The Electronic Atlas of Socio-Demographic Development of the Regions of the Republic of Kazakhstan: Elaboration and Main Stages of Creation

Nyussupova, G.,[1] Tokbergenova, A., [2] Aubakirova, G.[3] Kelinbayeva, R.[4] and Kalimurzina, A.[5]
Al-Farabi Kazakh National University, Department of Geography, Land Management and Cadastre, Almaty, Kazakhstan, E-mail: gulnara.nyusupova@kaznu.kz[1], tokbergen@mail.ru[2], aubakirova.gaukhar@gmail.com[3] zhar80@mail.ru,[4] kalimurzina.aisulu@gmail.com[5]

Abstract

The author's vision of the concept of the implemented web-atlas of the socio-demographic development of the regions of the Republic of Kazakhstan is described in the article. The prerequisites of the development of the electronic atlas as an original cartographic product are considered, the thematic and technological structures are described. The interface of the atlas follows the classical client-server paradigm, reflecting the needs and specifics of three groups of users: administrators, moderators and Internet users. The following tasks were solved in the creation of the web-atlas using GIS: design of technology for manual and automatic loading, storage, analysis and presentation of data; development of the information structure of the web-atlas both as a system in general and separate databases in particular; elaboration and creation a system of geoinformation-cartographic modeling for the assessment and construction of map elements; development and generation of technology for access to distributed resources of the atlas. The ESRI software applications and the Open source mapping server were used in the development of the socio-demographic web-atlas of the regions of the Republic of Kazakhstan. The cartographic module of the web-atlas is accompanied by scientific socio-demographic descriptions, explanatory texts, drawings, forms diagrams and tables.

1. Introduction

Abroad accumulated vast experience in creating such atlases. The first electronic atlas that received a wide international response was the Atlas of Arkansas (2010). The Atlas included about 100 maps, combined into 16 chapters, showing the physical and geographical, social and economic and historical and geographical characteristics of the state (Tokarchuk et al., 2015).

«The social atlas of Europe» (2014) is the first atlas of the whole of Europe, representing the historical, economic and human development of Europe. The Atlas has a clearly expressed hierarchical structure, covers the general geographic, natural and social and economic themes (Ballas et al., 2014). In the chapter «Demographic Atlas of Croatia – Web AIS» of the book «Cartography in Central and Eastern Europe» methods for creating an information demographic atlas are described (Hartmut et al., 2010).

The «The Atlas of the Real World: Mapping Our Life» discloses methods for creating socio-economic maps and contains maps and cartograms that show countries and regions by demographic and other indicators of the geographical distribution of social indicators (Dorling et al., 2010).

«Social atlas of Australian regions» and the Social Atlas of the City of Brisbane (2008) are complex cartographic works of scientific and reference and applied function showing all important features of the population, as well as indicators of the quality of life (Social atlas of Australia regions, 2008).

The «Atlas of Human Development of Brazil» (2013) provides up-to-date information on human development in the Brazilian regions, and also displays over 200 indicators for 1991, 2000 and 2010 (Atlas of Human Development of Brazil, 2013).

Since 2003 the project program «Social Atlas of Russian Regions» has been started in Russia. On the basis of the conducted researches the book «Russia of regions: in what social space do we live?» is published and released the disk «Social Atlas of Russian Regions» with analytical and cartographic material in 2005 (Russian regions: in what social space do we live?, 2005).

Kazakhstan has experience in creating electronic atlases and geoinformation atlas systems in various sectors of the economy. The Center for Remote Sensing and GIS «Terra» created an ecological and geographical atlas of the West Kazakhstan region

(Geldyyeva et al., 2010). In 2010 the Institute of Geography of the RK issued the National Atlas of the Republic of Kazakhstan in Kazakh, Russian and English languages in 3 volumes (National Atlas of the Republic of Kazakhstan. 2010). In 2012 Kazakhstan's scientists presented the «Social and demographic atlas of the West Kazakhstan region», which is a complex cartographic model of the population of the region. Thematic content of the maps is based on statistical data for the years of the census 1989, 1999 and 2009 (Sdykov et al., 2012). In 2017 the «Solar Atlas of Kazakhstan» was presented under the UNDP project, where the spatial distribution of solar resources of Kazakhstan was represented (Atlas of solar resources of the Republic of Kazakhstan).

The complexity of socio-demographic phenomena, their bright regional and intraregional differences determine the presented electronic atlas as a convenient tool for assessing socio-demographic development and decision-making at the state, regional and local levels. The electronic atlas demonstrate principles of organization and presentation of spatial information of socio-demographic indicators of Kazakhstan regions for 1991-2016.

2. Data and Methods

The creation of a socio-demographic section of the atlas information system is based on the method of geoinformation mapping, international and domestic experience of complex mapping of social and demographic processes. In developing the content of the maps, special attention was paid to methods for assessing social and demographic development (Nyusupova et al., 2017). During the vector mapping the ArcGIS 9.3 by ESRI and open source QGIS packages were used. Interaction between ArcGIS and QGIS performed using the shapefiles. Web oriented mapping service is based on the Java technology based GeoServer 2.14 [https://docs.geoserver.org/latest/en/user/] application. Client side map rendering is performed by OpenLayers 4.2 JavaScript library.

User interface of the Web atlas is developed in the ASP.NET Framework. Linked with popular web libraries like Bootstrap they allowed to create modern website-like atlas with proper input and output data validation on every form. The information base used while creating atlas was the official data of the Committee on Statistics of the Ministry of National Economy of the Republic of Kazakhstan on 14 regions of the Republic and Astana and Almaty cities, including statistical collections, materials of the information-analytical system «Taldau», as well as cartographic materials,

materials of scientific conferences and seminars, dissertation abstracts etc.

The choice of indicators for the creation of electronic atlas maps was due primarily to the following principles: the availability of information for mapping and modeling; the possibility of considering the socio-demographic processes under research in dynamics; comparability of thematic indicators for different territorial levels; the possibility of creating integral characteristics reflecting the socio-demographic levels of development of the regions of Kazakhstan. The main goal of creating an electronic atlas is to create a spatial geodatabase and thematic socio-demographic maps of the regions of the Republic of Kazakhstan on the basis of available statistical indicators and cartographic materials using GIS technology, digital cartography, a system of cartographic, statistical, analytical methods and mathematical modeling methods.

3. Analysis and Results

3.1 Stages of Developing Electronic Atlas

«Electronic atlas of socio-demographic development of the regions of the Republic of Kazakhstan» is a multi-purpose geoinformation and reference web resource that allows to create and maintain a single geoinformation database, to search for and provide the user with the required materials in text, graphic and cartographic form, presented in three languages (Kazakh, Russian and English) and operating on the server of the al-Farabi Kazakh National University (Electronic atlas of social and demographic development of the regions of Kazakhstan) 80 socio-demographic maps were formed in dynamics on the basis of groups of statistical indicators in the atlas.

The entire process of developing the electronic atlas was carried out in several stages:
1) collection, preparation and processing of spatial and statistical data;
2) development of the interface and functionality of the web application;
3) development of cartographic design of a web resource based on geoinformation software;
4) publication of web-based GIS services;
5) web-design of the electronic atlas portal;
6) web atlas testing.

The initial stage of data collection and processing allowed creating an integrated geodatabase that combined diverse spatial and statistical information from various sources. The spatial data base is represented by the following thematic GIS layers, as water resources (lakes and river network); transport

infrastructure in the form of roads and railways; administrative division, including the borders of the state, oblasts, as well as settlements and their characteristics. Methods of geoinformation analysis, remote sensing data processing and methods of digital terrain mapping were used based on the application of the licensed program ArcGIS 9.3.1 in creating a digital geographic basis for the socio-demographic atlas of the regions of the Republic of Kazakhstan. Each layer of the cartographic basis is accompanied by a database of attributive information, where data was entered in Kazakh, Russian and English on qualitative and quantitative characteristics characterizing the spatial object (names of geographical objects, their categories and values). Previously, the structure of all layers was developed; the wording of the names of layers and fields in the table of attributes was defined (Development and creation of the electronic atlas of the socio-demographic development of the regions of the Republic of Kazakhstan using GIS technology and information protection, 2016,).

3.2 Indicators of Socio-Demographic Development

The statistical information database consists of two major thematic blocks: demographic and social, represented in turn by a group of indicators (109 statistical and 88 calculated demographic indicators, as well as 174 statistical and 40 calculated social indicators). All the data of the thematic database are presented in dynamics for 4 years: 1991 (obtaining Kazakhstan independence), 1999 (first census of sovereign Kazakhstan), 2009 (second census), and also for 2016 (the latest officially submitted data) (Table 1).

All indicators of socio-demographic development in the web application of the atlas are divided into types - statistical indicators, calculated indicators and calculated indices. Statistical indicators are data from official statistical sources (www.stat.gov.kz, official statistical compilations, etc.). Each statistical indicator is presented in Excel format, filled in by a single template with an identification number, indicating the type of data source by years. The download of statistical data includes the functions of creating and uploading a template for the selected statistical indicator in Excel format, as well as automatically loading data from template-filled files, the ability to edit downloaded data or manually enter, view downloaded data by selected criteria (by indicators, years, regions) . At the same time, the application of the atlas implements the possibility of data parsing-the function of automatically loading the values of statistical indicators from the portal of open data of the Republic of Kazakhstan or from similar sites,

loading from which allows you to compare the fields by years, regions, values. Statistics are represented by absolute values associated with each administrative object on the map. Indicators of this kind include absolute birth rates, the number of students, employed and unemployed, the population, and others.

The calculated indicators are calculated directly in a web application using the implemented calculation constructor using arithmetic operands and formulas on the basis of statistical indicators of socio-demographic development. These are such relative indicators as population density, natural growth rate, birth rate, death rate, provision of children with places in pre-school organizations, the share of housing stock and many others (Figure 1). Calculation of integral indices of socio-demographic indicators in the context of the regions of the Republic of Kazakhstan for 1999-2016 was also carried out in the web application of the atlas on the basis of a systematized and processed statistical database for 1991, 1999, 2009, 2016, with the help of a calculation designer. In the atlas, the method of linear scaling was applied for an integrated assessment of the socio-demographic development of regions, which is the most complete and reliable, the data were systematize and unified, i.e. are reduced to one dimension.

Among all objective methods of quality of life linear scaling methods has a significant advantage. It is based on the definition of reference points (maximum and minimum values of indicators). The calculation is performed according to the equation (1) if the relationship of indicator and the quality of life is positive, according to the equation (2) if the relationship is negative.

$$I_!' = \frac{X_j{}^i - X_{min\ i}}{X_{max\ i} - X_{min\ i}}$$

Equation 1

$$\frac{X_1{}^{i\prime} - X_{min\ 1i}}{X_{max\ i} - X_{min\ i}}$$

Equation 2

The boundary for the share indicators is between 0% and 100%. This method is widely used in the world practice of assessing the quality of life. For example in HDI (Human Development Index). One of the main advantages of the method is that you can use a large number of different statistical data, transparency and simplicity of calculations, lack of expert assessments and unjustified weight coefficients, ease of interpretation of the results obtained.

Table 1: Structure of the thematic database

Thematic blocks	Groups of indicators	Thematic maps
Demographic	Marriages and divorces	Marriage; divorce
	Natural movement of the population	The natural movement of the urban, rural and entire population; birth rate, death rate and natural population growth; causes of mortality
	Migration	General population migration; migration in the city and in the countryside
	Infant and maternal mortality	Infant mortality; maternal mortality
	Life expectancy	Expected life expectancy (ELE) of urban, rural, female, male and the entire population; the difference between the life expectancy of urban and rural, males and females
	Population settlement and urbanization	Population density
	Population structure	The population over the age of 65, aged 15-64, aged 0-14
	Population	Population dynamics; population growth; ratio of urban and rural population
Social	Housing fund	Total, urban and rural housing fund; provision of total, urban, rural population with housing, the proportion of housing stock regions
	Health care	Morbidity of the population; provision of the population with doctors and medical staff; network of health organizations
	Culture	Libraries, cinemas, museums, theaters
	Education and Science	Pre-school organizations; provision of children with places in pre-school organizations; secondary, vocational, higher education; vocational and higher educational institutions; coverage of population with education; pedagogical staff; scientific organizations
	Offenses	Types of offenses; persons who have committed crimes; composition of convicts
	Labor and social security	Unemployment of the population; employment; nominal wages; pension provision; social benefits; level of economic activity of the population
	Tourism	Placement, Visitors by purpose of travel, Sanatoriums and dispensaries
	Standards of living	Gross regional product (GRP) by types of economic activity; the share of economic branches in the total GRP; living wage; average per capita nominal monetary incomes of the population
Integral		Index of socio-demographic development (ISDD); ISDD in crisis and full-scale method, Human Development Index

Figure 1: Registration form of the indicators

In addition, differences in individual indicators are more accurately taken into account in summation, the dynamics of real growth (decrease) in the quality of life index and each indicator within the limits of stable (reference) points are monitored.

Final formula for definitions the index of integral socio-demographic development of regions:

$$ISDD= (D+E+P+Q+R+S+T+F+U+V+H+W+B+C+X+Y+Z+AA)/18$$

Equation 3

18 indicators were used to assess the socio-demographic development of the regions, with the «weight» of all indicators being the same and equal to 1: life expectancy (D), infant mortality rate (E), maternal mortality per 100 000 live births (P), natural growth rate (Q), the provision with doctors per 10 000 people (R), the number of hospital beds per 10 000 people (S), the level of crime per 10 000 people (T), the number of students of all kinds educational institutions per 10 000 people (F), number of visits to theaters per 10 000 people (U), number of museum visits per 10 000 people (V), average housing provision per person (H), nominal cash income (W), share of population with incomes below the subsistence level (B), unemployment rate (C), provision of the population with cars in personal ownership for 100 people (X), number of received benefits (Y), provision of children with permanent preschool institutions for children per 100 places (Z), morbidity of the whole population per 100 000 people (AA), ISDD - the index of socio-demographic development.

At the next stage of the work, an interactive formation of thematic maps of the atlas was carried out, followed by visualization of them in the form of a cartographic work. When creating electronic socio-demographic maps in the Internet environment, the following determining factors were adhered to: the possibilities of implementing information retrieval functions; the possibility of integrated processing of cartographic and descriptive data; convenient forms of dialogue with the user and the availability of tools; the possibility of easy adaptation of maps to changes in the forms of input and output documents; the availability of a variety of data models specialized in information processing tasks, tightly integrated among themselves (Yablokov et al., 2016.).

The cartographic basis of the maps created in ArcGIS in the form of vector spatial layers was exported to the GeoJSON format, with the mapping of the attribute fields of the layer and the fields of the directory (population, area). Files in GeoJSON format were imported to the spatial database provided in the GeoServer setup. The open source QGIS program was used to convert vector layers to GeoJSON format. Computed values, like HID (Human Development Index), are stored separately also in the GeoJSON format. These data doesn't imported to GeoServer database because these data could be easily generated and doesn't contain primary information. Spatial data located in the GeoServer transferred to the client through WMS/WFS service, with images were sent like image tiles. Secondary data, stored in the GeoJSON format were sent to the clients browser directly, al drawing action performed by the client side JavaScript library. It should be noted that the spatial layer of the borders of the regions of the Republic of Kazakhstan by years shows on the maps all

administrative and territorial changes of the regions of the republic from 1991 to the present (merger, abolition and creation of administrative-territorial objects, expansion and reduction of their area).

Statistical information was structured, localized and associated with the cartographic basis. This approach allowed to display the territorial aspects (signs) of the information being processed and to use a wide range of geographical and cartographic methods for further analysis. The main ways of administrative information presentation include spatial visualization of databases, interactive maps, graphs, diagrams and other graphical ways of providing information. All social and demographic thematic maps of the electronic atlas are sets of maps, united in thematic sections and subsections (Table 1). Maps provide a spatial representation of the quantitative and qualitative characteristics of the population, its composition and structure, the characteristics of labor resources, the level of education and health, and, in general, the level of socio-economic development of the population.

The formation of thematic maps (the list of maps is presented in Table 1) was carried out by selecting statistical indicators to display the values. The most acceptable method of mapping relative and absolute demographic and social values is the method of color scales (cartograms). It is based on the coloring or hatching of territorial units (administrative regions) in accordance with the adopted scale, which gives a graphic picture of the intensity of various economic, demographic, social processes; allows seeing more clearly the spatial differentiation of socio-demographic development of regions.

The cartographic classification of quantitative phenomena was carried out manually and using standard classification schemes. For the vast majority of relative and absolute indices, the classification was made by a method close to the method of equal intervals. The aggregate values for individual regions, such as the structure of the population, the share of housing in the housing stock, the share of GRP by types of economic activity, etc., were visualized on maps by off-scale signs - circular diagrams. The bar graphs show the comparative figures or the value of this statistical series. An example is the data on the number of students, schoolchildren, provision of the population with doctors and medical staff, the number of types of offenses, GRP by types of economic activity and much more. The constructed map diagrams allow you to track the patterns, trends, relationships and the structure of socio-demographic data, which is difficult to see when studying the numerical values of the table.

An important step in creating a socio-demographic atlas was the interactive implementation of integrated maps. It is based on the use of particular indicators of various groups of indicators as indicators, calculated on the basis of mathematical calculations. Integral indices are calculated on the basis of collected statistical data on more than 50 indicators of various spheres of life: social, demographic and economic trends in 14 oblasts and Almaty and Astana cities for 1999, 2009 and 2014. The integral assessment of socio-demographic development is calculated by the following four methods: by point, by crisis, by the full method and by the human development index (HDI).

Calculations of the integrated assessment have identified a typology of regions according to the level of socio-demographic development of the regions. The obtained results make it possible to trace regional differences in complex indices formed from a set of partial data. The architecture of the web atlas of the socio-demographic atlas of the regions of the Republic of Kazakhstan, as a rule, follows the classical client-server paradigm. The interface reflects the needs and specificity of the work of three groups of users: a system user or administrator who provides access to the functionality of the web portal in accordance with the user's credentials, the moderator (the user of the IR with the authority to edit the web application directories, load and edit the primary information, generate maps) and the end-user of the Internet aimed at getting an open data view the values of indices and indices of socio-demographic development of regions and created on their basis maps, reporting.

The atlas user interface displays a systematized list of atlas data with the ability to search for indicators and maps through the «Indicator and Map Tree». All registered indicators are displayed in the hierarchical tree of indicators and maps (Figure 2). If you select the «Data» icon in the tree, the user moves to the index value review page, with the ability to sort and select data by region, year, and data source types. Registering a brief description of the map and linking them to certain indicators provides all Internet users of the atlas to search both the index tree and the word search function. There is no binding to the tree of indicators in forming integral maps.

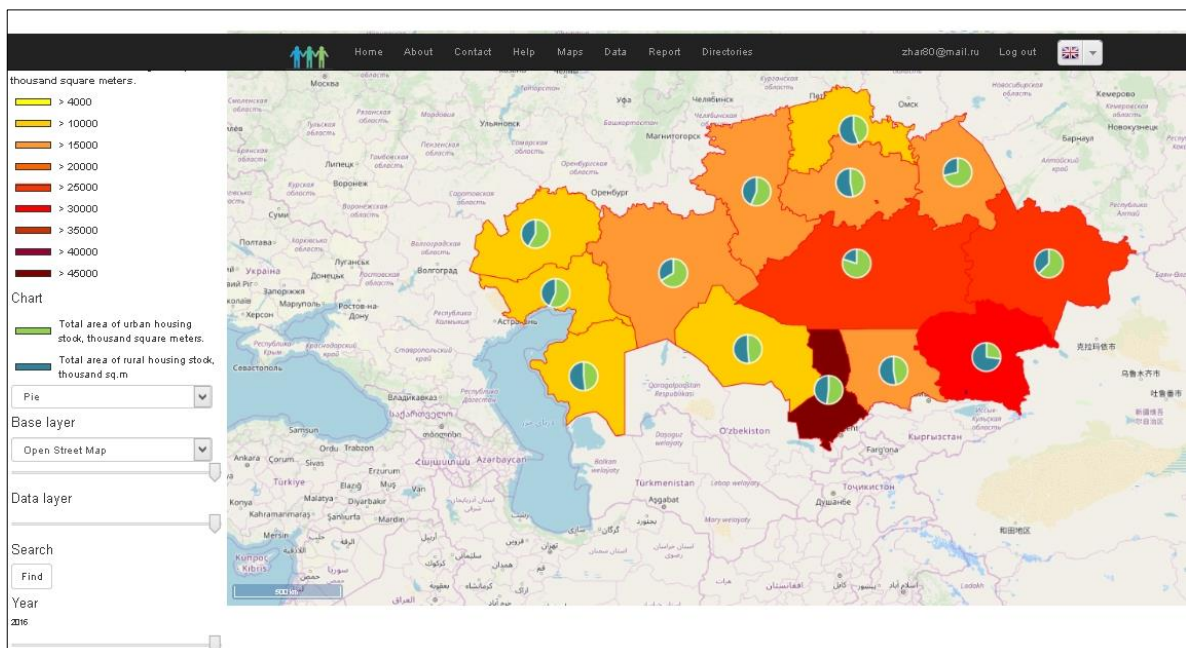Figure 2: Structure of the tree of registered indicators and maps

Figure 3: Visualization of the «Housing Fund» map

When selecting maps from the «Indicator and Map Tree», a cartographic viewer is called, which provides an opportunity for interactive interaction with maps for viewing and analyzing indicators of socio-demographic development. The main active visualization field intended for Internet users displays thematic maps, with the possibility of scaling cartographic mapping, language selection,

the left field reflects the legend of this map and brief explanatory information to it. In this case, the development of map legends was carried out in accordance with general principles: the coordination of quantitative classifications of indicators of various hierarchical levels, taking into account the features of socio-demographic phenomena and processes at each level; development of a single basic legend for each indicator based on the analysis of quantitative values of individual socio-demographic characteristics; accounting and highlighting in the legend with the help of a color solution the demographic threshold values of individual characteristics that separate the different stages of development of demographic processes in the regions of the republic.

Pointing the cursor on a certain region on the map leads to the formation of an information window with the values of all indicators displayed on the map. When selecting an indicator in the window, a diagram is called for comparing the dynamics of the indicator values in the selected region and the average republican value of the indicator with statistical information for the selected region. Multimedia facilities give new opportunities to demonstrate cartographic images not only statically, but also dynamically - in the form of animation. Using the «Time slider» tool allows you to display the dynamics of socio-demographic development indicators by years (from 1991 to 2016) (Figure 3). At the same time, the atlas web portal implements the ability to create and upload custom reports by region, indicator or years and export them in MS Excel format. Developed in the process of creating a socio-demographic atlas, the web-geographic information system is capable of providing a mass flow of primary information localized in space and time, its aggregation, processing and circulation in the form of a permanent socio-demographic monitoring accessible for use over the Internet. This creates a universal scalable information and management system of socio-demographic development that allows implementing a mode of situational awareness and can be used to solve state and regional tasks to improve socio-demographic processes. The acquired experience in the creation of electronic atlas mapping and the formed spatial geodatabase will become the basis for carrying out similar works both in individual regions of the republic and outside it.

4. Conclusion

Creation of the geoinformation platform of the web resource «Electronic atlas of socio-demographic development of the regions of the Republic of Kazakhstan» is new in the formulation, approaches and methods of implementation of the direction in the republic. The materials of the spatial geoinformation database «Socio-demographic development of the regions of the Republic of Kazakhstan», combined into a single system, are able to reproduce electronic maps, descriptive text, a series of map-forecasts, analytical maps, map-recommendations, providing a complete complex description of socio-demographic processes in the regions of the republic for years independent Kazakhstan.

The thematic socio-demographic maps of the electronic atlas, being an important part of the web-geoinformation system, will provide scientific, methodological and informational support for state, regional and local administrative structures in obtaining a quantitative and qualitative assessment of the existing socio-demographic trends in the development of the regions of the republic for developing programs, for improvement of socio-demographic indicators and improvement of the system of social and demographic management processes of the regions of Kazakhstan. The electronic atlas can be used for perspective scientific research and applied development, the development of thematic mapping, the formation of sectoral and universal spatial geodatabases and geographic information systems of applied orientation.

In general, the results of the research can be used to further improve the level and quality of life of the population in the regions of the republic, improve the social infrastructure, increase human capital, develop social and demographic policy of the Republic of Kazakhstan.

References

Atlas of Human Development of Brazil – http://www.atlasbrasil.org.br/2013/en/

Atlas of solar resources of the Republic of Kazakhstan - http://atlassolar.kz/

Ballas D., Dorling D., Hennig B., 2014, The Social Atlas of Europe, (Bristol: Policy Press)

Development and creation of the electronic atlas of the socio-demographic development of the regions of the Republic of Kazakhstan using GIS technology and information protection, 2016, Almaty. Report on the research work

Dorling D., Newman M. Barford A., 2010. The Atlas of the Real World: Mapping the way we live. (London: Thames & Hudson)

Electronic atlas of social and demographic development of the regions of Kazakhstan - www.atlassd.kaznu.kz

Geldyyeva G., Geldyyev B., Zubakin M., 2010. Thematic Mapping for Ecogeography Atlas of West-Kazakstan Region with GIS. ArcReview, 1 (52), 19.

Hartmut A., Aleksandar T., Dubravka S., Engemaier R., 2010. Cartography in Central and Eastern Europe. (Springer)

National Atlas of the Republic of Kazakhstan. Volume 1,2,3, 2010, (Almaty: Institute of Geography)

Nyusupova G.N., Kalimurzina A. Kelinbayeva R. Social and geographical research in the Republic of Kazakhstan with the use of GIS technologies/ European Journal of Geography. Volume 8, Number 3: July 2017 –UK. P.109-125.

Russian regions: in what social space do we live?, 2005, (Moscow: Pomatur)

Sdykov M.N., Golubev A.V., Tereshchenko T.A., Iskaliev D.Z., 2012. «Social and demographic atlas of the West Kazakhstan region». (Uralsk: Polygraphservice)

Social atlas of Australia regions, 2008. – http://phidu.torrens.edu.au/social-health-atlases

Tokarchuk S.M., Tokarchuk O.V., Trofimchuk E.V., 2015. Methodical foundations for the creation of regional electronic ecogeographical atlases, Pskov Regionological Journal, 22, 95-110.

Yablokov V.M., Tikunov V.S., 2016. Principles of creating a atlas information system based on the Internet for sustainable development of territories. Newsletter of Moscow University, 16 29-38.