

Tsunami Disaster in Solomon Islands in April, 2007

— Field survey on the damage reduction effect of coastal forest —

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Abstract: In the Solomon Islands, a large earthquake of magnitude 8.1 occurred on April 2, 2007, and the coastal area was badly damaged by the tsunami. We carried out a field survey in the southern coastal area of Gizo Island in August, 2007 in order to verify the effect of coastal forest in tsunami damage reduction. Most houses in the villages we surveyed had been washed away. We identified the position of the houses using satellite images before the tsunami disaster, and we obtained information on the structure, material and degree of damage of all houses by observation and interviews with the residents. Complete enumeration of coastal forest was carried out, while the representative landform was clarified by surveying the traverse baseline. As a result, factors which reduced damage to houses by the tsunami were considered to be the height of the house floor, ground height and the forest stand of the coastal area. Although the relationship between these factors could not be clarified due to heavy damage to the houses, it became clear that the coastal forest reduced the tsunami damage.

1 Introduction

The casualties exceeded 300,000 in the earthquake and tsunami that occurred offshore of Sumatra in Indonesia in December 2004. The occurrence of such a strong earthquake and big tsunami under no preliminary alert system condition led to this tragic disaster. In this disaster, casualties due to the tsunami were much higher than those caused by the earthquake. The structure and strength of houses against tsunami differs by country and region, in addition, the degree of damage differs according to the existence of structures such as breakwaters. In developing countries, it is not unusual to find regions that are defenseless against this kind of large tsunami. It is considered that coastal forest, grown as a windbreak or for fruit picking or for improving the landscape, plays a role in tsunami damage reduction, even if it is not a countermeasure against tsunami.

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In Japan, coastal forest has been partially designated as protection against tide break, and it is actually utilized. For example, it is reported that coastal forest effectively reduced the tsunami damage which occurred after a strong earthquake in the Japan Sea in May 1983 (Akita prefecture: 1984). However, the function of coastal forest in tsunami damage reduction is not sufficiently clear for effective control of coastal forest, so it is necessary to collect a large amount of case data. At present, the warning system against tsunami after strong earthquakes has been improved, and the strength of buildings and the urban structure is argued on the basis of stochastic information for prediction of earthquake occurrence, but awareness of the danger posed by tsunami is not great. If it becomes clear that multifunctional coastal forest is also effective in tsunami damage reduction, coastal forest will play a significant role in tsunami damage reduction through, not only forestation of the coastal area, but also establishment of effective control methods for coastal forest.

This paper is a prompt report of a field investigation carried out in the Solomon Islands of the South Pacific Ocean, which were severely damaged by the earthquake and tsunami on April 2, 2007, and it reports an outline of the relationship between the state of tsunami damage and the condition of coastal forest, topography and structure of houses. The final goal of this investigation is the establishment of tree species composition, disposition and management techniques for the coastal forest for tsunami damage reduction, as well as clarification of the functional limits of the coastal forest for tsunami damage reduction.

2 Outline of the Solomon Islands and earthquake and tsunami

A strong earthquake of magnitude 8.1 occurred in the Solomon Islands in the South Pacific Ocean (Figure 1)

at 7:40 a.m. (local time) on April 2, 2007. The epicenter was lat. 8.6°S and long. 157.2°E, south-southeast 45km offshore from Gizo town on Gizo Island, the state capital of the Western Province. The depth of the hypocenter was about 10km, and a big tsunami struck after the earthquake. At Gizo Island, located northwest of the hypocenter, the maximum inundation height of the tsunami was 4.3m and the maximum run-up height was 5.6m. At Simbo Island, located west of the hypocenter, the maximum inundation height was 5.2m and the maximum run-up height was 9.0m (Port and Airport Research Institute 2007). Moreover, it is reported that as diastrophism caused by the earthquake, a maximum of 1m subsidence happened on Simbo Island, and a maximum of 3.3m upheaval happened on Ranongga Island (Hokkaido University, University of Tokyo, Geological survey of Japan, and Asian Disaster Reduction Center joint urgent research commission on tsunami in Solomon Islands: 2007).

As shown in Figure 1, the Solomon Islands are part of the many islands of Melanesia in the South Pacific. Big earthquake and tsunami occur repeatedly in this area, and a tsunami of more than 10cm caused by an earthquake which occurred in the Solomon Islands was observed in Hokkaido in 1975. But the damage area of the tsunami caused by the earthquake on this occasion is the islands in the Western Province and the southern coast of Choiseul Island in Choiseul Province. The casualties amounted to 52, and 33 of them were concentrated on Gizo Island near the hypocenter. (U.N. Humanitarian-support Office (OCHA): 2007)

3 Survey area and methodology

The field survey was carried out in August, 2007, four months after the occurrence of the tsunami in the southern and western villages of Gizo Island. The damage was very serious and scars left by the tsunami were still visible. First, we made a reconnaissance of the villages which suffered a great deal of damage from the tsunami, and we investigated the extent of the damage and whether the damage reduction effect of the coastal forest could be examined. Then we selected

the villages where we would conduct detailed investigations, including interviews of residents, coastal forest analysis, traverse surveying, and so on, by taking the information on Google Earth imagery, the ease of access to the village etc. into consideration. As a result, in Titiana, Suva, Pailongge, Hakaroa and Vorivori, advanced investigation to obtain detailed data was conducted, and Leoko, Bibolo, Sagheraghi, and Kariki were limited only to exploration (Figure 2).

Investigation of the damage situation was mainly conducted around the houses. At the time of the investigation, few marks of houses could be found because many houses were carried away by the tsunami, so observations and interviews were performed there based on pictures taken before the disaster acquired from Google Earth in July, 2007. Examination items were the form of the house, and the damage grade (classified as washed away, movement, heavily or slightly or not damaged, etc.). The geographical feature position of the house was clarified for the typical house, by profile leveling of traverse baselines in the right-angled direction from the shoreline and cross-leveling between baselines as the occasion demanded.

With regard to the coastal forest, tree species, tree height, DBH (Diameter at Breast Height), height of base of crown and tree position were measured for all *Cocos nucifera* and other species of more than 5cm DBH near the course-of-traverse circumference.

4 Results

4.1 Relationship between damage and structure of houses on Gizo Island

The southern and western coast of Gizo Island was dotted with villages whose tsunami damage was serious. In every village, most houses and the church were built on flat land of tens to one hundred or more meters wide from the seashore to the base of hills. Size ranged from small villages of several houses to comparatively big villages of about 100 houses. The ratio differed in each village, but raised-floor dwellings accounted for from 50 to 90%, and the floor height

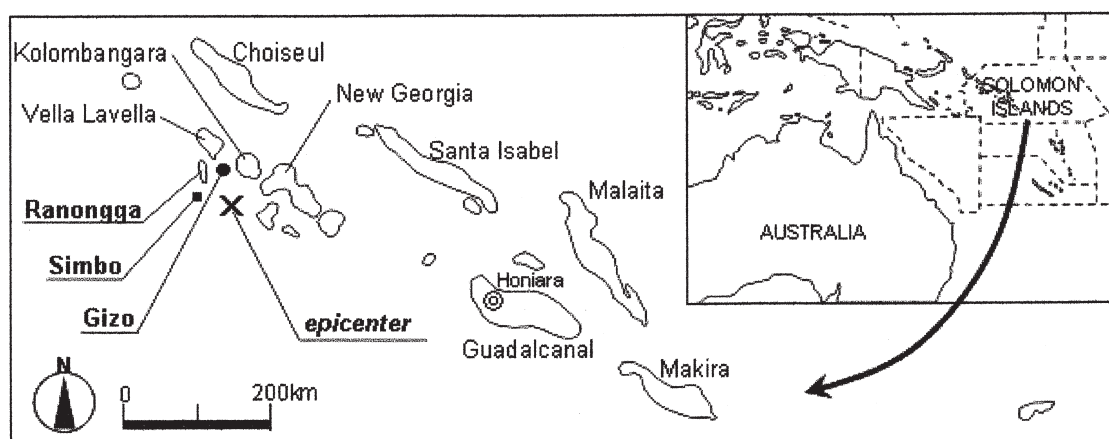


Figure 1: Location of Solomon Islands and the epicenter

varied from approximately 50 to 300cm (Photograph 1). Most of the posts in raised-floor dwellings were wood, and some posts were concrete or iron material. As wall material, *Metroxylon sago* was used overwhelmingly, and it was sometimes used for wood, block material..

Damage classification of houses was performed as follows. First, the stage in which the whole house remained was divided into three; 'not damaged', 'possible to reside' and 'impossible to reside'. Next, when only part of the house remained it was defined as 'severely damaged', and when a house was lost, it was classified as; 'only posts remaining', 'only base remaining' or 'washed away'. The results of this house damage classification are shown in Figure 3.

Although quantitative analysis is not progressing on the influence of house structure in this earthquake and tsunami, it is clear that the house structures mentioned above do not have sufficient strength against this kind of strong earthquake and tsunami, and according to interviews, several houses of block structure collapsed during the earthquake, before the tsunami hit. However, it is considered that the height of posts in raised-floor dwellings was effective in mitigating the tsunami damage. Frequency distribution of the post height in raised-floor dwellings in Titiana and Hakaroa village are shown in Figure 4.

4.2 Structure of coastal forest

The tree species appearing in areas along the shore did not differ greatly between villages; however, in Hakaroa, relatively dense forest stand remained on the shoreline side of the village. Also, in Vorivori village, dense forest stand existed in part. The main tree species of the coastal area are *Cocos nucifera*, *Calophyllum inophyllum* L., *Terminalia catappa* L., *Hernandia sonora*, *Barringtonia asiatica*, *Hibiscus filiceus* L., as well as several species of *Pandanus* and so on. *Cocos nucifera* is by far the largest in number and the DBH of mature individual trees is about 30cm, but its function as resistance against tsunami is not generally expected to be good because it has no branches. The maximum DBH of *Calophyllum inophyllum* L. was over 200cm, and that of *Terminalia catappa* L., *Hernandia sonora* and *Barringtonia asiatica* was over 100cm.

4.3 Typical profile of geographical features in each village

Two or more traverse baselines were prepared for every village, and typical geographical features were surveyed. The traverse baselines were set up in a right-angled direction from the shoreline, passing through the positions of houses in the 'washed away' category and through the remaining houses in the 'possible to reside' category in principle, and a vertical section survey was performed. Profile leveling was

performed by all the traverse lines, and cross sectional surveying was also carried out in Titiana and Pailongge villages for comparison of the absolute height of the traverse lines. These results are shown in Figure 5.

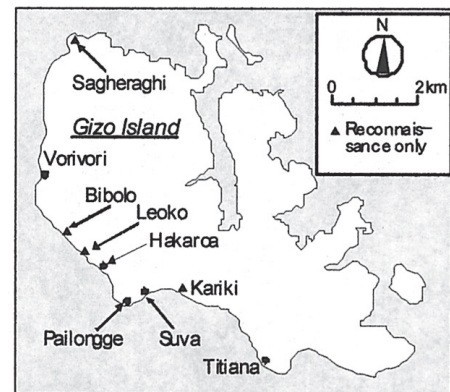


Figure 2: Location of investigation villages on Gizo Island



Photograph 1: Raised-floor dwelling of damage category 'impossible to reside'



Photograph 2: Severely damaged church in Titiana



Photograph 3: A house stopped by a coconut palm tree

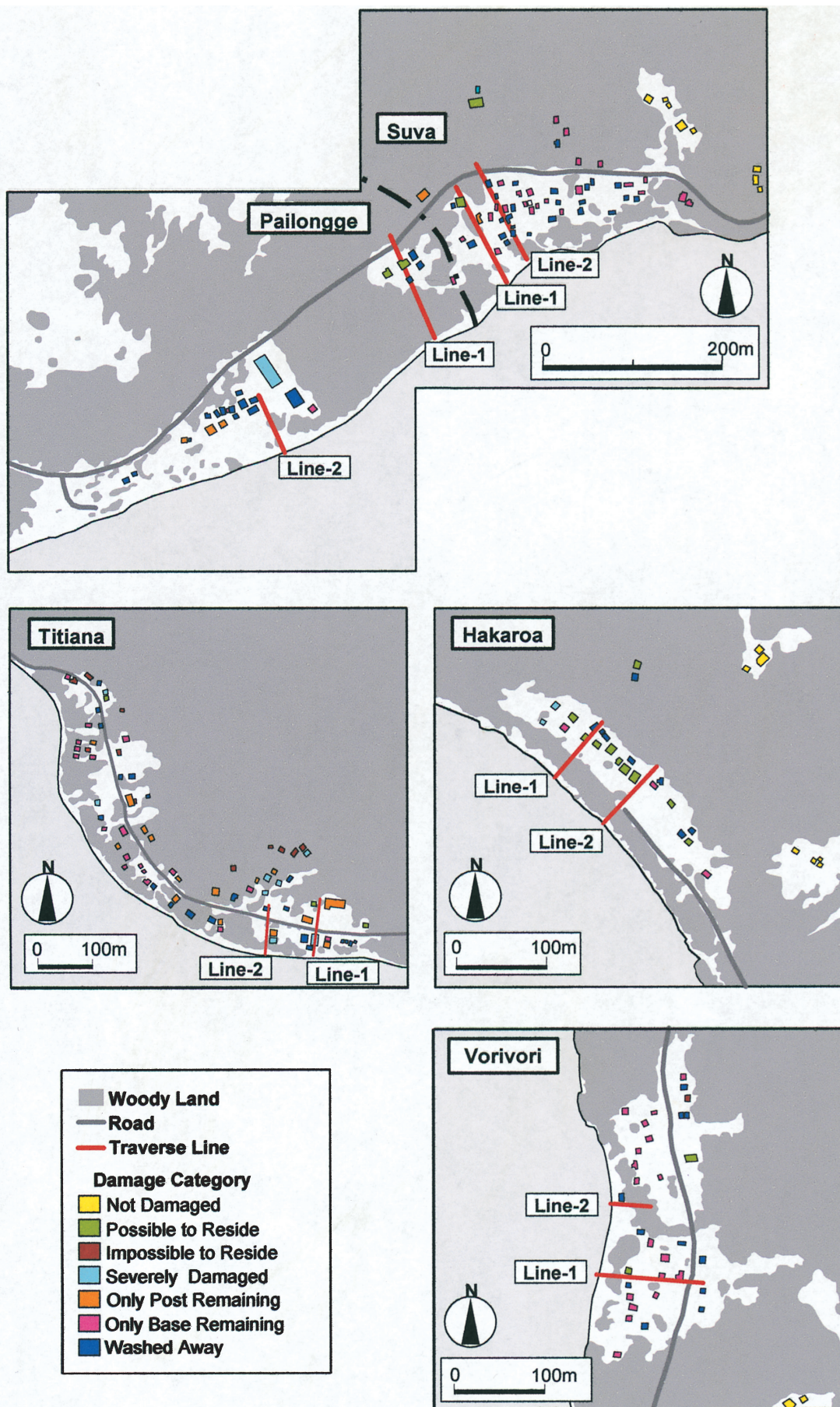


Figure 3: House damage classification and traverse line

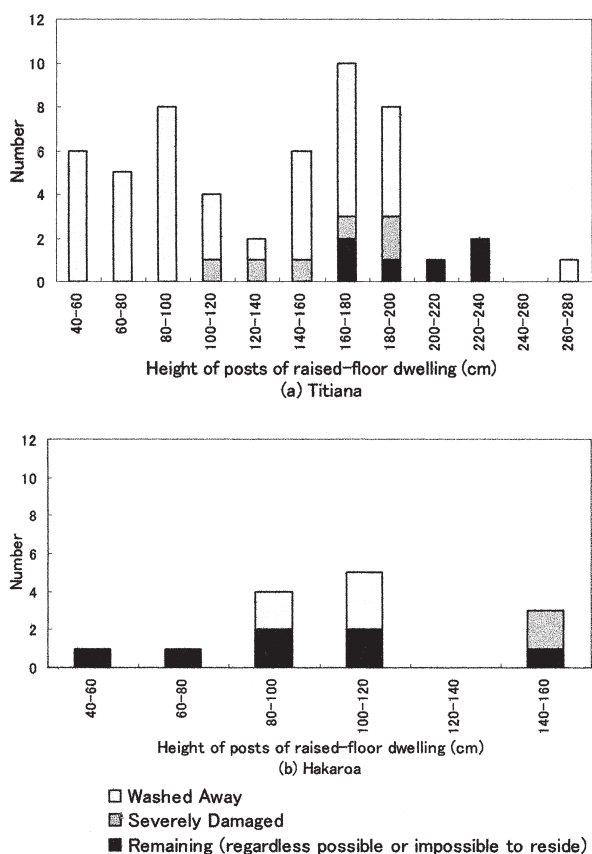


Figure 4: Frequency distribution of post height of raised-floor dwellings

5 Discussions

Based on the above-mentioned results, the tsunami damage reduction effect of the coastal forest is considered here for each village.

5.1 Titiana and Vorivori

The photograph of the skeleton of the big church located on the seashore in Titiana was distributed all over the world, and became a symbol of this tsunami damage (Photograph 2). Although there were 80 or

more houses before the disaster, at the time of the investigation, only six houses were occupied dwellings and they were comparatively distant from the seashore. 13 out of 400 residents died. The maximum height of the tsunami is assumed to be about 3.8m, judging by a trace which remains near the window of the church. As shown in Figure 3, traverse line, Line-1, was set up and passed through the ruin of the church. Line-2, located about 70m west of it, passed along the side of a slightly damaged house whose distance from the shoreline was almost equal to that of the church. Figure 4 (a) shows that the frequency distribution of the height of posts of raised-floor dwellings which remained as house figures, i.e. belonging to the 'not damaged', 'possible to reside' or 'impossible to reside' categories, shifts towards a larger value, compared to all the houses in Titiana. It is considered that the tsunami flowed below the floor of the houses or the load on the houses caused by the tsunami was small because of the structure of raised-floor dwellings. Villages other than Hakaroa also show the same tendencies. From Figure 5, Line-1 and Line-2 are almost equal in ground height, and the tree density on the shoreline side of the house along Line-2 is clearly higher than that of Line-1. However, it cannot be determined whether this is an effect of the raised floor, or an effect of high density coastal trees, since this remaining house is a raised-floor dwelling with post height of approximately 200cm. Moreover, since Titiana suffered destructive damage over the whole village, it was difficult to evaluate the tsunami damage reduction effect of the coastal forest using other evidence. However an example of the secondary effect of coastal forest in which a *Cocos nucifera* became a support and stopped a moved house was recognized (Photograph 3).

Almost the same situation was found in Vorivori. There was no difference in ground height between the traverse baselines, and a forest belt with higher density than that in Titiana existed on the sea side of a not

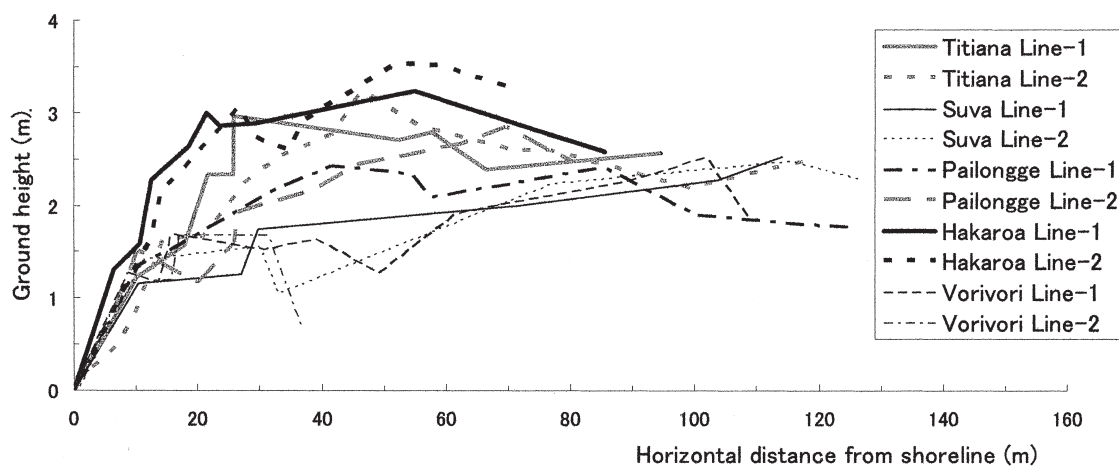


Figure 5: Result of profile leveling in each village

damaged house. However, since the height of the floor of the remaining house was about 300cm, it is not clear which had more effect.

5.2 Suva and Pailongge

Suva and Pailongge are neighboring villages and are located in the center of the southern coast of Gizo Island. Although there were about 80 houses in all, there were only four inhabitable houses at the time of the investigation. Each remaining house was a raised-floor dwelling with high posts. However, it is considered that this cannot be explained simply by the post height because among the houses washed away were some houses that were located very close to the remaining houses with almost the same post height. From Figure 3 and Figure 4, we can see that a forest belt with comparatively high density exists around a remaining house. Moreover, a *Cocos nucifera* wood of about 1.3 hectares with a density of 400/ha exists between Line-1 and Line-2 in Pailongge. In this village, the tsunami attacked 3 times from south, west and southwest, and it is thought that the coastal forest demonstrated a damage mitigation effect directly against the triple tsunami. That is, there is almost no difference in ground height between both traverse lines, and it is thought that the difference in damage grade is due to the existence of coastal forest and the difference in its density in the direction of movement of the tsunami.

5.3 Hakaroa

Hakaroa is the village, mentioned above, with the highest coastal forest density of all the investigated villages, and although there were not so many houses before the tsunami, the ratio of remaining houses is much higher than other villages. In this village, the houses were built in a long, narrow flat ground of about 50m width and about 200m length parallel to the shoreline, behind several meters of tree belt following about 10m of sandy beach. According to the results of interviews with residents, the tsunami passed through the inside of the village parallel with the shoreline, rather than rushing directly from the seashore. Moreover, according to Figure 5, the ground level of the coastal area is relatively high compared with the other villages. Its peak value is almost same as that of Titiana, but the ground slope near the shoreline is steep. Furthermore, according to Figure 4 (b), the distribution of the floor height of houses which held their shape after the tsunami differs from the other villages; that is, there is a high rate of houses which were not washed away in spite of having relatively low raised floors. This is considered to be because the tsunami height in this village was not as high, so the damage caused by the tsunami was comparatively small. Also, testimony that the height of the tsunami was about

160cm at maximum was obtained through interviews with residents. It is not clear whether the tsunami height was low due to the tree belt or due to the ground height of the seashore area. In addition, it is difficult to clarify this only using information acquired at this time because it was not a wave from the direction in which both tree belt and ground height would show greatest resistance against a tsunami.

6 Conclusions

This study was carried out after a lapse of about four months after the earthquake and the tsunami damage, and we investigated the relationship between tsunami, coastal forest and house damage in a situation in which many traces of the tsunami were left and people's memory of the tsunami damage was still fresh. There were some residents who seemed to overestimate the damage reduction effect of the coastal forest, and we were actually able to confirm it partially. However, at present, the effect of coastal forest cannot be dissociated from that of the structure of the houses and/or ground height. Hereafter, more detailed analysis and data accumulation will be required in order to attain the final goal of this research. In places where the strength of the buildings is low, and moreover they cannot install a breakwater and/or a coast embankment in the seashore due to socioeconomic background, etc., as in this investigation field, they have great expectations of the effect of the coastal forest. Therefore, an immediate examination of the method of establishment of effective coastal forests and the limit of the tsunami damage reduction function of coastal forests, etc. is required.

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