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Towards a Low-carbon Economic Sustainable Development: Scenarios and Policies for Kazakhstan

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ABSTRACT

This paper analyses analysis current and future dependence of agriculture, industry, oil and gas sector on water supply in Kazakhstan under varying socioeconomic and climate change scenarios. To conduct the scenarios analysis, a multiple linear model was used; the model has been widely used to examine complex water systems in the water resource planning sector all around the world. The paper results show that by 2050 total water demand under normal weather conditions could increase from 20188.62 m^3 in 2015 to 23010.18 m^3 under sustainable use scenario, to 26794.85 m^3 under current trends (CT) baseline scenario, and up to 30220.46 m^3 under the more resource intensive scenario, however, the future water demand may be affected by environmental changes. The largest change (relative to the CT scenario) in total demand of 32413.18 m^3 would result from the combined effect of the temperature increase and decrease in precipitation. More than 55% of this change would be in agriculture sector. Through exploring water scenarios, this paper could assist Kazakhstani resource managers and policymakers in designing more effective eco-environment management plans and strategies in the face of climate change.

Keywords: Resources Use, Sustainable Development, Economic Growth, Kazakhstan
JEL Classifications: Q43, O47

1. INTRODUCTION

Kazakhstan is a completely landlocked country situated in Central Asia with a population of approximately 17.5 mln, Table 1 (World Bank, 2015). Average population density is 6 inhabitants per km^2, but varies from 2 inhabitants per km^2 in the central province of Zhezkazgan to 20 inhabitants per km^2 in Almaty province in the southeast (Spankulova et al., 2020). It is projected that the overall national population will reach 24.3 million by 2050 with annual average growth 0.6% per year (KIER, 2012). In 2018, Kazakhstan's gross domestic product (GDP) was 227 USD million and real GDP was projected to almost double by 2030 and increase by five times by 2050 (KIER, 2012). However actual growth in Kazakhstan depends on the global economic situation and fuel price stabilization (Pomfret, 2005; Jumadilova, 2012; Xiong et al., 2015; Kurmanov et al., 2016; Cotella et al., 2016). In 2015, Kazakhstan has been seriously affected by external shocks, including lower oil prices (Saiymova et al., 2018). The GDP growth slowed from 4.1% in 2014 to 1.2% in 2015. Industry including oil and gas sector is main sector of Kazakhstani economy, accounting 44% of GDP, while the agriculture sector accounted for 5% (World Bank, 2018; Movkebayeva et al., 2019).

The climate of Kazakhstan is typically continental, with cold dry winters and hot dry summers. In the south, average temperatures vary from −3°C in January to +30°C in July (Vilesov et al., 2009). In

Table 1: Basic statistics and population (World Bank, 2018)

Physical areas	Quantity
Area of the country	272 490 000 ha
Cultivated area (arable land and are area under permanent crops)	23 480 000 ha
As % of the total area of the country	9%
Arable land (temporary crops)	23 400 000 ha
Area under permanent crops	80 000 ha
Precipitation	250 mm per year
Population	
Total population	17 550 000 inhabitants
Of which rural	45%
Population density	6 inhabitants per km^2
Economy and development	
Gross domestic product	227 437 mln USD per y
Value added in agriculture (% of GDP)	5%
GDP per capita	10 250 USD per y
Access to improved drinking water	
Total population	95%
Urban population	99%
Rural population	90%

Table 2: Water reservoirs in Kazakhstan (FAO, 2016a)

Volume, million m^3	Quantity
1–5	116
5–10	30
10–50	33
50–100	15
100–500	12
500–1000	5
1000 and over	3

the north, average temperatures vary between −18°C in January and +19°C in July, while records show temperatures of -45°C in January. Precipitation is insignificant, except in the mountainous regions. Average annual precipitation is an estimated 250 mm, ranging from less than 100 mm in the Balkhash-Alakol depression in the central-eastern region or near the Aral Sea in the south, up to 1600 mm in the mountain area in the east and southeast (WMO, 2019). About 70–85% of annual rainfall occurs during the winter, between October and April. Snow often falls in November (Aliyeva et al., 2020).

Average perennial river flows in Kazakhstan (general surface water resources in natural conditions) is 100.6 km^3 per year, including that formed in the country – 55.94 km^3 per year and the remaining part – 44.64 km^3 per year flowing from neighbouring countries - China, Uzbekistan, Kyrgyzstan, and Russia (Karatayev et al., 2017). The availability of water per capita in Kazakhstan is less than that world average. The water availability is 37 thousand m^3 per one km^2 and 6.0 thousand m^3 per capita a year in Kazakhstan (Karatayev et al., 2017). Over 50% of reserves of water resources have a volume of 1–5 million m^3 of water (Koshim et al., 2020) (Table 2). Kazakhstan has more than 39.000 rivers and streams flow on the country's territory; 7.000 of them have a length of over 10 km (GWP, 2014).

The territory of Kazakhstan is divided into eight hydro-economic basins: Aral-Syrdarya basin (SD), Balkhash-Alakol basin (BA), Irtysh basin (IR), Ural-Caspian basin (UC), Ishim basin (IS), Nura-Sarysu basin (NS), Shy-Talas basin (ST) and Tobol-Turgai (TT) basin (Zhupankhan et al., 2018). Water resources are extremely unevenly distributed within the country and are marked by significant perennial and seasonal dynamics (Issanova et al., 2018). The Tobol-Torgai and Nura-Sarysu river basins have only 3% of total water resources in the country (Table 3). Irtysh and Balkhash-Alakol river basin account for almost 75% of water resources generated within the country (FAO, 2016) (Table 4).

The purpose of this paper is to conduct analysis current and future dependence of agriculture, industry, oil and gas sector on water supply in Kazakhstan under varying socioeconomic and climate change scenarios. The paper contributes to an understanding of the system and its possible development (Movkebayeva et al., 2020; Saiymova et al., 2020). Furthermore, the paper could assist Kazakhstani resource managers and policymakers in designing more effective eco-environment management plans and strategies in the face of climate change. As said in Address to the Nation by the President of the Republic of Kazakhstan, sustainable resource management is critically important to the Kazakhstani economy (Smagulov, 2012; Smagulov et al., 2017). Currently, country total water withdrawal is 20.18 km^3, of which 14.76 km^3 or 66% is for agriculture sector (FAO, 2016a) (Table 5).

2. RESEARCH METHODS

2.1. Data Collection

To address the study objective, a literature review on Kazakhstan's water system was carried out. The literature review included governmental water strategies, water programmes, annual environmental reports, communications and presentations, primary and secondary data on historical water withdrawals and deliveries. The main sources of information and data providers were the National Agencies such as Kazakhstani Ministry of Agriculture, Kazakhstani Ministry of Energy, Office for National Statistics, Office of the Prime Minister of the Republic of Kazakhstan, National Water Resource Committee, Regional Environmental Centre for Central Asia, Kazakhstan Institute of Geography, Kazakhstan Institute of Economic Research, Astana Economic Forum and international organisations including Asian Development Bank (ADB), World Bank (WB), United Nations Water Programme (UNWP), United Nations Development Programme Kazakhstan (UNDP), UNESCO World Water Assessment Programme, UK Foreign & Commonwealth Office, Global Water Partnership Programme, Fund for Saving the Aral Sea (IFAS), UN Food and Agriculture Organization (FAO) and German Institute for Economic Research (DIW). In addition to the national and international reports, this literature review included analysis the outputs of the studies on water resource management in Central Asia conducted by (Golubtsov, 1996; Micklin, 1998; O'Hara and Hannan, 1999; O'Hara, 2000; Cai and McKinney, 2003; Wegerich, 2004; Severskiy, 2004; Siegfried and Bernauer, 2007; Long et al., 2010; Ryabtsev, 2011; Zizani, 2015; Howard and Howard, 2016; Valeyev et al., 2019; Rivotti et al., 2019). Moreover, we used the materials of energy research (Bekniyazova et al., 2016; Karatayev and Clarke, 2016; Omarbekova et al., 2017; Karatayev et al., 2017; Babazhanova et al., 2017; Karatayev and Hall, 2017; Koshim et al., 2018; Onyusheva et al., 2018; Karatayev et al., 2019; Kozhukhova et al., 2019; Saparaliyev et al., 2019a; Saparaliyev et al., 2019b; Yerkin et al., 2019; Yessentemirova et al., 2019; Movkebayeva et al., 2020; Kurmanalina et al., 2020).

2.2. Scenario Modelling

The general approach to estimating future water demand used in this study can be described as a product of the number of users (i.e., demand driver) and unit quantity of water as:

$$Q_{cit} = N_{cit} \cdot q_{cit} \quad (1)$$

Where Q_{cit} = water demand in user sector of study area i in year t; N_{cit} = number of users (or demand driver) such as population or economic growth; and q_{cit} = average rate of water requirement (or water usage).

Water-demand relationships which quantify historical changes in q_{cit} can be expressed in the form of equations, where the average rate of water usage is expressed as a function of one or more independent (also called explanatory) variables. A multivariate context best relates to actual water usage behaviours, and multiple regression analysis can be used to determine the relationship between water quantities and each explanatory variable. The functional form (e.g., linear, multiplicative, exponential) and the selection of the independent variables depend on the category of water demand. For example, public supply withdrawals can be estimated using the following linear model:

$$PS_{it} = a + \sum_j b_j X_{jit} + \varepsilon_{it} \quad (2)$$

where PS_{it} represents per capita public supply water withdrawal within geographical area i during year t, X_j is a set of explanatory variables (e.g., air temperature, precipitation, price of water and others), which are expected to explain the variability in per capita use, and it is random error term. The coefficients and b_j can be estimated by fitting a multiple regression model to historical water use data.

The actual models used in this study were specified as log-linear model with additional variables which served to fit the model to the data and also isolate observations which were likely to be outliers:

$$\ln PS_{it} = a_o + \sum_j \beta_j \ln X_{jit} + \sum_k \gamma_k \ln R_{kit} + \sum_l \delta_i D_{lit} + \sum_m p_m s_{mit} + \varepsilon_{it} \quad (3)$$

where PS_{it} represents per capita public supply water withdrawals within geographical area i during year t, X_j^s are a set of explanatory variables, R_k are ratio (percentage) variables such as ratio of employment to population, D_i are indicator variables designating specific water supply systems which assume the value of 1 for observations for the system and zero otherwise, S_m are indicator spike variables designating individual observations in the data, ε_{it} is the random error, and α, β^s, γ^s, δ^s, and are ρ^s the parameters to be estimated.

A large number of econometric studies of water demand have been conducted over the last years (Smith et al., 1983; Ogg and Gollehon, 1989; Hanemann, 1998; Renwick and Green, 2000; Jain et al., 2001; Brekke et al., 2002; Reynaud, 2003; Scheierling et al., 2006; Kostas and Chrysostomos, 2006; Alvisi et al., 2007; Olmstead et al., 2007; Babel et al., 2007; Ghiassi et al., 2008; Herrera et al., 2010; Dziegielewski and Baumann, 2011; Abildtrup et al., 2013; Polycarpou and Zachariadis, 2013; Koutiva and Makropoulos, 2016). More recently, Donkor et al. (2014) have performed a qualitative literature review on the urban water demand forecasting. They have reported that some methodological differences, such as forecasting models, explanatory variables included, and forecasting horizon are likely to affect urban water demand forecast. Arbués et al. (2003) have reviewed the literature on residential water demand modelling, in which the focus was on cross-sectional data for pricing purposes.

Table 3: Water availability in Kazakhstan, km^3 (FAO, 2016b)

River basin	Internal RSWR	External RSWR	Total actual RSWR	Total estimated groundwater reserves	Proven reserves
Aral-Syrdarya	3.36	18.93	22.29	9.29	1.13
Balkhash-Alakol	15.43	9.75	25.18	20.01	7.26
Irtysh	25.92	4.48	30.40	9.56	2.87
Ishim	2.77	0.00	2.77	2.31	0.16
Ural-Caspian	4.13	8.26	12.39	7.37	0.97
Nura-Sarysu	1.37	0.00	1.37	3.32	0.82
Tobol-Torgai	1.63	0.31	1.94	3.62	0.48
Chu-Talas-Assa	1.33	2.91	4.24	8.79	1.75
Total	55.94	44.64	100.6	64.27	15.44

Table 4: Water availability per capita in Kazakhstan, km^3 (FAO, 2016c)

River Basin	Internal RSWR	External RSWR	Total estimated groundwater reserves	Proven reserves	Total water resources
Aral-Syrdarya	6.68	1.00	2.92	0.36	7.02
Balkhash-Alakol	6.78	4.16	5.64	2.04	8.74
Irtysh	15.15	12.92	4.78	1.43	16.59
Ishim	1.34	1.34	1.17	0.08	1.42
Ural-Caspian	4.98	1.66	3.10	0.41	5.37
Nura-Sarysu	1.09	1.09	2.67	0.66	1.74
Tobol-Torgai	2.08	1.75	3.89	0.51	2.60
Chu-Talas-Assa	3.81	1.19	8.11	1.61	5.38
Average rate	5.95	3.31	3.93	0.94	6.86
Total	16.30	9.06	10.76	2.57	18.79

2.3. Scenario Description

Estimates of future water withdrawals were prepared for three different scenarios. The scenarios include a less resource intensive (LRI) outcome, current trends (CT) or baseline case scenario, and a more resource intensive (MRI) outcome. The scenarios were defined by different sets of assumed conditions regarding the future values of demand drivers (Table 6). All three scenariosrely on the population and GDP growth projections from Kazakhstani Institute of Economic Research (KIER, 2012). The three scenarios do not represent forecasts or predictions, nor do they set upper and lower bounds of future water use. Different assumptions or conditions could result in withdrawals that are within or outside of the range represented by the three scenarios.

Table 5: Water use in Kazakhstan, km^3 per year (FAO, 2016a)

Water withdrawal	Quantity
Total water withdrawal by sector	20.18 km^3 per y
Agriculture	14.76 km^3 per y
Public supply	0.87 km^3 per y
Industry	4.48 km^3 per y
Oil and gas sector	0.04 km^3 per y
Other	0.03 km^3 per y
Per inhabitant	1.32 km^3 per y
Surface water and groundwater withdrawal	19.98 km^3 per y

Scenario A –CT or Baseline Scenario: The basic assumption of this scenario is that the recent trends (last 20 years) in population growth, economic development, and institutional change will continue. With respect to population growth the "current trends" are represented by the official forecasts of population from Kazakhstani Institute of Economic Research. The CT scenario assumes that the factors such as water price and power generation will follow the recent historical trends or their official or available forecasts. This scenario also assumes that existing trends in the efficiency of water usage will continue. The main barriers preventing sustainable water usage will remain.

Scenario B – Sustainable Use Scenario (SU): In this scenario, total population and GDP growth at the same level as in Scenario A. However, industrial withdrawals of water are assumed to decrease as some less water-intensive industrial activities continue to expand

Table 6: Assumptions for factors affecting future water demand

Factor	Scenario A - CTS	Scenario B- SUS	Scenario C - MRI
Total population	Official projection	Official projection	Official projection
Economic growth	Official projection	Official projection	Official projection
Mix of commercial and industrial activities	CTs	No increase in water-intensive industry	Increase in water intensive industry
Power generation	CTs in line with National 2050 low carbon strategy	CTs in line with National 2050 low carbon strategy	CTs in line with National 2050 low carbon strategy
Water conversation	Continuation of historical trend	50% higher rate than historical trend	50% lower than historical trend
Future water prices	No price increase	Higher future price increases (1.5–2%/year)	Recent increasing trend but remain unchanged in real terms
Irrigated land	Constant cropland	Constant cropland	Increasing cropland
Temperature and precipitation	UNDP prediction	UNDP prediction	UNDP prediction

CTS: Current trends or baseline, SUS: Sustainable use scenario, MRI: More resource intensive

Table 7: Total water withdrawal scenarios by sectors by 2050, m^3

Sector - scenario	1990	2012	2015	2020	2030	2040	2050
CT							
Agriculture	27040.37	12349.95	14761.23	15550.68	16179.47	17144.61	18755.51
Public supply	1416.66	843.58	866.63	1028.15	1239.66	1612.07	2022.97
Industry	7110.7	4230.16	4482.23	4792.9	4984.7	5490.79	5821.69
Oil and gas sector	19.65	38.99	40.94	53.15	53.58	80.9	113.08
Other	15.92	22.76	37.59	50.03	64.36	73.68	80.88
Total	35603.3	17485.44	20188.62	21474.91	22521.77	24402.05	26794.85
LRI							
Agriculture	27040.37	12349.95	14761.23	14897.58	15633.17	16158.71	16544.61
Public supply	1416.66	843.58	866.63	863.18	993.49	1068.73	1114.5
Industry	7110.7	4230.16	4482.23	4516.74	4865.33	5074.48	5254.4
Oil and gas sector	19.65	38.99	40.94	35.85	40.18	53.7	61.8
Other	15.92	22.76	37.59	41.23	58.96	48.47	51.87
Total	35603.3	17485.44	20188.62	20354.58	21591.13	22404.09	23010.18
MRI							
Agriculture	27040.37	12349.95	14761.23	16563.91	18062.59	19414.59	20755.32
Public supply	1416.66	843.58	866.63	1019.27	1185.9	1448.38	2229.13
Industry	7110.7	4230.16	4482.23	5007.18	5468.76	6020.79	7001.78
Oil and gas sector	19.65	38.99	40.94	52.45	64.38	76.69	143.2
Other	15.92	22.76	37.59	50.13	71.48	76.79	91.03
Total	35603.3	17485.44	20188.62	22692.94	24853.11	27037.24	30220.46

CT: Current trends, LRI: Less resources intensive, MRI: More resource intensive or locate in Kazakhstan. The efficiency assumptions include more water conservation (e.g., implementation of additional cost-effective water conservation measures by agricultural and industrial users), as well as higher water prices in the future. Some barriers in water management will be addressed and regulated.

Scenario C –MRI Scenario: In this scenario, the efficiency assumptions include less water conservation than indicated by the recent trends in Scenario A. Agricultural withdrawals of water would increase as some water-intensive industry categories continue to expand. The price of water is assumed to remain unchanged in real terms, which implies that future price increases will only offset the general inflation. The MRI scenario assumes that barriers to sustainable management of water usage will remain.

3. RESULTS AND DISCUSSION

Table 7 provides a summary of the future water withdrawals scenarios for five categories of users within the major user sectors. Under the baseline (CT) scenario, total withdrawals would increase from actual value of 20188.62 m^3 in 2015 by 26794.85 m^3 (or 32.7%) in 2050. Most of this increase represents growth in withdrawals for agriculture and public supply sectors. Under the assumptions of the LRI scenario, total withdrawals would increase by 23010.18 m^3, or 13.9%.

Relative to the CT scenario for 2015, this represents a decrease of 3785.67 m^3. Most of this decrease comes from lower demands in agriculture, industry and public supply sectors. Under the MRI scenario, total withdrawals would increase from the reported value of 20188.62 m^3 in 2015 to 30220.46 m^3 in 2050. The total increase would be 10134.84 m^3, or 49.7%. Relative to the LRI scenario for 2015, this represents a 7210.28 m^3 increase in total withdrawals.

Table 8 shows the distribution of water withdrawals by sources and by river basins in Kazakhstan. Current withdrawals include 17492.1 m^3 renewable surface water and total surface water withdrawals would increase to 23070.37 m^3 in 2050. Aral-Syrdarya and Irtysh river basins will provide almost 60% of surface water supply by 2050.

Table 8: Water withdrawals by source of supply, CTS 2015-2050, m^3

River basin	Total	RWSR	Desalinated water	GWR	Mine water	Treated wastewater	Agricultural drainage
2020							
Aral-Syrdarya	7163.87	6876.76	0.00	263.81	1.30	36.15	0.00
Balkhash-Alakol	4357.55	3689.19	170.73	388.27	0.36	61.10	42.95
Irtysh	4279.72	4052.71	0.00	231.55	4.87	0.00	0.00
Ishim	445.35	386.69	0.00	54.47	1.57	3.59	0.00
Ural-Caspian	2503.34	1037.55	1268.09	174.18	19.75	0.00	0.00
Nura-Sarysu	514.76	375.83	0.00	84.19	49.04	6.54	0.00
Tobol-Torgai	271.71	227.16	0.00	38.06	7.12	0.00	0.00
Chu-Talas-Assa	1938.60	1844.01	0.00	96.92	1.90	0.00	0.00
Total	21474.91	18489.90	1438.82	1331.44	85.90	107.37	42.95
2030							
Aral-Syrdarya	7513.10	7211.99	0.00	276.67	1.36	37.91	0.00
Balkhash-Alakol	4569.98	3869.03	179.06	407.19	0.38	64.08	45.04
Irtysh	4488.34	4250.27	0.00	242.83	5.10	0.00	0.00
Ishim	467.06	405.54	0.00	57.13	1.64	3.76	0.00
Ural-Caspian	2625.38	1088.13	1329.90	182.67	20.72	0.00	0.00
Nura-Sarysu	539.85	394.15	0.00	88.30	51.43	6.85	0.00
Tobol-Torgai	284.95	238.24	0.00	39.92	7.47	0.00	0.00
Chu-Talas-Assa	2033.10	1933.90	0.00	101.65	1.99	0.00	0.00
Total	22521.77	19391.24	1508.96	1396.35	90.09	112.61	45.04
2040							
Aral-Syrdarya	8140.35	7814.10	0.00	299.77	1.48	41.07	0.00
Balkhash-Alakol	4951.51	4192.04	194.00	441.19	0.41	69.43	48.80
Irtysh	4863.06	4605.11	0.00	263.11	5.53	0.00	0.00
Ishim	506.05	439.39	0.00	61.90	1.78	4.08	0.00
Ural-Caspian	2844.56	1178.98	1440.93	197.92	22.45	0.00	0.00
Nura-Sarysu	584.92	427.06	0.00	95.67	55.72	7.43	0.00
Tobol-Torgai	308.74	258.13	0.00	43.25	8.09	0.00	0.00
Chu-Talas-Assa	2202.84	2095.36	0.00	110.14	2.15	0.00	0.00
Total	24402.05	21010.17	1634.94	1512.93	97.61	122.01	48.80
2050							
Aral-Syrdarya	8938.57	8580.33	0.00	329.16	1.62	45.10	0.00
Balkhash-Alakol	5437.04	4603.10	213.03	484.45	0.45	76.24	53.59
Irtysh	5339.92	5056.67	0.00	288.91	6.07	0.00	0.00
Ishim	555.68	482.48	0.00	67.97	1.96	4.48	0.00
Ural-Caspian	3123.49	1294.59	1582.23	217.33	24.65	0.00	0.00
Nura-Sarysu	642.28	468.93	0.00	105.05	61.18	8.16	0.00
Tobol-Torgai	339.02	283.44	0.00	47.49	8.88	0.00	0.00
Chu-Talas-Assa	2418.84	2300.82	0.00	120.94	2.37	0.00	0.00
Total	26794.85	23070.37	1795.26	1661.28	107.18	133.97	53.59

Table 9: Effects of possible climate changes on water withdrawals in Kazakhstan, m³

Scenarios and sectors	1990	2012	2015 water withdrawals	2050 water withdrawals	2015-2050 change
CTs scenario					
Agriculture	27040.37	12349.95	14761.23	18755.51	3994.28
Public supply	1416.66	843.58	866.63	2022.97	1156.34
Industry	7110.7	4230.16	4482.23	5821.69	1339.46
Oil and gas sector	19.65	38.99	40.94	113.08	72.14
Other	15.92	22.76	37.59	80.88	43.29
Total	35603.3	17485.44	20188.62	26794.85	6606.23
CT ΔT +1.4°C ΔP +5%					
Agriculture	27040.37	12349.95	14761.23	20896.53	6135.3
Public supply	1416.66	843.58	866.63	2264.41	1397.78
Industry	7110.7	4230.16	4482.23	5240.09	757.86
Oil and gas sector	19.65	38.99	40.94	93.07	52.13
Other	15.92	22.76	37.59	124.5	86.91
Total	35603.3	17485.44	20188.62	28618.61	8429.99
CT ΔT +1.4°C ΔP -5%					
Agriculture	27040.37	12349.95	14761.23	24693.77	9932.54
Public supply	1416.66	843.58	866.63	2599.52	1732.59
Industry	7110.7	4230.16	4482.23	4947.13	464.9
Oil and gas sector	19.65	38.99	40.94	78.06	37.12
Other	15.92	22.76	37.59	94.7	57.11
Total	35603.3	17485.44	20188.62	32413.18	12224.56

Future water demands can also be affected by changes in the future climate. Because the period of analysis for water demand scenarios extends until the year 2050, the average weather conditions may change in response to regional and global climate change. Climate models for Kazakhstan produced by UNDP indicate that by 2050, there may be a significant rise in ground air temperatures, from +1.4°C to +3.5°C (UNDP, 2008). Climate models also indicate a possible change of normal annual precipitations in range from −11% to +18%. Future water withdrawals may be affected by these temperature and precipitation scenarios. The effect of these changes will vary by user sector, depending on each sector's sensitivity of water withdrawals to temperature and precipitations.

Table 9 summarizes the effects of climate changes on water withdrawals in Kazakhstan. The largest change (relative to the CT scenario) in total withdrawals of 32413.18 m³ would result from the combined effect of the temperature increase and decrease in precipitation. More than 55% of this change would be in agriculture sector.

It is important to recognize the uncertainty in determining future water demands in any study area and user sector. Future values for one or more model variables cannot be known with certainty. Various assumptions must be introduced when projections are made for the water demand drivers as well as when projecting the values of the determinants of water usage. By defining three alternative scenarios a range of uncertainty associated with future water demands can be examined and taken into consideration in planning decisions.

4. CONCLUSION AND IMPLICATION

The paper has shown that total water supply needs in Kazakhstan will continue to increase to meet the demands of growing population and the concomitant growth in the economy. However, the growth in total water demand could be faster or slower depending on which assumptions and expectations about the future conditions will prevail. By 2050 total water demand under normal weather conditions could increase from 20188.62 m³ in 2015 to 23010.18 m³ under LRI scenario, to 26794.85 m³ under CT baseline scenario, and up to 30220.46 m³ under the MRI scenario. The scenario results also underline that future water demand may be affected by temperature and precipitation changes. The effect of these changes will vary by user sector, depending on each sector's sensitivity of water withdrawals to air temperature and precipitations. The largest change (relative to the CT scenario) in total demand of 32413.18 m³ would result from the combined effect of the temperature increase and decrease in precipitation. More than 55% of this change would be in agriculture sector. The system should be moved towards a more realistic pricing, i.e. introduction of a higher degree of user payment. In addition, a more decentralized management of the water supply infrastructure should be promoted. Decentralizing the water management from state water authorities to community-based water-user associations may help a more equitable and efficient water distribution. It may also make the system more transparent with involvement of local communities.

Currently, communities in Kazakhstan are not considered as valid decision makers and therefore not informed or engaged to participate meaningfully in decision-making processes. Agriculture sector as a main water consumer should be also reformed. Moreover, united information and data system on water system is needed. Improved data reporting would provide a basis for future studies of water demands. State resource agencies should consider actions that would improve the quality of water withdrawal data, as well as expand the scope of data collection to include data on return flows, which would permit estimation of consumptive use and preparation of water budgets within different hydrologic regions of Kazakhstan.

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