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# From Saddles to Harrows: Agricultural Technology Adoption during the Russian Colonization in Kazakhstan[1]

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*Abstract*

Technology adoption in agriculture is one of the key factors of change in rural areas of developing countries. Large-scale in-migration by groups using a more advanced production technology often triggers such change in autochthone populations. We analyse the determinants of adoption of new agricultural technology by nomadic pastoralists using unique micro-level data from a historical episode of massive Russian peasant in-migration into Kazakhstan at the turn of the 20th century. We find that distance to Russian settlers is a key determinant of technology adoption, even after controlling for socio-economic and environmental characteristics. This effect is stronger for wealthier and less mobile Kazakh families with pasture land more suitable for agriculture. The adoption of new technology follows a heterogeneous pattern within the autochthone population, with important implications for the evolution of inequality.

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# 1. Introduction

Throughout the world, current-day nomadic pastoralists are exposed to the increasing pressure on the livelihoods and natural resources on which they rely. They are losing their common pastures, because of the advancement of commercial agriculture, and this leads to rising poverty which is coupled with their political marginalization (Fratkin, 2005; Eneyew, 2012). For instance, Maasai in Tanzania are obliged to resort to farming to protect their land from encroachment (Fratkin, 2005). The same is true for Rendille in Kenya (Xiaogang, 2009), Qashqa'i in Iran (Beck, 1998), Fulani in Nigeria (Ekpo et al., 2008), Afar in Ethiopia (Gebre-Mariam, 2006), and Tibetan nomads in China (Ptackova, 2011). The increased centralization and intervention of national governments and colonial powers in the livelihoods of nomads had a destructing effect on the nomadic society throughout the twentieth century. It often resulted in sedentarization – either induced by economic forces, under the pressure of resource constraints (Beck, 1998; Conroy, 2001; Ekaya, 2005) or involuntary, through state-enforced measures (Blench, 2001; Roth, 2004; Eneyew, 2012).

The crisis of the nomadic pastoralism induced nomads to search for alternatives. Almost always this implied adopting agriculture and trying to increase its productivity, in the contexts where the nature is less convenient for sedentary agriculture. Nomads choose to adopt agriculture for various reasons: to diversify their income sources (Conroy, 2001), to secure their right for the use of pastures, or because of the impossibility to follow their nomadic routes occupied by new settlers (Beck, 1998). Thus, over time the nomadic production patterns become unsustainable and the technological change becomes inevitable and fundamental to the survival of these societies. In fact, development economists consider the adoption of new technologies as a key feature of the development process (Foster and Rosenzweig, 2010).

The existing analyses of the sedentarization of nomads and their conversion to agriculture are purely narrative. The detailed descriptions contribute to the understanding of the processes; however, testing theoretical hypotheses empirically and, more importantly, quantifying the sizes of various effects remains a crucial challenge. This paper attempts to fill this gap and to test quantitatively the factors that drive the technology adoption in a nomadic society under massive in-migration of sedentary settlers into the nomads' territories.

We investigate the transition to a new agricultural production pattern by the Kazakh nomadic pastoralists during the colonization of Kazakhstan by the Russian Empire. In particular, we aim at understanding the importance of such factors underlying the technological adoption as the physical

proximity to Russian settlers, the environmental factors (quality of soil, rainfall), the degree of nomadism, and wealth, as well as the interplay between these effects.

For this purpose, we have built a unique dataset based on the materials of the Russian Imperial statistical expeditions to Kustanay region (Northern Kazakhstan) in 1896. This dataset includes various socio-economic variables on the nomadic population (at the extended family level), such as wealth, degree of nomadism, quality of land on the winter stops (soil quality, rainfall), etc. More importantly, it includes variables that allow us to quantify the influence of settlers on the autochthone population, i.e. the geographical proximity. Regional scientists (Mattes, 2012; Audretsch, 2000; Bathelt et al., 2004) point out the importance of the geographical proximity for the transfer of knowledge. Similarly, development economists have documented the importance of social interactions and learning in the process of technology adoption (Conley and Udry, 2010; Bandiera and Rasul, 2006; Foster and Rosenzweig, 2010). Based on this, we consider spatial proximity to Russian settlers as a good proxy for the extent of learning about new agricultural technologies previously unknown to the Kazakh population.

Our main findings are as follows. First, the geographical proximity to the Russian settlements is a key driving force for the agricultural technology adoption by Kazakh nomads, even after controlling for socio-economic and environmental factors. Second, the effect of proximity is heterogeneous: closeness to Russian settlements matters relatively more for the technological adoption by Kazakh families that are richer, relatively less nomadic, and whose pastures have a relatively better land quality.

These findings are important for three reasons. First, while historians have stressed qualitatively overall strong effects of large-scale colonial in-migration on developing countries' autochthone populations, there is a scarcity of quantitative measures of such impact in precise dimensions of change in behaviour and outcomes of the domestic population. Second, to the best of our knowledge, there exist no economic analyses of technological changes in nomadic societies (while it is widely acknowledged that these societies are among those most vulnerable to exogenous pressure on resources). The existing extensive literature (e.g. Conley and Udry, 2010; Bandiera and Rasul, 2006; Young, 2009; Ransom, 2003) studies the technology adoption exclusively within sedentary societies. Finally, the heterogeneous effects that we document indicate the importance of such technological change for determining the divergent patterns of wealth and increasing inequality during (and following) the transition process.

The remainder of the paper is organized as follows. Section 2 discusses the historical context. Section 3 describes the dataset, whereas Section 4 explains how our main variables are constructed. Section 5 specifies the econometric model. Section 6 presents and interprets the empirical results. Section 7 concludes.

## 2. Context: Kazakh nomadic economy and sedentarization at the end of XIX – early XX cc.

Prior to the Russian colonization (that started in the eighteenth century and intensified during the late nineteenth century), nomadic herding constituted the basis of Kazakh economy. Nomadic pastoralism emerged in the vast steppes of Kazakhstan as a result of adapting to the arid environment characterized by climatic uncertainty and an extremely poor grass cover (Masanov, 2001). The essence of the Kazakh nomadic economy was a seasonal migration from winter to summer pastures and back, so as to guarantee the supply of pasturing grass for large herds (mostly horses and sheep, with a gradual increase in the role of cattle in the late nineteenth century). The grass was relatively abundant in the some areas during the summer; however, extremely harsh winters in those areas induced nomads to migrate to less windy and more geographically protected areas in winters, where livestock could access some grass under the relatively shallower snow cover.

Customary law regulated the access to transhumance routes and pastures. They were assigned to various kin groups and communities and administered by the eminent representatives of the communities. Land use was divided into several categories, each associated with a given stage of the nomadic pastoralist cycle. Winter pastures were closed-access and exploited by relatively small units – essentially extended families (called *aul*) that comprised several households closely related by blood. During the summer the abundance of grass on pastures allowed Kazakh extended families belonging to a given kin community to migrate together and whole kin community (consisting of several extended families) stayed on the summer pasture, where the access was less strictly enforced.

At the end of the XIX century, following the abolition of serfdom, tens of thousands of poor Russian peasants migrated into the Kazakh steppe, on land previously used as pasture by the local nomads. This massive inflow of migrants profoundly disrupted the traditional livelihood of the Kazakh population because of the considerable pressure on natural resources (Shakhmatov, 1964; Dakhschleiger, 1980). In about twenty years most of Kazakhs moved from being nomadic herders to becoming semi-sedentary pastoralists: although their main occupation still was animal husbandry, a large amount of time and resources was spent on agriculture, whose productivity was initially very low. Russian colonization of the steppe was one of the most large-scale migration processes on the continent of the epoch.

The transition of nomads towards the semi-sedentary livelihood was caused mainly by mass land withdrawal in favour of Cossacks and Russian peasant settlers (Masanov, 2001). Relatively rapid,

unauthorized (and, thus, poorly planned) peasant settlements on pastures previously used by nomads resulted in blocking customary transhumance routes by the fields of new settlers, decreasing the possibility for nomads' manoeuvres during years with harsh climatic shocks. The size of land allotments that was left in disposition of nomads was clearly insufficient for extensive grazing (Taizhanova, 1995). This often resulted in large losses of livestock, which, unable to find enough fodder, became weaker and more vulnerable to winter weather shocks. Given that animal husbandry was the main source of livelihood for Kazakhs, this had often tragic consequence for nomads. Thus, an ever larger fraction of Kazakh population started to rely partially on agriculture as an additional source of food.

Numerous extended families tried to maintain nomadic pastoralism under this conditions by starting to prepare hay for winter fodder and constructing mud houses on their winter pastures to protect better their animals in the winter seasons. This, however, led to a further disintegration of nomadic economy, given that these families – having to take care of hay production – could now migrate during transhumance to only summer pastures located much closer to their winter stops. Over time, the length of transhumance routes shortened, in some cases falling under 5 km. The inevitable adoption of agriculture induced Kazakh families to urgently look for ways to increase the productivity of agriculture, and the influence of their new Russian neighbours accelerated this process (Sedelnikov, 1907; Tikhonov, 1903; Dmitriev, 1903). The analysis presented below aims to quantify this influence of the massive in-migration of Russian peasants on the decision to adopt new agricultural techniques by the Kazakh population.

## 3. Data

We exploit three distinct data sources in this paper: (1) historical statistical tables, (2) official documents dating back to colonization era, and (3) maps.

Our first and main source is a unique dataset that we have constructed from the materials of the first statistical survey of the steppe areas of Kazakhstan (Materials, 1898-1908). It is a thirteen-volume publication, entitled "*Materials on Kirghiz (Kazakh) land use, collected and developed by the expedition for the analysis of steppe regions*" (hereafter, we refer to it as *Materials*). This agricultural census was guided by Fedor Scherbina, a well-known Russian statistician, and was financed by the Russian Tsarist government in order to identify land reserves in the new Eastern colonies and to better regulate the peasant migration flows. The fieldwork of the expedition was carried out over a period of 6 years, from 1896 to 1903. The result was a publication of a multi-volume edition containing census materials of the 12 regions (called *uezd*), covering the entire Northern half of Kazakhstan.

Content-wise, the dataset is an extensive and highly detailed agricultural census; virtually all of the extended families situated on the territory of these 12 regions were covered. The dataset has three levels of aggregation: (i) the information at the level of extended families (*aul*), (ii) some additional variables at the level of communities[5], and (iii) further variables at the level of socio-economic groups of households belonging to the same administrative district[6].

The dataset that we exploit in this paper comes from the Kustanay region in the Northern Kazakhstan. We have chosen it for two reasons: first, this region has a direct border with the Russian Empire, and second, there is substantial variation in geography (in particular, soil quality), which allows us to study whether geographic variables modify our main relationship of interest. The dataset includes information on 1511 extended families.

The variables belong to the following main categories: (1) demographic characteristics of the extended family (e.g. its size and gender composition); (2) socio-economic characteristics (livestock wealth per nuclear household, number of nuclear households conducting some agricultural activity, etc.); (3) information on livestock (size and structure of herds), (4) information on agriculture (arable crops, agricultural instruments possessed); (6) data on land use; (7) topographic and geo-botanical data.

One of the most valuable aspects of the dataset is the high spatial resolution of the information contained therein. The availability of maps (see Figure 1) attached to each volume of the *Materials* allows us to locate spatially the summer pastures of a community to which each extended family belongs. This, in turn, permits us to attribute to each extended family the environmental characteristics specific for their winter locations, using the GIS. Moreover, given the information on soil quality and rainfall for each summer pasture, we can include these geographic variables into our empirical analysis. To the best of our knowledge, these maps are the first and the only attempt to geographically localize the Kazakh nomadic communities.

[Insert Figure 1 about here]

How reliable is this data? Generally speaking, economic historians provide numerous arguments for why historical data might be of comparable (if not better) quality to modern datasets (see, for instance, McCloskey, 1976). The reliability of the materials on which our dataset is built was analyzed

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[5] A community consists of several kin-related extended families that jointly exploit the same summer pasture.

[6] The nuclear househols belonging to different extended families were aggregated by statisticians into socio-economic groups identified by their wealth (i.e. number of horses in their posession).

and confirmed by the quantitative historiographical studies of Volkova[7] (1982, 1983), and qualitatively by Makarov (1959) and Shakhmatov (1964). Despite some critiques by contemporaries concerning individual variables (Bukeykhan, 1903; Sedelnikov, 1907), the overall evaluation of the descriptive statistical quality of Scherbina's expedition material is highly positive. The inspector of the expedition, Kaufman (1897a), commented on the excellent quality of questionnaire.

We should note, however, that the cross-section micro-level data cannot provide a complete answer to some of the questions concerning the technology adoption process because of the static nature of the dataset which contrasts with the dynamic nature of the adoption process (Doss, 2006). More precisely, we do not observe the characteristics of adopters before and after the adoption decision. This might give rise to some identification concerns (we discuss them below).

Our second source – the historical documents from the period under study – help us to corroborate the quantitative findings from the dataset. We rely on original historical documents that have under-exploited until now, mainly for linguistic reasons (none of these documents have even been translated from Russian). These original descriptive sources consist of ethnographic comments by the statisticians who took part in Scherbina's expedition (e.g. Dmitriev, 1903), official reports to the Russian government (e.g. Kaufman, 1897a), economic reviews published by the regional administration (e.g. *Bulletin of Semipalatinsk Oblast*, 1896), and publications in Russian geographic journals which describe the traditional livelihood of the nomadic population in Eastern parts of the Empire, the process of arrival of Russian settlers, land use pattern and the process of transition from nomadic pastoralism to sedentary agriculture (e.g. Studeneckiy, 1929). These documents contain rich descriptive information which allows us to build a reconstructed overview of the historic events and living conditions of the epoch, as well as to corroborate some of the quantitative findings.

Finally, our third data source are geographic maps. The data on soil productivity types and the precipitations during a warm period of the year come from the *Atlas of the Kustanay oblast* which was published in 1963. This is the earliest source that allows to construct a spatially disaggregated environmental variables. Given that it is a half-century closer to the period under study than the contemporary maps and atlases, relying on the 1963 data should, at least to some extent, defend our analysis against the possible errors that may come from the long-term climatic variations in the region.

[7] Volkova (1982) compared the district-level aggregates of ten principal variables from the *Materials* with the same variables coming a different source (administrative reports) and analyzed the statistical correlation between them. Her conclusion is that, in general, the *Materials* can be considered as a highly reliable source.

The information on the soil productivity comes from the map "Agricultural lands valuation (rain-fed agriculture, grain crops)" (see Figure 2). The map has a resolution 1:2 500 000, which is sufficient for our purposes, as it captures enough spatial variation in soil productivity. Different colours denote soil of different quality, whereas continuous lines show the boundaries of pastures of a given kin community (hereafter, commune). Notably, one can observe that there is some variation in land quality even within the pasture area of some communes. The soil quality categorization was constructed using data on the long-term average yield of grain crops (spring wheat and millet), taking into consideration natural soil fertility and geographical conditions of the area (soil types, climate, topography, presence of lakes, forest cover, etc.). The land of the entire region is thus categorized into six groups by their productivity in conditions of rain-fed agriculture. The use of this map for our purposes gets thus an additional justification, given that Russian settlers brought into Kazakhstan the rain-fed agriculture techniques (it was not known by Kazakh before the arrival of Russians).

[Insert Figure 2 about here]

By definition, rain-fed agricultural systems do not use the artificial irrigation and depend entirely on the precipitations to meet crop requirements. Thus, it is crucial to account for the rainfall during the growth period. The information on the precipitations during the warm period comes from the map "Amount of precipitations during the warm period" with the spatial resolution 1:5 000 000 (see Figure 3). Considering the low precision of isohyets, this spatial resolution should be considered as sufficient for the needs of our analysis.

[Insert Figure 3 about here]

The historical map that we rely on is a map of traditional Kazakh land use, which is published as an appendix to the *Materials* (see Figure 1). It contains information about the limits of summer and winter camps used by kin communities (communes). Each extended family in our dataset belongs to a given commune which we have identified. On average, a commune consists of 36 extended families.

## 4. Variables

Given that the colonial statistical expeditions did not have an aim to study the adoption of agriculture by Kazakhs, our dataset does not have an exact measure of the adoption of various agricultural technologies. In this section, we discuss possible proxies for the dependent and independent variables and justify our choice of proxies.

### 4.1. Defining an adopter

Defining an adopter is a key element of any analysis of technology adoption. Numerous studies measure the adoption using a binary variable (see, e.g., Bandiera and Rasul, 2006, and Lee, 2011). Such approach is appropriate when the new technology cannot be implemented partially. Given that we are interested in a gradual transition from herding to agriculture, we prefer to define the adoption as a continuous variable. Here are the possible alternatives in our dataset.

A variable widely used in agricultural technology adoption studies is the proportion of land allocated to production using the new technology. The specificities of land use in the nomadic society and the historical context do not allow to use such continuous measure. Our dataset contains the information on the size of the sown plots, which – given that Kazakhs previously relied exclusively on pastoralism - could be used as a proxy for the land allocated to the new technology (here, agriculture). However, this approach has an important limitation: Tresviatskiy (1917) notes that the increase of the crop acreage reported by the Kazakh households did not always mean that Kazakhs themselves took care of the fields. An important part of these fields was cultivated by the Russian peasants who had no legal access to agricultural lands. This observation is confirmed in the report of the official of the Russian colonial administration Tikhonov (1903), who acknowledged that, for Kazakh population, a plot size had no particular relationship with the percentage of households engaged in agriculture. The main reason for this misreporting is the colonial administration law that prohibited renting out land in Kazakhstan. Kazakhs regularly broke this law and, to hide the actual rent[8], they declared the cultivated plots as their own. The Russian historian Makarov (1959) expressed a doubt as to whether the expedition was able to record properly the size of the sown plots. He suggested that Kazakhs were overstating the acreage to secure their property on land or to hide the fact of rent agreements with settlers. Thus, defining the adoption with the variable describing the size of the plots cultivated by the Kazakhs would lead to mistaken results.

Alternatively, one can measure adoption by using the information on the agricultural tools in possession of Kazakh families. This is a valid proxy under the assumption that the agricultural tools owned by Kazakhs capture more accurately the transition to agriculture, if, for instance, the presence of such tools is more easily observed by the census statisticians than the plot size. The contemporaries note

[8] As reported by historical sources (Kaufman, 1897b; Settlers administration, 1905; Dmitriev, 1903), the illegal land rent was very common in the studied Kustanay region.

that the supply of agricultural tools in the Kazakh steppe was considerable[9] and the existing demand was met easily. The expedition materials recorded two kinds of agricultural tools: ploughs and harrows. We next discuss arguments in favour of one of them.

The steppes of the Northern Kazakhstan at the moment of their colonization were vast spaces of virgin lands that had hardly ever been tilled. Once broken and involved in the arable farming, such land could provide a relatively rich harvest; however, special equipment such as heavy ploughs pulled by several pairs of oxen was absolutely needed to break them (Kaufman, 1897b; Dmitriev, 1903). The relatively high cost of such ploughs often excluded the poor from access to virgin lands. Renting such ploughs was possible and economically justified (as far as they were used mostly for breaking the virgin soils once in several years). However, our dataset does not contain information about ploughs rented. Although several families owned ploughs, using this as a proxy for adoption of agricultural technology might bias the results, as it would exclude those Kazakh families that did not own the ploughs but rented them (from Russian settlers or richer Kazakh families).

After the tillage, Kazakhs had to harrow the land on their own, without any further assistance from the settlers (Tikhonov, 1903). The harrows were more affordable and lighter; thus, harrows were actually owned by those who cultivated land. Moreover, the larger was the area cultivated, the higher was the number of harrows needed (because often the harrowing would happen simultaneously, or to have some insurance against breaking of a harrow while working). Thus, the number of harrows is a better proxy for the adoption of agricultural technology. To control for the variation in size of extended families, we use the number of harrows per nuclear household.

There is an additional reason for using harrows as a proxy for adopting *new* agricultural technology. Although there is plenty of evidence that Kazakhs were familiar with ploughs even before the in-migration of Russian peasants (Makarov, 1959), Kazakh had no previous knowledge of harrows. This is documented, for instance, by Dmitriev, who directed the statistical expedition in Kustanay region (1903). Thus, we expect the determinants of technology adoption exhibit a stronger effect when harrows (rather than ploughs) are used as a proxy for agricultural technology adoption.

[Insert Table 1 about here]

[9] See, e.g., Vnukov (IPOTUR, 1910) who states that "the development of agriculture in the steppe provoked a widespread presence of new agricultural tools". Argynbaev (2007) argues that at the end of XIX century these tools could be easily bought by Kazakhs from Russians.

The first row of Table 1 presents the descriptive statistics of our main dependent variable. Standard deviation is fairly high which indicates substantial heterogeneity in the milieu of adopters. Only 13 per cent of extended families do not possess harrows. The half of all extended families in the region possess, on average, between 0 and 1 harrow per household and 37 per cent of families report at least one harrow per household. This suggests that by the end of the nineteenth century, the process of adoption of agriculture in Kustanay was well advanced: the issue was not any longer whether to adopt the agriculture or not, but to what extent to rely on agriculture as an additional source of nutrition and to what extent to practice agriculture regularly. This confirms our choice of a continuous dependent variable rather than a cruder binary one.

### 4.2. Determinants of adoption

If technology adoption is a rational decision by households and extended families, the principal determinants of adoption are the factors that affect the costs or benefits of adoption: (1) the cost of learning, i.e. the distance to Russian villages that have a good knowledge of this technology, (2) the degree of sedentarization of the nomadic family, (3) socio-economic conditions of the family, e.g. its wealth, and (4) environmental characteristics (quality of soil and rainfall).

#### *4.2.1. Cost of learning*

One key determinant of technology adoption is the accessibility of information (Foster and Rosenzweig, 2010). A potential adopter should first get access to information about the new technology (here, rain-fed farming and the role of various tools) before deciding whether to adopt it or not. Intuitively, proximity to a Russian settlement increases the likelihood of communication and the information transmission. Thus, we include the geographical proximity between the Kazakh extended family and the nearest Russian settlement as one of the regressors in our model.

The Russian and Ukrainian peasant settlements were the loci of farming in the Kazakh steppe. It is thus likely that the adoption of agriculture by the nomads was facilitated by the presence of these new neighbours who were successfully practicing the rain-fed agriculture in the arid spaces of Northern Kazakhstan. Moreover, there is evidence that the "geographical proximity combined with some level of cognitive proximity, is sufficient for interactive learning to take place" (Boschma, 2005). In fact, contemporary descriptive sources confirm that this was likely the case:

*"[Some Kazakhs] have been stopping by the Russian towns and observing how the Russian ploughed. At first they hired Russian peasants for agricultural work, but when they saw how profitable the agriculture could*

*be, they started to plough themselves. Thus, according to the testimony of the Kirghiz (Kazakhs) themselves, they started labouring the soil and even now it is practiced under the influence and with the direct participation of the Russian population […] mostly the peasants".*

Tikhonov (1903: 69)

Our measure of proximity is the distance to the closest sedentary settlement in verstas (1 versta = 1.0668 km). As the second row of Table 1 indicates, the average distance to the nearest peasant settlement is 37.12 verstas (i.e. 39.6 km). 62 per cent of winter stops of extended families in our dataset are situated at a distance of less than 30 km from a peasant settlement (i.e. less than a day journey on horseback).

Conley and Udry (2008) warn against the use of geographical proximity as a driver of information exchange. They note that spatial proximity may hide unobservable spatially correlated shocks; in such a case, the geographic proximity would mean not learning but simply that other (possibly omitted) factors that influence technology adoption and use are correlated spatially, and the causal effect of learning be difficult to identify. However, given that we will control for several environmental characteristics (soil quality, precipitations) and, moreover, the arrival of Russian settlers can safely be considered as exogenous from Kazakh nomads' perspective, this problem should be less of a concern for our analysis.

#### *4.2.2. Degree of sedentarization*

Suppose the informational barrier is overcome for Kazakh families located closely to Russian settlements. Then, for families with relatively higher degree of sedentarization the benefit of technology adoption should be higher. However, it is important to understand the nature of this relation before including this factor into the model. The causality problem emerges: is it the transition of a Kazakh extended family to sedentary livelihood that favoured the adoption of agricultural technology or, contrarily, it is the desire to practice agriculture that motivated its sedentarization? The descriptive sources indicate that that the huge majority of Kazakh nomads felt the need to engage in land cultivation because of the rising land pressure (Taizhanova, 1995). The massive withdrawal of pastures during the colonisation provoked the frequent loss of herds during harsh winters. This caused the transition of numerous Kazakh families towards the semi-nomadic livelihood (Masanov, 2001). Contemporary economic reports (*Bulletin of Semipalatinsk oblast*, 1898) and the later studies of agriculture adoption (Makarov, 1959) claim that the land cultivation did not seriously prevent Kazakh families from

maintaining semi-nomadic lifestyle (but certainly influenced the distance of transhumance). Thus, the reverse causality is unlikely to be a major concern here.

The proxy for the degree of sedentarization is the number of months during which the same water source (at the winter stop) is used by the extended family. The extended family that uses the same water source 12 months is completely sedentarized. Contrarily, a family that uses the same source for less than 3 months (one full season) is nomadic. Thus, this continuous variable adequate describes the degree of sedentarization in the conditions of gradual transition of nomads to the settled livelihood. Only 0.5 per cent of extended families use the same water source during less than one season per year, i.e. remain purely nomadic. Most of the families (81.4 per cent) spend between two and three seasons at the same location, whereas a considerable share (10.5 per cent) is fully sedentary. Thus, at the moment of the census, the sedentarization process was in full expansion in the region.

A short comment on water availability is of order here. In some parts of Kazakhstan, water sources are unavailable throughout the full year (e.g. small rivers might dry up during the summer). The Northern regions of Kazakhstan (including Kustanay region) do not suffer from water scarcity which characterizes the Southern parts of the country. The data confirms that the water sources mentioned in the *Materials* are available, on average, 357 days per year. Thus, the variation in water availability is unlikely to introduce a bias into the estimation of the degree of sedentarization.

#### *4.2.3. Wealth*

The cost of adoption a new technology is not only informational, but also economic. Moreover, changing one's technology of production always implies some risk (e.g. the technology might not fit well the local geographic conditions or one can make mistakes in using it). Wealthier families are better able to support the negative consequences of such mistakes and thus able to assume higher level of risk. Thus, we include measures of wealth as regressors in our analysis.

Historical descriptive sources (Dakhschleiger, 1980; Studeneckiy, 1929; Dmitriev, 1903) support the view that the number of horses owned is the best measure of wealth for Kazakh households. This applies also to Kustanay region: the national average of the share of horses in the total livestock herd is 13.5 per cent, whereas for Kustanay region this share is 26.6 per cent (Dakhschleiger, 1980). Being situated in the North, this region benefited from environmental conditions favourable to horse breeding, but also from the proximity to the Russian markets. Horses rapidly became the main export item from Kazakhstan to Russia. Studeneckiy (1929) shows that horse herd farming had a clearly commercial nature in the North of Kazakhstan. Thus, there is a strong correlation between well-being of a Kazakh

extrended family and the increased proportion of horses in its herd structure (Dmitriev, 1903). We use the number of adult horses in possession of an extended family (again, normalized by the number of households) as a measure of wealth. Table 1 shows that the variation in this measure is quite high (which, incidentally, argues against the layman's view about the egalitarian nature of a nomadic society).

There are two potential problems with this measure of wealth. First, it may correlate with other factors driving agricultural adoption (Doss, 2006). Families with more horses may be wealthier and more susceptible to adopt agriculture. However, the larger the herds, the more frequently the family needs to change pastures (so as to provide enough grass for the animals). This implies lower degree of sedentarization and thus is likely to make the adoption of agriculture less beneficial. Surprisingly, however, numerous historical records indicate a *positive* correlation between the number of horses that a family possesses and the size of plots sown (Makarov, 1959). Studeneckij (1929) and Togzhanov (1934) explain that the agricultural development in Northern Kazakhstan began with the relatively wealthy families, because these were the only ones that had enough resources (draught power and tools) for breaking up the ground that has never been previously tilled.

The second is the causality problem, which emerges when the dynamic nature of adoption of agriculture is studied using static data (a single temporal observation). It may be the case that families that had adopted agriculture become better off and could increase the number of horses, so as to diversify their assets. Therefore, the early adoption of agriculture has also an impact on size and structure of herds. According to Makarov (1959), the successful practice of agriculture did not decrease the size of herds. Contrarily, it stimulated the development of herding and induced an increase of the share of horses in the structure of herds. Nevertheless, given high fixed costs at the early stage of transition to agriculture, we can assume that those families that reported larger herds at the moment of the census had larger herds also at the moment of adoption decision.

The above two concerns are, however, quite important. We thus also use an alternative measure of wealth: the number of yurtas[10] in possession of the extended family (normalized by the number of households). We check the robustness of our results to employing this alternative measure. This measure has the advantage that it is less strictly linked to the nature of dominant productive activity:

[10] *Yurta* (or *kiiz-uy*) – a traditional portable dwelling of Kazakh nomads.

despite the prevalence of mud houses among the sedentarizing Kazakh population, the yurt was still preferred as a summer dwelling by those households who could afford it (Tikhonov, 1903).

#### *4.2.4. Environmental characteristics*

Substantial differences in environmental conditions within the Kustanay region had a considerable effect on the extent of the agriculture adoption (Dakhschleiger, 1980). Historical sources confirm that Kazakhs were well aware of the environmental characteristics of the areas where they lived (more precisely of the soil quality) when making the decision to adopt new agricultural techniques (Kaufman, 1897b). The Kazakhs had also an excellent knowledge of the type of vegetation characterizing the soils suitable for agriculture. This indicates that the autochthones were able to distinguish the quality of the soils at least as well as new settlers did.

To construct measures of environmental conditions, we superimposed the maps of kin community pastures on the maps with the soil and rainfall characteristics using GIS. We then calculated the percentage of the territory of a commune's pasture affected by given environmental characteristics and attributed a numerical score (from one to six) to each extended family within the commune. A measure of environmental conditions – i.e. the index of soil productivity or of warm-period precipitations – is the weighted average of the score of land areas on which the pasture of the commune is located, with weights being the shares of the pasture occupied by a certain type of soil (soil quality index) or situated within a zone with a certain amount of precipitations (rainfall index). To take into account a possible non-linear increase in soil productivity, we also construct measures where the squares of scores is used:

$$\text{Soil quality index}_c = \left(6 * \frac{S_{soil1}}{S_c}\right) + \left(5 * \frac{S_{soil2}}{S_c}\right) + \cdots + (1 * \frac{S_{soil6}}{S_c}),$$

$$\text{Soil quality (quadratic) index}_c = \left(36 * \frac{S_{soil1}}{S_c}\right) + \left(25 * \frac{S_{soil2}}{S_c}\right) + \cdots + (1 * \frac{S_{soil6}}{S_c}) \quad (3.1)$$

Here, $c$ denotes the commune, $S_c$ the total surface of the commune's pasture, and $S_{soilJ}$ the surface of the commune's pasture with land of quality category J (1 being the best-quality land and 6 being the worst-quality one). Thus, higher values of the index correspond to higher average quality of land on the pastures of the commune to which an extended family belongs.

The rainfall measure is constructed analogously:

$$\text{Rainfall index}_c = (4 * \frac{S_{250-275}}{S_c}) + (3 * \frac{S_{225-250}}{S_c}) + (2 * \frac{S_{200-225}}{S_c}) + (1 * \frac{S_{175-200}}{S_c}),$$

$$\text{Rainfall (quadratic) index}_c = (16 * \frac{S_{250-275}}{S_c}) + (9 * \frac{S_{225-250}}{S_c}) + (4 * \frac{S_{200-225}}{S_c}) + (1 * \frac{S_{175-200}}{S_c}) \quad (3.2)$$

Here, $S_{\mathrm{m-n}}$ denote the surface of the commune's pasture with amount of warm-period precipitations between $m$ and $n$ millimeters. Thus, a higher value implies that a larger part of the commune's pastures are situated in the zone with more abundant precipitations.

Our two measures of environmental conditions have a fairly high (but far from perfect) correlation: 42 per cent of the warm-period precipitations index is explained by the variation of the soil quality index. Thus, whereas both measures capture the quality of environmental conditions for rain-fed agriculture, they seem to account for two substantively different dimensions of such quality.

## 5. Econometric model

Ideally, we would like to estimate the following linear model that analyses the agricultural adoption of Kazakh families as being determined by the cost of information about the new technology, the degree of sedentarization, wealth and environmental characteristics of the pasture land of families:

$$Adopt = \beta_0 + \beta_1 * InfoAcces + \beta_2 * Sedent + \beta_3 * Wealth + \beta_4 * Envt + \epsilon, \quad (5.1)$$

However, given that these measures of behaviour and characteristics are not observable, we replace them in our econometric model with their proxies. Thus, in its' basic form, we will estimate the following model:

$$Harrows_{ic} = \beta_0 + \beta_1 * Distsed_{ic} + \beta_2 * WaterUse_{ic} + \beta_3 * Horses_{ic} + \beta_4 * SoilQuality_c + \varepsilon_{ic}, \quad (5.2)$$

where $Harrow_{ic}$ denotes the number of harrows per household in extended family $i$ in kin community $c$, $Distsed_{ic}$ denotes the distance from the winter stop of family $i$ to the nearest Russian settlement, $WaterUse_{ic}$ is the number of months per year that family $i$ uses the same water source, $Horses_{ic}$ is the number of horses per household in family $i$, and $SoilQuality_c$ is the index of soil quality on the pastures of kin community $c$. We cluster the standard errors at the level of kin community (there are 251 clusters/communes in our data).

Furthermore, we perform two robustness checks of this model. First, we analyse to which extent the results obtained in our basic regression are driven by outliers (in particular, by families have a very high number of harrows per household). Second, we verify whether our results change if we use alternative measures of wealth and environmental conditions. To do so, we replace the wealth in horses with the number of yurtas per household (as well as estimate a regression with both measures of wealth

included) and replace the index of soil productivity with the index of precipitations during the warm period of the year.

The effect of a lower cost of information about the new technology is likely to be heterogeneous across families. In particular, as discussed above, we expect the effect of the distance to Russian settlements on the agriculture adoption to be stronger in families that are less likely to be wealth-constrained to buy harrows (i.e. wealthier families), in those for whom the benefit of a more productive technology is likely to be larger (i.e. families that are more sedentary and those with pastures in areas with environmental conditions more favourable for cultivation). To test for this heterogeneous effect, we introduce into our model the interaction terms between the distance to the nearest Russian settlement and characteristics of wealth, degree of sedentarization, and soil quality.

## 6. Results

This section presents the results of OLS estimation for the baseline model, as well as for the augmented model that explores the heterogeneous effects of the distance to Russian settlements.

[Insert Table 2 about here]

The first column of Table 2 report the results from the estimation with distance to Russian settlements as the only explanatory variable. We see that the results confirm our basic intuition: once Russian peasants settle closer to the winter stop of an extended family of Kazakh nomadic pastoralists, these latter are significantly more likely to adopt and possess a new agricultural technology (i.e. the number of harrows per household inside the extended family increases). The results in columns 2 to 4 indicate that this result is robust when controlling for the wealth of the Kazakh family (as measured in horses), its degree of sedentarization (as measured by the number of months per year it stays on its winter stop), and the suitability of land on its pastures for agriculture. The size of the effect is large: controlling for other determinants of adoption (column 4), one standard deviation decrease in the distance to the nearest Russian settlement (i.e. 41 verstas) increases the number of harrows per household by 0.41*0.511 = 0.21 harrows, or approximately 17 per cent of standard deviation of the dependent variable.

The coefficients on the wealth (measured in horses) is positive, significant, and robust in size across specifications: a family that is wealthier by one standard deviation (i.e. possessing 21.4 horses per household more) has 0.56 harrows more (per household), or 44 per cent of a standard deviation of the dependent variable. Unsurprisingly, richer families afford to buy more harrows. Columns 3 and 4

report the results when the degree of sedentarization is added as a regressor. We see that Kazakh families whose transhumance period is shorter possess substantially more harrows. One standard deviation increase in the degree of sedentarization (1.34 months more of use of the same water source) implies 0.36 more harrows per household, i.e. 29 per cent of a standard deviation of our dependent variable. This is compatible with simple intuition that more sedentary families are more active in agriculture and thus the benefit of an additional harrow is higher for such families.

In the regression of column 4 we add the key environmental characteristic – the quality of soil on the pastures of the commune of the extended family – as a regressor. The coefficient is positive and highly significant: families located on land better suitable for agriculture possess more harrows. Probably, this occurs for the same reason as above: the marginal value of new agricultural technology is higher for such families. The size of the effect is considerable but not enormous: one standard deviation increase in the soil quality (1.03 point on our index) corresponds to about 14 per cent increase in our dependent variable.

In columns 5 to 8 we explore the robustness of our findings to using alternative measures of determinants of technology adoption. In the regression of column 5 we use the wealth in housing (the number of yurtas per household) instead of the number of horses, and in column 6 we use both measures of wealth as regressors. In both cases, wealth proxies are positively correlated with technology adoption and the coefficients are significant at conventional levels. The sizes and signs of coefficients on other variables (in particular, on the distance to Russians) remain stable.

In the regression of column 7, we add as a regressor our second environmental characteristic: the index of rainfall on pastures. The coefficient on this measure is positive and highly significant, whereas the size of the coefficient on the quality of soil decreases substantially (and loses its significance). This might indicate that the index of rainfall is a better proxy for the suitability of land for rain-fed agriculture, or simply that it is more precisely measured (and correlated with the soil quality index). Given that these indices do not take into account the potential non-linearity of the effect of better environmental characteristics on agriculture, in column 8 we report the results of a regression in which the indices of soil quality and rainfall are quadratic. The regression coefficients on both measures carry a positive sign and are highly significant (which might be an indication of non-linearity of the relationship). Note that once both measure of environmental characteristics are included (in columns 7 and 8), the size of the coefficient on the distance to Russians decreases substantially, but remains significant.

As mentioned above, the descriptive statistics of the dependent variable show that there are some families that possess a very high number of harrows. To check that our results are not driven by those outliers, in column 9 we report the results of a regression in which we restrict our sample only to families that possess less than 3 harrows per household. The sample size decreases by about 100 observations; however, all the regression coefficients conserve their signs and significance.

Finally, in columns 10 and 11 we analyse the results of regressions with different dependent variables (respectively, ploughs per household and land area cultivated per household). There are two interesting findings that support our theoretical discussion above and qualify it. In the regression of column 10, our dependent variable is ploughs per household. As we noted in Section 4.1, Kazakhs had already some knowledge about ploughs even before Russian in-migration. Thus, distance to Russian settlements should play a smaller role for the number of ploughs per household. In fact, we observe that the coefficient on the distance has a negative sign, is very small in absolute size, and is not statistically significant.

In the regression of column 11, the dependent variable is land area cultivated (per household). As we mentioned in Section 4.1, this variable is likely to have some mis-reporting problems. However, it is nevertheless interesting to observe that the coefficient on the distance to Russian settlements is positive and significant. Controlling for wealth and degree of sedentarization, the families that are further away from Russian settlements report a *larger* area of land cultivated. Besides the mis-measurement issues, the most plausible explanation for this finding (combined with the negative effect of distance to Russians for the number of harrows) is à la Boserup (1958): families whose pastures were located closer to Russian settlements suffered a more severe pressure on land; therefore, they could cultivate less land, but did so more intensively (in particular, adopting new agricultural techniques and tools).

Next, we analyse how the effect of distance to Russian settlers on technology adoption differs along several key characteristics of Kazakh families. To do so, we estimate an augmented model where we add as regressors the interaction terms between the distance and the main characteristics (wealth, the degree of sedentarization, and the quality of soil). Table 3 reports the results of these regressions.

[Insert Table 3 about here]

In column 1, we look at the heterogeneity of effect of the distance to Russian, by the level of wealth. The coefficient on the interaction term is negative and highly statistically significant. To make the quantitative interpretation easier, let's consider two groups of Kazakh families, at the 10$^{th}$ and the

90th percentile of the wealth distribution in the population. For the first group, the slope of the relationship between distance and technology adoption is equal to -0.277 (= -0.177 + (-0.025*4)). For the second group, instead, this slope equals -0.952 (= -0.177 + (-0.025*31)). In other words, the effect of a closer Russian settlement on new agricultural technology adoption is almost 3.5 times larger for the richer families (those having on average 31 horses per household) as compared to the poorer ones (those having 4 horses per household).

Column 2 reports the results of the regression where distance to Russians is interacted with the degree of sedentarization. The coefficient on the interaction term is negative and strongly significant. Again, let's compare the groups of families at the 10th and the 90th percentile of distribution in terms of the degree of sedentarization. For the first (less sedentary) group, the slope of the relationship between the distance to the nearest Russian settlement and technology adoption equals -0.217 (= 2.441 + (-0.443*6)). For the second (sedentary) group, this slope is equal to -2.875 (= 2.441 + (-0.443*12)). This means that the more sedentary families respond (in terms of technology adoption) much stronger to the closer location of a Russian settlement.

Similarly, in column 3, we look at the interaction between the distance to Russians and quality of soil on pastures of the Kazakh families. Once again, the interaction term carries a negative and highly significant sign. For comparison, the slope of the relationship between distance to Russians and technology adoption for the families at the 10th percentile of quality-of-soil distribution equals -0.279 (= 0.263 + (-0.257*2.11)), whereas for the families at the 90th percentile of quality-of-soil distribution, it equals -0.996 (= 0.263 + (-0.257*4.9)). The effect is more than 3.5 times higher for families whose pastures are located on the soil that is more suitable for agriculture.[11]

Overall, the results show that the effect of spatial proximity of Kazakh extended families to the Russian settlements on the agriculture adoption by Kazakhs is much stronger for wealthier, more sedentary families that benefit from more favourable environmental conditions. These findings have an interesting implications for the evolution of inequality in the Kazakh society during the process of transition from nomadic pastoralism to sedentary agriculture. Sedel'nikov notes in his 1907 book entitled *The fight for land in the Kazakh steppe*:

[11] In the regression of column 4, we add all the three interaction terms. It is comforting to see that both the sizes and the significance of all the coefficients of the interaction terms are very similar to the ones in columns 1 to 3.

*"Reduction in pastures led to an increasing death of livestock in winter, and this forced weaker and poorer tribes to re-consider their future: given that the previous form of the economy could not provide their subsistence, they had to look for another one that better corresponds to the new situation… And now these tribes sedentarize in the north to live there for the entire year …"* (p. 23).

This, together with our findings above, implies that, as ever more Russian peasants moved into Northern Kazakhstan, the increasing spatial proximity to Russian settlers led to a decreasing inequality *between* Kazakh kin groups: the poorer and weaker kin groups were the first ones to sedentarize, and – given that we've established that the more sedentary families adopted new agricultural technology faster, it is likely that they were the first ones to benefit from this technology. However, the inequality within kin groups is likely to have increased, as the relatively wealthier families could afford more easily the monetary expenses needed to buy these new agricultural tools.

## 7. Conclusion

In this paper, we have analysed the relationship between a massive Russian peasant in-migration and the adoption of new agricultural technology by the Kazakh nomadic population, as well how the socio-economic factors and environmental conditions have influenced this relationship. In our analysis, we have used unique historical data from the Northern Kazakhstan built from colonial statistical expeditions of the late 19$^{th}$ – early 20$^{th}$ centuries. We document a large average positive effect of proximity to Russian settlements on the adoption of new technologies by autochthone families, and show that this effect is much stronger for wealthier and more sedentary families with pastures on land whose soil is more suitable for rain-fed agriculture.

Our findings confirm the existing results (from other contexts) concerning the effect of shorter distances (between early and late adopters) on facilitating interactions and reducing the cost of information about new technologies (e.g. Fritsch and Franke 2004). Moreover, the descriptive contemporary sources from Kazakhstan indicate the importance of the structural change in the economy that we have documented and quantified. For instance, Tikhonov (1903) reports that Kazakhs adopted the agricultural techniques from Russian peasants essentially by knowledge transmission mechanism: i.e. observing directly the production process of Russians, hiring settlers for agricultural work on Kazakhs' land, etc. Similarly, Kaufman (1897) and Studeneckiy (1929) highlight the fundamental role of settlers in teaching the Kazakhs to cultivate the land, to use agricultural implements and to do more sophisticated agricultural work.

A key difference of our study of technology adoption as compared to many existing ones, is that we take proper account of environmental characteristics. This is important because geographic proximity has often been used as a catch-all phrase (Mattes, 2012); however, it may hide other spatially correlated shocks that ought to be distinguished from the information-transmission channel, e.g. environmental conditions, proximity to markets, regional institutional heterogeneity, etc. The existing studies of technology adoption ignore this aspect and give little or no information about the environmental factors (Doss, 2006). This leads to an omitted variable bias and might lead to flawed conclusions. Contrarily, we account for common environmental shocks by controlling for agro-ecological factors, by including into the model soil productivity and warm period precipitations indices. We find that the size of the proximity effect decreases; however, even within the environment equally favourable for practicing agriculture those Kazakh families located closer to Russian settlements are more likely to adopt new agricultural technology.

An important caveat concerns cultural factors. Contemporary authors underline that Kazakh nomads were relatively open to new information coming from other cultures, and this facilitated information transmission and adoption of new techniques by Kazakhs (Sedelnikov 1907). This definitely played an important role in the speed of the process that we document; in fact, Dubois (1972) stresses that, generally speaking, technology adoption rate is higher when the social values of the system favour novelty and change. Notably, the learning and information transmission process occurred in Kazakhstan despite high linguistic barrier (Kazakh and Russian belong to different language groups, and very few Kazakhs had proficiency in Russian before the early 20$^{th}$ century). There is some evidence that Kazakhs were actively investing into learning Russian (Bukeykhan 1910; Sedelnikov 1907; Makarov 1959: 434; Dakhshleiger 1980: 167; Orazbekov 1977).

One limitation of our study is the static nature of the data. Technology adoption decision is fundamentally a dynamic process (Besley and Case 1993) and the cross-sectional micro-level data is, at best, a snapshot at a given point of time, where the econometric identification of causal effects comes from the (hopefully large) differences in the speed of adoption between units, driven by the spatially varying pressure of determinants of adoption. However, it is likely that some of the presumed determinants of technology adoption (wealth or sedentarization) are themselves in part influenced by the earlier adoption decision. Thus, to properly account for such reverse causality and aim at cleaner identification of causal effects, one needs observations for the same units, in a different moment of time.

The interaction between nomadic pastoral culture and the sedentary civilization has always been complex, often based on cooperation, but sometimes leading to tensions. Nowadays, such tensions

are aggravated by population pressure and the resulting expansion of cultivated areas by the sedentary, often at expense of the pasture lands of nomadic tribes. This inevitably leads to (at least partial) sedentarization of nomads and changes in their livelihood. The case of the colonization of Kazakh steppe by the Russian Empire that we have explored in this paper is one of the earliest well-documented and quantified processes of expansion of sedentary agricultural civilization on the lands of nomads. We hope that the conclusions made in this study may serve for a better understanding of the consequences of current agricultural expansion on the nomadic territories in other parts of the developing world.

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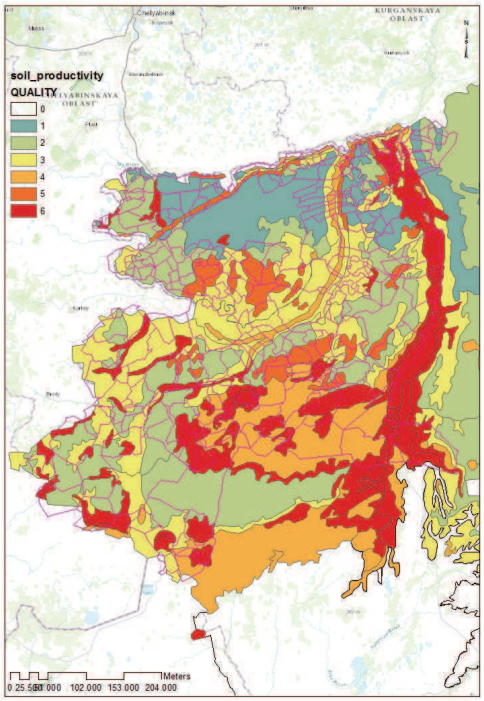
## Figure 1. Map of pastures of kin communities (from 1908 expedition)

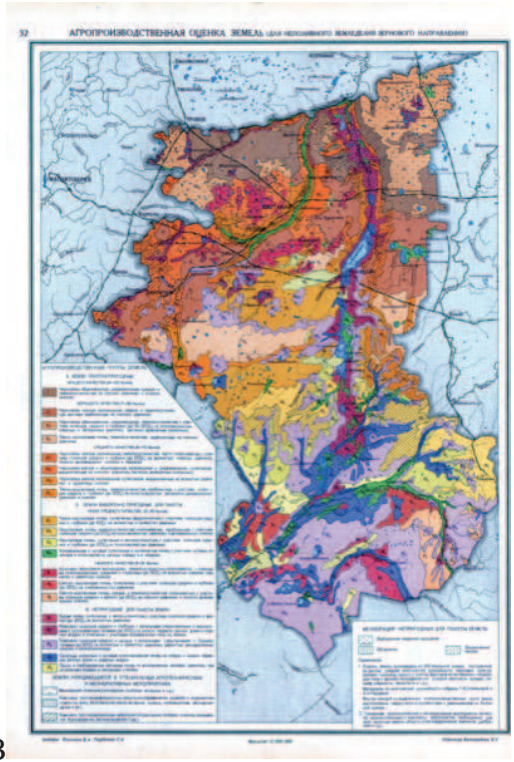

Original map is taken from Materials (1898-1908), Vol. V. 1:480 000.

Blue green – winter pastures and Nos. of communities.
Warm green – summer pastures and other common-use pasures.
Dark green lines – lands withdrawn from the use of Kazakhs.
Red lines – limits and Nos. of natural historical regions.
Yellow lines – limits of regions A, B, C, D, E, F, G and I, II, III.
Dark green heavy line – limits of “million versts’ allotment” 1, 2, 3 and 4.
Blue spots -- fresh lakes.
Grey spots -- salt-water lakes.

# Figure 2. Map of soil quality (1963 Atlas)




A



B

Note: Panel A: kin community pastures are superimposed, Panel B: original map by Nikolaev, V. and Turdeneva S., (1963). 1:2 500 000.

Legend: The evaluation of productivity is performed on a 100-point scale and is based on average productivity of grain crops and millet over several decades. It takes into account the factors of natural fertility of soils as well as climate, relief, water availability, forest cover.

A. Lands suitable for cultivation

I - Best quality lands (91 to 100 points)

I Ordinary loamy chernozems on flat plains and gentle slopes.

II – Good quality lands (71 to 91 points)

II-1 Southern loamy chernozems, sometimes calcareous on flat plains

II-2 Ordinary loamy chernozems with average and deep salt licks (up to 20%) on gently undulating plains with forest outliers.

II-3 Dark brown soils with heavy loam, calcareous, on flat plains.

III – Average quality lands (41 to 70 points)

III-1 Southern chernozems, shallow, with heavy loam, solonetzic, often with average and deep salt licks (up to 20%) on gently undulating plains, talus slopes and terraces.

III-2 Southern and ordinary chernozems, shallow or semi-shallow, sandy loam, leached on flat plains.

III-3 Southern chernozems, shallow, sandy loam on undulating plains and streamside slopes.

III-4 Dark brown soils, loamy, calcareous with average and deep salt licks (up to 20%) on undulating deluvial plains.

B. Lands selectively suitable for agriculture

IV Below average quality lands (21 to 40 points)

IV-1 Dark brown soils, sandy loam, leached, with average and deep salt licks (up to 10%) on undulating plains.

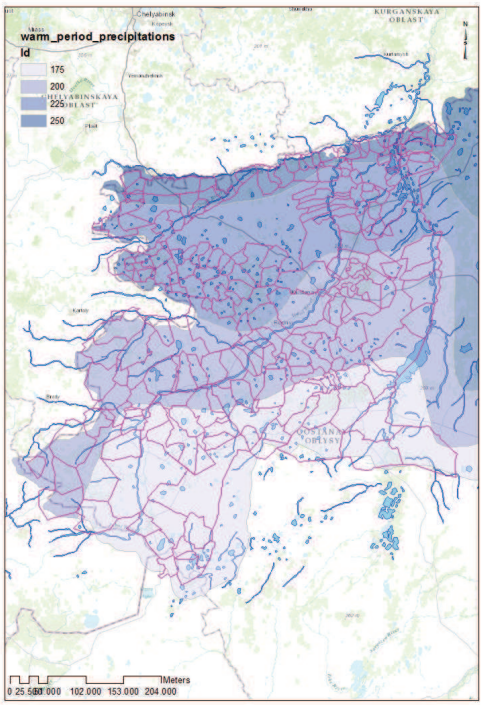
IV-2 Brown soils, loamy, solonetzic, calcareous with average and deep salt licks (up to 20%) on slightly undulating plains and delivial slopes.

IV-3 Brown soils, sandy loam, with average and deep salt licks (up to 20%) on slightly undulating plains.

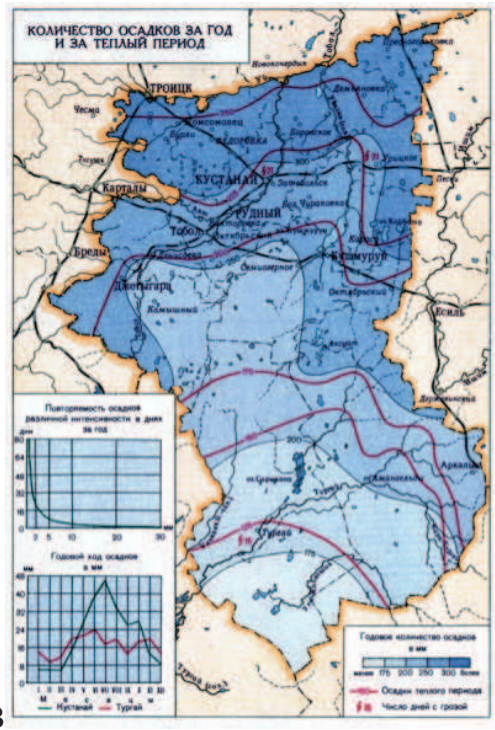
IV-4 Alluvial soils, meadow sabulous soils, loamy, with black alkali soils and solonchaks

C. Lands not suitable for agriculture

## Figure 3. Map of warm-period precipitations (1963 Atlas)




A




B

Note: Panel A: kin community pastures are superimposed, Panel B: original map by Klykova Z., (1963). 1:5 000 000.

Legend: Limits of the zones of the amounts of precipitations in the region are between 175 and 200 mm; between 200 and 225 mm; between 225 and 250 mm; and above 250 mm.

## Table 1. Definitions and descriptive statistics of main variables

| Variable | Proxy for | Definition | Number of observations | Mean | Standard deviation | Min | Max | Percentiles | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 10% | 90% |
| HARROWS | Adoption of a new agricultural technology | Number of harrows (per household) within the extended family | 1498 | 0.99 | 1.27 | 0 | 11 | 0 | 2.5 |
| DISTSED | Cost of information | Distance to the closest (Russian) sedentary settlement, in 100 verstas | 1402 | 0.37 | 0.41 | 0 | 0.25 | 0.05 | 0.9 |
| WATERUSE | Degree of sedentarization | Number of months per year the same source of the water is used | 1497 | 7.2 | 1.34 | 0 | 12 | 6 | 12 |
| HORSES | Wealth | Number of horses (in adult equivalent, per household) owned by the extended family | 1498 | 15.59 | 21.41 | 0.29 | 321.5 | 4 | 31 |
| YURTA | Wealth | Number of yurtas (per household) owned by the extended family | 1497 | 1.2 | 0.53 | 0 | 14 | 1 | 1.5 |
| SOILQUALITY | Environmental conditions | Soil productivity index | 1511 | 3.59 | 1.03 | 1.06 | 5.95 | 2.11 | 4.9 |
| RAINFALL | Environmental conditions | Precipitations index | 1511 | 2.29 | 0.97 | 0 | 4 | 1 | 3.62 |
| PLOUGHS | Investment in agricultural technology | Number of ploughs (per household) within the extended family | 1496 | 0.36 | 0.3 | 0 | 4 | 0 | 0.71 |
| PLOWLAND | Change in production pattern, from pastoralism to agriculture | Area (in desyatinas, per household) of land of the extended family on which some crop is sown | 1498 | 0.73 | 0.37 | 0 | 6.33 | 0.2 | 1 |

## Table 2. Determinants of agricultural technology adoption

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Harrows per household | Harrows per household | Harrows per household | Harrows per household | Harrows per household | Harrows per household | Harrows per household | Harrows per household | Harrows per household | Ploughs per household | Land area plowed (per household) |
| Distance to the nearest Russian settlement (in 100 verstas) | -0.796 | -0.79 | -0.6 | -0.511 | -0.48 | -0.5 | -0.233 | -0.216 | -0.205 | -0.004 | 0.104 |
| | (0.107)** | (0.105)** | (0.090)** | (0.096)** | (0.101)** | (0.097)** | (0.087)** | (0.080)** | (0.052)** | (0.025) | (0.041)* |
| Wealth in horses per household | | 0.027 | 0.027 | 0.026 | | 0.022 | 0.022 | 0.022 | 0.009 | 0.003 | -0.002 |
| | | (0.004)** | (0.004)** | (0.004)** | | (0.004)** | (0.004)** | (0.004)** | (0.002)** | (0.001)** | (0.001)* |
| Wealth in yurtas per household | | | | | 0.735 | 0.385 | 0.396 | 0.4 | 0.295 | 0.212 | 0.342 |
| | | | | | (0.237)** | (0.172)* | (0.168)* | (0.169)* | (0.104)** | (0.061)** | (0.074)** |
| Number of months per year that the same water source is used | | | 0.271 | 0.26 | 0.273 | 0.264 | 0.252 | 0.242 | 0.099 | 0.03 | 0.032 |
| | | | (0.047)** | (0.044)** | (0.046)** | (0.044)** | (0.039)** | (0.037)** | (0.022)** | (0.007)** | (0.009)** |
| Index of soil quality of the land of the kin community | | | | 0.17 | 0.193 | 0.174 | 0.075 | | 0.064 | 0.02 | 0.036 |
| | | | | (0.051)** | (0.053)** | (0.052)** | (0.051) | | (0.032)* | (0.013) | (0.019) |
| Index of rainfall on the land of the kin community | | | | | | | 0.301 | | 0.155 | 0.028 | 0.032 |
| | | | | | | | (0.054)** | | (0.039)** | (0.015) | (0.02) |
| Index of soil quality (quadratic) | | | | | | | | 0.02 | | | |
| | | | | | | | | (0.007)** | | | |
| Index of rainfall (quadratic) | | | | | | | | 0.06 | | | |
| | | | | | | | | (0.012)** | | | |
| Constant | 1.303 | 0.872 | -1.144 | -1.694 | -2.359 | -2.138 | -2.497 | -2.188 | -0.931 | -0.287 | -0.114 |
| | (0.100)** | (0.096)** | (0.333)** | (0.375)** | (0.457)** | (0.412)** | (0.378)** | (0.343)** | (0.231)** | (0.087)** | (0.136) |
| Observations (extended families) | 1389 | 1389 | 1387 | 1387 | 1386 | 1386 | 1386 | 1386 | 1281 | 1384 | 1386 |
| R-squared | 0.06 | 0.25 | 0.33 | 0.35 | 0.27 | 0.37 | 0.4 | 0.41 | 0.23 | 0.3 | 0.24 |

Notes: Standars errors, clustered at kin community level, are reported in parentheses. * denotes significance at 5% level and ** at 1% level.

## Table 3. Heterogeneous effects of distance to Russian settlements

| | (1)<br>Harrows per household | (2)<br>Harrows per household | (3)<br>Harrows per household | (4)<br>Harrows per household |
|---|---|---|---|---|
| Distance to the nearest Russian settlement (in 100 verstas) | -0.177 | 2.441 | 0.263 | 3.785 |
| | (0.106) | (0.608)** | (0.249) | (0.599)** |
| Wealth in horses per household | 0.039 | 0.026 | 0.027 | 0.040 |
| | (0.006)** | (0.004)** | (0.004)** | (0.005)** |
| Number of months per year that the same water source is used | 0.252 | 0.385 | 0.253 | 0.384 |
| | (0.043)** | (0.053)** | (0.042)** | (0.049)** |
| Index of soil quality of the land of the kin community | 0.165 | 0.158 | 0.251 | 0.223 |
| | (0.051)** | (0.047)** | (0.064)** | (0.058)** |
| Interaction between wealth (in horses) and distance to a Russian settlement | -0.025 | | | -0.028 |
| | (0.009)** | | | (0.007)** |
| Interaction between degree of sedentarization and distance to a Russian settlement | | -0.443 | | -0.488 |
| | | (0.092)** | | (0.082)** |
| Interaction between index of soil quality and distance to a Russian settlement | | | -0.257 | -0.224 |
| | | | (0.091)** | (0.067)** |
| Constant | -1.795 | -2.513 | -1.909 | -2.895 |
| | (0.376)** | (0.402)** | (0.370)** | (0.390)** |
| Observations | 1387 | 1387 | 1387 | 1387 |
| R-squared | 0.39 | 0.37 | 0.35 | 0.42 |

Notes: Standars errors, clustered at kin community level, are reported in parentheses. * denotes significance at 5% level and ** at 1% level.