# Kazakhstan's Wheat Production Potential

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## 1 Introduction

Located at the far eastern reach of the Eurasian wheat belt, the Republic of Kazakhstan is a major wheat (*Triticum* spp.) producing and exporting country. Its wheat production area ranges from 10 to 14 million ha and its average annual output is 9–22 million tonnes of grain. The main wheat production region is located in the northern/north-central regions (Fig. 1), where the topography is mainly flat and where production on rich and productive *chernozem* and *kashtan* soils accounts for roughly 70 % of the country's total wheat harvest (of which spring wheat comprises 90 %). The country's climate is typically semi-arid, with cold winters and warm summers. Droughts are frequent (occurring two years in every five, on average, predominantly during the May–August growing season when low rainfall and high temperatures often persist). Owing to the dry climate, northern Kazakhstan produces good-quality hard wheat. Some winter wheat is grown in southern Kazakhstan, but the annual harvest comprises a minor share of the country's total wheat production.

Kazakhstan's harsh winters are a cause of fluctuations in agricultural production. Large-scale irrigation does not exist. As a result, a reduced harvested area and yield

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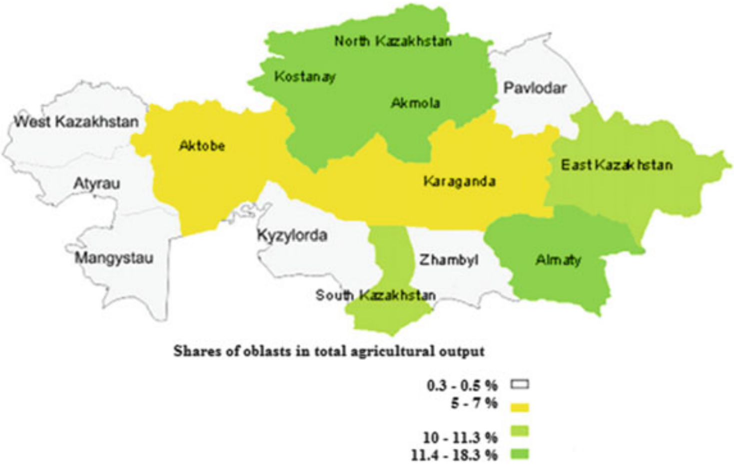

**Fig. 1** Regional concentration of agriculture in Kazakhstan, 2008–2010 average. Source: Statistics Agency of the Republic of Kazakhstan (2011): Kazakhstan in Figures. Online database

losses/crop failure are not exceptional, and these lead to frequent and high year-to-year variations in yield which are a considerable source of regional food insecurity. Furthermore, although Kazakhstan is among the top ten wheat producing regions, wheat yields have varied from year to year, despite a series of agrarian reforms. The average yield of around 1 tonne/ha is low by international standards and there is a pressing need to increase the level of wheat production in the country.

The wheat sector is dominated by the private sector and is characterised by three farm types: large privately operated agricultural enterprises, especially in the north of the country; small peasant farms; and household plots with only a fragile integration into markets. In the future, the drivers of agricultural development in Kazakhstan will probably be the large-scale, privately operated, profit-oriented farms. The small and medium-size farms will have an important role in local rural economies and food security, but the key actors in wheat production will be modern (medium and large) agricultural enterprises.

Wheat is one of the world's most important crops: about 37 % of the global population relies on it as their main food staple, and it accounts for some 20 % of all food calories consumed by humans. The global agricultural system faces a rapidly growing challenge: in the coming decades it must feed a substantially larger population in an increasingly volatile and shifting climate. Increasing the production of grain crops (including wheat) will be crucial in facing the global food security challenge, both to provide sufficient food grain and to meet the demand for animal feed, especially as income growth in emerging market economies increases the demand for meat and other livestock products.

In Central Asia, cereals make up about 50 % of staple foods, although this figure differs from country to country. Because of this, food security in the region is largely dependent on cereal production, most notably wheat. Of the five Central

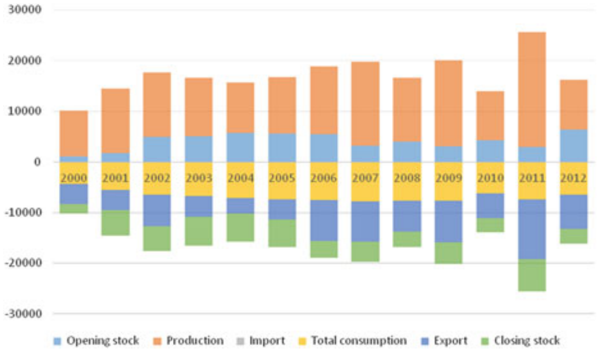

**Fig. 2** The wheat balance of Kazakhstan, 2000–2012. Data source: USDA (http://www.indexmundi.com)

Asian countries, only Kazakhstan is able to meet its cereal needs (mainly wheat). In general, the food security risk has diminished significantly in Kazakhstan since 2000 and the country is now self-sufficient in many foods. Sedik et al. (2011) suggest that, unlike the other countries in Central Asia, the potential risks to food security in Kazakhstan are now mostly confined to food price volatility arising from market volatility and instability and fluctuations in weather conditions, including water scarcity. By contrast, the other four countries in the region depend heavily on imported cereals. For example, the proportion of imported cereals made up of wheat is 97 % and 95 % in Tajikistan and Turkmenistan respectively (Bravi and Solbrandt 2012).

As the largest wheat exporter in Central Asia, Kazakhstan exports wheat grain and flour (Fig. 2), mainly to Commonwealth of Independent States (CIS) countries. Of the non-CIS countries, Afghanistan and Iran are the most important destinations for Kazakh wheat. Kazakhstan therefore plays a key part in local, regional and international food security, and the development of the country as a consistent and sustainable source of global wheat supply is of strategic importance.

Although the wheat sector is privatised, the Kazakh government recognises it to be a strategic sector and exercises strong control over production, marketing and export, and utilises public stocks to keep flour and bread prices stable. In addition, every year the government sets a target for exports, but the tools to implement this target are unclear. The government subsidy programmes during the second half of the 1990s were designed to revitalise production levels through the use of improved varieties, inputs, and machinery and equipment, but access to credit and investment finance remained poor.

There are two practical ways in which agricultural output in Kazakhstan can be increased: (1) increase the area of cultivated land; or (2) improve yields on existing land. The prospects for the former are limited. Local farmers face several challenges from sowing to harvest and then to access the markets. There are three crucial challenges, which together impose the greatest constraints on production: (1) competition with weeds for nutrients and moisture; (2) pre-harvest losses caused by pests (e.g. plant diseases and herbivorous insects); and (3) insufficient water.

These challenges are exacerbated by global climate change which creates uncertainty with regard to the prospect of sustainable and continuous growth of wheat yields in the region. According to climate change scenarios based on global climate modelling, further temperature increases with no significant increase in precipitation may lead to a drier climate. In parallel, the climate zone boundaries may shift northward, and wheat yields may be reduced by more than 25 %. Such risks cannot be ignored by policymakers.

The aim of this chapter is to analyse the future development trajectories of Kazakh wheat production. We begin with an analysis of the impacts of any potential future changes in climate and weather conditions in Kazakhstan in terms of temperature, precipitation, input levels and production capacity of wheat by applying an adapted version of the Food and Agriculture Organization of the United Nations (FAO) Global Agro-Ecological Zones (GAEZ) model. We then analyse the outlook for wheat production and exports using a system-dynamic approach.

## 2 Methodology

The methodology aims to determine probable trends in Kazakh wheat production and exports over the next four decades. Two approaches are employed. Firstly, we apply *agro-ecological and climate scenarios* to predict the probable climate and weather conditions in terms of temperature, precipitation, input level and production capacity in Kazakhstan. Secondly, we model the outlook for wheat production and trade based on a *system-dynamic approach.*

### *2.1 Agro-ecological and Climate Scenarios*

In order to explore the effects of climatic conditions on wheat production, we calculate the following indicators:

- average annual precipitation (mm/year), 1990–2013;
- mean annual temperature (°C), 1990–2013;
- reference evapotranspiration (ETo) between March and September (mm/growing period) for the years 2000, 2020 and 2050;
- aridity index (AI) (average annual precipitation/potential ETo) for the years 2000, 2020 and 2050;
- Fournier index (FI) for the years 2000, 2020 and 2050;
- length of growing period for the years 2000, 2020 and 2050;
- soil suitability index (SI) at low-, intermediate- and high-input levels.

The source of precipitation and temperature data was the Meteorological Service of Kazakhstan. The other indicators were obtained using the methodology developed by the FAO and the International Institute for Applied Systems Analysis

(IIASA), namely the GAEZ model, which is based on the second climate model of the Commonwealth Scientific and Industrial Research Organisation (CSIRO 2011).

The so-called reference crop evapotranspiration or reference evapotranspiration, denoted as ETo, is derived from a reference surface in the form of a hypothetical grass reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s $m^{-2}$ and an albedo of 0.23. This closely resembles a surface of green, well-watered grass of uniform height, actively growing and intercepting all sunlight. The FAO Penman–Monteith (PM) method is the standard method for the definition and computation of the reference ETo because it can be computed from just meteorological data, namely solar radiation, air temperature, air humidity and wind speed (FAO 2014).

In 1993, the United Nations Environmental Programme (UNEP 1993) defined the AI as the ratio of total annual precipitation to potential evapotranspiration (PET). PET is the rate at which evapotranspiration would occur from a large area completely and uniformly covered with growing vegetation which has access to an unlimited supply of soil water, and without advection or heat storage effects. Owing to the lack of measured PET data and other difficulties, AI has not been widely used, especially in developing countries. Agronomists and engineers mostly use the PM equation because the required weather data are easily accessible (Sahin 2012). Climate types correspond to different levels of AI and are listed in Table 1.

The FI is an erosion (soil degradation by water) indicator. The formula for calculating the index is as follows:

$$C_p = {P^2}_{max}/P$$

where $C_p$ is the FI (mm), $P_{max}$ is the rainfall amount in the wettest month and P is the annual precipitation (mm) (Oduro-Afriye 1996). Table 2 shows the different rainfall classes, which represent the different levels of rainfall erosion risk, and the related FI (mm) and amount of possible annual soil loss in tonnes/hectare.

The FI is an important indicator for the grain sector, as it measures soil erosion and determines attainable productivity. Highly eroded areas and fields cannot maintain their production potential because the soil will be degraded and lose its fertility potential.

As the intensity of farming should also be considered, we define the input use and management practices based on the GAEZ methodology (version 3.0). These are represented as follows:

- ***High-input advanced management:*** The farming system is predominantly market-oriented. Commercial production is a management objective. Production is based on improved high-yielding varieties, fully mechanised with low labour intensity and optimum applications of nutrients and chemical pest, disease and weed control.
- ***Intermediate-input improved management:*** The farming system is partly market-oriented. Production for subsistence plus commercial sale is a management objective. Production is based on improved varieties, on manual labour

**Table 1** Scale of the Aridity index

| Aridity index | Climate type |
|---|---|
| $0.05 \leq P/PE < 0.20$ | Arid |
| $0.20 \leq P/PE < 0.50$ | Semi-arid |
| $0.50 \leq P/PE < 0.65$ | Dry sub-humid |
| $0.65 \leq AI < 0.80$ | Semi-humid |
| $0.80 \leq AI < 1.0$ | Humid |
| $1.0 \leq AI < 2.0$ | Very humid |

Source: Sahin (2012) and UNEP (1993)

**Table 2** Rainfall classes, erosion risk, Fournier index and the amount of possible soil loss

| Class No | Erosion risk class | Fournier index $C_p$ (mm) | Soil loss (t/ha/year) |
|---|---|---|---|
| 1 | Very low | <20 | <5 |
| 2 | Low | 21–40 | 5–12 |
| 3 | Moderate | 41–60 | 12–50 |
| 4 | Severe | 61–80 | 50–100 |
| 5 | Very severe | 81–100 | 100–200 |
| 6 | Extremely severe | >100 | >200 |

Sources: Oduro-Afriye (1996) and Aslan (2003)

with hand tools and/or animal traction and some mechanisation. Production is medium labour intensive, uses some fertilisers and chemical pest, disease and weed control, adequate fallows and some conservation measures.

- ***Low-input traditional management:*** The farming system is largely subsistence-based and not necessarily market-oriented. Production is based on the use of traditional varieties (if improved varieties are used, they are treated in the same way as local varieties), labour-intensive techniques, no application of nutrients, no use of chemicals for pest and disease control and minimal conservation measures.

Following Fischer et al. (2012), the following guiding principles form the basis for constructing the SI in the FAO GAEZ model (i.e. GAEZ 3.0), which combines soil qualities with different levels of inputs and management practices:

- nutrient availability and nutrient retention capacity are key soil qualities;
- nutrient availability is of utmost importance for low-level input farming; nutrient-retention capacity is most important for high-level inputs;
- nutrient availability and nutrient-retention capacity are considered equally important for intermediate-level input farming;
- nutrient availability and nutrient-retention capacity are strongly related to rooting depth and the soil volume available; and
- oxygen available to roots, excess salts, toxicity and workability are regarded as equally important soil qualities, and the combination of these four soil qualities is best achieved by the multiplication of the most limiting rating with the average of the ratings of the remaining three soil qualities.

We use the FAO GAEZ model to predict the probable climate and weather conditions in terms of temperature, precipitation, input level and wheat production capacity in Kazakhstan. The projections are made for the next 40 years. The model develops projections by combining information on the SI, different soil qualities and the different levels of input use and management practices described above.

## *2.2 Future Perspectives on the Wheat Sector in Kazakhstan: A System-dynamic Approach*

Based on the analysis of agro-ecological conditions and the probable future development of the Kazakh wheat sector, we set up a stochastic system model for predicting Kazakhstan's wheat exports. We apply a relatively complex model, given that the future development of Kazakhstan wheat production and exports are influenced by a complex set of natural (e.g. global climate change), economic and social factors. The exact future values of all influencing factors are challenging to predict and are not readily available. To circumvent this problem, we employ a system-dynamic approach to analyse the future development trends of Kazakh wheat production. Sterman (2001) outlined the most important features of systems characterised by dynamic complexity of phenomena. These are: (1) a constantly changing character; (2) tightly coupled sub-systems; (3) governance by feedback; (4) non-linearity; (5) history-dependence; (6) a self-organising character; (7) an adaptive behaviour; (8) characterisation by trade-offs; (9) a counterintuitive character; (10) a policy-resistant feature. The majority of these criteria are true for Kazakhstan's wheat sector, thereby justifying the application of dynamic system modelling. When setting up a conceptual framework of an agricultural system, it is always a question as to which agricultural management system to assume. From the GAEZ 3.0 system typology we apply the high-input level option because, from our own on-site experience as well as based on literature findings (Kienzler et al. 2012), the farming system in Kazakhstan can be best characterised by this management practice. That is, the farming system is predominantly market oriented, and commercial farms dominate the wheat sector in Kazakhstan.

The structure of the system-dynamic model and the links between its different components are presented in Fig. 3. The aim of the model is to simulate the future development of the wheat sector in Kazakhstan. The model has three basic modules. This modular system offers the possibility to test different model specifications, and also allows regional downscaling of the analysis. The first component of the model represents the production module, which accounts for the average wheat yield conditions and the production area of wheat. The second module represents the food-chain of wheat sectors by interlinking production, consumption and export. The third module captures the behaviour of the domestic consumption of different wheat products.

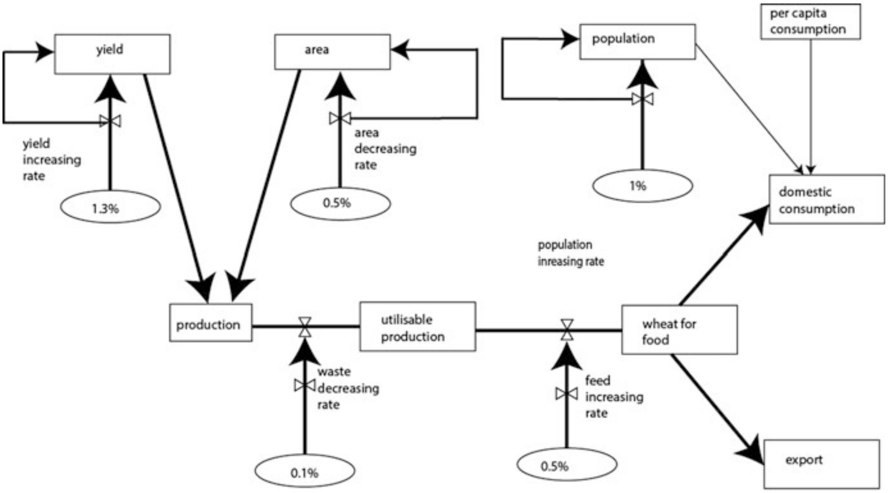

**Fig. 3** Conceptual framework for a Kazakh wheat-sector model

The construction of the system-dynamic model relies on several assumptions of land and production parameters, which can be defined as follows:

1. We assume a negligible initial level of non-food (feed) wheat use (maximum 1.5 % of domestic production). However, we assume a relatively dynamic expansion of wheat use for animal feed (i.e. a 0.5 % yearly growth rate). This assumption is based on government projections, which estimate a strong growth in animal husbandry in Kazakhstan (Nakipova et al. 2012; Sharipov et al. 2013). The agro-climatic conditions are important limiting factors of wheat production expansion in Kazakhstan (Laird and Chappell 1961). According to Conradt et al. (2012), there are considerable regional differences, but in most regions the meteorological parameters were found to have a determining role for production potential. The findings of Bokusheva (2010, 2011) support the importance of weather conditions for yield growth. As a consequence of global climate change, a reduction in the agricultural land area can be expected in the future. In our model we assume a moderate decrease (0.5 % annual change) of agriculturally useable land as a consequence of global warming.
2. Time series analysis indicates that there is a weak but statistically significant positive wheat yield trend in Kazakhstan. According to Pinstrup-Andersen and Pandya-Lorch (1998), the yield increase in Central Asia is predicted to be relatively low in the next decade (Table 3). Bruinsma (2009) argues that there is a considerable gap between the actual yield of wheat and the potential yield in Kazakhstan. Between 2003 and 2007 the average yield was around 1 tonne/ha, but if high-input technology is adopted, yields of more than 3.2 tonnes/ha could be achieved by 2050. With intensive technology, the yield could reach as much as 5.9 tonnes/ha. Improvements in the biological basis of wheat production (particularly the introduction of new varieties) can be an important source of

**Table 3** Increase in wheat production in different regions of the world

| Region | Area | Yield | Production |
|---|---|---|---|
| Central Asia | 0.25 | 0.88 | 1.13 |
| Rest of the former Soviet Union | 0.03 | 0.56 | 0.59 |
| Eastern Europe | 0.10 | 1.10 | 1.21 |
| West Asia and North Africa | 0.35 | 1.47 | 1.82 |
| Sub-Saharan Africa | 1.18 | 1.58 | 2.78 |
| Latin America | 0.55 | 1.54 | 2.10 |
| South Asia | 0.17 | 1.43 | 1.60 |
| East Asia | 0.11 | 1.19 | 1.30 |
| South-East Asia | 0.18 | 1.33 | 1.51 |
| Developed countries | 0.08 | 0.83 | 0.91 |
| Developing countries | 0.41 | 1.25 | 1.66 |
| World | 0.29 | 1.04 | 1.33 |

Source: Pinstrup-Andersen and Pandya-Lorch (1998)

yield growth. In Central Asia, new wheat varieties could lead to a yield increase of up to 1.5–2.5 tonnes/ha (Morgounov et al. 2009). On the basis of these considerations, we assume a moderate yearly yield increase of 1.3 % from the initial value of 1 tonne/ha.

3. Losses along the wheat production chain in Kazakhstan represent around 3 % of total production. This is the starting value in our model, and we assume a moderate reduction of this loss (i.e. a 0.1 % yearly reduction but up to a maximum loss of 1.2 % of total production).
4. Other assumptions: 1 % yearly population increase in Kazakhstan; 333 kg stable yearly per-capita domestic consumption of wheat (i.e. food, industrial processing and other uses).

We apply the system-dynamic model to simulate changes in the Kazakh wheat yield, production and exports over a 30-year time horizon (i.e. until 2050).

# 3 Results

## *3.1 Potential Agro-climatic Threats to Kazakhstan's Wheat Sector*

The yield potential (production capacity) attainable for different input levels and management practices (as defined in GAEZ 3.0) is shown in Fig. 4. The figure shows the yield of wheat that could be obtained in the 2020s and 2050s when implementing good agricultural practices and adopting management practices in the optimal way and at the optimal time (appropriate fertilisation, soil tillage, irrigation etc.). Input use and management practices as well as precipitation and

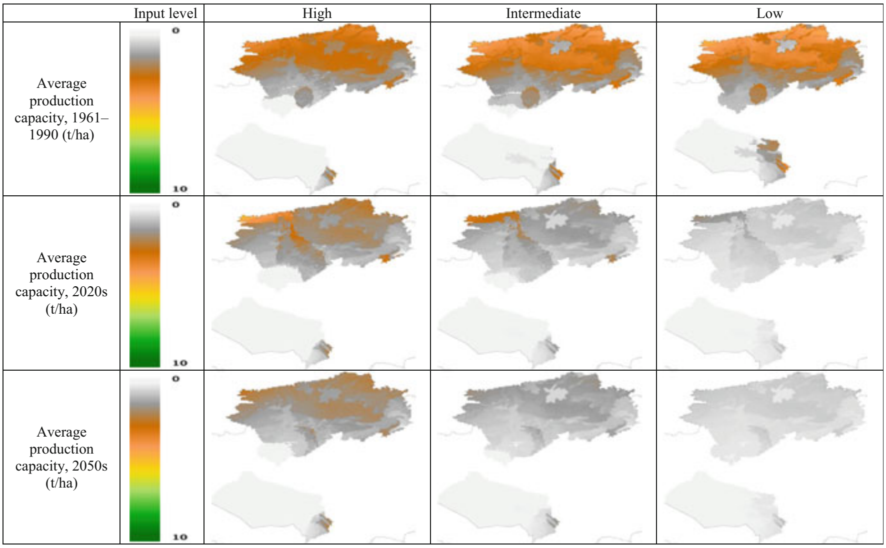

**Fig. 4** Average production capacity (potential yield) in the future at different input levels in the main wheat growing areas of Kazakhstan. Source: IIASA and FAO, GAEZ version 3.0 (http://www.gaez.iiasa.ac.at)

temperature and their extreme values have significant effects on the development of the wheat yield potential.

According to the results, the average annual precipitation is projected to decrease over the simulation period in Kazakhstan. These projections are consistent both with the observed historical trends and with the scenario of the GAEZ 3.0 model.

The ETo is projected to increase significantly in the main wheat growing areas of Kazakhstan (from 715 mm to 1 260 mm per growing period in northern Kazakhstan, and from 1 250 mm to 1 460 mm per growing period in southern Kazakhstan) because the mean temperature will increase, while the amount of precipitation will fall. The implications of these changes are that crops will transpire more and that more water will evaporate from the soil surface. The consequent loss of soil moisture content will lead to more frequent droughts.

The AI is projected to increase in the main wheat producing regions in Kazakhstan (from 0.2 to 0.3 in northern Kazakhstan and from 0.4 to 0.6 in southern Kazakhstan, on a scale of 0 to 1) which means that the risk of drought periods will be high for the next 40 years. The strong impact of droughts will be particularly problematic for non-irrigated crop production.

The FI is projected to decrease (from 520 to 300 mm in northern Kazakhstan, and from 490 to 200 mm in southern Kazakhstan), driven by the fall in precipitation. A decrease in FI can be beneficial for soil protection because with less precipitation, erosion decreases, thus leading to less soil degradation. An exception would be if the distribution of annual precipitation will be extreme as a result of extreme climate phenomena. In this case, soil erosion is expected to be a serious problem, as there will be more precipitation during rainfall events, which can cause severe erosion, mainly on the slopes.

The predicted annual increase in average temperature in the wheat growing areas of Kazakhstan clearly reflects the average temperature increase, as observed in the GAEZ historical data for the period 1960–1990 (3 °C in northern Kazakhstan; 2 °C in southern Kazakhstan). The number of wheat growing days will reduce because the temperature will not coincide with wheat's optimum growing temperature. This also implies that the incidences of cereal pests and disease are likely to increase, due to the warmer and more extreme climate (Zhang et al. 2014). Based on the model simulations, the production potential of wheat was between 2 and 4 tonnes/ha in the period 1961–1990. The model predicts that this yield level can be maintained only in the main wheat growing regions by using the high-input level. If farmers use intermediate- or low-input levels, yields are projected to fall to less than 1 tonne/ha.

Overall, for the Kazakh wheat sector, the simulation results for different levels of the SI indicate that there will be large differences in productivity between the 2020s and 2050s:

- At low-input levels, these differences will be positive (i.e. higher productivity in the 2020s than in the 2050s), because the suitability index in the main wheat production sectors will increase from moderate to medium. This implies low energy use by wheat production, leading to degradation of soils relative to the current situation. This implies that wheat production will decrease over time.
- At intermediate-input levels (i.e. moderate use of agricultural inputs and the adoption of less productive varieties), the positive differences between the two periods are not as clear, because the SI will remain largely unchanged. In this case, wheat production in Kazakhstan is likely to remain at its current level.
- If farmers produce wheat at a high-input level, the input impact on soil quality will be negative. The SI will decrease due to the high energy metabolism and over-use of irrigation and the soil. This is a threat for wheat production, because the SI will decrease from moderate to marginal and this could cause significant yield losses in the long term.

It is important to note that the model does not consider adaption to climate change. That is, farmers are assumed to use conventional tillage methods (ploughing, discing) and no adaptation of soil management practices (for example, no levelling of the soil surface over time and no use of mulching). This is expected to lead to reductions in organic material and moisture content in the soil, ultimately causing yield reduction. The relaxation of this assumption (i.e. considering the adaptation of farmers' practices) may reinforce the negative effects of climate change simulated by the model (Birkás et al. 2010).

According to the GAEZ 3.0 model simulations, the suitability of soils for growing wheat will decrease (from 40 to 10 in northern Kazakhstan and from 70 to 40 in southern Kazakhstan on a dimensionless scale of 0–100) because of the variable climatic and environmental factors. This implies that the current yield levels obtained in Kazakhstan using conventional techniques cannot be sustained in the future. Farmers would need to increase their input use intensity simply to maintain current yield levels.

As farmers will have to increase their input levels (fertiliser, pesticide and water) to maintain or increase wheat yields, soil salinisation is expected to rise. The increases in fertiliser use and irrigation will cause the accumulation of soluble salts, whereas increased evaporation will lead to an accumulation of salt in the topsoil.[1] This salinisation will cause a rise in soil pH, leading to yield loss if the pH falls outside the optimum range for wheat production (Lelley and Gy 1963; Antal 2005; Csajbók 2012).

### 3.2 *Wheat Production and Exports: A System-dynamic Approach*

Figure 5 shows projections for Kazakh wheat production and exports over a 30-year time horizon using the system-dynamic model. The results indicate that wheat production will increase from 13.5 million tonnes in 2010 to 18 million tonnes in 2035 (Fig. 5a). This growth will occur despite the projected deterioration of the agro-ecological potential of wheat growing conditions. At the same time, the expansion of the domestic consumption of wheat and its use for animal feed will result in a decrease in the future Kazakh wheat export potential. Exports are projected to decrease by 31 %, from 5.2 million tonnes in 2010 to 3.6 million tonnes in 2035 (Fig. 5b).

Our results do not support the ambitious plans of the Kazakh Ministry of Agriculture, which aim to increase wheat exports to 15–20 million tonnes by 2020 (UNDP-KazAgroinnovation 2013). At the same time, they are in line with the UNDP-KazAgroinnovation (2013) forecast, which highlights that the expected weather conditions will be unfavourable for growing spring wheat in key growing regions. According to this report, although the increasing atmospheric $CO_2$ concentration will improve the situation, in general, production conditions will worsen.

Genetic modification of the biological base of production could be an important tool for increasing the stability of production in Kazakhstan. However, the main constraint is that, in the case of wheat, the research is in a relatively early phase of development. Moreover, the sowing of genetically modified wheat varieties, which can represent an important source of yield growth, is banned by the Government of Kazakhstan so as to avoid the risk of losing Kazakhstan's export position on the global wheat market (Kamenova 2012; Curtis and Halford 2014).

We have conducted a sensitivity analysis of the simulated effects by altering various model assumptions. We considered stochastic variation on arable land change (by 0.5 % (standard deviation 0.1 %)) and a higher rate of increase of wheat for feed use (by 0.5 % (standard deviation 0.1 %)). The impacts on exports

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[1] http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_053151.pdf

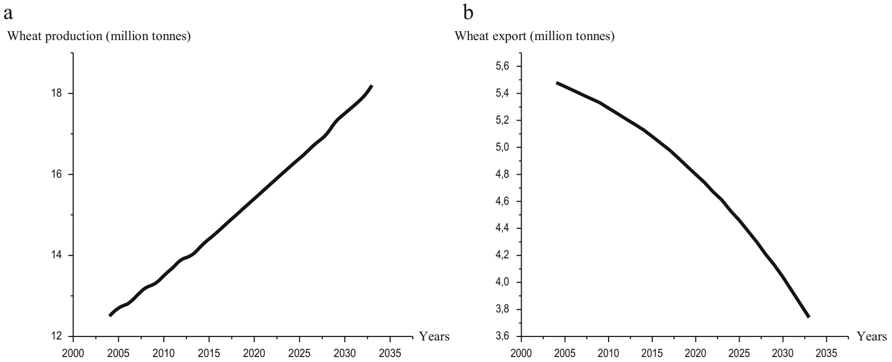

**Fig. 5** Thirty-year projections for (**a**) wheat production and (**b**) wheat export in Kazakhstan

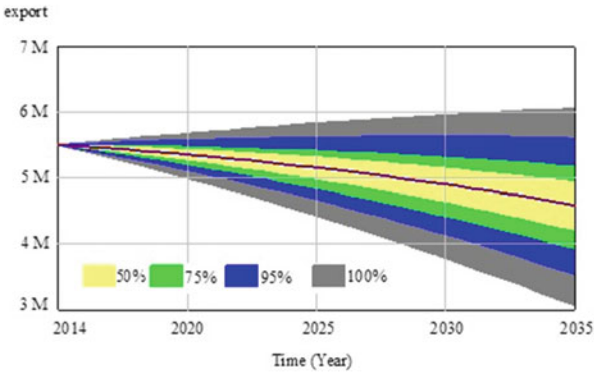

**Fig. 6** Sensitivity analysis of wheat exports of Kazakhstan (million tonnes)

are shown in Fig. 6. The central line shows the most likely projections of the volume of Kazakh wheat exports. On each side of this line there are four bands, indicated by different colours. The band adjacent to the expected value shows the 50 % confidence interval, and the next two bands denote the 75 and 95 % confidence intervals respectively. The outermost bands encompass all possible variations in Kazakh wheat export projections. The main finding of the sensitivity analysis is that the volume of Kazakh wheat exports is sensitive to relatively minor changes in some parameters, such as in the development of arable land and the use of wheat for animal feeding. However, the decrease in the future export projections tends to prevail over different simulations. This is because the yield growth and the reduction in wheat losses are expected to be more than offset by the reduction of arable land and the increase in the domestic use of wheat for human and animal feeding.

# 4 Discussion

Our simulation results have shown that the agro-ecological status for wheat production in Kazakhstan will deteriorate over the long term. The climate will be warmer and dryer, and the frequency of drought periods and weather extremes will increase, which may enhance the agro-climatic risk to the cereal sector in Kazakhstan. Without adaptation of management practices (e.g. higher input use, new varieties), wheat yields are expected to decline.

The current low yields and low efficiency of wheat production are caused by problems in outdated technology. Technology improvement may play an important part in alleviating the effects of climate change. The use of outdated production methods and inadequate machinery and equipment prevent the development of efficient wheat production systems and have negative environmental implications (e.g. deterioration of soils). Improving knowledge and skills is another important means of increasing wheat production efficiency and productivity. The farm extension system could make an important contribution in this regard, especially if it is focused on education and professional training in the adoption of new technologies.

The agriculture of Kazakhstan has suffered a considerable capital outflow over the past two decades. The net capital stock for land development decreased from USD 41 314 billion in 1992 to USD 34 028 billion in 2007.[2] The net capital value of machinery stock decreased from USD 14 247 billion to USD 2 905 billion between 1992 and 2007. At the same time, there are some traces of technological modernisation (for example, in 2007 Kazakhstan imported nearly 4 000 tractors valued at USD 120 million. One decade earlier, the country imported just 280 tractors, valued at USD 4.6 million). Similar developments are observed for other machinery; for example, the import value of combine harvesters reached USD 183 million in 2007. Technological modernisation is strongly dependent on state support. Between 2001 and 2011, agricultural subsidies in Kazakhstan increased from USD 136 million to USD 1 620 million.

Our model results indicate that wheat production will expand in Kazakhstan despite the decreasing agro-ecological potential. The possibility to increase the wheat production area is limited, on one hand, by increasingly unfavourable climatic changes and, on the other hand, by the over-representation of wheat in the agriculture of Kazakhstan. According to expert estimates (Anon. 2013), the optimal share of wheat coverage on arable land in Kazakhstan is around 45–50 %, whereas this ratio was nearly two-thirds in 2010.

An important response to climate change with sizable environmental benefits could be the adoption of water retentive agricultural technology. Such technology is presently used on about 14 % of the wheat area, but its share is expected to increase by 80 % by 2020, by which time the application of minimum tillage, which is conducive to the water retention of soils, is expected to expand by 30 % (Anon. 2013).

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[2] Measured in constant 2005 prices (FAOSTAT 2015).

The application of fertilisers fluctuates considerably in Kazakhstan, causing high year-to-year variation in yields. For example, the annual consumption of potash fertiliser fluctuated between 200 and 3400 tonnes during the period 2002–2012 (FAOSTAT 2015). Agricultural insurance is another important strategy for the stabilisation of the income of wheat producers in Kazakhstan. Currently, the agricultural insurance system covers around 75 % of total agricultural land, and this must be maintained in order to ensure the sustainable future development of the farming sector.

The reduction of waste along the whole production chain and the improvement of the market orientation of the grain sector are important strategic prerequisites to sustain the expansion of the Kazakh wheat sector. Fundamental for this is the expansion of storage capacity. To achieve this, the Kazakh government plans to support investments in storage capacity by 3.15 million tonnes in the period 2014–2020. Improvements to the transportation infrastructure are another key prerequisite for the future development of the Kazakh wheat sector. The further development of the railway system and investment in special railway trucks are crucial components, given that Kazakhstan is a landlocked country.

Production is just one part of the problem; another is the competitiveness of Kazakh wheat. The quality of Kazakh wheat varies considerably from year to year and across production regions. In Kazakhstan, only two parameters are used to measure wheat quality for domestic purchases: vitreousness and gluten content. The quality of Kazak spring wheat is higher than that from Russia (Table 4), giving Kazakhstan a competitive edge over its closest competitor. However, although Kazakh wheat has high protein levels (14–16 %) and gluten contents (21–40 %) the gluten strength is less than that of Australian wheat (Abugalieva and Pena 2010).

The role of the state in the regulation of agricultural markets is expected to change considerably should Kazakhstan join the WTO as planned. WTO accession is expected to considerably limit state subsidies, but – at the same time – Kazakh access to the world market is likely to improve. WTO accession may expand Kazakh wheat exports to the European Union by 47 %, to Turkey by 35 % and to sub-Saharan Africa by 6 % (Burkitbayeva and Kerr 2014), The exact date of WTO accession is uncertain and thus it is hard to predict its potential effects. However, the predicted increase in domestic consumption and animal husbandry is likely to reduce considerably the raw material base for export and thereby reduce the overall wheat export potential of Kazakhstan.

**Table 4** Distribution of wheat quality in Kazakhstan and Russia

| | Payne quality category | | | | | |
|---|---|---|---|---|---|---|
| Country | 10 | 9 | 8 | 7 | 6 | 5 |
| Kazakhstan | 8.2 % | 40.4 % | 2.0 % | 44.4 % | 1.0 % | 4.0 % |
| Russia | 5.0 % | 32.5 % | 12.5 % | 47.5 % | 2.5 % | |

Source: Abugalieva and Pena (2010)

## 5 Conclusion

We have analysed the future prospects for wheat production in Kazakhstan by firstly investigating the future climate and weather conditions of wheat growing and, secondly, modelling the future perspectives of wheat production and trade.

Our simulation results show that the agro-ecological status for wheat production in Kazakhstan will deteriorate over the long term. The climate will become warmer and dryer, and the frequency of drought periods and weather extremes will increase. Without the adaptation of management practices, wheat yields in Kazakhstan are likely to decline. The main management practices that can attain higher yields include increases in input use intensity, the adoption of new wheat varieties and investments in modern technologies.

Despite the projected deterioration of the agro-ecological potential, the expected productivity growth suggests a positive potential for wheat production expansion in Kazakhstan. Our simulation results indicate that wheat production in Kazakhstan may increase by up to 33 % over the next four decades. The extent to which this growth potential will be achieved will be determined by both economic factors and environmental factors, including technology problems and the influence of climate change. However, Kazakhstan's export potential is likely to decline over this period as a result of the expansion of the domestic use of wheat. Exports are projected to decrease by 31 %, from 5.5 million tonnes in 2005 to 3.8 million tonnes in 2035.

To attain the wheat production potential, policy action needs to be in line with the principles of sustainability, while at the same time reinforcing the long-term competitiveness of the agricultural sector. Public resources should be allocated to eliminate significant deficiencies, mainly in transport infrastructure and storage capacities, as well as to water and land management, plant and animal health and food safety systems, research, education and knowledge sharing. Agricultural enterprises account for about 65 % of Kazakhstan's grain production and tend to be large-scale operations. However, the government's efforts to develop modern large-scale agricultural production should be accompanied by efforts to integrate small-scale producers into agricultural markets with the aim to enhance their domestic and international competitiveness.

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