GLOBAL NAVIGATION SATELLITE SYSTEMS TECHNICAL SOLUTIONS DEVELOPMENTS OF FARMLAND PROCESSING IN LATVIA

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Abstract
Global Navigation Satellite System (GNSS) services in Latvia nowadays provide not only for a variety of navigation and surveying needs, but also they are used in agricultural production. The time period when satellite navigation systems equipment and services in agricultural businesses appeared in Latvia and were treated as objects of interest and research has passed. GNSS equipment and enabling modules are purchased, installed and used in agricultural equipment extending their capabilities. A growing number of entrepreneurs provide for this service segment. In the publication of 2014, the authors pointed out that a preparatory and investigation phase in using precision farming systems (including GNSS technology related to them) in Latvia has come to an end transforming into massive practical implementation in the process of agricultural business. The analysis of the obtained information confirmed that during the last year further satellite navigation technology usage in agricultural machinery has grown from simple and approximate level usage to high accuracy and stability navigation services. Growth dynamics and its further development forecasted earlier by the authors coincided with the last year's actual development indicators of a stable and growing demand for global navigation system services for farming machinery and technical solutions for their user segment.
The aim of the article is to justify the forecast expressed in the last year's publication regarding the increase of the use of precision farming systems thus confirming the fact that their application has moved from a research phase to massive practical implementation and operation in agricultural production.
Keywords: precision farming systems, global positioning systems, Geoinformation, real-time adjustments.

Introduction

During the time period of 2011 - 2013 the authors performed the research activities on technical solutions of farmland processing elements using global navigation satellite systems in Latvia, the results of which were presented in the article "Global Navigation Satellite System as farmland processing elements Latvian technical solutions" (Engineering for Rural …, 2014). The authors came to the conclusion that at the end of the last century and the beginning of this century in the world's developed countries, agricultural technology development direction, known as precision farming systems (Celms, Ratkevics, Baumane, 2014), has become increasingly popular in agriculture. With this we understand effective field management technology systems (EASY) which are based on four components: 1. the management of tractors, harvesters and similar units as well as operation optimization techniques directly from the driver's cab; 2. Increased productivity and efficiency of resource use; 3. Agro technologic process control on the field; 4. Information technology support to find better technology and business options for agricultural business (CLAAS Braukšanas optimizēšana, 2012).
In order to successfully ensure effective realization of field management technology systems' (EASY) main components, agricultural holdings form local geographic information systems (GIS) whose essential component is computerized spatial (geographical) oriented information system of soil properties research materials focused on resource-saving soil processing technology use opportunities. Effective field management technologies envisage a global navigation system (GNSS) comprehensive application including global positioning system (GPS) belonging to this group of systems (Celms, Ratkevics, Baumane, 2014). Along with navigation and positioning systems various sensor systems and technology software options are used in both cases. It must be recognized that development and usage of the GNSS systems with the possibilities of attached sensors together with information technology and software development pace continues to significantly outpace the development of agronomic thought and practices which are currently unable to follow synchronously the new technological advancement and possibilities.
It was found that the introduction of the latest technologies in Latvia is negatively affected by the limited intellectual agro service support by this meaning trained specialists (Blackmore, Moore, 1999). The lack of agro appropriate specialist training did not contribute application of new technologies - even in cases when equipment was available for local farmers. However, researchers of the Latvia

University of Agriculture carried out the research in this direction already in 2004 (Lapiņš, Cers, Putniece, 2013).
Besides, the studies carried out in Latvia to date give evidence that:
- effective field management systems increase productivity with the working element accurate and repeated motion in parallel routes by managing driving steering systems.
- Professional and properly organized GNSS - GPS application in parallel management systems of tractors and harvesters is a prerequisite for the implementation of resource-saving technologies.
- When working with several harvesters in one farm, it is necessary to use compatible, adjusted, validated navigation systems and programs (such as "GPS Pilot" and "Auto Pilot", "Agrocom Net NG" - "Agrocom Map" (Ess, Morgan, Parsons, 2012).

The available sources of literature and research publications point out that information of harvest and farmland treatment results is required for at least five years' period, which is not a one-time measurement or observation, because the data-matching quality from different years is very important to determine stable agricultural land areas and transform them accordingly (Celms, Ratkevics, Baumane, 2014).
To obtain more reliable results in addition to the direct measurement of the formation of the yield, it is necessary to apply indirect distance measurements associated with aerophotogrammetry measurements, remote sensing with digital image analysis and different light spectrum sensor measurements. These technological solutions demand specific knowledge and experience in organizing the collection and processing of the necessary information and matching it with the data obtained either earlier or from other systems. It is required to have the knowledge of GNSS application options and conditions for obtaining the position and positioned accuracy, data matching/ transformation rules (Celms, Ratkevics, Baumane, 2014). As was noted in the previous study, "In spite of the short history of development of precision farmland in Latvia, such services niche offer in recent years is not empty, there are entrepreneurs who several years takes and develops various technological processes of production and transport - up segments using directly GNSS and related opportunities". The company "CLAAS" operates in farming business providing implementation of the guaranteed compatibility program 'Telemetric' systems and service. The company provides control of technical systems and organize the logistics in large farms and partly provides security guards for the equipment (CLAAS Braukšanas optimizēšana, 2012).
The specialized agricultural services company "iAgro.lv" was formed in 2013 and expanded its activities in 2014 dealing with navigation and sensor package installation and service for agricultural machinery.
The publication of 2014 set the aim to confirm that a preparatory and investigation phase in using precision farming systems including GNSS technology related to them in Latvia has come to an end transforming into massive practical implementation in the process of agricultural business. The obtained results of the study showed that in recent years the use of modern GNSS solution volumes in Latvia for agricultural equipment and technology has increased and GNSS correction signal permanent station network "LatPos" can be regarded as an essential source of information for the identification of this growth in Latvia, especially with the respect to the exact user data segment. Using selected and keying the information source data for the period from 2011 to 2013 inclusive, it was determined that the period of GNSS service users - such as agricultural land processing a number of companies experiencing rapid growth. The aim of the article is to justify the forecast expressed in the last year's publication regarding the increase of the use of precision farming systems thus confirming the fact that their application has moved from a research phase to massive practical implementation and operation in agricultural production (Celms, Ratkevics, Baumane, 2014).
The following tasks were set to achieve the aim:
1. Make sure that there was not the identification source of alternative and reliable GNSS precise data users for agricultural businesses during the 2014 in Latvia;
2. By using the selected information source, to obtain and systematize information on the precise GNSS system users in Latvian agricultural businesses in 2014 and identify the growth rate of users;
3. In framework of the research aim, to find out the growth dynamics of the number of users and used GNSS services during the period up to January 2015 and a compare it with the forecasted growth of the previous study;

The research findings proved that in 2014 there was a rapid increase in the demand for accurate global navigation system services in farmland processing equipment and technical solutions in the user

segment. The source of information continues to show sufficient effectiveness and availability, and currently there is not an effective substitute to it.

Materials and methods

In order to assess the situation of the exact farmland processing system implementation and its results, the authors continued to examine performance of the previously identified GNSS real-time adjustments station system "LatPos" - as an information source of the number and qualitative date of active users of precision farming systems of numerical and qualitative indicators of information sources. At the same time, using all possible sources of information (surveys with equipment suppliers, service users and the community members, exploring public sources of information), taking into account the world practice recommendations, alternative precise data delivery systems' offers and real fixed cases in Latvia were searched and examined.

The selection and analysis of options was based on equivalent systems which offer GNSS / GPS systems precision of application for agricultural land with accuracy not less than 1 meter (actually examining the position accuracy of 0.1m). Others are not valid to be included among precision farming systems according to the available international literature on the criteria (Celms, Ratkevics, Baumane, 2014). To verify the precision farming technology user growth during 2014, the information that showed to convincing signs about system users was selected from the available DGPS system "LatPos" data archive and customer service information system – they were agricultural businesses where the intended usage and the facts were associated with corresponding agricultural machinery operation. The companies - which required services as precision farming machinery distributors and maintenance service operators were searched and identified. The results led to the accumulation of statistical information, selection and systematization. The available users were clearly identifiable as customers and users of precision agriculture, as well as those who ordered DGPS services for more than one unit of agricultural machinery. The analysis of the data was based on the results of the previous years and singled out those companies, which registered as precision farming equipment users in 2014 and which had former customer commitments.

The obtained information was arranged according to years, the previous years were checked and the analysis of the information performed resulting in the table of the number of users and use, the diagram of the growth dynamics and dynamics characteristics for the time period of 2011 - 2014 year. In conclusion, a comparison between the forecast for 2014 and the newly acquired actual growth was performed to find out convincing answers to tasks of the study.

Results and discussion

The precision farming system requirements for the determination of spatial coordinates accuracies require that the accuracy not less than 1 meter, but in practice it is 0.1 meters accuracy approximation. Other systems, according to the criteria mentioned in the international literature, are not added to the precision farming systems. The projected accuracy certainty today is only relevant in the civil application systems, which are capable of using GNSS / GPS data that are corrected online by DGPS (differential GPS correction) data in real time. Today two basic DGPS data extraction options - individual systems and network systems solutions are found in practice. In previous study it was found out that the developed countries' practice today is dominated by a network solution (collective) DGPS data acquisition systems use but individual systems' users in agriculture are not considered to be significant. The assessment of the situation in Latvia in 2013 showed that network solution DGPS - national base station network "LatPos" functions in Latvia without serious competition (Celms, Ratkevics, Baumane, 2014).

When the precise field management technologies research was initiated in Latvia in 2004, the cereal harvester "CLAAS Lexion 420" was used to form the first yield map in SIA "Vecauce", Ltd, in Glūdaiņi field (Lapins et.al. 2008) (Dinaburga, 2011). Using a specially equipped harvester, the location in the field was fixed with the accuracy of 1 meter, which was obtained by combining the signals of GPS and DGPS (differential GPS correction) - taking an individual data correction system because the collective DGPS at this time did not work in the country. As a result the harvest map with different productivity levels at intervals depending on the grain capacity in certain parts of the area was obtained relatively characterizing the soil fertility of certain areas. The yield map provided the opportunity to characterize the level of yield from a variety of field plots (Lapins et.al. 2008; Lapins et.la. 2012; Dinaburga et.al. 2008; Lapins et.al. 2011; Moore, 1997). Such maps created opportunities to assess the real situation in certain fields, and even parts of the harvest to identify influencing factors

(Dinaburga, 2011). It should be noted that in 200, the researchers of Latvia were forced to buy additionally (without a sensor kit and agricultural machines) and operate a special, relatively expensive individual, professional GPS permanent station set of systems management software, data transmission system and have additional costs of regular maintenance activities, calibration and the necessity to ask the help of highly qualified specialists. The result showed that in Latvia, like it is in developed countries, such individual equipment users in agriculture are not considered to be significant users. Individual system application is also difficult to control and therefore the study of individual systems was not further considered.

The practice of network solutions (collective) DGPS data acquisition system for use practices dominate in the developed countries, often these collective systems are built and maintained by the state. In the world there are cases where non-governmental bodies or several keepers (even competitors) maintain a collective system. It should be remembered that the collective system users' benefits are reinforced by the structural characteristics - when a large area is covered with DGPS station network, which provides a guarantee of high-precision data acquisition and covers a large area. For individual stations, if the distance from DGPS stations increases, then the positioning accuracy is reduced (Celms, Ratkevics, Baumane, 2014).

Repeating the identification process of a competing precise DGPS service providers in Latvia, it was confirmed that the first national DGPS base station network "LatPos" was established in 2005 providing today all the coverage of the territory with high-precision adjustment data and position coordinates accuracy in real-time with more than 1 dm. Later a similar station network for city of Riga - "EUPOS" was set up. In recent years, the company "Trimble" is trying to realize the precise DGPS services in the virtual network. Furthermore, the information on the installment of an individual correction station by the companies "Topcon" and "Hadnet invest" was found providing separate correction station installation for the needs of 5 farms in 2013 as well as on the expansion of base station network "Hadnet". The analysis of the obtained information led to the conclusion that only one system continues to dominate and grow as a serious DGPS signal supply structure in precision agriculture. It is the government established DGPS system network "LatPos", which is the only guaranteed accurate data covering system for the whole territory (Celms, Ratkevics, Baumane, 2014). The system's customers' base has even more in one year's time on the basis of users which used applications installed as individual stations holders and the "Trimble" virtual network users. The station network of the city of Riga "EUPOS" continues to maintain its limited service area, limited to Riga and its surroundings and is not therefore widely used in agriculture and not competitive. "Trimble" virtual network of practical use has not developed in that direction during the year. Even more, agricultural navigation systems supplier and service provider in Latvia "i Agro" has become the largest customer of "LatPos" system by means of which the number of subscribers during the year increased by 25 connections. LatPos customer base has also added virtually all agricultural entrepreneurs, those who by 2013 were individual DGPS stations' users.

So, once again, we can conclude that "LatPos" system network has no alternative in the precision farming sector covering the entire territory of the country by providing real-time measurement accuracy of more than 1 meter (Celms, Ratkevics, Baumane, 2014).

The DGPS service users' information obtained from "LatPos" regarding the precision farming systems was included in the table, which contains both the 2014 forecast and the actual figures achieved this year (Table 1).

Table 1

DGPS "LatPos" services for precision agriculture system users

	User of system	Years				
		2011.	**2012.**	**2013.**	**2014.** prognos	**2014.** Realy
1	„Cors Group Agrospeed u.c."	5	5	5	5	5
2	„Hofer&Pautz"	2	2	2	2	2
3	„Kone Kesko Riga"		1	1	1	2
4	„Agrikula"		2	2	2	2
5	„Tērvete" (iAgro)			1	1	3
6	z/s „Brasliņi" (iAgro)			1	1	2
7	z/s „Katlauki" (iAgro)			1	1	2
8	z/s „Ķauļi"			1	1	1
9	z/s „Ķiveļi"			1	1	1
10	z/s „Klagāti"(iAgro)			1	1	2
11	z/s „Zariņi" (iAgro)			2	2	2
12	iAgro.lv - equipment supplier				8	25
13	Second equipment supplier				1	1
	new users/connections prognosis 2014				9/3	
	Other real users with iAgro DGPS connections support					11
Summary: users/connections		**2/7**	**4/10**	**11/18**	**22/30**	**24/50**

The analysis of the information shown in the table confirms the volume growth dynamics of the accurate farming system users (see Fig. 1.) in relation to 2014 forecast and according to the real achievements of 2014 (see Fig. 2.).

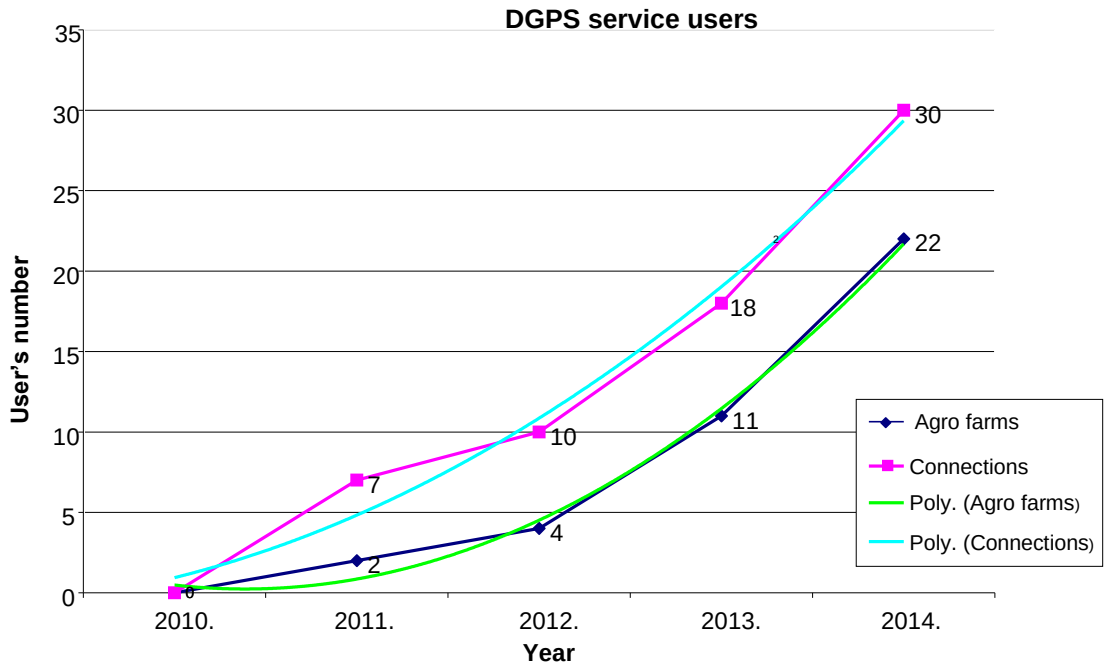

Fig.1. Accurate farming systems users and forecast to 2014.

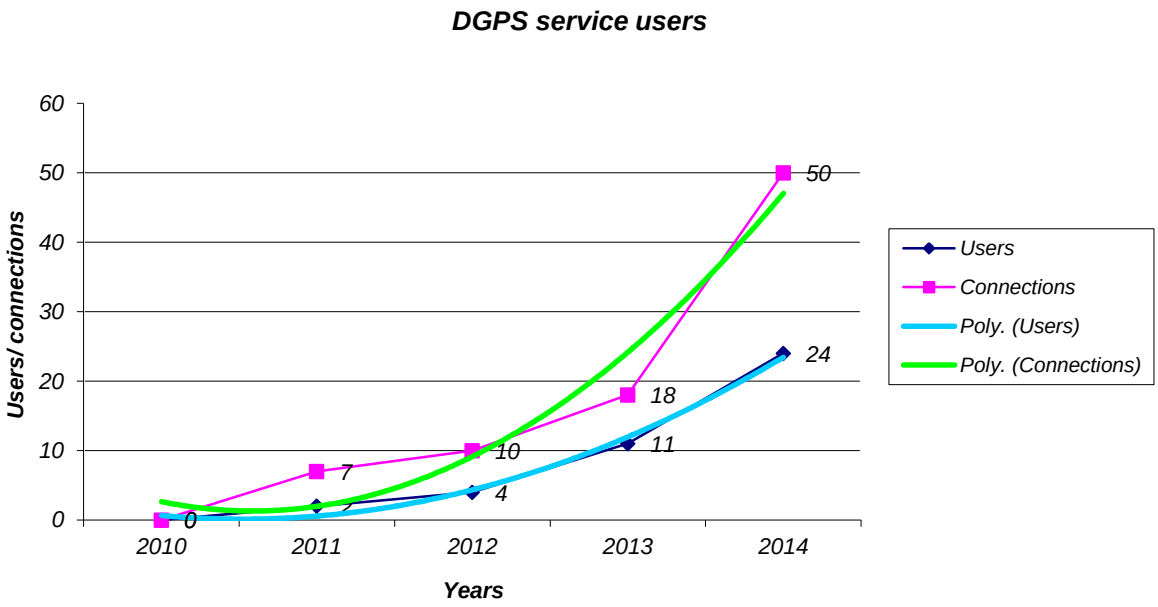

Fig. 2. Accurate farming systems user's realities to January 2015.

The differences are identified only in the fact that forecast in 2014 proved to be considerably modest and suggested by 22 users with 30 connections less than it has proved in practice with 24 users and 50 connections, which can clearly be considered that the numbers from 2011 year approximately doubled over the previous year. The assumption was also proved that the number of registered customers (Agro farms) is less that the number of connections. During the last year the number of connections increased for both existing customers and new subscribers - who have more than one service connection. As a new trend can be considered the fact that the equipment supply and service contractors (iAgro) also enters as a mediator among service functions "LatPos" and agro firms - as the ultimate beneficiaries. This is evidenced by the fact that the company ordered 25 steady working DGPS connections (half of the country's existing connections) - but for the company needs regularly no more than 2 connections are used (advertising and equipment installation needs), the other connections are operated on machinery supplied to customers. This situation is somewhat complicated by determination of end users - the number of farmers with a connection not changing the total amount of connection. Taking into account the fact that at least two more DGPS connections have been requested by the next agricultural equipment distribution businesses – one can foresee an even sharper increase in the number of users in the next few years. According to various calculations of experts and comparisons with the experience of the developed countries about 300 agricultural entrepreneurs could become relevant users of precise agricultural systems. By contrast, if we consider that potential users are all companies with 500 ha or more of registered agricultural land, then there are 491 potential users in Latvia, and the large number of users can also have much smaller land areas.

The previously predicted forecast is justified that even with a negative impact of different levels of economic and other crises, a common path will continue and will rely heavily on numbers of businessmen and professionals, their qualifications - who will be able to offer the adequate quality and the scope of services to farmers. It is also possible to confirm the findings that precision farming systems' introduction in Latvian agriculture is no longer considered an exclusive phenomenon which only large and rich holdings of developed countries can afford, even here they are becoming an everyday reality. The amount of precision farming systems using agricultural business identified in the research at the end of 2014 could be regarded as the beginning of the introduction to precision farming and further increase in the dynamics of the system implementation could be expected for several years. In addition, an assumption has been clarified that "LatPos" system data about users and their real-world activities is a great advantage - they are available in one place and are accurate last day data without the need for time-consuming surveys, questionnaires, declaration, follow-ups, official reports according to different standards. The source of information almost completely eliminates the subjective factors of human influence on the results (Celms, Ratkevics, Baumane, 2014). System features also allows for a much broader analysis of the material extraction of DGPS system practical applications in agriculture, the aspects of the use and users.

Conclusion

The obtained information and the results of the research with confidence confirm the growth dynamics of the precise GNSS systems' users in the agricultural sector in the country and support the hypothesis that the current period of development of the GNSS-related precision farming systems implementation and use presents systematically increasing dynamics in Latvia.

The dynamics of growth shows that an initial stage of preparation and research in precision farming system use in relation to GNSS technology by agricultural businesses and the practical implementation process in Latvia have been completed.

The forecast expressed in the last year's publication regarding the increase of the use of precision farming systems has been justified thus confirming the fact that their application has moved from a research phase to massive practical implementation and operation in agricultural production.

Latvian DGPS system "LatPos" nowadays can be considered as an alternative, almost perfect and wholesome scientific and statistical source of information on the Global Navigation Satellite System for precision farming in the agricultural sector offering simple, fast and timely information necessary prospectively.

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