A Modeling Suggestion for Predicting Damage of Complex Disasters About Vector-born Disease

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***Abstract*— This paper proposes to model the damage estimates for complex hazards caused by natural disasters. Although a single disaster system is currently in place for both natural and social disasters, the system for complex disasters is still in development. Complex disasters can be classified into different types, depending on the type of disaster. A study was conducted on the diseases caused by floods among complex disasters. Research methods were examined to suggest a complex disaster prediction model in conjunction with the existing natural disaster prediction model developed, and appropriate modeling methods were proposed estimating the infection rate of the disease. This paper will help build a complex disaster prediction system.**

Keywords-Natural disaster; Social disaster; Complex disaster; Prediction; vector-borne disease; Modeling.

I. INTRODUCTION

Property damage and casualties caused by natural disasters such as flood and earthquake have been an issue for a very long time. Several countries carried out studies to minimize the damage caused by disasters and have developed methods to calculate the expected damage and extent of occurrence.

However, this natural disaster can lead to complex disasters where various kinds of disasters occur at the same time. A single disaster means that only one disaster occurs, such as a flood or earthquake. A complex disaster is a disaster made out of single disasters that occur one after the other. In order to solve these complex disaster problems, we selected a flood and vector- borne disease disaster that can predict the extent of the damage by each single disaster calculation model.

In this paper, we calculated the possibility of infection of vector-borne diseases depending on the magnitude of the flood, which represents the spread of vector diseases. It also showed the extent of the damage expected as a result of the occurrence of the vector-borne disease.

II. ANALYSIS OF EXISTING DISASTER PREDICTION SYSTEM

We analyzed the flood damage prediction system and the vector diffusion prediction system to understand the information of the existing system related to the prevention and prediction of disaster damage. The Extreme Programming-Stormwater & Wastewater Management Model (XP-SWMM) system was selected as the flood damage prediction system and the Spatio-Temporal Epidemiological Modeler (STEM) system was selected as the vector diffusion prediction system. Each system is primarily used to identify the spread of floods and disease.

In order to run XP-SWMM and STEM systems, data must be entered directly by the user. In XP-SWMM system, the user must directly input the location information of the area and the rainfall data of the corresponding area [1]. In STEM system, disease information and data on local populations and transport systems should be entered in advance. When a disease occurs, the user must enter data about the location and information about the disease. [2].

III. COMPLEX DISASTER LINKAGE PLAN THROUGH VECTOR-BORNE DISEASE

XP-SWMM and STEM can be analyzed for floods and diseases, but they cannot be utilized in the event of a disaster in which both occur in combination. Therefore, a linkage plan about complex disasters is needed.

A. A modeling plan for complex disaster damage prediction

The rate of disease incidence caused by disasters is applied to the prediction model of social disaster, which indicates the extent of damage to the final complex disaster. To apply infection rate data of vector-borne disease to the STEM, a social disaster prediction model, the McDonald-Ross method should be applied, which is a method for analyzing the spread of the disease. The McDonald-Ross method is structured as shown in Figure 1.

h is the total population, h_s is the susceptible person, h_i is the infected person, h_r the recovered person, h_u the death rate, m_s the susceptible mosquito, m_i the infected mosquito, m_u the proportion of the dead mosquito, b the bite rate, h_b is the probability of infection from mosquitoes to humans, m_b is the probability of mosquito infection in humans, and b_y is the rate of recovery [3].

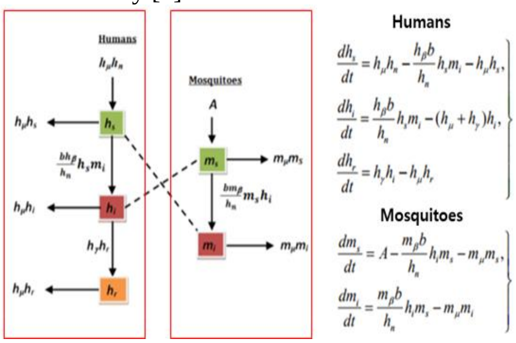

Figure 1. Structure of McDonald-Ross method

B. Calculation method of infectious disease rate

In order to calculate the infection rate to be applied to the McDonald-Ross method, the probability of mosquito occurrence in the floodplain when the flood occurred was calculated and then the disease infection rate was calculated.

First, if a flood occurred and a certain amount of time passed, we check for the existence of mosquitoes in the floodplain and calculate the number of bites per person according to the number of mosquitoes in the area. Next, we need to calculate the rate of infection of the disease in unit area using the number of bites per person.

The probability of mosquito occurrence is calculated by the number of mosquito species and the number of occurrences according to the flooded area. To determine if mosquitoes are present in the flooded area, a mosquito existence discrimination formula based on the Indices of Local Wetness (ILW) is applied. ILW represents a wetting index according to a water level threshold within a certain range. To represent the ILW value, the area to be measured is divided into the number of areas to be calculated.

The procedure for calculating ILW values is as follows. Divide the area of 10 square meters into 576 squares and set the flood threshold to 0.5 m. Calculate a value of 1 if the value of inundation in the flooded area is greater than the flood threshold value. Otherwise, calculate a value of zero. Then, add up the calculated values for each block to calculate the ILW value. Based on the calculated ILW value, the probability of occurrence of mosquitoes in the area to be measured is calculated [4].

The number of bites per unit area can be calculated from the mosquito incidence calculated and the number of mosquito populations when the mosquito occurs. The number of bites per person is calculated by dividing the number of mosquitoes per unit area by the number of people per unit area as shown in (1), then multiplying Human Blood Index (HBI) which is the probability of a person being bitten by a mosquito. The probability of HBI in this paper is 0.008% [5].

$$\text{Bites per person} = \frac{Mosquitoes\ per\ unit\ area}{People\ per\ unit\ area} \times HBI. \quad (1)$$

The number of bites per person can be used to calculate the infection rate of the vectors. The rate of infection can be calculated at (2) and the rate of infection can be calculated using the number of m of mosquito bites per person and the rate of transmission of mosquitoes r [6]. In case of mosquito transmission rate, the statistical value specified by each country can be applied. For example, in the United States, it is assumed that the disease occurred when the transmission rate of mosquitoes was more than 0.1 percent.

$$\text{P} = 1 - e^{-mr}. \quad (2)$$

IV. SIMULATION RESULT AND CONCLUSION

In the results of the natural disaster module XP-SWMM, the flood range and the inundation data are transferred to the input data from the disease connection module. Connection modules calculate the rate of infection, according to the amount of mosquitoes generated by the input data and provide it as input data for social disasters.

The output data of the link module are input to the social disaster module STEM to calculate the main diffusion path according to the type of the disease type, and finally, the spread range of the disease is calculated. Assuming that sufficient time has elapsed since the flood, we calculate ILW data and mosquitoes occurrence in Region A. If mosquito existence is detected, the infection rate of the disease can be calculated and the disease spread path can be confirmed as shown in Figure 2.

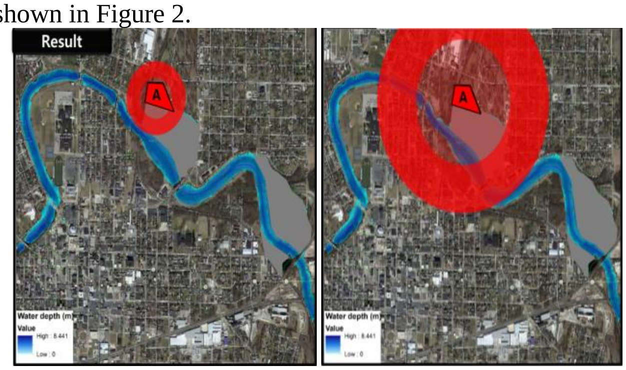

Figure 2. Examples of spread of Vector-borne disease by mosquitoes

In this paper, a study was conducted to integrate each analysis model of flood and disease. We proposed a connection method to integrate existing analytical models into a single model. We derived the expected diffusion result, according to the data value calculation. If we continue this study, it will be easier to identify and respond to the extent of damage about various complex disasters. If the research continues, we will eventually be able to integrate the various disaster analysis models into one.

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