National importance of surveying and ancient linear measures in the history of development of Russia

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Abstract. Issues of rational use of land resources are urgent contemporary problem. It is considered possible to solve it by analyzing centuries-old experience of history of land surveying, geodetic studies and mapping. The purpose of the study is to show the national importance of land surveying and ancient linear-measuring of boundary measures in the history of the state. The tasks of the article are connected with the analysis of types of geodetic surveys, linear measures and instruments during land surveying in different historical periods of development of the state. Historical and archival materials, ancient geodetic tools and maps were used as materials for the study. The study revealed that the development of surveying, the system of linear measurements and geodetic instrumentality had national importance to establish the boundaries of possessions, registration of quantity and quality of the land funds, protection of property rights, and termination of land disputes, valuation of land and establishment on the basis of equitable taxation. The main provisions of this study can add to the history of land relations in Russia and contribute to the further development and improvement of the state system of land surveying.

1. Introduction

The emergence of the first linear measurement of land property boundaries in the times of Ancient Rus and its principalities in the 10th – 15th centuries. History of state formation is closely connected with the development of land. The establishment and consolidation of state and private boundaries, the determination of the quantity and quality of land, the protection of ownership rights and the cessation of land disputes, the evaluation of land and the establishment of fair taxation on this basis were the main tasks on the way to the development of the state and the use of land resources. And here there was a need for measuring boundary works, which would guarantee the determination of the location of the boundaries, the description and evaluation of property and recognition of property rights. Measuring instruments were used for the works, and many of them not only became a part of history, but also significantly influenced the course of its development. It is known that since ancient times the first "earth-separating" tools were the hands and feet of a man, the length of his body, steps. But the first artificial measuring instrument, apparently, was a stick or a pole. If all measuring poles are compared with one and the same pole, this one pole becomes a standard. Therefore, the system of ancient measures of land gradually created a set of samples — verst, sazhen, arsheen, step, and others. Measures became an integral part of life, firmly established in everyday life, in traditions and foundations, and had state significance. A verst was originally defined as the distance from one turn of the plow to the other during plowing.
The verst was mentioned in the written sources of the 11th century. One verst consisted of 1000 sazhens in the time of Tsar Alexei Mikhailovich. One verst was equal to 500 sazhens at Peter the Great time (1066.8 m). A verst was also called a milestone on the road. The value of the verst was changed several times depending on the number and size of sazhens which were included in the verst. One of the main laws – the Code of 1649 established "Mezhevaya (Boundary) verst" – which included one thousand sazhens, and was equal to two vers (2.16 km). The "Boundary verst" was used as a boundary measure, usually in determining the land around large cities, and on the outskirts of Russia, especially in Siberia, and to measure distances between settlements. For measuring the distances in the European part of Russia, 500 sazhen’s verst was used. Long distances, in Eastern Siberia, were measured in days of travel. The Mezhevaya verst was gradually ousted in the 18th century, and in the 19th century the only verst which remained was a "track" verst, equal to 500 sazhens [1].

Sazhen was one of the most common measures of length in Ancient Russia. There were more than ten differently defined sazhens - different in purpose and size. Sazhen as an ancient measure of length was mentioned by Nestor in 1017. As a result of the measurements, the topographers got value of the sazhen – 151.4 cm. The results of the measurements of temples and Russian folk measures matched this value. Sazhen’s dimensional ropes and folding wooden "skladen" tools existed in the measurement of distances and in construction. The sazhens were used for measuring until the introduction of the metric system.

The basic unit of linear measures was arsheen. The arsheen was one-third of the sazhen. It was possible that initially, the arsheens were determined by the length of human step and was the basis for sazhens and versets. There were several arsheens – printed (pechatny), branded, official (kazennyi), folding and correct yardstick. Russian arsheen was a ruler with applied scale for measurement, and contained 16 vershoks or 28 inches. Three arsheens were equal to 7 feet (500 sazhens are equal to one verst). This measure was widely used not only in measuring works but was very popular in folk's economic and cultural life.

In Moscow Rus, arpent (Dessiatina) was a universal measure of land in the state and possessive lands; in the peasant ones it was replaced by "quarters", which were half its size and were divided into even smaller units. There were some local measure units: in the Great Novgorod— "korobyia" (1 kor. = 2 quarters of arable land), to the Dvina's area — "ropes". The next units - "vut" and "sokha"(plow). Novgorod "sokha" (plow), "soshka" and "obzha" were used to collect the dues from the peasants and state taxes [3].

2. Materials and methods

Historical and archival materials, ancient geodetic instruments and maps of different Museum collections were used as materials for the study. This includes instrumental collections of Educational and historical center of Moscow state University of Geodesy and Cartography, of Moscow State Polytechnical Museum, and of Moscow Museum of the company "Geostroyizyskaniya" (ZAOGSI). Geodetic instrument making today is undergoing a new stage of its development. The growing need for surveying instruments allows creating new models, developing new tools and technologies of topographic, boundary and cadastral surveys. The historical method of research allowed studying the texts of primary sources and finding material evidence for the study, as well as presenting the events of different historical periods in Russia. A historical-comparative method has a wide cognitive capabilities, reveals the essence of the study and the importance of land surveying and ancient linear-measuring measures in the history of the state.

3. The beginning of Russian Chronicles refers to the 11th century.

Back in those days the division of lands did not require complex measurements. It was enough to measure the lanes of land of equal width, and denote them with bordering signs-small pits, stakes, stones or furrows. Natural or man-made signs were used to indicate the boundaries. Rivers, streams, ravines, swamps, forests, trees, stones could all be part of the signs that determined the land boundaries. In addition to the designation of the boundaries were used like- poles, pits, mezanti, signs on trees, fences,
etc. There were no rules governing the location and shape of boundary markers. Everything depended on the custom and convenience of setting signs in the area. However, when trees or poles were marked by signs, often pits were dug, in which were placed the coals, stones and bones. On apicultural trees ["borti" (apiculture) the oldest form of beekeeping] and boundary oaks the signs represented various subjects, for example a hand, a skobel (special knife), a scythe, etc. [3] were made by axe.

The first artificial land boundaries - [the fence, lanes of uncultivated land, "mezhniki", "faces", "predely", etc.] appeared on business needs — for protection from wild animals, rapprochement with neighbors in high-value lands: arable lands, meadows, and beekeeping areas. The emergence of fisheries-hunting, cattle breeding and others also caused the appearance of the first signs indicating the places of land use of individuals. Thus, the boundaries of the possessions were formed during of land surveying. Boundary marks could be installed for separating of the land of one owner from another. Land relations were regulated by special boundary legislation. The accuracy of the boundary and its preservation were the cause of quarrels and clashes of owners, and the accuracy of land surveying depended on the applied surveying instruments and methods of the first boundary measurements. The value of land was increased with increasing population, and the boundaries of possessions protected by law and authority became stronger. In articles of the First Russian legislative document - "Russkaya Pravda " the first law regulations for protection of possession according to the rights of estates [4] were raised. The eighth Chapter of "Pravda" stated that every possession had its limits, approved by the government, and their signs were sacred to the people [4].

Methods of land delimitation depended on the structure of ancient Slavic settlements. All convenient lands were either considered the property of the settlement or divided between individual families. Plans of individual parcels were made on the base of the results of inspections, inventories and simple measurements. The lengths of the boundary lines were measured with a measuring rope, the areas of agricultural land and forests were determined. In the "Russian Truth" a guidance on the boundary marks was provided and boundaries that were established by measuring and determining areas of land for taxation. Distribution, modification and supplement of the local boundary laws led to the creation of specific legislation in the principalities (Novgorodskay, Pskovskay and Dvinskaya judicial Charters). There were the articles about the land boundaries, the decisions of disputes about lands and forests in the chapters of "Russian Truth", "Bortnaya" boundary shared part of the forest, "Roleinaya" one – divided arable fields. Boundary (meznoi) oaks marked the property lines, cut down the oak meant to destroy boundary marker [4]. As a result of the policy of creating a united state, there was a need for more accurate land surveying. The land use and accounting of the one could not be implemented without the measurement of land, i.e. geodetic works. There was a need for land surveying (location, description of borders, calculation of areas, issuance of legal documents for ownership, resolution of disputes about lands), as well as information about state borders and natural resources of state territories. In this regard, work begun on the creation of Scribe books (1500), which included descriptions of land and methods of establishing and describing of boundaries, was fixed by certificates (boundary, bills of sale, granted, etc.) [4]. Thus, we can say that in the 10th-15th centuries not only the first important concepts of surveying were developed, but also the first measuring instruments and the first techniques and methods of land measurements were established.

4. The development of the initial system of land surveying in the Moscow State during the scribe mezhevanie (surveying) in 16th – 17th centuries.

Moscow state, worrying about the safety of its borders, created fortifications along them, the descriptions of which already in the 16th century were accompanied by plans of the border lanes. The local system required frequent descriptions, measurements and delineations of estates and patrimonial estates. Plans of separate districts of the Moscow State were based on the results of inventories, inspections of the area and the simplest of measurements until 16th century. Grant of land for service, for Tsar or the Sate, was one of the reasons for the frequent land censuses in the 15th – 16th centuries. Scribe books were used in the 14th – mid 17th centuries, contained legal and financial issues (property valuation, tax rates; indicators of population statistics and land ownership; classification by land
The practical geometry was based on the determination of distances and areas (areas were measured with a rod and measuring ropes in dessiatinas of 80 sazhens in length and 30 sazhens in width at the Behest of 1684). In the Code of laws (Sudebnik) of 1497 there were several articles on the order of land surveying possessions and regulation of feudal-land relations. The landmark laws of Moscow state provided for punishment for violation of the borders. In the code of laws (Sudebnik) of Ivan III and Ivan IV (1497 and 1550) for the infringement between the princely, boyar and monastic lands were administered, in addition to the monetary penalty, the criminal punishment - the whip; meanwhile, monetary penalty was supposed for violation within the community between peasant lands [6].

The Council code of 1649 established a system of land surveying and determined the size of the sazhens, issued boundary laws that determined the order of land surveying, provided penalties for damage to boundary marks. In cases of requests from the owners to survey their estates the Code prescribed to survey them with old-timer witnesses, dig holes on the borders, set poles, and do all sorts of signs on the lands to exclude disputes. If for some reason the surveyor could not resolve the dispute with his power, the disputed lands were bypassed with the icon ("figurative walking") [4]. Penalty for damage of boundaries, forcible seizure of lands, and the wrong actions of surveyors also defined in the code: who damaged boundaries, and boundary posts; or pits would align, or the land plowed, and a court would prove it, those people should be whipped and be sent to jail for a week. The same punishment was also applied to the peasants who spoiled their boundaries, but without fine [7]. In 1684 a Scribe of land cadaster related to the formation of the Russian state.

5. Change of the main provisions of the subdivision during the development of the Russian state (the Russian Empire) during the reign of Peter the Great and continuation of reforms of the 17th – 18th centuries

One of the main problems of this period was a patchwork of lands. Such land fragmentation devalued land, and had a harmful impact on the economy, prevented the use of advanced crop systems, gave rise to disputes and agricultural unrest, and undermined the legal basis of ownership. With the existence of intermingled property was impossible "to approve the peace of mind of owners" and to set boundaries of ownership. New educational institutions and the publication of books related to surveying like *Geometry that is Land Surveying in Slavic* (1708), *Geometry, Methods of Compass And Ruler* (2nd ed.) were published, and had a significant impact on the future of the land surveying (1709) and *Practical Geometry* (1709) [5]. The survey was carried out by the surveyors of Peter the Great with the preparation of land maps of each county. At this time, accurate instrumental surveys were started to obtain maps of individual territories and the General map of the State with the determination of the coordinates of "astronomical points". The Senate decided in 1718: "The surveyors should study geodesy, and use theodolites and compasses in their works" [2]. Measuring chains and ribbons served as main instruments
back in that times. Two method were used for surveying parcels using measuring chains and stakes: the breakdown of the parcel into triangles or parallel lines method [9]. The structure of the geometry allowed them to determine distances and angles (with the measuring chains and the first astrolabes with telescope), differential leveling- (method of water leveling) and areas. The manual of A. F. Kleshnina (1723) set out the mathematical essence of the method of "zasecheck" (used in cases where the mutual location of two points was known and it was necessary to determine the position of the third point, often inaccessible for measuring) and explaining the method of equalizing the points, i.e. eliminating the so-called "triangle of errors" by changing the rhumbs and distances.

Peter the Great declared arsheen as the main unit for measures, supervision over the correctness of trading measures and weights were assigned to the town hall, magistrates, mayors, governors and especially the police.

![Normal arsheen 1806](image)

Normal arsheen was arranged as follows: on a massive rectangular base made of copper alloy, two limiters were installed, with polished chalcedony inserts fixed on the inner side. Chalcedony has a higher hardness than steel and does not wear out when inserting metal standard rods. Thus, the "arsheen’s standard" was like calibration device, a calibration "bench" for testing of the standards themselves. So, the surveyor after checking the "arsheen’s standard" out on the calibration “bench”, felt confident to use it. This tool was equipped with two sliders with scales, which allowed not only to accurately set the length of any rods less than the arsheen, but also to mark the working standard with the division of value in the tenth part of a vershok. Branded metal tapes and measuring chains with lengths of 5 and 10 sazhens with divisions of value were made of iron, steel or copper alloys. The error allowed for measuring chains and steel tapes should not exceed 5 lines (1.27 cm) for each sazhen of length.

With the socio-economic development of the state, land tenure required more precise definitions of boundaries, location and affiliation. Since the Order (Nakaz) of 1684, more than 65 years had passed, and many of the newly appeared possessions remained without approved borders, the old parcels lost their boundaries. These all had very negative impact on the land holdings in the state, giving rise to the appropriation, arguments, fights and murders on the borders. Poorly protected and unknown to the government lands could not bring income to the state. The Domestic Office (Pomestny Prikaz) was transformed into the Patrimonial Board (Votchinaya Colegia), and many of its functions were lost, which negatively affected the accounting and evaluation of land. However, the accuracy of field measurements based on geometry and the use of surveying instruments were improved. Military interests demanded display terrain and aquatic objects. The government organized surveys to obtain maps of individual territories and the General map of the state.

6. The formation of developed system of land survey at the time of the General survey of the Empire in the second half of the 18th–19th centuries

Catherine II had to solve the problem of insecurity of land relations. For restoring of the order in the area of land ownership to prevent "disputes between owners, lawsuits, fights, and death kills", the General rules was composed and new land survey office and land survey expedition in Senate were
opened, and also two provincial land survey offices in Volokolamsk and Serpukhov [10]. By conducting land surveying, the government sought not only to legalize their borders, but also to optimally arrange the type of management, to prevent the ways of violation of borders and the possibility of damage to natural resources. Several important legislative documents were issued in 1766: "The Methods of General Land Surveying" and "The Instruction for the Land Surveying of the All-Empire" which was made on the basis of the General rules. The instruction described how to draw up plans (1:8400) focused on the magnetic Meridian, which were used to draw up maps of counties (from 1:42000 to 1:336000) and atlases of the bordered lands, and detailed techniques and technologies of surveying. [11]. The angles of turn of the boundaries of land ownership for the first time were marked by wooden pillars with coats of arms, in treeless places triangular pits, and in flood areas – barrows were arranged. The Instructions determined the form of boundary marks, the rules of drawing up of plans, boundary books and documents [12]. Professor of astronomy from Oxford University E. Gunter (1581-1626) [13] proposed measuring chains, which were used for surveying, in the beginning of the 17th century.

![Figure 2. Measuring chain (England, 1795) the most convenient and advanced design. Ten-per-sazhen links of equal length with planted plaques of different shapes and with a different number of teeth](image)

Measuring chain usually was composed of 70 steel links, where every seven units (i.e., every seventh sazhen), was attached to the copper plaques engraved on them the numbers. Thus, sazhens and feet were counted on the plaques and according to the number of individual links. There were also "centesimal" measuring chains consisting of 100 links of 0.1 of sazen, or hundred-foot (one hundred links in length per foot). Compared with the chain – the measuring steel tape had several advantages: first, it was lighter, and secondly, did not stretch, less sagged in measurements through the pits and ditches, and therefore, gave more accurate results. But the tape was not as strong as the measuring chain and in case of rupture could not be corrected by local means. For measuring of small distances a thin canvas rope – braid – was used of 10 sazhens in length, which had scale divided into sazhens, feet, inches and even smaller parts. The braid was kept in a leather case with a rotating axis in its center, equipped with a folding handle. For ease and convenience of use, it surpassed even the measuring tape, but it was very stretched and did not last long, and for measuring lines in the open areas it was not suitable at all.

Formed in 1779 Konstantinovskyi Land Surveying Institute trained engineers in the field of land management and land surveying. At all times, Russia was an exclusively agricultural power, and land policy issues played a major role in the development of the state. That is why the role of a professional higher school in the boundary survey, legal, geodetic, geographical and cartographic study of land and other natural resources of the state was incredibly important. Education and training of highly qualified specialists, the development of professional Sciences of the geodesic cycle, the dissemination of scientific achievements and knowledge in the field of astronomy, gravimetry, photogrammetry and other Sciences, the improvement of land law, the establishment and protection of state borders – these were the main tasks that were solved as a result of educational activities, researches and expeditions of the Boundary Institute (Mezevoy Institute) [9]. The rules of land surveying, faced with new ways and conditions of economic use of natural lands, encouraged the government to simultaneously address the issues of regulation and management. There was a gradual formation of the system of surveying on a
legislative basis with accurate geodetic and cartographic supports. In different provinces of the Empire, the tasks of land surveying coincided, but the priorities at the same time, according to natural and climatic conditions, the availability of natural resources, the development of the economy, the national way of life, were different. Land surveying was still to be involved in the urgent state tasks: the elimination of the patchwork lands; the allocation of land to state peasants; the return of illegal possession of state lands; the delimitation of joint possessions; the provision of land to cities and many others.

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