irrigation demand is based on net crop water requirements for each catchment, multiplied with losses that are assumed to occur under the various irrigation typologies (see appendix A).
16. When calculating the relative share of the shortage, total demand is calculated without the 500 million cubic meters per year diversion at Kuchurgan.
17. The future moderate-impact wet climate scenario does not show considerable differences with the current climate because of a wetter growing season.
18. If more data become available, the WEAP model can be refined and more realistic scenarios can be investigated. The stress tests are meant to be illustrative of the magnitude of potential effects.
19. This is within four provinces within the Dniester basin, based on estimates derived from <http://www.fao.org/nr/water/aquastat/irrigationmap/UKR/UKR-gmia.pdf>.
20. Six catchments were split into two subcatchments to model independent water demand projections for Transnistria. Demand projections in the reference case already were estimated on the higher end.
21. A cost-benefit analysis assesses whether an investment will result in a net positive effect on society. It quantifies the positive effects and compares these to the associated costs to provide an economic justification for the intervention, expressed through a positive benefit-cost ratio.
22. These estimates are modest as they do not consider urgent rehabilitation needs of the drinking water system to ensure adequate service levels and solely focus on expansion of access. Moreover, no investments in sanitation, and wastewater collection and treatment were modeled, which tend to be much more expensive as compared with drinking water supply.
23. Although flood measures could not be modeled in the water balance assessment, they were included in the economic analysis building in EIB (2016).
24. Appendix A elaborates on the methodology and results in more detail.
25. Benefits are derived from health benefits from moving up the service ladder to piped household water connections and time savings related to rural water collection. It is estimated that a third of unconnected rural households spend 30 minutes or more per day gathering water. Intangible benefits such living comfort and long-term effects on learning and adult earnings are not included, or benefits to businesses derived from reliable supply.
26. Funded through the Millennium Challenge Corporation, now the Sustainable Development Account. Investment costs in irrigation and drainage are assumed as sunk costs.

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CHAPTER 5

Barriers to Sector Performance and Way Forward

Moldova's water endowments are not a binding constraint to development, both currently and in the future, as evidenced in the previous chapters. A water secure future depends on infrastructure investments, management, and institutions rather than on water availability. This chapter aims to assess water sector performance in terms of the management of water resources and water-related risks and the delivery of water-related services. It unpacks how sector architecture, governance, finance, institutions, information systems, as well as infrastructure and service provision support or constrain performance. It concludes with a set of recommendations for three crucial dimensions for water security in Moldova: (1) water resource management and resilience, (2) water supply and sanitation services, and (3) irrigated agriculture.¹

Sector Architecture, Governance, and Financing

Institutional Landscape

Several institutions are involved in Moldova's water sector, and although Moldova has progressed in implementing several critical administrative reforms, fundamental gaps remain in the overall water sector architecture that significantly affect its performance. There remains a lack of clarity in institutional roles, missing functions in some core sector agencies, as

well as uncoordinated infrastructure planning and implementation. It is expected that further reforms to the sector and the elaboration of a normal water supply and sanitation (WSS), as well as an irrigation development plan, will bring institutional change and help mobilize resources leading to better service delivery outcomes for end users.

National Level

At the national level, the Ministry of Agriculture, Regional Development and Environment (MARDE) is the central public institution responsible for the development of the national policy, legal, and regulatory framework and the implementation of policy documents, and planning of investments in the sector. MARDE was formed in 2017 through the merger of the Ministry of Construction and Regional Development, the Ministry of Agriculture, and the Ministry of Environment, bringing the previously fragmented mandates of water resource management, WSS and irrigation services, and environmental policy under one institutional home. MARDE is responsible for the development of the legal and regulatory framework for the use of natural resources, including management of waste, water resources management, and the provision of WSS services.

MARDE has several subordinate agencies. Among them is the Environmental Agency, created in 2018, responsible for the issuance of water extraction

Key Messages on Governance and Financing

- Moldova has a comprehensive legal framework in the water sector that has transposed legislation in line with the European Union's Water Framework Directive.
- However, ambiguities and shortcomings in the legislative framework continue to exist, such as on the status of basin committees and basin-level administrations.
- Hundreds of small WSS providers operate without regulation, national oversight, and technical support, risking the sustainability of public investments in rural water systems.
- Reform efforts across the sector have progressed, such as the creation of the Environmental Inspectorate and Environmental Agency under MARDE. The reform of Apele Moldovei is a priority to reduce the fiscal burden stemming from subsidies to its subordinate irrigation enterprises and to operationalize basin-level water resource management.
- Financing for water security is inadequate. Capital investments in water supply and wastewater are biased to urban areas. Investments in irrigation, water resource management (WRM), and flood protection have been extremely modest. Lack of strategic planning and a financing strategy underpins shortcomings.
- On-budget expenditures are far below the required needs to meet SDG target 6 on water, sanitation, and hygiene. They were 0.5 percent of gross domestic product (GDP) and 1.4 percent of government expenditure in 2017, below the international benchmark of 5 percent of government budget. Two-thirds of sector expenditures came from development partner resources in 2017.
- National domestic funding for water supply and sanitation has not yet been consolidated in a coherent national program. The National Ecological Fund (NEF) and National Regional Development Fund are the two most important domestic channels, the latter implemented through competent regional development authorities.
- Poor performance, lack of result orientation, and major transparency and governance issues hamper the effectiveness of NEF resources. It remains the most important funding source for rural local governments with low access, although outcome monitoring fails.

Way Forward

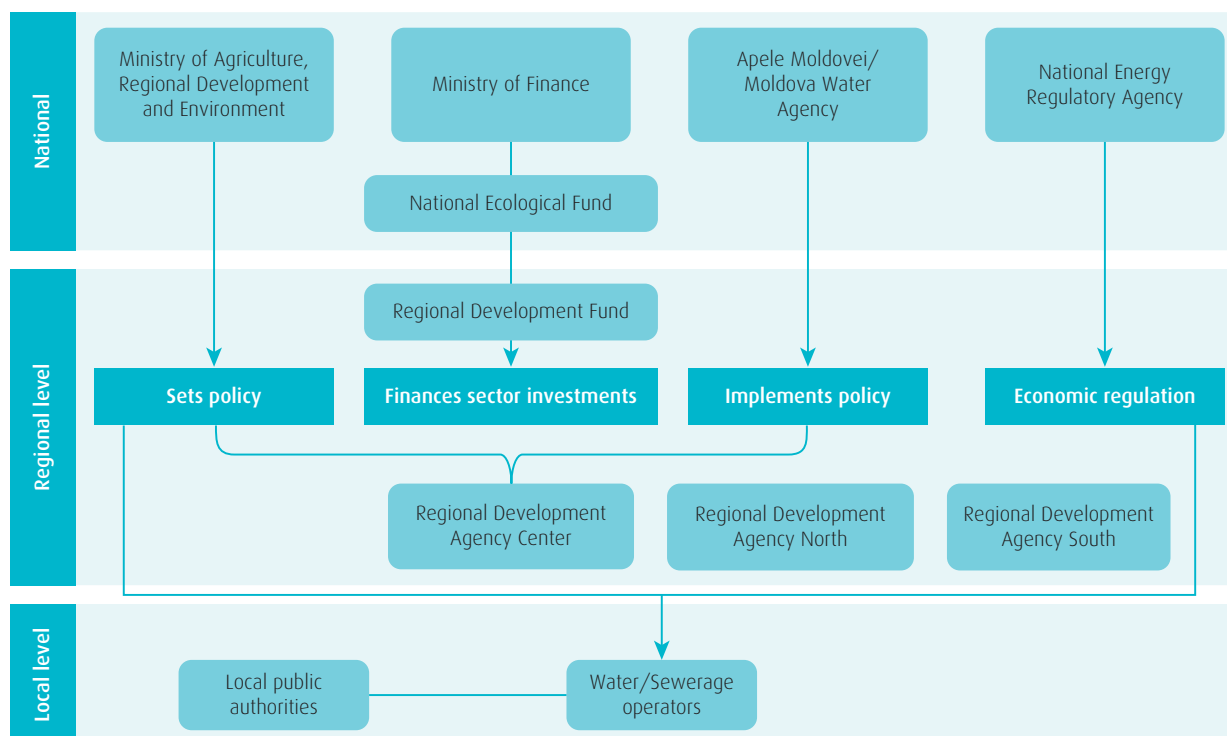
- Funding for rural water supply and small-town sanitation, irrigation, WRM, and flood protection should be increased; this requires a strategic financing approach, leveraging higher tariff and fee contributions and targeting capital subsidies to the underserved and public goods.
- Pending reform efforts require completion, as Apele Moldovei's reform, and further legislative changes are needed, specifically for integrated water resource management.
- An inclusive national WSS investment program should be established, consolidating funding streams under a dedicated WSS development entity, strengthening so-called missing functions that hinder performance. Such a plan and financing strategy could help address the urban bias in capital subsidies and refocus investments to small towns and rural areas, with tailored solutions.

permits, setting of pollution standards, and the monitoring of surface and groundwater quality. These responsibilities were formerly dispersed among five institutions (the State Hydrometeorology Service, the State Environmental Inspectorate, Apele Moldovei, the forestry agency Moldsilva, and the Agency for Geology and Mineral Resources). The Inspectorate for Environmental Protection provides support functions to the ministry, taking over responsibilities that were formerly fragmented. However, reforms for other subordinate entities of MARDE did not yet proceed, among others Apele Moldovei, Hydrometeorological Services, and the Agency for Geology and Mineral Resources.²

The National Energy Regulatory Authority (ANRE) is responsible for licensing operators and tariff regulation of drinking water and wastewater services, along with the regulation of other public utilities, such as electricity, gas, and petroleum. Water quality compliance for drinking water is monitored by the National Institute for Public Health. Figure 5.1 illustrates a simplified institutional landscape for WSS services.

Apele Moldovei, Moldova's Water Agency, subordinate to MARDE, is responsible for implementing the country's water policy. Apele Moldovei, despite its stated mandate, has a limited role in WSS, other than as the owner of some

Figure 5.1 Overview of Water Supply and Sanitation Sector Institutions



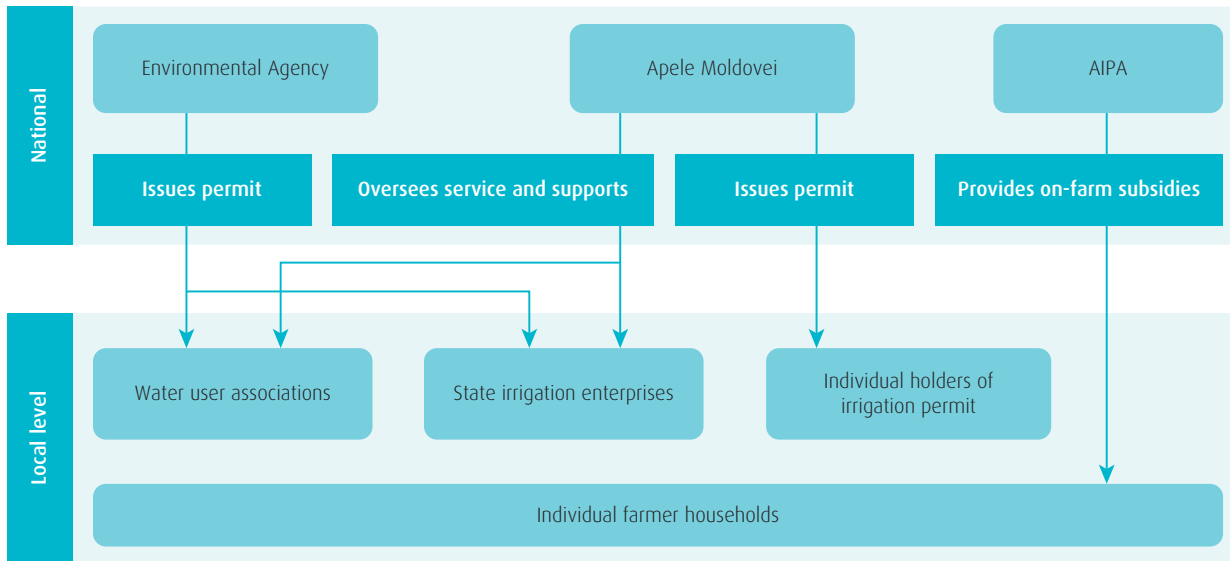
hydraulic infrastructure (water supply transfer pipes). The agency's structure, role, and responsibility are currently under review although the planned reform has stalled. Apele Moldovei is mandated to oversee and support irrigation services delivery by water user associations (WUAs), as well as through its loss-making state irrigation enterprises. Operational arrangements for management at the basin level are unclear because of the pending reform of Apele Moldovei. Apele Moldovei also issues permits for special water use for private irrigators outside of large systems. Irrigators in all areas can benefit from state subsidies for on-farm irrigation equipment and other measures, delivered through the Agency for Interventions and Payments in Agriculture (AIPA), also subordinate to MARDE. Figure 5.2 illustrates a simplified overview of the irrigation service delivery arrangements.

Donors and international financial institutions³ play an important role in the sector, including through technical and financial assistance. Development partner assistance is coordinated through the Ministry of Finance and through various sectoral councils (e.g., on Environment and Regional Development), although these mechanisms need to be revived and strengthened.

Regional Level

Three regional development authorities (RDAs) (center, north, and south, along with Gagauzia, which has a special status as an autonomous territory) are the key institutions in charge of coordination and planning of investment projects at the regional level for several mandated areas, including water and sanitation. RDAs are relatively well-staffed structures and have positive track records as implementors of large infrastructure projects and could have an enlarged role in the implementation of a national WSS sector program.

River basin districts, although nascent, have an emerging role to play in Moldova's water resource management and are aligned with the EU Water Framework Directive. Moldova has established two river basin districts, namely the Nistru River Basin District and Danube-Prut and Black Sea Basin. Their respective River Basin Water Management Plans (RBMPs) were prepared in 2016 and approved in 2017 and 2018. Basin committees have been created to facilitate the consultation process around the first RBMP, although they remain weak and underfunded. However, Moldova still has a way to go in terms of operationalizing basin management, specifically the creation of basin-level administrations. Even in

Figure 5.2 Overview of Irrigation Service Sector Institutions

a context of relatively abundant water resources endowments, building solid WRM functions for the future is critical specifically as irrigation development is pursued, requiring allocative trade-offs for different water uses during droughts and in hotspot catchments under an increasingly drier climate change (e.g., environmental flows and irrigation use).

Local Level

Moldova is divided into 32 districts, three municipalities, and two autonomous regions (Gagauzia and Transnistria). There are 1,681 localities across the country, 982 of which have their own local public authorities (LPAs), five with municipality status, 66 with town status, and 916 are villages with commune status.⁴ The Law on Self-Governance stipulates an autonomy principle and decentralizes local public services, including water and sanitation, to the LPAs, who in turn can either delegate this mandate to operators or directly deliver services themselves.

This has led to a landscape of 44 licensed utilities that provide water and sanitation services primarily in urban areas (district centers, and sometimes neighboring villages). In rural areas, local service provision through hundreds of unlicensed operators, as well as individual self-provision continue to play an important role. The reach of utilities delivering services in rural areas is low, especially compared with regional neighbors (World Bank 2019a). Across the board, operators receive limited technical support from government, a missing core function

in the sector that is usually fulfilled by a national water and sanitation agency.

Transboundary Level

Moldova is part of several international water treaties but a transboundary River Basin Management Plan for the Prut does not exist (Moldova-Romania-Ukraine), nor does it for the Dniester (Ukraine-Moldova).⁵ Moldova is party to the International Commission for the Protection of the Danube River (ICPDR), and has signed a bilateral agreement for transboundary coordination with Romania on the Prut. Moldova is a member of the Commission for the Protection of the Black Sea against Pollution and a signatory to the Common Maritime Agenda for the Black Sea, launched early 2020.

Moldova and Ukraine have signed a bilateral agreement on cooperation and management of the Dniester. The Moldovan Ukrainian Dniester Commission was established to aid negotiations on the Agreement on the Operation of the Dniester Hydropower Complex. Negotiations have stalled, because further evidence is needed to understand the environmental effect of the Dniester hydropower complex. Strengthened cooperation on the Dniester is needed to address critical issues, such as minimum flow requirements for various downstream uses, understand environmental and social impacts, as well as facilitate multilevel stakeholder involvement and dialogue on benefit, data, and information sharing.

Legislative Framework and Policies

Primary water legislation includes Moldova's Water Law 272 that establishes the legal basis for water resource management and stipulates the roles and responsibilities of the various agencies involved. The Law has undergone various amendments, the latest in November 2018, to transpose the principles of the EU Water Framework Directive into national law. The Law now includes principles of integrated water resources management, introduces the roles for basin district committees, and stipulates the legal framework for the regulation of protected areas, drought and flood risk management planning, and other aspects of integrated water resource management.

Law 303 on public water supply and sewer services regulates the provision of such services, including service quality and the roles and responsibilities of national, regional, and LPAs in the management, financing, operation, and monitoring of services. Changes in 2014 established the role of the regulator (ANRE) in tariff approval, and the introduction of mandatory licensing requirements for some WSS operators. A uniform methodology to set WSS tariffs was introduced, with several related normative requirements and procedures. Amendments in March 2019 to Law 303 provide local authorities with the option to deliver services themselves or to delegate this mandate to an operator under a delegation contract, introducing royalties and the setup of a development fund for future expansion and capital repairs. Local authorities can delegate services to self-owned municipal enterprises, to private or joint-stock enterprises, or to a neighboring regional operator under a service delegation contract, whereas the assets remain on the local government balance sheet. There are ambiguities in the legislation with respect to the licensing of operators. Although the law requires all centralized drinking water and sewer systems, regardless of size, to be under the management of licensed operators, other articles in the same law specify that for operators at the commune level to be licensed, they need to provide all three: water supply, and wastewater collection, and treatment services. This requirement is not applicable for operators in district centers, towns, or cities. This leaves many small local operators (small municipal enterprises) without license and economic regulatory oversight.

The Law 171 on Irrigation WUAs helped establish WUAs and arranged the transfer of state-owned irrigation systems by conclusion of a free long-term lease agreement. It regulates the relations between the WUAs and the public entity with state ownership

of irrigation systems, as well as the monitoring and supervision of WUAs by Apele Moldovei. As part of a general overhaul of state enterprises in Moldova, ownership of irrigation systems under management by Apele Moldovei's state irrigation enterprises, was transferred to the National Agency for Public Property. In 2019, ownership was again transferred back to Apele Moldovei. In April 2020, several legislative changes to laws and regulations took effect to remove impediments for farmers to access water for irrigation of agricultural land.

Moldova's overall WSS policy framework, as laid down in the National Water Supply and Sanitation Strategy 2014–28,⁶ mandates that LPAs have exclusive responsibility to establish, organize, coordinate, and control public services. In line with the EU-Moldova Association Agreement, Moldova has also committed to the establishment of efficient and effective public institutions according to the subsidiarity principle and to enhance safety and quality of services. Further important principles in Moldova's policy framework include the regionalization of water and sanitation services, whereby regionalized systems and connections of nearby localities should be developed and the aggregation of operators is foreseen to create economies of scale and scope. Policies on regional development are translated into three regional development plans for the north, center, and south. There is no national policy or strategy on integrated water resource management that addresses environmental and development agendas, integrating environmental protection, flood and drought resilience, as well as long-term development of the irrigation and water services sector.²

Financing Mechanisms and Expenditure Analysis

Financing Mechanisms and Institutional Implications

Although the Ministry of Finance allocates the budgetary resources in accordance with established practices, Moldova's water sector financing is characterized by fragmentation and a general lack of coordination and strategic planning. The National Ecological Fund (NEF) and National Regional Development Fund (NRDF) are the main domestic financing sources for the water sector. NRDF is designed to have an allocation of 1 percent of government revenues, whereas allocations to the NEF have varied over the past 9 years from MDL 100 to 450 MDL million per year. Funding under the NRDF is focused on urban

development, economic and tourism development, and WSS infrastructure for larger intermunicipal investments. The NEF is mandated to finance broad environmental activities, although its predominant focus has been on drinking water supply and sewer projects, leaving an estimated 15 percent for broader water management and environmental protection with limited allocations.

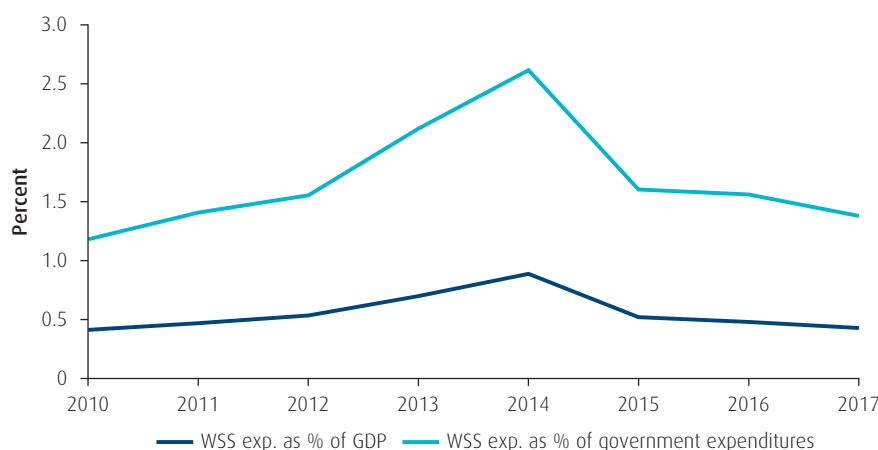
The NEF and NRDF have different institutional implementation mechanisms, with NEF funds executed directly by LPAs, whereas the NRDF is executed through RDAs. National Coordination Councils for Regional Development and Environment provide oversight and approve investment project financing by the NRDF and NEF, respectively. RDAs have well-staffed structures and a positive track record, benefiting from strategic support through GIZ and other partners. However, so far MARDE has not been successful in scaling up the NRDF by leveraging donor resources into the funding structure. In contrast, the performance record of the NEF is poor, characterized by weak results—orientation, lack of quality assurance, delays in execution of approved projects, as well as major transparency and governance issues. Out of an envelope of over MDL 3 billion in the past 9 years, it is estimated that approximately MDL 2.1 billion has been executed under the NEF. Reportedly, spent funds have not translated into effective and efficient infrastructure. The NEF lacks strategic planning oversight, instead funding fragmented and relatively small projects. Delays have also been encountered because of the lack of beneficiary contribution from the LPAs. The NEF essentially is a budget line with a small fund management team. This points to the lack of a national WSS development entity (or unit), that conducts due diligence on project preparation, monitors project implementation and service outcomes, and provides support to LPAs and operators to guarantee sustainability and facilitate service delivery arrangements (including regionalization). Although RDAs could support some of these functions, developing a clear institutional mandate and national home for such functions is needed, as these go beyond the policy mandate of the Water Resources Management Department under MARDE.

The National Agriculture and Rural Development Fund (NARDF) is financing rural development projects,⁸ including since 2019 submeasures that support local WSS investments. The NARDF is managed by the Agency for Intervention and Payments for Agriculture (AIPA) and funds are executed directly by LPAs. Again, this highlights the fragmentation in investment planning and financing

in the sector, with somewhat overlapping mandates across institutions and other necessary mandates not well assigned and funded.

Investment budgets under Apele Moldovei have been negligible so that flood protection infrastructure, watershed rehabilitation and river restorations, and rehabilitation measures for irrigation systems have not received funding under the existing RBMPs. There are limited central budget allocations to Apele Moldovei, the Environmental Agency, and other entities subordinate to MARDE to improve water and environmental management and monitoring functions. The dependence on central budget allocations for such critical functions could be addressed by overhauling the financing mechanisms for these functions. Environmental taxes are levied locally (OECD 2017) and no centralized funding mechanism exists, such as a Water Resources Fund, that would return water resource abstraction fees and other fees back to Apele Moldovei or the Environment Agency to support their operations. It is estimated that under the current financial framework, approximately MDL 150 million (US\$8 million) is collected annually in water-resource-related fees.⁹ As there are no flood protection levies in Moldova, the financing of flood management infrastructure requires a reexamination to increase revenues to support maintenance functions.

The medium-term Government Action Plan 2019–21 calls for the consolidation and optimization of various national funds, which is a sensible approach for funds supporting the water and sanitation sector. This diagnostic recommends that such consolidation and optimization should go together with the establishment of a dedicated WSS sector development entity and strengthening of the operational role of RDAs to deliver a national WSS program. Such a national dedicated WSS development entity should lead the preparation of the strategic investment plan, support and coordinate investment implementation by RDAs, and provide oversight functions on project implementation and use of funds and outcome monitoring. It could also take on the missing functions that presently constrain the sector and take the lead for sector development initiatives and policy operationalization. To build on RDAs' capacities for implementation of WSS investment funds, a widening of their mandates could be considered to allow RDAs to also focus on rural WSS development (not just regional and urban development). Because the outcome and progress of Apele Moldovei's reform is uncertain and given its limited capacity and experience in the WSS sector, the diagnostic recommends *not* to host WSS sector development functions with Apele Moldovei in the near and

Figure 5.3 Water Sector Expenditure Trends, 2010–17

Source: BOOST data for Moldova.

Note: GDP = gross domestic product; WSS = water supply and sanitation.

medium term. Until a vision for the WSS sector entity or unit is developed, an interim unit subordinate to MARDE could be strengthened to take up and develop critical WSS functions in the short term (e.g., the Public Institution for Implementation of Environmental Projects¹⁰).

Expenditure Analysis

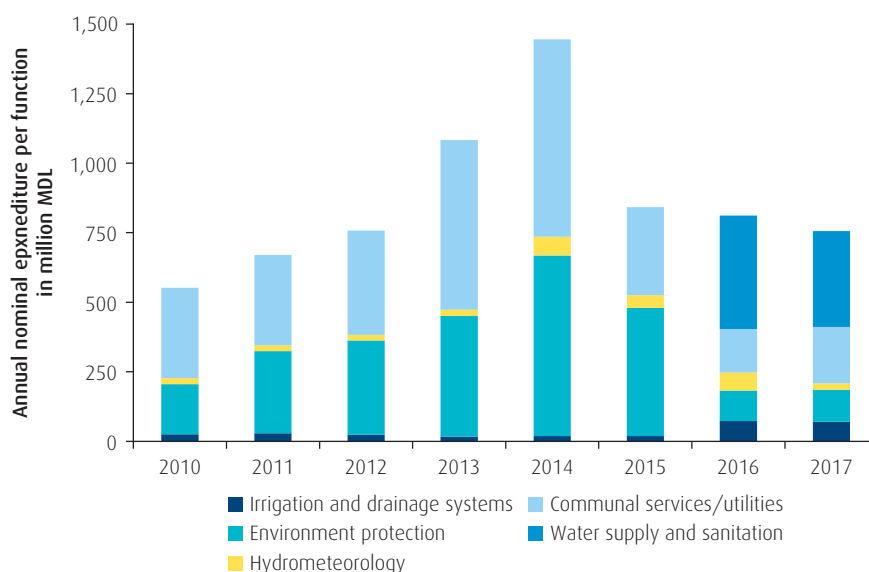
Moldova's WSS sector is financed from various domestic sources, including state and municipal budgets (including on-budget donor support), households, businesses, and off-budget donor funding. Fiscal resources flow from general government funds, channeled primarily through MARDE and its dedicated funds to its subordinate agencies and to LPAs. The diagnostic did not include a full-fledged public expenditure analysis, and rather carried out a rapid assessment of public financing in the water sector using various data sources covering the period 2010–17.¹¹

Budget allocations for WSS should be informed by a long-term investment plan and financing strategy, missing in Moldova. A financing analysis carried out in 2008 by the Organisation for Economic Co-operation and Development (OECD) refers to a range of 7–11 percent of government expenditures to be allocated to WSS if government targets and EU requirements for the Water Framework Directive are to be met (OECD 2008). Five percent can be considered an unofficial international benchmark for spending on WSS from the government budget, several factors higher than the 1.4 percent of government expenditure for Moldova in 2017 (figure 5.3). Figure 5.3 also shows

that Moldova's on-budget water expenditure as a percentage of GDP is extremely low and has been declining since 2013. In 2017, water expenditure as a percentage of GDP was less than 0.5 percent, declining from a peak of 2.5 percent in 2014.¹² The sharp reduction in water expenditures was driven primarily by lower budgetary allocations to investment projects. Between 2010 and 2017, total nominal expenditure in the sector averaged US\$13 per capita. As was the case with overall financing, nominal per capita spending grew between 2010 and 2014 from US\$8 to US\$23 but, because of the effect of the banking crisis, fell to approximately US\$10 by 2017.

The tracking of functional spending has been refined since 2016 with a change in categorization (figure 5.4). In 2017, total expenditures on water were MDL 755 million (or US\$43 million). More than 60 percent of on-budget expenditures were directed to urban WSS, whereas 13 percent went to communal WSS, 9 percent to irrigation and drainage, 3 percent to hydrometeorology, and 14 percent was classified as other, assumed to be for environmental protection and monitoring.

In 2017 capital investments were approximately 79 percent, followed by 14 percent for subsidies on operational and maintenance (nonwage recurrent expenditure) and 7 percent on wages. Spending on capital investments expanded rapidly between 2010 and 2014, but contracted after 2014, mostly at the central government level, maintaining the level of local capital expenditures. Locally executed expenditure, mostly from the NEF, forms the backbone of on-budget

Figure 5.4 Functional Spending in Million MDL, 2010–17

Source: BOOST data for Moldova.

spending, with more than 80 percent of spending made by local government authorities over the period 2015–17.

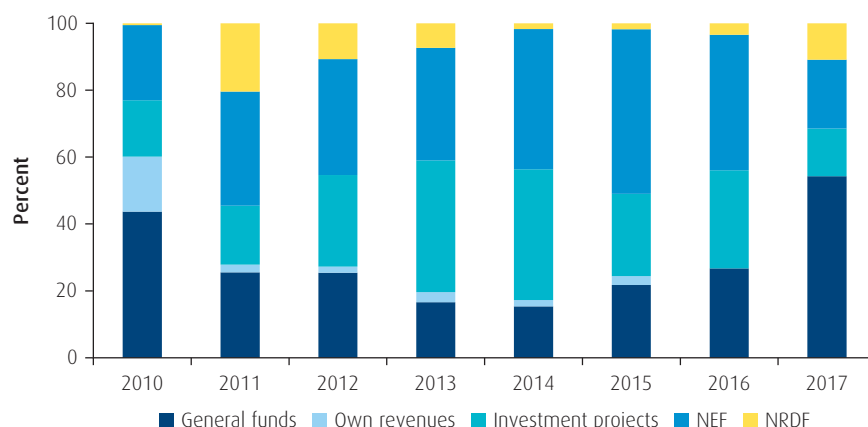
Although investments led to increases in access to piped public water in rural areas and small towns, urban areas saw improvements of service quality as connection rates were already high in 2010. Current levels of investments in infrastructure in the sector are far below estimated financing needs for Moldova to reach the Sustainable Development Goals (SDGs). Although the country lacks an up-to-date investment assessment to reach SDG 6, earlier estimates suggest that over US\$1 billion over a 15-year period is required in WSS alone, or US\$67 million annually.¹³ Current levels of expenditure for WSS, estimated to be approximately US\$30–35 million annually, are only half of what the country might need to meet its SDGs. Approximately two-thirds of investments are required in small towns and rural areas to expand access (World Bank 2015b).

Figure 5.5 illustrates the share of various funding sources. As can be seen, the NEF and NRDF together constitute between 30 and 50 percent of total government spending on water.¹⁴ Between 2010 and 2014, spending from the NEF was scaled up significantly, possibly the result of the EU budget support to the sector. Although execution levels of NEF funds have been highly variable, fund execution has been weak, deteriorating to 65 and 34 percent in 2016 and 2017, respectively.

Donor funds play a large role in the water sector of Moldova, comprising 67 percent of total spending in 2017. Most donor expenditures are project type investments, for large urban water systems, as indicated by the categorization for international development spending by the OECD (figure 5.6). This urban bias in WSS spending is not uncommon globally (World Bank 2016; 2019b) and is driven by multiple factors, such as political economy considerations, lack of a national institutional home for rural service delivery, decentralization of the WSS mandate to local governments without adequate resource allocation, a hesitation to invest in depopulating rural areas, and a lower affordability to sustain cost recovery and support debt servicing. The development of an *inclusive* national WSS sector investment plan and financing strategy, that would form the backbone of future government and development partner support, could help refocus subsidies to the underserved. Such a plan would need to include tailored service delivery arrangements and solutions across the rural-urban spectrum.¹⁵

Across the various subsectors—water resource management, WSS, and irrigation services—a strategic long-term financing approach is still missing. The core functions of integrated water resource management are underfunded through water resources and pollution discharge fees. State irrigation companies require large subsidies and are a drain on fiscal resources, hence the need to reform Apele Moldovei and its subordinate entities.

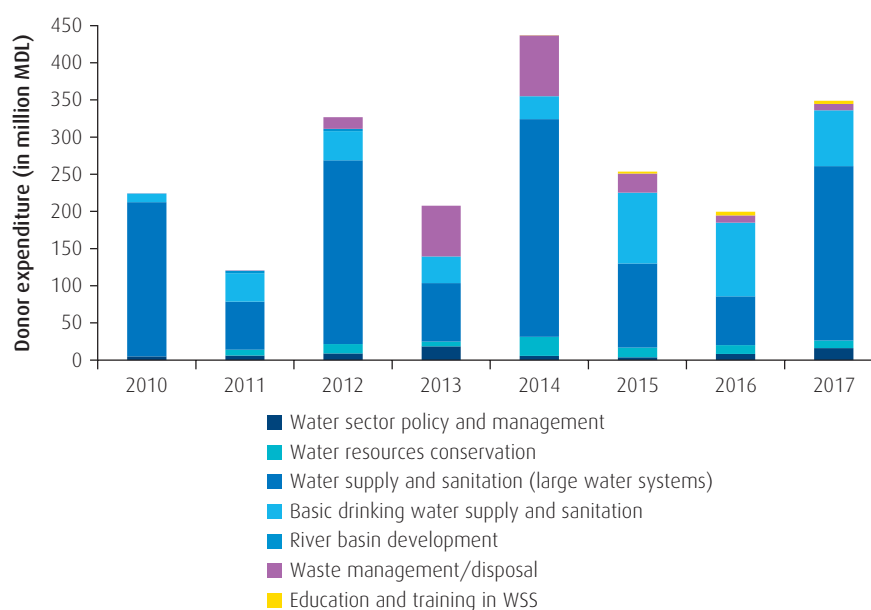
Figure 5.5 Public Spending on Water by Sources of Financing, 2010–17



Source: BOOST data for Moldova.

Note: NEF = National Ecological Fund; NRDF = National Regional Development Fund.

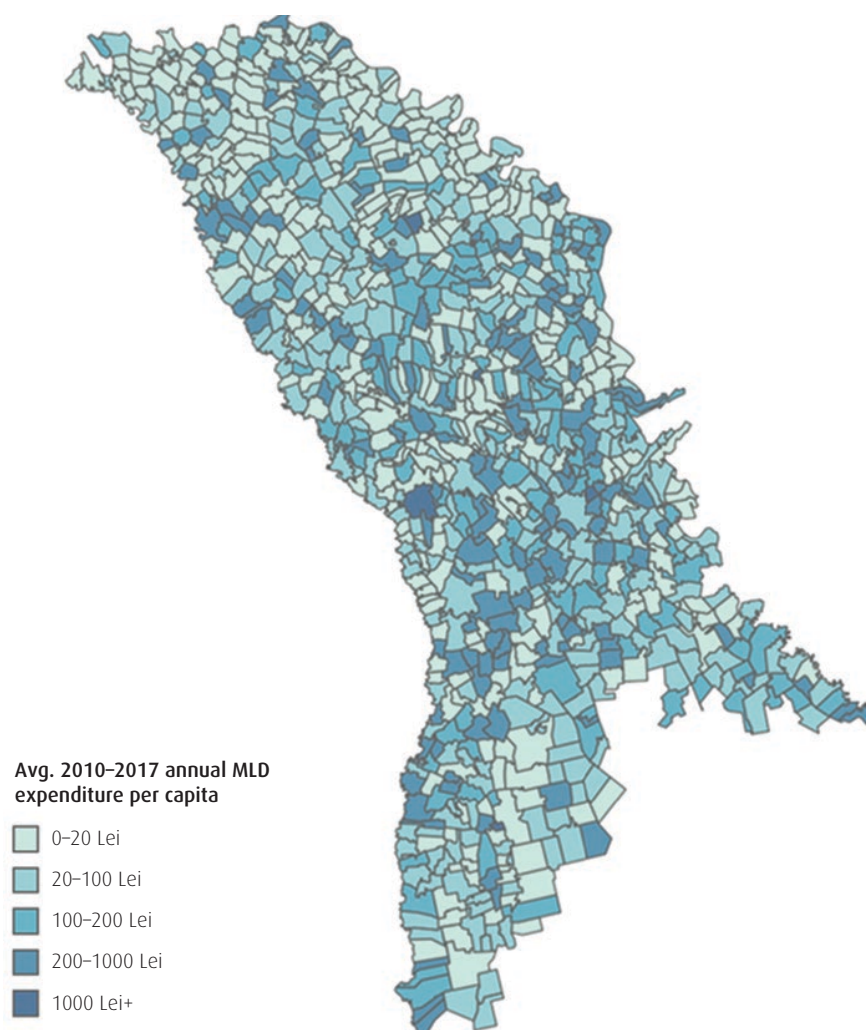
Figure 5.6 Donor Spending for Various Categories, 2010–17 (in nominal MDL)



Source: OECD DAC data.

Investment projects in WSS are not, at present, strategically programmed through a national planning and financing framework. Although there have been improvements in the operational cost recovery of utilities because of increases in tariffs, a more systematic approach to investment prioritization and financing is necessary. This is especially important when considering Moldova's stark inequalities in rural-urban water and sanitation outcomes. Urban LPAs benefit from nationally executed funds, such as project specific

investments and NRDF funds, whereas rural LPAs rely on NEF funds. Rural LPAs receive lower amounts and spent approximately US\$5 per capita annually (map 5.1). Although low in absolute amounts, local WSS expenditures were found to be well targeted to remote and low-density LPAs with the lowest water access. Fifty percent of funds benefit 20 percent of the population in communes with the lowest access rates. However, measuring the effectiveness of NEF spending remains difficult because of a lack of outcome monitoring.

Map 5.1 Average per Capita Expenditure across Local Governments in MDL, 2010–17

Source: Based on BOOST and Census 2013 data.

Performance for Water Resources Management and Resilience

Moldova is well endowed with renewable water resources, with 86 percent flowing in from upstream countries, and can secure the water demands associated with future development needs. However, key challenges lie with the quality of resources and the management of the resources in an integrated manner. Even in a context of rich water resources endowments, developing solid WRM functions, such as monitoring, drought, flood, and river basin planning and management, is critical for the future to ensure resilience. With expanding irrigation development, trade-offs, such as between

environmental flows and irrigation, will occur. Hence, allocation management and operations of hydraulic infrastructure, especially during droughts and in hotspot catchments will become increasingly important as the climate is warming. Flood events will increase, requiring flood management, forecasting, and protection functions to be well established to mitigate effects. Hydrometeorological networks, information systems, infrastructure, financing, and institutional capacities need to be in place. This section discusses the importance of strengthening information systems, policies, plans, institutional capacities, and financing to improve performance for water resource management and resilience. Many development partners are jointly working with the Government of Moldova to

Key Messages on Performance of Water Resources Management

- Even in a context of rich water resources endowment, functions such as drought, flood, and river basin planning and management; water allocation; and monitoring and forecasting are critical to manage trade-offs in vulnerable catchments and ensure resilience under progressive climate change.
- Policy makers are aware of the challenges in water resource management, specifically the need to strengthen and clarify mandates of Apele Moldovei through its anticipated reform.
- Consequences of slow reform are limited basin-level operational planning and allocation management, incomplete water permit registration, inefficient use of scarce financial resources because of subordinate loss-making irrigation enterprises, limited action on flood protection, and a lack of leadership on WSS, mostly a *de jure* mandate.
- Infrastructure investments and financing policies for WRM are underdeveloped, leaving Moldova's economy vulnerable to economic shocks of floods and droughts.

Way Forward

- Operational water management at the basin level is required, informed by River Basin Management Plans and aligned with national and regional development plans. The RBMPs need to prioritize investments and identify funding sources to implement those.
- Reform efforts for Apele Moldovei should be expedited, with a reorganization of management functions at the basin level and providing clarity vis-à-vis its functions; public good assets should be retained on its balance sheet, with adequate arrangements for their maintenance and operations.
- Moldova must strengthen its information systems for better water quality monitoring, abstraction management, and flood and drought forecasting; assessment of ground water quality and quantity is needed to better understand the potential of this strategic resource.
- The Water Information System and the State Water Cadastre should be rolled out and resources identified for their sustainable use. The latter is critical to improve the management of small-scale irrigation abstractions and should be combined with enforcement measures.
- Investments in flood and water management deserve more priority, focusing on infrastructure, nature-based solutions, and preparedness measures.
- To increase funds for WRM, the financing mechanism for water management and environmental protection needs to be reviewed and improved, with future earmarking of water-related fees and levies to secure allocations for WRM.
- Given the limited experiences and capacities of Apele Moldovei, WSS mandates may better be assigned to a dedicated WSS sector development entity or unit subordinate to MARDE.
- Transboundary dialogue with riparian countries needs to be further enhanced.

this effect, aligning policies and reforms with the EU Water Framework Directive as per the Moldova-EU Association Agreement, as well as with international commitments, such as the SDGs and the Paris Agreement on Climate Change.

Monitoring

Monitoring Systems of Water Bodies

The systematic and comprehensive monitoring of water bodies in Moldova started in the 1980s, carried out by several institutions including the State Hydrometeorological Service. Since its establishment in 2018, the Environmental Agency has been given the mandate to collect relevant environmental data and monitor both surface and groundwater quality, with a focus on the major rivers, Prut and Dniester. Monitoring programs have been introduced for the Prut and Dniester basins although they do not provide sufficient information on water quality and additional measures are proposed in the RBMPs.

Comprehensive monitoring of the Prut river has not been carried out because of lack of financial resources, insufficient equipment, and a lack of capacity (Republic of Moldova 2018). Along the Prut, information is collected from 30 monitoring stations situated along the main river itself, and do not encompass its tributaries. Only three provide continuous hydrological observation data: Sirauti, situated at the border with Ukraine; Ungheni, and the Costesti-Stânca Hydropower Plant on the border with Romania. In the Dniester river basin, monitoring is carried out in 68 hydrological sections located on 32 rivers, 7 reservoirs, and 2 lakes, although many stations have outdated equipment and further monitoring needs have been identified in the RBMP (Republic of Moldova 2017).

Cooperation on transboundary monitoring is established in Moldova's bilateral treaties with Romania and Ukraine, although insufficiencies in capacity and financial resources limit the country's efforts. Within the transnational monitoring network of the ICPDR, five monitoring points have been selected on the Prut river, with shared responsibility of Moldova and Romania (Republic of Moldova 2018).¹⁶ Moldova and Ukraine are expected to monitor water quality and sediment quarterly for two locations, Otaci and Palanca; however, it is unclear whether this has been implemented (Republic of Moldova 2017).

Despite efforts to expand the groundwater monitoring sector, experts agree that a more comprehensive and in-depth assessment of groundwater quantity and chemical status is needed given its strategic importance for drinking water supply. Currently, monitoring of water levels and quality is carried out

across 175 monitoring stations tapping into various aquifers, specifically those used as a drinking water source.¹⁷ Improving the knowledge on groundwater bodies is needed in the context of the transboundary nature of shared aquifers with Romania and Ukraine. This will require hydrogeological explorations and expanded monitoring of groundwater quality.

Water Management Information Systems

Transparent, complete, and up-to-date water resource management information systems are key to effective decision making, water allocation, and responding to water security risks. In Moldova, progress has been made although outcomes have been mixed and the ongoing use of systems remains a challenge. Although previous attempts to institutionalize information systems were not successful, a new initiative to develop an automated Water Information System (WIS) was approved by government decree in October 2019.¹⁸ The WIS combines tools, such as the GIS-based State Water Cadastre, as well as several complementary data management and modeling instruments.¹⁹ Moldova still requires a comprehensive policy on data management, which should articulate the roles and responsibilities of stakeholders, including the Hydrometeorological Service, the Geological Agency, Apele Moldovei, the National Institute for Public Health and others to ensure smooth access and good interinstitutional cooperation on data management. Changes in the Water Law in 2018 included provisions for a State Water Cadastre and established for the first time the registry of hydrotechnical constructions.²⁰ An inventory of these structures, identifying their legal status, level of siltation, status of maintenance and general condition, as well as the permitting status is being carried out and is a condition for improving water resource management.

The State Water Cadastre is a critical tool for the future integrated permitting of water, and discharge permits. Although the Environmental Agency issues water abstraction permits for various uses, Apele Moldovei is tasked with preparing water allocation plans, based on planned ground and surface water abstractions. Apele Moldovei issues and manages the annual permits for special water use²¹ that are required for the irrigation of agricultural land outside of centralized irrigation systems. However, the comprehensive rollout of the State Water Cadastre is a work in progress and a complete inventory of all water users is necessary for timely and efficient management of water resources. Because of inaccurate and incomplete reporting at the local level, as well as unauthorized use because of lack of enforcement mechanisms, a comprehensive

picture of water use remains elusive, and is a concern for management in hotspot basins. The system for discharge permits needs to be developed and integrated in the State Water Cadastre, which is not currently the case. It is envisaged that the WIS will become the platform for authorization of environmental permits. With development partner support expected to end in 2021, the sustainability risks for the continued use of the WIS remain high.

The rollout of the State Water Cadastre is especially urgent as MARDE's policies stimulate expansion of irrigated agriculture through subsidies for farmer-led investments in small systems and reservoirs (delivered by AIPA). Without adequate information on water abstractions and given the vulnerability of hotspot catchments as highlighted in chapter 4, such subsidy programs may pose water security risks if not embedded in a wider integrated planning effort, that considers climate risks.

In terms of groundwater abstractions, sector experts agree that there are likely many unauthorized abstractions for supplemental irrigation use. There are an estimated 7,000 wells in Moldova, of which only 2 percent are formally registered. The use of groundwater for irrigation is illegal because of the perceived risk of environmental soil degradation. However, in case groundwater use for irrigation will be allowed in the future under certain restrictions, it is critical that the information systems for permitting and related enforcement capacities will be strengthened, requiring political will and more resources. Regulations on the potential restricted use of ground water for irrigation would need to be informed by risk assessments considering groundwater quality, soil type, irrigation regime, and crop type.

Information Systems for Flood and Drought Risks

Several initiatives have been developed to support disaster preparedness and emergency responses, although Moldova's early warning systems require further improvements. The Civil Protection and Emergency Situation Services coordination authority under the Ministry of Internal Affairs is responsible for coordinating, monitoring, and updating disaster and civil protection plans, although these vary in adequacy among localities. Its Emergency Command Center is responsible for alerting the population, whereas the State Hydrometeorological Service provides forecasts to relevant authorities and the public. Although the operational capacity of the State Hydrometeorological Service has been strengthened in the last years, hydrological forecasts are still based on outdated empirical models. No operational hydrological

modeling system is in place and forecasts for flash floods are not provided yet (Europe Aid 2014).

Moldova's information systems for flood risk management require support across several priorities. A flood management plan was prepared in 2016 with support from the European Investment Bank, which details urgent structural and nonstructural measures to help the country mitigate and manage the effects of floods. Priorities include information management, flood forecasting and early warning systems, emergency preparedness planning, and public awareness. Such nonstructural measures were found to have high benefits relative to costs but remain unimplemented because of lack of funding and political will. Flood and drought risk management plans are under preparation for both river basin districts with EU support.

Weather-related risks in agriculture remain high because of the lack of index-based insurance products and readily available weather and market information. Under the NFARD, AIPA has introduced as part of the 2017–21 program of subsidy measures, one submeasure that provides subsidies to insurance premiums for farmers in horticulture, viticulture, and other sectors. Further analysis is needed to understand the barriers to uptake and the adequacy of insurance products available in the country.²²

Infrastructure and Financing

The previous section outlined some challenges for financing water resource management functions, as well as financing of maintenance of flood protection structures. Central budget allocation is modest for Apele Moldovei and for 2016–17 on average amounted to MDL 31 million (less than US\$2 million), of which half was allocated to subsidies to state irrigation companies, and the other half to its environmental mandate, mostly to support monitoring functions. This leaves the financing of flood infrastructure unmet. In addition, there is lack of clarity on the roles of Apele Moldovei vis-à-vis local governments for maintenance of certain flood management infrastructure.

There are more than 1,200 km of flood defenses and a lack of maintenance and safety monitoring undermines their value. In addition, the thousands of ponds and small reservoirs pose additional flood risks, because their conditions are poor and are at risk of failure in case of flash floods. Moldova's Flood Master Plan Report (EIB 2016) identifies a 5-year priority program including eight investment priority projects and five high-priority nonstructural measures. The total cost for the 5-year program is estimated to be US\$121 million, comprising US\$77 million for the structural measures and US\$44 million for the nonstructural measures. A larger set of measures was prioritized using a multicriteria assessment of urgency and effect. Rivers with the

highest flood risk include the Dniester, the River Bâc (which flows through the capital city, Chisinau), and the River Cogâlnic in the south of Moldova.

Flood and drought risk management plans have been prepared for the Dniester and for the Prut-Danube–Black Sea basins, following the EU Flood Directive methodology. These plans include a Program of Measures, informed by the earlier flood master plan. Despite a well-advanced understanding of flood risk and specific high-priority measures, financing sources have not been identified thus far. The fiscal crisis because of COVID-19 may likely lead to further delays in the implementation of investments.

Reform efforts must recognize that the Apele Moldovei agency retains its responsibility as owner and asset manager of public goods infrastructure, such as dams, large reservoirs, critical flood protection structures, and large water transfer systems from the main rivers inland. It is recommended that large hydrotechnical and hydraulic infrastructure will be retained on Apele Moldovei's balance sheet as was guaranteed through a 2020 government decree.²³ For certain large infrastructure, operations and maintenance could be delegated to service providers under transparent delegation contracts, such as for drinking water supply transfer infrastructure.

Floods and droughts were identified as major risks for water services, as were other weather-related hazards, such as storms, extreme winter temperatures, and landslides. The immediate effect of floods on water infrastructure relates to intake facilities that require proper physical protection, and to flooding of treatment facilities and/or pumping stations located close to the rivers or in exposed areas. Droughts affect raw water quality because of a lower dilution of pollution loads, and hence may hamper functioning of treatment stations. Resilience aspects will need to be better integrated in the design infrastructure facilities (KPC 2013).

Institutions for Water Resource Management and Resilience

The performance of Moldova's water resource management is not only hampered by infrastructure and financing, but also by institutional challenges. Driven by the EU Association Agreement, Moldova has implemented important administrative reforms, which were overseen by the Center for Reform Implementation, including the creation of MARDE. However, most critical to water resource management and the operationalization of the basin approach is the reform for Apele Moldovei. Although basin districts, as well as subbasins, have been delineated and multistakeholder²⁴ committees have been formed,²⁵ they operate voluntarily and lack sustainable budget allocations. Basin committees are key entities in policy formulation, and should be strengthened with clear responsibilities, roles, and support from Apele Moldovei.

Subbasin committees are important entities for stakeholder engagement and decisions about pollution control and river rehabilitation measures. An important challenge will be aligning local level planning with regional and national priorities. Lessons from pilot projects strengthening governance should be scaled up so that civil society is involved in policy making, local planning, and governance of services.

Concerning Apele Moldovei's reform, various proposals have been elaborated but no decisions have been enacted. Apele Moldovei's reform will require resources and political commitment to ensure adequate staffing for its core mandates, as well as retrenchment measures for redundant staff. The reorganization of the agency should follow a basin-level management approach in its structure,²⁶ as well as clarity on its functional mandate. Draft proposals include water protection and integrated water management, irrigation and drainage management, flood and drought risk management, and WSS. However, given the limited experience with WSS, as well as its already overwhelming current and future responsibilities in basin management, this diagnostic recommends not to overload Apele Moldovei with an added mandate on WSS.

Apele Moldovei's role with respect to oversight and monitoring of WUAs is clearly stipulated in the Law on WUAs. Several state irrigation companies were liquidated, their assets rehabilitated, and their management transferred to new WUAs based on a gratuitous lease. This process has been extensively supported by the Sustainable Development Account (SDA) with the WUAs gradually improving their performance. Since April 2020, several new WUAs have been formed and are planning to take over management responsibility of functional systems, currently under the responsibility of state irrigation enterprises. These irrigation enterprises continue to drain scarce fiscal resources from Apele Moldovei's budget.

Another issue that Apele Moldovei's reform could tackle is to provide clarity on overlapping functions between Apele Moldovei and local governments. Both are assigned the role of protection of surface water bodies, embankments, and flood plains, resulting in limited accountability and lack of action and investments on both ends.

Concluding, there are numerous consequences of the slow reform of Apele Moldovei, including (1) no decision on an operational entity tasked with river basin management, planning, and allocation; (2) lagging water permit management and unauthorized use; (3) fiscal drain because of subsidies to loss-making subordinate irrigation enterprises; (4) insufficient action on flood protection because of ambiguous mandates; and (5) lack of leadership on WSS, a largely *de jure* mandate of Apele Moldovei.

Performance of Water Supply and Sanitation Services

Persisting Urban-Rural Access Gap

Moldova's outcomes on access to WSS have serious shortcomings, although progress was achieved (figure 5.7).²² The COVID-19 pandemic reveals again the relevance of SDG 6 and the vital importance of water, sanitation, and hygiene services for all, including rural and specific vulnerable groups, such as Roma.²⁸

In Moldova, only one in eight rural households use a flush toilet, because most rural residents use

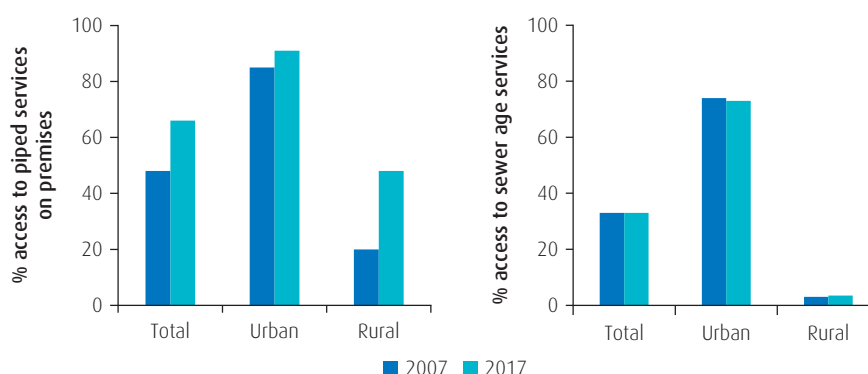
outdoor pit latrines of doubtful hygienic status with limited comfort, often lacking nearby handwashing facilities. Only one in three rural citizens receives a publicly provided water supply service, and often water quality may be compromised (World Bank 2018). Coping mechanisms of households are to simply invest in their own wells, piping, and indoor plumbing despite health risks because of poor quality water. There are various service delivery models in rural areas, ranging from regional or urban licensed operators in district towns serving rural areas, local operators, as well as self-supply, either with piping in the home or not. As can be seen in figure 5.8,

Key Messages on Performance of Water Supply and Sanitation Services

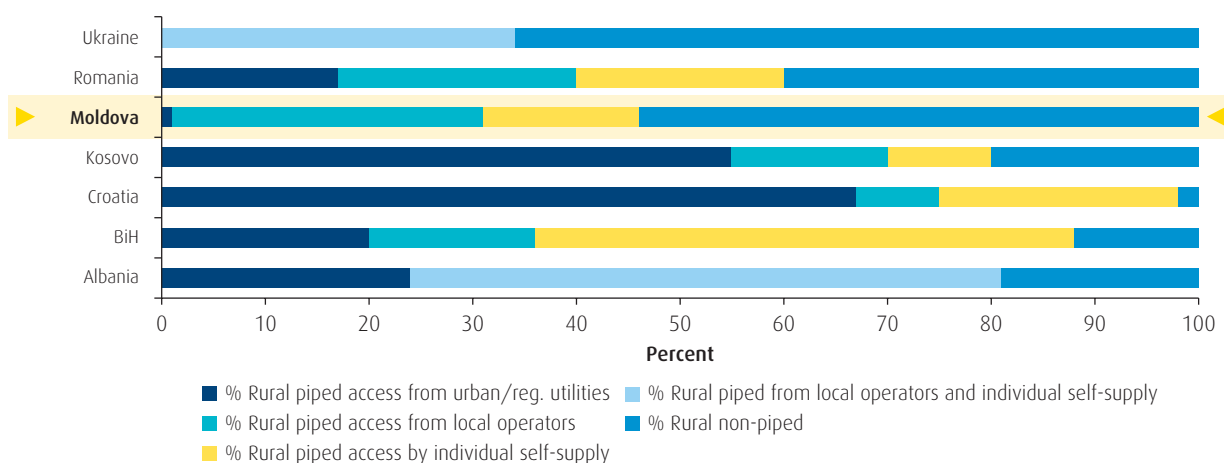
- Performance in water supply and sanitation is constrained by large coverage gaps in rural areas: only one in eight rural households uses a flush toilet and only one in three rural citizens receives a publicly provided water supply service, and often water quality is compromised.
- Sanitation and adequate wastewater treatment remain critical concerns, polluting water sources and increasing the cost if treated.
- Institutional weaknesses underpin many of the infrastructure, information, and finance gaps.
- Except for a few large operators, across the board efficiency and performance of district operators require further improvements.

Way Forward

- To reach universal access, Moldova needs to adopt a so-called portfolio approach for service delivery models. This includes (1) expanding services by licensed district and urban operators to neighboring villages, (2) increasing capacity and oversight of local municipal operators in the interim, and (3) support to individual self-supply solutions in remote small villages.
- This requires capacitated national institutions and service providers, because Moldova's challenge is not only the expansion of services, but also the need to improve the performance and quality of services provided. The role of RDAs, with competency in WSS investment implementation, should be leveraged.
- In the medium term, a national WSS development entity needs to be established that is responsible for sector oversight and policy implementation and to take on missing functions, such as national investment planning, project preparation, quality assurance, innovation, sustainability monitoring, and support to service providers in urban and rural areas to facilitate aggregation and compliance. In the interim, these functions could be strengthened and hosted with a dedicated unit under MARDE.
- Better capacities and financial performance of operators will be essential for successful delegation arrangements and further regionalization. A national performance improvement program is needed, with incentive payments and access to financing facilities to stimulate gains in energy efficiency, non revenue water reduction, customer orientation, and other areas.
- Given the large financing gaps, a financing framework is needed to mobilize more resources from tariffs, and government and partner transfers. The framework should prioritize capital subsidies to rural areas and ensure that relatively better-off population segments can gradually help shoulder investments through tariff increases.
- To improve financial viability, affordability concerns and unwillingness of households to connect need to be addressed. A mandatory connection policy for drinking water and sewer networks could be effective, combined with dedicated social support mechanisms to protect vulnerable households, and effective community engagement and outreach.

Figure 5.7 Progress on Piped Water and Sewer Services, 2000–17

Source: Based on JMP/WHO 2019.

Figure 5.8 Structure of Service Delivery in Rural Areas in Moldova and Regional Comparators

Source: World Bank 2019a.

Moldova has a high reliance on self-supply and a low penetration of utilities in rural areas, compared with other countries in the region.

Moldova, like many European member states or accession countries, embarked on an aggregation process for service provision (so-called regionalization). Mixed results and valuable lessons have been obtained thus far. Although the National WSS Strategy articulates three to six large regional operators, government and development partners now focus on a more realistic regionalization process, namely at the district level, better suited for Moldova's existing context. Although Apacanal Chisinau successfully developed the regional scale, the Apa Nord project that involved the merger of service providers in six districts was canceled. The voluntary nature of the aggregation, political interests

of local stakeholders, and weak financial positions of utilities hampered the process.

As of now, there are 44 operators that are licensed by the economic regulator ANRE, some formed as open joint stock companies,²² whereas others have a municipal enterprise status. Increasingly, local governments agree to contractually delegate services to the nearest licensed operator in the district center. This process requires upgrading and expansion of systems in rural areas, along with facilitation support to local governments, capacity building of the district operators, legal advice and financial due diligence, accountable and transparent contractual arrangements, and awareness campaigns for households. Sustainability risks are expected to be lower compared with the alternative, that is, provision

of services by small municipal enterprises or directly by the rural LPAs.

Because this regionalization process will require considerable resources, time, and funds, the reality in Moldova will remain for some time that hundreds of small rural operators continue to operate without much oversight or support. At the same time, rural LPAs continue to receive investments under the NEF, without monitoring their operators' performance, and without regulations to set their tariffs, or technical support to sustain operations. Globally, evidence is overwhelming that to sustain and improve rural service providers, monitoring, technical assistance, and investment support functions are critical (World Bank 2017, 2018). As a WSS sector development agency or entity is missing, these functions are not assigned, and information and support systems are absent. Under the Austrian-Swiss-funded APASAN project, important inroads were made in providing technical, legal, and financial support services to rural areas; however, they require institutional embedding.³⁰

Finally, attention is needed to the two-thirds of Moldovans who are living in rural villages that depend on self-supply from polluted shallow wells. Innovative solutions for small and remote villages may be needed, including incentive schemes that can improve indoor water supply reliability and quality to improve hygiene, as well as supporting systems for risk management and water safety monitoring. Subsidy schemes could be launched to improve on-site sanitation facilities, going beyond the general expectation that networked sanitation (sewer) is the only option.

Sanitation solutions will equally require a tailored approach to achieve universal access. Regional management models for wastewater solutions are needed to ensure enough professionalism. At the same time, on-site sanitation improvements and fecal sludge management service chains will need to be developed and regulated, accompanied by incentives to stimulate private investments by households (World Bank 2018). New standards and appropriate technical norms for sanitation will be needed to address solutions beyond centralized wastewater systems.

Concluding, to achieve universal access, Moldova needs to adopt a so-called portfolio approach for service delivery models. This includes (1) expanding services by district and urban operators to neighboring villages, (2) increasing capacity and oversight of local municipal operators in the interim, and (3) support to individual self-supply solutions in remote small villages. As discussed later, such an approach will require capacitated institutions and service providers, because Moldova's challenge is not only the expansion of services, but also the need

to improve the performance and quality of services provided.

Enabling Institutions for Water Supply and Sanitation Service Delivery

Reform proposals for Apele Moldovei require a reconsideration of functions for WSS. Draft proposals include functions to coordinate the implementation of the National Water Supply and Sanitation Strategy and help operationalize policies in the WSS sector. However, the agency's involvement in WSS has been limited and capacities will have to be built from scratch. Thus, the diagnostic recommends exploring alternative arrangements to create a dedicated WSS sector development entity or unit subordinate to MARDE that will take up critical functions that currently are fragmented, suboptimally executed, or simply missing. Such a dedicated WSS sector development entity would be responsible for sector oversight, investment planning, and policy implementation. It could typically include the following functions:

- Coordination, implementation support, and quality assurance for (a) national investment program(s)³¹
- Leading the development of a national WSS investment plan and financing framework and coordinate implementation through a consolidated WSS fund.
- Results monitoring and performance improvement support to service providers in urban and rural areas, possibly with performance-based incentive programs
- Technical support to service providers to facilitate regionalization, and support compliance with policies and guidelines for small municipal providers
- Supporting the development of technical standards and operationalization of new policies
- Human resource development and innovation for the sector

This entity would coordinate closely with important sector players, such as the water policy division under MARDE, the RDAs, the economic regulator ANRE, as well as the utility association Asociația Moldova Apa-Canal (AMAC).

In terms of the economic regulation of the sector, under the Law 303, ANRE has developed a comprehensive set of legislative regulations, including changes to allow for royalties and their accumulation in the Development Funds to allow operators to finance capital expansion and capital maintenance. ANRE also approves investment plans for the utilities, but not all licensed utilities have developed these plans. ANRE has not yet approved tariffs for all utilities, because approximately two-thirds of them have not been

able to provide the necessary data and underlying requirements for the tariff application. Only municipal enterprises at the commune level that provide all three services (water supply, wastewater collection, and wastewater treatment) fall under ANRE's jurisdiction as per the law. Because *de facto*, wastewater treatment services do not exist in rural areas, rural WSS providers operate without license.³² Given the capacity limitations and legalistic approach of ANRE, an alternative approach needs to be developed for economic regulation of smaller operators. This would start with performance monitoring, with instructive simplified tariff-setting guidelines, combined with incentives for rural LPAs to delegate services to licensed operators and/or to follow certain tariff requirements to ensure sustainable operations. Alternatively, provisions in the legal framework could be drafted that discontinue direct provision by the LPA, allow the assignment of a licensed operator of last resort, and/or specify a simplified licensing scheme for commune level operators.

Performance of WSS Service Providers

Moldova's overall Water Utility Performance Index (WUPI)³³ measuring performance elements such as coverage, quality of service, and management efficiency, increased from 58 to 66, moving closer to the regional average of 72 across countries that were part of a State of the Sector Review, carried out by the Danube Water Program in 2015 and 2018 (see also World Bank 2019a). Figure 5.9 indicates that although Moldova has kept up performance in areas

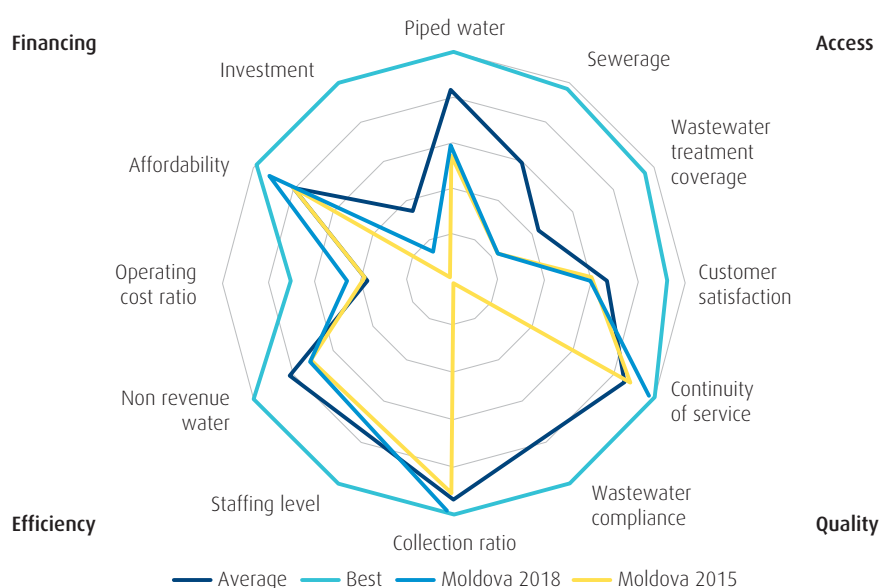
such as collection ratio, metering, service hours, and affordability, weaknesses remain in access, quality of wastewater services, and low levels of investment.

Urban providers have reached high levels of service continuity with 23 hours per day in 2018, almost doubling since the early 2000s.³⁴ However, drinking water quality remains a major issue. Although large utilities generally show good compliance with the norms after treatment, adequate treatment, such as continuous disinfection, is missing especially in rural systems, contributing to Moldova's communicable disease burden (Mediu 2014b). Customer satisfaction is low at 61 percent (World Bank 2018), and lower than most countries in the region. Water consumption shows a decreasing trend, similar as in the regions, with a decline in per capita consumption from 126 liters per capita per day to 97 liters per capita per day (IBNET 2019).³⁵ This is likely because of increased metering and increasing tariff levels. Despite increasing tariffs, financial sustainability remains a challenge.

There are large differences in the capacities of licensed operators. Most utilities are classified as medium to low performers, mostly attributed to low levels of quality of service, wastewater treatment facilities, low customer satisfaction and weak management capacity (see also World Bank 2019a).

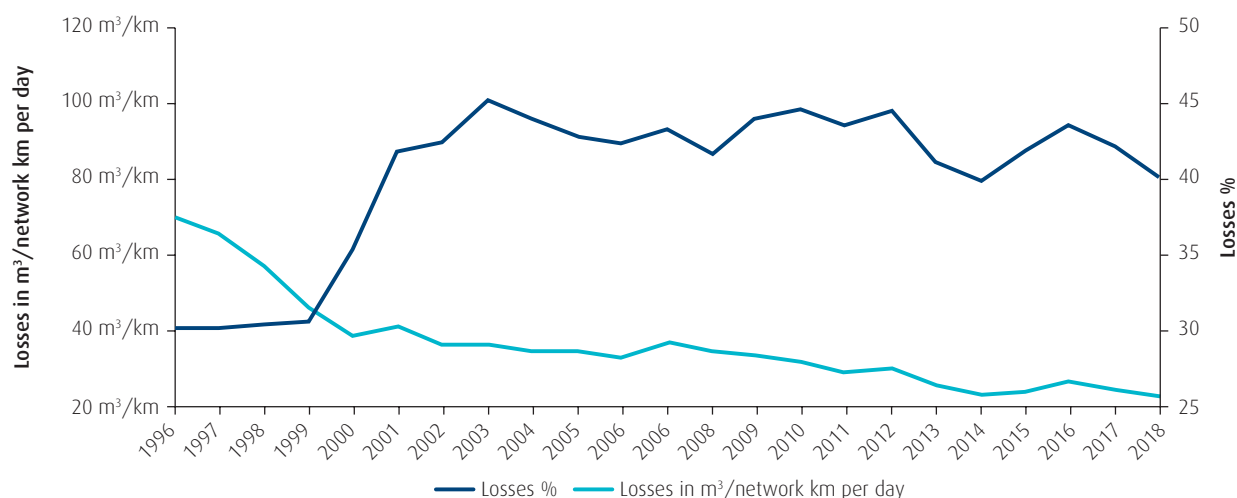
Utilities have been steadily increasing their efficiency, but there remains room for improvement. Nonrevenue water (NRW) continues to be a key challenge for most utilities in Moldova, although improvements can be observed (figure 5.10). NRW is composed

Figure 5.9 Performance of Moldova's WSS Service Delivery, 2015 and 2018



Source: World Bank 2019a.

Figure 5.10 Trend in Nonrevenue Water Indicators in Moldova



Source: IBNET data.

of both physical losses because of poor condition of infrastructure, as well as commercial losses, because of unauthorized water use, and poor billing, metering, and collection practices. Although NRW seems to show a stable trend, with an average of approximately 40 percent in 2017, the effectiveness of various NRW reduction measures is illustrated by declining losses per km of network (IBNET 2019).

There are also opportunities to improve efficiency of utilities, for example, energy efficiency, requiring utility-level energy audits and remedial action plans. Evidence from a limited sample of utilities in Moldova suggest that energy costs per unit of water sold are high, approximately US\$0.5 per cubic meter, whereas countries like Kosovo, North Macedonia, and Serbia have costs of US\$0.2 per cubic meter. This is likely because of pumping costs involved with internal water transfers to the north and center of the country and a relatively high reliance on deep groundwater. Analysis shows that Moldova can reap large quantitative benefits from efficiency measures, improving the financial viability of the sector (World Bank 2019a). To do so, incentives, management and technical capacities need to be developed.

Overall, the water sector in Moldova suffers from a lack of specialized staff with experience in water infrastructure management and implementation of investment projects. Municipal representatives often appoint utility management staff without the specific qualifications or competencies. The national water association, AMAC, created in 2000, is promoting knowledge and best practices, but has limited capacities and resources to do so. An incentive program should be created at the national level to

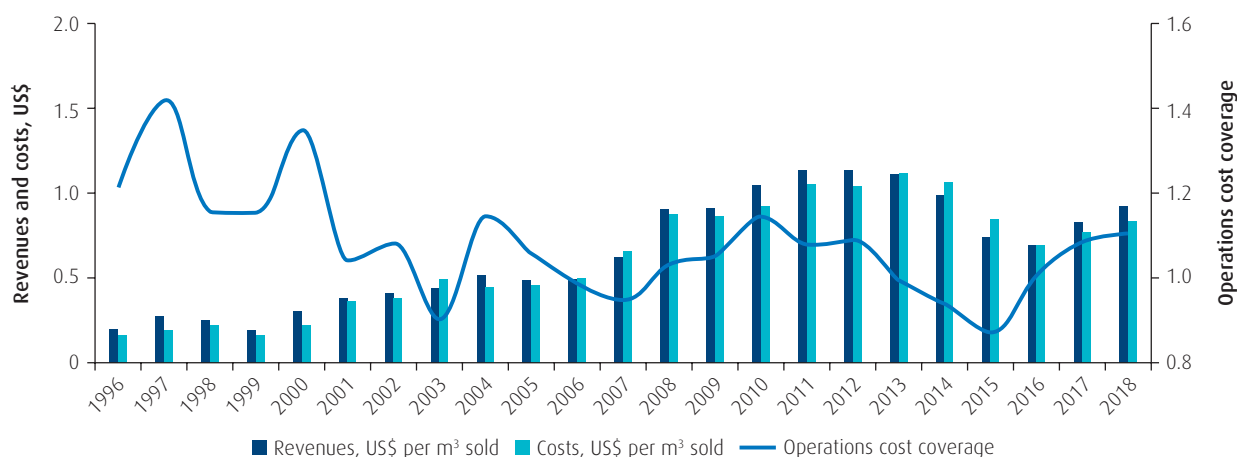
structurally enhance sector performance, again a missing function because of the absence of a dedicated WSS sector development agency.

Infrastructure and Financing

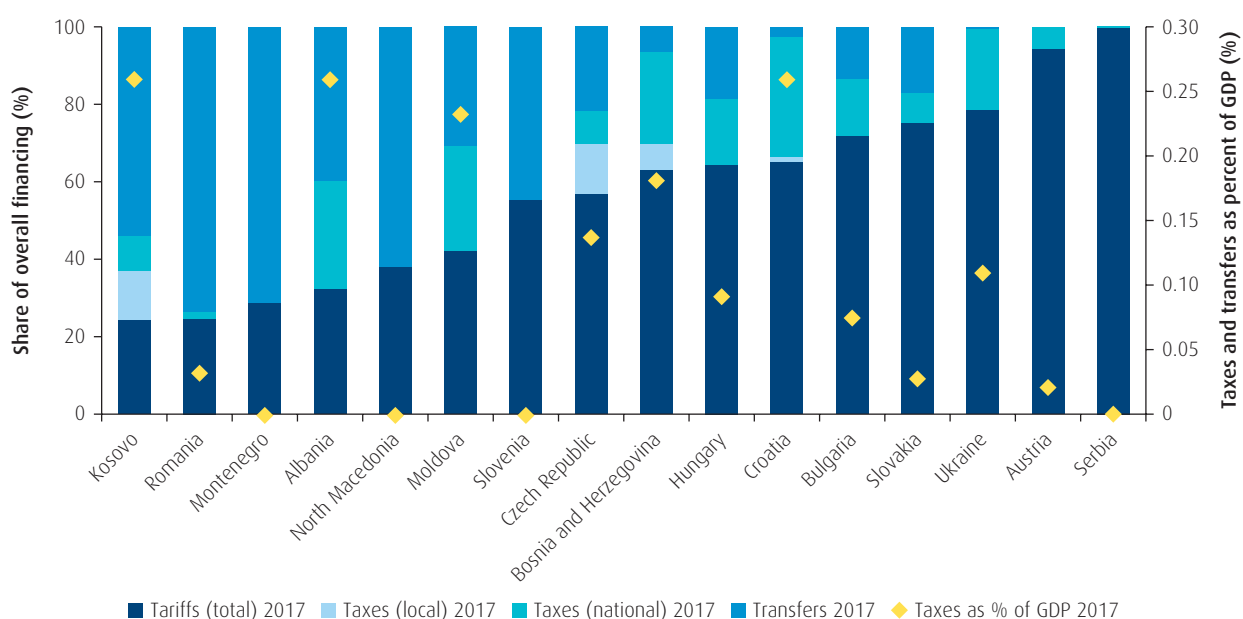
WSS infrastructure is deteriorating, and equipment is in poor condition with limited capacity. In 2012, only 90 percent of 742 water systems were deemed operational with 30 percent of pumping stations in unsatisfactory condition (Mediu 2014a). In 2017, there were more than 1,200 water systems, with their functionality rate unknown (NBS 2017). An inventory of AMAC showed that 110 of 158 wastewater systems are operational, with varying levels of treatment and 40 percent of the sewer distribution network is estimated to be in poor condition (AMAC 2015).

To remedy this situation and to sustain operations, significant funds are required, and tariffs collected by utilities remain the largest source of funding for operational and capital expenditures. However, the average operational cost recovery ratio across urban utilities is just 1.2 (figure 5.11). This means that on average, whereas revenues are sufficient to cover operating costs, they are not sufficient to cover long-term asset renewal or investment expansion.

To fund investments, revenues collected by utilities are augmented by fiscal transfers from national and local budgets, as well as a blend of international grants and loans. Financing for the water and sanitation sector, including both capital and operational costs, relies for 40 percent on tariffs, the remainder being funded through national budget transfers, like through the NEF and NRDF, and donor transfers (figure 5.12)

Figure 5.11 Trends in Operational Cost Recovery Indicators

Source: IBNET data.

Figure 5.12 Structure of WSS Sector Financing in the Danube Region, 2017

Source: World Bank 2019a.

(World Bank 2019a). To raise levels of service and expand coverage, increased financing from tariffs will be needed in the future.

The current level of investment is too low to match water sector needs. Financing of 1.4 percent of government expenditures in 2017 is below the 7 percent recommendation by the OECD (OECD 2008b) and the international benchmark of 5 percent of government expenditures. The country lacks a national investment plan and associated financing strategy to help mobilize domestic taxes, tariffs, as well as partner transfers. Such a strategic framework could help to prioritize capital subsidies to areas most in

need of services and ensure that better-off population segments in Chisinau and major towns can gradually help shoulder investments through tariff increases. Capital subsidy grants and loans with sovereign debt obligations should be targeted to rural areas with lower affordability of the population, whereas urban utilities should be supported to gradually move along the spectrum of financial cost recovery to creditworthiness through raising revenues from tariffs, combined with targeted social support mechanisms.

To improve financial viability, more needs to be done to overcome unwillingness of households to connect to systems due to concerns over affordability.

The mandatory connection of households to drinking water and sewer age networks would be an effective policy instrument to improve financial performance. However, this should be combined with dedicated social support mechanisms—for connections and potentially for social tariffs—to protect vulnerable households identified through the national social assistance registry. Such policies require changes in legislation and should go together with pro-poor policies that target specific vulnerable groups to access subsidies, preferably through a national dedicated funding mechanism. Such social support policies exist for heating support and gas connections but are lacking in the water sector. Extensive awareness raising efforts should address willingness-to-connect and willingness-to-pay challenges, focusing on communicating benefits from connecting to centrally managed schemes.

Performance of Irrigated Agriculture

With the decline of large centralized irrigation systems after the collapse of the Soviet Union, Moldova's agriculture sector has become increasingly vulnerable to weather shocks. Chapter 3 underscored the need to increase the resilience of the agriculture sector, both for rainfed as well as irrigated agriculture. Improving irrigation infrastructure is a part of this equation, but investment alone will not result in the desired socioeconomic outcomes of the intended transition to high-value agriculture. Adequate institutions to manage irrigation services and water allocations sustainably, as well as enabling conditions and complementary policies, are required so that farmers can take risks, invest in modernization, and access markets.

Key Messages on the Performance of Irrigated Agriculture

- Because of the collapse of many central systems, Moldova's irrigation potential is untapped, and performance is poor. The infrastructure is old and in a largely dysfunctional state.
- State irrigation enterprises operating these schemes pose a significant burden to Apele Moldovei's budget. The liquidation of state irrigation enterprises will reduce the burden of unsustainable subsidies for their operation; staff retrenchment costs need to be absorbed by the state budget to enable the reform of Apele Moldovei to proceed.

Way Forward

- There is a need to prepare a comprehensive irrigation development strategy and investment plan, informed by climate-resilience proofing and economic analysis of priority investments, where needed complemented with cost-effective storage solutions. The strategy should be embedded in a broader agricultural modernization agenda.
- A portfolio approach may be a useful framework for agriculture development, relying on a mixture of (1) centralized systems for high-value agricultural production, (2) farmer-led private small-scale irrigation development, and (3) improved climate-smart agriculture for commodity crops. These should be concurrently supported at the national and local levels through technical assistance and investments.
- The replication of the nascent water user association model as per the Law on WUAs needs to proceed, transferring functional—ideally rehabilitated—irrigation systems to WUAs for management, operation and maintenance, and strengthening the capacities of Apele Moldovei to provide adequate monitoring, oversight, and technical support to WUAs.
- Rehabilitation of central irrigation systems under future WUA management need to go together with: (1) favorable access to finance and subsidies for on-farm investments, (2) facilitating access to markets and postharvest infrastructure, (3) measures to address land fragmentation, and (4) advisory services to WUAs and farmers.
- Apele Moldovei's capacities, instruments, and use of technology and data need to be strengthened to better manage abstraction permits and water allocations, especially in view of the opportunities for accelerating private investment in small-scale irrigation.
- Incentive measures to encourage private investment in irrigation modernization as already offered through AIPA should be scaled up. Perverse subsidies for energy costs should be discontinued. Broader market competitiveness measures are needed to ensure export markets can be reached.
- Given Moldova's dependence on rainfed farming, and the potential of supplemental irrigation from groundwater, a comprehensive groundwater assessment is needed, combined with soil risk mapping. This could inform future policies for restricted and regulated use, if enforcement capacity is put in place.

Infrastructure and Revitalization of the Sector

Moldova's irrigation and drainage infrastructure was built during the 1970s and 1980s, and is now largely dysfunctional and smaller than in the 1990s, when the area was estimated to be 310,00 hectares. There are 77 central irrigation systems along the Dniester and Prut rivers with a *design* capacity to irrigate about 108,000 hectares of land. However, 42 percent are obsolete, 31 percent are nonfunctional, and only 27 percent have limited functionality.

Irrigation rehabilitation started with the support of the Sustainable Development Account Moldova³⁶ (SDA). Ten large irrigation systems were built of a high standard with fully pressurized supply, covering a command area of 13,500 hectares, and their management transferred to 10 WUAs.³⁷ Various factors, discussed in chapter 3, have hindered the rapid uptake of the irrigation services. Although increasing gradually, approximately 20 percent of the command area is now irrigated (estimated at 2,270 hectares in 2018), with uptake generally better along the Dniester than the Prut. In Moldova, centralized systems directly tap into the main rivers and are fairly modest in size, without the typical primary and secondary hydraulic infrastructure found in larger systems. Hence, typically one WUA would be assigned the management of one centralized system, with a cost structure representing that system.

A draft Government Action Plan for irrigation and drainage 2020–23 was published in March 2020.³⁸ It lays out a number of priority actions, such as the valuation and registration of irrigation assets, identification of investment needs for nonrehabilitated centralized systems, land registration and consolidation, liquidation of state irrigation enterprises, and the continued transfer of systems to WUAs for management and while transferring asset ownership to the Apele Moldovei in due course.³⁹ An assessment by SDA of 19 partially functioning centralized systems indicate approximately 18,000 hectares could feasibly be rehabilitated as systems have limited functionality and there is reportedly existing farmer demand.⁴⁰

This diagnostic estimates that in total 6,640 hectares is being irrigated in 2018, including 4,035 hectares under central systems and 2,605 hectares through small-scale private systems directly tapping into local streams of ponds⁴¹ (see chapter 2). In chapter 4, the expansion scenarios for central systems were developed based on the understanding that gradually all SDA rehabilitated systems would be fully used, and that another 26,000 hectares under central systems

would be rehabilitated. Small-scale private irrigation will play an increasingly important role and may see a large acceleration driven by improved market opportunities and further public support through subsidy schemes.

There is a need to prepare a comprehensive irrigation development strategy and prioritized investment plan, aligned with RBMPs and informed by climate-resilience proofing of the investments. The Holistic Regional Development future that simulated a tenfold increase from 6,640 to 62,000 hectares, showed hotspots and low reliability under climate change. Hence, the irrigation development strategy should reexamine and prioritize the rehabilitation of existing irrigation systems, as well as new systems, to avoid such hotspot basins, optimize economic returns, articulate measures to allocate water to the highest values in drier years, and explore cost-effective measures to augment supply from storage⁴² for both central systems and small-scale irrigation development. At the same time new norms are needed to avoid overdesign and tailor new investment projects to the needs of large and smaller farmers, reducing their life-cycle costs.

Enabling Conditions and Institutions for Irrigation

Government support to the agricultural sector is growing as economic opportunities are recognized. Public support mechanisms targeting small-scale irrigation development and use of drip and sprinkler irrigation are stimulating the transition to high-value agriculture, in part as a response to growing demand for high-value fruits and vegetables, including grapes and berries. The use of drip irrigation is increasingly taking place in Moldova, being the most common irrigation method for newly established fruit orchards and greenhouses. Government support is targeted to accelerate farmer-led investments in production, processing, and marketing of agricultural products, and includes training in business development.

During the last decade, Moldova's agriculture subsidy fund⁴³ doubled in value to US\$51 million, and benefited 4,357 farmers in 2018 alone.⁴⁴ The Agency of Interventions and Payments in Agriculture (AIPA) supports several measures to stimulate irrigated agriculture, including (1) cofinancing the establishment of new irrigated orchards, vineyards, and berry plantations; (2) cofinancing irrigation equipment (both on-farm and distribution networks); (3) subsidizing the cost of energy used for pumping water for irrigation; and (4) cofinancing the

Table 5.1 State Subsidies to Irrigated Agriculture, 2018

Subsidy type	Total subsidy paid, US\$ (MDL) million	Total number of beneficiaries	Irrigated hectares
Irrigation equipment (drip and sprinkler)	1.96 (34.6)	225	4,364
Energy subsidies for irrigation	0.22 (3.9)	30	2,898
Water tanks	0.20 (3.6)	11	35.3
New plantations	7.7 (125)	1,054	2,976 orchards 1,070 vineyards 169 berries

Source: AIPA data.

construction of water storage reservoirs. The subsidy comprises 50 percent of costs in most cases. These measures, except for the perverse energy subsidies,⁴⁵ are an important contributor to the development of the sector and help mobilize private investments. In 2018, subsidies disbursed for irrigation equipment of almost US\$2 million (MDL 34 million) have helped to stimulate private investments of three times this amount. The US\$7.7 million distributed (MDL 125 million) for new plantations helped to generate private investments of almost sevenfold that amount (table 5.1). Subsidies benefit both farmers located within central irrigation schemes, as well as those with their own private supply arrangements.

With an expected growing number of special water use abstractions for irrigation, the need to enforce permits and manage water use at the basin level is increasingly pressing. However, informal unauthorized irrigation from local reservoirs, ponds, and wells remains mostly unregistered and without an effective State Water Cadastre the management of water abstractions remains a challenge for Apele Moldovei. The demand for subsidies in support of irrigation expansion will most likely keep growing in the future and increased funding for subsidies needs to go together with comprehensive permitting, better water use allocation and monitoring, and advisory services to farmers.

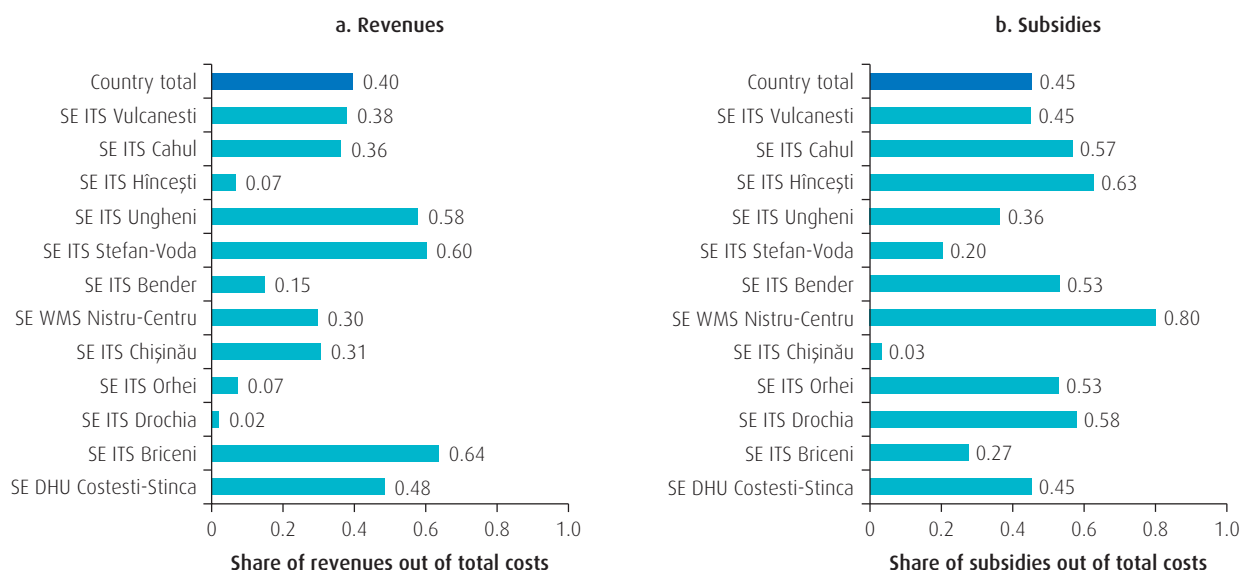
Before relaxing the restrictions on groundwater use for irrigation, adequate soil risk mapping, water quality assessments, regulations, and intensive enforcement mechanisms need to be put in place to avoid irreversible damage. Regulations for quality of irrigation water use are being developed to reduce the risk of irreversible soil degradation. The potential of groundwater development for supplemental irrigation use requires further investigation and the cultivation of salt-tolerant crops could be explored in areas with naturally occurring salinity.

The delivery of services under central irrigation schemes, requires the continued reform and capacity development of Apele Moldovei and WUAs. Although the draft Action Plan for Irrigation 2020–23 proposes further implementation of the Law by progressively transferring more systems to WUAs, capacities of Apele Moldovei must be strengthened to sustainably oversee and support WUAs in the management, operation, and maintenance of these schemes. The existing unit under Apele Moldovei has limited staff capacities and resources to adequately implement this role, and this assistance role is *de facto* implemented through the SDA project, requiring more institutional embedding within government structures. At the same time, the liquidation of state irrigation enterprises is needed to reduce the burden on the budget through unsustainable subsidies for their operation. Staff retrenchment costs for the liquidation of these companies will have to be absorbed by the state budget to enable the reform to proceed.

Enabling conditions that are important to help shift to higher-value agriculture are as follows (Mathematica Policy Research 2018): (1) enabling farmers' access to finance to purchase on-farm irrigation equipment and other inputs to change crops; (2) facilitating market access and postharvest infrastructure, as well as local labor; (3) tackling land fragmentation through longer-term land use and consolidation; and (4) providing advisory services to WUA and members in all aspects of irrigated agriculture and WUA management.

Performance of Irrigation Service Providers

The largely dysfunctional state of irrigation infrastructure under the state irrigation enterprises is a significant burden on the government's budget. Over MDL 16 million was transferred from Apele Moldovei

Figure 5.13 Shares of Revenues and Subsidies Out of Total Costs of Enterprises, 2016

Source: Financial records of state enterprises (SEs) under Apele Moldovei.

Note: WSS = water supply and sanitation; ITS = Irrigation Technological Stations.

for operational subsidies in 2016. Figure 5.13 illustrates that across the state irrigation enterprises, subsidies are generally larger than own revenues through irrigation fees, and most did not even cover half of the costs in 2016.

Because of their dilapidated state, several schemes do not provide any irrigation services. Of those systems that provide some level of irrigation service, crucial factors underpinning the losses include low volume of sales, inadequate tariffs, and high maintenance costs (Intexnauca 2018). Losses are covered by state budget subsidies, although there is a lack of transparency in how these are determined and allocated. Tariffs charged by state irrigation companies do not consider full operational costs, also because of the unreliable service.

Cost recovery tariffs will need to be established from the start once schemes are transferred for management to WUAs. In case further investments in public irrigation systems are provided and transferred to WUAs, adequate monitoring, oversight, as well as advisory services to WUAs and their members will be required to support the development of the nascent WUA model.

A preliminary analysis of the financial situation of these 10 WUAs shows that they are slowly on track for financially sustainable operations, although significant barriers remain. Although on average the command

area per WUA is approximately 1,250 hectares (ranging from 500 to 3,400 hectares), the area irrigated in 2018 per WUA varied greatly from only 30 to approximately 600 hectares (average of 185 hectares per WUA) and membership numbers vary greatly, from approximately 50 to more than 2,000, because not all farmers are willing to become members and some WUAs are dominated by large land owners. Tariffs are approved annually by the WUA and for 2018 varied in the range of approximately 3–4.5 MDL per cubic meter of water (US\$0.20 to US\$0.25 per cubic meter) provided through metered hydrants at the fields. This is a considerable rate, complemented with annual membership fees of approximately MDL 200–350 (Mathematica Policy Research 2018).

Analysis of WUAs' financial statements over the period 2016–18 indicates that their revenues have been increasing. However, schemes remain volatile because of irrigation being a supplemental source to rainfed farming and because of the influence of a few large water users. Large water users have helped to sustain revenues and build cash reserves in some WUAs (Mathematica Policy Research 2018). Positive profitability ratios were found for most WUAs: two out of 10 demonstrated negative profit margins in 2018. No significant assets were created by the WUAs, which is understandable as WUAs' mandate is primarily to manage state-owned assets (under a gratuitous lease arrangement). In the future, the asset base of WUAs

might increase as a result of the purchase of moveable assets like sprinklers, financed through reinvestment of WUAs' cash reserves.

The experience in 10 WUAs showed that larger farmers may be in a stronger position to increase irrigation use and high-value agriculture cultivation in the future, although small farmers could still benefit indirectly from increased demand for and prices of their land plots. The long-term sustainability of the WUAs operating these systems will depend heavily on the growth in irrigation use and the expansion of their user base. The WUAs in the Dniester, which had more experience with irrigation and high-value cultivation before system rehabilitation, are more likely to be sustainable than those in Prut. Finally, when considering rehabilitation and replication of the WUA model, it is important that systems are designed to better serve smaller farmers (in terms of pumping capacity, distance of hydrants), that systems are prioritized in localities in which some prior experience with high-value cultivation exists, where market linkages are in place and land consolidation has progressed or farmer networks are strong. Handholding support to WUAs will remain critical. To reduce the volatility in revenues of WUAs because of fluctuating weather-dependent irrigation needs, mandatory membership fees could be introduced (Mathematica Policy Research 2018).

Notes

1. For the purpose of this report the water services pillar of the water security framework is split out into separate water supply and sanitation and irrigation service delivery policy streams. The resilience and water resource management pillars are combined into one policy stream.
2. Some questions remain about the mandate for water quality monitoring which are expected to be resolved.
3. Specifically, the European Union; the European Bank for Reconstruction and Development; the European Investment Bank; bilateral governments such as Austria, Germany, Switzerland, Sweden, and the United States; as well as UN organizations.
4. The remaining 699 localities are too small to have an independent administration and are grouped with other towns or communes.
5. The frozen conflict on the left bank with Transnistria further complicates such transboundary basin plan development.
6. Currently under revision and expected to be issued in 2020.
7. An agricultural strategy and climate change adaptation strategy have been elaborated and touch upon several water-related aspects, albeit not with great specificity.
8. MDL 150 million has been allocated for local rural development, under which are included water and sanitation measures.
9. A fee of 0.3 MDL per cubic meter is required for all abstractions of groundwater and surface water (not for low-capacity shallow wells for private use).
10. This institution was established under the Government's Decree No. 1249 of December 19, 2018, as a public institution responsible for the day-to-day management of projects funded by international financial institutions.
11. The review was based on the Moldova BOOST database, National Bureau of Statistics, and OECD International Development Statistics.
12. Total public spending for the water sector presented does not include irrigation related investments that were implemented under the Transition to High Value Agriculture (THVA) Project of the Millennium Challenge Corporation's compact in Moldova (a total of MDL 2 billion from 2010 to 2015) as this value could not be broken down. Substantial changes in the classification of expenditures were made in 2016, making it necessary to make some assumptions when comparing items across this time period.
13. This includes investments for improving and expanding water supply, sanitation, and wastewater collection and treatment for universal access in rural and urban areas. Hence it is much higher than the estimate of US\$350 million for water supply expansion alone under the Holistic Regional Development scenario presented in the Economic Outlook of the water futures section that only includes expansion to 80 percent access in rural areas and 100 percent access in urban areas, and does not include sanitation and wastewater collection and treatment.
14. Own revenues refer to charges and fees raised by budget entities. Tariffs from corporatized service providers and state-owned enterprises do not show on the budget.
15. As part of the EU Association Agreement, a focus on preparing for future compliance with the European Urban Wastewater Treatment Directive will likely continue to mobilize capital subsidies (from grants and loans) to urban areas and larger agglomerations.
16. Lipcani, Costesti, Braniste, Valea Mare, and Giurgiulesti. Analyses are conducted monthly including a set of hydrochemical and hydrobiological parameters, as well as the quality of sediments.
17. Most stations tap into the Badenian-Sarmatian aquifer complex.
18. By Government Decree No. 491 of 23/10/2019, a working group was formed under Apele Moldovei's oversight and an IT company has been recruited to further develop the system.
19. For example, for hydrometeorological data storage and flood modeling (Aquarius) and for water allocation and planning (WEAP).

20. Accessible with user accounts under <http://rch.giscuit.com/adapt/dist/#/more>.
21. Abstractions with a capacity of above 10 cubic meters per day require permits and registration in the system.
22. Submeasure 1.7 as per http://aipa.gov.md/sites/default/files/Brosura_AIPA_en.pdf.
23. Certain assets, such as the large reservoirs at Costești-Stânca used to be under the management of dedicated state enterprises. Several years ago, assets were transferred to the Agency for Public Property and only in March 2020, they have been transferred back to Apele Moldovei, liquidating the state enterprises.
24. Thus far their members are local public authorities, public health centers, civil society organizations, and in the subbasins of the Raut and Bic rivers, Apele Moldovei and the RDA are also members.
25. Also 14 subbasin committees were formed, and some have managed to develop subbasin plans with the support of development partners.
26. Earlier drafts referred to regional zones (north, center, south).
27. Piped services on premises also includes piped self-supply from wells. Some discrepancy with national data may exist because of definitions.
28. As per UNDP (2007), 80 percent of Roma live in informal housing without basic water supply and sanitation provision.
29. Nisporeni company is the only company with multiple municipalities as shareholders. It is a successful example, although the complexity and facilitation required for this model has hindered its replication elsewhere.
30. The Association of Local Governments (CALM) provided on-demand advisory services to municipalities and their service providers to comply with legislation and regulatory requirements.
31. Preferably while consolidating the NEF and NRDF.
32. This is an ambiguous aspect of Law 303 that stipulates that licenses are required for all centralized systems. Only one commune operator is licensed as of today (that provides all three services).
33. The WUPI is a composite measure of ten dimensions of key performance indicators. See also <http://www.danubis.org>
34. World Bank (2019a) based on 41 water utilities with data available in IBNET.
35. As compared to highly inefficient water use in the 1990s, with per capita consumption as high as 460 liters per person per day.
36. Investments were funded through the Millennium Challenge Cooperation (MCC) under the Compact program 2010–15.
37. There are three WUAs that manage nonrehabilitated systems (transferred in 2014, 2017, and 2018) for 2,000 hectares.
38. This decree was approved at the time of writing.
39. A draft decree was published in March 2020 that transfers the assets of five state irrigation companies from the Public Property Agency to Apele Moldovei. It was not approved at the time of report writing.
40. Earlier assessments by Apele Moldovei indicate the feasibility for rehabilitating irrigation systems for 26,000 hectares
41. The draft Irrigation Action Plan states actual physically irrigated area of 3,400 hectares for 2018 under central systems.
42. Irrigation potential from the Costesti-Stanca reservoir and Cahul lake on the Prut and from the Dubasari reservoir in the south are proposed for further investigation as per FAO (2015). High salinity may be a constraining factor.
43. Under the National Fund for Agriculture and Rural Development (NFARD).
44. Agency for Interventions and Payments in Agriculture.
45. Although there is a rationale to incentivize investments that allow farmers to move to modern irrigation practices of high value crops, the rationale for continuing the operational subsidy is not justified as recurrent costs should be internalized in the farmers' business models.

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CHAPTER 6

Recommendations and Pathways to Water Security

Exacerbated by the COVID-19 pandemic and the resulting economic slowdown, Moldova is faced with a challenging development path. Moldova's future climate is uncertain, although a drying effect with more frequent and intense droughts and floods is most likely. Water security underpins much of Moldova's ability to rekindle dynamism in its economy. This can be achieved by harnessing its water resources, such as through modernizing agriculture to help diversify the economy and increase exports. Water security also means that citizens—both urban and rural—can live healthy and productive lives, with livelihoods resilient to droughts, pollution, or environmental degradation.

Although physical water resource endowments are not a current constraint for development, water security outcomes are far from optimal. Rather, water security outcomes are limited by infrastructure, investments, financing, management capabilities, and enabling policies. When examining three future development paths, with increasing investments in infrastructure, as well as increasing water demand, physical water resource endowments will impose only limited constraints to development. However, in scenarios of high growth in water demand, specifically because of irrigation expansion, several catchments become hotspots in periods of droughts during which reliability is compromised, and these effects are exacerbated by climate change.

Although the water balance assessments presented in this diagnostic have inherent limitations because of data granularity and assumptions, the model can

be instrumental for Moldovan experts and decision-makers to further explore water resource availability when considering specific investment projects, such as irrigation system expansion. Going forward, it is recommended to refine the model to assess specific effects at the catchment level under various future climate scenarios. Such analysis could be enriched with integrating measures that mitigate shortages, such as seasonal storage, demand management, and water efficiency measures. The better understanding gained from Moldova's water resources endowments will hopefully pave the way for investments and policy measures that are evidence based and robust in the face of climate uncertainty and that will deliver concrete water security benefits.

Given barriers to sector performance, Moldova requires a comprehensive and long-term approach to addressing the critical challenges facing its water sector. It needs to create an enabling environment so that accelerated investments turn into better water supply, sanitation, and irrigation services; management capacities are put in place to ensure water resources are leveraged sustainably now and in the future; and that resilience is built into the system.

Derived from the analysis in this diagnostic, this chapter aims to summarize the key challenges facing Moldova in ensuring its water security and suggests a possible roadmap for Moldova's decision makers. As Moldova continues its path toward building water security, the roadmap seeks to support decision makers in phasing the implementation

of the recommendations: foundational, short- and medium-term actions, as well as ongoing measures. Foundational measures underpin the critical barriers to performance and should be addressed as a matter of priority. Actions required in the short and medium term, although important, will likely require sequencing. Ongoing actions, such as the expansion or rehabilitation of infrastructure, should be done programmatically and in a phased approach in line with available finances and capacities.

Recommendations are organized around three critical pillars of Moldova's water sector performance that—if barriers are addressed—can help deliver economic, social, and environmental benefits:

- Water resource management and resilience
- Water supply and sanitation services
- Irrigated and climate-resilient agriculture

Recommendations for Water Resources Management and Resilience

Even in a context of rich water resources endowment, functions such as drought, flood, and river basin planning and management; water allocation; and monitoring and forecasting are critical to manage trade-offs in vulnerable catchments and ensure resilience under progressive climate change. Performance is not only hampered by infrastructure and financing, but also by weak institutions. The stalled

reform of Apele Moldovei unfortunately has had negative consequences, such as limited basin-level operational planning and allocation management, incomplete water permit registration, inefficient use of scarce financial resources because of its subordinate loss-making irrigation enterprises, limited action on flood protection, and a lack of leadership on water supply and sanitation (WSS), mostly a *de jure* mandate. An integrated approach at the basin level, informed by River Basin Water Management Plans (RBMPs) and aligned with national and regional development plans is needed to prioritize investments, to manage water across users, and to mitigate water-related risks. As depicted in figure 6.1, foundational actions relate to the clarification of the institutional framework for water resources management and the need to expedite the long-anticipated reform of Apele Moldovei.

This reform should align with the basin-level water resource management (WRM) approach, linked to empowered basin councils, a capacitated management agency, and with RBMPs linked to financial and human resources to implement priority measures. It should improve the water management information systems and implement flood protection and drought management. Moldova must strengthen its information and management systems for better water body quality monitoring, for water abstraction management, and flood and drought risk reduction. To increase funds for WRM, the financing mechanism for water management and environmental protection need to be reviewed and revised, with future earmarking of water-related fees and levies to secure allocations for WRM.

Figure 6.1 Roadmap for Water Resource Management and Building Resilience

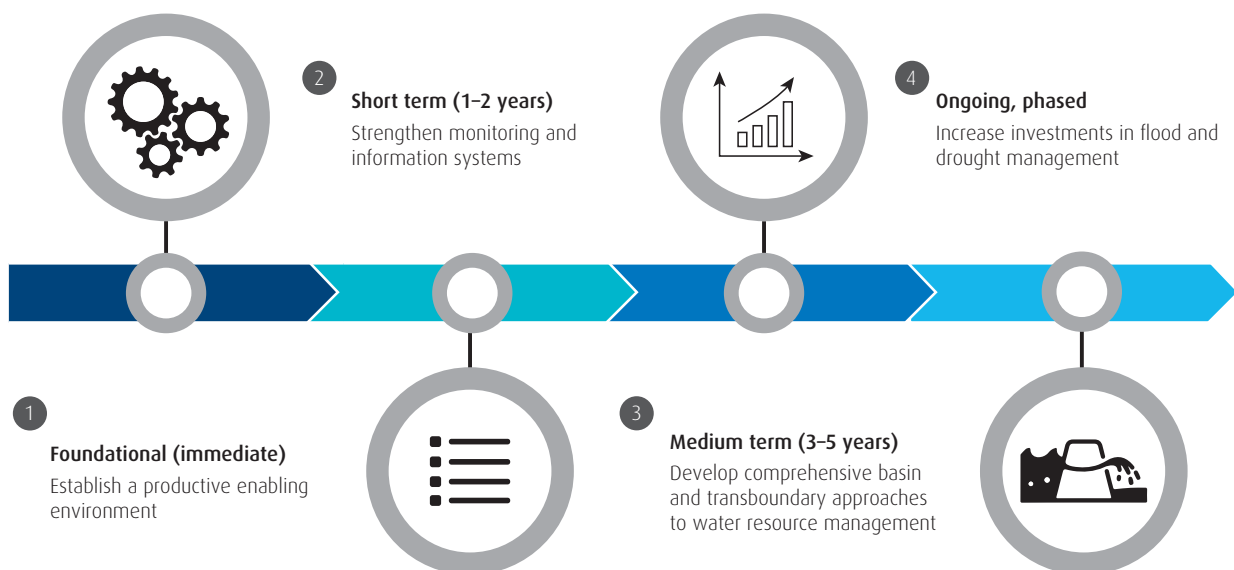


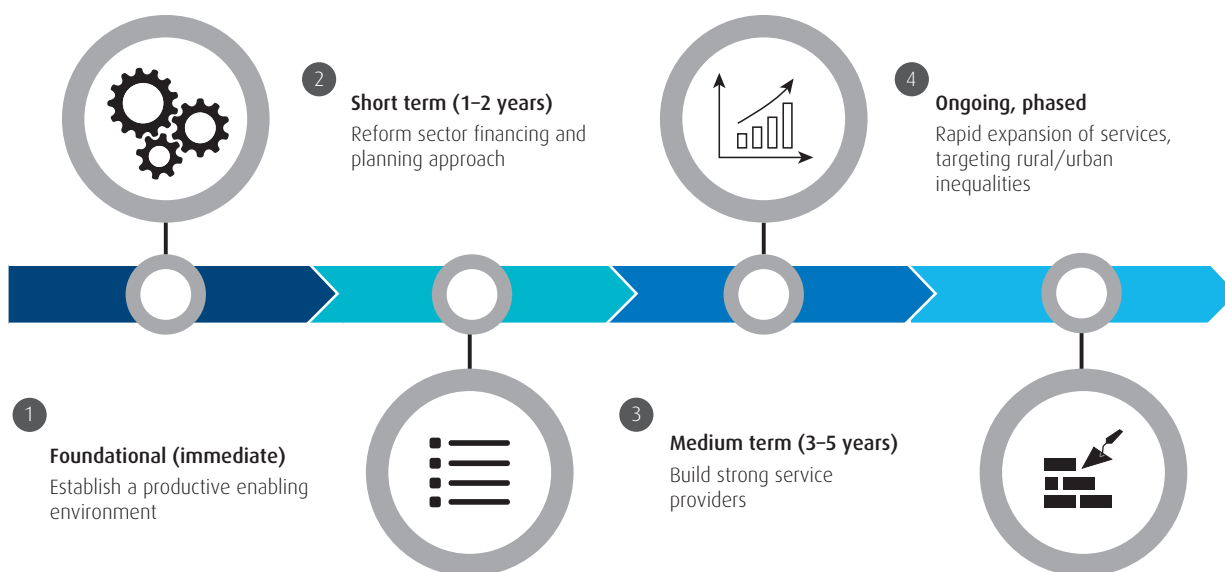
Table 6.1 Pathways to Water Resource Management Security and Resilience

Recommendations	Key actions	Priority
1. Establish a productive enabling environment	<ul style="list-style-type: none"> Finalize institutional reform of Apele Moldovei, clarifying its mandate and organizing its implementation structure at the basin level; secure human and financial resources for its operation. Retain public good assets on Apele Moldovei's balance sheet and ensure adequate arrangements for their maintenance and operation. This needs to go together with capacity development of the agency in its mandate, as well as the empowerment of basin councils. Do not overload Apele Moldovei with assigning new water supply and sanitation mandates and allow Apele Moldovei to concentrate on core water resource management (WRM) functions. 	Immediate
2. Strengthen monitoring and information systems	<ul style="list-style-type: none"> Strengthen information and management systems for better water management: for example, on water quality monitoring, groundwater assessment, hydrotechnical constructions, and flood and drought forecasting. Operationalize allocation planning and management. Establish and fully operationalize the State Water Cadastre combined with enforcement measures, harnessing the roles of the Environmental Agency and Apele Moldovei. 	Short term
3. Develop comprehensive basin and transboundary approaches to water resource management	<ul style="list-style-type: none"> Strengthen financing mechanisms for holistic WRM. Restructure water-related fees and levies to fund River Basin Water Management Plans (RBMPs) and increase budget allocations and continue to strengthen the nascent basin-level WRM approach. Further develop transboundary basin approaches building on work already carried out, and complete work on the effects of the Dniester hydropower complex. 	Medium term
4. Increase investments in flood and drought management	<ul style="list-style-type: none"> Increase investments in flood and water management, focusing on infrastructure, watershed rehabilitation and nature-based solutions, and preparedness measures. 	Ongoing phased approach

Recommendations for Water Supply and Sanitation Services

Performance in WSS is constrained by large coverage gaps in rural areas: only one in eight rural households uses a flush toilet and only one in three rural citizens receives a publicly provided water supply service, and often water quality is compromised. Efforts to improve services in rural areas and towns to close access gaps, increase productivity, bring social equality, and curb pollution of water sources will be critical to Moldova's water security. Institutional weaknesses underpin many of the infrastructure, information, and finance gaps in the sector, with missing institutional functions posing a barrier to overcoming low levels of coverage, inequalities and sustainability risks in the sector. These missing functions relate to national investment

planning, project preparation, quality assurance, innovation and performance initiatives, sustainability monitoring and support to service providers in urban and rural areas to facilitate aggregation, and regionalization of operators. Funding for the sector remains fragmented and has not yet been consolidated in a coherent national program and national WSS fund. Poor performance, lack of results orientation, and major governance issues hamper the effectiveness of the National Ecological Fund (NEF). Utilities have been increasing their efficiency, but there remains room for improvement through a more systematic approach. As depicted in figure 6.2, foundational actions relate to strengthening the missing functions by building capacities and developing instruments, whereas a national WSS development entity needs to be established in the medium term.

Figure 6.2 Roadmap for Water Supply and Sanitation Services**Table 6.2 Pathways to Water Supply and Sanitation Services Security**

Recommendations	Key actions	Priority
1. Establish a productive enabling environment (policies and institutions)	<ul style="list-style-type: none"> Strengthen WSS sector development functions, with a focus on investment planning, implementation support, quality assurance and results monitoring, support to service providers and regionalization, regulatory compliance, and innovation (with a view to establish a WSS sector development agency) 	Immediate
2. Reform sector financing and planning approach (legislation and governance reform)	<ul style="list-style-type: none"> Develop a national investment plan and financing framework. Consolidate funds into a national WSS program. Mobilize more resources from tariffs, government funds, and transfers; prioritize subsidies to areas with the most need; and tackle legacy of the underperforming NEF. Develop mandatory connection policies, combined with social support mechanisms to address affordability concerns. 	Short term
3. Build strong service providers (information and capacity building)	<ul style="list-style-type: none"> Transfer sector functions to dedicated WSS lead entity. Establish a performance and efficiency improvement program for utilities. Deliver result-based grants and access to financing facilities for utilities to stimulate gains in energy efficiency, nonrevenue water. 	Medium term
4. Promote rapid expansion of services, targeting rural-urban inequalities (infrastructure)	<ul style="list-style-type: none"> Focus on inclusion: adopt a portfolio approach for investments and service delivery solutions. <ul style="list-style-type: none"> Regionalization: expanding services by licensed district operators Oversight and support to local municipal operators in the interim Individual self-supply solutions in remote villages Leverage the role of regional development authorities in the delivery of a programmatic WSS investment plan. 	Ongoing phased approach

Note: RDA = regional development authority.

Recommendations for Modernizing Irrigated and Climate-Resilient Agriculture

The performance of irrigated agriculture remains poor because of the lack of an integrated vision of irrigation and agricultural development, weak institutions, and limited investments. Apele Moldovei's reform, including the liquidation of its irrigation companies, combined with increased support to the agency to replicate the nascent WUA model are required to move forward.

A national irrigation development strategy and investment framework is needed, informed by climate-resilience proofing and economic analysis of well-targeted priority investments and should be embedded in a broader agricultural modernization agenda. The strategy should include a portfolio approach, relying on a mixture of centralized systems for high-value agricultural production, farmer-led, private, small-scale irrigation development, and improved climate-smart agriculture for commodity crops. WUAs and farmers should be supported at the national and local

levels through technical assistance and investments to facilitate access to finance and scale up subsidies for on-farm investments. Enabling market conditions and value-chain linkages need to be put in place to ensure that investments translate into economic outcomes. The potential of groundwater development

for supplemental irrigation use requires further investigation and risk assessments. Figure 6.3 depicts a roadmap to overcome these barriers, with foundational actions taken to establish a comprehensive strategy and an investment planning and prioritization exercise and the completion of Apele Moldovei's reform.

Figure 6.3 Roadmap for Modernizing Irrigated and Climate Resilient Agriculture

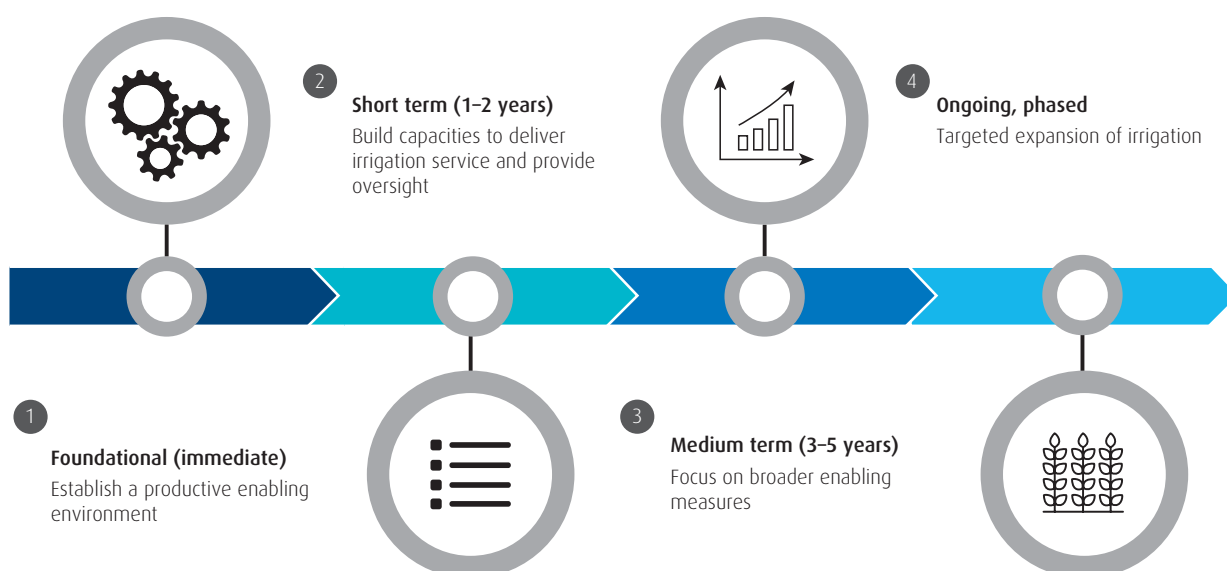


Table 6.3 Pathways to Modernizing Irrigated Agriculture

Recommendations	Key Actions	Priority
1. Establish a productive enabling environment (legislation and governance reform)	<ul style="list-style-type: none"> Finalize institutional reform of Apele Moldovei as the agency to oversee irrigation services and water user associations (WUAs). Prepare comprehensive irrigation development strategy and prioritized investment plan. 	Immediate
2. Build capacities to deliver irrigation services and provide oversight	<ul style="list-style-type: none"> Develop enabling measures to support WUAs and farmers: <ul style="list-style-type: none"> Create favorable terms to access to finance Facilitate access to markets and value chains Support land consolidation and longer-term land leases Provide advisory services to WUAs and farmers Develop enabling measures to support private sector development: <ul style="list-style-type: none"> Scale up subsidy measures to encourage private investment in irrigation modernization as already offered through the Agency for Interventions and Payments in Agriculture (AIPA). Revisit energy subsidies 	Short term
3. Focus on broader enabling measures	<ul style="list-style-type: none"> Improve Apele Moldovei's capacity to monitor and enforce irrigation water permitting requirements, better leverage technology, and oversee WUAs. Pursue liquidation of state irrigation enterprises. Retrenchment costs need to be absorbed by state budget to enable reform, and finances saved from subsidies allocated for the expansion of schemes. Carry out a comprehensive groundwater and soil risk mapping assessment Develop enabling measures to support rainfed farmers: <ul style="list-style-type: none"> Large-scale adoption of climate-smart water and agronomic practices by farmers Development and implementation of risk mitigation instruments, such as weather-based insurance National incentive and extension programs 	Medium term
4. Promote targeted expansion of irrigation	<ul style="list-style-type: none"> Increase investments for rehabilitation and expansion of central systems and replicate WUA model: transfer management, operation and maintenance of functional schemes, and development of capacity of WUAs. 	Ongoing phased approach



APPENDIX A

Methodological Underpinnings

This appendix provides a summary of the key input data and assumptions used in the water balance assessment for the 2018 baseline, the water futures scenarios, and the associated economic analysis.¹ It reflects changes and refinements that were made to the model up to February 2020. Training on the Moldova Water Evaluation and Planning (WEAP) was provided in January 2020 to approximately 15 professionals in Moldova and the model was made available to participants from the Ministry of Agriculture, Regional Development and Environment (MARDE), and Apele Moldovei. This appendix comprises five sections. The first section provides an overview of the approach to the water balance modeling, using the WEAP software, including temporal and spatial characteristics. The second section describes the analysis of supply to characterize water resource endowments, followed by a third section detailing assumptions used for water demands in baseline 2018 and future scenarios. Fourth, results of the water balance calculations are summarized in support of chapter 4. Lastly, key assumptions and data from the economic analysis are presented.

Overview of Modeling Approach

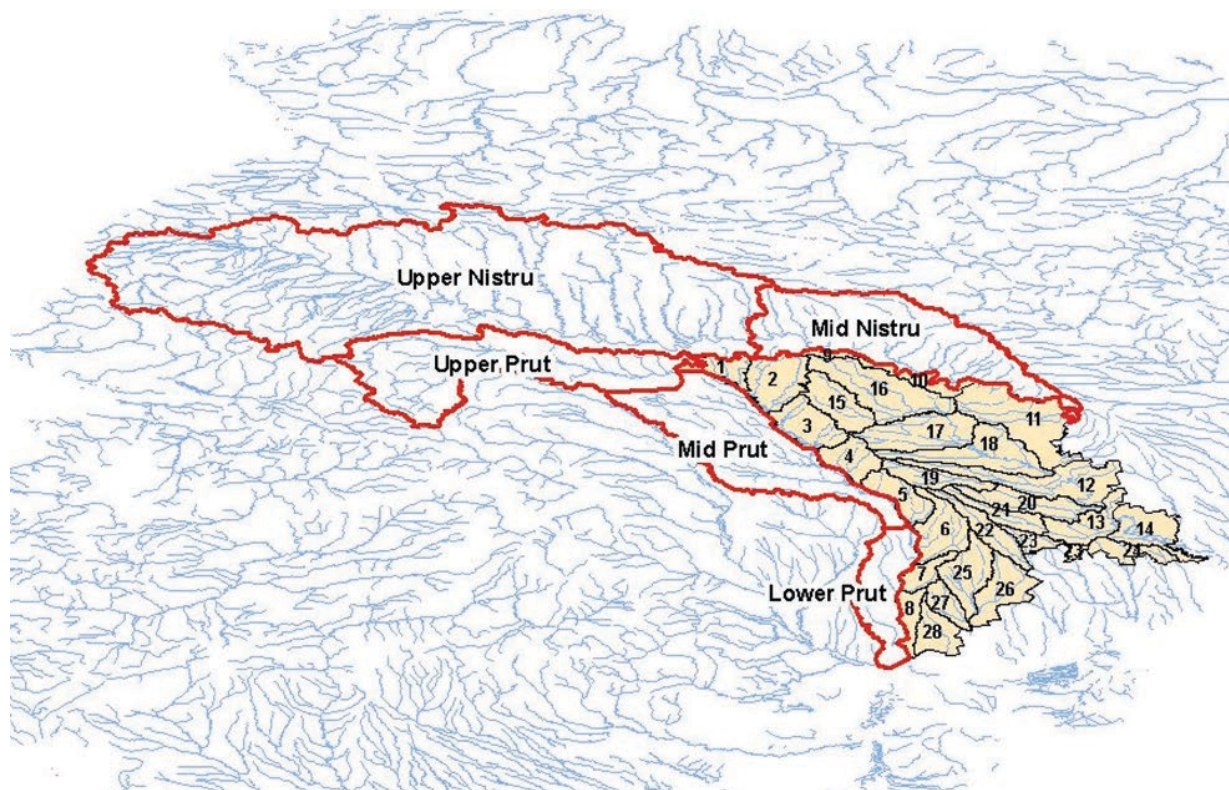
The WEAP model uses forecasts of changing water demand and supply to estimate potential water shortages under climate change in various sectors

of water use. WEAP is a software tool for integrated water resources planning that provides a mathematical representation of the river basins encompassing the configuration of the main rivers and their tributaries, the hydrology of the basin in space and time, water demands, and reservoir storage (Sieber and Purkey 2007). Computations are performed on a monthly timescale for a historical period that effectively reflects the current hydrology in WEAP (current meaning as of 2018). For the purposes of estimating water demand, and for reporting water balance results, the water supply and demand results were aggregated to a 28-catchment scale. This level of detail is greater than prior WEAP analyses for Moldova (see Sutton et al. 2013; Industrial Economics, Incorporated 2016), which were conducted for five subbasins in Moldova. Sensitivity analyses were conducted to estimate the effect of changes in hydrology (runoff) that might result from climate change in Moldova and its surrounding areas that are hydrologically connected.

Scope

Geographic Scope

The analysis is conducted at the scale of 28 internal Moldovan catchments, as shown in map A.1, with a further split of six of these catchments that are

Map A.1 Regional Geographic and Catchment Domain for WEAP

shared with the Transnistria autonomous region. This was done to reflect the possible differences in water management policy on the left and right banks of the Dniester (also called Nistru) river. Furthermore, the broader water supply analysis reflects consideration of transnational water flows from Ukraine and Romania, specifically from catchments of the upper, mid-, and lower Prut and the upper and mid-Dniester.

Crops

For irrigation and other subsequent economic analysis, and based on the abilities of existing crop models, consultation with Moldovan counterparts, and the availability of appropriate data to support modeling, the following crops were quantitatively evaluated to assess their irrigation water demand beyond the water requirements met by rainfall: wheat, maize, alfalfa, apples, wine grapes, vegetables, sugar beets, potatoes, and rainfed pasture (grasslands). An assumed crop mix was then used to model irrigation water demand (see the Results Summary Water Balance Assessment WEAP section), based on the Food and Agriculture Organization (FAO) data on local crop mixes and crop water requirements. Based on previous analysis, changes in the crop water demand under varying crop mixes do not have a significant effect on the overall water balance

analysis; however, changes in management of water, such as the techniques used for irrigation and their associated water use efficiencies, can have a significant effect on overall water balance. Crop yields were not modeled in relation to the WEAP but were used in the economic analysis, using the DSSAT model.²

Period

The model for the baseline 2018 uses inputs on water runoff in rivers to estimate total water supply. The data, provided by Apele Moldovei and the State Hydrometeorological Service, reflect a long-term average runoff in the historical period 1950–2016. This current supply (not to be confused with drinking water supply, which is a subset of overall water demand) is then compared with water demands for the baseline year 2018. For the three water futures, the projection year 2030 was used, estimating future demand in 2030. Because of uncertainties in overall economic and demographic development, it was agreed to use 2030 as the year for water future assessments.

Reservoir Locations and Volumes

These were used for the already existing five sub-basin models developed earlier, based on data provided

by Apele Moldovei, the United Nations Economic Commission for Europe (UNECE), FAO (2010), and Cazac and Boian (2008), who summarize reservoir and storage pond volumes by location within Moldova. In total, they report that Moldova has 1.1 billion cubic meters of storage, of which 108 million cubic meters is in the Lower Dniester Basin, 20 million cubic meters is in the Reut basin, 219 million cubic meters is in the Upper Dniester basin, 41 million cubic meters is in the Bregalnica basin, and 720 million cubic meters is in the Prut basin. For several key reservoirs, these sources also provide sedimentation information, which can be quite significant in Moldova because of significant erosion in the region. For example, the volume of the Dubasari reservoir in the Upper Dniester was 486 million cubic meters of storage when constructed in 1954, but has since declined 56 percent to 214 million cubic meters because of sedimentation.

Transboundary Flow

These agreements are also a critical determinant of water available in Moldova, because the Prut and Dniester rivers are shared with Romania and Ukraine, respectively. Although there are cross-boundary treaties for both the Dniester (signed with Ukraine on November 29, 2012; took effect in 2017) and the Prut (signed with Romania on June 28, 2010; took effect in early 2013), there are no flow requirements specified. Negotiations with Ukraine on the flow regime of the hydropower complex and the Dniestrovsky reservoir have stalled.

Water Supply

Water supply was estimated using a combination of analyses developed by the State Hydrometeorological Service and Apele Moldovei, as well as the CLIRUN model, as described in detail in the Overview of Sectoral Water Demand Analysis section.

Environmental Flow Requirements

In the absence of environmental flow requirements, the model has assumed a minimum flow requirement of Q10 for each of the internal catchments in Moldova³ (the 10th percentile flow, meaning the flow that is equal or exceeded 90 percent of the time, based on a 50-year period) This means that Moldova's water resources are reserved for environmental purposes at specific nodes in the WEAP system, essentially at the outflow point for each of the 28 catchments. For the downstream outflow of the country at the Prut, a Q10 flow has been used and for the outflow of the Dniester to Ukraine, a Q5 flow of 80 cubic meters per second has been used in line with references in OSCE and UNECE (2005). The model can include additional

nodes, or revised flow requirements, for environmental flow compliance at various flow levels if additional information becomes available.⁴ Sensitivity analyses were also performed for Q25 flow regimes.

Models Used

The following models were used for the water balance assessment:

CLIRUN

Monthly runoff in each catchment can be estimated using this hydrologic model widely used in climate change hydrologic assessments. CLIRUN models runoff as a lumped watershed with climate inputs and soil characteristics averaged over the watershed, simulating runoff at a gauged location at the mouth of the catchment. CLIRUN can run on a daily or monthly time step. Soil water is modeled as a two-layer system: a soil layer and a groundwater layer. These two components correspond to a quick and a slow runoff response to effective precipitation. A suite of potential evapotranspiration models is available for use in CLIRUN. Actual evapotranspiration is a function of a potential and actual soil moisture state following the FAO method. CLIRUN can be parameterized using globally available data, but local databases can also be used to enhance the data for the models. CLIRUN produces monthly runoff for each watershed, which were then used as inputs for the WEAP model.

WEAP

WEAP is a software tool for integrated water resources planning that provides a comprehensive, flexible, and user-friendly framework for planning and policy analysis. River basin software tools, such as WEAP, provide a mathematical representation of the river basin encompassing the configuration of the main rivers and their tributaries, the hydrology of the basin in space and time, and existing, as well as potential, major schemes and their various demands of water. WEAP was developed by the Stockholm Environment Institute (SEI) and is maintained by SEI-US.

Overview of Water Supply Analysis

Water Supply Modeled in WEAP

Supply in the Moldova WEAP comprises of two sources: surface water and deep groundwater. Surface water is estimated as runoff in the surface water river system and consist of two components: water within the river system, and local headwaters

interacting with the surface water system (shallow groundwater). Runoff in rivers is the difference between precipitation and evapotranspiration; as a result, runoff is affected by both the temperature and the precipitation indicators. Deep groundwater is assumed to be an inexhaustible source (at least in the short term) for the purpose of the modeling, because regeneration rates and the long-term sustainability of deep groundwater were not modeled because of data limitations and the complexity in modeling these processes. Water supply for the current climate was estimated through the following three steps and used to develop a consistent hydrologic tool to estimate runoff under two forecasted future climate predictions.

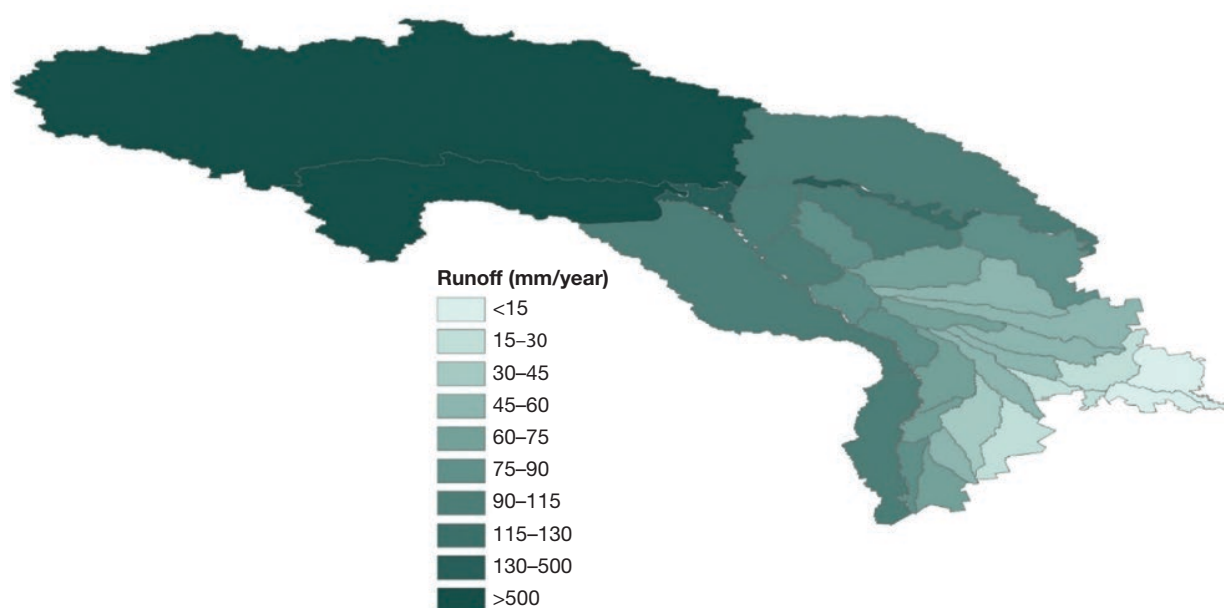
- For current climate (1950–2016), a regional scale runoff model developed by local Moldova researchers was used based on local hydrographic station data, provided by Apele Moldovei/State Hydrometreological Services (SHS).
- The rainfall-runoff model, CLIRUN, was then calibrated to align estimates of current rainfall and temperature to the results of the current runoff estimates.
- Future forecasts of climate were used, specifically monthly rainfall and temperature, from two General Circulation Models (GCMs), as inputs to CLIRUN to generate future runoff projections. The GCMs were selected to effectively capture the range of uncertainty in future rainfall, temperature, and runoff across more than 20 GCMs that have been applied by the UN Intergovernmental Panel on Climate Change (IPCC) for their Fifth Assessment (described in more detail later).

Current Runoff: Baseline 2018

Current monthly river runoff is estimated using a regional scale rainfall-runoff model developed by analysts in Moldova's SHS and Apele Moldovei. Current water flow across a 30×30 m gridded region including and surrounding Moldova was estimated, as shown in map A.2. The model used historical monthly temperature and precipitation data from SHS for the years 1950–2016⁵ to capture historical rates of interannual variability in runoff. As a general principle, river runoff is calculated in the closing sections of water management sites, or catchments, and typically these sections close on hydrometric gauges. Modern water management zoning of the basins of Moldova, and the Dniester, consists not only of water management sites that are closed at gauging stations, but also of sites that do not have monitoring in the closing range.⁶ For other sites, runoff can be calculated from constructed runoff maps, consistent with regulatory documents of Ukraine and Moldova.⁷ Detailed records on how these runoff maps were established can be found in the Moldova WEAP Technical Report (Industrial Economics 2020). Verification of the calculated data was carried out for catchments with hydrometric stations.⁸

The results of the detailed spatial analysis of runoff are then aggregated to the catchment level indicated in map A.1 so that the data can be used in WEAP. Table A.1 lists the annual 50th percentile (median) pattern of water supply that is generated from the SHS rainfall-runoff model, aggregated to

Map A.2 Long-Term Median (Q50) Annual Runoff in the Republic of Moldova and Surrounding Basins



the 28-catchment level used in the Moldova WEAP (summarized by four groupings of catchments), as well as the five larger catchments modeled outside of Moldova (map A.1). The corresponding monthly results show some degree of drying in southern Moldova throughout the year. In general, however, runoff is highest in the late spring and lowers in the late summer months. Under climate change

scenarios, runoff declines greatest in months when crop water demand is highest.

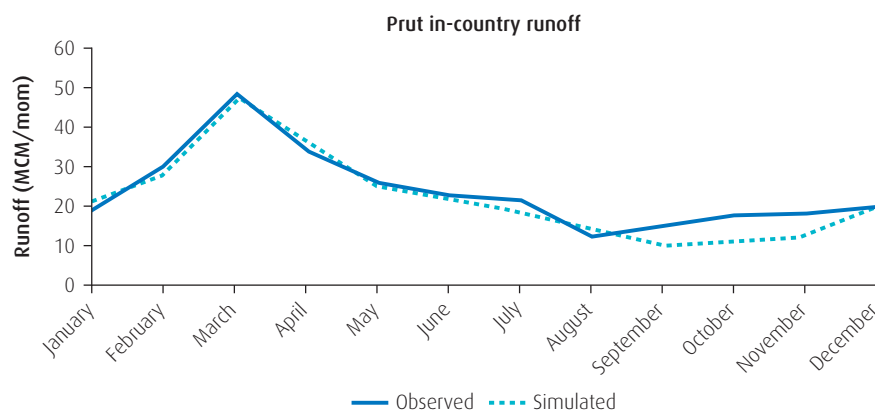
The results from the runoff data and model developed by Apele Moldovei and SHS were used to calibrate the runoff model, CLIRUN, which is described in Industrial Economics (2020). The calibration process led to certain changes to the existing CLIRUN model to ensure

Table A.1 Annual Runoff (Q50), Current Climate from SHS Modeling, by WEAP Catchment

Grouping		Catchment	Annual runoff (m ³ /s)	Annual runoff (mm/y)
Prut	Prut-Lopatnic	1	36	137
	Prut-Racovat-Ciuhur	2	66	115
	Prut-Camenca-Sovat	3	52	99
	Prut-Garla Mare-Delia	4	28	77
	Raut-Cula-Draghinici	5	33	84
	Prut-Lapusna-Sarata	6	37	70
	Prut-Larga-Tigheci	7	15	69
	Prut-Cahul	8	18	80
Dniester	Dniester-Naslavcea-Otaci	9	11	150
	Dniester-Soroc	10	28	118
	Dniester-Ciorna-Rabnita	11	85	80
	Ichel-Dubasari	12	41	46
	Dniester-Botna	13	10	22
	Dniesterl de sud-est	14	5	9
Sud Marea Neagra (Black Sea)	Raut-Copaceanca	15	44	90
	Raut-Cainar-Cubolta	16	103	109
	Raut-Solonet-Ciuluc	17	48	65
	Raut-Cula-Draghinici	18	42	54
	Bacul superior	19	24	72
	Bacul inferior	20	28	56
	Botna superioara	21	16	55
	Coghalnic	22	20	51
	Schinoasa-Ceaga	23	5	24
	Bebei-Copceac	24	2	7
Sud Dunarea (Danube)	Ialpug	25	22	43
	Lunga	26	13	25
	Salcia Mare	27	13	54
	Cahul-Vulcanesti	28	22	61
Outside Moldova	Upper Dniester	29	7,325	500
	Mid Dniester	30	350	99
	Mid Prut	31	289	94
	Upper Prut	32	2,647	756
	Lower Prut	33	103	90

Source: Moldova WEAP data.

Note: BAU = business as usual.

Figure A.1 Calibration of Prut Basin (in Country) Runoff in Million Cubic meters Per Year

Source: Moldova WEAP data.

Note: MCM = million cubic meter.

a better match with local data, namely, adjustments for seasonal runoff characteristics, as well as to lake evaporation parameters. Overall, the simulated runoff fits well with the observed runoff,² as illustrated for the Prut flow in figure A.1.

Water Demand Modeled in WEAP

The Moldovan WEAP model is focused on sources and uses of water within the country, and transboundary transfers from Ukraine (Dniester) and Romania (Prut) represent boundary conditions for the model. Water demand was aggregated to a 28-catchment scale; however, six catchments were divided into two demand nodes, for the right and left banks of the Dniester (Transnistria). This subdivision was provided primarily to allow future demand scenarios to have separate policy and investment components.

Future Climate Scenarios

Once calibrated, CLIRUN was used along with monthly precipitation and evapotranspiration projections of additional climate scenarios to project rainfall runoff in each of the relevant Moldova catchments. The rainfall inputs were derived from climate forecasts from two GCMs, which are part of the Coupled Model Intercomparison Project Version 5 set of global climate forecasting models of the IPCC. The year 2050 was used with a higher greenhouse gas emission scenario (Representative Concentration Pathway 8.5). Two models were used, representing an extremely dry scenario (GFDL-CM3), and one with a wetter growing season and overall annual runoff, which is only slightly lower (EC-EARTH) (figure A.2). A similar analysis was conducted for basins outside Moldova that contributed to Moldova's water supply resources, and the two models selected provide

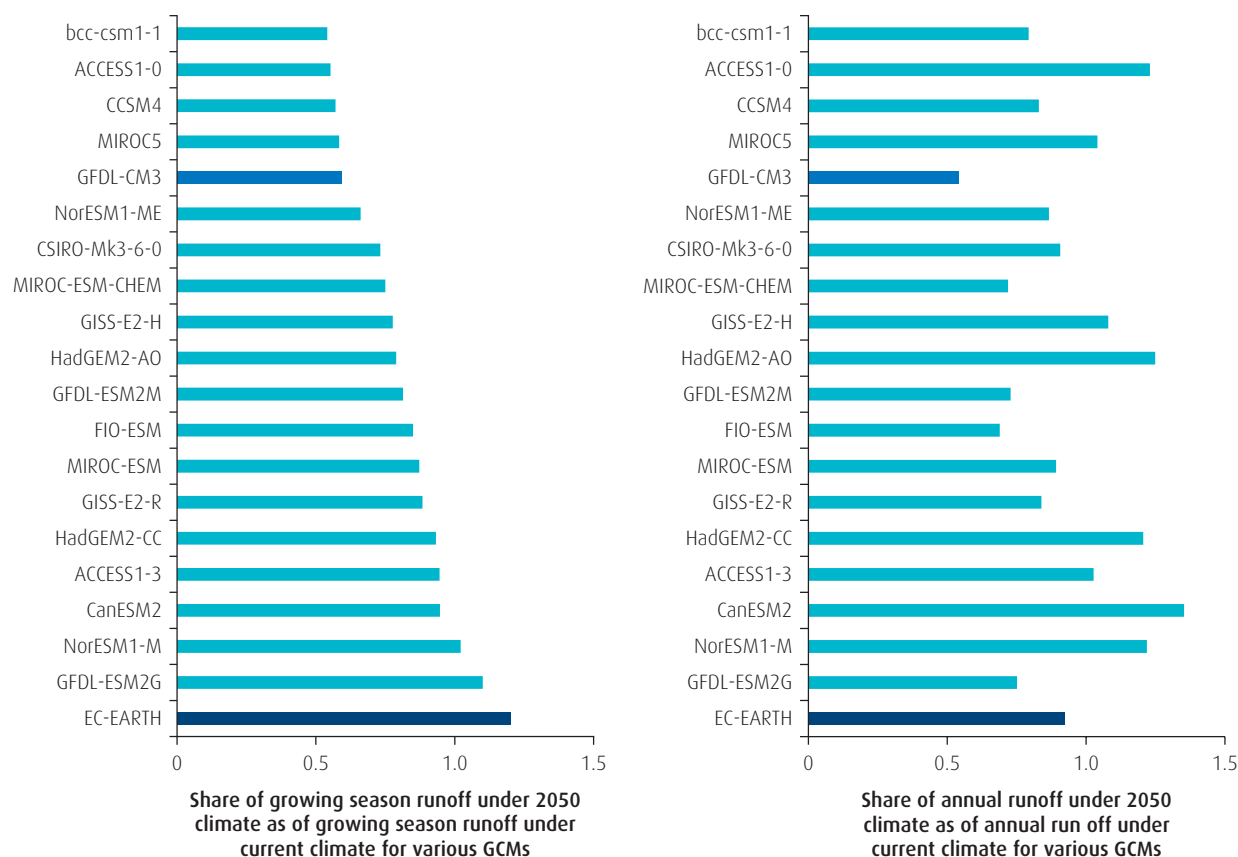
similarly and consistently wet and dry futures in those basins as well.

Overview of Sectoral Water Demand Analysis

Data collection and analysis were conducted to determine water demand in three major categories: drinking water (household), irrigation, thermal cooling water (for combined heat and power [CHP] plants), and hydropower water demand (fully nonconsumptive). Industrial included both utility and self-supplied industrial water use (manufacturing, etc.). The municipal household category was subdivided into water supply through centralized supply (including larger urban utilities and small local networked systems run by local service providers), and self-supply through point sources, typically individual wells. In this specification of the WEAP model, hydropower use is not consumptive; all other categories of demand include both estimated withdrawals and estimated consumptive use, as described later.

Municipal Water Demand

Municipal water demand (household demand) was estimated using a bottom-up approach. Demand reflects population distribution, by urban or rural location and centralized or decentralized water system. The first step was to segregate municipal users into urban and rural population, using a 10 percent sample of the Census data conducted in May 2014, obtained by the World Bank from the Moldova National Bureau of Statistics. The population results at the country level for this source are summarized in table A.2. For the scenarios, estimates of total national population and external migration for the 2030 projection year were developed based on historical rates reported in a UN

Figure A.2 Ratios of Runoff (Q50) for Forecast Climate Compared with Current Climate Runoff

Source: Moldova WEAP data.

Note: For CMIP5 GCMs (Sums 28 Moldova Catchments); GFDL-CM3 (Dry) and EC-EARTH (Wet) were chosen for the analysis. BAU = business as usual; GCM = general circulation models.

Population Situation Analysis (UNFPA 2016).¹⁰ These rates of migration were provided at the district level, and were used to project the general migration trend from predominantly rural to predominantly urban areas, as well as the overall population. The 2014 Census provided data for connection rates in rural and urban areas. These were extrapolated to the baseline year 2018, using the average urban and rural trends since 2000 (based on JMP data). This resulted in an average national connection rate of 90 percent for all urban areas and 37 percent for all rural areas from publicly managed central systems,¹¹ and results are included in table A.2.

The third step was to estimate sources of water: (1) surface water; (2) shallow groundwater, considered for the purposes of water balance modeling to be effectively part of the surface water system; and (3) deep groundwater, considered for water balance modeling to be effectively separated from the surface water system.¹² Expert judgement was used to estimate water sources for each of the four categories of household water demand (i.e., the matrix

of urban to rural and connected to unconnected). For urban connected systems, we used Pienaru et al. (2014), information from Apele Moldovei, and the AMAC (2017) combined. The model reflects that the Acva Nord enterprise provides water, abstracted from the Dniester to Balti, Soroca, and the Floresti districts and the provision of water by Apacanal Chisinau from the Dniester to Chisinau, Ialoveni, and nearby areas. Most other drinking water supply is sourced from deep groundwater. For rural connected systems, we assume that 10 percent of the water is sourced from surface water or shallow groundwater, based on available studies (World Bank 2018). Based on expert judgement, for the small segment of urban self-supply users, we assume that 75 percent is sourced from shallow groundwater wells, with the remainder from deep groundwater wells, and for rural self-supply users, we assume that 80 percent is sourced from shallow groundwater wells and springs and the remainder from deep groundwater wells. We further assume that all household water demands in the left bank region of the Dniester (Transnistria) are met from deep groundwater, based on direct

Table A.2 Urban and Rural Population and Connectivity Rates for 2018 and 2030

Scenario	Urban population and connection rate	Rural population and connection rate
2018 Baseline	932,326 (90%)	1,030,653 (37%)
BAU 2030	954,981 (93%)	570,096 (41%)
Scenario 1 2030	1,017,318 (96%)	857,310 (63%)
Scenario 2 2030	1,065,988 (100%)	1,137,460 (80%)

Source: Moldova WEAP data.

Note: BAU = business as usual.

communication with authorities in Tiraspol with the project team.

The fourth step was to estimate leakage rates, that is, physical water losses during production, transmission, and distribution, from centralized and self-supply systems. Based on expert judgement, IBNET data,¹³ and personal communications with local water authorities, we assumed transmission losses of 30 percent for urban centralized systems; 25 percent for rural centralized systems, which are less extensive and therefore have a lower rate of leakage compared with urban systems; and 10 percent for self-supply facilities, where leakage is mostly within home-based systems. These losses were included as part of the withdrawals and were all assumed to be returned to the surface water system as a part of the return flows from municipal water users.

The fifth step was to estimate total usage rates and consumptive use rates per person, on a liter per capita day basis. These rates were based on expert judgment and information on usage rates by category (e.g., toilet, shower, faucet, washing machine, internal leaks, bath, dishwasher, and other) for European households.

For Europe this is approximately 144 liters per capita per day and it was assumed that usage rates would be lower in Moldova, in part because of the more limited presence of household water devices, such as washing machines and dishwashers. Increased use of water for irrigation of home gardens was considered in the assumptions. The result of steps four and five are included in table A.3. The values in the last column represent estimates used as WEAP inputs in terms of per capita daily demand. The total demand is thus the sum of household actual demand (at the point of entry to the household) and physical transmission losses in the water system. The consumption percentage in the last column provides the net consumptive demand out of the total demand. The return flow amount thus includes both transmission losses and return flows through either wastewater collection systems, infiltrating septic tanks, or direct manual disposal (i.e., in rural settings).

Irrigation Water Demand

In the WEAP model, irrigation water withdrawals in each river basin were estimated based on the total

Table A.3 Household Water Use Inputs for WEAP, by User Category

Water source	Household level			Transmission level		WEAP inputs			
	Delivered (L/cap/d)	Consumed (L/cap/d)	To local water (L/cap/d)	Losses %	Losses (L/cap/d)	Demand (L/cap/d)	Returned (L/cap/d)	Efficiency %	Consumed %
Urban connected	125	30	95	30	54	179	149	83	17
Urban not connected (wells)	60	43	17	10	7	67	24	36	65
Rural connected	75	45	30	25	25	100	55	55	45
Rural not connected (wells)	50	40	10	10	6	56	16	28	72

Source: IBNET data.

Note: WEAP = Water Evaluation and Allocation Planning tool.

hectares of irrigated land in each of the 28 catchments, per hectare estimates of crop irrigation requirements, and estimates of irrigation efficiency (at catchment level) that are specific to known information on the nature of irrigation and conveyance equipment. For the purposes of parameterizing the WEAP, we recognize three typologies of irrigation systems in Moldova:

- (1) *State enterprise managed schemes* (generally called centralized irrigation systems). These are managed by Apele Moldovei through its subordinated state-owned enterprises (Irrigation Technological Stations [ITS], the Directorate of Costești-Stanca Hydrotechnical Unit [DHU], and the Chisinau Water Management System [WMS]). According to information from Apele Moldovei, approximately 130,600 hectares remain under the state-owned enterprise irrigation system, but most of these hectares are not currently irrigated. According to information from Apele Moldovei, in 2018 there were seven specific schemes identified as operational, with 1,766 hectares irrigated in those seven schemes. These systems draw from surface water with specific identifiable water bodies (named rivers and streams) for their intakes.¹⁴
- (2) *Irrigation schemes rehabilitated through the 2010–15 Compact Agreement funded by MCC* (now Sustainable Development Account). They are also under the oversight and monitoring of Apele Moldovei (and assets are owned by the state) but operated through WUAs. Information from SDA Moldova indicates that the total irrigation capacity across 10 schemes, if fully operated, is 13,500 hectares. In 2018, 1,770 hectares in nine schemes were irrigated, and SDA reports that the total irrigated hectares increased to 2,270 by 2019. These systems draw from surface water and have specific identifiable intake points.¹⁵
- (3) *Small-scale private systems* that rely on (local) surface water (ponds, streams, reservoirs, rivers). Less information exists on these systems, but an overview of irrigated hectares by district was provided by AIPA, indicating that in 2018 4,378 hectares were irrigated across the country. Taking account of irrigated hectares in the first two categories (state enterprise and WUA schemes) and their locations in districts, AIPA data suggest that approximately 2,605 hectares were irrigated in 2018 that are not within the areas irrigated by WUAs or state irrigation enterprise categories (see also chapter 2).¹⁶

Combining information on irrigated areas for all three of these categories of irrigated land, the distribution of irrigated hectares across catchments for the 2018 baseline was estimated. Based on projections for the three

2030 water futures, irrigated hectares were estimated for all catchments (for each of the three typologies) and are illustrated in map A.3. The area irrigated under state enterprise systems is assumed to remain at constant levels for the BAU 2030 and Scenario 1, but with additional investment in rural areas, to expand to 27,883 hectares under Scenario 2 in 2030. This is based on an assessment by Apele Moldovei of the total area that might be most economically farmed if rehabilitated.

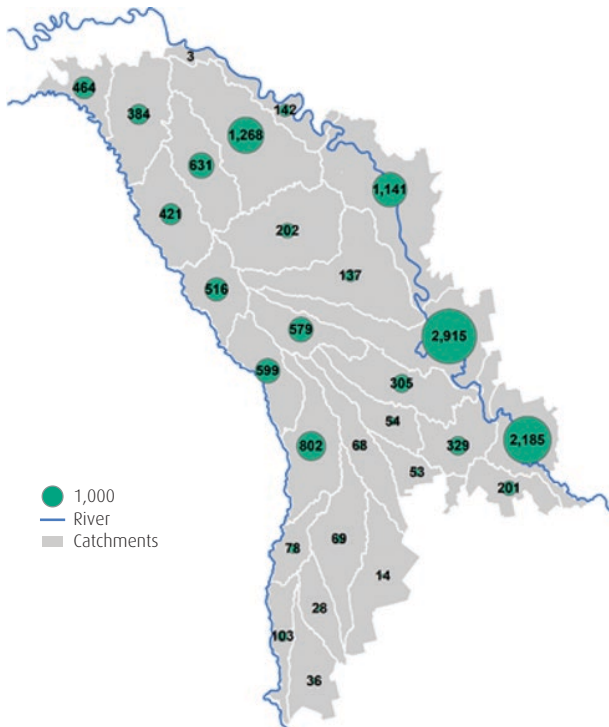
The management arrangement may well be changed, replicating the WUA model, to ensure a sustainable operation of the assets, depending on further sector reforms in Moldova. The spatial distribution of scheme expansion is based on existing system status and the feasibility for rehabilitation based on Intexnauc (2018a). The area under actual irrigation under the WUA-managed and rehabilitated schemes is assumed to grow to 50 percent capacity by 2030 under the BAU 2030 scenario, evenly distributed across the 10 schemes. This is consistent with the efforts of SDA Moldova to increase sustainable utilization of these schemes. Under Scenarios 1 and 2, it is assumed that through additional incentives and enabling policies the uptake of irrigation would be 100 percent of the command area. For the private small-scale schemes, for the BAU 2030 and Scenario 1 it is expected that continued support for irrigation expansion (on-farm and small-scale transmission and ponds) will be offered through AIPA leading to the doubling of the irrigated areas (based on the 2018 estimates in each of the catchments).

Under Scenario 2, a rapid scale-up of this incentive program is assumed, as well as private sector stimulus measures, that would result in a quadrupling of the hectares irrigated through small-scale systems by 2030 to approximately 20,800 hectares. Total irrigated hectares under Scenario 2 are therefore more than 62,000 hectares, almost ten times higher than the 2018 baseline and five times higher than the 2030 BAU scenario. The 62,000 hectares are still far below the 300,000 hectares under irrigation that are reported for the early 1990s. They represent only about 7 percent of the total area under cultivation in 2017, which was reported as 884,000 hectares (NBS 2017). Table A.4 provides the area irrigated for each of the catchments for the various water futures.

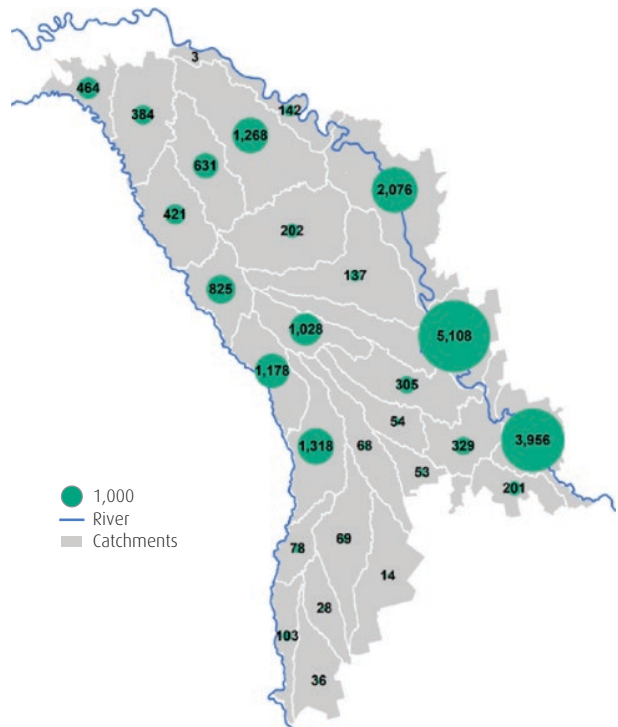
Crop water requirements are estimated on a catchment-specific basis using a methodology derived from the FAO CROPWAT model.¹⁷ The method relies on the crop water demand coefficient, which varies for each month of the growing season, reflecting the different stages of crop growth. For example, at the early planting stage, crops demand

Map A.3 Irrigation Expansion over Three Scenarios

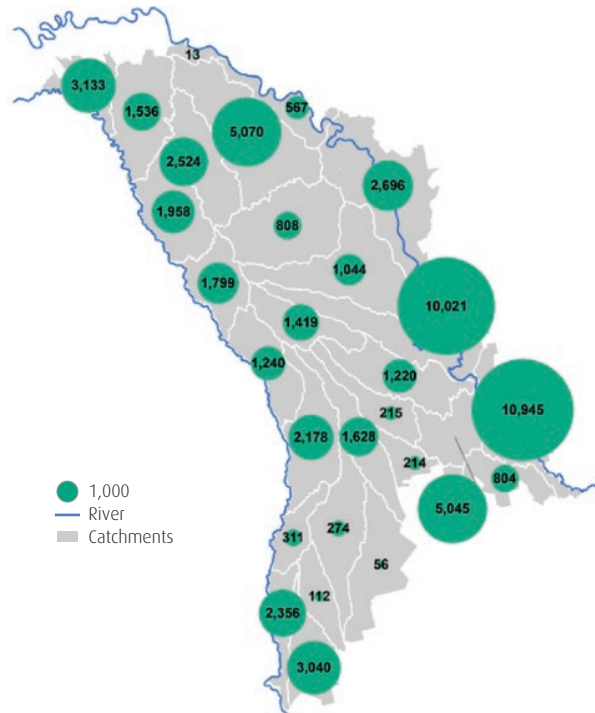
a. BAU 2030 (ha)



b. Scen1 2030 (ha)



c. Scen2 2030 (ha)



Note: BAU = business as usual.

Table A.4 Irrigated Area by Catchment and Scenario

No.	Catchment name	Baseline 2018	BAU 2030	Scenario 1 2030	Scenario 2 2030
1	Prut-Lopatnic	451.6	464.0	464.0	3,133.2
2	Prut-Racovat-Ciuhur	192.0	384.0	384.0	1,535.6
3	Prut-Camenca-Sovat	210.5	420.9	420.9	1,958.3
4	Prut-Garla Mare-Delia	330.5	516.0	824.8	1,798.8
5	Raut-Cula-Draghinici	419.4	599.3	1,178.0	1,239.7
6	Prut-Lapusna-Sarata	143.3	802.2	1,317.8	2,177.7
7	Prut-Larga-Tigheci	38.9	77.8	77.8	311.2
8	Prut-Cahul	84.8	102.7	102.7	2,355.8
9	Dniester-Naslavcea-Otaci	1.6	3.2	3.2	12.8
10	Dniester-Soroc	70.9	141.8	141.8	567.4
11	Dniester-Ciorna-Rabnita	466.4	1,141.3	2,075.7	2,696.4
12	Ichel-Dubasari	1,761.6	2,915.3	5,107.6	10,021.4
13	Dniester-Botna	255.9	328.6	328.6	5,045.4
14	Dniesterl de sud-est	365.0	2,184.8	3,956.2	10,944.5
15	Raut-Copaceanca	315.5	631.0	631.0	2,523.6
16	Raut-Cainar-Cubolta	633.8	1,267.5	1,267.5	5,070.2
17	Raut-Solonet-Ciuluc	101.1	202.1	202.1	808.5
18	Raut-Cula-Draghinici	68.7	137.3	137.3	1,044.3
19	Bacul superior	306.3	579.2	1,028.0	1,419.4
20	Bacul inferior	152.2	305.0	305.0	1,219.5
21	Botna superioara	26.9	53.8	53.8	215.2
22	Coghalnic	43.5	68.0	68.0	1,628.1
23	Schinoasa-Ceaga	26.7	53.4	53.4	213.7
24	Bebei-Copceac	100.5	201.0	201.0	804.2
25	Ialpug	34.3	68.6	68.6	274.3
26	Lunga	7.0	14.0	14.0	56.1
27	Salcia Mare	14.0	27.9	27.9	112.1
28	Cahul-Vulcanesti	18.0	36.0	36.0	3,040.0
Total		6,641	13,727	20,477	62,227

Source: Moldova WEAP data.

Note: BAU = business as usual.

less water than during full leaf stage and grain filling, when the crop water requirement is larger. To calculate crop water requirements, an assumed crop mix was used (cereals, vegetables, potatoes, sugar beets, fruits, and pastures), as detailed in Industrial Economics (2020). The crop calendar was used to develop a monthly scale crop water coefficient for a representative hectare. This is then used to calculate the net crop water requirement using an estimate of potential evapotranspiration for Moldova, and effective precipitation estimates by month and catchment (from the historical climate data described earlier). The result is a monthly average net crop water requirement expressed in meters

per hectare per catchment¹⁸ (Industrial Economics 2020). The annual pattern logically sees a peak of the net crop water requirements in May throughout August, when growth requirements are highest and generally exceed available precipitation.

The per-hectare net crop water requirements (in meters) are roughly the same for each of the water futures. However, they change for the dry and wet climate scenarios, because future climate conditions result in changes in precipitation and potential evapotranspiration. Table A.5 illustrates average annual total water demand and crop water demand from irrigation, with slightly different values for the

Table A.5 Crop Water Demand and Irrigation Water Requirements

Average hectare for assumed crop mix (mm/ha)		Current climate	Dry climate (GFDL-CM3)	Wet climate (EC-EARTH)
Baseline	Crop water demand	214	251	228
	Crop precipitation uptake	124	113	134
	Crop irrigation water requirement	90	138	95
	Crop irrigation water requirement (% total)	42%	55%	41%
BAU 2030	Crop water demand	214	250	228
	Crop precipitation uptake	123	111	132
	Crop irrigation water requirement	91	139	96
	Crop irrigation water requirement (% total)	43%	56%	42%
Scenario 1	Crop water demand	214	250	227
	Crop precipitation uptake	122	111	131
	Crop irrigation water requirement	91	140	96
	Crop irrigation water requirement (% total)	43%	56%	42%
Scenario 2	Crop water demand	217	253	230
	Crop precipitation uptake	121	110	130
	Crop irrigation water requirement	95	144	100
	Crop irrigation water requirement (% total)	44%	57%	44%

Source: Moldova WEAP data.

different scenarios.¹⁹ It underscores the supplemental nature of irrigation in Moldova, because more than half of annual water requirements is on average met through precipitation, and the irrigation water demand—specifically in the growing season—is a supplemental but extremely critical source to ensure yield optimization. The net crop water requirements in meters per hectares can simply be converted to the consumptive irrigation water use in cubic meters per hectares²⁰ to determine inputs for the WEAP model based on efficiencies, source, and area under irrigation for the different categories of schemes.

Irrigation efficiency and source water assumptions were developed for each of the three categories of irrigation schemes, as follows:

- *Centralized systems managed by state irrigation enterprises or in future by water user associations:* Based on available information, these systems are assumed to be older but still functional systems and are likely employing mostly flood irrigation (Sutton et al. 2013; Industrial Economics, Incorporated 2016). An average irrigation efficiency of 50 percent for flood irrigation was assumed based on expert judgement and prior work in the region. Although it is possible that in part of these systems farmers may be using on-field sprinkler technology, the overall efficiency was kept at 50 percent because of the poor state of the old conveyance technologies (Intexnauca 2018a). The systems draw from surface water with specific

identifiable water bodies for their intakes and were modeled as such.²¹ Under Scenario 2, a large expansion of these systems is envisaged; however, their management may be transferred to WUAs (although assets are retained by Apele Moldovei). In the future, combined with rehabilitation and on-farm modernization of equipment, there will be room for increasing the irrigation efficiency.

- *Centralized systems managed by WUAs and rehabilitated by the SDA Compact:* These systems are assumed (confirmed by site visits) to be a combination of pressurized drip irrigation, sprinkler technology, and more traditional irrigation (furrow). They draw from surface water with specific identifiable intake points.²² Based on expert judgement and prior work in the region, a relatively high irrigation efficiency of 85 percent for these systems has been assumed, because all schemes were fully rehabilitated between 2010 and 2015 and conveyance losses are assumed to be limited.
- *Small-scale private systems:* These systems mostly rely on local surface water (ponds, reservoirs, streams) that are part of the overall surface water system. Less information exists on these systems and, as informed by AIPA data, many are associated with subsidies provided for investments in sprinkler or drip irrigation. Based on expert judgement and experience in the region an irrigation efficiency of 75 percent is used for these systems (limited conveyance losses).

In WEAP irrigation water demand, for the various scenarios, is modeled as an aggregate node for each of the three previously mentioned categories of irrigation systems. The irrigation water demand in WEAP then combines the following elements: (1) the monthly crop irrigation water requirements in meters per hectares, multiplied by 10 to convert to cubic meters per hectare; (2) the area cropped under each irrigation category for each catchment (which varies per scenario); and (3) the application of irrigation efficiency per category type. An irrigation efficiency of 50 percent implies that the remaining 50 percent of the water is lost to return flows. This means that the total irrigation water demand from the relevant source is two times (the reciprocal of 50 percent) the crop irrigation water requirement.

Industrial Demand

Industrial demands were considered using population-based estimates of industrial (e.g., manufacturing, services) demand per capita that were originally derived from 2012 estimates (Pienaru et al. 2014). A total of

50 liters per capita per day of industrial demand (of which 20 is institutional) is used for urban settings, and 25 liters per capita per day (of which 10 is institutional) in rural settings. For the BAU 2030 projections, it is assumed that industrial demand growth is 3 percent per year,²³ whereas the institutional component remains constant over time. Table A.6 illustrates the usage rates for the different scenarios, based on assumptions for the growth rate of industrial demand, illustrating a 6 percent growth annually for Scenarios 1 and 2. It is assumed that 50 percent of industrial demand is sourced through centralized systems, in both rural and urban settings (with the same source as for drinking water users) and the remainder is self-supplied (wells) from surface water or from the local groundwater system.

Transmission losses and consumptive use rates were also considered when developing WEAP industrial demand estimates. For simplicity and because of lack of data, a single aggregate rate of 20 percent usage was used similar to the United States. Transmission loss rates were assumed to be the same as for drinking water systems (table A.7).

Table A.6 Industrial Water Use Rates per Scenario

Scenario	Urban (L/cap/d)	Rural (L/cap/d)	Assumption
2018 Baseline	56	28	Increased from 2012 to 2018 using 3 percent annual growth
BAU 2030	71	36	Increased from 2012 to 2018 using 3 percent annual growth
Scenario 1 2030	92	36	Urban usage assumed to grow at 6 percent from 2018 to 2030, but limited to free economic zone areas of the country; rural constant at BAU 2030 level
Scenario 2 2030	92	82	Urban same as Scenario 1; rural industrial component is assumed to grow at the same rate as urban industrial demand

Source: Moldova WEAP data.

Note: BAU = business as usual.

Table A.7 Industrial and Institutional Water Use Inputs for WEAP, by Source

Water source	Industrial use 2018			Transmission level		WEAP inputs			
	Delivered (L/cap/d)	Consumed (L/cap/d)	To local water (L/cap/d)	Losses %	Losses (L/cap/d)	Demand (L/cap/d)	Returned (L/cap/d)	Efficiency %	Consumed %
Urban connected	28	5.6	22.4	30	12	40	34	86	14
Urban not connected (wells)	28	5.6	22.4	10	3	31	26	82	18
Rural connected	14	2.8	11.2	25	5	19	16	85	15
Rural not connected (wells)	14	2.8	11.2	10	2	16	34	82	18

Source: Moldova WEAP data.

Note: WEAP = Water Evaluation and Allocation Planning tool.

Energy Water Demand

The energy sector demands water for cooling of CHPs. Withdrawals were considered separately with individual consumptive rates and water sources customized for the demand node based on the type of thermal power plant and cooling method. Table A.8 illustrates the three CHP complexes, their overall power production capacities, abstraction, and consumptive uses. Water demand for these plants were assumed not to change for the 2030 water futures, as informed by the Moldova 2030 Energy strategy. For Kuchurgan, modeling results were more accurate when WEAP only includes the consumptive use (55 million cubic meters per year) as the annual abstraction volume. This more closely replicates the nature of the net abstraction from the river itself, rather than the 555 million cubic meters per year from the lake itself.

Hydropower Demand

Two existing hydropower facilities were included in WEAP, namely Dubasari in the Upper Dniester basin, and Costești-Stanca in the Prut basin with a total combined generation capacity of 64 MW. These plants do not technically withdraw or consume water for the system, and so have no effect on the water balance in the current configuration of the WEAP. A large reservoir hydropower plant could, in practice, have an effect on water use, according the plant's release rules and, for a new plant, the filling time for the reservoir. Those types of plants are not included in this version of the the Moldova WEAP.

Environmental Flow Requirements

Environmental flow requirements for Moldova's internal catchments were set at the Q10 flow, that is, the

10th percentile flow, meaning the minimum flow that is equal or exceeded 90 percent of the time. These flows are reserved for environmental purposes at specific nodes in the WEAP system, essentially at the outflow point for each of the 28 catchments. The Q10 flows were estimated through statistical analyses of the historical modeled runoff described earlier. Environmental flow requirements are not abstractions, but rather reserved requirements for instream flow. As a result, environmental flow requirements are not included in total demand, but nonetheless can affect the level of unmet demand and reliability of supply by displacing abstractions to ensure adequate instream flow to support ecosystem functions. For the downstream country outflow node of the Prut river, a Q10 flow was used.

For the Dniester downstream outflow node of 80 cubic meters per second²⁴ was used based on the interpretation of a bilateral agreement between the Republic of Moldova and Ukraine on minimum flow (see OSCE and UNECE 2005), which corresponds with a Q3 flow. To illustrate the variability of the natural flows, figure A.3 illustrates the flow percentiles for the Prut and Dniester river outflows of Moldova, the flow across the 28 internal catchments, as well as for the external flows into Moldova's rivers from the combined upper, mid-, and lower Prut basins and the combined upper and mid-Dniester basins.

The Q10 assumption is a simplified but consistent method to model an environmental flow requirement, but it is not based on technical assessment of environmental requirements in riverine ecosystems of the Republic of Moldova, or water flow needs of specific environmentally sensitive or protected areas. An ongoing study, implemented by UNDP and financed by the Swedish government, is examining environmental

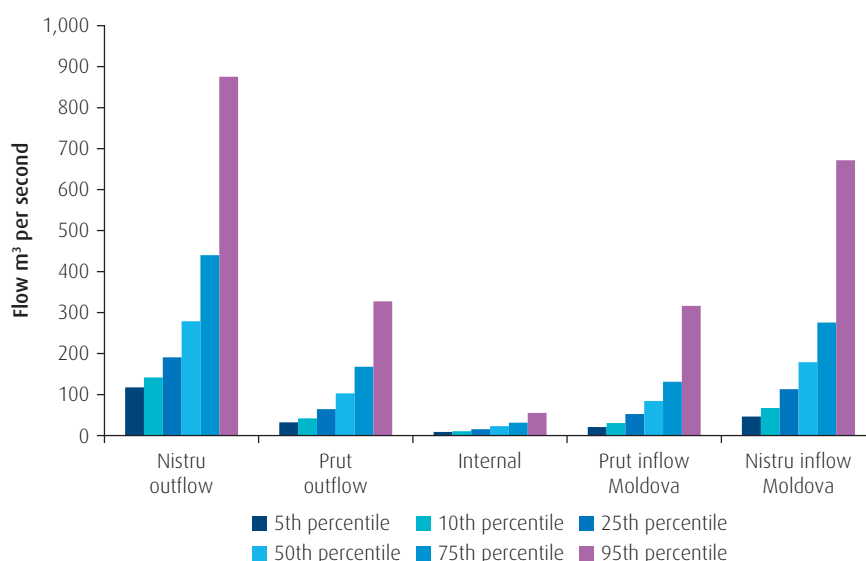
Table A.8 Thermal Cooling Water Use Inputs for WEAP, by Source

CHP name	Location	Power capacity (MW)	Abstraction (Million m ³ /y)	Use rate (%)	Notes
Kuchurgan	Dniester de sud-est (Catchment 14)	2,520	550	10	Cooling pond: Plant is cooled by abstraction from Lake Kuchurgan, which is effectively used as a cooling pond. Net consumptive use is estimated as net evaporative losses based on rates at similar plants in the United States.
Balti (CHP Nord)	Raut-Copaceanca (Catchment 15)	24	0.177	60	Recirculation: Using cooling towers and local district heating for heat dissipation. Consumptive rate is based on cooling tower losses during the non-heating season only (closed system with no losses for heating season). Source is deep groundwater.
Chisinau (CET2/CHP2)	Bacul Inferior (Catchment 20)	24	1.1	60	Recirculation: as for CHP Nord. Water is sourced from the Chisinau central water supply system.

Source: Moldova WEAP data.

Note: CHP = combined heat and power; MW = megawatt; WEAP = Water Evaluation and Allocation Planning tool.

Figure A.3 Variability of Natural Flows for Moldova's Downstream Outflow, Internal Catchment Flow, and Upstream River Inflow



Source: Moldova WEAP data.

flow requirements for the upstream Dniester, with preliminary results indicating a Q5 flow. In the future, it is advisable, once more information is available on specific environmental flow requirements throughout the country, to model those in an updated WEAP version. Rather, the water balance assessment carried out sensitivity analysis for different levels of environmental flow requirements: one for a more stringent Q25 environmental flow, and one for a removal of all environmental flow constraints (except for the Dniester country outflow, which was continued throughout the analysis at 80 cubic meters per second). Chapter 4 illustrates, for Scenario 2, the trade-offs that are occurring between environmental flow and irrigation water demand, underscoring the need for determining and enforcing such requirements in the future, especially under an expanded irrigation regime and a drier climate.

WEAP System Schematic of Demands

The result of the previously described parameterization of the WEAP model is a Moldova WEAP model that could be used for further analysis and refinement and that has been handed over to the government during the January 2020 training, including related training materials and instructions translated into Romanian. Map A.4 provides an illustration of the schematic representation. Red circles represent water demand nodes (thermal cooling demand, irrigation nodes, or drinking and industrial demand nodes), with demand

flows as green arrows and return flows as red arrows. Deep groundwater supply is shown as green boxes, and environmental control nodes as purple circles.

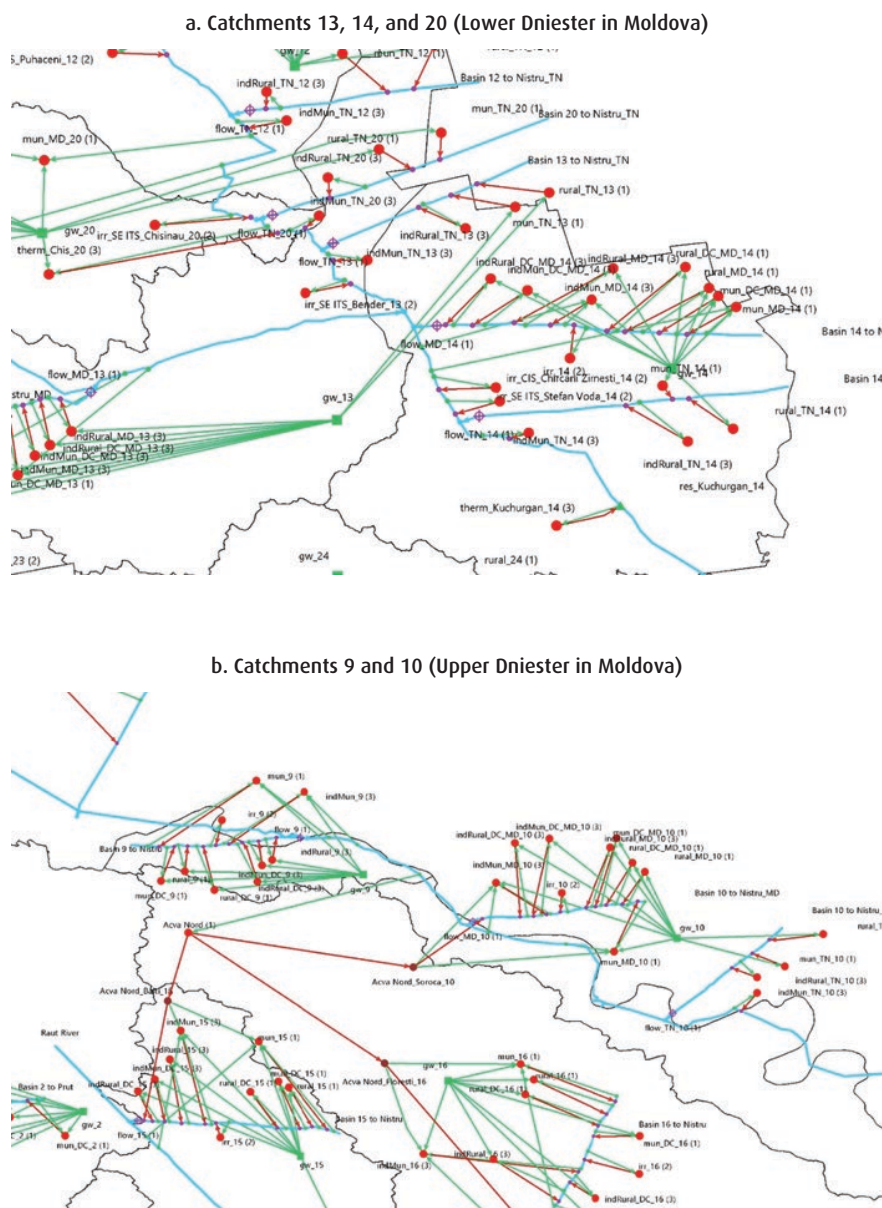
Results Summary Water Balance Assessment WEAP

A summary of the WEAP results by scenario are presented in tabular form in tables A.9 to A.11 for Moldova and are discussed in chapter 2 for the baseline 2018, and in chapter 4 for the three water futures. Catchment level water balance assessments are available upon request.

Key Assumptions Economic Assessment

The economic assessment relies on a cost-benefit analysis (CBA) to compare a range of investment interventions to improve water security. The CBA was carried out from the perspective of the Government of Moldova assessing the holistic costs and benefits of public water security interventions. The CBA should be interpreted as a broad assessment of three development scenarios (water futures) and their associated suite of investments and policies across water-related sectors rather than a detailed financial assessment. The costs and benefits over a scenario's lifetime, assumed to be 30 years, are then discounted to a present-day value. The CBA also uses an incremental approach, in which economic performance indicators are calculated on the incremental cash flows only

Map A.4 Examples of WEAP Schematics Depicting Rivers and Major Municipal, Irrigation, and Industrial Water Demand Nodes



Source: Moldova WEAP data.

through a comparison of the project compared with a do-nothing counterfactual. The investment scenarios concern three streams: irrigated agriculture, municipal water supply, and flood protection.

Irrigated Agriculture

To estimate the economic benefits associated with each water future, a crop model²⁵ was used to estimate yields per hectare, using a different crop mix suitable for each category of the irrigation scheme. The crop mix was chosen to represent a feasible

bundle of crops per scheme type, because the level of sophistication of the different categories varied. Benefits were estimated by multiplying the yield per hectare with real inflation-adjusted farm-gate prices and comparing these to estimated revenues from rainfed yields. Benefits thus accrue as annual increases in revenue to farmers from higher crop yields of irrigated versus rainfed production. Prices for crops were derived from the IFPRI crop model (Decision Support System for Agrotechnology Transfer, DSSAT). The following categories of irrigation schemes were used (consistent with the application in WEAP):

Table A.9 Water Balance Elements for Moldova WEAP

Water balance item	Unit	Base 2018	BAU 2030	Scen 1 2030	Scen 2 2030
Inflow across country and internally produced (surface)	MCM/year	15,248	15,248	15,248	15,248
Internally produced water (surface water)	MCM/year	1,878	1,878	1,878	1,878
Inflow across borders upstream (surface water)	MCM/year	13,370	13,370	13,370	13,370
Outflow across borders downstream (surface water)	MCM/year	15,224	15,217	15,221	15,208
Total surface water consumption	MCM/year	86	93	98	137
Total groundwater consumption	MCM/year	25	21	23	28
Total water consumption (ground and surface water)	MCM/year	110	114	121	165
Return flow from deep groundwater to surface water	MCM/year	53	53	63	82
Reused return flows	MCM/year	5.5	5.5	4.7	2
Unmet water demand	MCM/year	-3.5	-4.5	-4.3	-14

Source: Moldova WEAP data.

Note: Environmental flows are the same for the baseline 2018, totaling 336 MCM/year internal and 3,846 MCM outflow. MCM = million cubic meters; WEAP = Water Evaluation and Allocation Planning tool; BAU = business as usual.

Table A.10 Key Water Resources Indicators Derived from Moldova WEAP

Key water resource endowment indicators	Unit	Base 2018	BAU 2030	Scen 1 2030	Scen 2 2030
Population (including Transnistria)	million	3.14	2.96	2.97	3.04
Total internal renewable surface water resources	MCM/year	1,878	1,878	1,878	1,878
Total internal renewable groundwater resources	MCM/year	300	300	300	300
Total internal renewable water resources	MCM/year	2,178	2,178	2,178	2,178
Total internal renewable water resources per capita	m ³ /cap/year	694	735	734	717
Total renewable water resources	MCM/year	15,548	15,548	15,548	15,548
Total renewable water resources available per capita	m ³ /cap/year	4,952	5,246	5,242	5,122
External out of total renewable water resources	%	86	86	86	86
Withdrawal out of total renewable water resources (incl. Kuchurgan)	%	5	5	5	6
Withdrawal out of total internal water resources (incl. Kuchurgan)	%	33	34	35	39
Consumption out of total internal water resources (incl. Kuchurgan)	%	5	5	6	8
Withdrawal per capita (incl. Kuchurgan)	m ³ /cap/year	231	250	256	282
Consumption per capita	m ³ /cap/year	35	39	41	54

Source: Moldova WEAP data.

Note: MCM = million cubic meters; BAU = business as usual.

- *Large-scale centralized schemes managed by Apele Moldovei or WUAs in the future.* The condition of these old systems is not suitable for the highest levels of precision irrigation; therefore, the yield potential cannot yet justify investment in the high-input forms of agriculture that are possible elsewhere. Crop yield and revenue potential were determined based on a crop mix of 25 percent maize, 25 percent sunflower, 20 percent apples, 20 percent grapes, and 10 percent vegetables, and

with adjustments on yield to reflect the marginal yield increase associated with flood type irrigation (rather than precision high input irrigation).

- *Large rehabilitated fully pressurized systems managed by WUAs.* Farmland in this category can in theory support the highest level of precision agriculture feasible in Moldova, because pressurized hydrants are available at regular distances at the field level. Crop yield and revenue can reach nearly

Table A.11 Water Withdrawals and Consumption Derived from Moldova WEAP

Key data on withdrawals and consumption	Unit	Base 2018	BAU 2030	Scen 1 2030	Scen 2 2030
Irrigation water withdrawal: surface	MCM/year	9	17	24	94
Irrigation water withdrawal: groundwater	MCM/year	—	—	—	—
Industrial water withdrawal: surface	MCM/year	21	26	29	32
Industrial water withdrawal: groundwater	MCM/year	9	10	12	27
Municipal water withdrawal: surface	MCM/year	60	66	64	62
Municipal water withdrawal: groundwater	MCM/year	69	65	73	83
Thermal water withdrawal: surface (excl. Kuchurgan)	MCM/year	57	57	57	57
Thermal water withdrawal: groundwater	MCM/year	0	0	0	0
Total water withdrawal (excl. Kuchurgan)	MCM/year	225	240	260	355
Total water withdrawal (incl. Kuchurgan)	MCM/year	725	740	760	855
Total ground water withdrawal	MCM/year	78	75	86	111
Total surface water withdrawal (excl. Kuchurgan)	MCM/year	147	165	174	245
Irrigation water consumption	MCM/year	6	12	18	58
Industrial water consumption	MCM/year	4	5	6	9
Municipal water consumption	MCM/year	43	40	41	42
Thermal water consumption	MCM/year	56	56	56	56

Source: Moldova WEAP data.

Note: At the Kuchurgan Combined Heat and Power Plant an estimated 550 MCM/year is diverted from the Dniester, of which 500 MCM is not consumed and discharged again, that is, nonconsumptive withdrawal. MCM = million cubic meters; BAU = business as usual; WEAP = Water Evaluation and Planning System tool.

full potential with a mix of 40 percent apples and fruit orchards, 20 percent tomatoes and vegetables, 20 percent maize, and 20 percent grapes, assuming that there are markets for crops produced.

- *Small-scale irrigation systems that are privately operated.* These small irrigation operations rely on local sources of irrigation water and are likely to reflect use of sprinkler and relatively high-input agricultural practices. The assumed crop mix was 40 percent apples and fruit orchards, 20 percent tomatoes and vegetables, 20 percent maize, and 20 percent grapes. The yield potential for farmland is assumed to be somewhat lower than for fully pressurized newly rehabilitated schemes, because the capacity for drip irrigation may not be present everywhere.

The crop yields per scheme-type and crop mix are presented as decadal averages in table A.12 and consider the effect of climate change.

Capital costs were derived from in-country actual costs from the construction and operation of SDA rehabilitated schemes (MCC Compact) and adjusted downward to reflect lower cost requirements per hectare for large-scale centralized systems. For the centralized systems under management by WUAs, these costs are considered a grant to farmers as the investment already took place (sunk cost). However, farmers in these schemes will be

responsible for their incremental on-farm investment (drip-irrigation infrastructure) and relatively high recurrent costs of operations and user fees, both included in the CBA. Operation and maintenance costs from SDA schemes were used as a proxy for private farms—representing the highest input cost for private farmers and WUAs—schemes and including inputs, such as fertilizer, energy costs for pumping, and equipment, whereas a lower input cost was used for large-scale centralized schemes (US\$755 per hectare per year compared with US\$153 per hectare per year, respectively).

Results are summarized in table A.13. Over the useful life of schemes (30 years) and at a 5 percent discount rate, there are high benefits from investing in the full utilization of the already rehabilitated schemes under WUA management, as well as in supporting the expansion of private small-scale schemes, with benefit-cost ratios (BCRs) ranging from 4.6 to 10, indicating that benefits significantly outweigh costs and that benefits under expansion scenarios accrue at a higher rate than costs. However, results for the rehabilitation or reconstruction of large centralized schemes are less positive, mostly as a less economically productive crop mix is assumed. An expansion of area irrigated, as seen in Scenario 2, indicates marginal economic results, with a net present value of –US\$0.6 million.

Table A.12 Crop Mix and Yields over Time

Crop Mix Decade	Yields over time (ton/ha/y)			
	2010s	2020s	2030s	2040s
Rainfed				
Maize	4.78	4.07	4.64	3.23
Sunflower	2.17	2.17	2.17	2.17
Wheat	2.07	2.00	1.97	2.09
Private				
Maize	6.55	5.58	6.36	5.74
Apples (high input/high output)	42.37	42.78	42.17	42.06
Grapes	5.62	5.29	5.50	5.26
Vegetables	14.66	14.29	14.34	14.17
WUAs				
Maize	6.55	5.58	6.36	5.74
Apples (high input/high output)	42.37	42.78	42.17	42.06
Grapes	5.62	5.29	5.50	5.26
Vegetables	14.66	14.29	14.34	14.17
Large centralized				
Maize	6.55	5.58	6.36	5.74
Sunflower	0.20	0.20	0.20	0.20
Apples (medium input/medium output)	21.75	22.10	21.43	21.24
Grapes	5.62	5.29	5.50	5.26
Vegetables	14.66	14.29	14.34	14.17

Source: World Bank data.

Note: WUA = water user association.

Table A.13 Summary Results of Cost-Benefit Analysis for Irrigation

Scenario	Expansion of private Small-scale schemes	Uptake of existing rehabilitated schemes (Under WUA management)	Rehabilitation and expansion of centralized schemes
BAU-2030			
NPV (million US\$)	133	820	N/A
BCR	4.6	10.0	N/A
Scenario 1-2030			
NPV (million US\$)	133	879	N/A
BCR	5	10.1	N/A
Scenario 2-2030			
NPV (million US\$)	928	2,065	-0.6
BCR	4.6	10.6	0.9

Source: Moldova WEAP data.

Note: BAU = business as usual; BCR = benefit-cost ratio; NPV = net present value; WUA = water user association.

In assessing the robustness of these results, a sensitivity analysis was carried out on prices (table A.14). Using prices published by the National Bureau of Statistics (NBS) in Moldova, which are generally lower than the prices in the IFPRI crop model, the analysis still shows positive results for BAU 2030

and Scenario 1, as well as for the private small-scale schemes and existing rehabilitated schemes under Scenario 2. However, the results for rehabilitating or reconstructing new large centralized schemes becomes even less attractive, with an NPV of -US\$3.3 million and BCR of 0.2.

Table A.14 Prices Used for Sensitivity Analysis

Crop	Prices from Crop Model (IFPRI) Current US\$/Ton	Prices from NBS 2017 Current US\$/Ton
Alfalfa	270	—
Apples	387	200
Grapes	379	256
Maize	419	154
Pasture	270	—
Vegetables	405	150
Wheat	329	126
Sunflower	154	—

Sources: IFPRI and Moldova National Bureau of Statistics 2017.

It can be concluded that although there are significant benefits to small-scale private schemes focused on high-value crops, with benefits outweighing costs by four to five times, these are not necessarily guaranteed in larger central systems. This finding is consistent with other research in the sector, which suggests these schemes, under their current operating format and existing crop mixes, are not economically efficient. The BCR would increase considerably if complementary measures would be implemented to support a change to a higher-value crop mix than what is modeled. The higher benefits for already rehabilitated schemes (managed by WUAs) are a result of assumed sunk investment costs and an assumed transition to high-value crop mixes and a high-input, high-output model. However, in reality, this shift is not as easy to facilitate because of barriers in the enabling conditions, such as access to finance, markets, land consolidation, etc.

Municipal Drinking Water Supply

Two categories of economic benefits were included in the estimation of benefits across scenarios, namely, (1) time savings and (2) health costs avoided. Time saving benefits accrue to rural households, which had previously collected water outside of their homestead. In a household survey carried out in the country in 2017 it was found that roughly one in three rural households travel 30 minutes or more per day to gather water. Applying the shadow price for labor of 50 percent, at the 25-percentile wage rate, and assuming an average household size of 3 in line with the 2014 Moldovan Census, the value of time saved would be about \$237 per capita per year for those households that move from being unconnected to being connected.

Health savings accrue to households through increased access to adequate water supply. Even in a lower-middle-income economy, such as Moldova, inadequate water supply results in a relatively high burden of diarrheal disease, largely driven by effects to elderly and children under 5 years old. In quantifying these

effects, the CBA estimated 208 disability-adjusted life years (DALYs) attributable to inadequate water in Moldova per year using the Value of Statistical Life (VSL) for Moldova as provided by Robinson, Hammitt, and O’Keeffe (2019), in combination with a Population Attributable Fraction of 14 percent for the change from an improved source other than piped water to basic piped water on premise, as estimated by Pruss-Ustun et al. (2014). Capital costs were estimated per user connected based on an assessment of costs of similar urban water supply projects in Moldova.²⁶ Costs for urban water supply projects were estimated at US\$700 per capita, although a lower range of US\$450–US\$200 was used for rural areas outside of cities.²⁷

Comparing the benefits with costs investing in water supply has large benefits for people. Although the BCRs associated with water supply are lower than those of expanding irrigation, in the range of 1.2–1.5, this reflects a conservative approach in valuing benefits to people from water supply (see the Economic Outlook of water futures section). These results underscore the need for better provision of reliable piped water, and hand hygiene. Results are likely an underestimation of the true benefits because of challenges in quantifying intangible benefits, such as comfort and knock-on effects associated with improved health to a population, such as cognitive functioning and higher levels of productivity and resilience to future pandemics, as well as social and environmental benefits.

Flood Protection

A significant amount of work has been carried out in-country in assessing the economic effect of floods in Moldova. Flooding poses a real and expensive risk to Moldova’s economy and to its people, estimated to be at least US\$62 million annually (EIB 2016). The EIB Flood Protection Master Plan Report 2016 builds a robust approach to estimating the costs and benefits with proposed flood interventions across the country. It used hydrological flood hazard and flood risk mapping

Table A.15 Summary of Flood Protection and Mitigation Measures across Three Futures

	Investment approach	Cost: Structural and nonstructural	Prioritization criteria
BAU 2030	Limited investment approach: New dykes on the River Prut. Rehabilitate and improve dykes on the River Dniester. Rehabilitate and improve dykes and increase the capacity of the River Cogâlnic. Enhancement of the existing flood forecasting systems.	US\$21,081,417 US\$300,000	Only measures that were rated as <i>Very High Priority</i> included
Scenario 1	Moderate investment approach: <i>As BAU 2030 plus</i> Rehabilitation and new flood gates for Vatra dam to increase the flood storage volume. Improvements of the River Bic in Chisinau, including channel enlargement and new flood defenses. Reorganization of the hydrological data management systems.	US\$46,803,682 US\$480,000	Measures that build resilience in <i>urban and industrial centers</i>
Scenario 2	High investment approach: <i>As Scenario 1 plus</i> New dykes and rehabilitation of existing dykes on the River Prut (high priority). Provide more flood storage: modify the Costești-Stanca dam management rules and repair existing gates. Provide flood storage volumes upstream of Bălți through the improvement of an existing dam and the construction of a new dam. Rehabilitate and improve dykes of the rivers Răut and Răuțel in Bălți. Enlarge the river channels in Bălți. LiDAR survey and reforestation measures.	US\$77,528,478 US\$43,340,000	Full <i>Short-Term Investment Plan</i> costs

Source: Moldova WEAP data.

overlaid with a range of flood reduction measures to assess the resultant change in the effect of floods on people and assets. The objective of the report was to develop an investment plan covering the period to 2036 that has an acceptable investment profile, as well as all the prioritized work.

Moldova's Flood Master Plan Report 2016 identifies eight short-term investment priority projects for the country, along with five high-priority nonstructural measures: interventions that are implementable within the time frame of 5 years. The total cost for the short-term priority projects is estimated to be US\$121 million, comprising US\$77 million for the structural measures and US\$44 million for the nonstructural measures. A larger set of measures was prioritized using a multicriteria assessment of urgency and effect; short-term measures have BCRs higher than 1, indicating high estimated benefits.

The water futures used to develop a further prioritization for each of the three water futures, with increasing level of investments, are summarized in table A.15.

Notes

1. Additional details are available in Industrial Economics (2020). This report is available upon request from authors.

2. The Decision Support System for Agrotechnology Transfer (DSSAT) is a decision support system used to facilitate simulations of crop responses to climate and management. The DSSAT software includes over 20 models for the main food and fiber crops; many of the models were specifically developed for climate change impact studies and have been calibrated and validated in a few hundred sites in all agroclimatic regions. The DSSAT models have been used widely for evaluating crop water requirements and yields, as well as climate change effects and changes in yields associated with the introduction of irrigated agriculture.
3. Essentially the outflow node for each of the internal catchments going to the next downstream catchment. These flows are reserved at the top for environmental purposes, and thus cannot be withdrawn by various demand.
4. Currently funded by the Swedish government, assessment of environmental flows for the Dniester is being carried out (with preliminary estimates for this flow to be at Q5).
5. No digital data were available from 2016 to 2018 to expand the current climate period to 2018.
6. See, in particular, the system for calculating the water balance of the Dniester basin: <http://vb.dniester-commission.com>.
7. See documentation of these principles for hydrotechnical and amelioration facilities in "Determination of Hydrological Characteristics for the Conditions of the Republic of Moldova": http://www.legis.md/cautare/getResults?doc_id=8972&lang=ro.

8. Only five stations revealed a discrepancy between the calculated data and the observed data of more than 20 percent. All these five stations differ in azonal conditions of runoff formation and are subsequently excluded from the mapping. Of the remaining 80 stations, for 14 stations the difference was between 10 and 20 percent, and for the remaining 66 stations it was less than 10 percent.
9. Errors were 0.95, 0.20, and 6.4 percent for the median, 75th, and 95th percentiles of in-country runoff. For the basins outside Moldova, the errors are about 2.7, 0.07, and 8.3 percent for the median, 75th, and 95th percentiles.
10. Center for Demographic Research with UNFPA, Moldova, *Population Situation Analysis in the Republic of Moldova* (Chisinau: UNFPA, Moldova, 2016).
11. This was cross-checked against information included in a series of studies on water supply conducted for the three major regions of Moldova (North, Central, and South) (Pienaru et al. 2014). The study included estimated projections of connection rates for 2020 from 90 to 93 percent in urban areas, and for rural areas from 23 percent (in the north) to 60 percent (in the south). Note that for the Dniester left bank areas we assumed a 90 percent connection rate in urban areas and a 37 percent connection rate in rural areas, for all scenarios.
12. Note that an assessment of the recharge characteristics and sustainability of deep groundwater sources was beyond the scope of this work. As a result, deep groundwater is tracked as a water supply source, but it is treated as an inexhaustible source for the purposes of our assessment. Subsequent analysis should be conducted to assess whether the levels of deep groundwater usage under each of the scenarios is within sustainable yields, as well as an assessment of water quality from the deep. For the modeling in WEAP, it is assumed that connected systems, when and if they rely on any source of water, apply water treatment where necessary, to arrive at compliant water quality standards.
13. See <https://www.danubis.org/eng/utility-database/country-profile/>.
14. Irrigated hectares by scheme from "Information Note: On the Management of the Hydro amelioration Fund According to MARDE Request No 16-07/448 of 04 February 2019." Intake water bodies by scheme were identified in the scheme level profiles in the Diagnostic study by SDA (Intexnauca 2018a).
15. Information on scheme-level characteristics and irrigated hectares shared with the project team by SDA Moldova.
16. The 2,605 hectares attributed to private small-scale systems is not a simple difference between the AIPA total across Moldova (4,378 hectares) and the irrigated hectares in other categories. AIPA data did not distinguish between irrigated area within or outside the boundaries of their central systems.
17. See <http://www.fao.org/land-water/databases-and-software/cropwat/en/> for additional details.
18. This value is slightly different for the three agroecological zones of Moldova (north-center-south) as the crop water coefficients were determined based on these three zones.
19. Differences for the water future scenarios are driven by the expansion of irrigated areas in different catchments of Moldova. The catchments are allocated to different agroecological zones that have slightly different modeled crop water requirements.
20. After converting them first to monthly cubic meters per hectare through multiplication with a factor 10 (dividing by 1,000 [converting millimeters to meters] and then multiplying by 10,000 square meters per hectare).
21. The intake in specific water bodies was identified as per the description of scheme profiles in (Intexnauca 2018a).
22. Information on scheme-level characteristics and irrigated hectares shared by SDA Moldova.
23. Based on GDP growth rate projections of 3.8 percent per year and an elasticity factor of 0.8.
24. This corresponds to a Q3 flow approximately.
25. To determine yields, the DSSAT crop model was used, described in detail in Sutton et al. (2013). For some crops (e.g. sunflower, not examined in Sutton et al. [2013]), the incremental effect of irrigation on crop yield was estimated using the IIASA/FAO (2012) analysis. The crop model was calibrated to specific agroclimatic regions of Moldova and accounted for the effect of climate change over time.
26. Capital costs from the Regional Sector Programme on Water Supply and Sanitation: Development Region Centre Study were used. See "Modernization of Local Public Services in the Republic of Moldova," implemented by GiZ on behalf of BMZ, EU, and SIDA.
27. Capital costs from Swiss/Austrian funded APASAN project for rural water supply projects.

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