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DEVELOPMENT OF A NAVIGATION SPACE FOR AGRO FIRM

Abstract. The paper shows that the Agro-industrial Complex is almost entirely composed of spatial-temporal data. Consequently, the digitalization of the Agro-industrial Complex is associated with the formation of spatial-temporal data using information from navigation systems. Therefore, the 51 points of the Implementation Action Program "Digital Kazakhstan" provides for the country to create a National Spatial Data Infrastructure. The National Spatial Data Infrastructure of the Republic of Kazakhstan is designed to solve the problems of digitization of space-temporal data at the Government to Government, Government to Business and Government to Citizen levels. The solution of issues of digitalization at the Business to Business level is practically left to the Agro firms themselves. One of the problems of this process is the development of reliable navigation spaces. The goal of our research is the development of a navigation field for conducting Precision Agriculture throughout the territory of a particular Agro firm. The research tasks included the study of the specific features of the territories of the Agro firm and the proposal of a High-precision Satellite Navigation System suitable for conducting Precision Agriculture in any part of the territories of the economic entity with an accuracy of 3 cm. For this, the technology of creating the High-precision Satellite Navigation System of the Republic of Kazakhstan was used. To assess the accuracy of the navigation field, the studies were conducted in three modes: DGPS service; RTK service; PP service. For the experiments, the Mobile Differential Station of the High-precision Satellite Navigation System of the Republic of Kazakhstan and a network of its Differential Stations with the center of Differential Correction and Monitoring in Astana were used. Studies have shown that the territory of the Agro firm is not located in a single array of agricultural land, the relief of the territories is rather complicated, and the network of the High-precision Satellite Navigation System of the Republic of Kazakhstan does not provide sufficient accuracy for maintaining a Precision Agriculture system in the studied array. The observations also showed that, due to the elevation differences and remoteness of the objects, in most parts of the Agro firm there is no reliable GSM connection. Considering the above features of the territories in terms of the relief and remoteness of the plots, we proposed a scheme with the additional placement of 4 Base Stations of Differential Correction and the Center of Differential Correction and Monitoring on the territory of the Agro firm. Calculations showed that this arrangement of the Base Stations can provide 2.5-3 cm accuracy of the navigation field throughout the territory of the Agro firm, allowing you to carry out the full range of Precision Agriculture, which consists of Precision farming and Precision animal husbandry. It should be noted that this kind of research in the country was conducted for the first time.

Keywords: digitalization, spatial data, national spatial data infrastructure, navigation, high navigation satellite system, precision agriculture, agro firm.

Introduction. The creation, formation, and development of the National Spatial Data Infrastructure (NSDI) are one of the major steps in increasing the competitiveness of any country on the world market [1-3]. Kazakhstan is still among those countries that have not created their own NSDI. At the same time, the state program "Digital Kazakhstan" was adopted in the country [4]. As part of this program, it is necessary to digitize the Republic of Kazakhstan. The Agro-industrial complex (AIC) is almost entirely composed of spatial-temporal data or geo-data. Consequently, the digitalization of the AIC is associated with the creation, formation and development of spatial-temporal data. Therefore, 51 paragraphs of the Activities on the implementation of the Digital Kazakhstan Program provides for the establishment by the

country of the NSDI of the Republic of Kazakhstan (NSDI RK). This underlines the importance of our research.

The main problems and ways of solving the NSDI RK were outlined earlier by us [6]. The NSDI RK is designed to solve the problems of digitization of spatial-temporal data at the levels Government to Government (G2G), Government to Business (G2B) and Government to Citizen (G2C). The solution of issues of digitalization at the level of Business to Business (B2B) practically remains with the agro formations of the Agro-industrial complex. Digitization of Agro firms in the Agro-industrial complex in the republic requires some detailing of this process.

So, if a National SDI is created, then Agrarian SDI (Agro SDI) should be one of its branch components. The structure of Agro SDI provides for the creation and formation of all basic spatial data of the Agro-industrial complex. However, the basic information of Agro SDI is generally difficult to use without its subsequent refinement (detail) for solving the production problems of Agro formations. For example, Precision agriculture (PA) includes Precision farming, Precision livestock farming, Precision pork, Precision poultry farming etc. and product processing, using agricultural machines, tractors, trailed equipment, etc. For the introduction of PA in the activities of Agro firms, it is required to create, generate and constantly update a huge amount of additional thematic data, lists, registries, etc. [7] using the potential of "Geo Industry 4.0". However, such studies in the republic are only at the level of initiations and the development of small “polygons” [8]. They are being implemented so far without developing adequate navigation space, which allow them to be used for reliable management of PA throughout the entire territory of a particular Agro formation, which makes our research relevant.

The goal of the research is the development of a navigation space for conducting Precision agriculture throughout the territory of a specific Agro firm.

Research objectives are the study of the characteristics of the territory of the Agro firm and the proposal of a High-precision satellite navigation system suitable for farming throughout the territory of an economic entity with an accuracy of about 3 cm.

Methods. To ensure the required accuracy of the navigation space, the network and technology of creating the High-precision Satellite Navigation System of the Republic of Kazakhstan (HSNS RK) with the center of differential correction and monitoring of the HSNS RK in Astana [9] is applied.

To assess the accuracy of the navigation space (farm, agro landscape, field, object) and improve the accuracy of the electronic map binding, studies were conducted in three modes: DGPS service - for navigation with an accuracy of 0.5 to 3 m in the planned coordinates and 0.7-6 m in height, depending on the equipment used by the user; RTK service - for accurate positioning in real time with an accuracy of 0.02-0.5 m in the planned coordinates and 0.06-0.7 m in height; PP service - final data (post) processing in cameral conditions in order to obtain the coordinates of points with an error of less than 1 cm.

The experiments were carried out using the Mobile Differential Station (MDS) of the HSNS RK [9], a network of differential stations with a center for differential correction and monitoring of the HSNS RK in Astana.

If necessary, we use the information available in the public domain, for example from Google Earth.

Results. Figure 1 shows the location of the territory of interest on Google Earth relative to the city of Astana in the form of vector data, and figure 2 is based on a raster substrate from Landsat 8 TM. On the left, the main grounds are located close to the central manor and the departments, on the right are distant lands (code name - Zhaken 1). I.e., the territory of the Agro firm is not located in a single array of agricultural land, which requires some effort to create a single navigation space in order to collect digital information to represent them in the spatial data infrastructure in particular, and to form a system of Precision agriculture in general.

As can be seen from figure 3, the system of High-precision satellite navigation system of the Republic of Kazakhstan does not provide the necessary accuracy for maintaining a system of Precision agriculture throughout the country.

The study area (figure 4 - a label in the form of a car) still remains outside the coverage area of the HSNS RK with the required accuracy. The relief of the Agro firm's territory also plays a significant role (figure 5), especially the location of the base area. The central manor and branches of the Agro firm are located on the bank or relatively close to the river bank (in the figure is the red zone). Then, the relief has a long rise (from pink and light brown to a rich green zone) with a subsequent decrease. Behind the

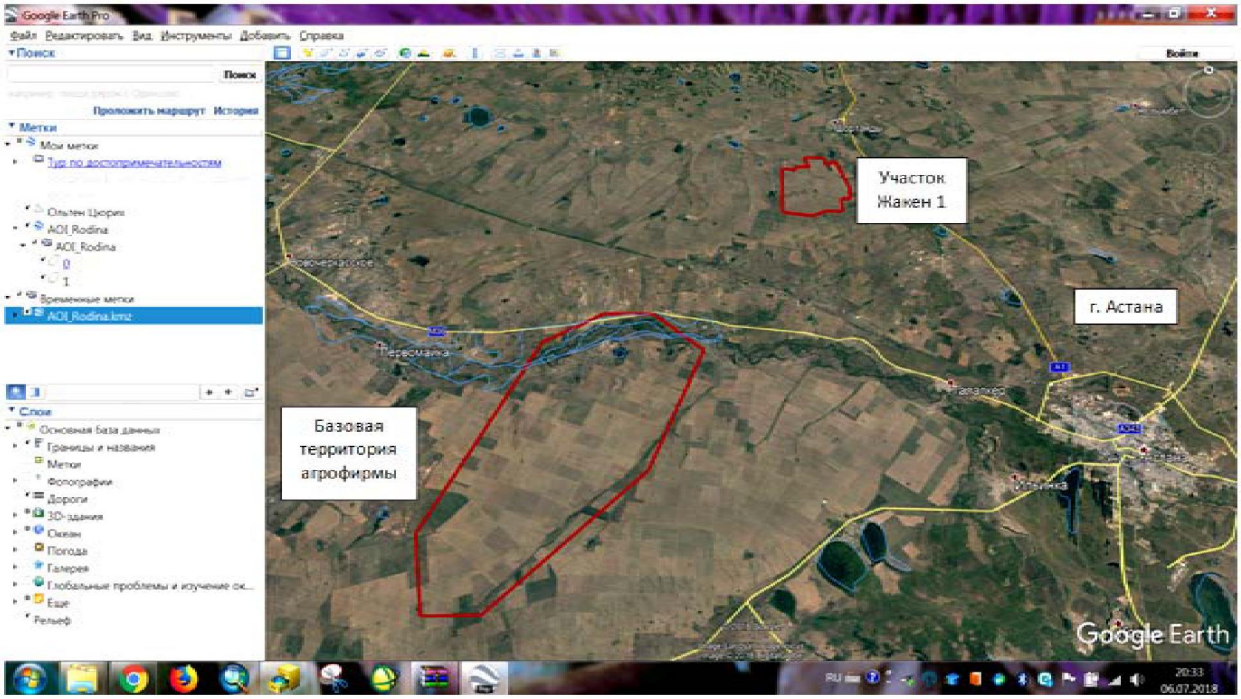


Figure 1 – Location of the territory of the Agro firm
on Google Earth relative to the city of Astana (vector)

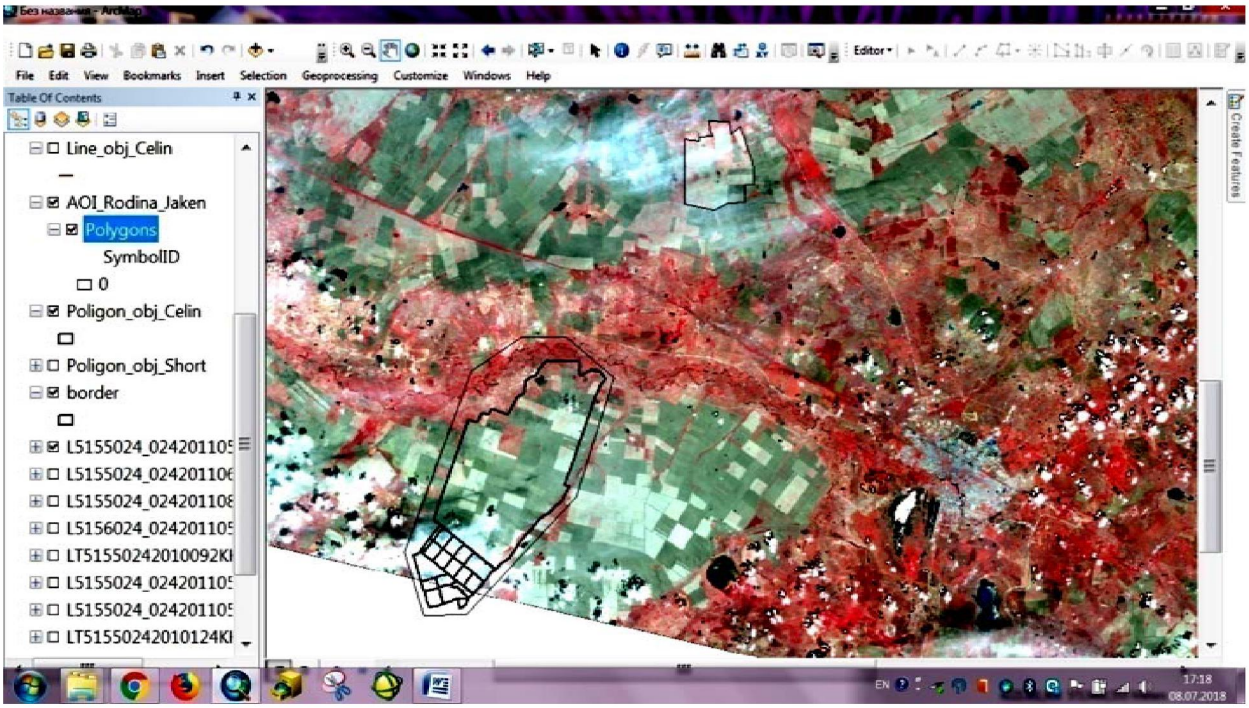


Figure 2 – Location of the Agro firm on a raster substrate (Landsat 8 TM)

highest zone there is a tract, where a sharp lowering of the relief occurs and a watercourse forms towards the main river. At the same time, the territory of Zhaken 1 (figure 5b) is almost a flat territory, without noticeable differences in relief.

Observations also showed that due to the heterogeneity of the territory over the relief, most of the Agro firm is not covered by a reliable GSM connection and the Internet.

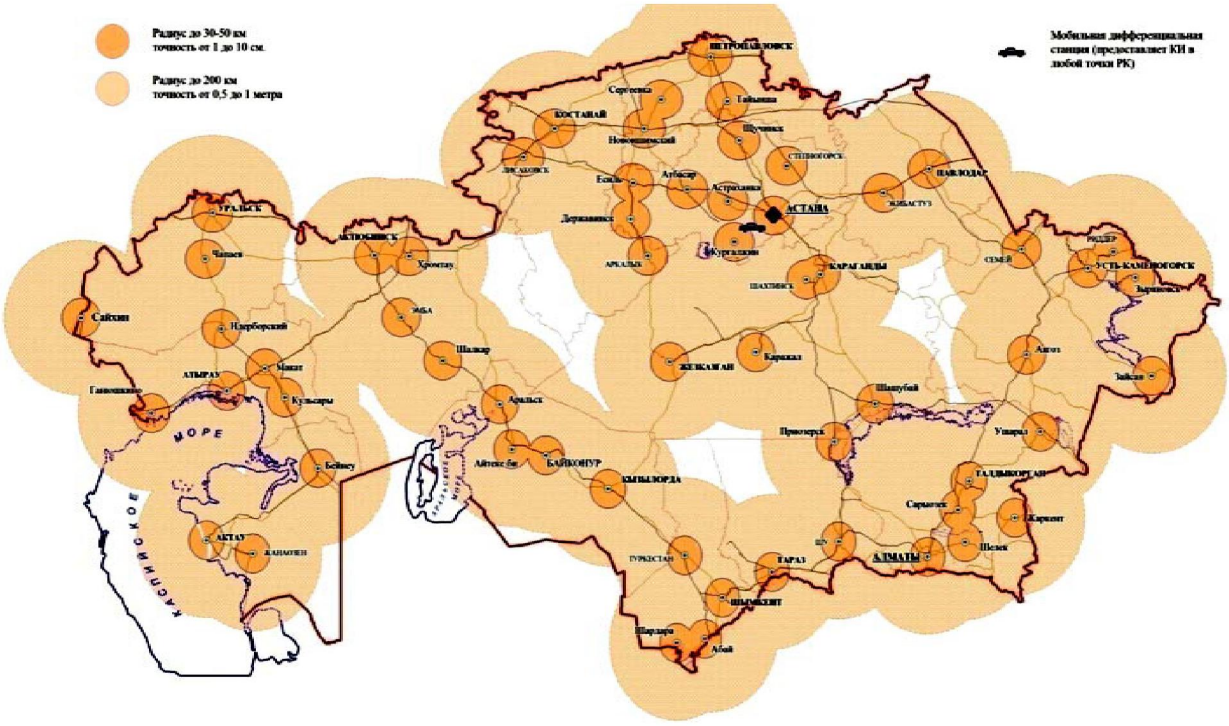
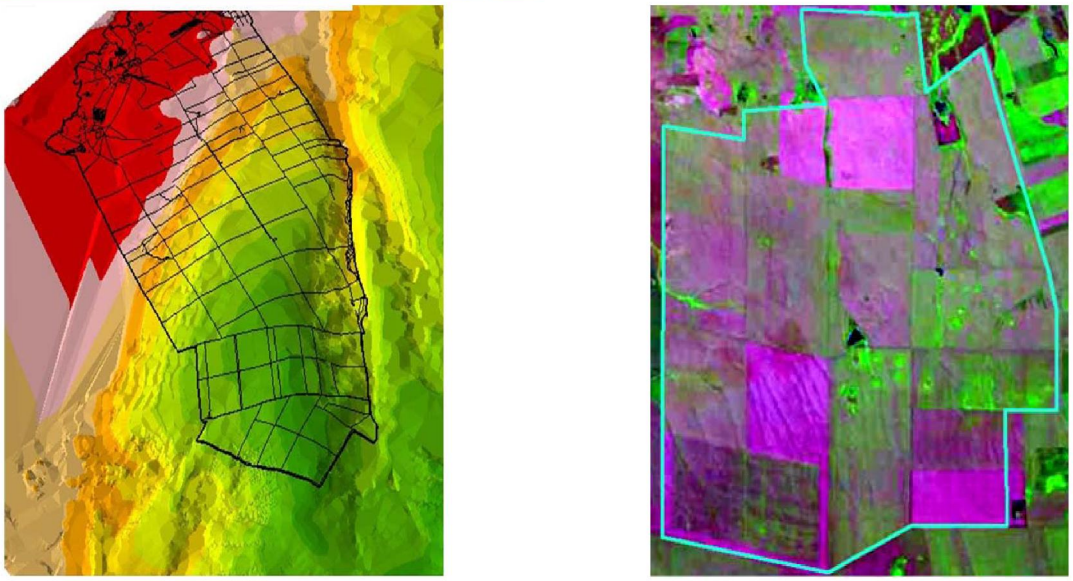


Figure 3 – Coverage of High-precision navigation satellite system the territory of the Republic of Kazakhstan

Figure 4 –
Scheme of coverage of the territory of interest
with an accuracy of 1-10 cm



a b

Figure 5 – 3D model of the territory of an Agro firm with superimposed field layout
(a - is the base territory, b - is the Zhaken 1)

Figure 6 – Layout of BS of differential correction and the CDCM on the territory of the Agro firm

Considering the above features of the territory according to the relief and remoteness of the plots, we have proposed the following scheme for placing additional base stations of differential correction (BS) and the center of differential correction and monitoring (CDCM) on the territory of the Agro firm (figure 6).

As shown by calculations based on preliminary experience of creating and putting into operation of the HSNS RK, this BS location scheme can provide 2.5-3 cm accuracy of the navigation field throughout the Agro firm, allowing you to carry out the entire complex of Precision agriculture. It should be noted that this kind of research using the HSNS RK technology in the country was conducted for the first time and should be considered as agrarian innovation [10].

Discussion. In principle, Global navigation satellite systems such as NAVSTAR (GPS), GLONASS, GALILEO and BEIDOU [11-14] can be used to develop a single navigation space of the study area using the appropriate ground-based navigation equipment.

In addition, such high-tech firms as Trimble [15] Leica Geosystems [16] have their own commercial network of navigation installations.

Besides, at present, most agricultural machinery (machinery, tractors, combines, etc.) are equipped with built-in navigation devices for conducting precision work in agricultural fields and facilities [17–20]. However, without additional serious financial costs, direct use of the above navigation systems and equipment is often quite difficult. Therefore, we have taken as a basis for the development of high-precision navigation space for the studied Agro firm, repeatedly tested, officially commissioned, domestic HSNS RK [9].

Conclusion. Thus, as a result of studying the particular location of certain areas, terrain and radio communications, we have proposed a highly accurate satellite navigation system for a particular Agro firm, which was developed by analogy with the HSNS RK and can be used to maintain a Precision agriculture system with an accuracy of 2.5-3,0 cm. It should be noted that this kind of research using the HSNS RK technology in the country was conducted for the first time and should be considered as agrarian innovation.

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АГРОФИРМАНЫҢ НАВИГАЦИЯЛЫҚ КЕҢІСТІГІН ДАЙЫНДАУ

Аннотация. Еңбекте агроөнеркәсіптік кешен дерлік кеңістіктік-уақыттық деректерден тұратыны нақтыланған. Демек, агроөнеркәсіптік кешенді цифрландыру, навигациялық жүйелерден алынған ақпаратты кеңістіктік-уақыттық деректердің қалыптастырумен байланысты. Сол себептен «Цифрлы Қазақстан» бағдарламасы шараларының 51 бабы елге ұлттық кеңістіктік деректер инфрақұрылымын құруды межелеген. Қазақстан Республикасының ұлттық кеңістіктік деректер инфрақұрылымы негізінен Government to Government, Government to Business и Government to Citizen деңгейлерінде кеңістіктік-уақыттық деректерді цифрландыру мәселелерін шешуге бағытталған. Business to Business деңгейінде цифрландыру мәселелерін шешу іс жүзінде агроқұрылымдардың өздері қарастыру керек. Бұл үрдістің маңызды мәселелерінің бірі сенімді навигациялық кеңістік құру және оны дамыту болып табылады. Зерттеудің мақсаты - белгілі бір агрофирма аумағында дәл ауыл шаруашылығын жүргізу үшін навигациялық өрісті дайындау. Зерттеу міндеттері агрофирма аумағының ерекшеліктерін зерттеу және 2,5-3,0 см дәлдікпен шаруашылық субъектісінің территориясының кез келген бөлігінде дәл ауыл шаруашылығын жүргізу үшін жарамды жоғары дәлдіктегі жерсеріктік навигациялық жүйені құру. Мұндай мақсатқа жету үшін Қазақстан Республикасының жоғары дәлдіктегі жерсеріктік навигациялық жүйені құру технологиясы пайдаланылды. Навигациялық кеңістіктің дәлдігін бағалау үшін зерттеулер үш режимде жүргізілді: DGPS қызметі; RTK қызметі; PP қызметі. Эксперименттер жүргізу үшін Қазақстан Республикасының жоғары дәлдіктегі жерсеріктік навигациялық жүйесінің жылжымалы дифференциалдық станциясы әрі Астана қаласында орналасқан дифференциалды түзету және мониторинг орталығы және оның дифференциалды станциялар желісі пайдаланылды. Зерттеулер нәтижесінде, агрофирма аумағы бірбүтін ауылшаруашылық жерлерінде орналаспағаны, аумақтардың рельефі өте күрделі екені, ал Қазақстан Республикасының жоғары дәлдіктегі жерсеріктік навигациялық жүйе желісі нақты проблеманы шешу үшін жеткілікті дәлдік бере алмайтыны анықталды. Байқаулар сондай-ақ, агрофирмнің көптеген бөліктерінде объектілердің биіктігі мен қашықтығына байланысты сенімді GSM байланысы жоқ екенін көрсетті. Аймақтардың жоғарыда аталған жер учаскелерінің ерекшеліктерін ескере отырып, біз дифференциалды түзетудің 4 базалық станциясын қосымша орналастыруды және агрофирма аумағында дифференциалды түзету және мониторинг орталығын құруды ұсындық. Біткен еңбектің нәтижесі бойынша, базалық станциялардың орналасуы агрофирма аумағында 2,5-3 см навигациялық кеңістік бере алатыны анықталды. Бұл жетістік дәл ауыл шаруашылығының (дәл егіншілік пен дәл малшарушылығы) толық спектрін жүзеге асыруға мүмкіндік береді. Келтірілген зерттеулердің республикада алғаш рет жүргізілгенін атап өту керек.

Түйін сөздер: цифрландыру, кеңістіктік деректер, ұлттық кеңістіктік деректер инфрақұрылымы, навигация, жоғарғы дәлдіктегі навигациялық жүйе, дәл ауылшаруашылығы, агрофирма.

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РАЗРАБОТКА НАВИГАЦИОННОГО ПРОСТРАНСТВА ДЛЯ АГРОФИРМЫ

Аннотация. В работе показано, агропромышленный комплекс практически полностью состоит из пространственно-временных данных. Следовательно, цифровизация агропромышленный комплекс, связана с формированием пространственно-временных данных с использованием сведений навигационных систем. Поэтому, 51 пункт Мероприятия по реализации Программа «Цифровой Казахстан» предусматривает создание страной национальной инфраструктуры пространственных данных. Национальной инфраструктуры пространственных данных Республики Казахстан призвана решать проблемы цифровизации пространственно-временных данных на уровнях Government to Government, Government to Business и Government to Citizen. Решение вопросов цифровизации на уровне Business to Business практически остается за самими агроформированиями. Одной из проблем этого процесса является разработка надежных навигационных полей. Цель наших исследований - разработка навигационного поля для ведения точного сельского хозяйства на всей территории конкретной агрофирмы. Задачи исследований входило изучение особенности территорий агрофирмы и предложение системы высокоточной спутниковой навигации, пригодной для ведения точного сельского хозяйства в любой части территории хозяйствующего субъекта с точностью до 3 см. Для этого использована технология создания национальной инфраструктуры пространственных данных. Для

оценки точности навигационного поля исследования проведены в трех режимах: DGPS сервис; RTK сервис; PP сервис. Для проведения экспериментов использованы мобильная дифференциальная станция системы высокоточной спутниковой навигации Республики Казахстан, сеть её дифференциальных станций с центром дифференциальной коррекции и мониторинга в г. Астана. Исследования показали, что территория агрофирмы расположена не в одном массиве сельскохозяйственных угодий, рельеф территорий достаточно сложный, а сеть Системы высокоточной спутниковой навигации Республики Казахстан не обеспечивает достаточную точность для ведения системы точного сельского хозяйства на изучаемом массиве. Наблюдения так же показали, что в силу перепадов высот и удаленности объектов, на большей части территорий агрофирмы нет надежной связи GSM. Учитывая вышеприведенные особенности территорий по рельефу и отдаленности участков, нами предложена схема с дополнительным размещением 4 базовых станций дифференциальной коррекции и центра дифференциальной коррекции и мониторинга на территории агрофирмы. Расчеты показали, что данная схема расположение базовых станций может обеспечить 2,5-3 см точность навигационного поля по всей территории агрофирмы, позволяя вести весь комплекс точного сельского хозяйства, которая состоит из точного земледелия и точного животноводства. Следует отметить, что такого рода исследования в стране проведено впервые.

Ключевые слова: цифровизация, навигация, система высокоточной спутниковой навигации, пространственные данные, инфраструктура пространственных данных, точное сельское хозяйство, агрофирма.

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