

Modelling the Site Selection of Temporary Yards for Disaster Waste Treatment

—Case Study of Enshu Area, Shizuoka Prefecture, Japan—

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Abstract: This study aims to model the site selection of temporary yards for disaster waste treatment. After the Great East Japan Earthquake of 11 March 2011, necessity is widely well known to preliminarily set up temporary storage spaces for disaster waste in order to achieve speedy disposal and revival. In fact, there are many problems, such as skills, talent, cost, and complicated procedures, the municipalities cannot step into the selection project easily. Regarding this background, we created a selection model by Geographic Information System (GIS). We clarified the site conditions by land availability, land competition at a disaster, secondary disaster prevention, and required area in step. Then we generalized the site conditions to selection procedures and adopted in the Enshu area, Shizuoka Prefecture, Japan. As a result, in Kosai City, there is a shortage of public open spaces that would be regarded as actually used, and it is forced to use the private open spaces. In addition, candidate sites are not evenly distributed. We pointed out that (1) With GIS support, it is possible to narrow down the candidates considerably even with several simple operations; (2) The site condition and the order (land use, disaster use site, secondary disaster prevention and area) are important; (3) This GIS-based model is easy to respond to changes in parameters corresponding to tsunami disasters and area conditions. It is helpful for governmental officials to screen the candidates in making disaster waste treatment plans.

Keywords: temporary yards, disaster waste, land use, GIS

1. Introduction

The Great East Japan Earthquake on 11 March 2011 caused severe damage to the buildings and infrastructures in northeast Japan (Tohoku). This disaster created more than 20 million tons of disaster waste and 11 million tons of tsunami deposits, which

prevented traffic and infrastructures being rebuilt and reconstructed (Ministry of the Environment). In general, disaster waste will be gathered in temporary yards then classified and processed. At the time of the Great East Japan Earthquake, local governments mostly used public spaces as temporary yards, however, where they unavailable, they also used private land. It took long time to negotiate with local people and landowners in several cities. As a result, waste processing started late (Miyagi Prefecture, 2014). Moreover, some temporary yards were closed earlier for other purposes, and some had to wait for lifting ground level sunk by earthquake. These processes caused delay of waste disposal. This delay led to the fact that it took three years to complete waste disposal. This experience taught the importance of making disaster treatment plan including temporary yards.

In the Nankai Trough Earthquake which is expected to occur in the near future, catastrophic damage is expected mainly in Shikoku region and Tokai region (Central Disaster Management Council, 2013). In addition, more than 250 million tons of disaster waste and 59 million tons of tsunami deposits are expected (Central Disaster Management Council, 2013). The Ministry of the Environment (2014) and Japan Society of Material Cycles and Waste Management provided materials and guidelines on disaster waste treatment plan. However, the onerous information and conditions are making the progress slow because of poor knowledge, skills, and talent. By October 2016, for instance, only 3 municipalities in Aichi Prefecture have opened disaster waste treatment plan in spite of assumption that catastrophic damage will occur (Disaster Waste Management Plan in Aichi Prefecture, 2016). In addition, many disaster waste management plans do not mention the site selection of the candidate of temporary yards in details. Some local governments do not involve the selection of temporary storage spaces, concerning about declining

land prices and the opposition from residents.

Management of disaster waste is drawing much attention regardless of domestic and overseas. Asari et al. (2011) summarized introduction about disaster waste disposal of natural disasters overseas and disaster waste disposal after the Great East Japan Earthquake. Arai et al. (2015) briefly referred to the site selection of the temporary storage yards. They did not go into details under the site conditions. In this research, we aimed to conceptualize the site selection of temporary yards for disaster waste as a GIS model. We selected the candidates of temporary yards and validated the model in Enshu area of Shizuoka Prefecture. Furthermore, we prepared a set of procedures for adopting the model so that it could be widely used with minimum of data inputs.

2. Study Methods and Study Target Area

2.1 Definition of Words

Regarding proposed temporary yards for disaster waste, the use of the words differs depending on the municipalities and organizations. According to the Disaster Waste Management Guideline by the Ministry of the Environment, all temporary yards are referred to as *kariokiba*, and those are referred to, depending on the process, as "temporary storage yards primarily to put down disaster waste", and "temporary storage places mainly to crush and to incinerate disaster waste". These names are cumbersome. On the other hand, Japan Society of Material Cycles and Waste Management calls temporary yards *kariokiba*, primary storage places *1st shusekisho*, and secondary accumulation places *2nd shusekisho*. However, in terms of temporary placements, many municipalities conform to the Japanese Ministry of Environment and call a series of places *kariokiba* meaning temporary yards. Therefore, in this research, according to the standards of the Ministry of the Environment, we called all temporary yards *kariokiba*, and defined according to the process as "primary temporary yards"

and "secondary temporary yards". The "primary temporary yards", in this research, were places where disaster waste is collected from the area by residents and traders, and it should be settled in dozens of places in the city. The "secondary temporary yards" are places where disaster waste from the primary temporary yards is classified, sorted and put down temporarily. These are to be installed in several places in the city.

2.2 Study Methods

In this research, we prepared temporary yards selection model. We considered the site selection model based on past research, cases, municipal disaster waste treatment plans, and guideline of Ministry of Environment. We also adapted to the target area and we selected temporary yards by the site selection model created in this research and test the site selection flow. In this case we selected candidate sites of the secondary preliminary yards in 3 cities in Shizuoka Prefecture. Regarding the site selection flow, we used the Geographic Information System (GIS), especially Esri's ArcGIS.

2.3 Field

In this study, we considered case of Kosai City, Hamamatsu City and Iwata City in Shizuoka Prefecture, where huge tsunami damage due to the Nankai Trough Earthquake is anticipated. It is 200,000 ha in total (Geospatial Information Authority 2015), and 900,000 people live in the area (Census 2015). This region is a part of Nagoya metropolitan; therefore, many factories and residential areas are located. Through such topography, residential distribution and industrial distribution, the Nankai Trough Earthquake will cause massive damage in these coastal municipalities. Hamamatsu City (2017) estimated, due to the Nankai Trough Earthquake, about 18,570 deaths, 116,000 destroyed buildings, and 18.7 million tons of disaster waste. Besides

Hamamatsu City, bulk embankment construction is being carried out as a measure against the tsunami, but flooding due to the tsunami cannot be avoided. Regarding disaster measures, Hamamatsu City made a disaster waste treatment plan in 2017, but the other two cities have not prepared yet.

3. Modelling Site Selection of Temporary Yards for Disaster Waste

3.1 Conditions for Sites Selecting

Several conditions were presented in the existing site selection processes of candidates of temporary yards of disaster waste. Based on Japan Society of Material Cycles and Waste Management (2012), the Ministry of the Environment (2014), the Cabinet Office etc., we summarized the site conditions. There were a variety of information sources, and items range to 24. "Land use", "topography", "transportation", "law regulation / social restriction" and "consensus" are listed as major items. It is certainly necessary to consider these conditions for site selection of candidates of temporary yards. However, taking all these conditions into consideration is a cumbersome task. And in reality, many municipalities are in short of candidate sites of temporary yards. Therefore, not all these conditions can currently be considered.

In this research, we created a GIS model based on the conditions that should be taken into consideration at the minimum, not all conditions like other research and material. Specifically, (1) Regarding land use, restrictions imposed by landowners and usage are large even in unused areas and low utilization areas. Therefore, classes of land-owners were regarded as the top priority. (2) Regarding conditions of terrain, the inclination and area were taken into consideration. (3) Regarding social regulation, we took secondary disaster risks into account. For instance, tsunami, sediment-related disasters and so on. (4) As consensus, we considered land-owners. Regarding the excluded conditions, it was limited to the extent considered in

the final stage consideration.

3.2 Tentative Place Candidate Site Selection Model

Based on the conditions selected in 3.1, a site selection model of temporary yards for disaster waste was created. In selecting the site conditions, firstly we decided to select the ones that were considered as major premises and were considered to have few changes in the conditions. We set up 4 prerequisites.

The site selection model of candidate temporary yards for disaster waste is shown in the figure. 1.

3.2.1 First Condition

We selected the usable land from land use map by GIS. In urban land use, it is difficult to acquire private land. In some cases, it is possible to use private abandoned areas such as cultivation, but there are obstacles in cost and time, such as administrative procedures with landowners and work for returning land. Also, it is desirable that natural land use such as forests and river beds should be avoided in view of fear of secondary disasters and environmental assessment.

3.2.2 Second Condition

We excluded the land expected to be used at the time of a disaster. Open spaces such as public open spaces are sometimes important land as evacuation centers and Self-Defense Forces' (SDF) activity bases in the event of a disaster.

3.2.3 Third Condition

We should avoid land that is to face secondary disasters. Tsunami affected areas and places where sediment-related disasters are expected etc. were taken into consideration as necessary process. In this condition, for instance the flood level of the tsunami can be a variable parameter.

3.2.4 Fourth Condition

Narrowing down by area was performed. There are not area standards for each of the temporary yards, but it is expected that efficiency in sorting and managing etc. will be improved if it is a wide temporary yard. If necessary, the selection condition should be changed and evaluated as a parameter.

4. Case Study in Enshu Area of Western Shizuoka Prefecture

4.1 Usage Data

We adapted the site selection model as Figure. 1 to 3 cities, Kosai City, Hamamatsu City and Iwata City in Shizuoka Prefecture. The following data was used.

(1) Land use. We used data of land use data from a Data for City Planning provided by Shizuoka Prefecture. (2) Land reservation for a disaster revival. In the case of a disaster, establishment of various functions such as morgue and extraordinary offices is expected. However, the location could not be taken into consideration because it is not clear. We

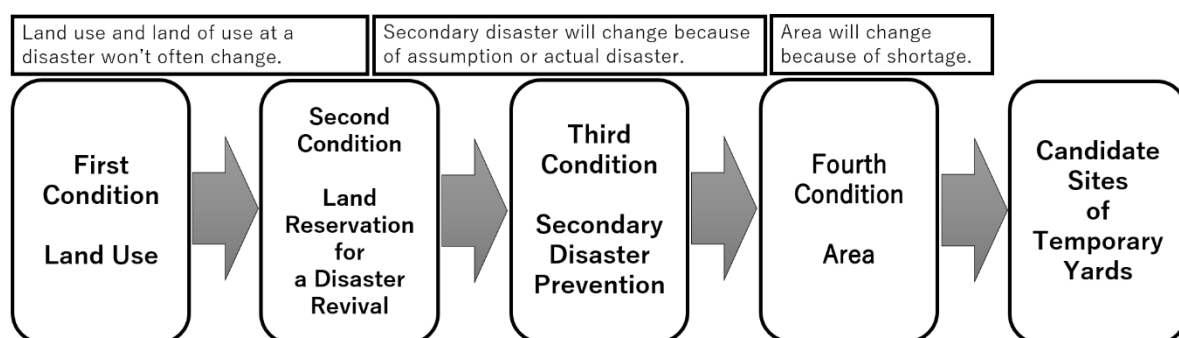


Figure1: Site Selection Model of Candidates of Temporary Yards

considered of it in 5th section. (3) As for the exclusion conditions for prevention of secondary disasters, we used topography and tsunami inundation area. Regarding flooding areas, we used tsunami flooding depth data (10-meter raster data) of Nankai Trough Earthquake Case 1, which was expected to be the highest tsunami in the target area, created by the Committee for Modeling a Nankai Trough Megaquake set up at the Cabinet Office in 2012.

Since the regional characteristics are different depending on the target location, we need to consider the conditions depending on target area.

4.2 Site Selection Flow

We selected candidate sites of temporary yards in this section.

4.2.1 First Condition

We selected public open spaces, private open spaces, and public facility sites from the land use data of Data for City Planning. These are easily gained for temporary yards for disaster waste treatment. The other land was excluded as the land use which is not in conformity with the temporary yards.

4.2.2 Second Condition

We excluded the reserved land for a disaster revival. The places used at the time of disaster was overlaid as the point data and land including it was excluded by the space search tool of GIS. The condition of the space search was only duplication, and we did not exclude the neighboring patch. In addition, as mentioned in section 4.1, since we did not consider all reserved sites for a disaster revival, we examined temporary housing and morgue etc. in 5th section.

4.2.3 Third Condition

We considered of terrain conditions and tsunami affected areas. Regarding the topography, the

inclination angle was allowed to be less than 10 degrees. All tsunami affected areas was excluded. Miyagi Prefecture Department of Environment and Life Earthquake Waste Management Division (2014) found that in some places, sedimentation of the ground was recognized by the Great East Japan Earthquake and in other places, the bulking to the temporary yards was done to prevent secondary disasters in the tsunami affected area. It is understood that the tsunami inundation area is not suitable for temporary yards for disaster waste.

4.2.4 Fourth Condition

Temporary yards prefer larger sites, but we could not find area standards in the disaster waste treatment plans or the guideline of the Ministry of the Environment. Based on the area of the temporary yards for disaster waste in Miyagi Prefecture established in the Great East Japan Earthquake, we decided that the top 95% area, 2.4ha and more is considered appropriate.

4.3 Results

Results of each processes by GIS are showed below.

4.3.1 First Condition

Public open spaces and private open spaces were appeared in each city. Only Hamamatsu City had public facility sites. In Kosai City, the proportion of public open spaces was large, but the total area of public spaces was small.

4.3.2 Second Condition

There was no significant decrease compared with the result under the first condition. However, some large-scale lands had been reduced or eliminated due to elimination of the reserved sites for a disaster revival.

Table1. Used Data. We use data below and analyze ourselves.

category	data source	data	area	year
Land use	City planning basic survey	Land use	Kosai city	2010
			Hamamatsu City	2010
			Iwata City	2010
Land of use at a disaster	National land numerical information	Administrative district	Shizuoka Prefecture	2017
		Evacuation facility	Shizuoka Prefecture	2012
	Open data catalog Shizuoka	Medical transport base	Shizuoka Prefecture	2013
		Medical material center	Shizuoka Prefecture	2013
		Waste Treatment Facility	Shizuoka Prefecture	2013
		Emergency firefighting aid team activity base	Shizuoka Prefecture	2013
		Police base	Shizuoka Prefecture	2013
		Regional goods bases	Shizuoka Prefecture	2013
		Disaster hospital	Shizuoka Prefecture	2013
		Self Defense Force activity base	Shizuoka Prefecture	2013
Secondary disaster prevention	The Geospatial Information Authority	Digital elevation model		
	Tsunami affected area	Nankai trough earthquake assumption case1	Shizuoka Prefecture	

4.3.3 Third Condition

Firstly, from the topographical condition, there were few reductions of candidate sites. However, in Kosai City some public spaces could not be used in part because the hills are spreading in inland areas. Many candidate sites, however, could not be used from the tsunami disaster condition. The area of tsunami affected area was 7,200 ha. It is important to note that the large public open spaces in coastal areas are unavailable.

4.3.4 Fourth Condition

We narrowed down candidates of temporary yards by area. As a result, many places were excluded. There were significant decreases. Public open spaces decreased from 171 to 1 place in Kosai City, in Hamamatsu City it decreased from 1,016 places to 27

places, in Iwata City it decreased from 499 to 18 places. Narrowing down of private open spaces was also done.

4.3.5 Results

From the four conditions, the candidates of temporary yards for disaster waste are shown in the figure (Figure 2, 3). The number and area of candidate sites were narrowed down and decreased. In Kosai City, as a result of the selection, the public open spaces available was 1 place (2.6 ha), the private open spaces available was 4 places (15.9 ha), and the effective proposed temporary yards total 18.5 ha. In Hamamatsu City, there are 27 public open spaces (163.5 ha), 23 private open spaces (139.7 ha), and 3 public facility sites (67.6 ha). Iwata City had 18 public open spaces (80.8 ha) and 15 private open spaces

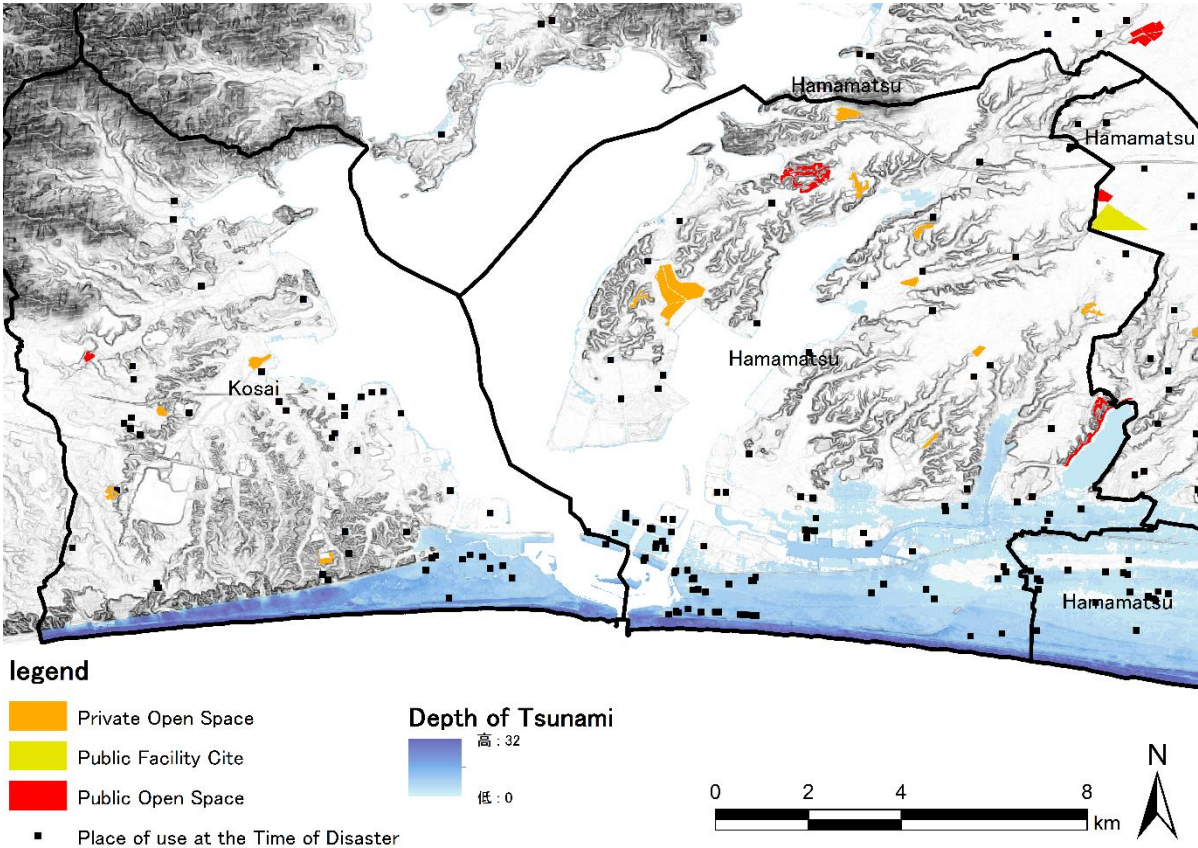


Figure2. Results in Kosai City and Western Hamamatsu City

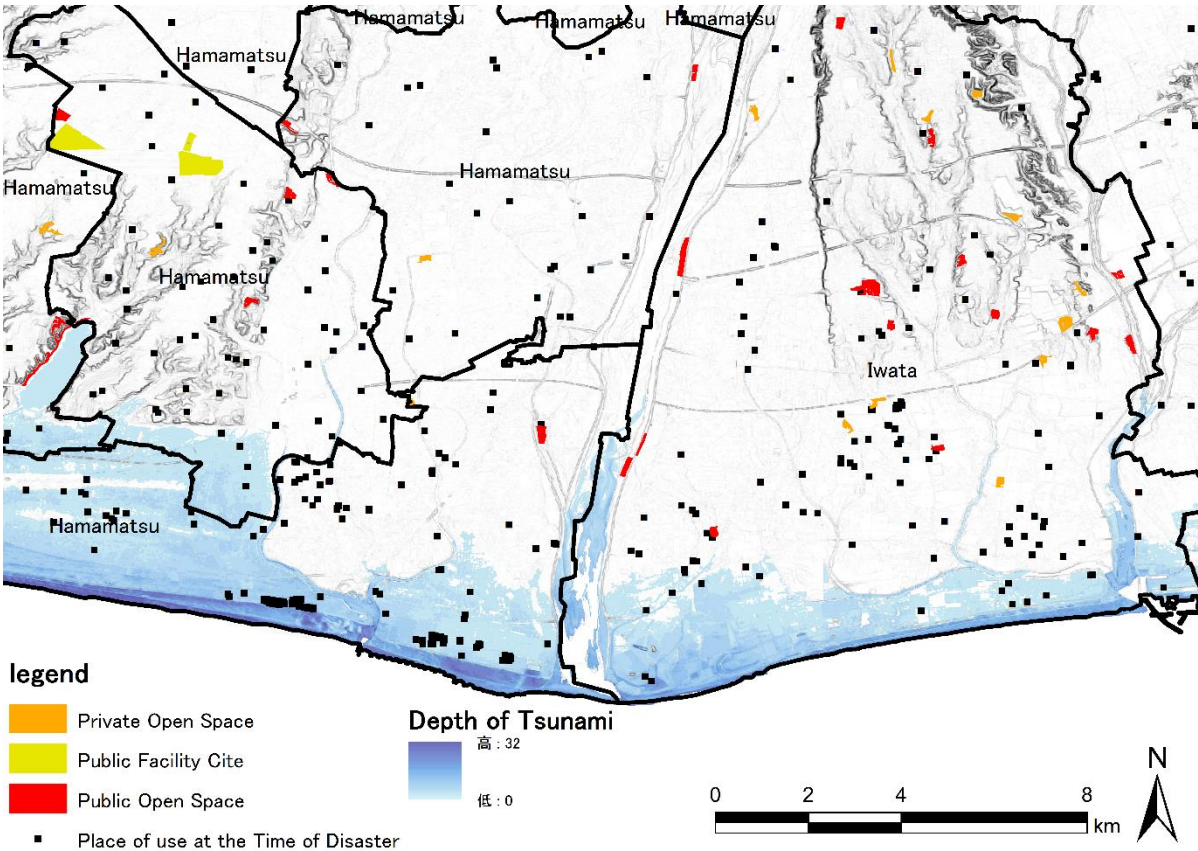


Figure3. Results in Eastern Hamamatsu City and Iwata City

(51.1 ha). Also, the distribution was biased. In Kosai City, public open spaces were located near the western edge, and the distance from disaster waste generation area was likely to be long. Even in private open spaces, the candidate sites were not selected in the east or south of the city area. In Hamamatsu City, only a few places were selected in the south wards and eastern wards, but in other places, in addition to the public open spaces, private open spaces and land for public facilities were also selected. Also, relatively large candidate sites were also scattered. In Iwata City, the candidate sites by public open spaces were well-balanced, except for the tsunami-affected areas in the south. Including private open lands, it was considered that sufficient candidate sites were selected.

5. Discussion

With the site selection model of temporary yards for disaster waste, the candidates of provisional sites narrowed down efficiently even with the several conditions judged to be necessary at the minimum. On the other hand, these candidate sites are afraid of conflicting with conditions that are not taken into consideration. However, we think that problems caused by these unselected conditions are easily solved. When disaster occurs, municipalities decide temporary yards for disaster waste by visiting the candidates of temporary yards. Therefore, it is considered that on GIS process of created model, site conditions are sufficient.

Not all reserved lands for a disaster revival were taken into consideration in this paper. In the event of a disaster, reserved lands for a disaster revival such as temporary housing, water supply facilities, etc. may compete with temporary storage yards for disaster waste. It is assumed that land reservation for a disaster revival responsible to human life and hygiene environment are prior to temporary yards for disaster waste. Therefore, it should be forced to be chosen

from the remaining limited candidate sites. Thus, it is necessary to change the parameters such as the area conditions to select the candidates of temporary yards more effectively when the candidates of temporary yards are insufficient or unevenly distributed.

In this case study in the three cities of Shizuoka Prefecture, we decided the Tsunami affected area of Nankai Trough Earthquake Case 1, from the material of Central Disaster Management Council. Actual tsunami affected areas, however, will be known after a disaster. When selecting preliminary candidates of temporary yards, it is desirable to assume several patterns of tsunami affected area to make it possible to deal with low cost even when damage is smaller than assumption.

Land use changes day by day. Also, due to the construction of embankments and roads, there is a possibility that the situation of inundation assumption changes. Tajima et al. (2014) also pointed out that it was expected that vacant land acquisition, disposers, final disposal sites, local government staff would change. The disaster assumption would be not decisive, and on the other hand, there would be no way to confirm such a plan by practical use (Tajima et al., 2014). It is desirable not only to select candidate sites of temporary storage yards for disaster waste but also to review the candidate sites appropriately.

In this case study, we cited three cities of Shizuoka Prefecture, broad plains and the spread of industrial and residential areas are characteristic. In Kochi Prefecture, for example, long-term inundation thanks to the subsidence of the ground by the Nankai Trough Earthquake has been known (Kochi Prefecture et al.). Also, it is difficult to secure flat lands on Rias coast such as northeast Japan or on mountainous area. *“The cause of the disaster, types of local industry, building densities, and so forth”* (Sakai, 2012) should must influence disaster waste. We should consider the characteristics of the area.

Regarding the required area, the Hamamatsu City Disaster Waste Treatment Plan (2017) adopted a method of calculating the area of the secondary temporary sites based on the balance of loading into and out of waste. By constructing such a flow system, there is a merit such as a reduction in required area in selecting candidate sites of temporary yards for disaster waste.

6. Conclusion

We modeled site selection of candidates of temporary yards for disaster waste. In this research, the following points were found.

- (1) For the site selection model of candidates of temporary yards for disaster waste, it is possible to narrow down considerably even with several simple site conditions.
- (2) Each condition and the order (land use, reserved sites at a disaster revival, secondary disaster prevention and area) are important. It is easy to change parameters due to changes in tsunami disasters and area conditions.
- (3) In case studies using GIS model, problems such as uneven distribution and lack of sufficient candidate sites remain.
- (4) The thorough review and selection of the selected candidate sites should be carried out.

It is necessary to verify the site selection model in other cases and research based on actual circumstances of local governments. Moreover, we could not verify the cost and speed of processing in this research. These are important factors in actual disasters. We would like to promote verification from various factors such as cost, processing speed, transportation, etc., as well as the site selection of the potential disaster waste temporary storage sites.

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References

- 1) Aichi Prefecture, 2016. Aichi Prefecture disaster waste treatment plan. [in Japanese].
- 2) Central Disaster Management Council. Nankai Trough Huge Earthquake Measure Consideration Working Group, 2012. About the Damage Assumption of the Nankai Trough Great Earthquake. [in Japanese].
- 3) Central Disaster Management Council. Nankai Trough huge earthquake Measure Working Group, 2013. Damage assumption of the Nankai Trough huge earthquake (Second Report) [aspect of the damage]. [in Japanese].
- 4) Hamamatsu City, 2017. Hamamatsu City disaster waste treatment plan. [in Japanese].
- 5) Japan Society of Material Cycles and Waste Management. The Task Team on Disaster Waste Management and Reconstruction, 2011. *Strategy of separation and treatment of disaster waste – Focusing on the Great East Japan Earthquake 2011 -*. [in Japanese].
- 6) Kochi Prefecture. Portal site prepared for the Nankai Trough Earthquake. The largest class Nankai Trough Earthquake, URL: <http://www.pref.kochi.lg.jp/sonae-portal/earthquake/tokucho.html>. (last date

- accessed: 07 August 2017). [in Japanese].
- 7) Kosai City, 2017. Kosai City regional disaster prevention plan. [in Japanese].
 - 8) M. Asari, S. Sakai, T. Yoshioka, Y. Tojo, T. Tasaki, H. Takigami, K. Watanabe, 2013. Strategy for separation and treatment of disaster waste: a manual for earthquake and tsunami disaster waste management in Japan, *J Mater Cycles Waste Manag*, 15: 290-299.
 - 9) Ministry of the Environment. Disaster Waste Management Information Site.
http://kouikishori.env.go.jp/archive/h23_shinsai/damage_situation/. (last date accessed: 07 August 2017). [in Japanese].
 - 10) Miyagi Prefecture Environmental Division Earthquake Waste Management Division, 2014. Record of Disaster Waste Disposal <Miyagi Prefecture>. [in Japanese].
 - 11) Niigata City, 2016. Niigata City disaster waste treatment plan. [in Japanese].
 - 12) R. Tajima, N. Hirayama, M. Osako, 2014. Theory and practice of pre-disaster planning for disaster waste management. *Society for Social Management Systems Internet Journal*. 1 – 12.
 - 13) Tahara City, 2016. Tahara City Disaster Waste Treatment Plan. [in Japanese].
 - 14) S. Sakai, 2012. Debris Management. *EAP DRM knowledge notes; Megadisaster knowledge notes; NO.4-4. Recovery planning*.
 - 15) Y. Arai, Y. Ikeda, T. Inakazu, A. Koizumi, S. Motegi, S. Yoshida, S. Iino, 2015. Model Analysis of Transportation Planning for Earthquake Disaster Debris -Issues Relating to Temporary Storage Space-, *Journal of Japan Society of Civil Engineers, ser. G (Environmental Research)*, 71(6): II 263- 271 [in Japanese].