CENSUS CARTOGRAPHY
CORE BASE OF CENSUS- AND SURVEY-TAKING

Introduction: The Instituto Nacional de Estadísticas (INE-Chile) is the technical body responsible for producing, analyzing and disseminating Chile's official statistics. As measuring tools, it uses censuses, such as the Census of Housing and Population, the Census of Agriculture, industrial censuses and others, as well as administrative records and representative samples of a given universe.

The census is the largest statistical operation carried out by a country, since it must reach every home and person, informant themself being the direct source that provides the data. To achieve this, the census mapping is a key tool in the operational and logistical aspects for organizing such a project, ensuring total coverage of the national territory and enabling a graphic display of the information.

Since the census cartography is a "simplified" mapping, aimed to be used as basis for gathering census information on site, its role is rather "complex" as it must meet elemental requirements such as being constantly up-to-date and disaggregated into urban and rural areas according to the borders defined by Chile's political-administrative division and census subdivisions; covering 100% of the national territory and allowing statistical data modeling.

From this perspective, since 1993 INE-Chile embraced the challenge of improving its mapping information, working jointly with the Municipal Works Department (DOM, by its Spanish acronym) and the Military Geographic Institute (IGM), through standard cartography (scale 1:50,000), gradually evolving in terms of the mediums that generate, store, and distribute spatial information, replacing analog by digital media. But even though these progresses allowed an evolution in terms of production, planning and data collection, this mapping still had some limitations in terms of data, source, availability, and updating methods.

Thus, in 2004, through the Sampling Frame Project, known as Marco Maestro (MM) in Spanish, INE-Chile restructured its methodologies and quality standards, gradually improving its cartographic databases, updating them every year, investing in human capital and training, making its technical department more professional, and incorporating technologies and infrastructure. Today, image mosaics and metric data updated to 2008 for significant areas of the country are available.

But even though progress has been made in many aspects, there is room to improve. Today, INE-Chile faces an even greater challenge, since the institution is currently planning the Eighteenth Census of Population and Seventh Census of Housing, which will be held in 2012. INE-Chile is currently working on the planning and preparation of base maps for the pre-census and census-taking, backed by major projects such as the National System of Coordination of Territorial Information (SNIT, in Spanish), working in conjunction with the IGM in the updating of regular maps and with DOM. Besides, INE has signed

agreements and alliances with other public and private entities for developing this project that is today our greatest challenge (description below).

GOALS

Main goal:

- To have up-to-date digital maps, covering all the national territory, for census and survey taking.

Secondary goals:

- To create partnerships, sign agreements and launch tender processes to get up-to-date base maps.
- To have base cartography of the whole national territory in digital format.
- To produce - timely and efficiently - plots and maps required for the planning, generation and delivery of data from the different stages of the censuses and related studies.

Methodology

Our mission is to prepare base census mapping and to generate up-to-date maps of urban and rural areas at various scales of representation.

Regarded as the primary input to carry out on-site work, the census mapping is used to support the pre-census stage (2010-2011). Through this process preliminary data on housing and people is collected in order to update areas that are not included in the base map, thus enabling the logistical planning of the 2012 Census.

Since the timeliness and quality are considered fundamental principles, the following activities are carried out to obtain the base map:

a) Incorporation of MM updates until 2010: In order to reduce the gap in the quality of statistical output to developed countries, the Sampling Frame (MM) was included as a strategic project in INE´s Plan for Public Statistics 2005-2010 which is intended to develop official statistics in readiness for the incorporation of Chile into the OECD. This project will see the implementation of a sampling frame that will be updated continuously with current information and location of homes, to ensure significant improvement in the accuracy of household surveys and reduction of non-sampling errors, as well as taking into account the construction of new private homes between censuses. By 2009 the new sampling frame for INE´s household surveys, will be defined as: "Universe of fixed geographical boundaries, called blocks, providing cartographic information, and information about the number of houses in each block, based on Census 2002, updated with newly constructed housing to ensure the selection of representative samples.

The MM Project brought with it the need to improve the available base mapping, because it is necessary to include in the sampling frame the growth of new constructions of occupied private dwellings, from the Directorates of Municipal Works DOM'S, using the information contained in Forms Received and final plans for new constructions emerging after the Census in 2002, as shown in Figure 1.

This is based on the integrated digital mapping to identify each block and its respective number of households.

Figure 1: Incorporation of lots on the base maps

This update has been done every year since 2005, incorporating the most important urban areas in terms of their population, and extending to every region of the country. In late 2009, the INE will have 241 cities as of 2008 (see Table 1), corresponding to 95.5% of the urban population, which is very significant, since it means that all the work pre-census will start with high quality, up to date mapping already available. This will reduce significantly the collection and updating of geographic information that will be necessary during the pre-census and census. Previously, updating the maps to account for the changes of the previous 8 to 10 years was carried out during the pre-census and census, greatly increasing the workload at a time when resources where already stretched.

In 2010, when the pre-census is in full development, information gathering will focus on obtaining from the same addresses of municipal works or other data sources, current, up to date maps, which will include the 4.5% of the urban population not considered within the MM. These are generally urban areas which are small in terms of size and amount of people, and work will be focused on improving the cartographic base in these areas where there are insufficient resources to change to a metric cartographic base, whether obtained through aerial survey or satellite imagery.

b) INE-IGM Agreement: One of the most complex issues facing the INE in terms of cartographic bases is accurate mapping of rural areas. The census is national and our mission is to cover 100% of the territory and to reach every household. By 2009 (projection to June 30), rural areas accounted for 13.05% of the total population of our country, and 319 communes out of 346 contained rural areas. Therefore, confronting the problem of

representating these areas is not a simple task, and the IGM is a key ally in this respect. Being the official body responsible for the mapping of our country, it is the organization which makes available the cartographic bases.

For Census 2002, INE acquired the standard digital mapping coverage of the IGM (1:50.000) for the south-central area, in the regions: Coquimbo, Valparaíso, Region Metropolitana, O'Higgins, Maule, Bio-Bio, Araucanía and Los Lagos, leaving the remaining regions of the extreme north and extreme south of the country to work with the cartographic bases from the 1992 census. During the last census, the need to update these cartographic bases in the field resulted in difficulties due to the extent of the changes over the inter-censal period and the scale of the territories involved.

The digital update for rural areas is not an easy topic to address, largely due to the size of the territory and the costs associated with collecting and representing the information. In 2002 INE achieved this updating during the census itself using census mapping paper – the cartographic bases were not updated digitally.

Two years ago INE developed pilot programs to find the best solution to upgrade its rural mapping and thus have a good basis on which to tackle these tasks once the pre-census work starts. This was also essential to incorporate the latest technologies available at that time. In the year 2007, the first pilot project was carried out through a public tender, 6 rural communes were updated based on Quickbird images of 0.6 meters resolution of natural color. Then during a second pilot in 2008 13 rural communities in different regions of the country were acquired through a public tender. This approach was based on obtaining Spot 5 satellite imagery, ortorectificates 2.5 m resolution, natural color, as well as updating the mapping of the main elements of the countryside; taking as a basis the elements recognized for the Census 2002.

In 2010 the challenge is to update the digital maps available for rural areas (Census 2002) and the IGM is therefore an important factor in this work, which will be achieved through an agreement to work together on updating digital mapping (1:50,000), based on the approval of the bases available to the institution, whether in terms of their reference systems such as Datum and Projection (PSAD56 to SIRGAS2000), as well as the incorporation of new elements of the countryside contained in the main layers of information such as roads, drainage facilities. All this will be achieved through the removal or extraction of information on satellite images made available by Google Earth (Digital Globe Quickbird-).

This information will be available by 2010 when INE will begin working with these bases in production of cartography for the census, for example maps of communes, districts and populated entities relevant to each particular area such as villages and hamlets.

c) Base mapping change: These changes to the cartographic base have 2 main goals: the first is to have digital mapping of 100% of the national territory. This includes the standard mapping of rural areas in the country's northern regions such as: Parinacota and Arica, Tarapacá, Antofagasta and Atacama, which already have their digital mapping and are in the midst of production to provide rural maps for the pre-census. It also includes standard

mapping at various scales for the regions of the far south: the regions of Aisen, Magallanes and the Chilean Antarctic. This work is also underway in order to be ready during 2010. The Second goal is to change the metric basis of existing digital maps, mainly because the sources of origin or the processes of updating were not to in line with the quality standards now required by INE. In urban areas, work is focused on the acquisition of 31 new urban areas planimetry based on metrics generated by a mosaic of satellite images, which will be available with its mapping and its mosaic of satellite images at the end of 2009. This will complete the acquisition of a total of 93 urban areas with digital planimetry metrics corresponding to the largest urban metropolis's, their urban communities with the greatest concentrations of urban population, as shown in Table 1.

For the rest of the urban areas the methods of updating are based primarily on information that is obtained from the regional bureau or other public bodies that make available this information. However, there are a significant percentage of populated locations with no information available from any formal source, and for these areas the updating will be carried out using the information available through Google Earth Pro.

This practice makes it possible to quickly gauge the differences in the post-census growth and, if the satellite coverage permits, to correct errors in the updates during the census period, as shown in Figure 2.

Correcting these cartographic bases in the office from the satellite images reduces considerably the errors in the field work since it provides assurance about the spatial reference of the enumerator.

Figure n° 2: Updating Cartographic in Google Earth Pro base.

Reg	Urbano	Base Métrica	Reg	Urbano	Base Métrica	Reg	Urbano	Base Métrica	Reg	Urbano	Base Métrica	Reg	Urbano	Base Métrica
1	Iquique	x	5	Limache	x	7	Longaví		9	Padre las Casas	x	13	Ñuñoa	x
1	Alto Hospicio	x	5	El Melón		7	Parral		9	Pitrufquén		13	Pedro Aguirre Cerda	x
1	Pozo Almonte		5	Nogales		7	San Javier		9	Pucón		13	Peñalolén	x
2	Antofagasta		5	Olmué		7	Villa Alegre		9	Villarrica		13	Providencia	x
2	Mejillones		5	San Antonio	x	8	Concepción	x	9	Angol	x	13	Pudahuel	x
2	Taltal		5	Algarrobo		8	Coronel	x	9	Collipulli		13	Quilicura	x
2	Calama	x	5	Cartagena		8	Chiguayante	x	9	Curacautín		13	Quinta Normal	x
2	Tocopilla		5	El Quisco		8	Florida		9	Purén		13	Recoleta	x
2	Maria Elena		5	Las cruces		8	Hualqui		9	Renaico		13	Renca	x
3	Copiapó	x	5	San Felipe	x	8	Lota	x	9	Traiguén		13	San Joaquín	x
3	Caldera		5	Catemu		8	Penco	x	9	Victoria		13	San Miguel	x
3	Tierra Amarilla		5	Llaillay		8	San Pedro de la Paz	x	10	Puerto Montt	x	13	San Ramón	x
3	Chañaral		5	Putaendo		8	Santa Juana		10	Alerce		13	Vitacura	x
3	Diego de Almagro		5	Santa María		8	Talcahuano	x	10	Calbuco		13	Puente Alto	x
3	El Salvador		6	Rancagua	x	8	Tomé	x	10	Fresia		13	Pirque	
3	Vallenar	x	6	Codegua		8	Hualpen	x	10	Frutillar		13	San José de Maipo	
3	Freirina		6	Lo Miranda		8	Lebu		10	Los Muermos		13	Colina	x
3	Huasco		6	Doñihue		8	Arauco		10	Llanquihue		13	Batuco	
4	La Serena	x	6	Graneros		8	Cañete		10	Puerto Varas	x	13	Lampa	
4	Coquimbo	x	6	Las Cabras		8	Curanilahue	x	10	Castro		13	Tiltil	
4	Andacollo		6	Machalí	x	8	Los Álamos		10	Ancud		13	San Bernardo	x
4	Vicuña		6	San Fco. de Mostazal		8	Los Angeles	x	10	Quellón		13	Alto Jahuel	
4	Illapel		6	Gultro		8	Cabrero		10	Osorno	x	13	Buin	x
4	Los Vilos		6	Olivar Alto		8	Monte Águila		10	Purranque		13	Bajos de San Agustín	
4	Salamanca		6	Peumo		8	La Laja		10	Río Negro		13	Hospital	
4	Ovalle	x	6	Pichidegua		8	Mulchén		11	Coihaique	x	13	Paine	
4	Combarbalá		6	Quinta De Tilcoco		8	Nacimiento		11	Puerto Aisén	x	13	Melipilla	x
4	El Palqui		6	Rengo	x	8	Santa Bárbara		11	Villa Mañiguales		13	Curacaví	
4	Monte Patria		6	Requínoa		8	Huépil		12	Punta Arenas	x	13	Talagante	x
5	Placilla de Peñuelas		6	San Vicente de Tagua Tagua		8	Tucapel		12	Puerto Natales	x	13	El Monte	
5	Valparaíso	x	6	Pichilemu		8	Yumbel		13	Santiago	x	13	Isla de Maipo	
5	Casablanca		6	Litueche		8	Chillán	x	13	Cerrillos	x	13	La Islita	
5	Concon	x	6	Marchihue		8	Bulnes		13	Cerro Navia	x	13	Padre Hurtado	x
5	Las Ventanas		6	San Fernando	x	8	Coelemu		13	Conchalí	x	13	Peñaflor	x
5	Puchuncaví		6	Chépica		8	Coihueco		13	El Bosque	x	14	Valdivia	x
5	Quilpué	x	6	Chimbarongo		8	Chillán Viejo	x	13	Estación Central	x	14	Lanco	
5	Quintero		6	Nancagua		8	Quillón		13	Huechuraba	x	14	Los Lagos	
5	Villa Alemana	x	6	Santa Cruz		8	Quirihue		13	Independencia	x	14	San josé de la Mariquina	
5	Viña del Mar	x	7	Talca	x	8	San Carlos		13	La Cisterna	x	14	Paillaco	
5	Los Andes	x	7	Constitución	x	8	Yungay		13	La Florida	x	14	Panguipulli	
5	Calle Larga		7	San Clemente		9	Labranza		13	La Granja	x	14	La Unión	
5	Rinconada		7	Cauquenes	x	9	Temuco	x	13	La Pintana	x	14	Futrono	
5	San Estéban		7	Chanco		9	Carahue		13	La Reina	x	14	Llifén	
5	La Ligua		7	Curicó	x	9	Cunco		13	Las Condes	x	14	Río Bueno	
5	Cabildo		7	Sarmiento		9	Freire		13	Lo Barnechea	x	15	Arica	x
5	Quillota	x	7	Hualañé		9	Gorbea		13	Lo Espejo	x			
5	La Calera	x	7	Molina		9	Lautaro		13	Lo Prado	x			
5	Hijuelas		7	Teno		9	Loncoche		13	Macul	x			
5	La Cruz		7	Linares	x	9	Nueva Imperial		13	Maipú	x			

Board 1: Listing 241 Urban project in MM

d) Restructuring of formats, graphical output and introduction of new platforms: The territorial division used by the INE for the census and sample surveys, is used for operational purposes but is based on the Political and Administrative boundaries and the Census Subdivisions.

For the 2002 Census, the graphical outputs consisted of over 35,000 plans which represented: communes, census districts, villages and hamlets in rural areas as well as Urban Plans and Census Zone plans for cities and towns. For the 2012 census the plans will include the new regions, communities and subdivisions established by the population growth in the post-census period. For this, the preparation of these plans are based on systems of mass reproduction of census mapping, which define simplified maps making it possible to identify the geographic spatial reference for the data to be incorporated.

The challenge now is to address in the medium term, new processes of mass production of maps, incorporating new data from various sources, as well as enabling rapid and convenient access to users who need it, through a new platform for data, centralized in a Geographic Database (Geodatabase). This is the vision that the INE aims to develop as a means to support mapping, which includes all processes and all users as shown in Figure 3.

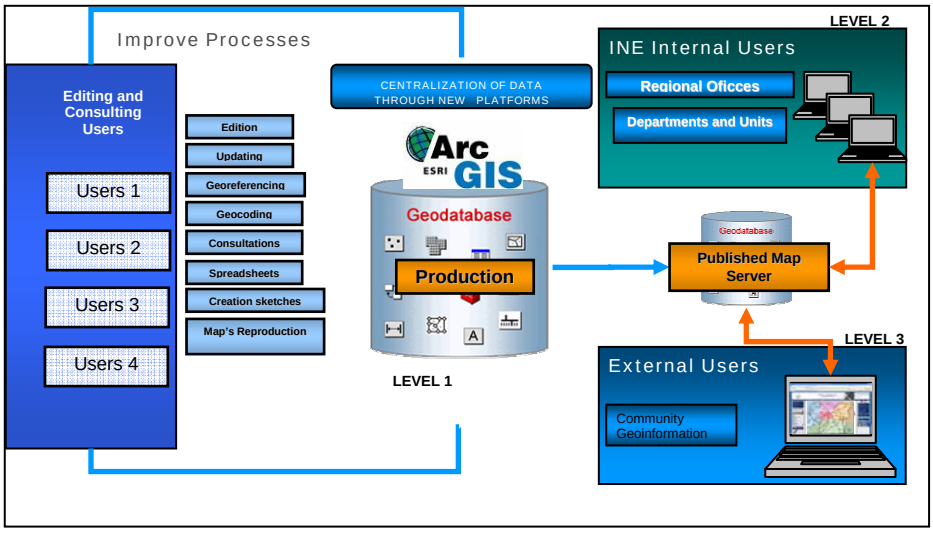

Figure 3: Vision of the stages of implementation in a Geodatabase INE

e) Updating Census Boundary and PAD: Corresponding to the hierarchy of administrative areas, the territorial division is based on the Political Administrative Division (PAD) of the country and in the subdivision of smaller areas, which affect the planning and land use. Within the first ranking are: Region, Province and Commune (PAD) and then from the last level of the PAD, the territory is divided again. These subdivisions in rural areas are called Census Districts, which contain the locations of population. The urban territory is divided into Districts and Zones, the latter comprised of census blocks, as shown in Figure 4.

This task is fundamental and must be performed prior to field work. In order to update the boundaries it is necessary to work together with the National Coordination of Land Information (SNIT) and the Subsecretary of Regional Development since the work of INE

should be based on what the law states as territorial division. We also studied all those minor subdivisions such as districts and census zones. These areas are defined exclusively for operational purposes, considering the amount of population and land area they cover.

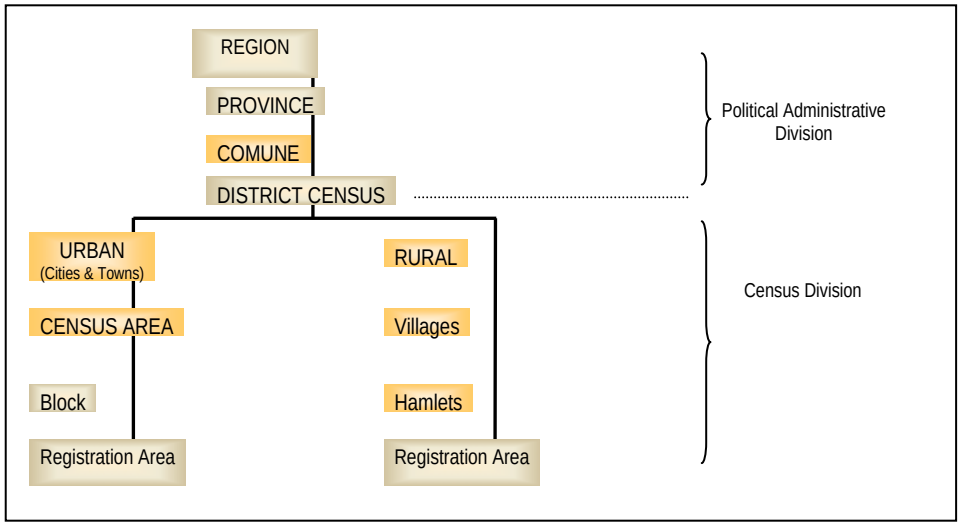

Figure 4: used by the Ine's Territorial Division

f) Digital Map Library: The objective is a new operating structure capable of capturing, organizing and reproducing images of census maps and other documents, for storage, control and secure access to information. This is consistent with the development policies of INE, which are aimed at strengthening technological platforms that will lead to improved processes for the production of national statistics.

Currently the plans for census and sampling purposes are in different formats: large, distinct and different data storage systems which make management and consistent updating of the plans difficult. It is for this reason that it is in the institution's long term interest to find new methods to safeguard, manage and use cartographic information.

At present, the INE has purchased equipment for the digital map, and is developing a document management system which can capture, store, view and reproduce census maps and other documents, primarily based on previous census's and samples. The key to this system is in the metadata, which in a generic sense is defined as "Data about data. There is a need to describe, identify and characterize information objects, in this case the plans, through fields that identify data, and facilitate the management, search, access and location of records.

This will allow us to reduce significantly the time and paper required to gather the basic mapping information which will be dispersed to the daily work of internal users, allowing them to dynamically update the databases of mapping information as shown in figure 5. After the pre-census 2011 and 2012 census, the mass reproduction will be much more

efficient, and it will be possible to capture digital maps of each area. There will be an internal coding, allowing us to record and sort information, avoiding loss or degradation of information, as well as backups, and easy Web access which will be available to each of the users who need this information.

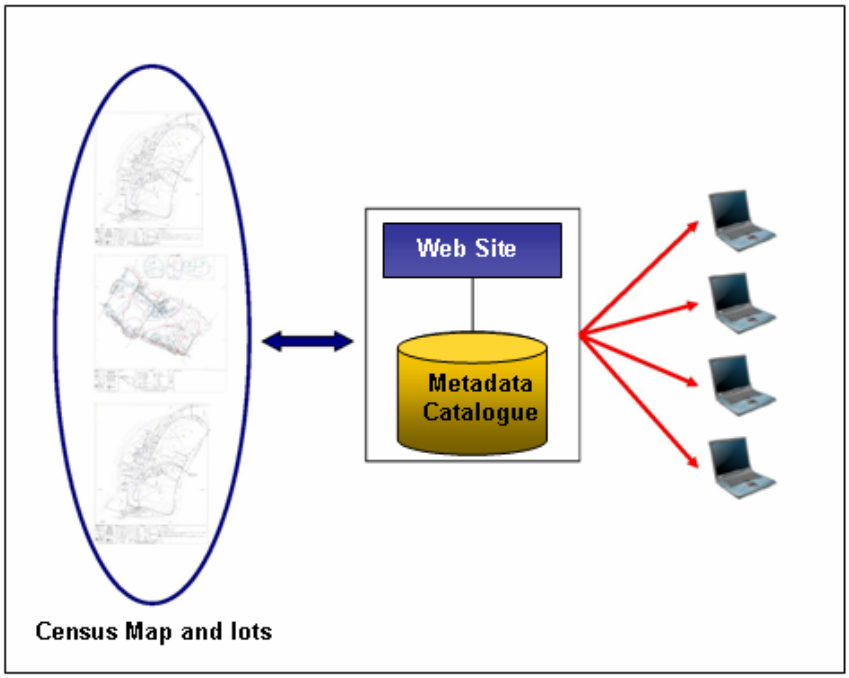

Figure 5: Digital Map Library

Results: To provide accurate and up-to-date maps of the whole country in digital format disaggregated into urban and rural areas. These quality maps will be made available through accessible platforms to support all census and sampling stages.

Conclusions: The census mapping offers a myriad of benefits, improving the products and services that INE-Chile provides to our country. A permanent, organized, professional, serious and renewed work with public and private entities is without a doubt a clear signal that our institution is moving towards a substantial improvement of the official statistics with the help of mapping, which, through timely analysis and representation of the data obtained, strongly support public and private management in making decisions that directly affect citizens.

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