Factors in Stimulating Evacuation Behavior on Flood

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Background

Northern Kyushu Torrential Rain on July, 2012

It went on raining hard in Northern Kyushu area for several hours from midnight to morning on July 12th, 2012.

- The maximum rainfall per an hour hours: 108mm
- The maximum rainfall per 24 hours: 507.5mm

Damage

- Loss of lives 31
- Injured 11
- Totally destroyed house 363
- Seriously damaged house 1500
- Partially damaged house 313
- House flooded above the floor level 1175
- House flooded below the floor level 1019
The Shirakawa River
Catchment Area: 480 km², Length: 74 km

Kumamoto City
Otsu Town
Kikuyo Town
Aso City
Mt. Aso
Kumamoto Univ.

Flood forecast area
Annual rainfall

Aso area 3249.8mm
Kumamoto City 1992.7mm
Average of Japan 1651.1mm

Catchment Area 480km²
Length 74 km
Amount of Rainfall (Aso Area), June-July, 2012

Aso Valley

Bochu-Obsevation

Aso-Otohime-Obsevation

Nango Valley

Kugino-Obsevation

Takmori-Obsevation
Rainfall per an hour (Aso Area) 7.12, 2012

Cumulative rainfall (mm)

Rainfall per an hour (mm)

Time

Rainfall per an hour

Cumulative rainfall

1 3 5 7 9 11 13 15 17 19 21 23

106

451

Rainfall per an hour per an hour (Aso Area) 7.12, 2012
The torrential rain in Aso area rushes down a steep slope of the middle of river, and runs in the downtown of Kumamoto city.

It takes 120 minutes for the rain in Aso area to flows through Shira river into the downtown area of Kumamoto city.
The Aim of This Study

◆ To survey evacuation behavior on the flood on July 12th, 2012.

◆ To analyze factors of promoting autonomous evacuation.

◆ To analyzes whether households’ participation level of common activities in a local community affected their evacuation behavior.

◆ To analyzes whether the difference of ordinary activities between the two local communities leaded the difference of their evacuation behavior.
Hazard map of study area

Legend

<table>
<thead>
<tr>
<th>Expected depth</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 0.5 m</td>
<td>Yellow</td>
</tr>
<tr>
<td>0.5-1.0 m</td>
<td>Green</td>
</tr>
<tr>
<td>1.0-2.0 m</td>
<td>Blue</td>
</tr>
<tr>
<td>2.0-5.0 m</td>
<td>Purple</td>
</tr>
</tbody>
</table>

Tatsuda-1chome

Tatsudajinnai-4chome

- 32 people were rescued by the helicopters.
- 50 people were rescued by the boats.

Study area of questionnaire

- Totally or seriously destroyed house: 211
- House flooded: 309
### Summary of questionnaire survey

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Tatsudajinnai-4chome and Tatsuda-1chome, Kitaku, Kumamoto</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Date</strong></td>
<td>December 8(^{th}) and 9(^{th}), 2012</td>
</tr>
<tr>
<td><strong>Method of survey</strong></td>
<td>Visiting and asking questions</td>
</tr>
<tr>
<td><strong>Num. of household in study area</strong></td>
<td>Tatsudajinnai-4chome: 175 households</td>
</tr>
<tr>
<td></td>
<td>Tatsuda-1chome: 435 households</td>
</tr>
<tr>
<td><strong>Num. of respondents</strong></td>
<td>Tatsudajinnai-4chome: 92 households</td>
</tr>
<tr>
<td></td>
<td>Tatsuda-1chome: 209 households</td>
</tr>
</tbody>
</table>

#### Summary of questions

<table>
<thead>
<tr>
<th>Personal attribute</th>
<th>Sex, Age, Can or not evacuate by yourself</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Household attribute</strong></td>
<td>Num. of family, Year of living, Structure of house</td>
</tr>
<tr>
<td><strong>Evacuation behavior and awareness</strong></td>
<td>Change of awareness before/after flooding and evacuation behavior</td>
</tr>
<tr>
<td></td>
<td>Acquisition conditions of information about weather and flood</td>
</tr>
<tr>
<td><strong>Understanding of social conditions in your neighborhood</strong></td>
<td>Conditions of commuting and going to school of neighbors, Evacuation conditions of neighbors, Business conditions of neighborhood stores, Conditions of neighborhood roads</td>
</tr>
<tr>
<td><strong>Conscious of Disaster prevention</strong></td>
<td>Experience of flood, possibility of flood of the Shirakawa River, Preparedness of flood</td>
</tr>
<tr>
<td><strong>Relationship with community</strong></td>
<td>Association with your neighbors, Participation in common activities in local community, etc.</td>
</tr>
</tbody>
</table>
Time series of flood risk awareness and evacuation rate.

- They were absent.
- They didn't try to evacuate.
- They couldn't evacuate.
- They evacuated.

The road was partially flooded.

Evacuation order

- Absent
- Think about flood
- Sure about flood
- Decision of evacuation
- Evacuated
### Recognition of neighbors’ conditions. (n=288)

<table>
<thead>
<tr>
<th>Conditions of going to school</th>
<th>Usual</th>
<th>Early</th>
<th>Many students were absent.</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conditions of commuting</td>
<td>Usual</td>
<td>Early</td>
<td>Many neighbors were</td>
<td>Don't know</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A part of neighbors</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>evacuated.</td>
<td></td>
</tr>
<tr>
<td>Conditions of evacuation</td>
<td></td>
<td></td>
<td>A part of stores closed.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Roads closed.</td>
<td></td>
</tr>
<tr>
<td>Conditions of neighbor stores</td>
<td>Usual</td>
<td>Traffic jam</td>
<td>Most of stores closed.</td>
<td>Don't know</td>
</tr>
<tr>
<td>Conditions of neighbor roads</td>
<td>Usual</td>
<td>Traffic jam</td>
<td>Roads closed.</td>
<td>Don't know</td>
</tr>
</tbody>
</table>
## Acquisition rate of information by group

<table>
<thead>
<tr>
<th>Means of information acquisition</th>
<th>All n=264</th>
<th>Evacuated n=121</th>
<th>Not n=143</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>River conditions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oneself</td>
<td>70%</td>
<td>82%</td>
<td>59%</td>
<td>4.13**</td>
</tr>
<tr>
<td>TV • Radio</td>
<td>17%</td>
<td>19%</td>
<td>15%</td>
<td>0.77</td>
</tr>
<tr>
<td>Internet</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
<td>0.21</td>
</tr>
<tr>
<td>Relation etc.</td>
<td>6%</td>
<td>6%</td>
<td>6%</td>
<td>-0.17</td>
</tr>
<tr>
<td>Neighbors</td>
<td>12%</td>
<td>13%</td>
<td>10%</td>
<td>0.68</td>
</tr>
<tr>
<td>Fire volunteer</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>0.24</td>
</tr>
<tr>
<td>Male</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Weather information</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oneself</td>
<td>32%</td>
<td>32%</td>
<td>31%</td>
<td>0.13</td>
</tr>
<tr>
<td>TV • Radio</td>
<td>22%</td>
<td>17%</td>
<td>26%</td>
<td>-1.87*</td>
</tr>
<tr>
<td>Internet</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>0.24</td>
</tr>
<tr>
<td>Relation etc.</td>
<td>5%</td>
<td>7%</td>
<td>4%</td>
<td>0.86</td>
</tr>
<tr>
<td>Neighbors</td>
<td>7%</td>
<td>7%</td>
<td>6%</td>
<td>0.36</td>
</tr>
<tr>
<td>Fire volunteer</td>
<td>1%</td>
<td>2%</td>
<td>1%</td>
<td>0.70</td>
</tr>
<tr>
<td>Male</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Evacuation order</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TV • Radio</td>
<td>4%</td>
<td>2%</td>
<td>5%</td>
<td>-1.05</td>
</tr>
<tr>
<td>Internet</td>
<td>2%</td>
<td>2%</td>
<td>1%</td>
<td>0.17</td>
</tr>
<tr>
<td>Relation etc.</td>
<td>2%</td>
<td>2%</td>
<td>3%</td>
<td>-0.63</td>
</tr>
<tr>
<td>Neighbors</td>
<td>6%</td>
<td>7%</td>
<td>5%</td>
<td>0.59</td>
</tr>
<tr>
<td>Fire volunteer</td>
<td>3%</td>
<td>4%</td>
<td>2%</td>
<td>0.93</td>
</tr>
<tr>
<td>Male</td>
<td>1%</td>
<td>0%</td>
<td>1%</td>
<td>-1.42</td>
</tr>
<tr>
<td><strong>Advice</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relation etc.</td>
<td>11%</td>
<td>14%</td>
<td>9%</td>
<td>1.24</td>
</tr>
<tr>
<td>Neighbors</td>
<td>25%</td>
<td>31%</td>
<td>19%</td>
<td>2.34*</td>
</tr>
<tr>
<td>Fire volunteer</td>
<td>10%</td>
<td>14%</td>
<td>6%</td>
<td>2.06*</td>
</tr>
</tbody>
</table>
Time series of evacuation rate in terms of a check on the river conditions and advice of evacuation.

(a) The relation between evacuation and a check on the river conditions.

(b) The relation between evacuation and advice of evacuation.
## Scoring means of each item of the questionnaire

<table>
<thead>
<tr>
<th>Probability of flood</th>
<th>Have you read a flood hazard map and recognized a flood risk? Yes :1, No :0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Have you confirmed the evacuation route and place? Yes :1, No :0</td>
</tr>
<tr>
<td></td>
<td>Have you prepared the emergency kits? Yes :1, No :0</td>
</tr>
<tr>
<td></td>
<td>Have you participated in the evacuation drill? Yes :1, No :0</td>
</tr>
<tr>
<td></td>
<td>Have you participated in fire volunteer or activity of voluntary disaster prevention? Yes :1, No :0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Preparedness</th>
<th>Have you read a flood hazard map and recognized a flood risk? Yes :1, No :0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Have you confirmed the evacuation route and place? Yes :1, No :0</td>
</tr>
<tr>
<td></td>
<td>Have you prepared the emergency kits? Yes :1, No :0</td>
</tr>
<tr>
<td></td>
<td>Have you participated in the evacuation drill? Yes :1, No :0</td>
</tr>
<tr>
<td></td>
<td>Have you participated in fire volunteer or activity of voluntary disaster prevention? Yes :1, No :0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relationship with community</th>
<th>Complaint or worries Do you have any neighbors hear your complaints or worries? Yes :1, No :0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Care Do you have any neighbors take care of you when you are sick? Yes :1, No :0</td>
</tr>
<tr>
<td></td>
<td>Familiar with neighbors I have neighbors cooperate a living :3, Daily stand chatting :2, Only greeting :1, Not at all :0</td>
</tr>
<tr>
<td></td>
<td>Acquaintance with neighbors Acquaintance with all neighbors :3, Half of neighbors :2, A few neighbors :1, Not at all :0</td>
</tr>
<tr>
<td></td>
<td>Frequency of greeting Everyday :4, Once a week :3, Once a month :2, Once a year :1, Not at all :0</td>
</tr>
<tr>
<td></td>
<td>Prevention of crime and fire Have you participated in the prevention activity of crime and fire? Yes :1, No :0</td>
</tr>
<tr>
<td></td>
<td>Community learning Have you participated in protective activity of community history or culture? Yes :1, No :0</td>
</tr>
<tr>
<td></td>
<td>Activation of community Have you participated in the activation activity of community? Yes :1, No :0</td>
</tr>
<tr>
<td></td>
<td>Sports Have you participated in the community activity of sports or taste? Yes :1, No :0</td>
</tr>
<tr>
<td></td>
<td>Community development Have you participated in activity of community development or community support? Yes :1, No :0</td>
</tr>
</tbody>
</table>
Comparison between daily activity of evacuated household and non-evacuated household.

<table>
<thead>
<tr>
<th></th>
<th>Evacuated n=121</th>
<th>Not n=143</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Probability of flood</strong></td>
<td>1.41</td>
<td>1.06</td>
<td>2.18*</td>
</tr>
<tr>
<td>Flood hazard map</td>
<td>0.12</td>
<td>0.08</td>
<td>0.85</td>
</tr>
<tr>
<td>Evacuation route and place</td>
<td>0.29</td>
<td>0.29</td>
<td>-0.08</td>
</tr>
<tr>
<td>Emergency kit</td>
<td>0.22</td>
<td>0.12</td>
<td>2.23*</td>
</tr>
<tr>
<td>Evacuation drill</td>
<td>0.19</td>
<td>0.10</td>
<td>2.11*</td>
</tr>
<tr>
<td>Fire volunteer</td>
<td>0.07</td>
<td>0.03</td>
<td>1.38</td>
</tr>
<tr>
<td><strong>Complaint or worries</strong></td>
<td>0.80</td>
<td>0.72</td>
<td>1.52</td>
</tr>
<tr>
<td>Care</td>
<td>0.57</td>
<td>0.52</td>
<td>0.81</td>
</tr>
<tr>
<td><strong>Familiar with neighbors</strong></td>
<td>2.26</td>
<td>2.07</td>
<td>1.88*</td>
</tr>
<tr>
<td>Acquaintance with neighbors</td>
<td>2.02</td>
<td>1.83</td>
<td>1.64*</td>
</tr>
<tr>
<td>Frequency of greeting</td>
<td>3.62</td>
<td>3.66</td>
<td>-0.49</td>
</tr>
<tr>
<td>Residents’ association</td>
<td>0.70</td>
<td>0.70</td>
<td>0.05</td>
</tr>
<tr>
<td>Prevention of crime and fire</td>
<td>0.16</td>
<td>0.12</td>
<td>0.89</td>
</tr>
<tr>
<td>Community learning</td>
<td>0.13</td>
<td>0.10</td>
<td>0.67</td>
</tr>
<tr>
<td>Activation of community</td>
<td>0.09</td>
<td>0.07</td>
<td>0.62</td>
</tr>
<tr>
<td>Sports</td>
<td>0.35</td>
<td>0.27</td>
<td>1.31</td>
</tr>
<tr>
<td><strong>Community development</strong></td>
<td>0.23</td>
<td>0.11</td>
<td>2.57**</td>
</tr>
</tbody>
</table>

** 1 % level of significance, * 5% level of significance

What kind of household evacuated?

About flood probability of the Shirakawa River
⇒ The household who evaluated the probability high evacuated.

About the preparedness for disaster
⇒ The household who prepared emergency kit and/or participated in an evacuation drill evacuated.

About relationship with community
⇒ The household who was familiar with neighbors, acquaintance with neighbors, and/or participated in community development.
### EVACUATION BEHAVIOR MODEL

\[
P(\text{evacuate}) = \frac{\exp(V)}{1 + \exp(V)}
\]

\[
V = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4
\]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-1.82</td>
<td>2.73**</td>
</tr>
<tr>
<td>X1: Area dummy</td>
<td>-0.49</td>
<td>1.55</td>
</tr>
<tr>
<td>X2: Expected flood depth on hazard map</td>
<td>0.31</td>
<td>1.79*</td>
</tr>
<tr>
<td>X3: Dummy of checking river conditions</td>
<td>1.12</td>
<td>3.31**</td>
</tr>
<tr>
<td>X4: Dummy of urging to evacuate</td>
<td>0.69</td>
<td>2.55**</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Likelihood ratio</th>
<th>Hitting ratio</th>
<th>Num. of sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.215</td>
<td>66.9%</td>
<td>260</td>
</tr>
</tbody>
</table>

** 1 % level of significance, * 5% level of significance
The evacuation simulation for food.

- Evacuation rate of the observations
- Evacuation rate estimated by the model
- Evacuation rate if all households check the river conditions.
- Evacuation rate if all households are urged to evacuate.
- Evacuation rate if all households check the river conditions and are urged to evacuate.

Evacuation rate

<table>
<thead>
<tr>
<th></th>
<th>All(n=260)</th>
<th>Tatsudajinnai-4chome(n=83)</th>
<th>Tatsuda-1chome(n=177)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evacuation rate of the observations</td>
<td>52%</td>
<td>67%</td>
<td>60%</td>
</tr>
<tr>
<td>Evacuation rate estimated by the model</td>
<td>48%</td>
<td>65%</td>
<td>55%</td>
</tr>
<tr>
<td>Evacuation rate if all households check the river conditions.</td>
<td>50%</td>
<td>66%</td>
<td>55%</td>
</tr>
<tr>
<td>Evacuation rate if all households are urged to evacuate.</td>
<td>52%</td>
<td>67%</td>
<td>58%</td>
</tr>
<tr>
<td>Evacuation rate if all households check the river conditions and are urged to evacuate.</td>
<td>55%</td>
<td>68%</td>
<td>60%</td>
</tr>
</tbody>
</table>
The relation between relationship with community and the advice of evacuation.

<table>
<thead>
<tr>
<th></th>
<th>Advised to evacuate (n=100)</th>
<th>Not (n=164)</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Complaint or worries</strong></td>
<td>0.86</td>
<td>0.69</td>
<td>3.23**</td>
</tr>
<tr>
<td><strong>Care</strong></td>
<td>0.60</td>
<td>0.51</td>
<td>1.25</td>
</tr>
<tr>
<td><strong>Relationship with neighbors</strong></td>
<td>2.31</td>
<td>2.06</td>
<td>2.46**</td>
</tr>
<tr>
<td><strong>Acquaintance with neighbors</strong></td>
<td>2.20</td>
<td>1.74</td>
<td>4.06**</td>
</tr>
<tr>
<td><strong>Frequency of greeting</strong></td>
<td>3.64</td>
<td>3.65</td>
<td>-0.06</td>
</tr>
<tr>
<td><strong>Residents’ association</strong></td>
<td>0.75</td>
<td>0.67</td>
<td>1.46</td>
</tr>
<tr>
<td><strong>Prevention of crime and fire</strong></td>
<td>0.20</td>
<td>0.10</td>
<td>2.17*</td>
</tr>
<tr>
<td><strong>Community learning</strong></td>
<td>0.16</td>
<td>0.08</td>
<td>1.87*</td>
</tr>
<tr>
<td><strong>Activation of community</strong></td>
<td>0.07</td>
<td>0.09</td>
<td>-0.48</td>
</tr>
<tr>
<td><strong>Sports</strong></td>
<td>0.33</td>
<td>0.30</td>
<td>0.57</td>
</tr>
<tr>
<td><strong>Community development</strong></td>
<td>0.24</td>
<td>0.12</td>
<td>2.32*</td>
</tr>
</tbody>
</table>

** 1 % level of significance, * 5% level of significance

The households forming proper human relationship with their neighbors were advised to evacuate.
The state of evacuation in Tatsudajinnai-4chome and Tatsuda-1chome

Many households in Tatsudajinnai-4chome were rescued. Many households stayed in flood hazard area.
Usual activities of local community lead the emergency activities which are advice of evacuation and the lead of evacuation.

<table>
<thead>
<tr>
<th>Relationship with community</th>
<th>Jinnai-4 (n=92)</th>
<th>Tatsuta1 (n=208)</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood hazard map</td>
<td>0.13</td>
<td>0.08</td>
<td>1.21</td>
</tr>
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CONCLUSION

The factors affected the evacuation behavior were follows.

- Check on the river condition
- Advice of evacuation
- Preparation of emergency kit
- Participation in an evacuation drill
- Familiar with their neighbors
- Acquaintance with their neighbors
- Participation in activities of community development

From the evacuation behavior model, it was made clear that a check on the river conditions and advice of evacuation would promote an autonomous evacuation.
First, it is necessary for the households in the flood hazard area to recognize a flood risk through a risk communication.

Usual activities of local community lead the emergency activities.

It is rediscovered that daily practice of common activities in local area is the key to constructing the disaster mitigation type society.