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From Saddles to Harrows: Adoption of Agriculture under the Russian Peasant Colonization in Kazakhstan

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1 Introduction

Nowadays as never before numerous nomadic tribes throughout the world are exposed to the pressure over their way of life, over natural resources they use. They are situated in different parts of the world but they share the same problems: loss of commune pastures, advancement of commercial agriculture, increase in urban migration, rising economic inequality and political marginality (Fratkin, 2005; Eneyew, 2012). It is the case of Massai in Tanzania who are constrained to resort to farming in order to protect their land from encroachment (Fratkin, 2005), Rendille in Keniya (Xiaogang, 2009), Qashqa'i in Iran (Beck, 1998), Fulani in Nigeria (Ekpo et al., 2008) and Afar in Ethiopia (Gebre-Mariam, 2006), Tibetan nomads in China (Ptackova, 2011) etc. The increasing dependence on national governments and colonial powers had destructing effect on the nomadic society during the twentieth century; often resulting in sedentarization – either "voluntary", under the pressure of constraints (Ekaya, 2005; Beck, 1998; Conroy, 2001) or involuntary, in response to state enforced measures (Roth, 2004; Blench, 2001; Eneyew, 2012).

Changes in ways of life of sedentarizing nomads inevitably implied changes in the production mode. Crisis of the nomadic mode of production made them search for alternatives and often they have found them in agriculture adoption. Nomads choose to adopt the agricultural techniques for different reasons. Under the influence of pull or push factors: either in order to diversify income sources (Conroy, 2001), or to secure their right for the use of pastures, or because of impossibility to follow their nomadic routes (Beck, 1998). Often there is a combination of several factors. Thus technological change becomes inevitable and fundamental to the development of nomadic societies. As a matter, the adoption of new technologies is considered to be an important feature of the development process (Foster and Rosenzweig, 2010, p. 35).

The crucial challenge of this study is to understand the mechanisms underlying the technology adoption within the nomadic societies and to describe spatial and non-spatial factors that affect it. One of its' contributions is the extension of geographical scope of the studies on technology adoption to Central Asian region. We study the case of Kazakhstan colonized by the Russian Empire. The unique dataset we exploit was constructed from the materials of Russian Imperial statistical expedition to Kustanay ujezd in 1896.

Using this dataset we analyse the influence of the massive in-migration of peasants on the decision to adopt the agriculture by the nomads and the role of socio-economic factors and environmental conditions in this process. The influence of settlers on the autochthones, their possible interactions and information exchange are described through the geographical proximity. Regional scientists (Mattes, 2012; Audretsch, 2000; Bathelt et al., 2004) point to the importance of the geographical proximity for the integration of knowledge[1]; and development economists conclude on the importance of social interactions and learning in the process of technology adoption (works by Conley and Udry, 2010; Bandiera and Rasul, 2006; Foster and Rosenzweig, 2010). Hence we assume that spatial proximity favoured the encounter between the nomads and the sedentaries, induced a learning process and the subsequent adoption of the new technology.

As a matter, the studies on the sedentarization of nomads and their passage to agriculture are purely narrative. The detailed descriptions contribute to the understanding of the processes but the hypotheses lack largely the empirical verification. The present study is designed to fill in the gap and to test quantitatively the factors that drive the technology adoption in the nomadic societies under the influence of massive in-migration on their territories.

Moreover, the studies of nomadic society and the studies of technology adoption have hardly ever crossed within a single study. To our knowledge, the present paper is a first attempt to approach the technology adoption within the changing nomadic society. There is an extensive literature on the technology adoption but all case studies analyse the technology adoption and diffusion within the sedentary societies (Conley and Udry, 2010; Bandiera and Rasul, 2006; Young, 2009; Ransom, 2003). Whilst the functioning of the nomadic society and has its' own functioning: perceptivity of new information, notion of distance, measure of well-being. The fact that the information spreads within a culturally heterogeneous society – from one culturally distinct group (sedentary Russians) to another (nomadic and semi-nomadic Kazakhs) – matters a lot.

The rest of the article is organized as follows. In Section 2, we describe the historical context. Section 3 describes the data and the estimates of the variables. Section 4 presents the empirical analysis. Section 5 interprets and discusses the results. Section 6 concludes.

2 Context

Before the Russian colonization, nomadic herding constituted the basis of Kazakh economy. The nomadic herding emerged in its' vast steppes as an adaptation to the marginal environment characterized by climatic uncertainty and poor vegetation. The essence of the Kazakh nomadic economy was a constant movement from winter to summer pastures and back in pursuit of pasturing grass for the numerous herds. The grass was abundant on the

[1] "The transfer of knowledge deeply relies upon proximity, as the assimilation of the exchanged knowledge is not possible at all without it" (Mattes, 2012).

north during the summer and accessible under the shallow snow cover on the south during the winter. This predefined the longitudinal character of migrations.

Customary law regulated the access to routes and pastures; they were assigned to kins and administered by the distinguished representatives of the communities. There were several categories of land use associated with stages of the nomadic round: winter pastures had closed access and were exploited by relatively small units – extended families (*auls*) comprising several households; during summer time the abundance of grass on pastures allowed for the reunification of the whole kin and thus the access was less strictly enforced.

At the end of the 19th 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 way of life of the Kazakh population causing considerable pressure on natural resources (Shakhmatov, 1964; Dakhschleiger, 1980). In about 20 years most of Kazakhs moved from being nomadic herders to becoming sedentarized farmers. Russian colonization of the steppe was one of the most large-scale migration processes on the continent of the epoch and developed in two waves. First was the Cossack military colonization in the second half of the XVIII century when military lines – chains of fortifications - advanced into the Kazakh steppes.

The passage of nomads towards the sedentary and semi-sedentary way of life was caused mainly by mass land withdrawal in favour of Cossacks, settlers, manufacturers etc (Masanov, 2001). Rapid, unauthorized (and, thus, unplanned) settlements on pastures previously used by nomads resulted in blockage of customary nomad routes between winter and summer pastures by the fields of peasants, thus decreasing the possibility for manoeuvres during harsh winters. The size of land allotments that was left in disposition of nomad auls was insufficient for extensive grazing (Taizhanova, 1995).

This often resulted in tragic consequence for nomads – the loss of herd. Without herds nomadism was impracticable and thus the nomadic auls were forced to sedentarize. This increased even more the pressure on land and led to the global crisis of nomadic economy.

Some auls still being nomadic began haying for winter fodder, constructing mud houses in their winter pastures. Further disintegration of nomadic economy gave birth to semi-nomadic way of life, when auls migrated literally around winter camps with length of migration routes not exceeding 5 km. With the adoption of the new, sedentary, life style a new mode of production was needed. The adoption of agriculture became inevitable.

The Kazakhs began to change their way of life under the influence of settled neighbours (Sedelnikov, 1907; Tikhonov, 1903; Scherbina, 1903). The further analysis is designed to verify empirically the influence of the massive in-migration of peasants on the decision to adopt the agriculture by the nomads.

3 Data

This section describes the data used to verify the hypotheses – statistical materials of Russian colonial expedition collected in 1897, a map of land use attached to the Materials, pedological and precipitations maps, and, finally, written historical sources; it defines as well the choice of the variables for the empirical model and their measures.

3.1 Database

This study benefits from a unique data set coming from the *materials of the first statistical survey of the steppe areas of Kazakhstan* (Scherbina, 1903) – "Materials on Kirghiz land use, collected and developed by the expedition for the analysis of Steppe regions" (further Materials). Statistical studies under the direction of a foremost Russian statistician F. Scherbina were organized by the decision of Russian tsarist government with the purpose to identify land reserves and to regulate the peasant migration flows. The fieldwork was carried out over a period of 6 years, from 1896 to 1903. As a result a 13-volume edition was published. It contained materials on the 12 sub-regions (ujezds[2]) covering the Northern and the Western areas of Kazakhstan.

Being historical the data have all the richness of the modern datasets. It is an extensive and very detailed agricultural census (i.e. virtually all of the extended families situated on the territory of these 12 *ujezds* were covered). Its' representativity approaches 100%. The dataset has three levels of aggregation: the information on the nuclear households is aggregated on the level of extended families (*auls*), on the level of communities[3] and on the level of groups of wealth.

The data used for this paper comes from the Kustanay *ujezd* in the Northern Kazakhstan, a region neighbouring with the Russian Empire in the North and reporting one of the highest levels of agriculture adoption in the Steppe area. In this *ujezd* the expedition succeeded to cover 2156 extended families (*auls*). In conditions of low population density in the steppe it meant almost complete census of Kazakh population. Thus, despite the fact that the sampling was based on purely subjective selection of households, the sample is considered as representative.

The data consists of the following main categories: 1) the historical and ethnographic information; 2) demographic information (size and gender composition of families); 3) socio-economic characteristics (number of heads of livestock per family, number of sowing families etc); 4) information on herding (size and structure of herds), 5) information on agriculture (arable crops, agricultural instruments); 6) data on land use; 7) topographic and geo-botanical data.

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[2] Second largest administrative unit in Kazakhstan at the end of XIX c. after *oblast*.

[3] Several kin-related extended families.

One of the most valuable aspects of the data is its' high spatial resolution. The availability of scheme maps (see Appendix A) attached to each volume of the Materials makes it possible to locate spatially each observation and hence to attribute to the observations the environmental characteristics[4] specific for their locations. Further this will allow including the agroecological variables into the empirical model. Despite their quiet average quality[5] these maps are the first and the only attempts to localize the Kazakh communities.

In terms of the quality of such data sources in general, McCloskey (1976) argues that, because these data served for applied (and not research) purposes, its' quality is at least as good as the data collected by researchers. The reliability of these specific data was explored and confirmed by the quantitative studies of Volkova[6] (1982, 1983), qualitative analysis of Makarov (1959) and Shakhmatov (1964). Despite the critiques by contemporaries (Sedelnikov (1907), Bukeykhan (1903)) the overall estimation of the statistical investigations of Scherbina's expedition is highly positive. The inspector of the expedition, A.A. Kaufman, commented on the high quality of questionnaire (Kaufman, 1897a).

Despite the confirmed reliability of the data, it should be noted that it was designed with a political motivation behind and, thus, the results are to be interpreted with caution.

The data was not specifically designed to analyse the adoption of agriculture. The caution is needed when exploring the Materials with the purpose to understand the adoption process. The cross-section micro-level data cannot answer some questions concerning the technology adoption because of the static nature of the statistical study and the dynamic nature of the adoption process (Doss, 2006). There is no possibility to observe the characteristics of adopters before and after the adoption. Here the endogeneity concern emerges. By the moment when the expedition took place the process of adoption was already underway, changing the characteristics of the adopting units; thus the characteristics at the time of adoption are unobservable.

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[4] The data on the environment comes the Atlas of the *Kustanay oblast*, *1963* (from maps "Agricultural lands valuation (rainfed agriculture, grain crops)" and "Amount of precipitations during the warm period"). These maps are half-century closer to the described events than the modern maps; this allows to minimize the discrepancy in climatological conditions

[5] Sedelnikov, Russian political activist and a deputy of the first State Duma, (1907, p. 79) notes that the maps attached to the volumes with tables need to be treated with caution as some respondents, especially sedentary Kazakhs, misreported by indicating the neighbouring summer stops as belonging to them. The map of the boundaries of land properties is constructed exclusively on the basis of verbal testimony without any fieldwork. This led to the withdrawal by the Russian administration of the "excess land" from those "large landowners" who misreported.

[6] Volkova compared the ten principal variables from the Materials of expedition and the similar variables coming from the administrative reports and explored the correlation between them. Her conclusion is that in general the Materials may be considered as a reliable source.

The causal relationships between the adoption and the characteristics of the adopting families are unclear. It is impossible to say whether the larger and wealthier families were more likely to adopt agriculture or the improved production technologies resulted in their increased wealth. In this case the regression analysis in itself may only provide the information about the correlation, not the causality.

That is why it is important to mention another data source – *historical documents of the epoch*. The present study has the chance to use the unique historical documents that have little been exploited before for the reason that they have never been translated from Russian. These original descriptive sources consist of ethnographic comments by the statisticians of expedition of Scherbina, official reports to the government, economic reviews, publications in geographic journals coming directly from the historical epoch under study and describing the traditional way of life of local nomadic population, the process of arrival of Russian and Ukrainian settlers, legal framework, land use and the process of transition from the nomadic way of life towards the sedentary. The documents contain rich statistical and descriptive data which makes possible to create a reconstructed overview of the historic events and way of living in the epoch but also to confirm or to reject certain assumptions on the causality.

The distinct data sources are *the maps* that allow for the inclusion into the model of the agroecological variables, determinants of agriculture adoption. There are two types of maps used for the purposes of this study: geographic information maps and the historical land use map. The former contain the data on soil productivity types and the precipitations during a warm period of the year; the latter allow for spatial location of the observations from the main database (on the community level).

The geographic information maps come from the “Atlas of the Kustanay oblast” published in 1963; this is a half-century closer to the studied historic period than contemporary maps and atlases. This temporal approaching to the described epoch renders possible to diminish the presumable error that may come from the long-term climate variations in the region.

The information on the soil productivity comes from the map “Agricultural lands valuation (rainfed agriculture, grain crops)” (Annex C). The map has a resolution 1:2 500 000 which is sufficient for our purposes – it provides enough spatial variability in types of soil productivity. The variability is observed even within the smallest unit – the communes. The valuation of lands is constructed using the data on the long-term average yield of grain crops (spring wheat and millet), with consideration of natural soil fertility and geographical conditions of the area (soil types, climate, topography, presence of lakes, forest cover etc.). The lands are united into six groups by their productivity in conditions of rainfed agriculture. Thus, the used of this map is additionally justified by the fact that the Russian settlers have brought into the Kazakh Steppe the rainfed agriculture techniques.

By definition, rainfed agricultural systems do not use the artificial irrigation and depend entirely on the precipitations to meet crop requirements. Thus it is of utmost importance to consider 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 (Annex D). Considering the low precision of isohyets this spatial resolution may be considered sufficient for the needs of this study.

The historical map is a map of Kazakh land use (Annex E). It contains information about the limits of summer and winter stops used by communities. This map makes part of the data recorded by the statistical expedition of Scherbina and thus is a part of the Materials. The communities mapped may also be identified in the main database. Each observation (aul) in the database belongs to a certain community and is identifiable within; the communities consist of 36 auls in average.

This possibility to identify the observation within the community gives the possibility to create the environmental variables and to introduce them into the model.

However, T. Sedelnikov (1907), a contemporary and a colleague of the statistician Scherbina, was criticizing the map attached to the Materials. He claimed about the absence of professional cartographers in the expedition and the low quality of the maps produced – the limits were determined only from verbal testimonies of Kazakhs. But for the purpose of this study the quality of maps may be considered as acceptable as far as for the purpose of analysis it is sufficient to identify the approximate location of communities.

The maps were digitalized and superimposed in order to produce the environmental variables identifiable within the main database (Annexes C and D).

3.2 Measures of the variables[7]

Not being designed to study the agriculture adoption, the database does not provide the exact measures of the phenomena of interest. Hence, most variables in this study are approximations, which is characteristic of social studies in general (Doss, 2006, p.13).

In this section the variables will be defined and the choice of the approximations for the variables, both dependent and independent, will be justified.

Defining an adopter

How an adopter is defined is a key element of the study. A number of factors and limitations determine the choice of the relevant variable; these are the nature of the data, the type of technology itself, the historical and environmental context of the adoption process and the research question.

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[7] Variables com from the data of the statistical expedition in Kustanay ujezd, Turgay oblast conducted in 1898, the level of aggregation is extended household level unlessspecified otherwise

The data discussed above is a cross-section. By definition it has a static nature and hence contains information on the families that presumably practice agriculture or not at a certain point of time when the survey was realized (year 1896).

Numerous studies measure the adoption with a dichotomous variables (e.g. Lee, 2011; Bandiera and Rasul, 2006). Such approach is appropriate when the new technology may not be partially implemented. Being interested in a gradual shift from herding to agricultural practice we *define the adoption as a continuous variable*.

The specificities of land use in the nomadic society and the historical context do not allow using a continuous measure, which is popular in adoption studies – "the proportion of land allocated to new technologies". The database contains the information on the sown plot size but the limitation in using this variable comes from the historical context.

Tresviatskiy (1917) noticed that the increase of the crop acreage reported by the Kazakh households did not always mean that the Kazakhs themselves handled the fields in question. He claimed that an important part of these fields was cultivated by the Russian peasants who have not been officially settled yet and thus had no legal access to agricultural lands. This observation is confirmed in the report of the official of the Russian colonial administration T.I. Tikhonov (1903) who acknowledged that a plot size had no particular relationship with the percentage of households engaged in agriculture.

The law forbidding any kind of rent in Kazakh steppe was at the core of this misreporting. In order to hide the actual rent[8] the nomads declared the cultivated plots as their own. I.F. Markov, the soviet historian, expressed doubt as to whether the expedition was able to record properly the size of the sown plots. He suggested that the Kazakhs were overstating the acreage to secure their property on land or to hide the fact of rent agreements with settlers (Makarov, 1959, p. 398). Thus, defining the adoption with the variable describing the size of the plots cultivated by the Kazakhs is inappropriate.

The alternative measure of adoption may be constructed using the information on the agricultural implements in possession of the Kazakh auls. The hypothesis is that the agricultural tools owned by the Kazakhs define more accurately the transition to the agriculture – they were more easily observable by the census takers than the plot size. Finally, the contemporaries testify that the supply of the instruments in the Steppe was sufficient[9] and has been meeting the demand.

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[8] The illegal land rent was very common in the studied Kustanay ujezd (Kaufman, 1897b; Settlers administration, 1905; Dmitriev, 1903).

[9] Vnukov (IPOTUR, 1910) states, "the development of agriculture in the steppe provoked wide spreading of new agricultural tools". Moreover, in the end of XIX century these tools became easily available for Kazakhs (Argynbaev, 2007, p. 72)

There are two kinds of agricultural instruments documented in the Materials: ploughs and harrows. The choice between them is not that obvious, as it seems on the first sight, and should also be based on a thorough analysis of the production technology, environmental and historical setting.

The Steppes of the Northern Kazakhstan at the moment of their colonization were the vast spaces of virgin lands that have hardly ever been tilled. Once broken and involved in the arable farming they provided rich harvests but the special equipment was needed to break them: heavy ploughs pulled by four pairs of oxen (Kaufman, 1897b; Dmitriev, 1903, p. 132). The high cost of such ploughs often excluded the poor from the access to rich virgin lands.

Several solutions were available for those who wished to engage in agriculture but could not bear the cost of heavy implements and draught animals. First, they could share the cost of rent of the implements by arranging the cooperative agreements[10]. Second, they could occupy the land previously broken and abandoned by the settlers after 4 to 6 years of cultivation once the soil was exhausted (Makarov, 1959, p. 401). Third, the cooperation was also possible between the Kazakhs and the settlers – the first provided the drought power, the last contributed with the heavy ploughs. And finally, there was a specific form of metayage[11] -- the settlers paid the land rent by ceding the third part of the ploughed virgin lands to the Kazakhs (Kaufman, 1897b, p. 153; Tikhonov, 1903, p.64). The rent of the ploughs was economically justified as far as they were used mostly for breaking the virgin soils once in several years.

Thus the number of ploughs in possession of the auls is not an appropriate measure of agriculture adoption as far as the adopting Kazakh families were rarely the owners of the ploughs. Numerous actual adopters risk not to be considered in the analysis if they are defined as plough owners.

Further, after the tillage, the Kazakhs had to harrow the land on their own, without any further assistance from the settlers (Tikhonov, 1903, c. 68). Thus, presumably, the variable, which describes the number of harrows per aul, defines better the agriculture adoption. Being more affordable and light the harrows were actually owned by those who cultivated.

Abundant fertile lands in the Northern Kazakhstan and a low population density preconditioned the practice of extensive shifting agriculture both by the settlers but also by the Kazakhs that learned from them. In search of higher yields the parcels were changed every several years, after the soil exhaustion. On every new place the ploughs were needed to break the new ground. But further, between the shifts, the harrows were widely used as the

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[10] e.g. II administrative aul of Dzhetygarinskaya volost (Dmitriev, 1903, p. 130).

[11] By the year 1896 this form of rent became even more popular because the settlers have already recovered from the migration, set up and enlarged their economies, acquired the livestock and hence could afford the rent on more advantageous conditions (Kaufman, 1897b).

instruments of tillage[12] (Dmitriev, 1903, p. 134) and provided a relative independence for those who adopted the agriculture recently.

Thus, the adopter may be defined as the one who owns harrows. The degree of adoption is measured by *the average number of harrows per household within the extended family (aul)*. This definition does not exclude poor Kazakh families that practiced subsistence agriculture and is considered as the most appropriate approximation defining the agriculture adoption within the limits of this study.

The average number of harrows per household within the extended family (aul) is created by dividing the number of harrows per extended family (aul) by the number of households within aul. This eliminates the effect of the size of the aul. Annex A presents the descriptive statistics of the variable. Standard deviation is high which indicates that data is spread out over a large range of values. It implies that average number of harrows per household vary considerably among the Kazakh auls and evidences about the heterogeneity in the milieu of adopters.

Only 13% of auls do not possess harrows at all. The half of all auls in the Kustanay ujezd possess between 0 and 1 harrow in average per household and 37% of auls report at least one harrow per household. Probably, this evidences that the adoption process is in its' final stage and the variable describes the degree of specialization in agriculture, the gradual shift from herding to agriculture. Thus, at the end of XIX – beginning of XX cc. when the data was collected, the question was not anymore to adopt or not but to what extent specialize (how many harrows do we need if we practice agriculture regularly and the cultivated area is growing). This confirms the choice of the continuous dependent variable rather than dichotomous.

Determinants of adoption

After Foster and Rosenzweig (2010, p.3) the principal determinants of technology adoption are schooling, wealth and neighbours-adopters. In this study some specific factors are added regarding the cultural setting, environmental conditions and characteristics of technology itself.

Communication and learning. The crucial variable for this study is the one that describes the accessibility of information. It is assumed that a potential adopter should first get access to information about the new technology (here, rainfed farming) before adopting it.

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[12] "Within the several years the agriculture does not labour the soil with a plough and, thus, gets along without the exterior help" (Dmitriev, 1903, p. 132). This phenomenon concerns particularly the Kustanay ujezd; it is reported that nearly all harrows in this ujezd were with iron teeth (Dakhshleiger, 1959, p. 224), hence solid enough to labour the soil.

The only factor that both describes the information links and is available in the database is the geographical proximity. The main hypothesis test will mainly rely on this variable, which describes the proximity between Kazakh *auls* and Russian settlements. Intuitively, being in proximity increases the likelihood of communication and the information transmission.

Foster and Rosenzweig (2010, p.3) claim that the prior adoption by neighbours is supposed to influence the accessibility of information. They propose "the number of adopters in the village" as a measure of prior adoption.

But in context of vast spaces of Central Asia the notions of distance and neighbourhood have certain specificities that ought to be described first in order to justify the variable choice. Within the nomad areal characterised by the dispersed settlement it is common to consider the habitations at a distance of a day journey as neighbouring ones. The structure of a settlement itself is different within the nomadic society – it consists mainly of the relatives and is characterised by the commonality of the socio-economic life of its' members. The proximate neighbours share the same production mode and may hardly be the source of information about the new technology. Thus, "the number of adopters in the village" proposed as a measure of prior adoption by Foster and Rosenzweig (2010) would not be appropriate within the studied social and cultural environment.

Historical conditions allow hypothesizing that the Russian and the Ukrainian settlements were the loci of the arable farming in the Kazakh Steppe. Hence, the adoption of agriculture by the nomads was probably inhibited by the presence of newly acquired neighbours – Russian peasants who were successfully practicing the rainfed 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).

The extent of prior adoption (alternatively, the information accessibility) would rather be measured by the distance towards the closest peasant settlement. The corresponding variable in the dataset is "a distance in versts (=1.0668 km) to the closest sedentary settlement".

Data reporting the distance from the Kazakh auls to the Russian settlements may highly depend on the subjective perception of respondents because the distances were not measured but estimated by the respondents. Firstly, the Kazakhs were not used to measure the distance in units like kilometres or versts[13] and hence their estimations of distance tend to be somewhat biased and attracted by round numbers. Secondly, the definition of the settlement

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[13] "Traditionally, the distance is measured by the time, or rather by the time of travel" (Dmitriev, 1903, p. 14)

itself is not explicit in the questionnaire (hence, there is a risk that some would consider the central town, others – peasant settlements in the steppe). It produces the outliers in the data; this may explain the fact that the standard deviation is larger than the mean value of the variable (see Annex A). Nevertheless, 62% of observations are situated at a distance of a day journey (30 km from the settlement) and may definitely be considered as neighbouring.

This study has a specificity to explore the information transmission between the representatives of different peoples and different cultures (sedentary versus nomadic, European versus Asian), hence considering the spatial proximity alone is not enough to conclude on the possibility of social interactions. In view of this the cultural proximity ought to be considered. Within the cultural proximity it is the language barriers that should be discussed first.

In the absence of corresponding variables that would report on the Russian language proficiency within the Kazakh nomads we would refer to the historical documents of the epoch. Sometimes there are direct indications of Russian language acquisition by the nomads (Bukeykhan, 1995 (1910), p. 70; also Orazbekov, 1977, p.139), but mostly indirect, witnessing about the real interactions between the settlers and the nomads[14].

"Experienced people, they said, 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 – sometimes the Cossacks, but mostly the peasants".

Tikhonov (1903, p. 69)

"The role of Russian settlers consisted in instructing the Kazakhs how to labour the soil, to handle the agricultural instruments, and to do agricultural work in general".

Studeneckiy (1929, p. 93)

Nevertheless, the critique made by Conley and Udry (2008) is relevant for this study: by relating observable geographic proximity to an unobserved flow of information we cannot distinguish learning from any other phenomena with similar outcome. One example that may be traced in historical literature and is regularly mentioned in written sources of the epoch is the proximity to markets. It should be considered that the proximity to peasant settlements might implicitly include the information on the proximity to the markets. Russian functionary Tikhonov (1903, p. 64) notes in his report that every Russian settlement represents an economic center in the Steppe and opens access to the market to the residents of the Steppe. Markets could contribute to the adoption by increasing the monetary benefits from the

[14] But also see (Makarov, 1959, p. 434; Sedelnikov, 1907; Dakhshleiger, 1980, p. 167).

cultivation and making agricultural instruments available (Sedelnikov, 1907, p. 24; Dakhshleiger, 1980, p. 202). It should be considered while interpreting the results.

Another critique towards using a geographical proximity factor as a driver of information exchange was made by Conley and Udry (2008). They warn that spatial proximity data may hide unobservable spatially correlated shocks that ought to be distinguished from the information impact. However, the distinction is possible if the long distance information links appear in the database, which is the case for this study (see Annex B).

Measure of sedentism. One of the factors closely related to the process of agriculture adoption by the Kazakh auls was a degree of their sedentarization. It is important to understand the nature of this relation before including this factor into the model. The causality problem emerges: whether the passage of the Kazakhs towards sedentary way of life favoured the agriculture adoption or, vice a verse, the desire to practice agriculture motivated the sedentarization.

We find in the descriptive sources that most Kazakh nomads were driven by necessity to engage in land cultivation (Taizhanova, 1995). Mass withdrawals of pastures during the colonisation were at the origins of loss of herds during the harsh winters. This caused the passage of the Kazakh auls towards the semi-nomadic way of life (Masanov, 2001). Moreover, the economic reports of the epoch (N., 1898, p. 14), and the later studies on agriculture adoption (Makarov, 1959, p. 422) claim that the land cultivation did not prevent the Kazakh households from nomadizing. Reverse causality is excluded.

The proxy variable for the sedentarization level is “a number of days during which the water sources near the winter camps are used”: if the water source is used 365 days per year it means that aul is staying the whole year in the same place and may be considered as completely sedentarized; if less than 90 days (a season) – the aul is nomadic. Thus the variable describes the degree of sedentarization what is adequate in the conditions of gradual transition of nomads towards the settled way of life.

Only 0,5% of the auls still remain purely nomadic, i.e. they use the water source during less than one season per year. Most of the households (81,4%) spend between two and three seasons in the same place. And a considerable 10,5% is completely sedentary. Thus, the sedentarization process is in full expansion in the ujezd.

The Northern regions of Kazakhstan (Kustanay ujezd included) do not suffer from water scarcity common for the Southern Kazakhstan. The data confirms that the water sources mentioned in the Materials are available in average 357 days from 365. Thus the water unavailability is not susceptible to introduce a bias in the estimation of sedentarization level.

Wealth measures. It is assumed that prosperity level of a production unit affects its' decision to adopt a new technology. Well-to-do economies resist better to shocks and are more able to assume risk.

The analysis of the descriptive sources leads to a conclusion that the number of horses is the most appropriate measure of wealth for the Kazakh Steppe in general and in Kustanay ujezd in particular. Most of the documents of the epoch describe the economic capacity of Kazakh auls by a number of horses belonging to them. These are the reports of the resettlement administration (Dakhschleiger, 1980, p.102), economic reviews (Studeneckiy, 1929, p.102), comments to statistical materials (Dmitriev, 1903, p.91) etc.

This measure of wealth is particularly appropriate for the Kustanay region[15]. Being situated in the North it benefited from the environmental conditions favourable for the horse breeding, but also from the proximity to the Russian markets. Horses became the main assets being exported from the Kazakh auls to the market. Studeneckiy (1929, p. 102) demonstrates that the horse herd farming had a clearly commercial nature in the region. Due to this the increase in well-being of a Kazakh aul resulted in the increased proportion of horses in the herd structure (Dmitriev, 1903, p.91).

Thus the variable "number of adult horses in possession of an aul" available in the database will describe the measure of wealth. As well as the dependent variable it is averaged by the number of households within aul. Standard deviation is higher than the average; this indicates that data is spread out over a large range of values, i.e. the number of horses per household vary considerably among the Kazakh auls. This probably confirms the hypothesis about the economic stratification in the Kazakh society at the end of XIX – beginning of XX cc.

There is a danger that this measure may implicitly contain information about other factors related to the agriculture adoption (Doss, 2006, p. 21). Auls with more horses may be wealthier and more susceptible to adopt agriculture. But simultaneously, the larger are the herds, the more frequently they need to change the pastures. This implies the nomadic way of life and is susceptible to complicate the agriculture adoption. Surprisingly, numerous historic documents evidence about the positive correlation between a number of horses and a sown plot size (Makarov, 1959, p. 416). Studeneckij (1929, p. 87-89; Togzhanov, 1934) noted that the agricultural development in Northern Kazakhstan began with the well-to-do auls as far as only large and wealthy economies had enough resources (draught power and instruments) for breaking-up the ground that has never been tilled previously.

Another danger comes from the causality problem, which emerges when we try to study the dynamic process of agriculture adoption using the static data registered at a certain point in time. Concerning the wealth measure it may be the case that those auls who have

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[15] In average in Kazakhstan horses constituted 13,5% in the structure of a herd; in Kustanay ujezd this percentage run up to 26,6% (Dakhscleiger, 1980, p.94).

adopted agriculture become better off and increase number of heads in their horses herds in order to diversify their assets. Thus agriculture has also an impact on size and structure of herds. After Makarov (1959, p. 420) the successful practice of agriculture didn't diminish the herds' size; on the contrary it stimulated the development of herding and induced the increase of the proportion of horses in the structure of herds.

Nevertheless, taking into account that the initial capital was needed to get into agriculture we assume that those auls that reported larger herds at the moment of survey had larger herds at the moment of adoption decision.

Another variable that may be a good indicator of wealth because of its' non-agricultural nature is "number of yurts in possession of an aul". The wealthier was the household, the more yurts it owned. Despite the prevalence of mud houses among the sedentarizing Kazakh population the yurt was still more preferable as a summer dwelling by those households who could afford it (Tikhonov, 1903). The common reason for that is a poor quality of mud houses because of the absence of traditional knowledge on house construction and the unavailability of materials other then mud.

Agroecological factors. Well-marked differences in growing conditions within the Kustanay ujezd had a substantial effect on the extent of the agriculture adoption (Dakhschleiger, 1980, p.191). Ignoring these factors in the model may induce the omitted variable bias and lead to erroneous conclusions.

We assume that the characteristics of the environmental conditions, and precisely of the soil quality, were observable by the Kazakhs. Otherwise stated, it is supposed that the Kazakh were aware of the soil productivity in their region when taking the decision to adopt. Kaufman (1897b, p 150) wrote that "the land is valued for its' fertility", that the Kazakhs became well aware of the potential productivity of virgin lands. The Kazakhs have also learned the types of grass characterizing the soils suitable for agriculture. This shows that the autochthones, as well as settlers, were able to distinguish approximately the quality of the soils.

The variables were produced with the help of the maps described above. The maps with the soil and rainfall characteristics were superimposed with the maps of communities. The percentage of the territory of commune affected by an environmental characteristic was calculated and the coefficient is attributed for each aul within the commune. For each environmental characteristic (e.g. a soil productivity group or a zone with a certain amount of precipitations) there was a column with these coefficients.

The environmental variables – index of soil productivity or warm period precipitations index – were a product of the proportions of the territory of the commune occupied by a certain type of soil (soil quality index) or situated within a zone with a certain amount of precipitations (rainfall index) and the simple weighs, which take higher values when attributed to the groups with higher soil productivity or higher amount of precipitations (in conditions of arid climate).

$$\text{Soil quality index}_c = (6 * \frac{S_{soil1}}{S_c}) + (5 * \frac{S_{soil2}}{S_c}) + (4 * \frac{S_{soil3}}{S_c}) + (3 * \frac{S_{soil4}}{S_c}) + (2 * \frac{S_{soil5}}{S_c}) + (1 * \frac{S_{soil6}}{S_c}), \quad (3.1)$$

where c stands for "commune", S for surface, and the agricultural productivity of soil decreases from soil1 to soil6. The higher is the index, the bigger is the surface of the commune covered with a good quality soil.

$$\text{Rainfall index}_c = (4 * \frac{S_{250-275}}{S_c}) + (3 * \frac{S_{225-250}}{S_c}) + (2 * \frac{S_{200-225}}{S_c}) + (1 * \frac{S_{175-200}}{S_c}), \quad (3.2)$$

The higher its' absolute value the bigger is the part of the commune that is situated in the zone with more abundant precipitations (precipitations are indicated in mm).

However, by assigning linearly changing weighs we introduce a heavy assumption that the effect of soil productivity/amount of precipitations is changing linearly from category to category, i.e. the difference in soil productivity between group 1 and group 2 is assumed to be the same as between group 2 and group 3 etc., which is probably not the case. In order to consider a non-linear increase in soil productivity the indices with the squared weighs are to be introduced into the model.

4 Methodology

While estimating the effect of peasant colonization on the autochthone nomadic society we want to see whether the information exchange with the Russian peasants had a significant impact on the agriculture adoption by the Kazakh nomads. It is assumed that when the nomads decide to switch to the land cultivation, their decision may be driven by socio-economic and environmental factors, but also by the accessibility of the information on the agricultural technology.

The conceptual model is specified using the following linear relationship:

$$Adopt = \beta_0 + \beta_1 * InfoAcces + \beta_2 * Sedent + \beta_3 * Wealth + \beta_4 * Envt + \epsilon, \quad (4.1)$$

In practice the adoption is not observable and in the model it is measured by a continuous variable describing the average quantity of harrows per household within an aul i. The information accessibility is estimated by a spatial proximity of an aul i to the closest sedentary/Russian settlement (in versts, 1 verst = 1.0668 km). The wealth of an aul i is estimated by an average number of horses per household within this aul and by the average number of yurts in its' possession. Finally, the environment is described by soil quality and amount of precipitations indices attributed to a community to which an aul i belongs.

Multiple regression analysis is used to estimate the factors affecting the dependent variable. In its' basic framework the regression is the following[16]:

$$Harrows_{ic} = \beta_0 + \beta_1 * Distance_{ic} + \beta_2 * WaterUse_{ic} + \beta_3 * Horses_{ic} + \beta_4 * Yurt_{ic}, \quad (4.2)$$

Therefore, spatial proximity variable (Distance), which is designed to describe the social learning effect, may hide unobservable spatially correlated factors (Conley and Udry, 2008), e.g. growing conditions, proximity to output markets etc.

The closer is the Kazakh aul to the Russian sedentary settlement the higher is the probability that they share the same environmental characteristics (environmental neighbourhood): soil types, topographical features, rainfall amount etc. As a matter the colons founded their settlements in regions with conditions favouring the cultivation. Obviously, the same factors could be in the basis of the decision to adopt. Thus, there are some relevant explanatory variables, which are omitted from the model in its' basic version, in other words we face a possibility of endogeneity.

Hence it is meaningful to disentangle the effects of social learning from the sensibility to growing conditions. The data offers possibility to introduce the instrumental variables describing the growing conditions: indices of soil productivity and warm period precipitations.

$$Harrows_{ic} = \beta_0 + \beta_1 * Distance_{ic} + \beta_2 * WaterUse_{ic} + \beta_3 * Horses_{ic} + \beta_4 * Yurt_{ic} + \beta_5 * SoilQuality_c + \beta_6 * Rainfall_c, \quad (4.3)$$

Given the clustered nature of data, with the environmental variables aggregated on the communes level whereas the other variables are aggregated on the level of auls, the assumption of independence of the residuals is violated; this may lead to the overstatement of the statistical significance of the coefficients. In order to counter this problem and to take into account the clustered nature of data we use a cluster option for OLS regression; thus the standard errors take into account that the observations within the communes are correlated.

The higher is the number of clusters the more the cluster-robust standard error estimator converges to the true standard error (Wooldridge, 2003). It is also preferable if the cluster sizes are roughly equal. Kezdi (2004) claims that for accurate inference 50 clusters are enough, whereas the environmental data included into the model is grouped into 251 clusters/communes.

The variable describing the proximity to markets is available in the database and will be included in the final model, though because of its' too close association with the "Distance

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[16] Where i identifies an observation at aul level, c identifies an observation at a commune level; commune consists of several auls.

to the closest settlement" variable[17] we anticipate a multicollinearity problem. Probably, in the majority of cases a market place and a settlement are one and the same.

As a matter, there is no real possibility to include the instrumental variables for all the unobserved characteristics that influence the agriculture adoption. E.g. we cannot evaluate the Russian language skills of the Kazakh nomads so to conclude on the actual possibility of the information exchange between these two ethnic groups. We may observe neither the quantity, nor the quality of encounters between the colons and the autochthones. In this framework, the distance to the closest settlement is imperfect approximation to describe the whole extent of social learning process. But still we believe that the existing instrumental variables diminish the endogeneity risk.

5 Results

This section presents the results of OLS estimation for the baseline model and its' several modifications (Annex G). An unspecified simple regression model with the only explicative variable – distance to the sedentary settlement – is given in Annex F. The results report a significant effect of spatial proximity of Kazakh auls to Russian settlements on the agriculture adoption. The negative sign of the coefficient evidences about the decrease of number of harrows per household while the aul gets further from the settlement. The coefficient on the distance variable indicates that the auls situated 100 versts (106,68 km) further from the sedentary settlements will possess in average per household 0,8 harrows less; the result is statistically significant at 1%. That is a strong effect, taking into account that the average number of harrows within aul is 1.

Obviously, this specification of the model can only evidence about the correlation between the dependent and independent variables; the control variables must be included in order to minimize the effect of different factors on the result. Four main specifications of the model are presented in Annex G. All the specifications contain socio-economic characteristics, the environmental factors are added in the second specification and, finally, the third comprises the distance to market variable.

First, the socio-economic variables are controlled for (Annex G, Model 1): *"the number of days per year when the water source near the winter camp is used"* (approximation for the level of sedentarization of an aul), *"the average number of horses per household within aul"* and the *"average number of yurts per household within aul"* (approximations for wealth). Expectedly, including these controls decreases both the magnitude and the significance of the effect of distance variable on the adoption. The the fact that the aul is situated 1 verst further from the settlement is associated with decrease of average number of

[17] The descriptive sources confirm that "every Russian settlement in the Steppe represented an economic center" (Tikhonov, 1903, p. 64).

harrows in possession on 0,006, ceteris paribus. In other words, theoretically between two auls, which are characterized by the same income and the sedentarization level, the one 100 versts closer to the Russian settlement will have in average 0,6 harrows per household more, which is not negligeable.

The level of sedentarization and the wealth of an aul do affect the agriculture adoption as well. The coefficients report positive influence on the dependent variable and are significantly different from zero, ceteris paribus. Indeed, it makes sense that more sedentarized auls or wealthier auls adopt better the agricultural technologies. Holding other factors fixed, additional month spent on the winter camp is associated with 0,28 increase of the average number of harrows per household, additional season spent on the winter camp is associated with 0,83 increase in harrows per household. Every ten additional horses in the herd[18] increase the average number of harrows by 0,22, assuming that all other variables in the model held constant. Every additional yurt per household is associated with an increase in number of harrows by 0,38.

The variable "distance to the closest settlement" is designed to fix the social learning effect. But it may also comprise the unobservable spatially correlated factors, e.g. agro-ecological characteristics of regions or proximity to market. Models 2 and 3 (Annex G) additionally control for environmental determinants of adoption – growing conditions that are described by the soil productivity index and precipitations during the warm period index; Model 4 additionally controls for "distance to the closest market" in order to disentangle the both effects.

Curiously, the index of soil productivity reports the coefficients, which are not significantly different from zero, whereas the effect of precipitations index is positive and significant at 1%. As discussed previously, with the linearly changing weighs in the soil productivity index we introduce a heavy assumption that the change of productivity from category of soil to another is the same. To capture possible nonlinear evolution of productivity we introduce into the regression the environmental variables with squared weighs (Model (3)). Indeed, both variables become statistically significant, their standard errors decrease and the adjusted R^2 of the model slightly increases. This may evidence about the fact that the squared weighs describe better the change of productivity from one category to another within the environmental indices.

The effect of the distance to the closest market place on the agriculture adoption is not easily interpretable as far as the cubic transformation was necessary in order to capture the nonlinear relationship. Curiously, the effect of the distance to marketplace is positive and significant – the closer the winter camp of an aul is to market the less there are harrows per household. The possible explanation is that, mostly, the agriculture was adopted for subsistence purposes and thus the proximity to output market was not a driver of adoption.

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[18] Average number of horses per household within aul.

Moreover, we may conclude that the results are stable and not driven by the extreme values (Annex H). When the dependent variable is restricted to three harrows per household within aul, and even when it is restricted to two harrows in average per aul, the coefficients of all explanatory variables keep their signs and remain significantly different from zero. This evidences about the robustness of the results. The only exception is the coefficients for the "distance to marketplace" variable, which loose their significance once the database is restricted. Probably, this confirms the hypothesis formulated above that the distance to markets is not an influential factor for the agriculture adoption.

R squared is an estimate of how much variation in dependent variable is explained by the independent variables. Thus, it is a measure of the overall fit of the model. For this model the *R* squared is equal to 0,413, i.e. 41,3% of the variability of the average number of harrows per Kazakh household is accounted for by the variables in the model.

Overall, the results demonstrate that there is an effect of *spatial proximity of Kazakh auls to the Russian settlement on the agriculture adoption that remains significant after controlling for environmental factors and proximity to markets.*

6 Discussion and conclusion

This paper studied the influence of the massive in-migration of peasants on the adoption of agriculture by the nomadic population, the role of socio-economic factors and environmental conditions in this process basing on the historical data from the Northern Kazakhstan, end of XIX – early XX cc. The influence of settlers on the autochthones, their possible interactions and information exchange were described through the geographical proximity. The main finding is that the proximity to the settlements favours the agriculture adoption by the nomadic auls.

Obviously, shorter distances facilitate interactions and, thus, the proximity is susceptible to describe the access to information. Indeed, Fritsch and Franke (2004) claim that geographic proximity plays a major role in the knowledge transmission. This is confirmed by the observations of Tikhonov (1903), in his report he assumes that the Kazakhs adopted the agricultural techniques from Russian peasants by knowledge transmission: observing, hiring settlers for agricultural work etc. Kaufman (1897) states as well that the role of settlers was to teach the Kazakhs to cultivate the land, to use agricultural implements and to do the agricultural work.

The geographic proximity has often been used as a catch-all phrase (Mattes, 2012), it may also hide other spatially correlated shocks that ought to be distinguished from the information impact, e.g. environmental conditions, proximity to markets, regional institutional heterogeneity etc.

As a matter, the studies of technology adoption ignore this aspect and give little or no information about the environmental factors (Doss, 2006, p. 4). This causes the omitted variable bias and leads to the flawed conclusions. One of the key points of the study is that we account for common environmental shocks by controlling for agro-ecological factors – we include into the model the soil productivity and warm period precipitations indices. The results of the regression show that even within the environment equally favourable for practicing agriculture those Kazakh economies that are closer to the Russian settlements choose to specialize in agriculture.

It should be mentioned here that the cultural paradigm of the Kazakh nomadic society was one of the factors that promoted the rapid agriculture adoption. Nomadic openness towards the outer world and perceptiveness towards the new information (Sedelnikov, 1907), which are proper for the nomadic societies in general, facilitated the encounter between the Kazakhs and Russian settlers, in its' turn this encounter made the information on agricultural techniques accessible for the nomads. Indeed, in the study of Dubois (1972) one of the central conclusions is the one that predicts high rate of adoption when the social values of the system favour novelty and change.

The hypothesis that the Russian cultural (technological) influence was more pronounced within the sedentarized auls is confirmed by the results of regression analysis. The result is intuitive. Despite the evidences that the nomadic way of life did not prevent the Kazakhs from cultivating the land, sedentary and semi-sedentary auls reported higher levels of specialization in agriculture. The agriculture is by definition a sedentary mode of production.

It is not surprising that wealthier auls report the higher level of adoption and specialization in agriculture. The rapid commercialization of wheat cultivation was not the only reason for such result. Among possible explanations Foster and Rosenzweig (2010) mention the effect of scale associated with learning; Doss (2006) points at the increased capacity of wealthier units to deal with the risk; Studeneckiy (1929) associates this correlation with the market driven motivation of the adopters. The case-specific reason is that the wealth and the social weight are highly correlated and thus wealthy nomads have better access to resources in general and to the community's pastures in particular.

The major shortcoming of this study is the static nature of the data. There is some dynamic structure to the technology adoption decision (Besley and Case, 1993) and the cross-sectional micro-level data is a snapshot at a point of time. In our case this point of time is situated before the completion of the adoption process. Thus the coefficients should be interpreted with caution. The causality problem imposes. Without additional extensive analysis of descriptive sources it is impossible to understand what comes the first – wealth or agriculture adoption, sedentarization or agriculture adoption etc. There is a possibility to extend the present database with a repeated statistical survey that took place five years later. Panel data would allow to observe changes in terms of the extent of agriculture adoption but also to control for heterogeneity across the observations (Doss, 2006).

Ultimately, we hope to be able to complete the model with the data on social networks –the appurtenance to the kin groups. Kins constituted the core structure of the nomadic society and we suppose that the information flow and the knowledge exchange were facilitated within kins. The diffusion of information within the social network may be another unobserved factor that has influenced the agriculture adoption and hence, is to be included into the model.

The present paper contributes to the literature on technology adoption by adding the case of agriculture adoption within the nomadic society and to the nomadic studies by introducing a quantitative analysis of the technology adoption process.

While there will be the nomadic pastoral tribes on earth, there will always exist a dilemma of the optimal interaction between the sedentary and the nomadic civilizations. Nowadays this dilemma risks to be aggravated by the growth of population on the planet, the need to expand the cultivated area, possibly, in expense of the lands of nomadic tribes. This will lead to the sedentarization of the nomads and changes in the production mode. But at the moment the quantitave studies are sorely lacking in this field. The case of the colonization of Kazakh steppes by the Russian Empire, explored in this paper, is one of the earliest well documented processes of expansion of sedentary agricultural civilization on the lands of nomads. The observations and the conclusions made in the present historic study may lay a foundation to a better comprehension of consequences of the currently unravelling agricultural expansion on the nomadic territories.

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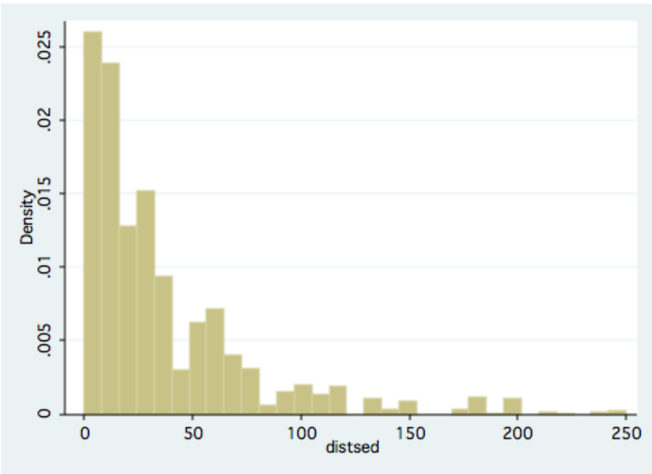
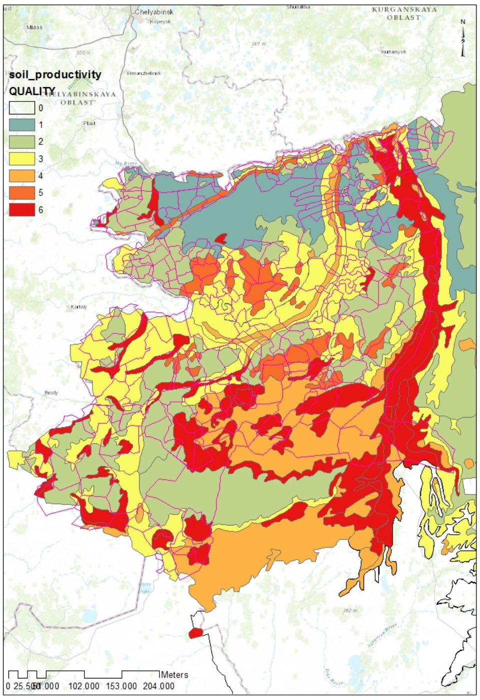
Annex A – Descriptive statistics

Variable	Definition	Observations	Mean	Standard deviation	Min	Max
HARROWS	Average number of harrows per household, within the extended family	**1498**	**0,99**	**1,27**	**0**	**11**
DISTSED	Distance to the closest sedentary settlement	**1402**	**37,12**	**41,04**	**0**	**250**
HORSES	Average number of horses (in adult equivalent) per household, within the extended family	**1498**	**15,59**	**21,41**	**0,29**	**321,5**
WATERUSE	How many days per year is the source of the water used?	**1497**	**215,93**	**40,29**	**0**	**365**
YURTA	Average number of yurtas per household, within the extended family	**1497**	**1,20**	**0,53**	**0**	**14**

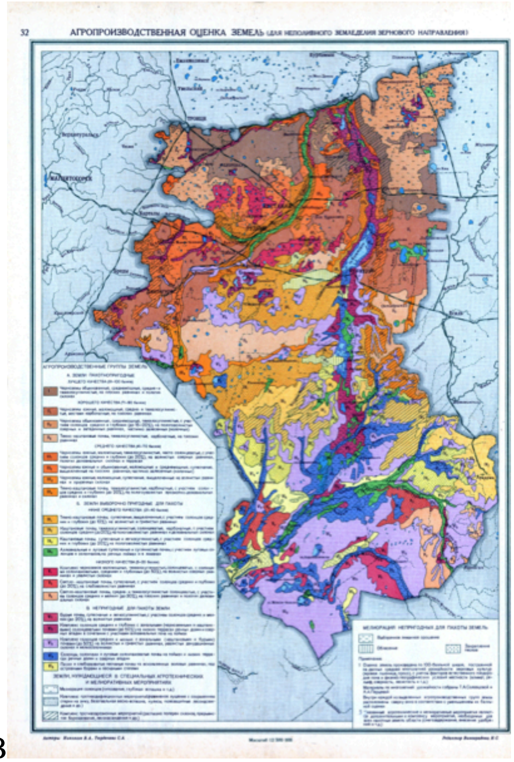
Annex B – Histogram of the distribution of variable "distance to the closest sedentary settlement"



Annex C – Map of the soil quality groups (A – digitalized, B- original)

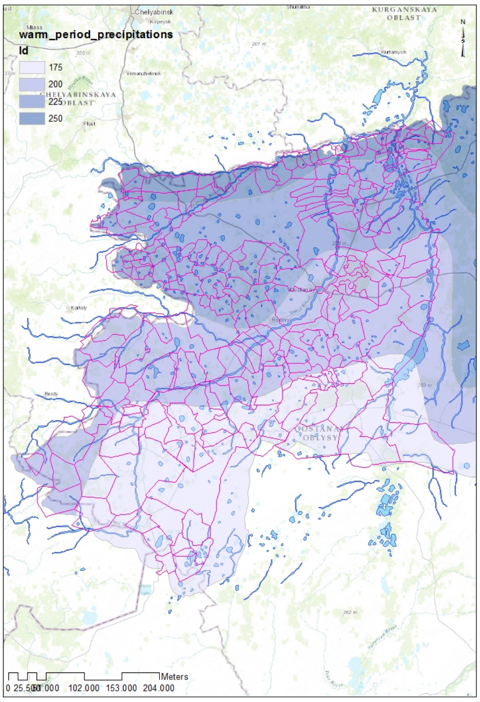


A

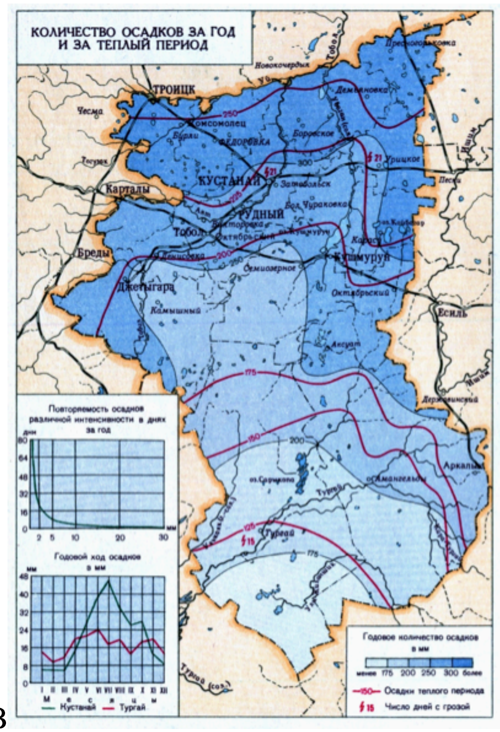


B

Annex D – Warm period precipitations (A-digitalized, B- original)

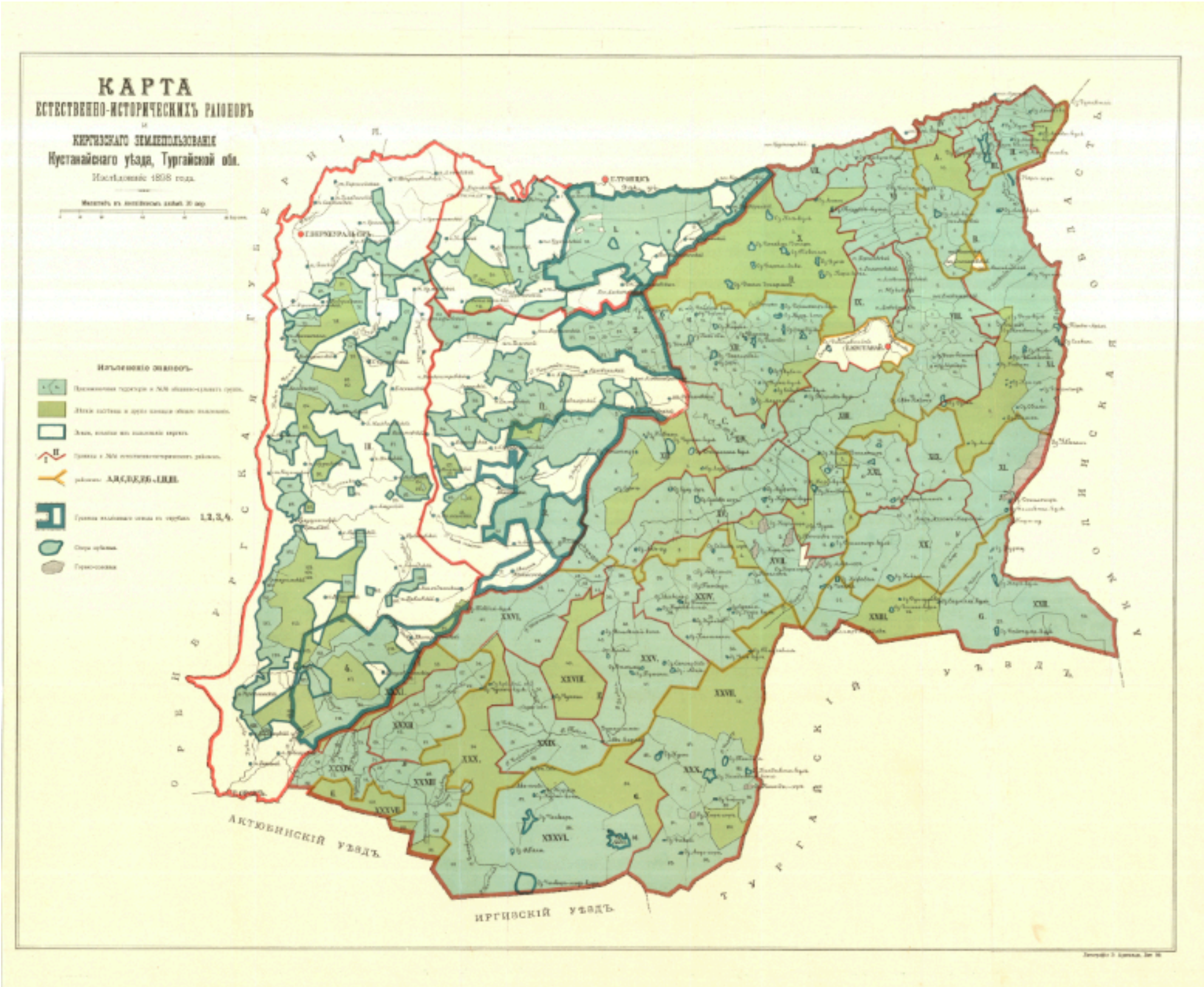


A



B

Annex E – Map of Kazakh land use produced by the expedition of Scherbina



Annex F – Unspecified simple regression model.

	Harrows
Distance to settlement	-0.00796***
	(-9.80)
_cons	1.303***
	(28.88)
N	1389
R^2	0,064

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Annex G – Results of specified OLS regression with cluster-robust standard errors

	(1)	(2)	(3)	(4)
	Harrows	**Harrows**	**Harrows**	**Harrows**
Distance to settlement	-0.00591***	-0.00233**	-0.00216**	-0.00410***
	(-6.55)	(-2.69)	(-2.70)	(-3.63)
Days per year when the water source is used	0.00920***	0.00840***	0.00807***	0.00805***
	(5.83)	(6.43)	(6.49)	(6.48)
Horses	0.0224***	0.0222***	0.0225***	0.0227***
	(5.22)	(5.32)	(5.36)	(5.45)
Yurt	0.378*	0.396*	0.400*	0.400*
	(2.14)	(2.36)	(2.36)	(2.36)
Soil productivity index		0.0749		
		(1.47)		
Index of precipitations during a warm period		0.301***		
		(5.60)		
(Soil productivity)^2			0.0197**	0.0214**
			(2.82)	(3.06)
(Index of recipitations during a warm period)^2			0.0599***	0.0565***
			(5.18)	(4.88)
(Distance to market)^3				1.91e-08***
				(3.87)
Constant	-1.568***	-2.497***	-2.188***	-2.150***
	(-4.17)	(-6.61)	(-6.37)	(-6.29)
N	1386	1386	1386	1369
R^2	0,347	0,401	0,412	0,413

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Annex H – Results of specified OLS regression with cluster-robust standard errors and the restricted dependent variable

	(1)	(2)
	Harrows < 3	**Harrows < 2**
Distance to settlement	-0.00268***	-0.00185**
	(-3.89)	(-3.26)
Days per year when the water source is used	0.00309***	0.00147**
	(4.37)	(2.77)
Horses	0.00935***	0.00546**
	(3.81)	(3.19)
Yurt	0.295**	0.146*
	(2.70)	(2.19)
(Soil productivity)^2	0.0135**	0.0108**
	(2.79)	(2.86)
(Index of precipitations during a warm period)^2	0.0284**	0.0144*
	(3.24)	(2.17)
(Distance to market)^3	5.82e-09	2.81e-09
	(1.74)	(0.93)
Constant	-0.695**	-0.161
	(-3.28)	(-1.06)
N	1265	1155
R^2	0,228	0,147

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$