



AALBORG UNIVERSITY
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Title: Implementing GIS-based system to document cases of abandoned properties by forcibly displaced people in Honduras

Semester: 4

Semester theme: Geoinformatics - Master Thesis

Project period: Summer examination 2017 - Ordinaer

ECTS: 30

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nbr 20151530

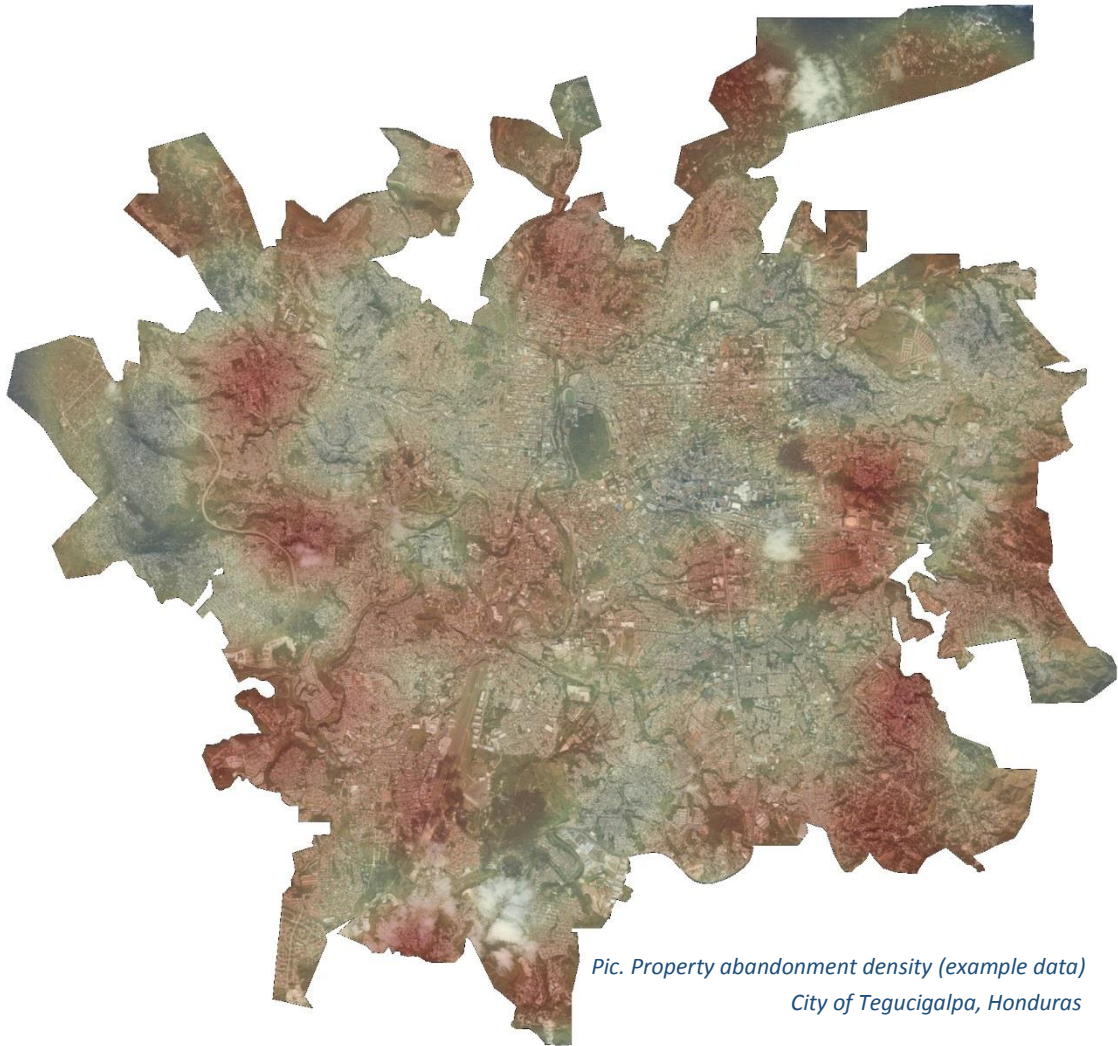
Synopsis:

Honduras for many years struggles with variety of criminal activities, including those related to drug trafficking and trade. Due to generalized violence and organized criminal gangs, vast amount of Hondurans were forced to flee their homes and look for security in other parts of the country. Around 70% of parcels are lacking cadastre which is vital in order to facilitate rapid land registration process and ensure security of title. Therefore, the aim of this thesis is to implement a system that will enable registration of abandoned homes or property and support the restitution process as well as facilitate stakeholders, enabling efficient and thorough data acquisition in distributed and timely manner.

Pages: 72 Pages
Appendix: 0
Enclosures: 0

By signing this document, each member of the group confirms participation on equal terms in the process of writing the project. Thus, each member of the group is responsible for the all contents in the project.

IMPLEMENTING GIS-BASED SYSTEM TO DOCUMENT
CASES OF ABANDONED PROPERTIES BY FORCIBLY
DISPLACED PEOPLE IN HONDURAS



AALBORG UNIVERSITET (KØBENHAVN)

MASTER OF SCIENCE: GEOINFORMATICS

FINAL THESIS

SEBASTIAN KROLIKIEWICZ

I would like to thank Professor Henning Sten Hansen and Assistant Professor Jamal Jokar Arsanjani from the Aalborg University for their supervision and guidance through the process of researching and writing this thesis.

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Abstract

Honduras for many years struggles with variety of criminal activities, including those related to drug trafficking and trade. Due to generalized violence and organized criminal gangs, around 41 000 households (174 000 persons) were internally displaced within 20 of the most affected municipalities, however, network of gangs extend throughout the country so the actual number could be higher.

The report of the Special Rapporteur on the human rights of internally displaced persons on his mission to Honduras reveals challenges that persist with regard to data and research in order to gain a full picture of displacement dynamics, trends and patterns.

Thus, the objective of this thesis is implementation of GIS-based tool that will enable local authorities and humanitarian organizations to record cases where homes or property were abandoned. Facilitating stakeholders with a tool that is capable of instant data collection, aggregation, yet effortless visualization and analysis is intended to improve coherent respond to humanitarian crisis in Honduras.

At present, data is collected through the network of churches that cooperate with the government and international relief actors, in the form of non-georeferenced addresses or even paper based maps, thus introducing modern GIS system will systematize and improve data collection process and enable rapid analysis in order to implement evidence based approach in circumstances where lack of vital cadastral registry makes ownership registration as well as property tenure verification Impossible.

Due to high risk, data collection does not imply deploying staff to the location to conduct cadastral surveying therefore introducing GIS system will enable necessary data acquisition remotely. Prior to system implementation phase, different data collection approaches in open-source geospatial technology will be compared in order to roll out the most suitable solution.

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1. Introduction

1.1. Overview and cause of the internal displacement in Honduras

Generalized violence and organized criminal gangs scattered over the country of Honduras caused the displacement of over 190 000 people according to The Internal Displacement Monitoring Centre (IDMC). Communities are forced to flee their homes and look for security in other parts of the country. Only in 2016, 16 000 people were forced to abandon their properties (Norwegian Refugee Council, 2017).

The main reason leading people to flee are the various criminal activities of gangs known as *mara*. Some of the *mara*'s activities that, for many years has threaten a vast amount of population and compelled people to abandon their homes include drug trafficking and trade, extortion, murders, kidnapping and sexual violence (Cantor, 2016). An alarming amount of gang members, fluctuates, depending on the source of the figure, from over 5 200 reported by the National Programme for Prevention, Rehabilitation and Social Reinsertion; through 25 000 members according to Honduran police, to 116 000 quoting alternative research number (United Nations, 2016). Due to the different nature of activities and their impact, it is extremely difficult to assess the correct figures. Furthermore, Honduras experience one of the world's highest homicide rate.

The global report on homicide conducted by the United Nations Office on Drugs and Crime (UNODC) in 2013, placed Honduras as first on the list of countries with the highest murder rates in the world within the decade 2003-2013. In 2015 alone, approximately 8000 people were killed, leading to a shocking murder rate of 90.4 per 100,000 inhabitants (Figure 1).

Central America

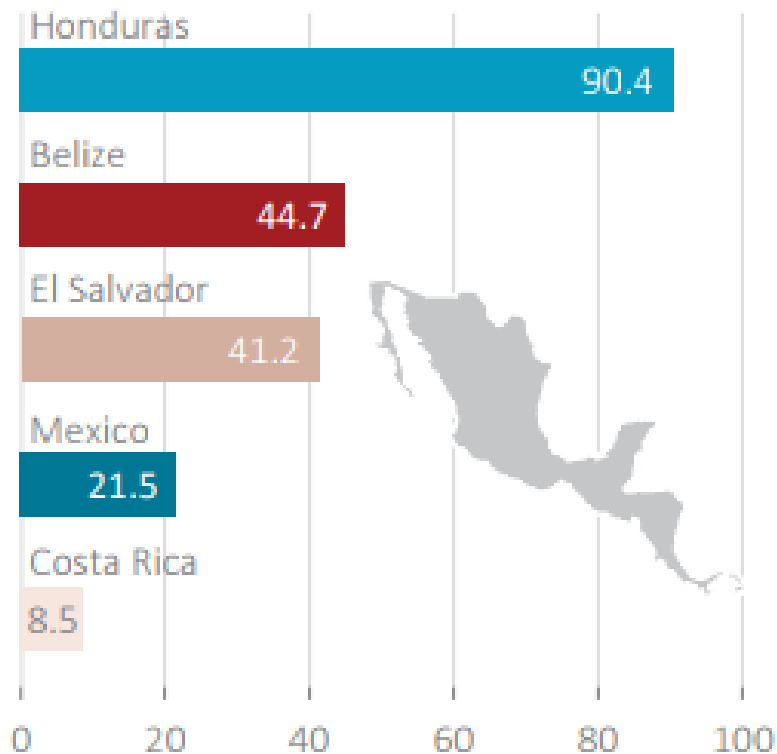


Figure 2 Homicide rates at the national level, selected countries of Central America (rate per 100,000 population). Source: (UNODC, 2014)

In the infamous city of San Pedro Sula located in the north-west of the country, 171 murders per 100 000 inhabitants in 2014 in comparison to the average global rate of less than 6, makes capital of Cortés Department the most violent city in the world. As reported in Human Rights Report for 2016 (United States Department of State, 2016) gangs ordered residents of the two largest communities, San Pedro Sula and Tegucigalpa, to vacate their homes. Despite of the government response by increasing law enforcement operations and presence in the affected neighborhoods, vast amount of people fled their homes seeking secure place to live (United States Department of State, 2016).

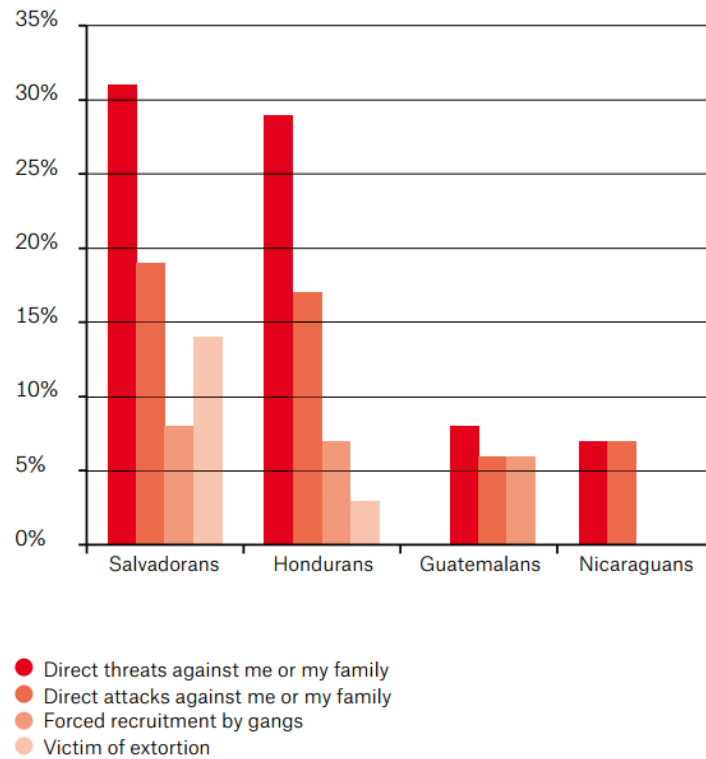


Figure 3: Migration related to direct violence (States of the Northern Triangle of Central America). Source: (Medecins Sans Frontieres, 2017)

Figure 2 presents relation between migration and direct violence in States of the Northern Triangle of Central America. Almost 30 percent of Hondurans had fled their property due to direct threats and around 17 percent due direct attack.

In addition, poor socioeconomic conditions in the country result in lack of opportunities and creates environments where especially young people are vulnerable to crime activities. According to the World Bank, Honduras is a low middle-income country that faces major challenges. In 2016 more than 66 percent of the population lived in poverty. In rural areas, extreme poverty reaches approximately 25 percent where daily budget does not exceed 1.90 US dollar (World Bank in Honduras, 2016). Reduction of poverty is not conducive either by vulnerability to natural disasters like hurricanes and tropical storms that in addition trigger landslides and flooding (Figure 3). Honduras is also experiencing a lingering drought that causes crop failures and results to food insecurity (Bilak, 2016). Frequently occurring events have damaging impacts on the economy, causing the loss of billions of dollars. During the last 20 years, an annual economic loss of over 2.6 per cent of GDP was caused by over 65 per cent extreme natural disasters. According to the Natural Disaster Hotspot study conducted by

the World Bank, Honduras is on the 9th place with relatively high mortality risk from exposure to two or more hazards. The Climate Change and Global Warming expect to intensify the frequency and magnitude of natural events deteriorating socioeconomic struggle and add complexity to migration patterns (World Bank, 2009; Global Facility For Disaster Reduction And Recovery, 2010; Shaw, 2014).

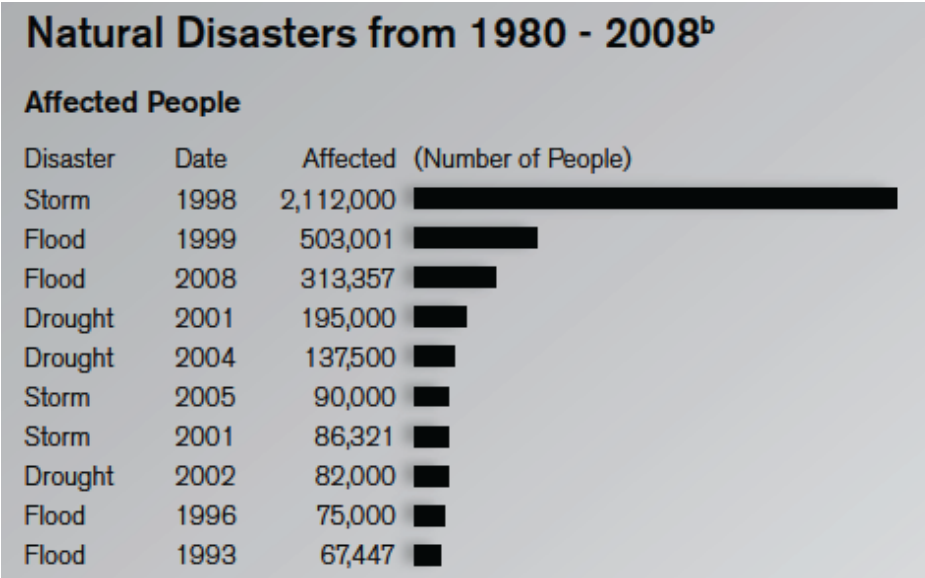


Figure 4: Natural disasters in Honduras from 1980 to 2008. Source: (World Bank, 2012)

One of the main impacts of forced displacement is the loss of housing, land and property (HLP). According to the profiling¹ study, about 33% of surveyed households reported having to abandon housing in their places of origin, and 6% reported having to abandon land, crops or livestock. Currently, there are no specific policies or legal frameworks for the protection of abandoned HLP due to forced displacement, and consequently, there is no comprehensive data or registry that allows to identify and monitor the situation of abandoned properties in the country.

The United Nations Refugee Agency (UNHCR²) National Office in Honduras (NOHON) has been working with different state institutions, particularly with the Inter-Institutional Commission

¹ "Profiling exercises collect all kinds of data disaggregated by sex, age, location and diversity. Once analyzed, these data become the evidence base for decision making, securing funds and designing policies that ensure sustainable solutions for displaced people." <http://www.jips.org/en/profiling/about-profiling>

² <http://www.unhcr.org/>

for the Protection of Persons Displaced by Violence (CIPPDV), to support them in developing appropriate legal frameworks and policies for IDPs. One of the members of the CIPPDV is the Municipalities Association of Honduras (AMHON³), whom which the UNHCR will start cooperating through and Memorandum of Understanding, focusing on identification and registration of abandoned HLP for IDPs, to be linked to the official registration systems for properties in the country (national and municipal cadastral systems⁴).

In parallel, the UNHCR has also been working with different national and international NGOs in the country to strengthen protection networks, including the identification, assistance and referral of Internally Displaced Persons (IDPs). A key actor is CARITAS⁵, a humanitarian aid organization which is an important provider of protection and assistance to IDPs and persons at-risk of displacement through its network of churches around the country, particularly those in high-risk communities (Figure 4). The work with CARITAS has involved developing an online documentation system for cases of IDPs assisted (in pilot phase), as well as a mapping of high-risk communities in different municipalities of the country. In the live stage the tool should be physically presented in the community to improve accuracy of recording abandonment cases, therefore, the system has to be simple enough to allow very basic forms and equipment to be adapted to local conditions supporting bottom- up land record creation.

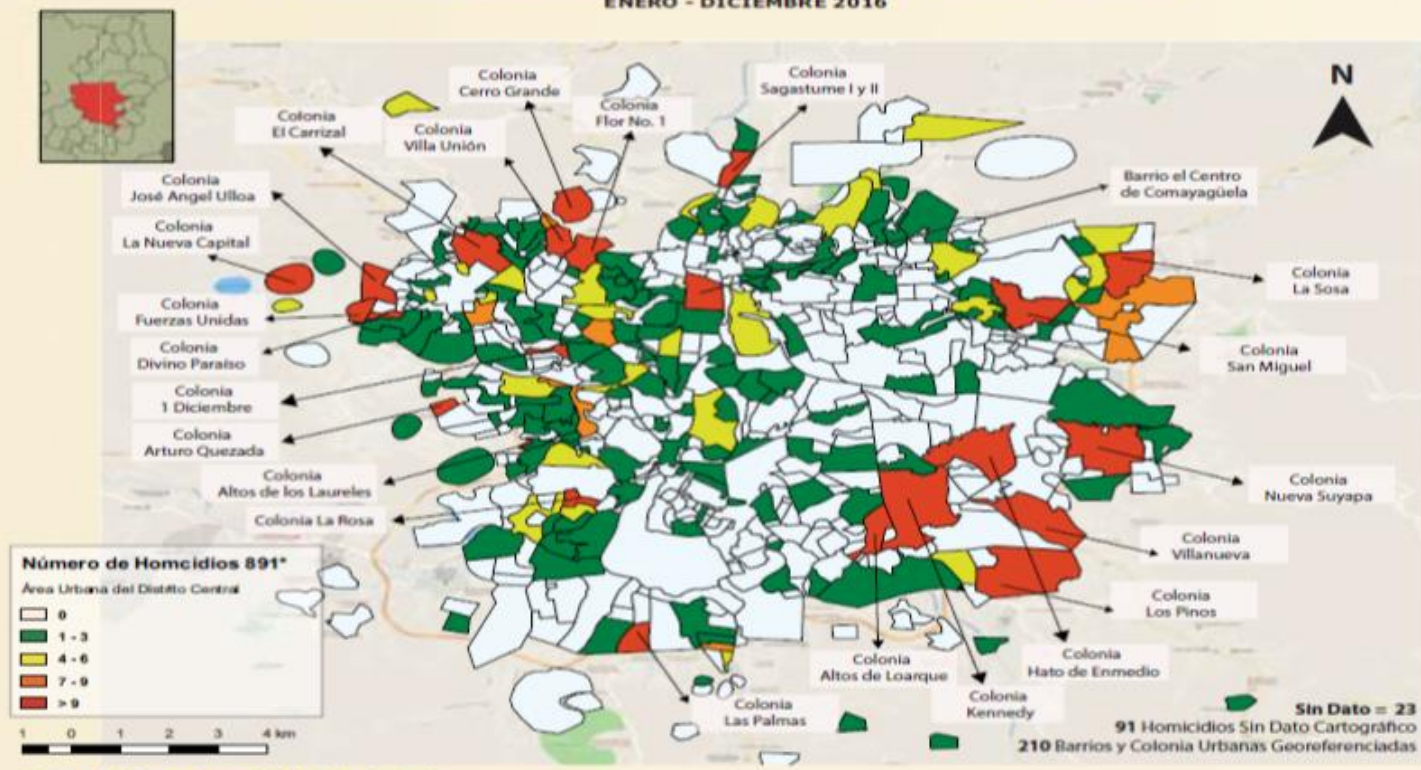
Within this work, the UNHCR has identified that church representatives and collaborators hold information of specific cases of IDPs who have had to abandon HLP, which would be very important to document and systematize in a structured and harmonized way. For such purpose, the UNHCR has offered its technical support to develop a documentation tool or platform that allows to systematize, analyze and visualize this information. In collaboration with the UNHCR, this paper is a determination in order to deploy the most suitable solution.

³ <http://www.amhon.org/inicio/>

⁴ The national cadastral system is managed by the Property Institute of Honduras (IP, <http://www.ip.gob.hn>); in parallel, there also municipal cadastral systems.

⁵ www.caritas.org/

MAPA 2
GEOREFERENCIACIÓN DE MUERTES POR HOMICIDIOS SEGÚN BARRIOS Y COLONIAS
MUNICIPIO DEL DISTRITO CENTRAL, FRANCISCO MORAZÁN
ENERO - DICIEMBRE 2016



* Datos del área urbana del Distrito Central
 Fuente: Dirección General de Medicina Forense/Policia Nacional/Monitoreo de Medios/Observatorio Nacional de la Violencia - UNAH - Honduras
 Fuente Cartográfica: Cartografía UNAH

Figure 5: Homicide rate in the neighborhoods and colonies of Central District municipality (Francisco Morozan).
 Source: UNCHR office in Honduras

1.2. Geographical extent and spatial distribution of gangs

Some patterns of the displacement as a direct result of gangs activities related to taking control over strategic territories were observed in Honduras, as well as other countries in the Northern Triangle of Central America region such as Guatemala and El Salvador. The trans-border zones and capitals play a strategic role in the drug and human trafficking, therefore, these areas are the most affected by organized criminality. However, influences of gangs are spread throughout the entire country and are distinct also in rural areas, especially the ones that facilitate the access to border areas, therefore allowing the flow of drugs, weapons and people as well as access to natural resources (CIDEHUM, 2012). The main risk areas and expelling zones of victims of organized crimes are presented in figure 5.

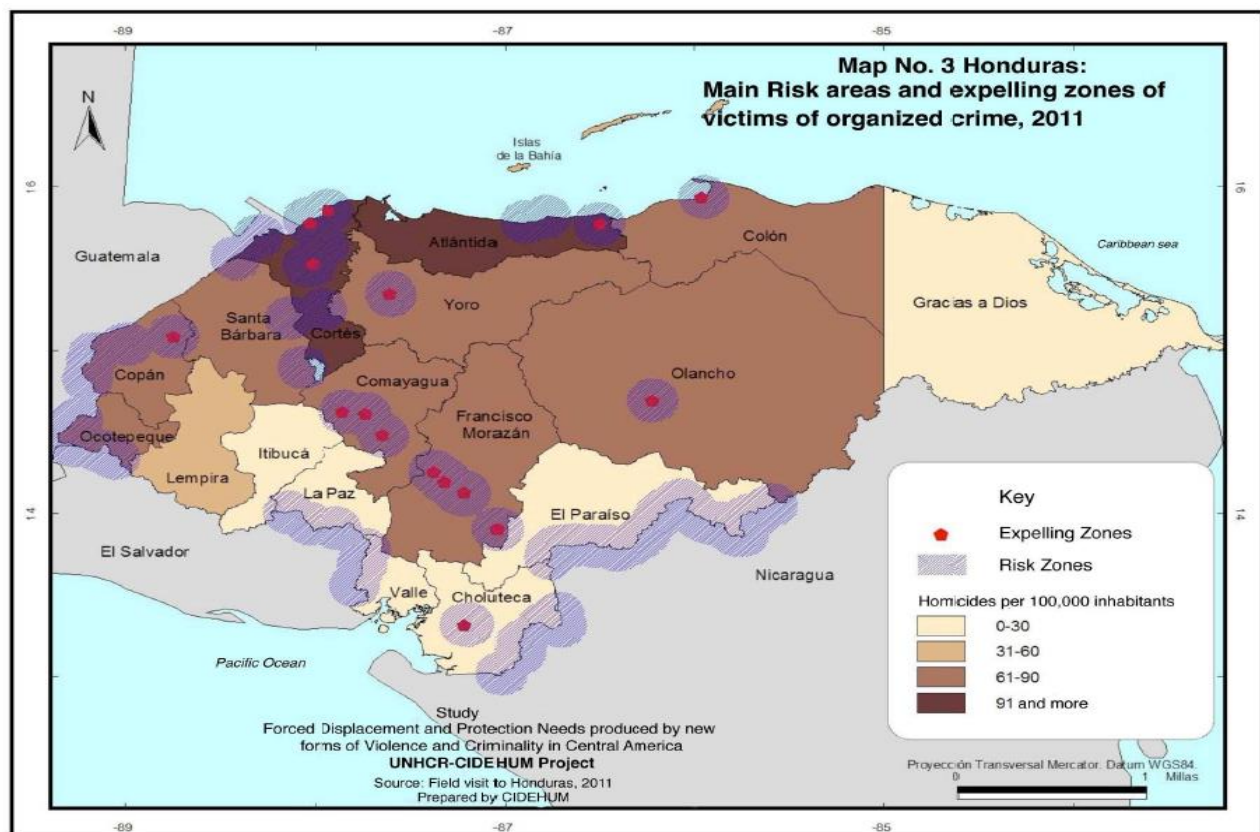


Figure 6: Main Risk areas and expelling zones of victims of organized crime in Honduras, 2011. Source: (CIDEHUM, 2012)

The displacement takes place mainly in urban areas where the concentration of gang members is at its highest and the structures are stronger (United Nations, 2016). At times, entire blocks in the city are deserted due to people's insecurity, where nearly every citizen is forced to pay extortion fees to the various gangs that took over the city (Haugaard & Kinoshian, 2015). The most affected areas are the three largest urban areas: the capital city of Tegucigalpa and the surrounding metropolitan area; La Ceiba, the third largest in the country; and the city of San Pedro Sula, the country's economic and industrial capital. Nonetheless, gangs are present in some rural areas such as the municipality of Tela located between La Ceiba and San Pedro Sula where MS13, one of the two major gangs has set up a solid base of operations (Insight Crime/Asociación para una Sociedad más Justa (ASJ) (2015)).

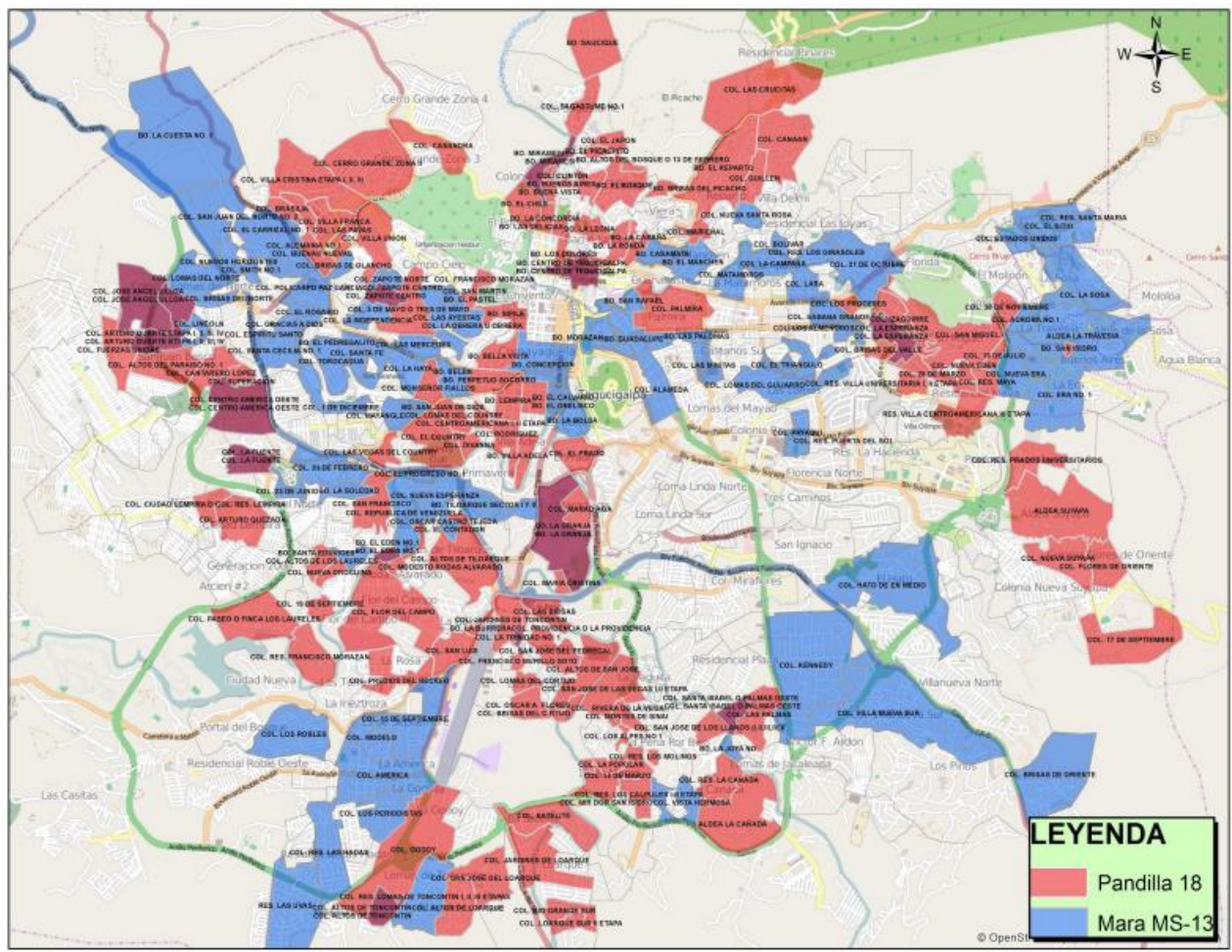


Figure 7: Presence of the two most active gangs in Tegucigalpa: MS-13 and Pandilla 18. Source: Insight Crime/Asociación para una Sociedad más Justa (ASJ) (2015) from Honduras Police Intelligence

The map of gang presence provided by police intelligence unit does not give a clear pattern and understanding for the reason why gangs occupy these territories while other parts of the city remain unaffected (Figure 6). The largest gang Pandilla 18 is present in about 150 *colonias* (neighborhoods) in Tegucigalpa out of 220 and bordering on the north city of Comayagua. The second biggest gang MS-13 is active in about 70 city sections. There are also *colonias* where both gangs are present simultaneously, it's mainly within city center. Accordingly, around 90 percent of the Municipality of the Central District is affected by gangs organized through small units called *clicas* that are generally clustered by *colonia*. The distinct boundaries which can be observed on the police intelligence map are related to geography, history and other shared features. Furthermore, the situation is rather dynamic and gangs tend to expand their activities on neighboring *colonias* which has appalling consequences and cause displacement of residents (Insight Crime/Asociación para una Sociedad más Justa (ASJ) (2015)).

In order to identify the trends related to internal displacement, in the year 2014, the Government of Honduras -with the help of an inter-agency assistance and support of United Nation High Commissioner for Refugees and other international bodies- conducted an extensive profiling⁶ exercise to capture scale of the displacement along with a more comprehensive analysis (Inter-Agency Commission for the Protection of Persons Displaced by Violence, 2015). The profiling covered 20 (out of around 300) of the most affected municipalities where a number of 41 000 households were abandoned (Figure 7). Nevertheless, this number does not reflect the total number since IDPs profiling did not cover the entire country. According to the research, the majority of the displaced people tend to stay within their native department and within the large urban settings where displaced persons can remain more anonymous and have greater chance of finding employment and have better access to services as well as can stay close to their relatives and maintain social network. For instance, as high as 97 percent of people displaced in Distrito Central or 86 percent in San Pedro Sula remained in the same municipality (United Nations, 2016).

⁶ "Profiling exercises collect all kinds of data disaggregated by sex, age, location and diversity. Once analyzed, these data become the evidence base for decision making, securing funds and designing policies that ensure sustainable solutions for displaced people." <http://www.jips.org/en/profiling/about-profiling>

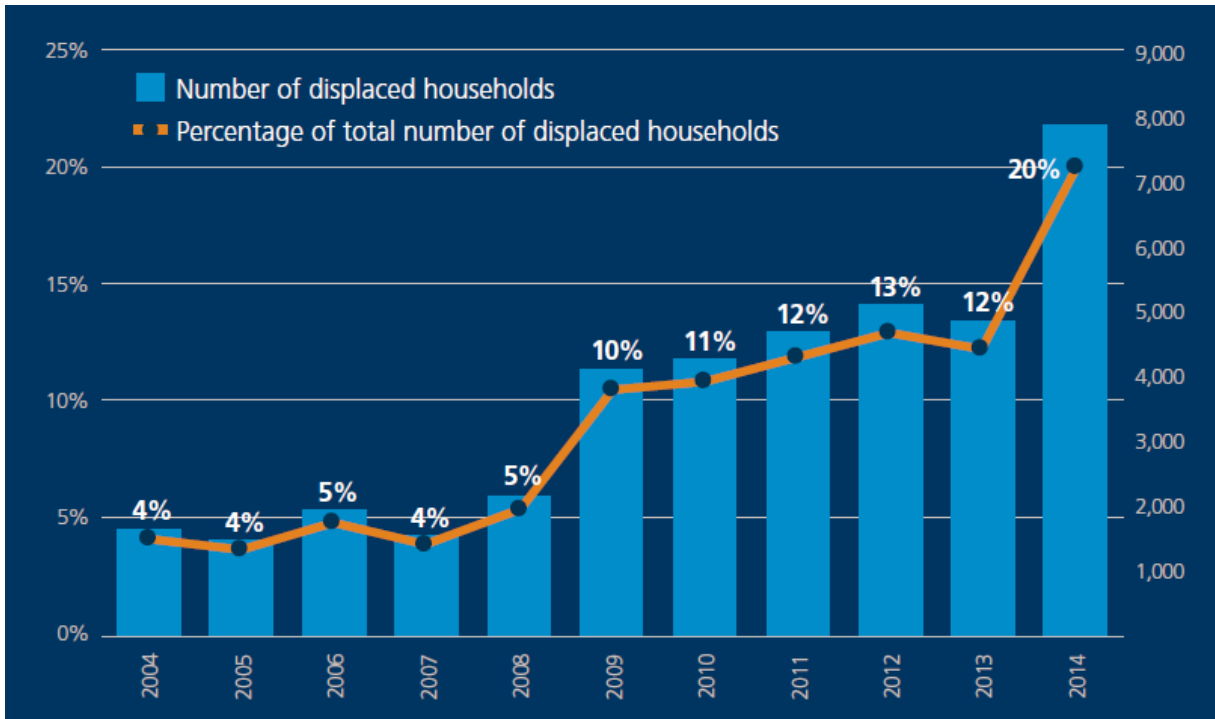


Figure 8: Households Affected by Internal Displacement in 20 Municipalities in Honduras (Nov-Dec 2014). Source: Bilak, 2016

Although, the outcome of the profiling identified areas of origin and arrivals and gathered information on living conditions of the displaced, profound research and data collection is needed in order to strengthen and better address the protection solutions of vulnerable communities. Yet, “The report from 2016 of the Special Rapporteur on the human rights of Internally Displaced Persons on his mission to Honduras” reveals challenges that persist with regard to data and research in order to gain a full picture of displacement dynamics, trends and patterns. Similarly, established in 2013, The Inter-Institutional Commission for the Protection of Persons Displaced by Violence promotes the research of displacement trends in the most affected municipalities. In this sense, high level agreement among different entities and the displacement issue recognition by the Government has been acknowledged (Inter-Agency Commission for the Protection of Persons Displaced by Violence, 2015).

1.3. Cadastral system and land ownership in Honduras

An estimated 2.2 million urban and 0.8 rural land parcels (around 70%) are not registered and are lacking cadastre that accommodate precisely defined borders of the properties and provide owners with a document confirming their legal rights. It is a major issue that hinders the restitution process of Internally Displaced People whenever the return to abandoned property is allowed. Accordingly, a vital cadastral system and its data is fundamental to an efficient and rapid land registration process that ensures security of title (Rabley & Falk, 2004). Such a situation does not favor especially the displaced population of Honduras that has already undergone various misfortunes.

In the past, the main obstacle in providing ownership security to the citizens of Honduras and especially highly vulnerable Internally Displaced People, was the lack of the fundamental framework in the form of Cadastral Management that facilitates effective integration of cadastral survey and property registration (Martinez, et al., 2000). In addition, a situation where four different organizations at municipal and national level were responsible for legal cadastre (land registration), created confusion on where to apply for ownership in case of land transaction. The legislation was modernized in 2004, by creation of Institute of Property (IP) that focuses on the property law to strengthen and provide legal security to property owners, issuing and supervising the use of appropriate regulations and strategic spatial information throughout the national territory. Yet, implementation is a slow process as well as corruption mismanagement and widespread abuse are alleged by Transparency International's partner in Honduras (Transparency International, 2014)

In 2013 a pilot of SIGIT⁷ system that was designed to improve the management cadastral including geographic information and land use planning was rolled-out in three municipalities (Puerto Cortes, Omoa and Tela). The system improves by far cadastral maintenance at the local level with national updating mechanism and its implementation is an important step

⁷ "The Integrated Land-Management System, SIGIT, is a pilot project based on open-source technology and developed under the URBAL III Project's umbrella. It is sponsored by the European Economic Community and supervised by Kadaster in the Netherlands. SIGIT's goal is to conform a general platform to manage land and cadastre at the municipalities having links with nationwide institutions" <http://puertocortes.gob.hn/sigit/home.jsf>

towards improvement of management and protection of property rights. However, covering the whole country with a cohesive structure is a complex process that may take significant amount of time. Despite the legal and technological improvement, Property Rights Index⁸ (Figure 8) is still very low, yet, it's growing in comparison with year 2011 where only 14 percent of Hondurans were legally entitled to their property and only 30 percent of these properties were registered (USAID, 2012). In such circumstance where the majority of the population does not have a legal right to the property and where lack of cadastral registry makes ownership verification impossible, it is important to collect evidence of residency in consistent, systematized and coordinated fashion.

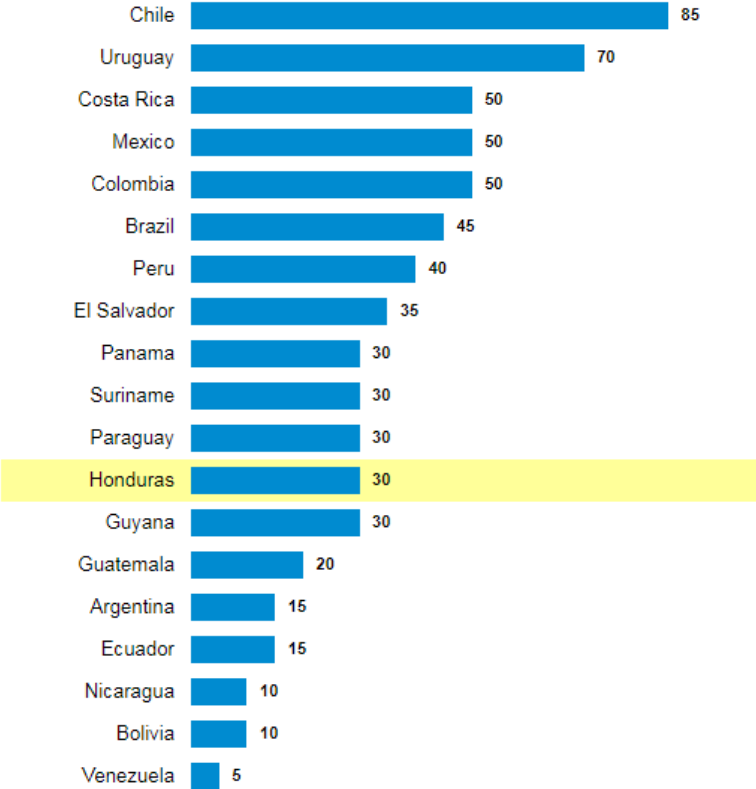


Figure 9: Property Rights Index - Honduras Compared to Continent (2016). Source: <http://www.globalpropertyguide.com/Latin-America/Honduras/property-rights-index>

⁸ "A subcomponent of the Index of Economic Freedom, the Property Rights Index measures the degree to which a country's laws protect private property rights, and the degree to which its government enforces those laws. Higher scores are more desirable, i.e. property rights are better protected. Scores are from 0 to 100" <http://www.globalpropertyguide.com/Latin-America/Honduras/property-rights-index>

Another instrument that allows comparison of intellectual as well as property rights of by country based on the strength of these rights was developed Property Rights Alliance⁹ and published since 2007 helps decision makers to more effectively address their policies. Taking into account the political and legal environment, performance of the administration in terms of enforcement and recognition of citizens' right to their property, figure 9 presents a global comparison of these variables focusing on Honduras and Denmark to gain a contrasting picture of how the situation differs in developed countries. In this comparison, Honduras occupies the 83rd position while Denmark ranks as 11th out of 130 countries that are covered by the study. The International Property Index scale ranges from 0 to 10 where Honduras oscillates around 4.5 while Denmark scores about 8 in what emphasizes the adverse score for the first country.

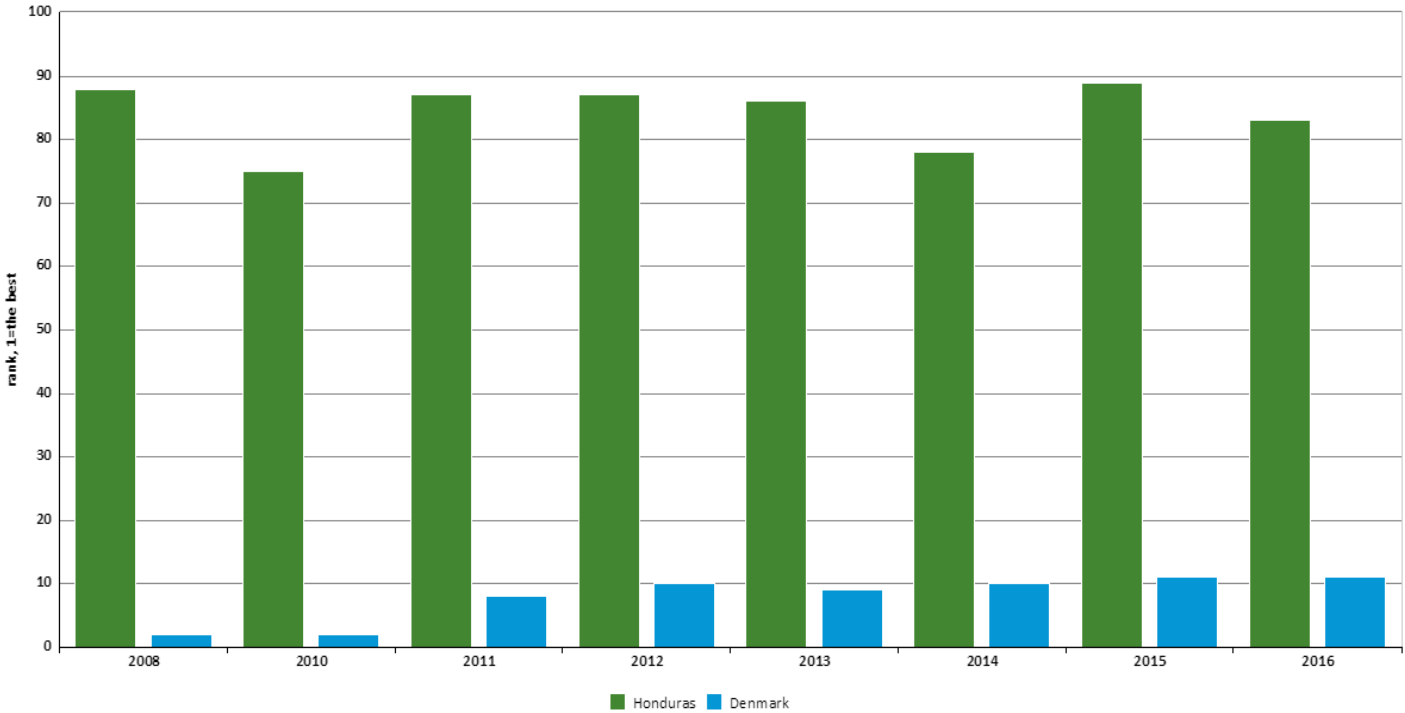


Figure 10: Global Ranking of the International Property Right Index (IPRI). Source: <https://knoema.com/IPRI2015/international-property-rights-index-2016>

⁹ “Property Rights Alliance (PRA), and an affiliate of American’s for Tax Reform, stands as an advocacy organization dedicated to the protection of physical and intellectual property rights, both domestically and internationally.” <http://www.propertyrightsalliance.org/about/>

Therefore, the collection of property abandonment data is especially difficult in conditions where weak property rights for citizens remain a major constraint and modern land management system was only introduced in recent years. Despite of efforts made in the organization of cadastral systems with the help of international aid, there is a delay in recording even current information that again lead to land tenure insecurity.

1.4. Problem statement and research questions

In the circumstances where nearly 60 percent of the land is not documented and the owners have no legal rights to their property, ensuring the restitution process of affected populations is extremely difficult. The study of Honduras is not an exception, only 30 percent of World's population have a legal entitlement and hence control over their ownership (Barbieri & Gassen, 2017). In many weak economies all over the world, the lack of a system that handles property rights, leads to fraud, disputes and have adverse impact on economic growth. Such an implication have a background in technological absence as well as a lack of trust in institutions that should provide legal framework to protect property rights of their citizens. However, the first step towards improvement was conducted in 2004 when establishing the legal part of the property management strengthened the land administration process. In addition, creation of innovative structures in the form of the Institute of Property improved collection of cadastral information in georeferenced fashion and revised legalization of land tenure (Ortega, 2017). Adaptation of such a unified cadastre and land registration system is a major achievement. Nevertheless, such a comprehensive and extended governmental system require long-term adaptation in order to be fully functioning and have the nationwide coverage. Yet, property registration system remains unreliable, thus, the problem described requires taking steps in order to support populations of concern in Honduras. Lack of data, crucial to ensure or support the restitution process trigger the research where the main focus is on data collection process. Adopting a system that will enable documentation of abandoned property cases will facilitate

stakeholders and enable the coordination of action in order to provide based on evidence assistance.

Currently, cases of abandoned properties along with cadastral data of the property are collected through a network of churches that cooperate with the government and international relief actors, in the form of non-georeferenced addresses or paper based maps. Thus, introducing a GIS system will systematize and improve data collection process and enable rapid analysis and visualization. Data oriented approach will help to comprehend spatial distribution and better design response and allocate measures to stop and prevent internal displacement as well as secure the rights of affected populations to lost property. Furthermore, data analysis and visualizations are the key to better advocate and support decision makers to acknowledge and design response that is data driven.

Therefore, the aim of the this thesis is to implement a system that that will enable registration of abandoned homes or property and support the restitution process as well as facilitate stakeholders, enabling efficient and thorough data acquisition in distributed and timely manner.

Yet, a high number of abandonment cases requires appropriate and organized documentation practices in order to help the decision making institutions to understand the displacement and take the coordinated action to provide assistance based on evidence; therefore establishing a comprehensive tool that will enable data collection is desired by the humanitarian actors in order to facilitate displacement prevention, enable protection, return or resettlement of the displaced people (Inter-American Commission On Human Rights, 2015).

The research will proceed through several stages, therefore, formulated questions have to be understood as a sequence that will lead to final the outcome and conclusion. Prior to the implementation phase, meeting with stakeholders will reveal the desired capabilities, working environment and functionalities of the systems. Different data collection approaches in open-source geospatial technologies will be reviewed and compared in order to roll out the most suitable solution. This overview and tests of the existing data collection solutions will allow to grasp the utility and functionalities included and assign system essentials based on these insights. Furthermore, getting acquainted with the methodology of systems implementation will enable to draw a roadmap that will secure a proper direction for the project. Review of

available open-source components that will best serve the purpose of the system will lead to design the architecture and infrastructure¹⁰.

After the infrastructure is set, the presentation of the results based on sample data will follow and as last comes the evaluation phase that will allow to draw conclusions.

The research questions are listed below:

- How can GIS technology support stakeholders in building a coherent framework in response to humanitarian crisis in Honduras?
- How to design a comprehensive GIS systems taking into consideration various technical constraints and user capabilities?
- Does the designed GIS system fulfil its function and is it essential for stakeholders?

The objectives of the thesis are to support analytical and data related issues apart of policies, laws and practices that are necessary to build framework that will guarantee the protection and wellbeing of the affected populations.

¹⁰ *"Infrastructure describes the actual set of components that make up a system, while architecture describes the design of the components and their relationships. In a nutshell, a system is built on an infrastructure that has a particular architecture."*

2. Theories and methods

Addressing the research objectives that are focusing essentially on providing interested parties with user friendly data collection tools which will enable the documentation of properties abandoned by displaced people require a review of existing geospatial methods by which the data can be acquired and design the right approach based on the findings.

The first action in the following study was therefore, an in depth consultation with interested parties in order to recognize the functionalities the desired system will be capable to support as well as acknowledge technical constraints in the country and within the stakeholder means respectively. Therefore, several teleconference meetings with the National Office of the UNHCR in Honduras revealed system requirements that will be used in order to design and implement a registration system for abandoned land or housing due to forced displacement.

This made-up to deliver “Data collection process and system functionalities assessment” subchapter will be consequently followed by theories of cadastral surveying, in order to acknowledge existing methodologies based on appropriate literature. These methods will be accordingly described in the subchapter “Cadastral surveying principles and methods”.

Subsequently, the subchapter “The conceptual systems design” will present principles of the main GIS mapping techniques that based on the findings are potential solutions to serve the studied objectives. After comparing the advantages and disadvantages of the presented solutions, the most adequate system will be extensively analyzed.

2.1. Data collection process and system functionalities assessment

The main sources of information during data collection process will be church representatives or collaborators, whom have knowledge of cases of abandoned houses and land in the areas or communities covered by each church, and whom can also collect this information when providing protection or assistance to IDPs. Given security conditions, it is not feasible to collect data directly in the communities, but rather, data collection would be conducted in the premises of the churches prioritized for the initiative. For the data collection tool will be piloted during a full-day working sessions with key collaborators of each church will be organized to document the cases known in each community under their jurisdiction.

During these sessions, the tool will be displayed on large screen so church collaborators can navigate through maps of their communities, identify the location of each case of housing or land abandoned known, and record basic information for each case.

The UNHCR protection and information staff will provide technical support for the exercise, particularly during the pilot and training of the tool. The recruitment of a technical focal point that can support the roll out of the tool in each selected church will be considered based on the results of an initial pilot.

In a first phase, the exercise will be prioritized in 10 churches that UNHCR has already started to support, including through the procurement of computers. In some of these there will good access to internet but in others it can be limited; as an alternative, the UNHCR will explore the procurement of mobile internet USB sticks. Alternatively, church collaborators could also be gathered in a common place (such as the location of their respective Diocese), where access to hardware and internet connectivity can be guaranteed.

In order to fulfil the objectives of the data collection, the following functionalities were revealed:

- High resolution maps: the tool should allow to navigate high-resolution maps of the prioritized areas / communities where informants can locate the houses or lands abandoned to be documented. Data collection through traditional cadastral survey where certified staff take measurements of the property is not possible due to the threat of gangs. Therefore, spatial

attributes of property such as parcel boundaries (basic building block in land administration system) must be collected remotely based on satellite imagery.

- Location search: as the information could be known with different levels of specificity, allowing users to search locations by addresses or referential features is important.
- Geometry data collection: the tool should allow to draw abandoned houses or lands parcel geometry over the basemap.
- Attribute data collection: the tool should allow to collect basic information about each house or land abandoned to be documented.
- Online and offline data collection: this would be a desired functionality given that internet connectivity might not be always possible or of good quality.
- Desktop-based application: given the envisaged data collection process, the tool should be able to be used from laptops or PCs that can be connected to a projector during working sessions with church collaborators. Alternatively, tablets with HDMI connection could be used in case there are Android-based applications.
- Security: given the personal nature and the sensitivity of the data to be collected, the tool should ensure data storage and handling complies with high security standards; different access rights should be possible to assign (i.e. data entry, data extraction, etc.).

After consulting the stakeholder, the data type to be collected and the expected functionalities were determined. As a primary functionality, the ability of collecting spatial data by drawing a geometry (polygon) over a parcel of land was considered. In addition to spatial data, descriptive information in common data types are expected to be attached to parcel geometry. These data includes mainly attributes that are collected by the Institute of Property in a simplified cadastral form (Figure 10). However, to serve the purpose of the project, this paper based form was revised by the UNHCR office. The following information was defined as essential therefore have to be included in the survey:

- Metadata (location of parish where the exercise was conducted, date, informant names and registration number)
- Property location (address, city/village, municipality, district, area in ha, type of property);
- Personal information about the owner/tenant (names, nationality, sex, family size, civil status, number and type of identification, profession);
- Current place of residence (address, municipality, district);
- Contact information (address, telephone number);
- Tenancy (occupation type, property type, type of the document);
- Displacement data (displacement date, displacement cause, perpetrators);

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Figure 11: Simplified cadastral information form used by the Institute of Property. Source: UNHCR National Office

2.2. Cadastral surveying principles and methods

Cadastral data serves as a core of land administration and with its different functionalities such as land mapping, registration, cost estimation and development is very important element in every society sustainable development (Huong, 2010). Cadastre is a consistently organized database of property data within a certain administration and is based on a comprehensive survey of a property's boundaries. Moreover, the cadastre aims to provide broad information about land and serves a number of purposes, however, it mainly intend to support land tenure (legal cadastre) or land taxation (fiscal cadastre) (Hanstad, 1998). Therefore, by providing security of tenure, valid cadastral system plays a fundamental role in ensuring the rights of Internally Displaced People to their property.

The information that build the cadastre is usually represented as spatial/geometric and non-spatial attributes, where the spatial ones refer to maps and plans that outline the boundaries, area and location of a parcel, ideally in digital form and non-spatial refer to text records that describe attributes of the land or property (United Nations, 1996).

Cadastral survey is aimed to establish parcel's geographical location, its boundaries and surface area. Parcel definition varies from between authorities, the definition published in INSPIRE Directive refer to an *“area defined by cadastral registers or equivalent“* and Working Party on Land Administration describes parcel as a *“single area of land or more particularly a volume of space, under homogeneous real property rights and unique ownership”* (WG-CPI, 2006) whereas for practical purpose the United Nation defines parcel as a *“closed polygon on the surface of the Earth”* (Huong, 2010). The example of Danish and Australian cadastral parcels are presented in the figure 11 and 12.



Figure 12: Danish Cadastral Parcel example (Frederiksberg kommune). Source: <https://kortforsyningen.dk>



Figure 13: Spatial Cadastral Database (SCDB) in Australia. Source: <https://www0.landgate.wa.gov.au/business-and-government/land-data/cadastral-data>

There are different techniques and each of them have their own accuracy and cost (United Nations, 2005). Depending on the purpose for which the survey is conducted it was necessary to review the objectives of the project to avoid waste of time and resources where it's not vital. Nevertheless, the European cadastral surveying system is a reference for proper assimilation of cadastral practices due to its long history and where most of the countries have 100 % coverage of cadastre (WG-CPI, 2006). Hereby European Permanent Committee on Cadastre (PCC)¹¹ have been considered as the determinant of cadastral system core elements. The listed below components are the output of the cadastre core elements confronted with previously identified project objectives:

- National Unique cadastral parcel identifier that guarantees interoperability between different systems

In the situation where 70% of properties are not registered, owner or tenants for an obvious reason do not hold the cadastral code. Therefore, the ID issued by the National Persons Registry¹² can be used as the unique identifier and also can be the key in order to harmonize data across the organizations.

- Area defined by the boundaries

The cadastral traditional delineation of the parcel boundary is understood as recording the turning points or corners along property perimeters using for example GPS surveying techniques. Taking into consideration that the project's objectives do not aim to obtain de facto and precisely measured cadastral information due to quoted earlier constraints, a pseudo-cadastral term was introduced to emphasize non-verified by ground expertise nature of this data. Therefore, sensu-stricto cadastral methods will not be considered as a solution but can be useful in gaining a broad understanding of the topic and help to deploy a suitable system. Pseudo-cadastral data can be supplementary to the cadastre administered by respective authorities but mainly serve the purpose of evidencing abandonment and/or ownership. Therefore, the cadastre fundamental features such as parcel boundaries are vital and have to

¹¹ *"The Permanent Committee on Cadastre of the EU (PCC) and the Cadastral Expert Group of EuroGeographics set up a joint working group (WG-CPI) to work on the project "Role of the cadastral parcel in INSPIRE and national SDIs with impacts on cadastre and land registry operations" to define the role of the cadastral parcel in INSPIRE and national SDIs."*

¹² *The National Registry of Persons is the institution that is in charge of recording all the facts and acts relating to the civil status of natural persons, from birth to death, as well as issuing identification documents and the necessary means For their participation in the civic and social life of the country. <http://www.rnp.hn/>*

be recorded to meet the objectives of the project. According to the theory that property boundaries must be clearly definable and recognizable (Hanstad, 1998; Donnelly 2012), omitting dispute issue, physical demarcation of boundaries delineated by structures like hedges, fences, wall, shafts, dikes or farming edge can be achieved through ground surveys or remotely via digital photogrammetry or satellite imagery. Some studies conclude that cadastral parcels over in 80 percent overlay with topographic objects (Luo, 2016) therefore producing delineating cadastral parcels through imagery is highly effective. Accordingly, in the context of this project, the key focus are for this reason general boundaries.

The second method is relevant and will be considered in the further study, but it is valid to mention that hereby delineated boundaries are not fixed legally (Hanstad, 1998).

- Georeferenced in digital form (postcode cannot fulfil the general need of georeference)

In like manner to previous element, georeferencing data through traditional cadastral survey where certified staff collect GPS control points and other measurements of the property is not possible due to the threat of gangs. Therefore, these attributes must be collected remotely by adopting GIS system that will be capable of acquiring georeferenced parcel boundaries based on available satellite imagery and other suitable basemaps.

- Origin and history of the parcel that serves legal aspect

Due to very limited coverage of legal registry this element cannot be considered as a core one, nevertheless, data model will allow the storage of this information whenever an interviewed person can provide ownership certification. Otherwise, appropriate authorities will be able to recover any existing data based on National Persons Registry ID.

In addition to core elements, supplementary information can enrich cadastral system but are not necessary from the viewpoint of vital cadastre. These additional characteristics are for instance: owner, lease, rights and restrictions, administrative boundaries, buildings or constructions, land use, land cover, address, description etc. However, taking into consideration the specificity of this project, all the above core and additional attributes were reviewed to fully meet the objectives of the IDPs property documenting exercise.

The theoretical concept of how the data will be collected and what functionalities are expected to fulfil the objectives of the exercise were confronted with the methodologies of cadastral data acquisition. As stated in the data collection process, it is not feasible to collect cadastral data as a whole in the traditional fashion due to the threat of gangs, therefore inability of deployment of certified surveyors. According to the theory, even when cadastre is based on satellite mapping that is significantly being used by land registration authorities to acquire real time information on land management, it then have to be again acknowledged by cadastral surveyors (Alkan et al., 2017). For this reason the legal boundaries of parcels cannot be delineated from satellite imagery without ground truth evidence from the field (Ahn & Song, 2011). Nevertheless, taking into account that the objectives of the data collection do not aim to build sensu-stricto cadastral system, traditional cadastral surveying as a holistic concept have to be disregarded and replaced by the technique that will allow to collect data remotely. Therefore, adoption of an appropriate GIS tool that could facilitate this process was defined as a key role although, paper based system, when well organized can fulfill the land administration task. Nevertheless, a modern GIS based system can handle remote data acquisition and is much more efficient at any part of the process of capturing, storing, distributing, analyzing, managing and presenting the data.

Moreover, in a situation where data collection must be carried out in a timely manner and where the stakeholders have to rely on their in-house capabilities taking into account human and budget constraints, open-source GIS technology comes with the various solutions. There are various open-source technical resources to operate the processes of data collection and management, therefore the following subchapter focuses on presenting several potentially suitable approaches of building remote mapping capacity to support pseudo-cadastral data acquisition.

2.3. Conceptual design of an open-source GIS systems

Appropriate needs assessment that will lead to successful implementation of system have to combine user/customer needs assessment and the system architecture design (Peters, 2012). Yet, in order to deploy a system that will meet the expectations and fulfill objectives of the project, it's necessary to understand system requirements and the technology. The first step was evaluated during a system functionalities assessment, therefore, in this subchapter the focus will be on identifying potentially relevant system architecture and its components. Three potentially relevant mapping solutions and the architecture necessary to set up these systems will be demonstrated. However, taking into consideration budget constraints, only free and open-source components are being examined.

The emerging open-source¹³ movement is equally noticeable in an open-source GIS software development, where for all the categories of components necessary to implement Spatial Data Infrastructure (SDI)¹⁴ there is a variety of free products available. The core components that allow to build a fully interoperable GIS solution that is following open-source paradigm are: desktop GIS, Web Map Server, spatial database management system, server GIS (Steiniger & Hunter, 2012). These free and open software tools have advanced functions and are capable of performing spatial data analysis just as expensive commercial software tools (Sui, 2014).

The analysis of these open-source approaches and suitability to the project objectives taking into account data collection environment will help to indicate the most desirable and appropriate solutions. The proposed architecture includes Web GIS, desktop GIS and Mobile Data Collection. The conceptual design will only reveal the principles of the systems architecture, for the reason that only in web mapping, several approaches have evolved in the recent years. However, universal concept of interoperability and recommendations of Open

¹³ "Open-source software (OSS) is computer software with its source code made available with a license in which the copyright holder provides the rights to study, change, and distribute the software to anyone and for any purpose. Open-source software may be developed in a collaborative public manner. According to scientists who studied it, open-source software is a prominent example of open collaboration." Source: https://en.wikipedia.org/wiki/Open-source_software

¹⁴ "A spatial data infrastructure (SDI) is a data infrastructure implementing a framework of geographic data, metadata, users and tools that are interactively connected in order to use spatial data in an efficient and flexible way." Source: https://en.wikipedia.org/wiki/Spatial_data_infrastructure

Geospatial Consortium's¹⁵ (OGC) in GIS software architecture have remained (Dunfey et al., 2006).

Therefore overall methodology for creating the system architecture is presented in the next chapter. The prototype of the chosen system will be tested for its effectiveness and usability in the later part of the study.

2.3.1. Open-source Web GIS

For the purpose of spatial data collection Web GIS approach is being proposed as one of the potential solutions. In this subchapter an overview on building Web GIS application using open-source geospatial software components will be presented.

Technological advancement and wide range of open-source web mapping solutions enable to develop sophisticated web mapping applications by adopting components integrated within one coherent framework. Nevertheless, these components are themselves complex and can interact with various configurations (Abdalla, 2016). In this sense, distributed Web GIS offers high level of customization and advantage of embedding raster imagery like satellite imagery and vector layers of already entered and called back parcel data of the properties or administrative division of Honduras as a reference for easier navigation.

The general framework is composed of Spatial database, Web Map Service, Web GIS libraries and Client (Figure 13)

¹⁵ "The Open Geospatial Consortium (OGC), an international voluntary consensus standards organization, originated in 1994. In the OGC, more than 500 commercial, governmental, nonprofit and research organizations worldwide collaborate in a consensus process encouraging development and implementation of open standards for geospatial content and services, sensor web and Internet of Things, GIS data processing and data sharing." Source: https://en.wikipedia.org/wiki/Open_Geospatial_Consortium

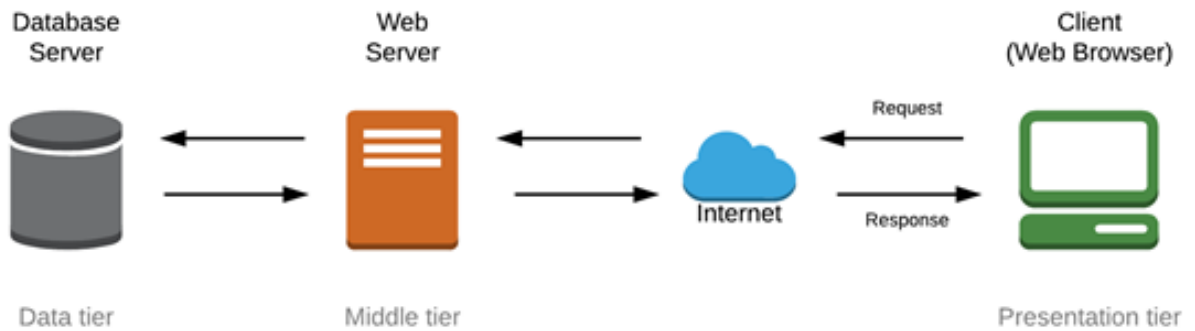


Figure 14: Web GIS infrastructure. Source: After Fu & Sun, 2011

Spatial database is an important part of Web GIS architecture that allows storage and querying of data. PostGIS, which is a spatial extension of PostgreSQL, is one of the most popular open-source relational database management systems (DBMS¹⁶). Parcel boundaries and other features can be stored in such a database and called to be visualize whenever the user request it. PostGIS provides solid backend capable of performing spatial analysis functions.

GeoServer and MapServer are two of the best-known open-source servers that handle vector and raster data (Zavala-Romero et al., 2014). These services are commonly known as WFS (Web Feature Service¹⁷) and WMS (Web Map Service¹⁸). Both enables interoperability by rendering spatial objects form the database, this objects can include parcels previously drawn and stored by the users as well as variety of different additional layers that may facilitate data acquisition.

¹⁶ "Database Management System or DBMS in short refers to the technology of storing and retrieving users' data with utmost efficiency along with appropriate security measures. DBMS allows its users to create their own databases as per their requirement. These databases are highly configurable and offer a bunch of options."

Source: http://www.kciti.edu/wp-content/uploads/2017/07/dbms_tutorial.pdf

¹⁷ "Interface Standard (WFS) provides an interface allowing requests for geographical features across the web using platform-independent calls"

¹⁸ "A Web Map Service (WMS) is a standard to provide visualisation of geospatial data over the Internet. WMS allows you to consume information on a map over the Internet or to publish map layers from your GIS or image processing system onto the Web." Source: http://www.e-cartouche.ch/content_reg/cartouche/webservice/en/text/webservice.pdf

The Web GIS libraries are Application Programming Interfaces (API's¹⁹) that implement WMS and WFS to display geographic data as a dynamic map in the browser (Zavala-Romero et al., 2014). These libraries are usually developed using JavaScript that have a significant impact on Web-based GIS systems extending its capabilities and creating a robust and interactive interface. The comprehensive study focused on identifying the best mapping web mapping technology by comparing 16 open-source libraries, suggests that Leaflet and OpenLayers libraries are the excellent lightweight and highly capable solutions due to their extensibility and amount of powerful extensions (Farkas, 2017; Roth et al. 2014). Both of the libraries support WMS services like Google Maps, OpenStreetMaps as well as give possibility to embed own rasters as a basemap.

Web mapping applications based on open-source components are widely used and proven to be efficient (Fu & Sun, 2011). However, in order to deliver fully functioning Web GIS applications knowledge of several coding languages and data handling formats is essential in order to build user friendly and intuitive application. The most common and used include the front-end (application interface) Hypertext Markup Language (HTML)²⁰ that builds all the static components like buttons, input fields or checkboxes and the dynamic one PHP²¹ that is used for interaction between user and system by facilitating input of attributes in database and is used to establish secure connection with the database. PHP serves also data handling that can be called by JavaScript and loaded on the map using different client-server data exchange formats like KML, XML or GeoJSON. JavaScript is considered to be one of the most crucial programming languages. The mapping requirements that mostly involve data entry are rather simple and does not imply complex data analysis and manipulation therefore such a client-side²² technology embedded in JavaScript libraries is capable of including all the necessary functionalities retaining high performance (Farkas, 2017).

¹⁹ "API is an interface to a software component that can be invoked at a distance over a communications network using standards based technologies." Source: <https://www.3scale.net/wp-content/uploads/2012/06/What-is-an-API-1.0.pdf>

²⁰ "HTML is the standard markup language for creating web pages and web applications. HTML is a format that tells a computer how to display a web page. The documents themselves are plain text files with special "tags" or codes that a web browser uses to interpret and display information on your computer screen." Source: https://www.austincc.edu/hr/profdev/eworkshops/docs/HTML_Basics.pdf

²¹ "PHP is a server-side scripting language designed primarily for web development but also used as a general-purpose programming language." Source: <https://techterms.com/definition/php>

²² "Client-side refers to operations that are performed by the client in a client-server relationship in a computer network. Typically, a client is a computer application, such as a web browser, that runs on a

Distributed Web GIS and its flexible infrastructure allow for strong data-management with multiple users however, is generally more adequate in publishing and exploring geospatial data rather than facilitate simply data entry that is required in this project.

Web GIS architecture that will handle spatial data collection and its most common components were described above. However, in order to fully explore the topic and select the most appropriate components, further research must follow and many gaps still need to be addressed in order to develop fully functional tool. For instance, migration from local platforms to the cloud solution is what complicates the system development process (Ananda et al., 2016); security problem and users authorization have to be managed in order to ensure data protection. Yet, creating Web GIS applications takes a lot of knowledge in programming along with having understanding of informatics.

2.3.2. Distributed open-source Desktop GIS

Desktop GIS is a software installed on a computer to create, visualize and analyze data (Sherman, 2008), whereas a distribute Desktop GIS is based on client-server architecture that can be developed using free and open-source software. Similarly to WebGIS, a backend where all the data is stored serves an integrated object-relational database with spatial capabilities (e.g. PostgreSQL and PostGIS). However, the client interface is in this case Desktop GIS (e.g. Quantum GIS) that provides comprehensive and powerful GIS capabilities to assist advanced spatial analysis, spatial data creation, and visualize results on a map in professional fashion.

In order to enable exchange of data between locally installed database and the centralized cloud based database, it is necessary to replicate the initial database where the data model is created. This will allow to work remotely and synchronize back to the master database whenever internet connection allows (QGIS User Guide, 2017).

user's local computer, smartphone, or other device, and connects to a server as necessary." Source: <https://en.wikipedia.org/wiki/Client-side>

The QGIS Offline Editing Plugin has a functionality to automate the synchronization process (Figure 14) by copying the content of the centralized database to a SpatiaLite²³ database and storing the offline inputs in a replicated version on a local machine. After restoring the network connection, the offline edits are merged with the master dataset (QGIS User Guide, 2017).

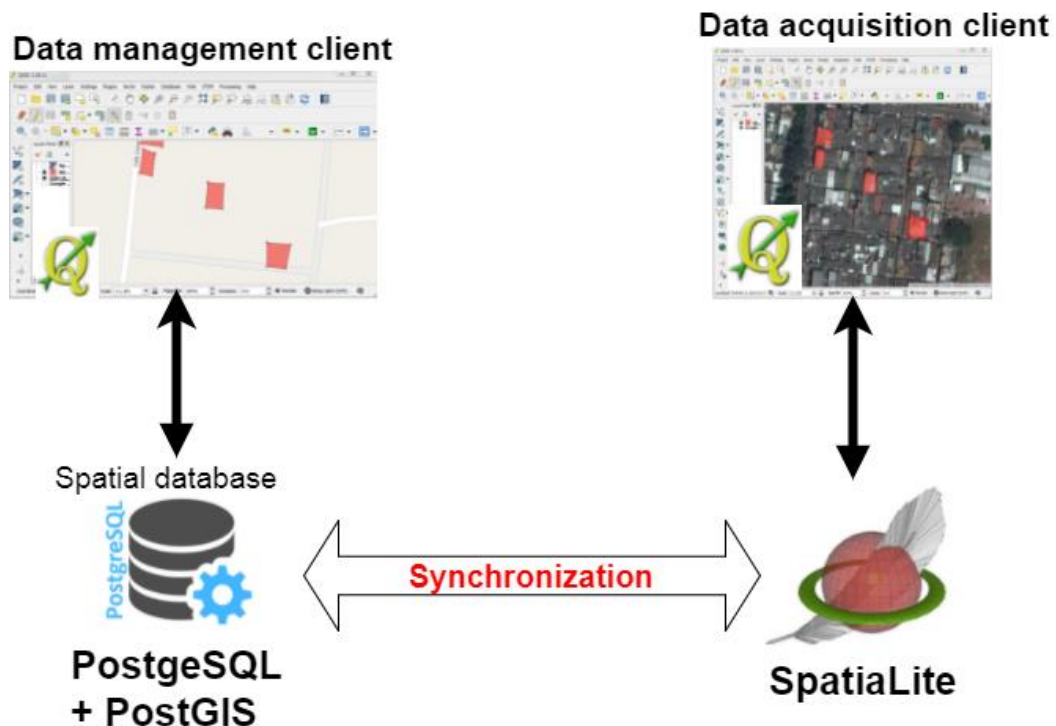


Figure 15: Synchronization between master database and SpatiaLite replication. Source: Own

Moreover, Quantum gives a possibility to customize GUI²⁴ in order to provide end-user with a light version of this very extensive software. A set of tools and menus can be limited to simplify the frontend appearance in order to provide users with only these buttons or panels that are

²³ "SpatiaLite is a spatial extension to SQLite, providing vector geodatabase functionality. It is similar to PostGIS, Oracle Spatial, and SQL Server with spatial extensions, although SQLite/SpatiaLite aren't based on client-server architecture: they adopt a simpler personal architecture." Source: <https://en.wikipedia.org/wiki/SpatiaLite>

²⁴ "A Graphical User Interface (GUI) is a pictorial interface to a program. A good GUI can make programs easier to use by providing them with a consistent appearance and with intuitive controls like pushbuttons, list boxes, sliders, menus, and so forth." Source: <https://ece.uwaterloo.ca/~nkvand/Coderep/gui%20examples/GUI.pdf>

necessary to perform the required tasks (Sherman, 2008). The manipulated configuration can be saved to .ini file and shared together with the installation package allowing dissemination of the customized interface. Open-source code of QGIS gives also possibility to build completely standalone mapping application by taking advantage of Python programming and PyQGIS²⁵ libraries, however, it requires advanced coding skills (Westra, 2014).

2.3.3. Open-source Mobile Data Collection Systems (MDCS)

Mobile Data Collection Systems concept was initially introduced to address the information gaps in developing countries where lack of programmers hinders deployment of sophisticated IT services (Hartung, 2012). In such a complex condition, relatively new mobile data collection tool have the potential to facilitate the collection of vital information, upload this data, clean it and ultimately analyze to improve decision-making intervention without the necessity of setting up infrastructure that requires time and human resources. In this sense, MDCS provide functionalities that save time, enhance data quality along with possibility of spatial data collection (point, polyline, polygon) and recording GPS coordinates.

The Mobile Data Collection Systems are a combination of client application running on mobile device using android application with remotely accessible database server (Figure 15). Furthermore, modern MDCS solutions are also capable of collecting data via web browser that gives the flexibility of collecting data on laptop or PC.

²⁵ “PyQGIS is the blending of Quantum GIS and Python to extend and enhance your open-source GIS toolbox. With PyQGIS you can write scripts and plugins to implement new features and perform automated tasks.” Source: <http://locatepress.com/ppq>

Below are more detailed descriptions of the components and their capabilities is presented:

- **Web-client application:** Provides user friendly drag-and-drop form designer. The designing process is graphical and does not require programming skills even when building complex logic form thanks to XForms²⁶ standard.
Afterwards, the form is disseminated and filed by the data collectors that after submission will be uploaded and stored to the cloud based server (aggregator).
The application also allows to edit, view and analyze data stored in the aggregator that simplifies data management process. Some of the platform have API functionality thus allow to retrieve data in third party software.
- **Aggregator:** Local or cloud based server that facilitates data storage. Cloud based servers are very convenient due to virtually unlimited scalability. Hosting server in a cloud allows to pilot the system without need of configuring and maintaining local server (Hartung, 2012). Data can be exported to various formats in order to perform more sophisticated geospatial analyses in a desktop GIS environment.
- **Collect client** (android based application that allows data entry in online and offline mode after downloading empty form from the server). Client application is downloaded on the mobile device using e.g. Google Play²⁷ store. Afterwards, the application has to be configured in order to sync with a server in order to download a form and upload it back after conducting the data collection or whenever internet connectivity is re-established. This allows the use of Collect client even in areas where network connectivity is an issue.

²⁶ “XForms is an XML application that represents the next generation of Forms for the Web. By splitting traditional XHTML forms into three parts - data model, instance data, and user interface - it separates presentation from content, allows reuse, gives strong typing - reducing the number of round-trips to the server, as well as offering device independence and a reduced need for scripting. Source: <https://www.w3.org/TR/2002/WD-xforms-20020118/index-all.pdf>

²⁷ “Google Play (formerly Android Market) is a digital distribution service operated and developed by Google. It serves as the official app store for the Android operating system, allowing users to browse and download applications developed with the Android software development kit (SDK) and published through Google” Source: https://en.wikipedia.org/wiki/Google_Play

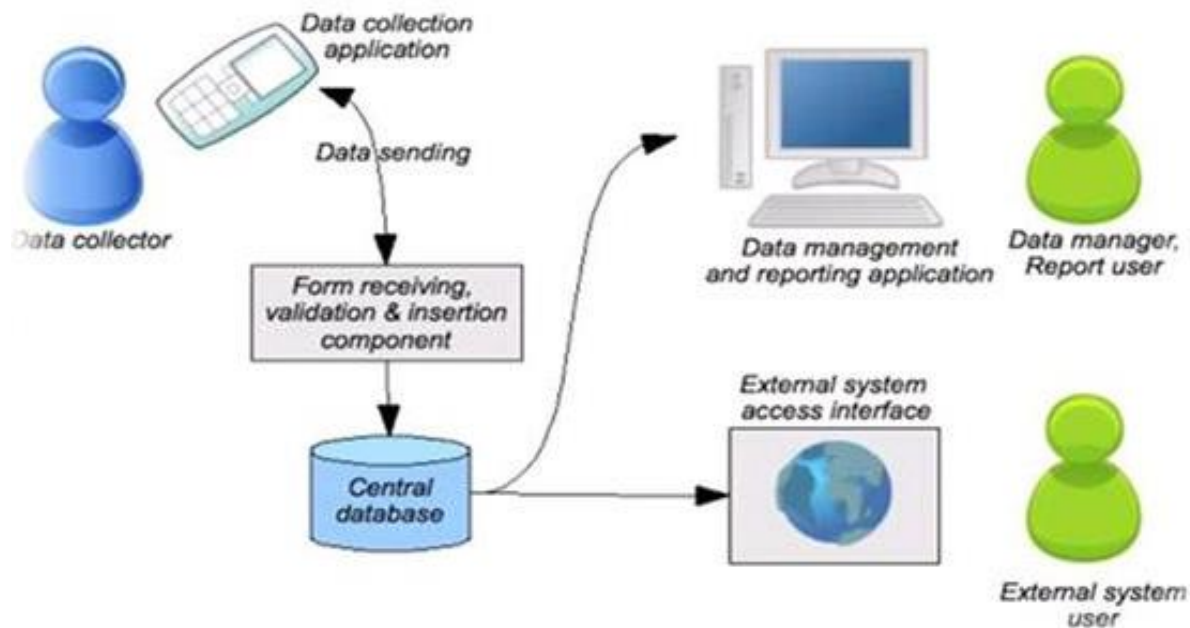


Figure 16: Mobile Data Collection Systems architecture. Source: <http://geoodk.com/>

This modular design allows customization and integration with multiple freely available GIS Collect clients that are capable of recording geometry data type e.g. GeoODK, GeoDataCollect, OpenMapKit, FieldTask. These applications are utilizing commonly used Google maps services that serve as a mapping basemap but also can accommodate georeferenced imagery loaded from the device drive. Flexible custom forms of MDCS streamline data collection and are reducing data entry errors by introducing features such as e.g. single selection of pre populated fields. Collected data can be immediately accessed via online database management client. In this way, viewing, analyzing and editing data or managing your project settings like for example giving permissions to project participants (viewing, editing, submitting rights) is very simple and can be performed by non-experienced users. Such a comprehensive system is potentially a strong competitor among presented two other spatial data collecting solutions.

The Conceptual design of an open-source GIS systems subchapter presented some of the insights of architecture and development of three potentially feasible mapping solutions that can address the objectives of the data collection exercise. The performance of each of these GIS systems will be dependent on components used and configuration. Nonetheless, it's not feasible to develop in parallel these three different solutions, therefore, the systems' review

(Table 1) will allow to evaluate the adequacy of each of the approaches. Although, the empirical research is vital, taking into account time constraint, the following indicators were introduced to help determining the optimal solution. For each of the indicators, values that range from 1 to 3 will describe relevance to the project. The approach that gets the most points will be implemented and tested on sample data to review its performance and capabilities.

Table 1: System relevance indicators. Source: Own

	Web GIS	Desktop GIS	MDCS
Spatial data type support	3 PostGIS (Geometry types that are defined by the Open Geospatial Consortium (OGC) standard.	3 PostGIS (Geometry types that are defined by the Open Geospatial Consortium (OGC) standard. Can be directly exported to various formats (shp,GeoJSON).	1 Exported CSV file requires conversion to e.g. shapefile in order to perform analysis in desktop GIS.
Setting up data entry functionality	1 Necessary to create JavaScript function for each of the variable/geometry that will enable PHP to pass geoJSON/JSON/XML to the database.	2 Relatively easy to create data model	3 Survey exceptionally easy to build (XForm).
Simplicity of system implementation	1 Requires programming knowledge and relatively extensive amount of components.	2 Less components than Web GIS, however, requires synchronization of databases and customization of front- end.	3 Exceptionally easy due to high interoperability between the components
Ease of use	3 Only when well designed and implemented.	2 Requires customization and configuration	3 Designed with the thought of inexperienced GIS users therefore very intuitive.
Offline mode support	1 Requires creation of static maps by downloading tiles using e.g. RgoogleMaps package.	1 Requires installation of a WMS server on the machine or saving tiles as georeferenced image.	3 Previously zoomed extend saves tile in the cache on the device.
Interoperability with other systems	3 Possible by establishing connection to PostgreSQL database.	3 Possible by establishing connection to PostgreSQL database.	3 Allows data fetching with third party applications via API.

System security and data protection	2 SQL query opens the application to SQL injection ²⁸ attacks. However, GeoServer offers protection by validating the supplied data by regular expressions (Grønning, T).	3 Spatialite facilitate sophisticated authentication schema where each user has its own specific permissions profile (http://www.gaia-gis.it/gaia-sins/spatialite-arch-2.3.1.html).	3 Data encrypted on client and server side
In build functionalities (data exploration)	1 Requires additional development.	3 Many common GIS functionalities provided by core features and plugins.	3 Real time access to database via data manager.
Development possibilities	3 Very comprehensive, however, requires coding skills.	2 QGIS community is very active therefore variety of plugins available.	1 Most of the development possible on the server side, therefore requires server maintenance skills.
Flexibility in changing data model	1 Complex and requires programming skills and SQL scripting.	1 Possible on the backend side (SQL scripting).	3 Exceptionally easy (XForm).
Development time	1	2	3
Maintenance and configuration	1 Requires programming skills and SQL querying.	2 Requires SQL querying.	3 Exceptionally easy through project editing and settings tools.
SUM	21	26	32

Web GIS the flexibility and modularity gives possibility to fully customize and integrate different solutions into an evolving architecture (Mantegari et al., 2011). However, the complexity does not favor its implementation and maintenance, therefore overall score ranks this mapping approach on the last place. Ranked second Distributed GIS is offering a powerful geospatial data analysis however, these extensive functionalities are desired only on the data management level meaning that “triumph of form over content” is clearly noticeable (from the user side only data entry service is expected). Ranked as first comes MDCS which according to the study, is the most appropriate approach reflecting the nature of this project. Its simplicity

²⁸ “SQL injection vulnerabilities are caused by software applications that accept data from an untrusted source (internet users), fail to properly validate and sanitize the data, and subsequently use that data to dynamically construct an SQL query to the database backing that application.” Source: <https://www.us-cert.gov/sites/default/files/publications/Practical-SQLi-Identification.pdf>

of deployment and usability, together with on-the-fly data exploration functionalities embedded in easy to navigate data management client, have a strong potential to facilitate stakeholders and decision-makers in the desirable tool.

2.4. Deploying Mobile Data Collection System

As presented in the previous subchapter, this study justifies the use of open-source Mobile Data Collection System integrated with a web-client application in order to facilitate data collection in online and offline environment.

In the open-source ecosystem of MDC, for each of the component there are number of options available. The invention of Open Data Kit (ODK)²⁹ which is a collaboration between Google and the University of Washington's Department of Computer Science and Engineering served as the foundation for other freely available mobile data collection tools and components that can be integrated in fully functional data collection solution. The theoretical solutions will not always prove to be useful or successful, therefore empirical research is vital. In the next subchapters, assembling Mobile Data Collection System from the open-source components will be described. Afterwards, the system will be tested and sample data will be entered, both using web-client and mobile based application to reveal system strengths and weaknesses. Furthermore, usability and performance will exposed its relevance to project's objectives.

²⁹ [http://peacetech.wiki/index.php?title=Open_Data_Kit_\(ODK\)](http://peacetech.wiki/index.php?title=Open_Data_Kit_(ODK))

2.4.1. Data aggregator and form management

Thanks to open-source standards, data collection can be managed independently by setting up own servers where the data will be aggregated. However, this rather laborious step can be omitted due to the possibility of creating a free hosted account at *kobo.humanitarianresponse.info* that is professionally supported by United Nations Office for the Coordination of Humanitarian or at *kobo.unhcr.org* hosted and managed by UNHCR on the enterprise server. The second option was chosen due to the possibility of receiving technical support from the server administrators in case of problems.

By creating an account on the aforementioned website, we can directly access data aggregation and form a management platform that is a core component as it binds all the other components together.

Immediately afterwards we can initiate a project. This step is done by simply filling project name (the only mandatory field) and other additional description (Figure 16).

Create New Project from Scratch

Project Name
Honduras data collection

Description
Enter short description here

Please specify the country and the sector where this project will be deployed. This information will be used to help you filter results on the project list page.

Sector
Humanitarian - Coordination / Information Management

Country
Honduras

Help KoboToolbox improve this product by sharing the sector and country where this project will be deployed. All the information is submitted anonymously, and will not include the project name or description listed above.

CREATE PROJECT

Figure 17: Creating a project in KoBo Toolbox. Source: <https://kobo.unhcr.org>

2.4.2. Form builder

After creating a project we can start building a form that in fact can be compared to creating a table in a traditional database. It can be done in two ways. By taking advantage of Graphical User Interface for XLSForm embedded in KoBo Toolbox platform or upload XLSForm created in spreadsheet using e.g. Excel.

2.4.2.1. Adding questions

Drag-and-drop like fashion of creating a form at KoBo platform doesn't require any technical knowledge. Yet, it also allows for building complex and advanced forms using XForm standard. In this way, it facilitates possibility of sharing data across systems and institutions.

Questions to the form are added by clicking on the '+' button that is below every question (Figure 17).

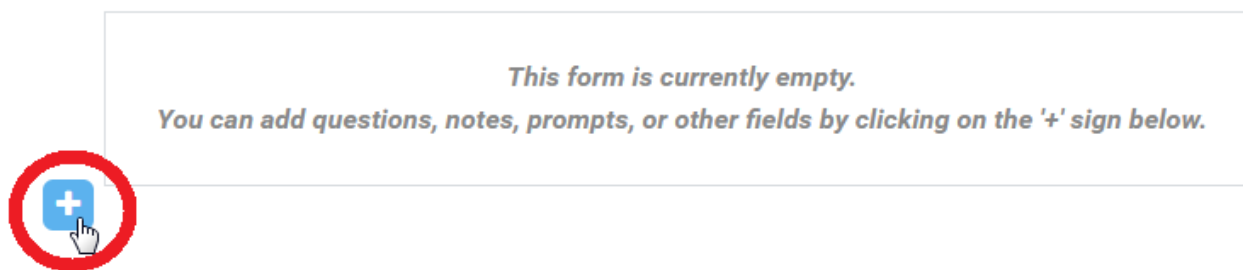


Figure 18: Adding a question to the survey. Source: <https://kobo.unhcr.org>

Then there is the possibility of typing a question. In these case an enumerator will be asked to draw the boundary of the parcel (Figure 18)



Figure 19: Adding a question to the survey. Source: <https://kobo.unhcr.org>

2.4.2.2. Selecting data type

Once “Add Question” is clicked, the data type menu will be expanded. At this point we can select one of the various types of question response. In this respect, selecting “Area” type will trigger the possibility of drawing polygon type of geometry on a map (Figure 19).

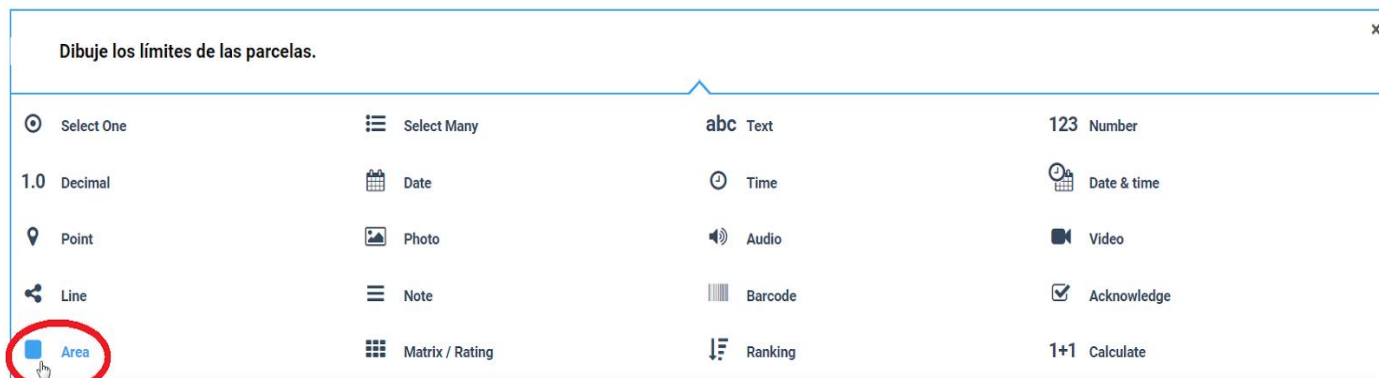


Figure 20: Selecting data type in expanded question menu. Source: <https://kobo.unhcr.org>

The question posed in this way will ensure the correct storage of the answer in the database. However, it's important so make sure that the name of the column is logical and understandable. Therefore, by clicking on the Settings button, we are able to replace the

default “Dibuje_los_limites_de_las_parcelas” by more meaningful attribute name “parcel_area” (Figure 20).

In the Settings window we can also make sure that the mandatory questions won't be omitted by selecting “Mandatory Response” check window.



Figure 21: Settings window. Source: <https://kobo.unhcr.org>

Another used types of response in this project includes:

- “Select One” - user can choose one of several options;
- “Text” - user can enter a text response;
- “Number” - user can enter an integer;
- “Decimal” - user can enter a decimal number;
- “Date” - user can enter a date;

Such a variety of response types not only ensures correct data format in the database but can be utilized to facilitate the ease and correctness of the typed answer. For instance, “Select One” type of response was used in the question where the enumerator has to indicate the department and municipality in which the abandoned property is located (Figure 21). By pre populating answers, we are sure that stored data won't be misspelled and will be consistent with the current administrative division of Honduras.

Option	Value
Atlantida	atlantida
Comayagua	comayagua
Copan	copan
El Paraiso	el_paraiso
+ Click to add another response...	AUTOMATIC

Figure 22: “Select One” type of response. Source: <https://kobo.unhcr.org>

2.4.2.3. Skip logic feature

Another useful feature is the “Skip Logic” functionality. It perfectly fits to hierarchical nature of administrative division. For instance, once the selection is made in the question about the department in which the parcel is located, only the municipalities forming that unit will be displayed in the next question. In order to apply this option to the question, we have to pre populate municipalities as “Select One” type of response for each single department accordingly and select correct equation in the “Skip Logic” settings. For example, when Francisco Morazan is selected as the department, only parentage municipalities will be available for selection in the next question (Figure 22).

Settings

Question Options

Skip Logic

Validation Criteria

This question will only be displayed if the following conditions apply

Departamento del inmueble = Francisco Morazan

+ Add another condition

- Atlantida
- Comayagua
- Copan
- El Paraiso
- Francisco Morazan**

Figure 23: Applying “Skip Logic” feature. Source: <https://kobo.unhcr.org>

2.4.2.4. Validation Criteria feature

By taking advantage of “Validation Criteria” feature, we can avoid unintended or invalid answers. This can apply to a question where an expected text response needs to conform to particular rules. For instance, in case where we want to restrict user to enter string that conform to specific existing in the country, format of Identification ID.

To achieve that, we have to apply in “Validation Code” field relevant expression syntax (regex)³⁰ (Figure 23).

For example, Identification ID that has format consisting of first two uppercase letters and six digits separated by dash would look like this:

`regex(.,'^[A-Z]{2}-[0-9]{6}$')`

In case user will enter an ID in another format, the error message will be displayed and will ask the user to verify it.



Figure 24: Applying validation syntax in order to ensure correct format of Identification ID. Source: <https://kobo.unhcr.org>

³⁰ “A regular expression (abbreviated regexp or regex) is a way to describe sets of characters using syntactic rules. Many programming languages use or support regular expressions. A regular expression is then used by a special program or part of a programming language.” Source: https://simple.wikipedia.org/wiki/Regular_expression

2.4.2.5. Building form in Excel

As mentioned previously, a form can be also created in Excel and uploaded as a project.

Herby, the basics of building a survey will be presented, however, the methodology of building advanced forms can be found at xlsform.org.

Building a survey starts from filling out records in the 3 mandatory columns under the survey tab in our spreadsheet (Figure 24).

These columns are: type, name, and label (<http://xlsform.org/#appearance>).

	A	B	C
1	type	name	label
2	text	parish	Parish
3	date	fecha	Fecha
4	text	informante	Informante
5	integer	nr_registro	Número de registro
6	select_one xn6af02	dep_inmueble	Departamento del inmueble

survey	choices	settings
--------	---------	----------

Figure 25: Building the survey in Excel spreadsheet. Source: <https://kobo.unhcr.org>

The **type** column specifies data type to be entered e.g. text, date, integer, select one. Yet, the **name** column represents field name in the database and **label** column contains text that will be displayed for user. When it comes to select one or many type of data from pre populated list, the choices have to be specified in the separate tab in our XLS document (Figure 25). The structure is the same as in the survey tab, however, we have to remember to type the correct list name in order to refer to appropriate question in the survey. In this example, list of the departments in Honduras is getting filled.

	A	B	C
1	list name	name	label
2	xn6af02	atlantida	Atlantida
3	xn6af02	comayagua	Comayagua
4	xn6af02	copan	Copan
5	xn6af02	el_paraiso	El Paraiso
6	xn6af02	francisco_morazan	Francisco Morazan

survey **choices** settings

Figure 26: .Building list of choices for “Select One” type of question. Source: <https://kobo.unhcr.org>

2.4.2.6. Deploying the form as a data collection project

Before initializing the data collection process, we have to deploy a form by simply click “Deploy” button in the KoBo navigation panel (Figure 26). After the deployment authorized users will be able to collect data which after submission, will be merged in the aggregator.

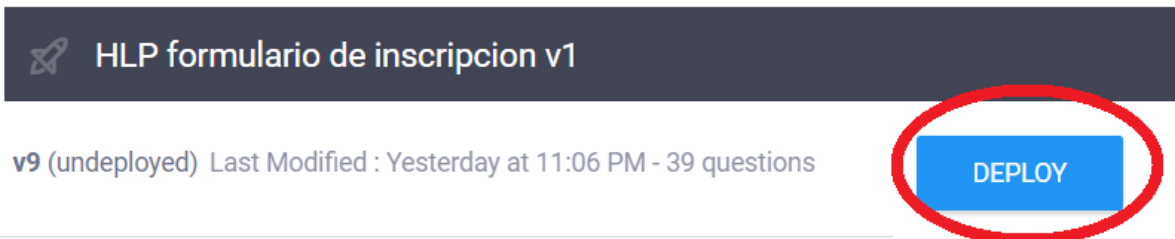


Figure 27: Deploying the form. Source: <https://kobo.unhcr.org>

Before piloting the tool in Honduras, the process of trial data collection will be conducted in order to make sure that the deployed form was created correctly. All necessary adjustments during the testing phase will prevent failures during the pilot. Yet, different form versions can be deployed for trial purposes and later deleted. The revised version will be deployed for the actual survey.

2.4.3. Data Collection Client

In order to be able to fill-out and submit the survey user have to create his own account and be authorized by the administrator of the project. This is done by entering username and setting “Can Submit”, ”Can View” or “Can Edit” permission (Figure 27). “Can Submit” will only grant user with option of collecting data without having ability of viewing the results. “Can View” permission will allow the user to submit the data and see the results, while “Can Edit” will give rights to make any kind of changes in the project. For instance, modify the form or administrate the users.

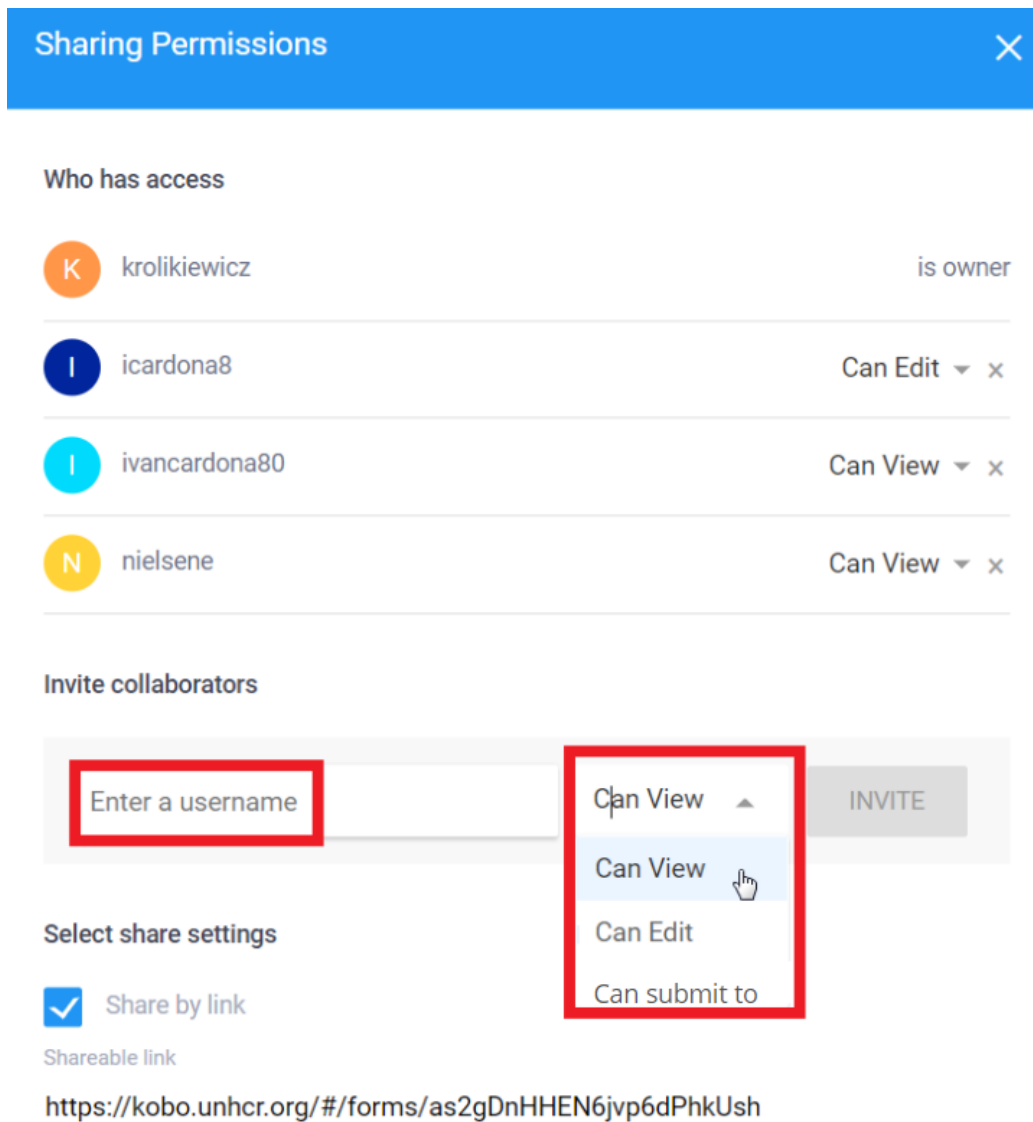


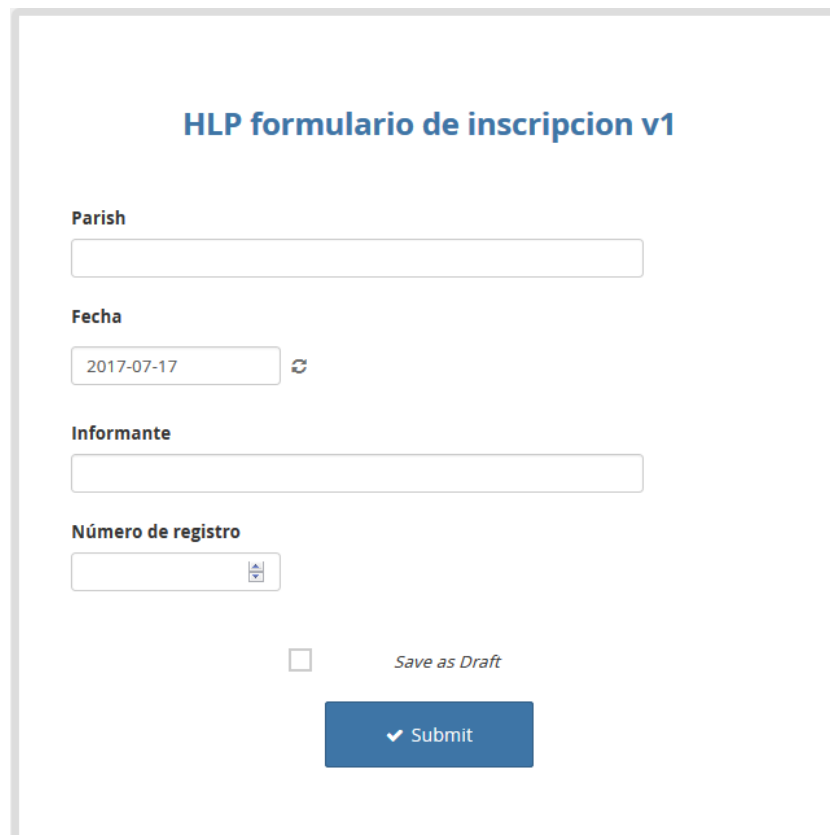
Figure 28: Sharing permissions settings. Source: <https://kobo.unhcr.org>

Furthermore, KoBo Toolbox allows to collect data in numerous ways, thanks to XForm technology and open-source initiatives. Web-based client gives opportunity to enter data online in a browser while the mobile based application is more suitable to collect data offline using smartphone or tablet. Integration of these approaches gives the possibility of trouble-free data collection through various devices. The introduction to both solutions can be found below.

2.4.3.1. Web-based

The Kobo Toolbox platform facilitates integration with Enketo, a web-based open-source application that allows to fill-in and publish submissions as well as edit already submitted data directly from the browser.

This is how the shortened version of the form look like in Enketo application (Figure 28).



The image shows a web-based form titled "HLP formulario de inscripcion v1". The form contains the following fields and controls:

- Parish:** A text input field.
- Fecha:** A date input field showing "2017-07-17" with a refresh icon to its right.
- Informante:** A text input field.
- Número de registro:** A dropdown menu.
- Save as Draft*
-

Figure 29: Accessing the form via Enketo application. Source: <https://kobo.unhcr.org>

The most important part of the survey is focused on the spatial data acquisition. Therefore, at this point, ability of Enketo to support this process will be evaluated.

At first, the ability of drawing polygon type of geometry is supported by the application. User is delineating the parcel by marking vertices of the property. Once done, “Close Polygon” button joins first and last entered vertex (Figure 29).

Secondly, the ability of searching the address is supported by the Enketo therefore, one of the objectives has been achieved (Figure 29).

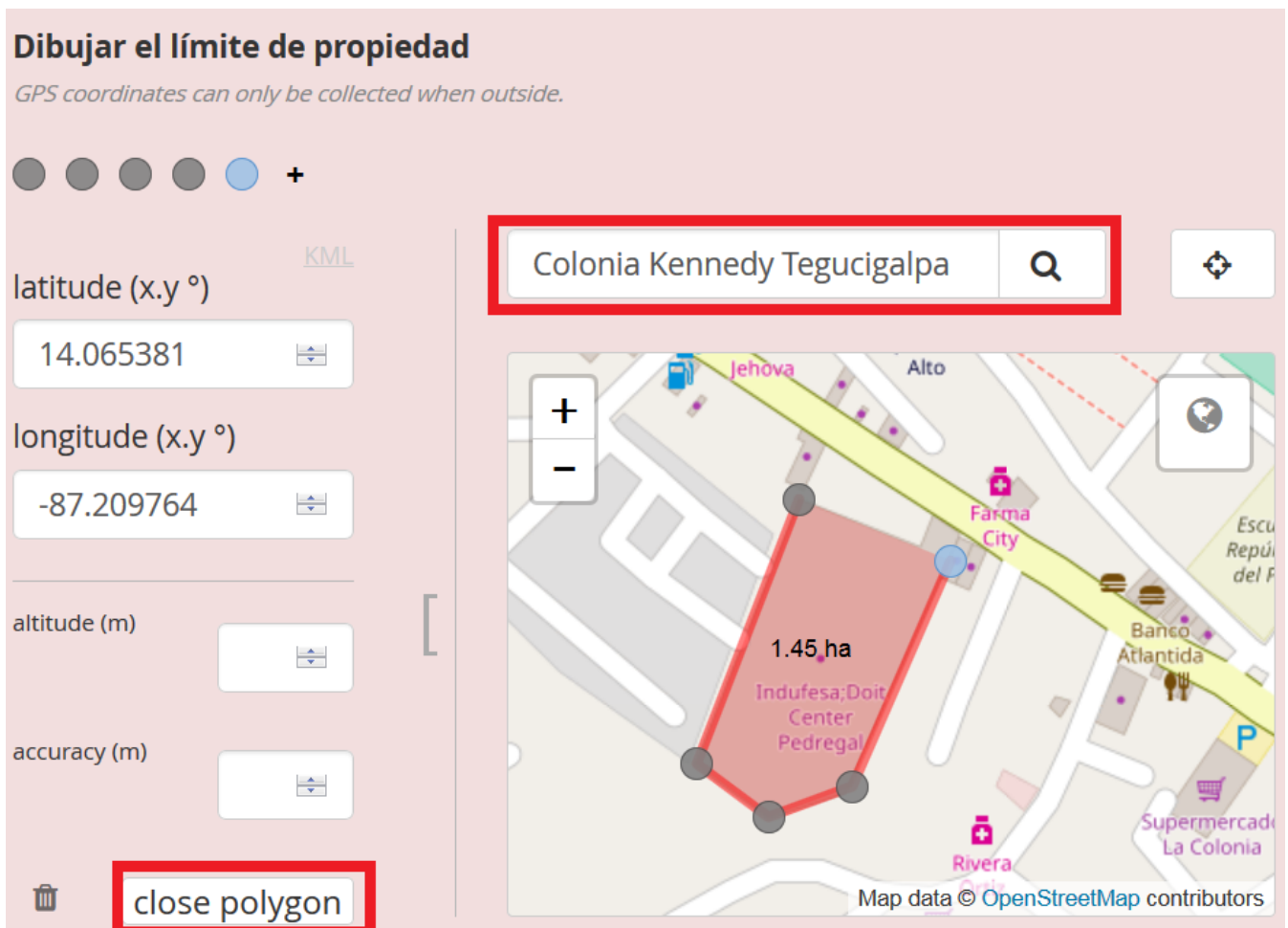


Figure 30: Mapping window, search and drawing functionalities. Source: <https://kobo.unhcr.org>

Secondly, ability of drawing geometry over satellite imagery has been enabled (Figure 30). By default, Enketo supports only the OpenStreetMap basemap, therefore in order to enhance the mapping window to two more basemap layers, help of the KoBo administrator in the UNHCR was needed to adjust config.json file by adding following script on the server side of Enketo:

```
"maps" : [ {
  "name": "OSM",
  "tiles": ["http://{s}.tile.openstreetmap.org/{z}/{x}/{y}.png"],
  "attribution": "Map data © <a href=\"http://openstreetmap.org\">OpenStreetMap</a>
contributors"
}, {
  "name": "Satellite",
  "tiles": "GOOGLE_SATELLITE",
  "minzoom": "1",
  "maxzoom": "20"
}, {
  "name": "Hybrid",
  "tiles": "GOOGLE_HYBRID",
  "minzoom": "1",
  "maxzoom": "20"
}]
```

The script added satellite and hybrid Google Maps tile services. Hybrid basemap contains streets and points of interest labels therefore it's easier to orientate in the area. Moreover, the zoom was increased to maximum in order to take full advantage Google Web Map Service capabilities and be able to draw parcel boundaries with higher precision.

Colonia Kennedy Tegucigalpa



Figure 31: Enabling satellite and hybrid basemaps in Enketo. Source: <https://kobo.unhcr.org>

2.4.3.2. Mobile based

There are multiple client applications to collect data on Android mobile device. To meet the objectives of this project, only the applications with strong GIS component are considered.

The following table gives overview on some of the most leading application (Figure 31). The first two are dedicated to develop OpenStreetMap project while the last two are ESRI products, therefore a paid license is required. GeoODK among the rest of the applications was developed to allow collection of geographic features including polygon type of geometry, thus it is the most suitable solution.

	Assessment type uncoordinated coordinated	Form logic OSM tags Simple custom Complex custom	Geometry Points Points, Tracks all	Server required No Yes	Output formats Geo-type only CSV-type Geo and CSV	Integration with OSM none possible
Maps.Me					KML	
OsmAnd					GPX	
ODK				 (ODK/KoBo)	CSV (KML for Point)	
GeoData Collect				 (ODK/KoBo)	GPX	
GeoODK				 (ODK/KoBo)	CSV (KML for Point)	
OpenMap Kit				 (POSM)	CSV and OSM	
Survey123				 (ArcGIS)	CSV and GDB	
Collector for ArcGIS				 (ArcGIS)	CSV and GDB	

Figure 32: Mobile Data Collection tools comparison. Source: <http://blog.cartong.org>

The application can be download from Google Play store. At GeoODK has to be linked with KoBo server by providing URL to our account in “ODK aggregate settings” (Figure 32).

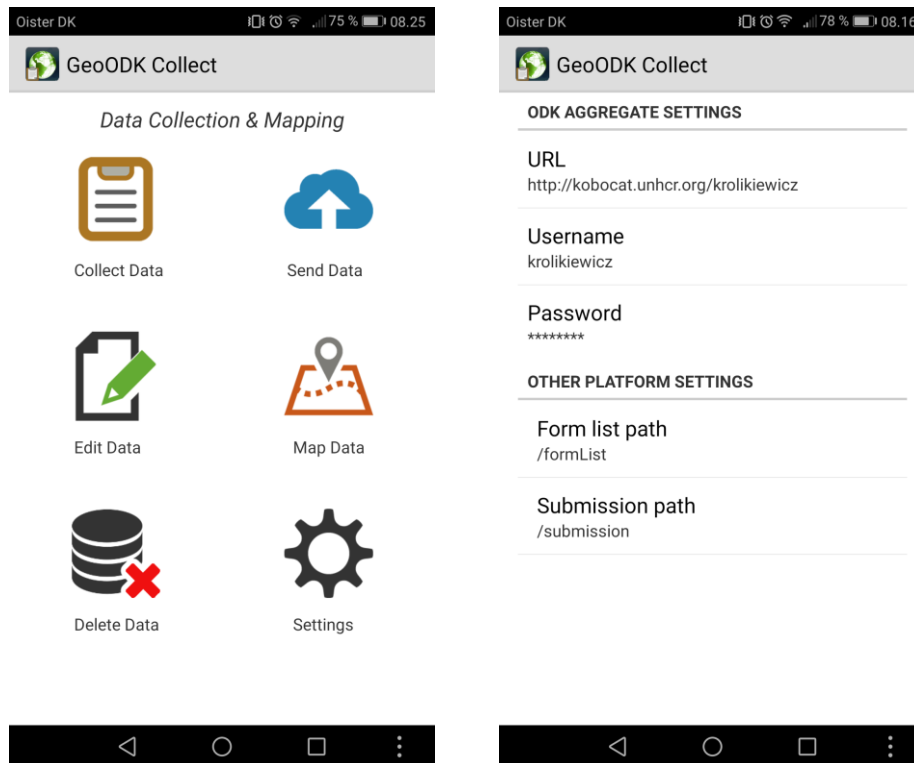


Figure 33: Linking GeoODK with KoBo. Source: Own

Immediately after, we will be able to get blank form that we have previously created using KoBo form builder (Fig. 44). At this point we are ready to start filling the form. The map is displayed whenever user is asked to record geoshape (Figure 33).

Right after, the data can be explored, analyzed or exported in various formats. It can be done in the offline mode, however, map tiles have to be cached beforehand by zooming to the area of interest. Yet, GeoODK gives possibility of loading offline maps previously copied to the device. The filled form will be stored on the machine and can be sent to the server whenever internet connection allows, the form can be sent to the server and merged with rest of the submissions. There can be also edited if necessary.

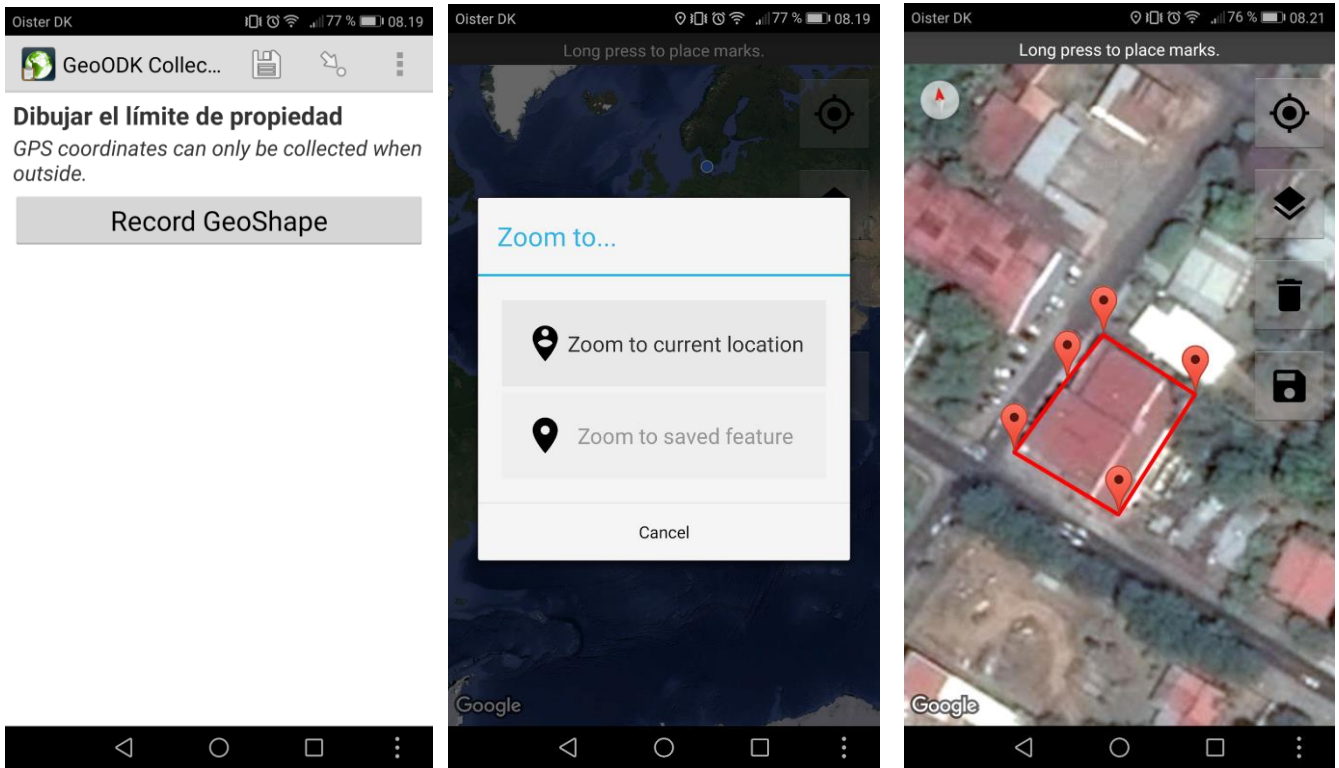


Figure 34: Recording parcel boundary in GeoODK application. Source: Own

3. Results and discussion

In this chapter, the results of the proposed system testing phase will be presented and discussed in relation to the desired front end functionalities as well as back end capabilities to explore data, perform analysis and integrate with third party applications. Moreover, the advantages and limitations of the proposed mapping solutions will be discussed.

3.1. Functionalities and usability evaluation

As the main functionality, ability to embed **high resolution satellite imagery** was identified. At present, utilization of Google map services provides with DigitalGlobe³¹ high resolution basemap. The resolution of imageries in Honduras is not as high as in United States and Western Europe (60 to 30 cm) but high enough to identify standalone buildings or parcels especially in rural settings (Figure 34).



Figure 35: Rural area of La Criba. Source: Own

³¹ "DigitalGlobe is the world's leading provider of high-resolution Earth imagery, data and analysis."
Source: <https://www.digitalglobe.com>



Figure 36: Dense type of building in urban settings, Tegucigalpa. Source: Own

In urban settings (Figure 35), where the type of building is very dense, it might be a bit more challenging to identify a particular building, however, the person familiar with the area should not have difficulties. In case where higher resolution basemap will be needed, satellite or orthophoto imagery can be hosted as a tile services via GeoServer and serve the Enketo client.

For offline purposes, GeoODK provides the functionality of loading tiles from the storage on the mobile device. However, this functionality haven't been tested due to time constrain.

Location search functionality is enabled in the Web based mapping, however GeoODK or any other Mobile Data Collection client have no location searching functionality. This can be considered as a major fault, however, the application is expected be used in the close proximity to the abandonment cases therefore "Zoom to current location" feature (Figure 33), that uses build in GPS sensor helps user to orientate the map without the necessity of panning and zooming in search of the desired location.

Drawing geometry functionality is fairly easy in both, web and mobile application, however, it's easier to use web to record a polygon of multiple geopoints. Additionally, "Close polygon" option allows to connect first and last entered point in order to create the polygon.

Attribute data collection is systems' very strong side. User friendly way of filling the survey form, in both, web and mobile version meets the requirements of delivering intuitive and self-explanatory solution. Yet, "Skip Logic" and "Validation Criteria" features are very useful when it comes to ensuring correct data format, yet enable data cleaning process to be shortened.

For **online** environment it's recommended to use web based solution, while **offline** environment is better supported by mobile based GeoODK application. However, that requires zooming to the area while being connected to the internet. In this way tiles will be cached on the device and can be used in the offline mode. Additionally and as already mentioned above, mobile application provides the functionality of loading tiles from the storage on the mobile device. Also web application Enketo can be used in the offline mode, however it does not support mapping part of the survey. For offline usage of web application, Enketo for now facilitates non spatial attributes only, mapping functionality has not been yet supported.

Due to data confidentiality, **security** issue is another matter that had to be considered. However, the proposed system has several security features. At first, only approved users can have access to the project (blank form). Secondly, the possibility of setting project-specific user permissions can restrict users to only submit survey (if necessary, only the project administrator can have rights to access and manage the data). Secondly, authorized enumerators require authentication by providing username and password in order to access and submit a form. Data itself is stored on a server that is located in UNHCR headquarters in Geneva, where data protection is highly important. Moreover, data on the device GeoODK supports the ability to encrypt the content of a form the moment it is marked as completed and ready for submission on the mobile device. It is done by implementing asymmetric key encryption³². Decrypting the data after copying it to another device can be done by applying private key that is never shared by the user.

³² Source: <https://opendatakit.org/help/encrypted-forms/>

3.2. Data exploration capabilities

KoBo platform allows monitoring data collection and performs basic analysis and mapping.

Form submitted by enumerator is immediately merged with the rest of the data and can be analyzed without necessity of exporting to different format.

At first, we can explore data in the table view (Figure 36), from there we can open each individual data record and edit it in Enketo viewer. It's very easy way of correcting data, however, lack of querying functionality does not make it easy to search for particular record in large datasets.

Value and header format: Include groups in headers Group separator:

View or Edit	start	end	Parish	Fecha	Informante	Número de registro	Departamento del Inmueble	Municipio	Zona
Open	2017-09-17T09:14:...	2017-09-17T10:33:...	Colonia Kennedy T...	2017-09-16	Jose Tomas Villeareal	131324	Francisco Morazan	Distrito Central	Urbana
Open	2017-09-17T09:18:...	2017-09-17T09:26:...	Colonia Kennedy T...	2017-09-16	Jose Tomas Villeareal	123243	Francisco Morazan	Distrito Central	Urbana
Open	2017-09-17T09:26:...	2017-09-17T10:22:...	Colonia Kennedy T...	2017-09-03	Jose Tomas Villeareal	544334	Francisco Morazan	Distrito Central	Urbana
Open	2017-09-17T09:28:...	2017-09-18T16:54:...	Colonia Kennedy T...	2017-09-20	Pedro Sanchez	435432	Francisco Morazan	Distrito Central	Urbana
Open	2017-09-17T09:30:...	2017-09-17T10:30:...	Colonia Kennedy T...	2017-09-10	Pedro Sanchez	435465	Francisco Morazan	Distrito Central	Urbana
Open	2017-09-17T09:32:...	2017-09-17T09:34:...	Colonia Kennedy T...	2017-09-04	Pedro Sanchez	433437	Francisco Morazan	Distrito Central	Urbana
Open	2017-09-17T09:34:...	2017-09-17T10:27:...	Colonia Kennedy T...	2017-09-19	Jose Tomas Villeareal	323231	Francisco Morazan	Distrito Central	Urbana
Open	2017-09-17T09:40:...	2017-09-17T10:28:...	Colonia Kennedy T...	2017-08-29	Pedro Sanchez	434342	Francisco Morazan	Distrito Central	Urbana
Open	2017-09-17T09:42:...	2017-09-17T09:48:...	Colonia Kennedy T...	2017-09-05	Pedro Sanchez	434521	Francisco Morazan	Distrito Central	Urbana
Open	2017-09-17T09:49:...	2017-09-17T09:51:...	Colonia Kennedy T...	2017-09-12	Pedro Sanchez	323212	Francisco Morazan	Distrito Central	Urbana
Open	2017-09-17T09:51:...	2017-09-17T09:53:...	Colonia Kennedy T...	2017-09-11	Jose Tomas Villeareal	653223	Francisco Morazan	Distrito Central	Urbana
Open	2017-09-17T09:53:...	2017-09-17T09:54:...	Colonia Kennedy T...	2017-09-11	Jose Tomas Villeareal	432343	Francisco Morazan	Distrito Central	Urbana
Open	2017-09-17T09:54:...	2017-09-17T10:31:...	Colonia Kennedy T...	2017-09-05	Jose Tomas Villeareal	123456	Francisco Morazan	Distrito Central	Urbana
Open	2017-09-17T10:11:...	2017-09-17T10:12:...	Cuyamelito	2017-09-05	Pablo Alvarez	324354	Copan		Rural
Open	2017-09-17T10:12:...	2017-09-17T10:14:...	Cuyamelito	2017-09-10	Pablo Alvarez	432154	Copan		Rural
Open	2017-09-17T10:18:...	2017-09-17T10:22:...	Cuyamelito	2017-09-11	Pablo Alvarez	324354	Copan		Rural
Open	2017-09-17T09:57:...	2017-09-17T10:32:...	Cuyamelito	2017-09-04	Pablo Alvarez	4323545	Copan		Rural
Open	2017-09-17T10:08:...	2017-09-17T10:31:...	Cuyamelito	2017-09-06	Pablo Alvarez	324321	Copan		Rural
Open	2017-09-17T10:09:...	2017-09-17T10:32:...	Cuyamelito	2017-09-03	Pablo Alvarez	432454	Copan		Rural
Open	2017-09-17T10:14:...	2017-09-17T10:29:...	Cuyamelito	2017-08-28	Pablo Alvarez	324354	Copan		Rural
Open	2017-09-17T09:48:...	2017-09-17T10:33:...	Colonia Kennedy T...	2017-09-04	Jose Tomas Villeareal	546532	Francisco Morazan	Distrito Central	Urbana

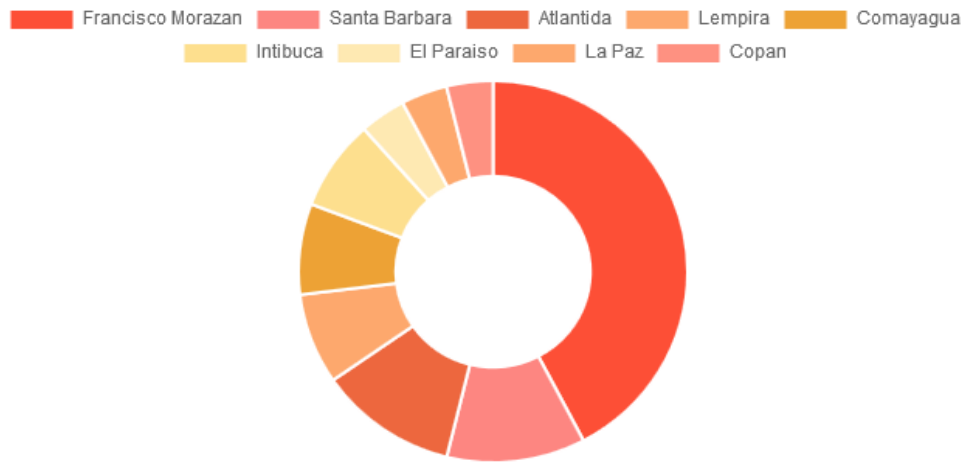
« previous 1 next »

Figure 37: Exploring data in table view. Source: Own

Secondly, automated reporting functionality allows to better grasp trends in survey's' attribute data. The most satisfactory results can be achieved when a question is a "Select", "Number" or "Date". Only for these data types, KoBo reporting tool can create charts. The chart below is constructed from the answers to the question about the current department of residence of a victim (Figure 37). In addition to the chart, frequency and percentage records are following below.

Lugar de residencia actual (Departamento)

TYPE: "SELECT_ONE". 26 out of 26 respondents answered this question. (0 were without data.)



Value	Frequency	Percentage
Francisco Morazan	11	42.31
Santa Barbara	3	11.54
Atlantida	3	11.54
Lempira	2	7.69
Comayagua	2	7.69
Intibuca	2	7.69
El Paraiso	1	3.85
La Paz	1	3.85
Copan	1	3.85

Figure 38: Example of a chart based on "Select" type of question. Source: Own

The “Text” type of data entry cannot be presented as a chart, however it still is aggregated to frequency and percentage counts. The reason for that can be the qualitative nature of text data that is rather complicated to describe using quantitative methods.

Another useful feature that allows to grouping answers by other answer that has to be “Select” type. For instance, in the below example, the answers to the question about the current municipality of residence of a victim are grouped by “Zona” that indicates rural or urban property settings (Figure 38).

Lugar de residencia actual: Municipio

TYPE: "SELECT_ONE". 26 out of 28 respondents answered this question. (2 were without data.)

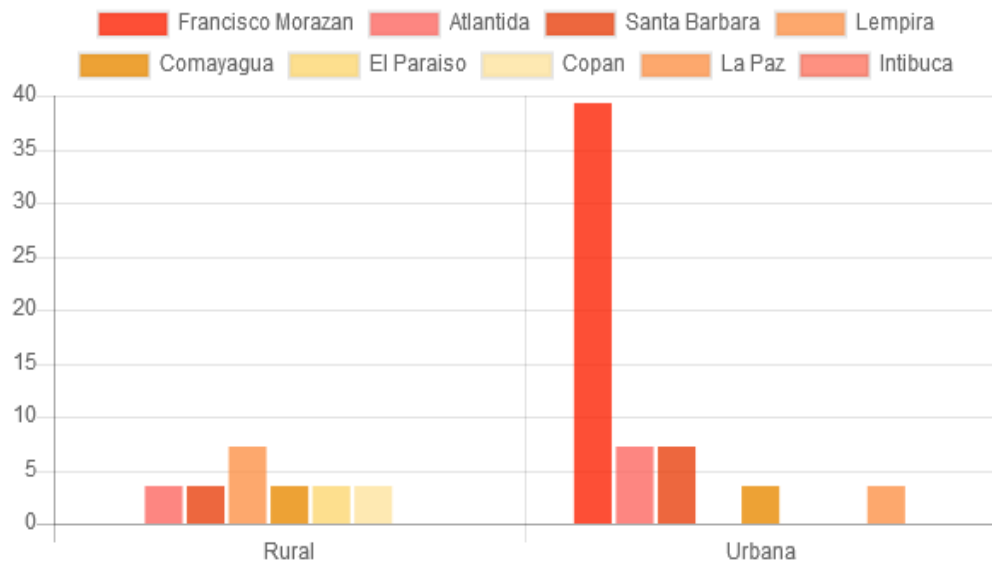


Figure 39: Grouping question by another question. Source: Own

Moreover, there are several different types of chart that can be selected along with colors and size. This gives the possibility of correctly presenting data to have a better understanding of data distribution, relationships between parts of the data and grasp trends in data.

Another functionality integrated in the platform is the mapping feature. However, for now, only point data is supported. For this reason, in order to visualize data in the application it's worth considering adding additional questions where point data, for instance centroid of the property, will be recorded. In this way, all the cases can be displayed on a map right after submission. Figure 39 presents an example where sample point locations of abandonment cases recorded in the south of Tegucigalpa are visualized on satellite imagery basemap.

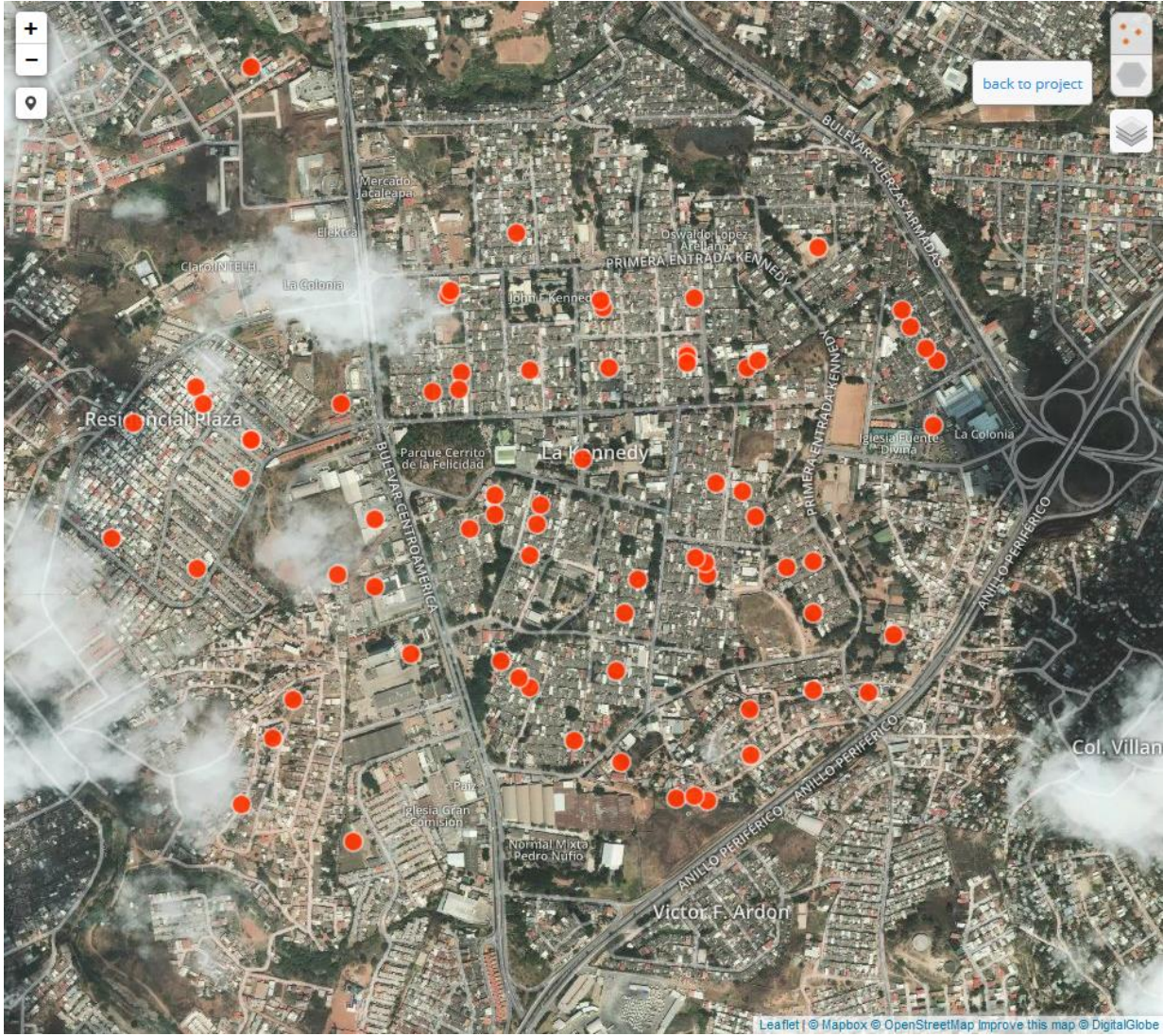


Figure 40: KoBo point data mapping functionality. Source: Own

Additionally, platform facilitates clustering functionality that allows to better grasp density of the Cases (Figure 40). In addition, several different basemaps are available, therefore it is possible to present the results in different ways.

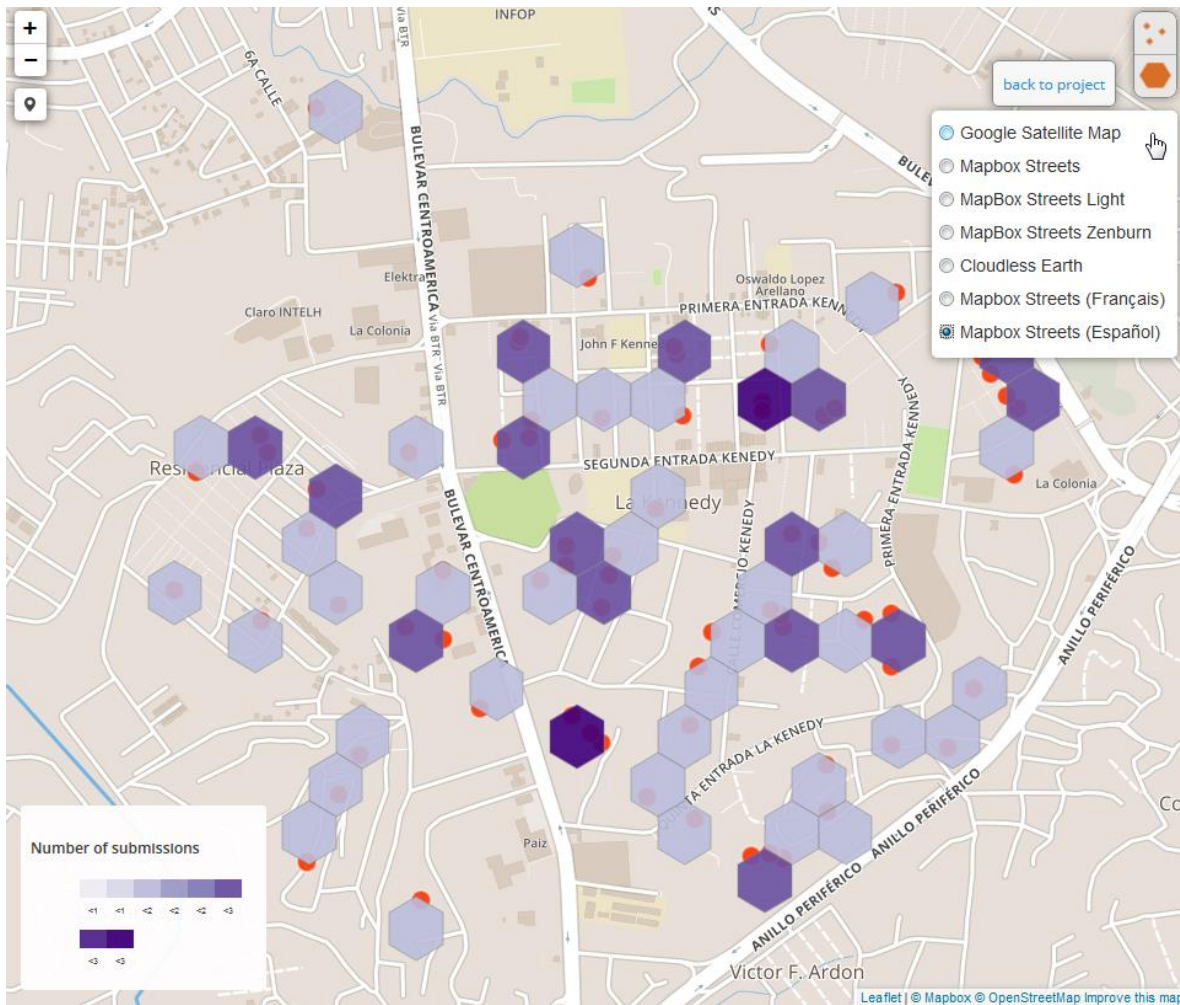


Figure 41: Clustering functionality. Source: Own

Taking into account rapid development of Mobile Data Collection tools and very active open-source community, all the geometry types will most likely be supported in the nearest future. New reporting functionalities were already announced to be released, for instance drag and drop dashboard like data summarizing.

Furthermore, taking advantage of API functionality gives possibility of integrating KoBo with another third party software. In the following example (Figure 41), the collected data can be retrieved in json³³ format and can be passed via link to a software that have capabilities to interpret it.

<https://kobocat.unhcr.org/api/v1/data/5018?format=json>

```
"Datos_de_contacto_Direcci_n": "El Progreso 54",
_xform_id_string": "as2gDnHHEN6jvp6dPhkUsh",
"Nombres_completos": "Jose",
"Nacionalidad": "Honduras",
"Nombre_del_inmueble": "Guarizama",
"meta/instanceID": "uuid:1fda53c1-c2d4-4df5-849c-52b9d15454d2",
"end": "2017-08-31T15:12:46.000+02:00",
"Tenencia_Tipo_de_documento": "ID",
"Tipo_de_inmueble": "terreno",
"N_mero_de_registro": "4544",
"Sexo": "m",
"start": "2017-08-31T09:34:27.000+02:00",
"No_de_identificaci_n": "4845454",
"Datos_de_contacto_Telefono": "457548888",
"Informante": "Martinez",
"_status": "submitted_via_web",
```

Figure 42: An example of collected data in JSON format. Source: Own

Finally, the significant advantage of the proposed system, is possibility to promptly export data to various formats like XLS, CSV, KML or Excel Analyser. However, KML format supports only point type of geometry, therefore one more step is required in order to convert set of points that form a polygon into vector file. For instance, using GeoODK online converter, CSV file can be converted to vector file based on a certain field where the polygon vertices are stored. The output is a zipped shapefile which can then be used in any GIS software. In addition to online converter, Python script can be also downloaded from GitHub repository in order to convert data offline. However, it is a pity that the format for storing the geometry features is not automatically readable by most GIS software. For now, it is stored as string of latitude, longitude and elevation separated by comma.

³³ "JSON or JavaScript Object Notation is an open-standard file format that uses human-readable text to transmit data objects consisting of attribute–value pairs and array data types (or any other serializable value). It is a very common data format used for asynchronous browser/server communication, including as a replacement for XML in some AJAX-style systems". Source: <https://en.wikipedia.org/wiki/JSON>

An example below presents shapefile previously converted from CSV file. After projecting file in WGS 84 in order to standardize spatial information to the latest revision of coordinates system, accessing accuracy was conducted applying satellite imagery basemap in QGIS software. It can be stated that the system fulfills the objectives, the geometry as well as all the non-spatial attributes are preserved appropriately (Figure 42). However, the system does not allow to maintain spatial relationships between individual objects. It means that gaps and overlaps may occur between neighboring parcels. Especially overlaps are vital due its potentially influential impact on land ownership disputes.

Objectives of the project does not recognize such a functionality, however, if this was acknowledged, the other approaches must have been considered due to the possibility of feeding the front end with previously entered data and apply topology rules that will prevent disputes and help manage integrity of geometries. Taking into account, that project objectives focuses on building evidence registry, rather than cadastral system with its perfectly adhering parcel edges, such a functionality can be considered in separate study.

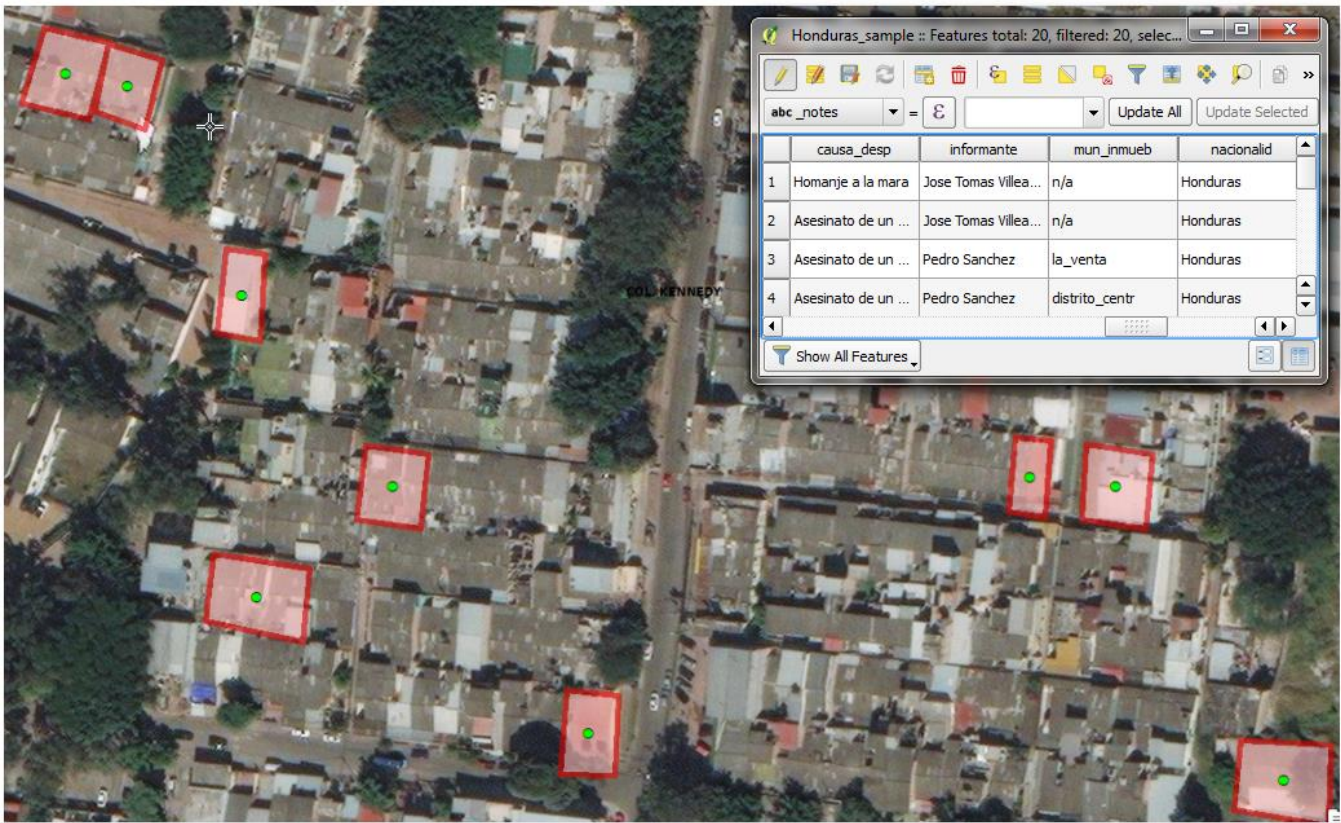


Figure 43: Data quality assessment in QGIS. Source: Own usability

At this point, by taking advantage of powerful desktop GIS and georeferenced data, we can manage the data, present it by creating professional maps as well as perform traditional and advanced spatial analysis. An example below presents one basic example, how the collected data can be visualized by using Kernel Density tool which calculates a magnitude-per-unit area from point dataset (Figure 43). Thus it can be used to more meaningfully visualize density of abandoned houses. Moreover, the surface can be influenced by adding weight from one of the attributes. For instance, by inputting number of family members affected by the displacement we can present more heavily these cases where the figure is higher. Yet, by assigning the weights to cause of the displacement, we can present its severity more explicitly, according to adopted scale. Providing such a geospatial visualization products to decision makers, has potential to impact identification and understanding the patterns and trends and help revealing relationship between occurring phenomenon. This process without spatial reference would have been much more difficult.

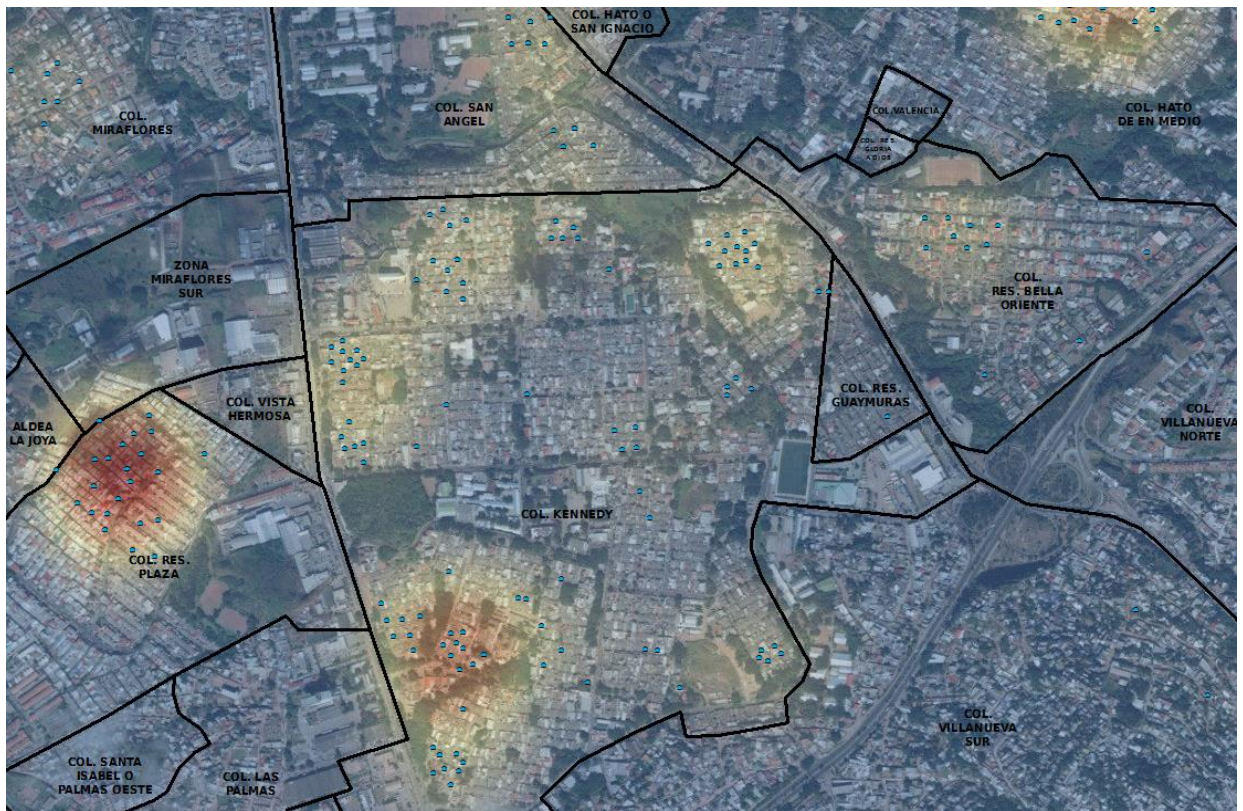


Figure 44: Kernel density spatial analysis based on sample data. Southern Tegucigalpa. Source: Own

The results of system functionalities and performance test, suggests that the proposed solution will be capable to complete all the required tasks. However, the pilot that will take place in Honduras will allow to test its performance in low-resource environment.

Lacking some of the insignificant functionalities can be justified by having 'ready to go' solution that is saving time of development and resources.

Although the employment of traditional hierarchical and relational database systems like PostgreSQL will often be better for aspect of data storing and maintaining, KoBo proves to meet the project objectives by facilitating comprehensive environment capable to collect, store, disseminate and analyze data. It has a number of advanced features built in based on open-source libraries that can be used by non-professional personnel. Therefore this flexible technology solution proves to have an advantage over the other considered systems. Taking into consideration different technical constraints and users capabilities as well as system online and offline environment, not all theoretical solutions were evaluated to be useful, therefore it's necessary to compromise between what is desirable and what is practical.

Yet, in circumstances where new features are still being actively developed, further improvement intentions of the proposed system are also very promising.

Summing up, the system has a potential of supporting decision makers to better target the most affected areas in order to carry out collaborative program in order to fight against crime and allocate resources based on security demand to protect people and their property. Honduras is not the only country in the region facing displacement caused by violence. Due to the geographical settings, other countries in the region are a natural corridor of drug trafficking from South to North America. Therefore, if successful, the system has the potential of being implemented in other affected countries.

4. Conclusion

By revealing the existing gaps in cadastral register in Honduras and its effect on efficient property restitution process of affected population, this study was prepared for the purpose of providing decision makers with a comprehensive tool to enable mapping and analysis of property abandonment cases, by deploying an appropriate technology. GIS, together with satellite technologies enabling earth observation at high spatial resolution can provide interested parties with powerful capabilities to better address responses to displacements, the area that needs urgent attention. On the other hand, GIS technology is confronted with a lot of challenges in the practical usage, particularly in the developing countries such as Honduras. Unreliable internet connection, security issues and lack of trained staff can be major challenge to collect data quickly and reliably. Therefore, based on the comparative analysis of three distinct approaches, Mobile Data Collection System, integrated with a comprehensive client application was proposed as a set of tools that addresses these obstacles in the most suitable manner. Taking into consideration that there are no costs associated with deployment, maintenance and staff training, this user friendly, free and open-source application holds a great potential. Moreover, taking into consideration various requirements and limitations, the recommended system enables spatial and non-spatial attributes capture, storage, management, analysis and visualization in timely manner, with the assurance of data quality and credibility. The recommended approach allows to collect data in an offline- and online environment, monitor data collection and perform basic analysis and mapping functions. Yet, modular thus flexible design facilitates interoperability with other GIS and data management technologies and applications and therefore has the ability to strengthen the collaboration between stakeholders in order to design a coherent respond framework in complex humanitarian emergencies. Moreover, despite of aiming on facilitating decision-makers with reliable data acquisition tools, the outcome of data collection exercise can provide mapping authorities in cadastral system a spatial element in the form of parcel boundary, and thus contribute to building national land tenure registry.

The proposed the system is not a solution to the most fundamental problem which is protection of vulnerable IDPs, but should instead be an element of a larger strategy to improve analysis

that can facilitate stakeholders in evidence based decision making to prevent forced displacement, strengthen the national protection system and mitigate the impact of violence. Taking into consideration long process of high level agreement between engaged parties, it was not feasible to conduct the system pilot, however, efforts are underway to ensure coordination with national authorities and across humanitarian response sectors, therefore the final result is expected in the future. Nevertheless, system usability has been acknowledged by the stakeholder during the trial session in the UNHCR country office in Tegucigalpa.

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