LA GRANJA:
REVISTA DE
CIENCIAS DE LA VIDA
pISSN:1390-3799; eISSN:1390-8596
http://doi.org/10.17163/lgr.n30.2019.10

Scientific paper / Artículo científico
SUSTAINABLE DEVELOPMENT

SPATIAL ANALYSIS OF MILLENNIUM EDUCATIONAL UNITS IN ECUADOR AND ITS COVERAGE OVER POVERTY AREAS

ANÁLISIS ESPACIAL DE LAS UNIDADES EDUCATIVAS DEL MILENIO EN EL ECUADOR Y SU COBERTURA EN ZONAS DE POBREZA

Gustavo Ernesto Navas*[1], Robinson Llerena Paz[1] and Fernando Vaca[2]

[1] *Carrera de Ingeniería de Sistemas, Universidad Politécnica Salesiana, Av. Moran Valverde y Rumichaca, Quito, Ecuador*
[2] *Grupo De Investigación Infraestructura De Datos Espaciales, Inteligencia Artificial Geoportales Y Computación Aplicada IDEIAGEOCA, Instituto Geográfico Militar, Av. Seniergues y Gral. Telmo Paz y Miño, Quito, Ecuador*

*Corresponding author: gnavas@ups.edu.ec

Article received on October 8th , 2018. Accepted, after review, on March 28th, 2019. Published on September 1, 2019.

Resumen

Uno de los parámetros que más influyen en la pobreza es la mala calidad en la educación. El estudio sistemático de la pobreza es fundamental para mejorar la aplicación de planes y proyectos. En el Ecuador, a partir del año del 2005 inicia el "Proyecto para mejorar las condiciones de escolaridad, el acceso y la cobertura de la educación" en zonas de alto índice de pobreza a través del Gobierno Nacional Educacion2016. Este estudio realiza un análisis espacial de dicho proyecto gubernamental del Ecuador mediante el uso del software libre. Dicho análisis se fundamenta en la existencia de las instituciones educativas públicas denominadas "Unidades Educativas del Milenio" (UEM), cuyo fin es mejorar la calidad académica, satisfacer la demanda estudiantil rural y atender a sectores históricamente relegados, partiendo de 57 unidades educativas operativas en el año 2016 y utilizando técnicas de análisis espacial estadístico, apoyados en una base de datos relacional robusta como es el caso de PostgreSQL, con el fin de determinar cuál es su área de afectación a la población, creando varios tipos de coberturas para identificar las parroquias y el porcentaje de pobreza que es atendido por este proyecto educacional, logrando determinar que existe un 77% y el 96% de UEM, en zonas de extrema pobreza.

Palabras clave: Análisis espacial estadístico, UEM, unidades educativas del milenio, análisis espacial, PostgreSQL-PostGIS, pobreza.

Abstract

One of the most influence parameters in poverty is the poor quality of education. The systematic study of poverty is essential to improve the implementation of plans and projects. Since 2005, Ecuador began the 'Project to improve education conditions, schooling access and coverage of education' on high poverty areas through the National Government Educacion2016. This study performs a Spatial Analysis of the above governmental project of Ecuador by

the use of free software. This analysis is based in the existence of public educational institutions called 'Millennium Educational Units', whose purpose is to improve academic quality, meet rural student demand and serve historically relegated sectors. It is sought using statistical spatial analysis techniques, supported by a robust relational database such as PostgreSQL for determining their impact area on the population by creating various types of coverage to identify the parishes and the poverty percentage that is being benefited by this educational project, managed to determine that there is a percentage between 77 % and 96 % of UEM, located in areas of extreme poverty.
Keywords: Statistical Spatial Analysis, UEM, millennium educational units, spatial analysis, PostgreSQL-PostGIS, poverty.

Suggested citation: Navas, G.E., Llerena Paz, R. and Vaca, F. (2019). Spatial analysis of Education Millennium Units in Ecuador and its coverage over poverty areas. La Granja: Revista de Ciencias de la Vida. Vol. 30(2):111-121. http://doi.org/10.17163/lgr.n30.2019.10.

Orcid ID:
Gustavo Ernesto Navas: https://orcid.org/0000-0002-2811-0282
Robinson Llerena Paz: https://orcid.org/0000-0003-1512-2759
Fernando Vaca: https://orcid.org/0000-0003-3375-2236

1 Introduction

UNICEF, and particularly the Economic Commission for Latin America and the Caribbean (ECLAC), remarks the importance of a systematic monitoring of poverty in order to reduce poverty and achieve a more equitable country (Unicef Ecuador, 2015). Education in Ecuador lacks of an academic quality level in the poorest populations; in 2005 the Millennium Educational Units education project started, aiming to reduce this gap and offer education to children with limited economic resources (Ministerio de Educación, 2016).

The Millennium Educational Units (MEU) is a project to endow primary and secondary public educational institutes that were created to improve the country's education and reach the poor sectors, reason for which these institutions are located in poor areas at the national level, with high rates of unmet basic needs and social problems such as internal and external migration, schools characterized by low educational quality and the absence of minimum conditions for the training of girls, boys and young people (Ministerio de Educación, 2016).

The first MEU was built in 2008 in the parish of Zumbahua, in the province of Cotopaxi. According to information from the Ministry of Education (1 November 2013) 31 MEU were created by 2013, at a cost of USD 69'318,199.30, attending 23,282 students; and 33 MEU are being built (the "New Educational Infrastructure"program). The Ministry's website presents updated information to 2015, and indicates that there are 53 MEU in operation, 60 in construction and 212 will be created (Ministerio de Educación, 2016). Geoportals in Ecuador allow to have a georeferenced inventory of state projects such as: risk zones, nature reserves and everything that can be observed on a map (Navas and Prieto, 2011). The information from the Geoportal of (Ministerio de Educación, 2016) was the basis of the study carried out.

On January 19th, 2016, the (Ministerio de Educación, 2016) publishes the news about the inauguration of the Millennium Educational Unit (MEU) Nueva Generation in Morona Santiago province, celebration in which attended the Education Minister Augusto Espinosa and the President of the Republic, Rafael Correa Delgado. This study is based on 89,8 % of educational units created up to 2016. Millennium Educational Units are an integral part of a government policy to improve the quality of public education. Each MEU is created to ensure access to school in rural areas which are excluded from educational services (Ministerio de Educación, 2016). MEU is based on various location criteria for its construction.

The main criteria for the study are (Peñafiel Larrea, 2014): a) Location of the property, it must not be located in risky areas; must be located in a location with easy access to the population; and it should be located near green areas for public use and recreational areas. b) Accessibility to the property, it must have a first, second and third order road infrastructure; it must provide easy access conditions for emergency service vehicles, firefighters, transportation, garbage collectors and input entry and it shall have two clearly defined access routes. c) Land area, the land area for the construction of a Millennium Educational Unit is 2.2 hectares, equivalent to 22,000 square meters.

This paper proposes a method that has allowed to measure the poverty coverage that each MEU has, using free software tools and statistical spatial analysis techniques; likewise, it allows to observe the relationship with the poor parishes of Ecuador, using techniques proposed by the model (Bertolotto and McArdle, 2011) that include the use of free software spatial analysis tools PostgreSQL - PostGIS and the Open layer web viewer, geoserver maps to display the results obtained.

The representation of the geometric properties of spatial objects, as well as their structures are essential for GIS operations, analysis and visualization (Groger and Betsy, 2012). Spatial data types refer to shapes such as points, lines, and polygons parenciteBoundless2012a, the data itself are vector elements which can be points, lines, and polygons with their attributes, and these can be represented by bar and pie charts indicating percentages or trends (Peters, 2012). Geographic feature data can also be displayed with spatial distributions (Fu and Jiulin, 2011), to achieve this the data have been stored in a PostgreSQL database with its spatial extension PostgreSQL-PostGIS. Spatial analysis has multiple applications in health, agriculture, defense, security, cadastres, planning, location services, transportation, geology, energy, and it uses various formats for information management such as: XML, GeoJson, Xslt, among others (Shklar and Rich, 2011; Babar, 2010), (Accessibility of Web based GIS applications 2010) (Ayen López, 2012). The spatial analysis is generated through a series of operations such as layer overlay, joints, spatial intersections, erase operation, and proximity analysis (Martínez Llario, 2013).

For this work, join, intersection and buffer operations have been used, which by specialized statements in the handling of point and polygon geometry and with the help of statistical tools can be used to check whether the MEU are located in Ecuador's poorest parishes and to determine what percentage of the poverty level is covered by each parish.

There are many tools that allow to run each of the aforementioned operations, for example, ArcGIS and MapInfo, which are paid applications whose cost is high, and

QGis which is a free application. The advantage of using a relational database like PostgreSQL with its PostGIS extension is that it is not required to enter the graphical interface of the GIS application, which warrants specific knowledge of the tool by the user. A relational database allows to enter the information and operations that are required to be executed, the same as being linked to the graphical application allows the result to be displayed transparently to the user. Additionally, the registration of new information in the database does not prevent all established operations from continuing to be applicable to the new data.
The use of a relational database allows to enhance the use of the tools available to these technological programs of spatial analysis; one example is to get the geographic location of these educational units, as well as to identify which and what type of populations will be benefited.

1.1 Description of the data

Poor areas are located on Ecuador's socio-economic map, where poverty rates are presented for each parish, including data on estimates of the gap between rich and poor according to the World Bank; this information was obtained from the website of Universidad de Azuay (Universidad del Azuay, 2018) (http://gis.uazuay.edu.ec/).

Poverty measurement requires a prior conceptual definition of that social reality; therefore, there are several poverty indicators or indices that inevitably refer to poverty paradigms or approaches, such as the GINI index, and the unsatisfied basic needs (UBN) index that serves to identify critical gaps in basic needs such as education, health and housing. The GINI index (Montero Castellanos, 2018), is an economic measure for calculating income inequality among the inhabitants of the study area; it is normally used to measure income inequality within a country, but can be used to measure any form of unequal distribution. The GINI coefficient is a number between 0 and 1, where 0 corresponds to perfect equality (all have the same income) and where 1 corresponds to perfect inequality (one person has all income and the others none) (Damm, 2013).

UBN is a direct method to identify critical deficiencies in a population and characterize poverty using four areas of basic people's needs (housing, health services, basic education and minimal income) available in the population and housing censuses conducted by INEC (INEC, 2010), and it has been considered as the most appropriate index for this study; being also the method employed by the Economic Commission to Latin America (CEPAL) (INEC, 2017).
The information provided by INEC has data on the poverty rates of each parish tabulated in an Excel file, but without geospatial data, unlike data obtained from the website of Universidad de Azuay website, where poverty data are represented by the GINI index for each parish, with the corresponding geographic coordinates stored in a shapefile. In order to have a table with NBI indexes and geographical location per parish, a merger of the two tables mentioned above was carried out, for which a PostgreSQL - PostGIS query was developed by linking these two tables by means of the name of parishes, cantons and provinces. The result obtained in this consultation was 60% of the total parishes, where the remaining 40% was prepared manually. The following code snippet is an SQL query to the database to bind the results.

```
select pp."provincia", pp."canton", pp."
    parroquia", pp."no_pobres", pp."pobres", pp
    ."porcentaje_no_pobres", pp."
    porcentaje_pobres", po.the_geom
from "pobreza_porcentaje" pp, public."POBREZA"
    po
where pp."provincia"=po."PROVINCIA"
and pp."canton"=po."CANTON"
and pp."parroquia"=po."PARROQUIA"
```

The information and position of the MEU were downloaded from the geoportal of Ministerio de Educación (2016) in KML extension; the obtained coordinates are in the worldwide geographic coordinate system WGS84, whose equivalence is the code EPGS: 4326. The WGS84 (World Geodetic System, 1984) is a global-covered datum of the entire planet and is the most commonly used today (Westra, 2013). In short, for this analysis it is necessary to obtain two data tables, the first containing the poverty information at the parish level, which is the fusion of the data of Universidad de Azuay and INEC, and the second table corresponding to the geospatial location of the MEU.

1.2 Methodology

The data used for the study were obtained from the geoportal of Ministerio de Educación (2016) which displays 53 geographical coordinates representing the position of each educational unit. To identify whether the MEU is in the poorest areas of the country, a spatial analysis was performed with PostgreSQL - PostGIS statements. Spatial analysis is a set of methods whose results change when the locations of the analyzed objects also change (Huang et al., 2011).

The difference between a database and a spatial database are spatial data that represents geographic elements. This spatial data isolate spatial structures such as boundaries and dimensions. A uniform area of study around each educational unit was established (5, 10 and 20 Km), to be able to quantify the poverty level of people attending these educational institutions, since the fact of identifying and clarifying the type of the students attending each MEU is a very complex task because the population of Ecuador is located in several scattered areas of the country.

In order to carry out this calculation, the area to be considered as coverage of each institution was distributed with respect to the different existing centers, which are the coordinates of the MEU (Peter, 1977), where the movement from the center area to its peripheral sectors should be minimal (Buzai, 2011).

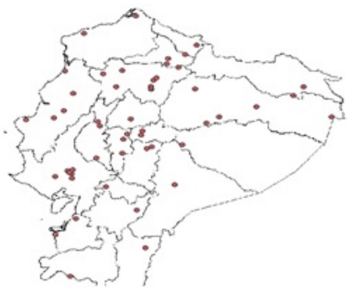

Figure 1. Map of MEU location in a circular 5Km area.

Figure 2. Map of MEU location in a circular 10Km area.

In a study (Buzai, 2011), states that regular polygons provide better results than irregular polygons, and that the circle is the regular polygon of greater desirable conditions. The circular influence area is a simple and easy approach method to implement, but it should be noted that this methodology does not consider the existence of barriers nor the road network where students normally move; in this type of analysis it is recommended that the circular area has a radius of 0.5 km in urban areas, taking into account that a person takes from 5 to 10 minutes to walk and in the rural area it can increase considerably, since the overlap possibility between institutions is low (Córdoba, 2012).

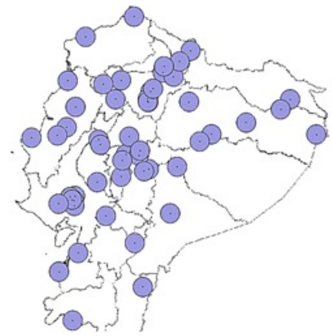

Figure 3. Map of MEU location in a circular 20Km area.

In this study, the areas where MEU are located were not classified as rural or urban, for this reason these were analyzed in a homogeneous way, generating for each MEU three different circular coverages with radiuses of 5, 10 and 20 km around, taking into account that the time to move is approximately 5 to 30 min in public transportation. It should be mentioned that the municipal ordinance of Quito also considers circular areas where it is provided that students must live two kilometers away from the educational institutions in urban area (Secretaría de Educación y Deporte, 2015). Figures 1, 2 and 3 show Ecuador divided by provinces and the location of each millennium educational institutions, where MEUs are represented by points generated in the worldwide geographic coordinate system WGS84, whose equivalence is the code EPGS:4326, which are the centroids of each circular area of 5, 10 and 20 km radius respectively, intended to indicate the coverage area of each educational unit.

For this analysis process, another ordinance of municipal schools in Quito has also been taken into account with respect to the rural sector, considering that the student must live in the parish in which is located the educational institution (Secretaría de Educación y Deporte, 2015). The poverty results of each study with the different parameters of the MEU with respect to the population will help to answer the question of this research, and will allow to see if the educational institutions are located in poor areas of Ecuador. The coverages will be separated by circular influence areas with radiuses of 5, 10 and 20 km, and the study will be deepened in the analysis of circular area and areas of influence at the parish level, and these will be discussed in the following sections.

1.3 Analysis by circular areas

For this analysis, an intersection was performed in PostgreSQL - PostGIS, between the circular areas of the MEU and the poverty map as shown in Figure 4. This intersection indicates the coverage that each MEU has with respect to the parishes on the poverty map. The resulting map shows circumferences divided into several segments; these segments are the area covered by each parish with respect to the circular influence area of each MEU. Each segment has two important data, the area percentage of the intersection between the parish and the MEU and the poverty percentage that each parish has.

The influence area of each MEU covers several parishes with different poverty percentages. Each parish fragment within the circumference has been weighted by reason of the value of its area, thus facilitating the use of the weighted average, which is the average number to which a coefficient, called weight, has been assigned to take into account its relative importance. The weighted average of a data group $X_1, X_2, ..., X_n$, with its corresponding weights $W_1, W_2, ..., W_n$, can be obtained through the following formula (1) (Paz, 2007).

$$\overline{X_w} = \frac{\sum_{i=1}^{n} X_i W_i}{\sum_{i=1}^{n} W_i} \tag{1}$$

Likewise, in order to know the index of unsatisfied basic needs (UBN) for each school, the weighted average was calculated with the data obtained from the intersection, as well as the geospatial poverty data tables and MEU location performed with a PostgreSQL - PostGIS query in which the poverty calculation by circular coverage is analyzed.

```
select u."UEM",
mp."provincia",
mp."canton",
mp."parroquia",
mp."porcentaje_pobres",
mp."porcentaje_no_pobres",
 st_area (u.st_buffer) as "area_uem",
st_area(st_intersection(st_transform(st_setsrid(mp.the_geom,4326),32717),u.st_buffer)) as "
    area_parroquia_uem",
st_area(st_intersection(st_transform(st_setsrid(mp.the_geom,4326),32717),u.st_buffer))/ st_area
    (u.st_buffer) as porcentaje_area,
sum((st_area(st_intersection(st_transform(st_setsrid(mp.the_geom,4326),32717),u.st_buffer))/
    st_area (u.st_buffer))*"porcentaje_pobres")
OVER (PARTITION BY "UEM" ORDER by UEM",1)/sum(st_area(st_intersection(st_transform(st_setsrid(
    mp.the_geom,4326),32717),␣u.st_buffer))/␣st_area␣(u.st_buffer))
OVER␣(PARTITION␣␣BY␣␣"UEM"␣␣ORDER␣␣by␣␣"UEM",1)as␣␣media_ponderada,
st_intersection(st_transform(st_setsrid(mp.the_geom,4326),32717),u.st_buffer)
from␣"mapa_pobreza"␣mp,␣"cobertura_uem"␣␣u
WHERE␣ST_intersects(st_transform(st_setsrid(mp.the_geom,4326),32717),
u.st_buffer)
```

Table 1. PostGIS query code to obtain poverty by circular coverage.

1.4 Poverty calculation by circular coverage

The *st_buffer* function is used to obtain the circular polygon around the point representing the educational institutions. It shows a geometry that included the object with a set distance to the input geometry, in this case the resulting geometry will be a circle representing the circular buffer around the MEU. The circular area analysis focuses on an intersection between circular polygons representing the coverage of MEU and parish polygons contained in Ecuador's poverty table; i.e., the result of this study is based on the spatial analysis that was performed between two polygon-type geometries. Subsequently, the weighted average was calculated with the data, the weights of which are given for each resulting area of the intersection. This analysis was obtained using the code presented in Table 1.

Columns resulting from the above-mentioned consultation are the name of the MEU, the province, canton, parish and the poverty percentage of each parish. These first data were obtained directly from their corresponding tables. The following data are detailed below with their corresponding statements. It can be seen in Figure 4 that the MEU coverage is the red circle defined as the circular influence area.

The code indicated below is used to determine the surface of this figure with their corresponding radiuses of 5, 10 and 20 km. It should be emphasized that this section only indicates how to obtain the area with a radius of 10km, since for 5 and 20 km the value must be changed in the *st_buffer* function of the sentence, for the use of this function, the radius must be transformed into meters:

First, the table is created in the database:

```
Create table cobertura_uem  as (select *,
    st_buffer(the_geom,10000) from
        Ubicacion_UEM       )
```

As the next step, the table created was used to calculate the circular area.

```
select area  (st_buffer).
```

For the intersection area between the MEU coverage and the parishes, the coordinates of the intersection boundary, i.e., the geometry (*the_geom*), were first calculated with the *st_intersection* function for later performing the transformation to the 32717 system and then obtaining the area with the *st_area*, where the code is as follows:

```
Select st_intersection(st_transform(st_setsrid(
    mp.the_geom,4326), 32717), u.st_buffer)
    from "mapa_pobreza" mp, "cobertura_uem" u
```

The area percentage was calculated by dividing the previous two areas, i.e.,:

```
st_area(st_intersection(st_transform(st_setsrid
    (mp.the_geom,4326),32717),u.st_buffer))/
    st_area (u.st_buffer) as porcentaje_area,
```

Each MEU must have its poverty percentage relative to the poverty data of the parishes that intersect it, so it is necessary to calculate the weighted average of each MEU, for which the query must be sorted and partitioned to carry out the sum of the product and the value of each poverty percentage (X_i) of each parish by the area that covers the circular area to each parish that intersects, this value is the weight (W_i) that is given to the value (X_i).

Therefore, the PostgreSQL - PostGIS query to define equation (1) is given by the following code:

```
sum((st_area(st_intersection(st_transform(
    st_setsrid (mp.the_geom,4326),32717),u.
    st_buffer))/ st_area (u.st_buffer))* "
    porcentaje_pobres")  over  (PARTITION BY "
    UEM" ORDER by "UEM",1)/sum(st_area(
    st_intersection(st_transform(st_setsrid(mp.
    the_geom,4326),32717),u.st_buffer))/
    st_area (u.st_buffer)) OVER  (PARTITION BY
    "UEM" ORDER by "UEM",1) as media_ponderada,
st_intersection(st_transform(st_setsrid(mp.
    the_geom,4326),32717), u.st_buffer)
```

1.5 Analysis by parish

This analysis took into consideration that the influence area is given by the boundaries in which the MEU is located, for this reason the poverty percentage covered by each MEU is given by the UBN index of the parish where it is located.As in the previous analysis, the poverty map and the timely location of each MEU were used.

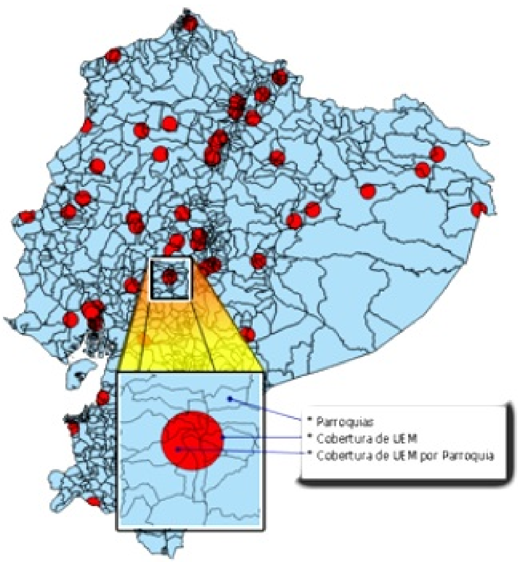

Figure 4. Mapa de las áreas que cubren las UEM en cada parroquia del Ecuador.

1.6 Poverty calculation by parish coverage

First, an assessment will be carried out to verify which points belong to the location of the MEU located in the irregular polygons representing the parish, this is achieved thanks to the *St_contains* statement, which determines whether one geometry is fully within another. PostgreSQL - PostGIS statement used in this case is as follows.

```
CREATE TABLE UEM_PARROQUIAS AS (select u."UEM", mp."provincia", mp."canton", mp."parroquia", mp.
    "porcentaje_pobres", mp.the_geom
from mapa_pobreza mp, ubicacion u
where st_contains (mp.the_geom, st_setsrid(u.the_geom,4326)))
```

1.7 Geospatial Viewer

To make these results easy to read and understand, a geographic viewer has been created with the help of the programs already mentioned above, which are part of OpenGeo suite (Boundless Server, 2012) which is a free software development kit (SDK) that provides the following tools:

1.7.1 PostgreSQL-PostGIS

As already mentioned PostgreSQL - PostGIS is a PostgreSQL extension that allows to store map information and perform spatial analysis between points, lines, polygons and other geometric shapes (Boundless, 2012)

1.7.2 GeoServer

It is a web server that can serve in isolation or over a Tomcat application container or similar. GeoServer has a web management interface that allows to serve maps and data of different formats for web or desktop applications such as GIS.

1.7.3 OpenLayers

It is an open source library in javascript to make interactive maps, mainly visible in Web environments able to connect with GeoServer (or other map sources, such as google maps), to present the layers of a server of maps/data in a browser. It provides a simplified user interface that seamlessly attacks WMS and WFS services for the user and developer (Morales, 2012; Hazzard, 2011; Perez, 2012). Each of these components performs a specific job joined under a diagram to have a map web application as shown in Figure 5.

Figure 5. Geographic visualizer diagram.

2 Results

The data presented in Table 1 are the result of the first analysis showing the number of MEU belonging to each range of poverty percentages, and the influence area of educational establishments for students living within the circular area of 5, 10 and 20 km radius, including the analysis in which those living in the parish where the MEU is created will be benefited.

If 50 % of poverty is taken as a midpoint, Table 2 shows that the ranges above this value cover more than 70 % of MEU in all influence areas, indicating that most of these institutions are created in poor areas to extreme poverty. A total absence of MEU can also be seen in areas where poverty is less than 25 %. Figure 2 shows the percentage of MEUs in the different coverages in 25 % poverty ranges. It can be observed that:

- In the four types of coverage, no MEU is found in poverty below to 25 %. .
- In all four coverages, the MEU percentage increases while the poverty percentage is higher.
- There is a significant amount of MEU in ranges higher than 75 % of poverty.

The percentages are 81 %, 81 %, 96 % and 77 %, respectively, considering a universe of 53 MEU, also taking as a midpoint 50 % and performing a sum between the ranges of 50 %-75 % and 75 %-100 % with each circular coverage area of 5, 10, 20 km by parishes; for this reason, poverty rates higher than 50 % divided into quintiles of 10 % will be taken into account to identify the number of educational institutions for each poverty range. Having the data correctly structured in a relational database ensures the consistency of the data and the results obtained.

UEM COVER	INBI poverty percentage 0 %-25 %	INBI poverty percentage 25 %-50 %	INBI poverty percentage 50 %-75 %	INBI poverty percentage 75 %-100 %
5 Km circle	0	10	18	25
10 Km circle	0	10	12	31
20 Km circle	0	2	16	35
By parish	0	12	14	27

Table 2. Number of MEU in poverty ranges per coverage area.

Poverty levels are divided by quintiles with the aim of easing the investigation; these quintiles are called: low (50 % – 60 %), low average (60 % – 70 %), average (70 % – 80 %), high (80 % – 90 %) and very high (90 % – 100 %). The distribution of schools with poverty higher than 50 % is more equitable, however, Figure 6 shows a trend ranging from high average poverty onwards.

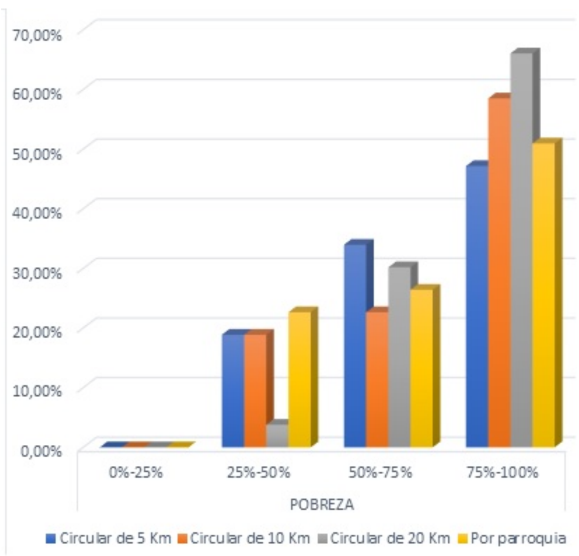

Figure 6. MEU percentage in poverty ranges.

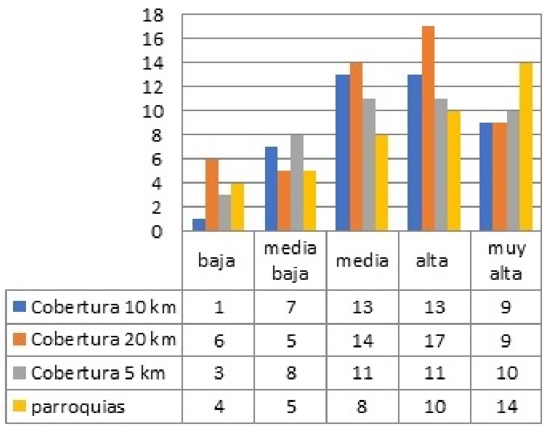

Figure 7. Number of MEUs covering poverty ranges higher than 50 %.

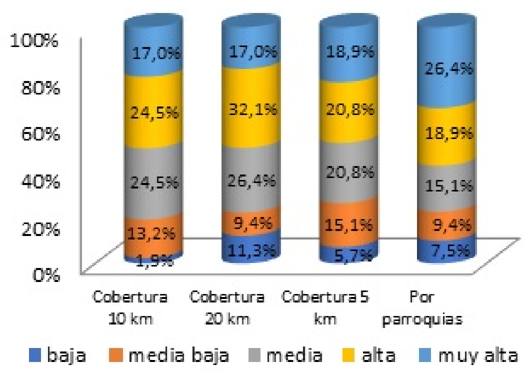

Figure 8. MEU percentage in quintiles by poverty coverage.

It can be seen in Figure 7 that in the four coverage areas the values tend to areas with average poverty, increasing in the first three cases to high and very high poverty. The lowest poverty level covering a MEU belongs to Réplica Montufar educational institution located in Quito, Quito Canton, Pichincha province with 34,16 %; and the highest level is that of the MEU Chontapunta located in Chontapunta, Tena canton, Napo province, with 99,61 % of poverty.

The median calculated in this data set corresponds to 76,65 % (orange color), whose value belongs to MEU Paiguara, indicating that 26 educational institutions are above this value and 26 institutions have lower-than-median values. The graph of the frequency distribution in Figure 4 has a right bias, indicating that the median is higher than the average; reason for which it can be inferred that most MEUs tend to be located in the poorest sectors of the country. In other words, the value of the arithmetic mean is 74,29 % (green), which indicates that the average covered by the educational institutions in this study is about 50 % of poverty.

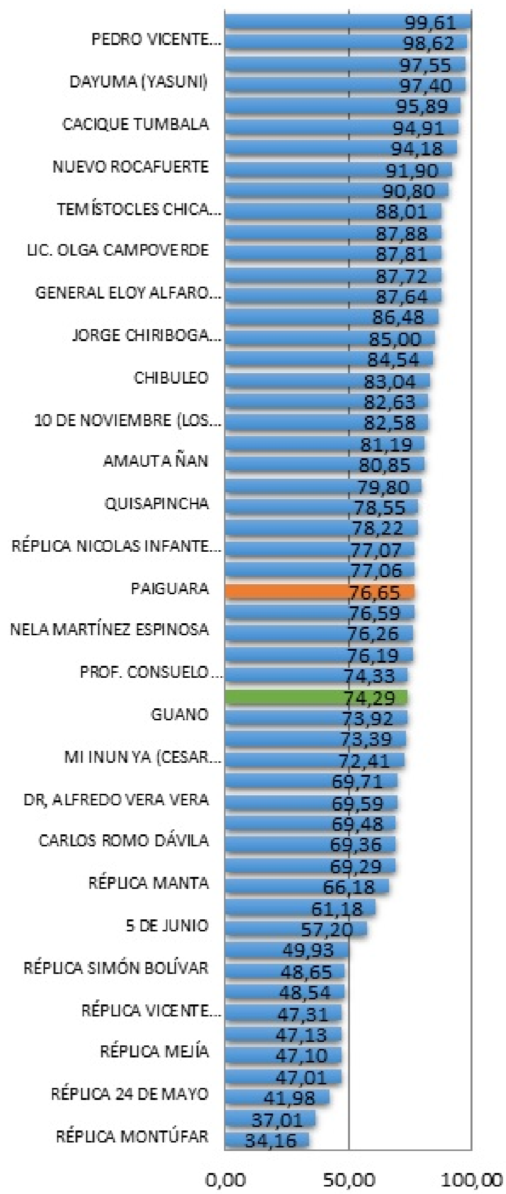

Figure 9. Poverty percentage covered by each MEU.

3 Conclusions

It has been shown with polygon intersection methods in PostgreSQL-PostGIS and using mathematical methods that 84 % of the created MEU are in areas where the unsatisfied basic needs are above 50 %. It has been possible to deduce using circulars with variable radiuses of 5,10 and 20 km and irregular polygons such as the areas of the parishes of each MEU, that the educational units mentioned in this research are built in rural areas and satisfy the most deprived population.

It can be concluded in the individual analysis of each MEU that there are 33 educational institutions above the arithmetic poverty average with ranges higher than 74,29 %, being MEU Chontapunta the institution in an area where its UBN index is 99,61 %, located in the province of Napo, Amazon region. There are 21 institutions below average, being the educational institution Réplica Montufar located in Quito, Quito canton, Pichincha province the MEU that covers the lowest poverty level with 34,16 %.

References

Ayen López, J. A. (2012). Catastro y nuevas tecnologías. Technical report, Saaerbrucken: Lap Lambert Academic Publishing GmbH & Co.

Babar, S. (2010). Accessibility of web based gis applications. Technical report, Saaerbrucken: Lap Lambert Academic Publishing AG & Co.

Bertolotto, M. and McArdle, G. (2011). Data reduction techniques for web and mobile gis. *Advances in Web-based GIS, Mapping Services and Applications*, 9:139.

Boundless (2012). Postgis. Online. último acceso: 04 de 09 de 2015.

Boundless Server (2012). Introduction boundless server. Online.

Buzai, G. D. (2011). Geografía y sistemas de información geográfica. *Revista Geográfica de América Central*, pages 15–67. Online:https://bit.ly/2Ni3SN6.

Córdoba, G. (2012). Áreas de influencia, tipos y aplicaciones en geomarketing. Online. último acceso: 12 de 01 de 2015.

Damm, A. (2013). Thatcher y el coeficiente de gini. Asuntos Capitales. Online: https://bit.ly/2ZdiYKp.

Fu, P. and Jiulin, S. (2011). *WebGIS Principles and applications*. Esri Press.

Groger, G. and Betsy, G. (2012). *Handbook of Geographic Information*, chapter Geometry and Topology, pages 303–321. Springer.

Hazzard, E. (2011). *Openlayers 2.10 beginner's guide*. Packt Publishing Ltd.

Huang, H., Li, Y., and Gartner, G. (2011). A load balancing method to support spatial analysis in xml/gml/svg-based webgis. *Advances in Web-based GIS, mapping services and applications*, pages 153–168.

INEC (2010). Población: Necesidades básicas insatisfechas total nacional. Technical report, Instituto Nacional de Estadística y Censos. Online: https://bit.ly/2xTLcuj.

INEC (2017). Reporte de pobreza y desigualdad. Technical report, Instituto Nacional de Estadística y Censos. Online: https://bit.ly/2FnRsRb.

Martínez Llario, J. C. (2013). Postgis 2. análisis espacial avanzado.

Ministerio de Educación (2016). Visualizador geográfico. Online: http://geoportal.educacion.gob.ec/.

Ministerio de Educación (2016). Proyecto emergente de unidades educativas del milenio y establecimientos réplica. Online: https://bit.ly/2ZUdQHO.

Montero Castellanos, Y. (2018). Índice de gini. Economipedia. Online: https://bit.ly/2T7nraQ.

Morales, A. (2012). Las mejores aplicaciones gis open source. MappingGIS. Online:https://bit.ly/1mWhK9e.

Navas, G. and Prieto, P. (2011). Geoportales en el ecuador. *La Granja*, pages 58–64. Online: https://bit.ly/2Zfbzdb.

Paz, I. K. (2007). Media aritmética simple. *Boletín Electrónico*, (7):1–13. Online: https://bit.ly/2KUgojd.

Peñafiel Larrea, F., editor (2014). *Acuerdo Nro. MINEDUC-ME-2014-00034-A*. Ministerio de Educación del Ecuador. Online: https://bit.ly/2Mrd3LM.

Perez, S. (2012). *OpenLayers Cookbook*. Packt Publishing Ltd.

Peter, H. (1977). *Análisis Locacional en Geografía Humana*. Ed. gustavo Gili.

Peters, D. (2012). Building a gis. Technical report, Redlands: Esri Press.

Secretaría de Educación y Deporte (2015). Secretaría de eduación y deporte. inscripciones instituciones municipales. Online: https://bit.ly/33kxtep.

Shklar, L. and Rich, R., editors (2011). *Web Application Architecture*. John Wiley & Son Ltd, Chichester. Online: https://bit.ly/2ZocEQl.

Unicef Ecuador (2015). Pobreza y pobreza infantil multidimensional. Online: https://uni.cf/31uNc9c.

Universidad del Azuay (2018). Infraestructura de datos espaciales. Online: https://bit.ly/2MqKqOv.

Westra, E. (2013). *Python Geospatial Development*. Packt Publishing Ltd.