Paper:

Urban Recovery Process in Pisco After the 2007 Peru Earthquake

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Post-disaster urban recovery is a significant matter in disaster management that represents government efforts after a disaster and victim satisfaction with these efforts in affected areas. Understanding the recovery process is a procedure necessary for evaluating government strategy. From this view, the authors dealt with the recovery process at Pisco, the area most devastated in the 2007 Peru Earthquake. Research was conducted through the following procedure: (1) a field survey including interviews was carried out in July 2012 to clarify post-earthquake conditions in urban Pisco, especially from the viewpoint of the physical environment, (2) recovery conditions were compared with damage conditions investigated by CISMID just after the event using satellite imaging and building recovery data obtained in the survey, and (3) post-earthquake recovery was quantitatively analyzed in terms of building recovery. Results indicated that 93.2% of seriously or severely damaged buildings had been reoccupied. In addition to quantitative analysis, recovery-related problems are discussed based on interviews. Results will be useful in the next stage of our research using remote sensing data for the chronological understanding of the post-earthquake urban recovery process in Pisco.

Keywords: 2007 Peru Earthquake, Pisco, urban recovery process, building examination, satellite image

1. Introduction

The Mw 8.0 Pisco Earthquake occurred on August 15, 2007. The epicenter was about 145 km southeast of Lima. Ica Region was the area most seriously damaged due to the earthquake, in which 134,312 houses were affected. Pisco District, our research object, is located in the middle of Pisco Province (**Fig. 1**). The number of affected houses in the district was 14,008, including 4,106 collapsed buildings [1].

In general, post-disaster urban recovery is a significant matter in disaster management that represents government efforts after a disaster and victim satisfaction with these efforts in affected areas. Understanding the recovery process is a procedure necessary for evaluating government strategy. From this view, the authors dealt with the recovery process in the Pisco District in order to clarify the current status of rebuilding and recovery efforts after the 2007 Pisco Earthquake.

Just after the earthquake, lots of damage surveys were conducted and damage conditions were reported by institutes such as EERI [2], or JSCE and JAEE [3]. The number of research papers on the recovery process is comparatively few, however [4]. This paper mainly reports how the city has recovered in the five years since 2007.

2. Framework of Research on Recovery Process in Pisco

The procedure employed in research is detailed in the sections that follow.

2.1. Perspectives of Field Survey

A field survey was carried out in July 2012 to clarify post-earthquake conditions in urban Pisco, especially from the viewpoint of the physical environment. The authors then conducted interviews with salesclerks in building-materials stores about temporary housing.

2.2. Comparison Between Damage Conditions and Current Status Using Satellite Imaging

Current recovery conditions are compared with damage conditions investigated by CISMID in 2007 using satellite imaging and building recovery data obtained in the survey.

2.3. Analysis of Rebuilding Conditions

Post-earthquake recovery was quantitatively analyzed in terms of building recovery based on the above com-

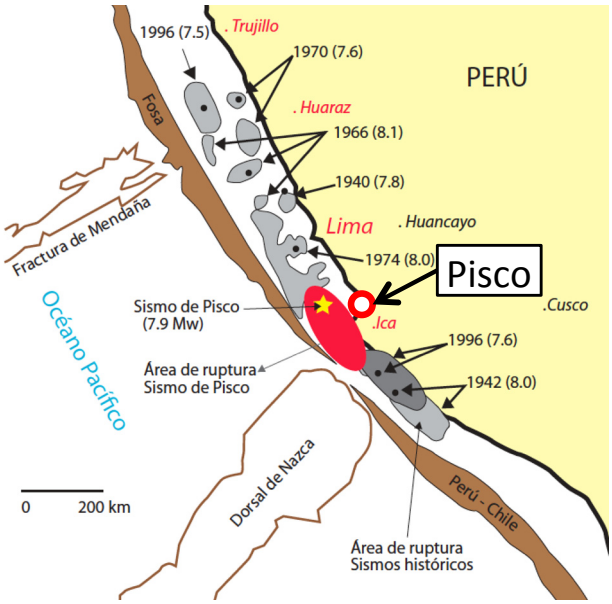

Fig. 1. Location of Pisco Province (INDECI).

parative study. It refers to the building recovery ratio and newly developed areas that had changed dramatically for five years.

2.4. Discussion

Apart from the quantitative consideration, it is important to follow the qualitative aspects such as the support system for affected residents. Recovery-related problems are discussed based on interviews.

3. Field Survey in July 2012

3.1. Outline of the Survey

The field survey in Pisco District was carried out on July 7, 8, and 9, 2012. The authors made photographic or video records of building conditions in the whole area by walking and driving about 98 km.

After the survey, the authors had an opportunity to ask salesclerks at building-materials stores about the construction of temporary housing.

3.2. Recovery Status Observation

Some important facilities are concentrated in the central area of Pisco. Most of them had been reoccupied by the time of the field survey. **Fig. 2** shows the recovery status of the Central San Clemente Cathedral of Pisco, which had been seriously damaged by the earthquake. **Fig. 3** shows two other public buildings, City Hall and the Police Station.

Walking around in central Pisco, we found many unrebuilt lots, as shown in **Fig. 4**.

The government provided some subsidies to affected householders who lost their houses in the earthquake. However, living in temporary housing prepared by NGOs,

Fig. 2. Central San Clemente Cathedral of Pisco.

Fig. 3. Recovery of public facilities.

Fig. 4. Empty lots.

Fig. 5. New front gate instead of solid new house.

some of those receiving subsidies used the money for installing new front gates as symbols of their houses (**Fig. 5**).

Several new settlements developed in the outskirts of the Pisco District will be discussed in the next chapter.

3.3. Temporary Housing

In order to coordinate reconstruction efforts, the Fund for the Reconstruction of the South (FORSUR) was established just after the earthquake. **Fig. 6** illustrates the reconstruction stage indicated by FORSUR [5]. Temporary housing were supposed to be in a stage of transition according to FORSUR recovery strategy. There remained many temporary housing around the district, however, when the authors investigated. There were also blocks that were occupied by temporary housing as new settlements into which affected people moved after the event (**Fig. 7**).

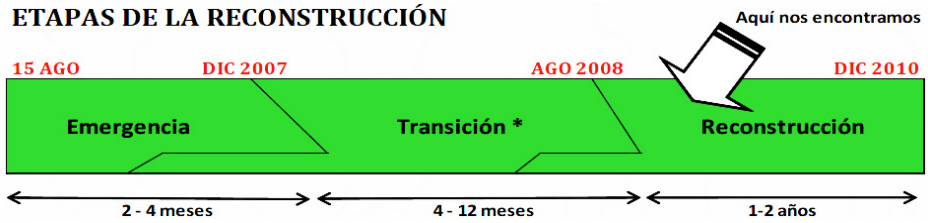

Fig. 6. Reconstruction stage in FORSUR strategy [5].

Fig. 7. Remaining temporary housing.

Fig. 8. Temporary house construction.

The authors then visited a few building-materials stores to get some information on temporary housing construction (**Fig. 8**). Salesclerks gave us information useful for understanding the temporary house construction situation as follows:

(1) Although house units for sale are not for temporary housing but for huts, affected people often buy them themselves, and they are not provided by the government for temporary use.

(2) If the user daubs house parts with waterproof paint once a year and changes the roof often, the house can be used for about ten years. It does not last long without maintenance.

(3) The total price of the material, not including handling, and time necessary for construction is

[3 × 3 m] S/.1,350 ($519), one day
[3 × 4 m] S/.1,600 ($615), two days
[3 × 6 m] S/.2,400 ($922), two days.

Exchange rate: as of Oct. 30, 2012

4. Recovery Conditions in Pisco

This chapter examines recovery conditions in Pisco based on the field survey and satellite imaging.

4.1. Data Used

In order to quantitatively compare current recovery status with the building damage situation in Pisco, GIS dataset produced by CISMID and satellite image in addition to records by the survey.

Satellite imaging from QuickBird taken on June 3, 2007, for pre-earthquake status and on August 27, 2007, for post-earthquake status were used. To better understand the current situation, imaging from GeoEye taken on July 10, 2010, was used.

GIS data used for analysis was produced by CISMID just after the earthquake. CISMID conducted continuous building damage surveys, and developed the database. Polygon data for recognizing building damage conditions is distinguished by lot, and the building damage level is classified into four types: serious, severe, slight, and no damage. Imaging of building damage conditions made by CISMID is shown in **Fig. 9**.

Although Matsuzaki et al. [6] point out some amounts of omission error in GIS data, it is valuable for grasping the damage situation.

4.2. Examination of Recovery Conditions

While there were many reoccupied buildings in the field survey, there also remained many empty lots that seemed not to have been reoccupied after destruction. Making the assumption that the condition of empty lots represents the current recovery situation in Pisco, the authors examined recovery conditions using satellite imaging and GIS data. The area for this analysis was determined by GIS coverage.

At first empty lots were macroscopically distinguished using the image map of 2010. The authors then examined the adequacy of lots chosen lots based on the damage levels in GIS investigated by CISMID. Empty lots included misjudged data, however, as pointed out by Matsuzaki [6], such as a lot that had been not occupied by any buildings since before the earthquake. The original empty lots were, therefore, eliminated from among objects for analysis.

Figure 10 shows the map resulting from this process: yellow polygons means are empty lots, and transparent polygons with green lines indicate new developed areas, which will be explained in the next section. Empty lots were picked based on a comparison between 2007 and 2010 maps, as shown in **Fig. 11**.

The number of polygons in terms of damage level with empty lots was counted as shown in **Table 1**. The total number of polygons is 12,079 according to CISMID

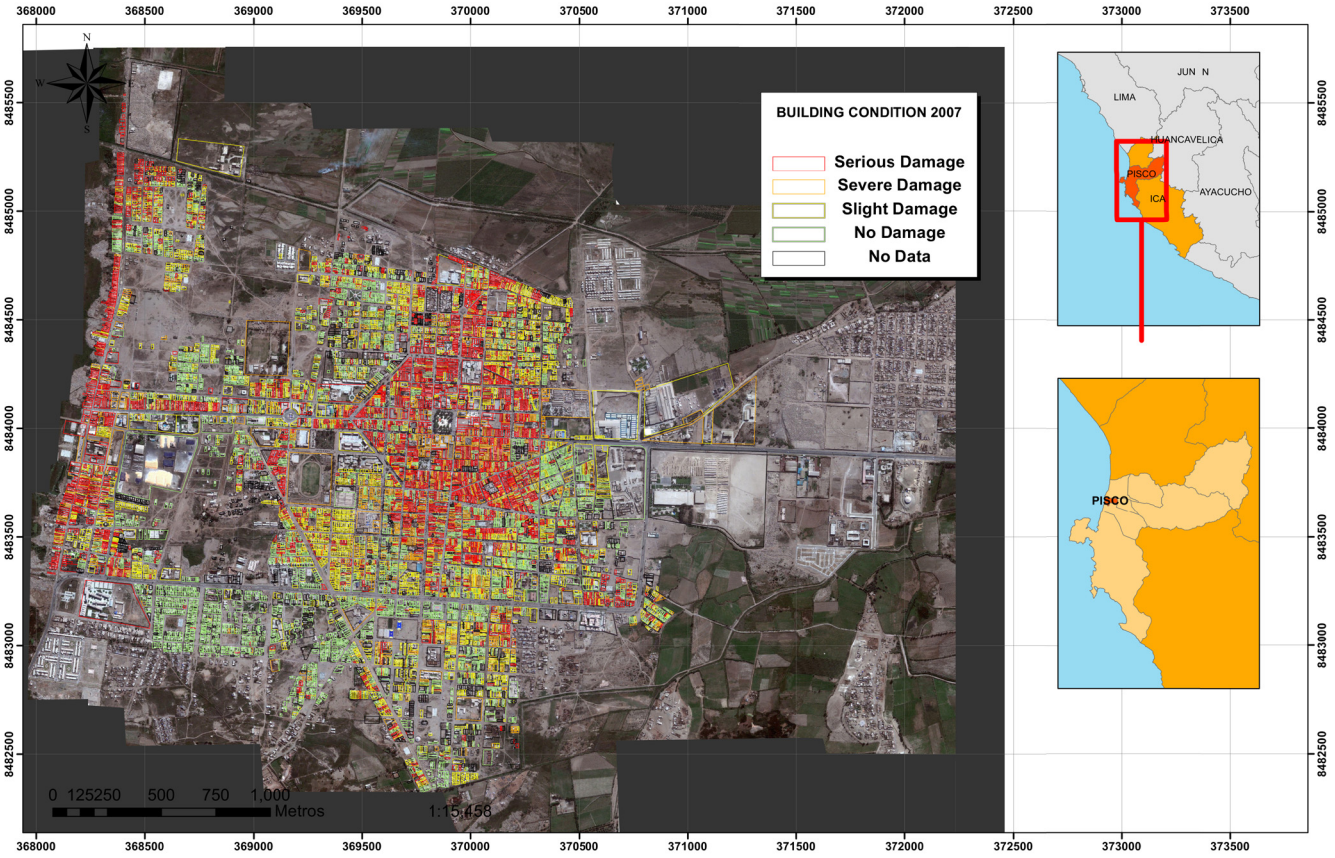

Fig. 9. Building damage conditions due to the 2007 Peru Earthquake (CISMID).

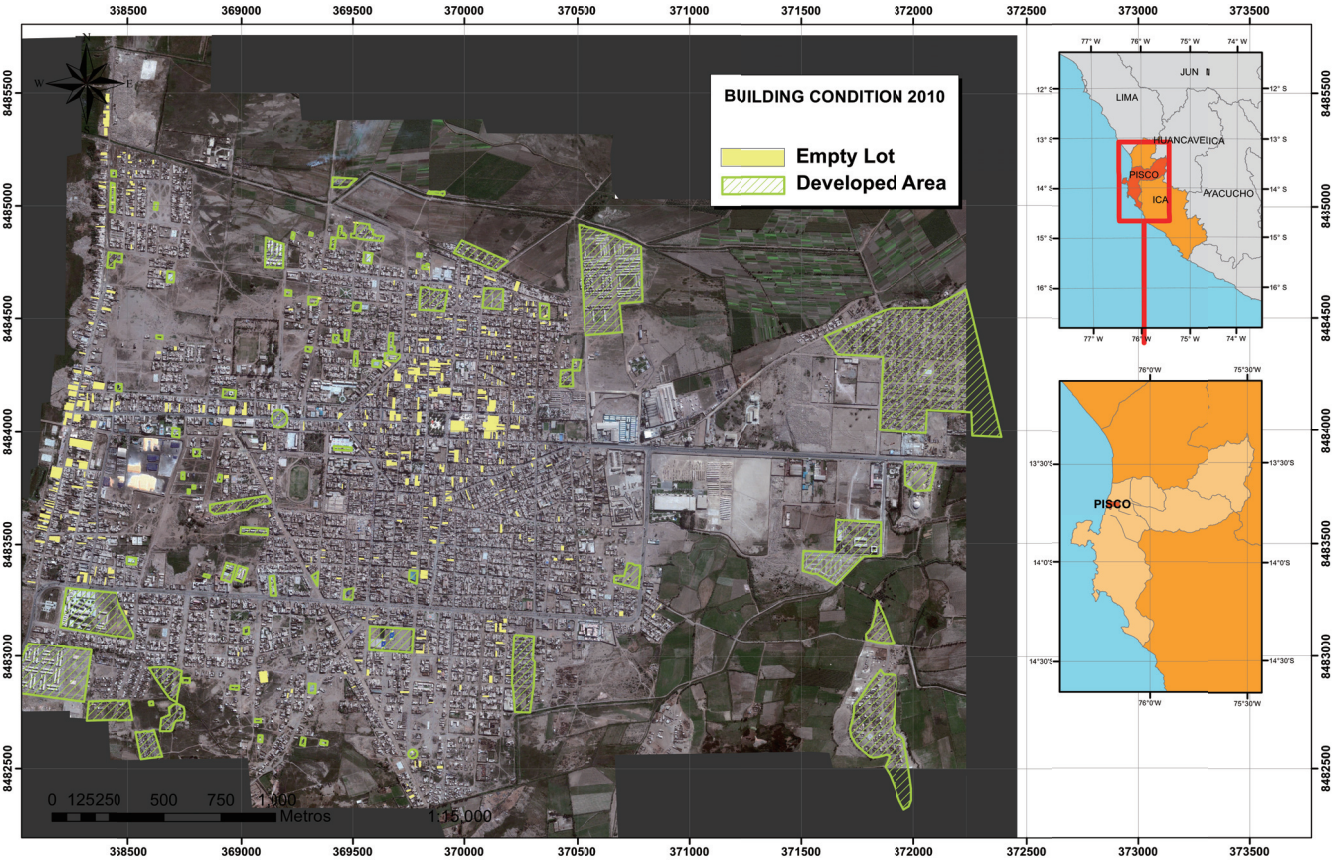

Fig. 10. Recovery conditions based on satellite imaging as of July 2010 and the field survey in July 2012.

Table 1. Number of polygons in terms of damage level.

Damage level	Total by CISMID	Total after the elimination (a)	Empty lot (b)	Recovery ratio (%) (b/a)
Serious	3,181	3,132	388	87.6
Severe	3,449	3,439	59	98.3
Sub total (Damage basis)	6,630	6,571	447	93.2
Slight	2,780	2,771	31	98.9
No damage	1,513	1,509	10	99.3
Sub total (Whole basis)	10,923	10,851	488	95.5
No Data	1,149	1,149	4	-
Others	7	7	0	-
Total	12,079	12,007	492	-

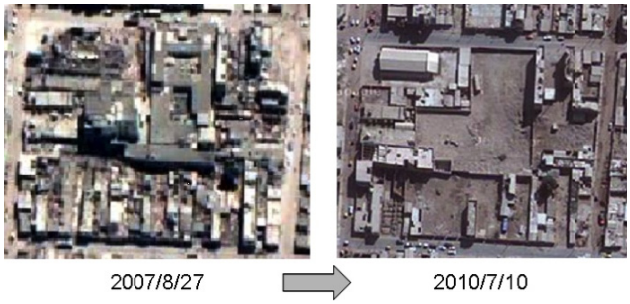

Fig. 11. Empty lots selection based on comparison between 2007 and 2010 imaging.

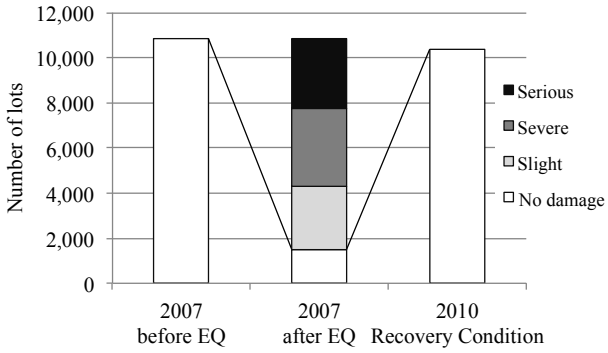

Fig. 12. Damage and recovery condition.

data, but the figure after the elimination is used to evaluate recovery conditions here. Polygons categorized into "no data" and "others" are counted, too. **Fig. 12** shows damage and recovery conditions as results of analysis.

Based on analysis, 87.6% of seriously damaged buildings and 98.3% of severely damaged buildings had been reoccupied by the time of the survey.

The recovery Ratio can be counted from two aspects: one is the damage basis based on seriously and severely damaged buildings, and the other is the whole basis based on all buildings in the object area. Results are 93.2% on the damage basis and 95.5% on the whole basis though evaluation did not consider types of houses, i.e., temporary or permanent. Pisco District had achieved more than

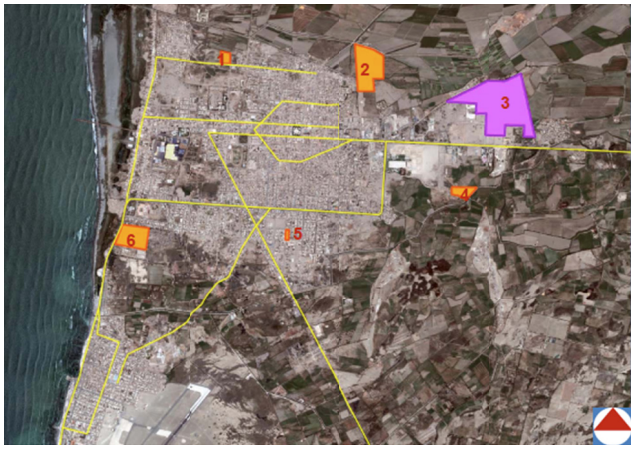

Fig. 13. Housing project for Pisco (Ministro de Vivienda, Construcción y Saneamiento [7]).

90% recovery more or less, in terms of rebuilding from the viewpoint of the physical urban environment.

4.3. New Developed Areas

While residents had reoccupied or repaired their damaged houses individually since the earthquake, the governments devised future plans for Pisco. The housing project shown in **Fig. 13** is one of the plans provided by the Government [7].

Hereafter we deal with urban development in Pisco. Comparing 2007 and 2010 imaging, dramatically changed blocks are chosen. Chosen areas are illustrated with green lines in **Fig. 10**, and comparable photos are laid out on the map in **Fig. 14**. Noteworthy places were chosen as shown in the fifteen frames from A to O. The picture at the left or top in each box indicates the destructive situation as of 2007. The other one in each box shows recovered conditions as of 2010.

Some of the areas planned by the Government are shown in **Fig. 13**: Areas B, D, E, G, J, and N in **Fig. 14** according to Areas 1 to 6 in **Fig. 13**, respectively. **Table 2** shows the number of buildings inside and outside of the central area of Pisco, which is covered by the analysis in

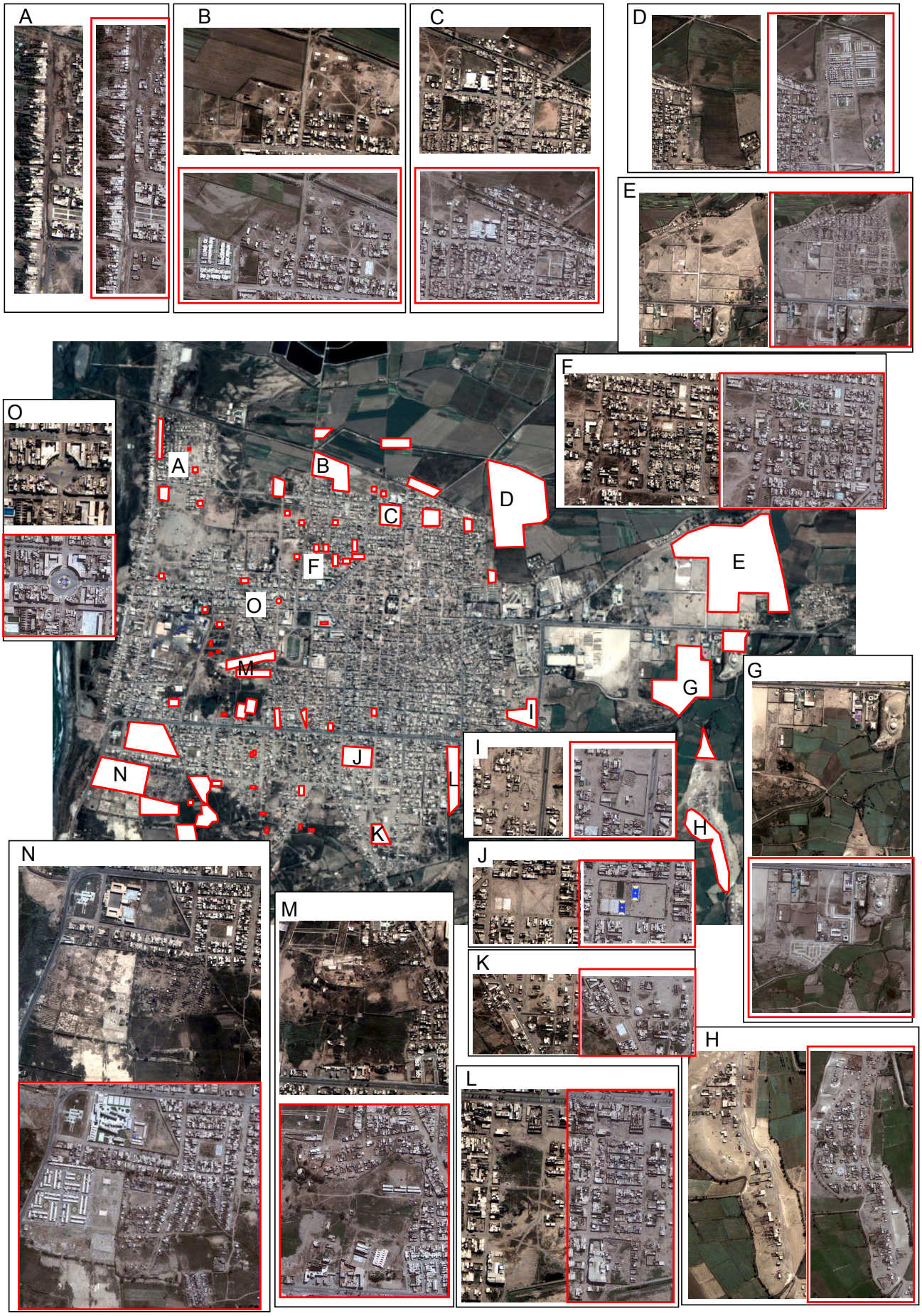

Fig. 14. Urban development areas in Pisco recognized by comparative study using satellite image.

Table 2. Number of buildings in developed areas.

Area	Inside Pisco	Outside Pisco	Total
A	24	-	24
B	94	4	98
C	113	26	139
D	10	81	91
E	226	1157	1383
F	16	-	16
G	-	14	14
H	-	73	73
I	2	-	2
J	5	-	5
K	1	-	1
L	-	81	81
M	23	-	23
N	-	166	166
O	0	-	0
Total	514	1602	2116

Section 4.2., for each developed area. Area E called H.U. Alto El Molino has the largest population, with 1,350 lots in an area of 25.6ha [7].

In order to quantitatively recognize changes in the recovery process, the authors counted the number of buildings, not lots, in 2007 and 2010 imaging, respectively, with the naked eye. The whole covered area, shown in **Figs. 9** and **10**, were distinguished between "inside," which means the area CISMID investigated after the earthquake shown in **Fig. 9**, and "outside" of Pisco because the town has been expanding.

Our macroscopic examination indicated that 2,116 buildings were constructed in developed areas after the event. The number of new buildings corresponds roughly to 17.6% of total lots in the research field shown in **Table 1**.

5. Recovery-Related Problems

Now that we have quantitatively understood the post-earthquake urban recovery conditions in Pisco District, it is important to follow the context of the process.

I asked some specialists about problems of recovery during the survey, and they suggested the "compensation voucher" problem as pointed out by Miyashiro [8].

The Building Materials Bank issued compensation vouchers for S/.6,000 (US$2,313 as of Oct. 30, 2012) to victims who had lost homes. Although the amount of S/.6,000 was not enough to construct a house, vouchers were supposed to be used to buy construction material to repair or rebuild houses.

Most of the victims were not rich and wanted money, not vouchers, so they sold vouchers to get money for less than the price of S/.6,000. In those days, the government provided free food everyday, and NGOs gave them tents. They did not have to worry about their daily lives. They therefore used the money they got for selling vouchers for whatever they wanted instead of the construction of their own houses.

Other proper support systems could have been proposed. If the government had, for example, prepared optional support, such as (1) vouchers for construction material, (2) subsidies for renting a house, or (3) provision of a new house in a non-damaged area, victims could have chosen one according to their conditions after the event.

This is one aspect of problems. INDECI issued a report about what they learned from the earthquake [9]. It is important to consider the relationship between objective changing conditions in damaged areas and urban recovery strategy.

6. Conclusions and Future Research

Post-disaster urban recovery is a significant matter in disaster management that represents government efforts after a disaster and victim satisfaction with these efforts in affected areas. Understanding the recovery process is a procedure necessary for evaluating government strategy.

From this view, the authors have dealt with the recovery process at Pisco, the area most devastated in the 2007 Peru Earthquake. Research was conducted through the following procedure. (1) A field survey, including interviews, was carried out in July 2012 to clarify the post-earthquake urban conditions in Pisco, especially from the viewpoint of the physical environment. (2) Recovery conditions were compared with damage conditions investigated by CISMID just after the event using satellite imaging and building recovery data obtained in the survey. (3) Post-earthquake recovery was quantitatively analyzed in terms of building recovery.

Results indicate that 93.2% of seriously or severely damaged buildings have been reoccupied, and that the number of new houses has increased in new developed areas that were planned by the government.

In addition to quantitative analysis, recovery-related problems were discussed based on interviews. Compensation vouchers of S/.6,000 provided by Building Materials Bank to victims to support the rebuilding of their houses were sold to get money. There are many things to be learnt from the post-earthquake experiences, and these should be discussed in the future.

Quantitative recovery conditions will be useful for the next stage of our research. This is a chronological understanding of the post-earthquake urban recovery process in Pisco. In future research, we would like to explore possibilities for using remote sensing data for monitoring the post-disaster urban recovery process.

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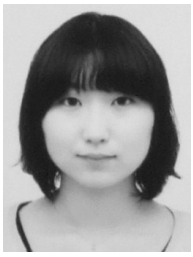

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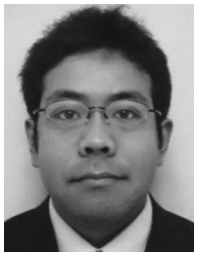

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