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ANALYSIS OF OPTICAL HIGH RESOLUTION SATELLITE IMAGERY FOR THE EVALUATION OF SOCIAL VULNERABILITY IN LIMA CITY

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SUMMARY:
The Peru is a country hit by earthquakes of major intensity that affect its. The natural development of populations and the migration from the Peruvian Andean zones towards the coast has reflected a growing exposure to be affected by the effects of an earthquake. Unfortunately, to assess the vulnerability of buildings there is not sufficient information, as for example the urban cadastre. This study proposes the use of high-resolution satellite images to infer the social class and to infer the type of construction and type of building. This identification of social class may indicate the seismic vulnerability level. The method of classification is the detection of objects like pools within the house and the use of the NDVI concentrations that determines the social class in an urban area. Finally, thematic maps of concentration of swimming pools and vegetation are developed to infer the social class and therefore the quality of buildings and thus to determine its seismic vulnerability.

Keywords: Social Vulnerability, High Spatial Resolution, Satellite imagery, Social class classification.

1. INTRODUCTION

Peru is located in a seismic prone area and the development of the cities are so fast and do not pay attention to the regulation on building constructions, so it is of interest to study the type of building on urban area to know their vulnerability in case of an extreme earthquake. One of the main data source to assess the type and condition of the building are the census or inventory data that is developed for the local governments. In most of the municipalities in Peru there is not a policy to develop this kind of data, not only because of lack of economic resources but also because the absence of technical people that can understand the problem and conduct this work. Therefore it is necessary to develop a methodology to carry out a fast inventory of buildings and to recognize their vulnerability against earthquakes. Recently high resolution imagery is becoming more accessible, not only because price, but also because multiple satellites are observing the earth surface constantly given a rich source on information about the land use. Lima city is characterized by people of different social classes; these social classes may indicate the type of building where they live, in terms of quality and if they followed the regulations during the construction of the building. Low class people generally they construct their houses by themselves, as they can and without following the regulations of the National Building Code.

In this study it is proposed to used high resolution satellite imagery to recognize the social class of the people by identify some characteristics of their houses like pools and greenness and thus to classify the vulnerability of the urban area. Finally the land information is integrated with PRISM sensor data to identify areas that are built over important slope to evaluate also hazard of these area.

2. UMBRELLA PROJECT

This research is under the project "Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru" the purpose of this project is to developed technologies and measures for prediction and mitigation of earthquake/tsunami disasters caused by large-magnitude inter-plate earthquakes occurring off the coast of Peru.

This project is divided into five active groups. Group 1 will research on seismology and geotechnical issues, and give the final response of the soils. Group 2, will study the source, effects and countermeasures of tsunamis produced by an earthquake. Group 3, will identify the most typical building problems and will propose retrofitting methods or will give some advises to improve the actual building code. Group 4, will develop methodologies to identify the land use, by using the satellite imagery and integrating all the information in a GIS platform to assess the risk of the building as well as to develop a methodology for fast assessment of the damaged area by an earthquake or tsunami. Finally, Group 5 will take the entire group's output and will disseminate this knowledge and propose policies for a sustainable development of the population. This project is under the support of Japan International Cooperation Agency, Japan Science and Technology Agency, Peruvian International Cooperation Agency. And the institutions directly involved in this study are the Chiba University and Tokyo Institute of Technology, from the Japanese side and the Japan Peru Center for Earthquake Engineering Research and Disaster Mitigation, National University of Engineering, from the Peru side.

3. STUDY AREA

The area of study is the district of La Molina in Lima, Peru. This district has a population of approximately 130000 habitants. This district is very special in Lima Metropolitan area, because here it can be found people of different social classes and therefore different construction type and building quality. Another issue in this district is that it is growing very fast and the new developed urban area is taking place on terrain with important slope. Because soil conditions, buildings in this district have suffered of important damage in past earthquakes, therefore it is important to know the type of building that are built on this area. In Figure 1 it can be seen the location and extension of La Molina district, that is located in the middle east of Lima. Although this is a district with relatively good economical resources, the situation of the cadastral information is still in the beginning stage that is why it is necessary to use another source of information to evaluate and assess the type of buildings..

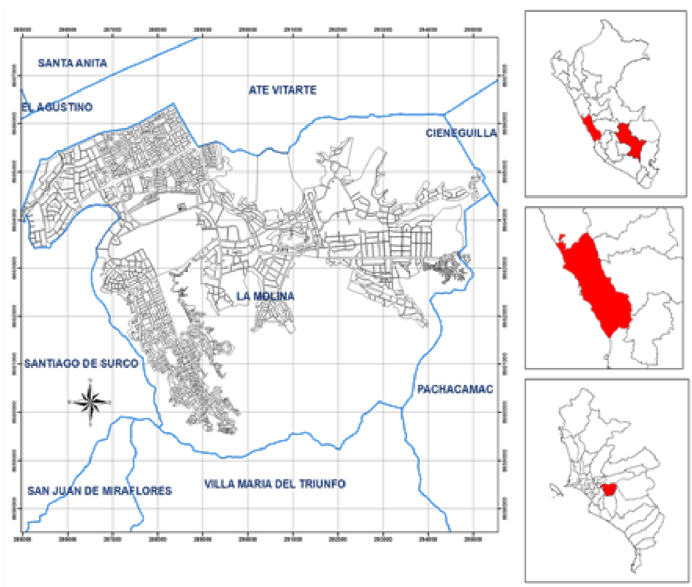

Figure 1. District of La Molina in Lima, Peru.

4. DATA CHARACTERISTICS

The date used in this work is the multispectral Worldview 2 which major characteristics are shown in Table 1.

Table 1. Worldview 2 scene characteristics.

Characteristic	Value
Acquisition date	March 11, 2010
Number of bands (M – P)	8 – 1
Rows/Columns (M – P)	4031/5463 – 16124/21852
Bits per pixel	16
Spatial resolution	2.0 m MS/0.5 m PAN
Wavelength (nm): - Coastal (Band 1) - Blue (Band 2) - Green (Band 3) - Yellow (Band 4) - Red (Band 5) - Red edge (Band 6) - NIR 1 (Band 7) - NIR 2 (Band 8)	 - 427 nm - 478 nm - 546 nm - 608 nm - 659 nm - 724 nm - 831 nm - 908 nm

As we can see in Table 1 the number of multispectral bands that are included in one image is good enough to detect many materials over the earth surface. This advantage is taken as the base for the analysis. In this research Worldview 2 images were selected instead of Ikonos (Cook et. al., 2000) images because two reasons: first: there is a better resolution 0.50 m vs. 0.60 m, and second spectral resolution in case of Worldview 2 has more sensibility as it can be seen in Figure 2.

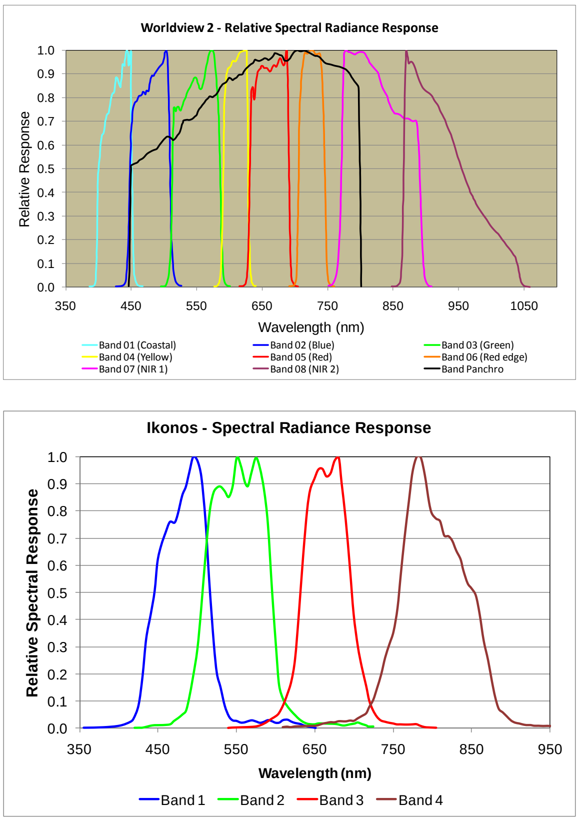

Figure 2. Spectral response comparison between Worldview 2 and Ikonos images.

5. METHODS AND PROCEDURES

To assess the seismic vulnerability of an urban area can be done by evaluating of housing census data, but it has the drawback that that method cannot be generalized, one approach based on contextual analysis of image and GIS data is presented by Ebert et al (2008) where an approach based on proxy variables that were derived from high resolution optical and laser scanning data was applied, in combination with elevation information and existing hazard data social class we investigate the location of swimming pool within an urban area. Another approach for building inventory is presented by Dutta et. al (2005) where very high resolution satellite optical data from Quickbird satellite with object-oriented classification scheme was used for an overall accuracy of 85% in detailed classification of urban land cover.

In La Molina district it can be found different types of land use depending on the social classes. As it is shown in Figure 3, high social class area (a) has an important green area and important features are the pools inside of the lot, middle class area (b) has also important green area but no pools, and low class area has few vegetation and no pools. Therefore if pools and vegetation can be detected in an automatic manner we could infer the type of social class in the area and as consequence the social vulnerability of it.

(a) (b) (c)

Figure 3. Difference between land use in La Molina.

For image classification exits a bunch of methods, mainly classified into two big groups: unsupervised and supervised methods. One of the methods of supervised classification is described by Mohd et. al. (2007) the Spectral Angle Mapper (SAM) this is a physically-based spectral classification that uses an n-dimensional angle to match pixels to training pixel area. The algorithm determines the spectral similarity between two spectra by calculating the angle between them, treating them as vectors in a space with axes equal to the number of bands. Smaller angles represent closer matches to the training pixels.

Luc et. al. (2005) depicts how to obtain the angle between two spectra that are being compared. In Figure 4 it can be seen, in a three bands dimension space, if spectral angle (θ) is small then the tested (t) and reference (r) spectral vectors are similar. In Eq. 1, we can see the numerical calculation, where the angle (θ) is a kind of correlation value between two samples in an n-dimensional spectral space.The date used in this work is the multispectral Worldview 2 which major characteristics are shown in Table 1.

$$\theta = \cos^{-1}\left(\frac{\sum_{i=1}^{n} t_i r_i}{\sqrt{\sum_{i=1}^{n} t_i^2 \sum_{i=1}^{n} r_i^2}} \right) \quad (1)$$

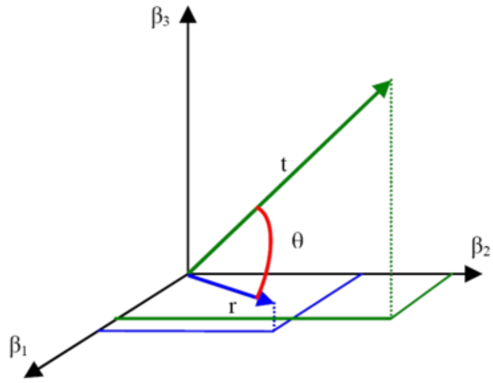

Figure 4. *r* reference spectra vector, *t* spectra vector to be compared, θ spectral angle.

Pixels that are in pools are selected as trained pixels. Pixels were selected over the image, and their spectral response was analyzed. Figure 5, shows how the pixels were selected and the average of the digital number of these pixels.

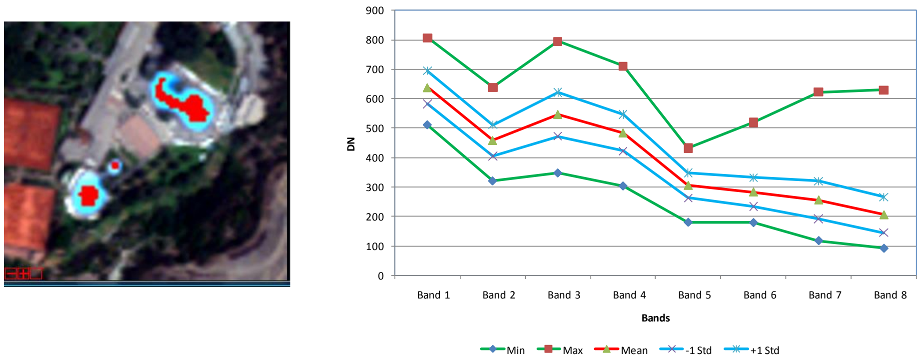

Figure 5. Trained pixels and their spectral response.

Another parameter that was used is the NDVI to detect the concentration of vegetation in the area.

6. RESULTS

The SAM method for classification gave good results and the pools could be detected, the number of pools in one block where automatically counted and the image was transferred to GIS map and then classified by this number.

Additionally, the NDVI also was calculated and the number of pixels that represent vegetation where counted in each block.

Figure 6 shows the thematic map considering the number of pools by block, it can be seen that there are some areas where the number of pools is considerable given areas of high class. In Figure 7, is presented the thematic map representing the concentration of vegetation in each block, high concentration of vegetation indicates high class, while very low concentration may indicate low class.

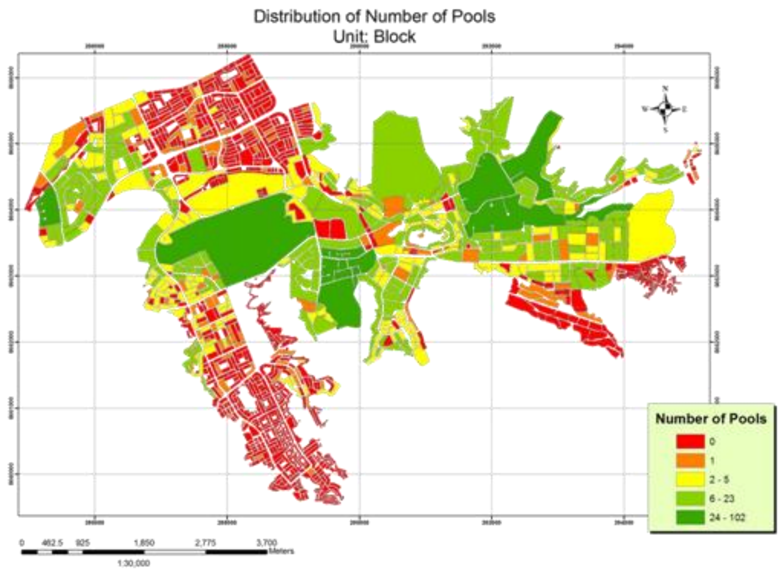

Figure 6. Classified map indicating the number of pools by block.

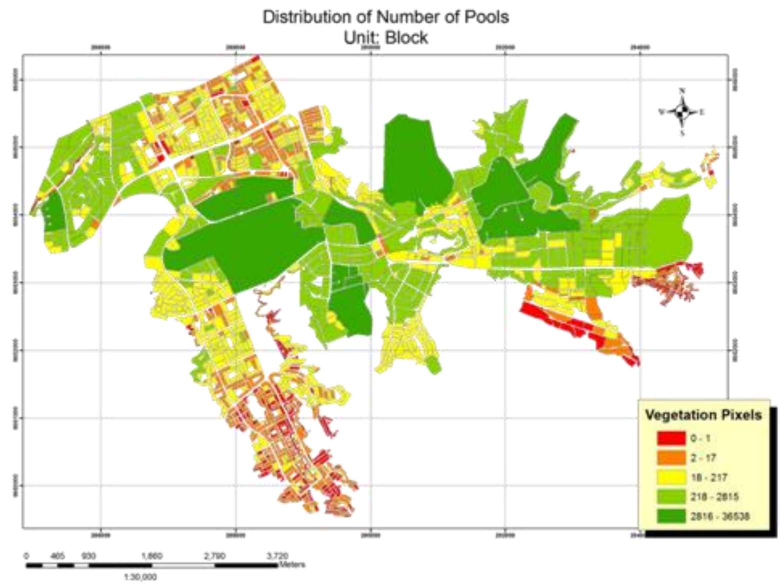

Figure 7. Classified map indicating the number of vegetation pixels by block.

Also it was conducted a field survey for verification of the results given good agreement with the two indexes. In Figure 8, it can be seen that for different type of land use it is possible to correlate the number of pools and the NVDI.

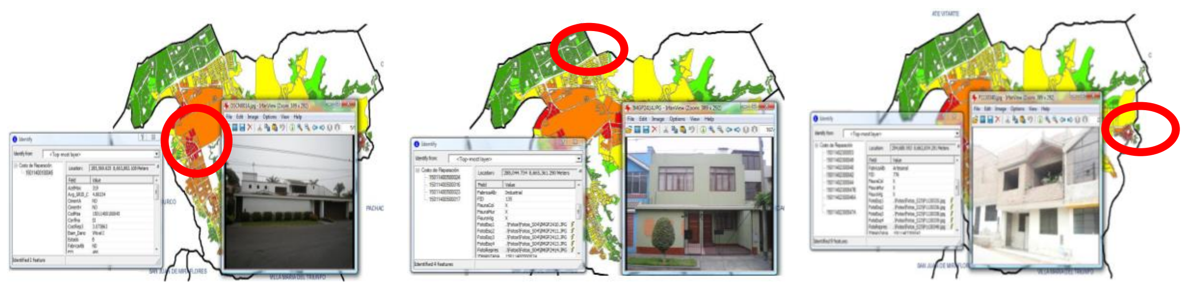

Figure 8. Field survey of different sectors.

7. FIELD SURVEY

After the two parameters have been assessed, the map of La Molina District can be reclassified into a kind of vulnerability map. It means that blocks that have more pools and a Normalized Difference Vegetation Index NDVI, with high values may be considered as low vulnerable blocks, and for the opposite values, blocks with no pools and low values of NDVI may indicate that in there exist buildings that are in high risk in case a severe earthquake.

As in the Figure 8, it is shown the different types of houses that are predominant for different sectors in La Molina District. As it can be seen there are three very different types of houses and those show different quality of house. These differences may suggest different levels of vulnerability, from low vulnerability against earthquakes, in the case of areas of high income families and relative high vulnerability for low income family's house, passing for the middle class that in some cases build their houses with the no participation of an engineer.

To verify the results obtained by these procedures and under the agreement with the Ministry of Housing, Construction and Sanitation it was carried out the field survey of some representative blocks in La Molina District. It was evaluated some external characteristics of the buildings like, material, number of stories, condition, structural system, among other and this field survey. As it can be seen in Figure 9 the thematic map of building condition, there is a good agreement between the automatic evaluation for the proposed method and the real data taken from the field.

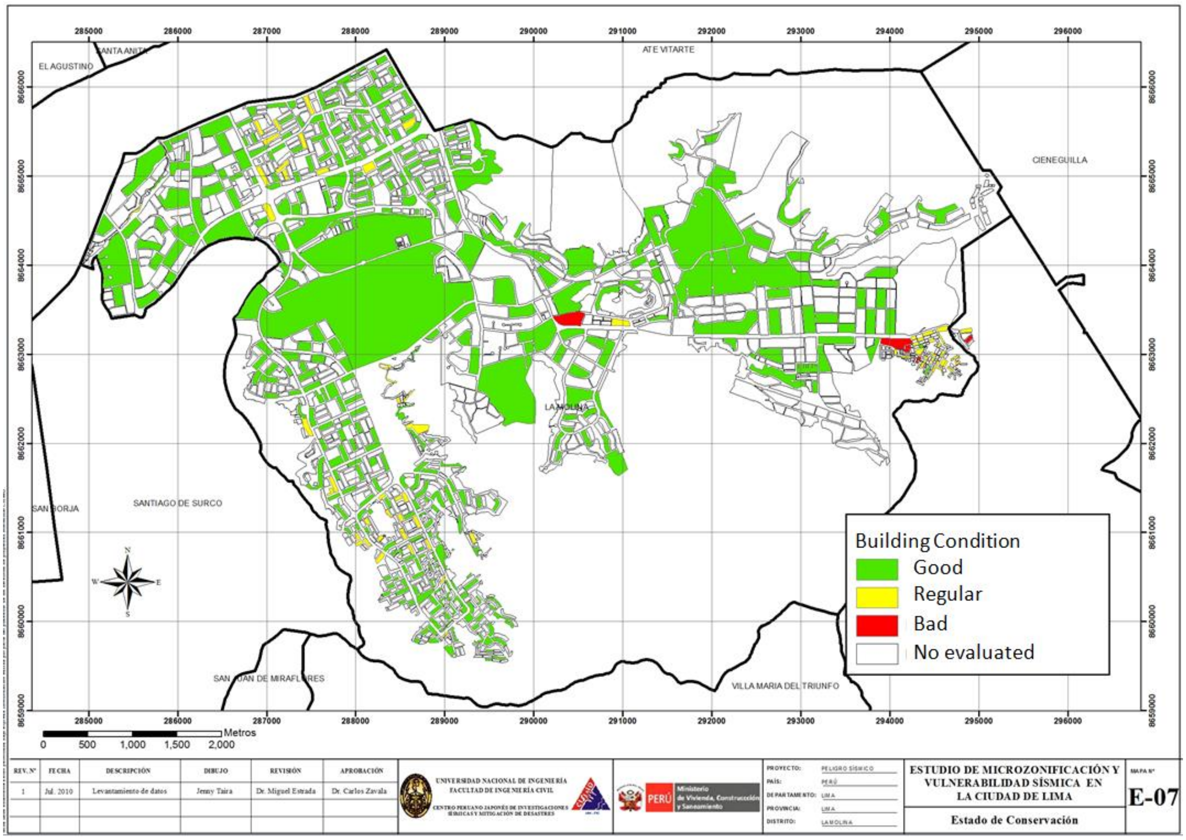

Figure 9. Building condition in representative blocks at La Molina District.

8. CONCLUSIONS

It can be shown that from satellite information it can be inferred the type of social class based on two characteristics of the urban area: the number of pools and the concentration of vegetation. While the number of pools and the concentration of vegetation is high it is and indicative that the social class of the people who live there is high and therefore their houses may be well constructed, while on the other side where pools do not exist and the vegetated area is minor may indicate a social class where the construction of the houses may have not follow the standards and therefore their seismic vulnerability could be considerable.

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