Kazakhstan: *Economy-wide Effects of Adaptation in Agriculture*

Applying the e3.kz Macro-econometric Model to the Cases of Irrigation Systems and Precision Agriculture

Executive summary

SEPTEMBER 2021

Kazakhstan faces severe droughts. Investments in irrigation systems could boost Kazakhstan's economy and create up to 78,000 additional jobs per year compared to the drought scenario, shows the unique e3.kz model developed by the GIZ project on Climate Resilient Economic Development (CRED).

The investigated adaptation measures reduce the climate change induced costs in agriculture by up to 584 billion Tenge per year and provide benefits not only to the agriculture sector, but to the whole economy. A **macroeconomic analysis with the model e3.kz evaluates the economy-wide impacts of sectoral adaptation options allowing to identify those with high effectiveness as well as positive effects on the economy and the environment.** Scenario analysis is used to compare a scenario with an adaptation measure against a scenario with only climate change. **Policymakers can then compare the results of different adaptation options to identify "win-win" actions.**

- Irrigation systems help to combat climate change in the agriculture sector. Further adaptation measures supplement the transition to a climate resilient economy.
- GDP is **up to 1.2% per year higher when investing in irrigation systems and up to 78,000 additional jobs per year are created.**
- Parallel driving as one aspect of precision agriculture requires lower investment which is favorable for small-scale farmers who do not have huge financial resources. Small economic stimuli result in small effects on GDP and employment.

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Current situation in agriculture

Agriculture plays an essential role in Kazakhstan's economic and social development. In 2019, around 5% of GDP is related to agriculture and about 13% of the workforce or 1.2 million people are employed in this sector. Although this share has fallen since 2010 from originally 28%[1], the sector is still important for income generation *(Bureau of National statistics of the Republic of Kazakhstan, 2021).*

According to the strategy document "Kazakhstan 2050", agriculture is one of the key sectors to develop and diversify the national economy *(OECD, 2020; ADB, 2018)*. Current agricultural policies are oriented towards boosting domestic production to substitute imports and promote exports.

Cropland is predominantly cultivated by agro-holdings and large-scale farms. Livestock and vegetable farming in the rest of the country is dominated by small farms of rural households (*OECD, 2020*). Wheat production is the most important segment in agriculture contributing not only to food security within the country. Kazakhstan is also a leading wheat exporter (*UNDP, 2019*).

Due to a lack of maintenance and investments in irrigation and drainage systems after the fall of the Soviet Union, former irrigated farmland was abandoned causing salinization and soil degradation. Another threat is overgrazing which degrades pastureland.

A major challenge is the high wheat yield variability in the mainly rain-fed northern area which is likely to amplify due to rising temperatures, changes in precipitation patterns and increased pest and disease outbreaks (*USAID, 2017; World Bank, 2016*). Due to lower precipitation in the south and southeast, large areas of arable land are artificially irrigated. While the share of irrigated land remains low at 0.9%, water demand in agriculture is high and accounts for around two-thirds of the water consumption. About 11-15% is lost during transport mostly due to the obsolete irrigation infrastructure and to the low cost of water supply (*OECD, 2020*). Increasingly noticeable climate change is likely to exacerbate the already volatile production and income risks.

Furthermore, Kazakhstan is highly dependent on transboundary rivers which also show a reduced water flow due to intense water use (*"Green Economy Transition Concept", 2013*).

The government addressed agricultural productivity and environmental issues in its "Green Economy Transition Concept". Nevertheless, the concept falls short of formulating climate resilient strategies to be better prepared for extreme weather events and gradual changes in the agriculture sector.

Impacts of climate change in agriculture

Temperature increase, changes in precipitation, and shifting of arid zones to the north are expected to intensify the risk of land degradation and erosion resulting in lower agricultural productivity in Kazakhstan. The vulnerability of national development, food security and natural environment is exacerbating by climate change.

Agriculture is one of the economic sectors most vulnerable to climate change. Drought has been identified as a very significant risk especially for the rain-fed wheat production (*World Bank, 2015, 2016; MNE et al., 2017*). In combination with low precipitation in summertime and extreme temperatures, water can be scarce and desertification in flatland areas in western, northern, and central Kazakhstan speeds up. At the same time, temperature increase causes glacier melting which amplifies flood risk in southern and eastern regions in the medium term but threatening water supply by mid-century. Since 1950 Kazakhstan's glacier mass decreased by 14-30% (*USAID, 2017*). Main challenges associated with these climate change impacts are soil degradation and desertification.

Climate projections expect further increasing air temperature, an expansion of the drought zones in the north and center. Furthermore, an increase in average annual precipitation is expected, despite a decrease in summer period. Additionally, an increase in extreme weather events is anticipated such as heat waves, droughts, floods, landslides, and mudflows (*MNE, 2017; USAID, 2017; Navarro, Jordà, 2021*).

1: It is important to take into account that the methodology for statistical data collection on employment was changed in 2014: from then onwards certain categories of self-employed people in agriculture are no longer included in the statistics (see *Center for Research and Consulting, 2020*).

In the future, some regions may expect better conditions for agriculture due to an increase in precipitation; in other areas droughts could have negative impacts. According to the UNDP (2020), economic losses of wheat yields are estimated to decline 33% (or 457 billion Tenge in 2019 prices) of the current potential by 2030 and 12% (608 billion Tenge in 2019 prices) by 2050. A similar pattern is foreseen for grazing capacity, with livestock productivity reduction of 10% (or 108 billion Tenge by 2030) to 15% (or 170 billion Tenge by 2050) of the current potential. In the most severe climate scenario, the decrease could reach 10% to 20%. In contrast, sunflower seed yields are supposed to profit from climate warming which leads to an increase of 8% (almost two billion Tenge) by 2030 and around 4% (almost one billion Tenge) by 2050 compared to current gross output. Overall, crop production is more vulnerable to risk than livestock (*World Bank, 2016*).

Options for building climate resilience in agriculture

According to the New Environmental Code adopted in 2021, agriculture is one of the priority areas for climate change adaptation (*Article 313*). Several options exist for farmers to adapt to climate change partly also known from the "Green Economy Concept" adopted in 2013 as the introduction of water-saving technologies, cultivation of water-efficient crops and restoring of water infrastructure and leakage control. Additionally, the use of moisture saving technologies (conservation agriculture, no-till farming) can contribute to soil conservation (*UNDP, 2020; World Bank, 2016*).

Precision agriculture optimizes return on inputs while preserving resources (*EBRD et al., 2018*). Other options include fertilization and improved crop protection to limit pests and diseases. Selective breeding and pasture improvement through rotational grazing aims at avoiding overgrazing and increasing livestock productivity. Improved weather forecasting and early warning systems for extreme weather events can also help to limit the economic losses caused by climate change (*FAO, 2017*). Each of these individual techniques can at least partially offset yield losses in drought years. In contrast, insurance against crop failures compensates farmers at least partly, but cannot prevent losses. The techniques require investment in new machinery and equipment, knowledge, and training.

Crop farming and livestock technologies are already analyzed regarding their cost and benefits in terms of mitigation and adaptation potential (*EBRD et al., 2018*). Cost-benefit-analyses of investments into particular adaptation measures already indicate the value of adaptation benefits derived from them (see Table 1). Additional macroeconomic analyses which are currently missing to assess the economy-wide impacts of single measures would greatly enable decisionmakers to adopt the most effective adaptation measures that also have positive effects on the economy and job creation (win-win measures).

Table 1: Cost-benefit-analysis of adaptation measures

ADAPTATION MEASURES	INVESTMENT (million USD)	ADAPTATION BENEFITS PER YEAR (million USD)
Drip irrigation of arable lands	83	112
Precision agriculture (parallel driving)	80	10
Investment in field machinery (tractors, harvesters)	1,000	63
Conservation agriculture (no-till farming): investing in modified and direct seeders	263	250
Improved greenhouses	4	1
Pasture improvement through rotational grazing (investment in infrastructure rehabilitation, pasture vegetation needed)	144	70
Fattening units	290	72

Macroeconomic analysis of adaptation measures

Cost-benefit-analyses show suitable solutions for the respective sectoral climate change related issue. A macroeconomic analysis goes a step further and evaluates the economy-wide impacts in terms of changes in GDP, employment, and production of sectoral adaptation options.

The e3.kz model for Kazakhstan was developed to analyze the economy-wide impacts of climate change and sector-specific adaptation measures. It helps to identify adaptation measures that are highly effective and have positive effects on the economy, employment, and the environment. This can only be achieved if the socio-economic relationships are captured, as well as the relationships between economic activity, energy and the environment, as with the so-called E3 (economy, energy, emission) models.

In scenarios, assumptions are made about the frequency and intensity of extreme weather events and combined with sector- and country-specific climate damages. Costs and benefits of adaptation measures are covered as well, which are borrowed from expert studies. If no specific data is available, own assumptions are made which can later be adapted if better data becomes available. All these initial impacts cause chain reactions in the e3.kz model. The **model results** do not only **show the direct effects but also the indirect and induced macroeconomic consequences** (GDP, jobs, imports, sector-specific output) **for Kazakhstan** due to economic interrelationships. On the one hand, model results show **what could happen under climate change scenarios** (awareness raising). On the other hand, policymakers can **identify those adaptation measures that are highly effective and have positive effects** on the economy, employment, and the environment (win-win options). Thus, they are better prepared.

Economy-wide impacts of climate change adaptation in agriculture

The macroeconomic effects of the adaptation measures "Rehabilitation and expansion of irrigation systems" and "Precision agriculture: parallel driving" are presented as examples. Irrigation systems are well suited to limit drought damages but due to poor maintenance in the past and the need for additional irrigated land, high investments are needed. Parallel driving as one aspect of precision agriculture requires lower investment which is favorable for small-scale farmers who do not have huge financial resources.

Rehabilitation and expansion of irrigation systems

The rehabilitation, modernization, and expansion of irrigation and drainage systems is key to prevent from water scarcity and to improve agricultural productivity under climate change scenarios. Droughts are expected to occur more frequently and more severely causing increasingly higher economic losses in agriculture, affecting jobs and food security.

Scenario assumptions and implementation

Investments in the reconstruction and expansion of water infrastructure (e. g. canals, drainage, reservoirs) as well as water-saving technologies are the main pillars to increase agricultural productivity. With this, the irrigated area can be increased by one million hectares without a significant increase in water consumption (*Kazakh Government, 2020*). Related costs amount to almost one trillion Tenge (*Astana Times, 2019*). Including expected replacement investments to maintain the water infrastructure, overall investments amount to 100 billion Tenge on average per year. Without financial incentives from government, farmers pay the investments themselves and try to pass on the costs to the consumers. Otherwise, the government subsidizes the investments which may lead to expenditure cuts in other areas.

Most of the drip irrigation systems must be imported either from Europe, Israel or China. Only a few local producers exist (*EBRD et al., 2018*). The rehabilitation and extension of the irrigation and drainage systems involves mainly local construction works.

In addition to the direct effects (construction works, material imports, higher agricultural output), these effects account for further indirect and induced effects, e. g., an increase of production in upstream and downstream sectors of agriculture and construction as well as for price and income effects, which in turn influence consumption expenditures.

***Table 2**: Key assumptions for investments in irrigation systems used as input for the e3.kz model*

ADAPTATION MEASURES	CUMULATED INVESTMENT (2021 – 2050)	ADAPTATION BENEFITS PER YEAR (in terms of higher agricultural output)
Investment in reconstruction of canals and reservoirs	2,894 billion Tenge	537 billion Tenge
Investment in drip irrigation	105 billion Tenge	47 billion Tenge

Model results

The **economy-wide effects** of the investments in water infrastructure in agriculture **are positive**. Both the intensified construction activity and higher crop yields due to the additional irrigation facilities have **a positive impact on GDP which is up to 1.2% (resp. 833 bn. Tenge) per year higher** compared to situation where droughts occur but no adaptation measures are taken. Foregone export chances and increases in agriculture imports to compensate for yield losses during drought years can now be partly prevented. The import of drip irrigation systems has per se a negative effect but does not prevail. Total exports increase by 0.24% (resp. 30 bn. Tenge) whereas total import growth is 1.1% (resp. 133 bn. Tenge) lower than without adaptation.

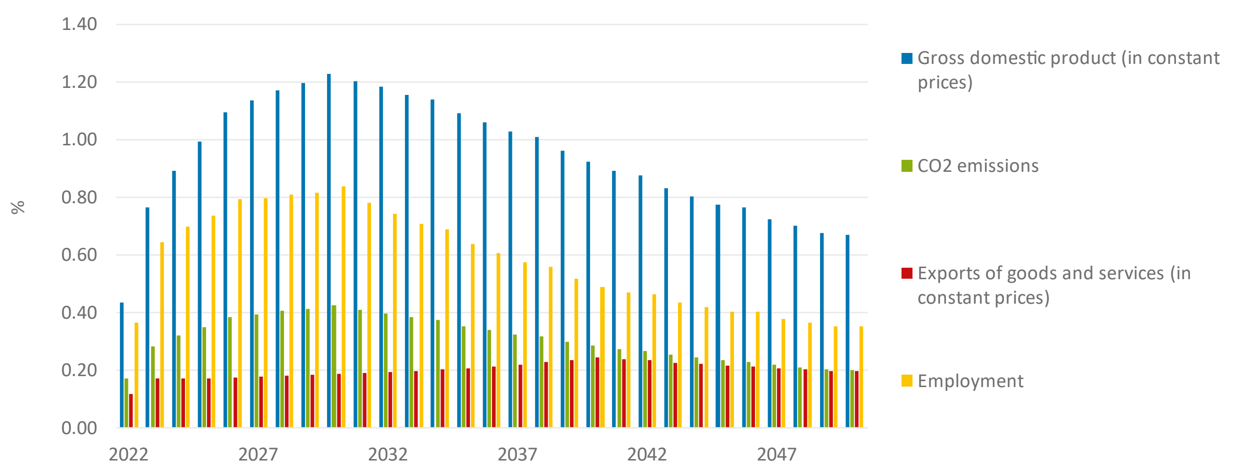
The intensified construction activity increases the demand for building materials such as concrete. During the construction period additional jobs in the construction sector are created. Thereafter, regular maintenance and replacement investments are necessary and preserve jobs.

Permanent jobs are created in agriculture by restored and additional irrigated land. Farmers can generate additional income from selling their products either to the world market or domestically. Supplying (e. g. fertilizer manufacturer) and purchasing industries (e. g. flour producers) profit as well – in terms of additional turnover and jobs – from the higher agricultural productivity not only in drought years. According to the e3.kz model results, **building irrigation measures will in total create up to 78,000 additional jobs** (respectively 0.8%) per year compared to a situation where no adaptation is done and droughts occur.

The higher economic activity shows on the one hand positive impacts on income and thus spending opportunities of households and investment plans of companies. On the other hand, energy demand and CO_2 emissions increase by up to 0.5% resp. 0.4% because additional mitigation options are not considered.

Figure 1: *Economic effects of* ***investment in irrigation systems*** *on components of GDP and employment (differences in percent compared to drought scenario)*

LONG-TERM IMPACTS OF IRRIGATION MEASURES



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Precision agriculture: parallel driving

Various technologies for agriculture management are available to support farm management in optimizing yields while preserving resources. Amongst them are yield monitoring, remote sensing and GPS and GIS technologies. The system of parallel driving is a key element of precision agriculture (*EBRD et al., 2018*).

Existing machinery can be upgraded with GPS and computer systems. The costs can be kept low compared to the purchase of new machines which are usually equipped with GPS by default. Farmers benefit from reduced outgoings and repeated passes. Thus, yields increase, and fuel consumption can be reduced.

Table 3: Key assumptions for investing in parallel driving used as input for the e3.kz model

ADAPTATION MEASURE	CUMULATED INVESTMENT (2021 – 2050)	ADAPTATION BENEFITS PER YEAR (in terms of higher agricultural output)
Investment in precision agriculture: parallel driving	100 billion Tenge	4 billion Tenge

Scenario assumptions and implementation

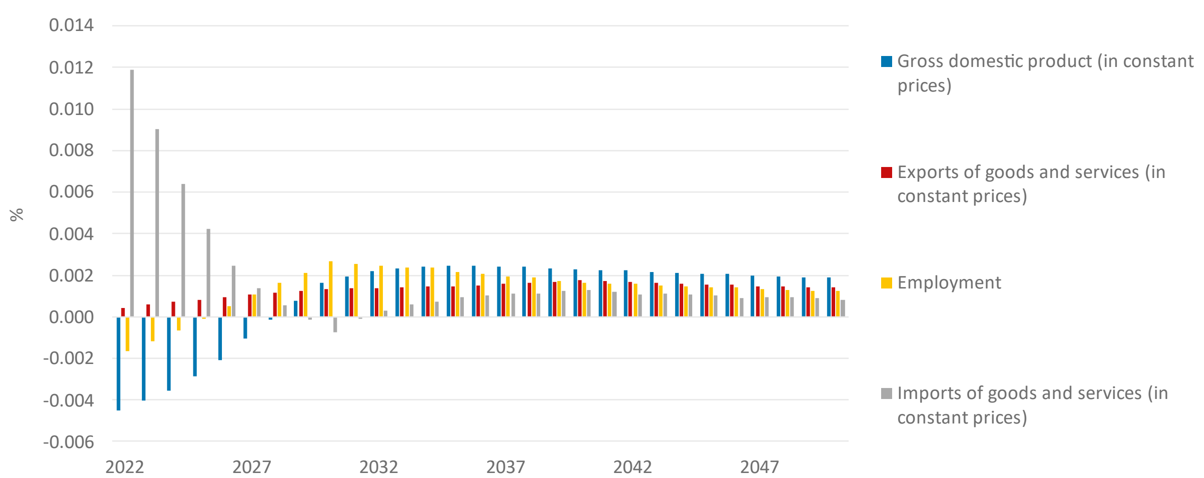
The equipment of the machines with GPS takes place gradually. Government supports the investments which limits other public spending but does not affect prices for agricultural goods. The more machines are upgraded, the greater the benefits. This is reflected in declining agricultural imports as well as increasing exports. Since GPS and computer systems are mainly imported (*EBRD et al., 2018*), total imports are increasing by 0.012% compared to a situation without adaptation.

Model results

The impacts of this measure for the national economy are rather small. As long as the benefits from the adaptation measure cannot be fully exploited, the economic growth is at a lower level. Afterwards, GDP is slightly higher (0.002% respectively 1,800 million Tenge per year) compared to a situation without this measure. Employment, food, and energy security can by improved within a limited scope. Employment is 0.003% respectively 1,800 persons higher per year compared to a situation without adaptation. According to EBRD et al. (2018) up to 122,000 tons of CO_2 equivalents can be saved per year.

Figure 2: Cost-Benefit-Analysis of parallel driving *on components of GDP and employment (differences in percent compared to drought scenario)*

LONG-TERM ECONOMIC BENEFITS OF ADAPTATION



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Key messages

The government of the Republic of Kazakhstan adopted the Ecological Code in January 2021 which shows ambitions to mainstream climate change adaptation into policies and development plans at the national and sub-national levels. Modelling results will help to understand which planned adaptation measures (or a combination thereof) are better suited in terms of economy-wide impacts. Thus, adaptation options which are supposed to be beneficial for the agriculture sector should be examined regarding their impacts for the whole economy before implementation.

The consequences of climate change are already noticeable and will become more frequently and more severe. Food security might be at risk. Jobs and income are endangered not only in agriculture. Policymakers should be aware of what could happen to manage adaptation strategies and to initiate a climate resilient economic development.

- Many adaptation measures exist for agriculture. Cost-benefit analysis helps to rank the individual technologies following techno-economic assessments *(FAO and EBRD, 2017).* Additionally, **macroeconomic analyses should be conducted to detect the economy-wide impacts of single measures and enable decision-makers to adopt win-win options.**
- **Investments in adaptation provide co-benefits**, as the two adaptation measures analyzed with the e3.kz model exemplarily demonstrate. Economic losses in agriculture can be reduced also in up- and downstream industries. **Measures that primarily support the domestic economy are even more beneficial.** For example, construction activities create jobs in Kazakhstan. **Products such as drip irrigation systems are mainly imported and curtail the advantages.** Nevertheless, in both cases permanent jobs can be created in agriculture and related industries.
- Combating climate change requires a holistic approach including both mitigation and adaptation action: The e3.kz model results show that higher economic activity causes more emissions. The CO_2 mitigation potential may be leveraged with efficiency improvements and the use of renewables. The currently elaborated Kazakhstan's Low-Emission Development Strategy recognizes sustainable development as the overarching context for climate policy and indicates close links between adaptation and mitigation, their co-benefits and adverse side effects.
- **Combinations of adaptation measures** such as the expansion of irrigated land, the use of water harvesting, and water-efficient infrastructure **is very important if water is scarce**. Adaptation measures providing small(er) benefits at low(er) costs are also important, in particular for small-scale farmers who do not have huge financial resources.
- **Financing of adaptation measures through international funds is not assumed**. Given the promises of the industrialized countries to support climate protection measures such as adaptation measures with USD 100 billion per year in the future, the prospects for (partial) funding of the measures are good. In this case, **the macroeconomic effects of the measures would be even better.**
- Although the financial and economic impacts are relevant for policymakers to decide which adaptation measure is “most effective”, other criteria must be considered as well such as health aspects and ecosystem services (biodiversity, regulation of the water balance).

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Economy-wide Effects of Adaptation in Agriculture

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Data and basic assumptions are mostly up to date and were discussed with national sector experts in 2021. Further contextualization and expansion of the results of the scenario analysis as well as economic evaluation of different adaptation measures should be respectively coordinated with the Ministry of National Economy, the Economic Research Institute and the Ministry of Ecology, Geology and Natural Resources in Kazakhstan.

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