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Grid-based Socioeconomic Database For Exposure Estimation in Flooding Risk Analysis

LingFeng Chang[1], Wen-Tsun Feng[2], MingDaw Su[3*],

Abstract

Floods are among the most frequent and costly natural disasters in terms of human hardship and economic loss. Most of the governments invest heavy resources to provide information for impact mitigation of this natural disaster. Flood Risk Maps are vital information in regional planning for flood disaster mitigation. This precious information about flooding disaster characteristics cannot be established with the absences of socioeconomic data and vulnerability models for damage assessment.

This paper will present a grid-based spatial database to capture the regional variations in socioeconomic data for better loss and risk assessments in risk analysis for flooding disaster mitigation. A 40m by 40m digital terrain model(DTM) available in Taiwan was commonly used in flood simulation. Although a new version DTM with 5m by 5m resolution has been established for better capture of terrain variations, a grid framework with 40m resolution will be used for this database construction considering the necessity for spatial variation representation in socioeconomic data.

Multiple sources were used for this database establishment including: Population Census, Agriculture Census, Commercial & Industrial Census, Building Administrations, Land use survey, Address Coordinate database, Manufactory and Business Registration, etc. Data from the above sources were spatially disaggregated from their original spatial units into the grid framework with 40m resolution.

Keywords*Flood risk, Socioeconomic, Exposure, Flood loss assessment, Census*

LingFeng Chang, Ph.D
Associate Research Fellow,
Agricultural Engineering Research Center,
TaoYuan, Taiwan
changlf@aerc.org.tw

Wen-Tsun Feng, Ph.D.
Research Fellow and Acting Director,
Agricultural Engineering Research Center, Taiwan
TaoYuan, Taiwan
wtfang@aerc.org.tw

MingDaw Su, Professor
Dept. of Bioenvironmental Systems Engineering,
National Taiwan University,
Taipei, Taiwan.
sumd@ntu.edu.tw

Introduction

A natural disaster is caused by major adverse events in natural (hydrological, geological, or metrological) processes. An adverse event will not rise to the disaster level if it occurs in an area without vulnerable population or economic activities. In a vulnerable area, it can have disastrous consequences causing loss of life, property, and lasting damage, requiring years to repair.

According to review on last 20-year records, the UNISDR shows that 90% of disasters are weather-related (floods, storms, droughts, etc.) and the rate of weather-related disasters is growing. Although the casualty from flood is reduced but it still affected more people than most of the other natural disasters (UNISDR,2015).

There is a growing importance and understanding that data collection, analysis, and management can help to identify disaster risks and make disaster management more efficient and effective. The need for systematic data for disaster mitigation and prevention is an increasing concern of both development and response agencies. According to Margareta Wahlström, UN Special Representative of the Secretary-General for Disaster: "Access to information is critical to successful disaster risk management. You cannot manage what you cannot measure." This paper proposed a grid-based socio-economic database for exposure estimations in the flood risk analysis and mitigation and even in emergency responses.

Risk Management Framework

In the process of handling the natural disaster impact to the society, a risk management framework as shown in figure 1 is usually followed. Risk must be identified and evaluated so that impact mitigation may be planned. A monitoring system may be established for early warning as the hazardous event occurs to reduce the impacts or damages. The recovery stage will follow the event and eventually into the risk analysis stage for reinvestigate the risk for better future events. The risk analysis and mitigation planning will be referred as "risk management" and the preparedness and recovery as the "emergency response". Risk management is much more important asit may reduce the panic and the severity of damages as the event hits.

Risk analysis is the key component in the risk management process and the analysis results will become vital basis for selection and implementation of disaster prevention and mitigation measures. The risk analysis of natural hazard composed of four components as hazard, exposure, vulnerability and resilience.

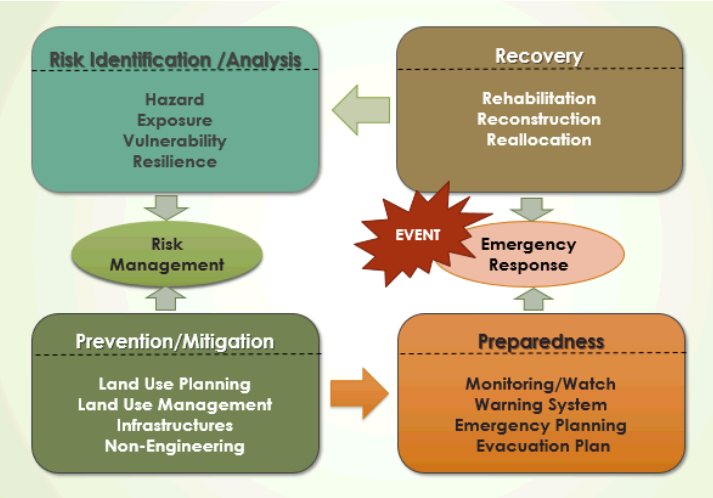

Fig. 1 The Risk Management Framework

The hazard may be defined as source of potential harm (ISO 31000, 2009). In flooding disaster, the hazard can be expressed as the inundation depths. The exposure is the extent to which an organization and/or stakeholder is subject to an event (ISO31000, 2009). In the case of flood disaster, the exposure is the population, housing, and other economic activities such as industry, commercial and agriculture that are inundated in the event. Vulnerability is the intrinsic properties of something resulting in susceptibility to a risk source that can lead to an event with a consequence. So it will be the relationship of the loss versus flooding depth for each categories of the above exposures. At last, resilience is the adaptive capacity of an organization in a complex and changing environment. In case of flood, resilience will be the capacity of the risk receptor to adapt to the disaster. The resilience can be viewed as the social vulnerability of the risk receptors because this will more related for socio-economical characteristics of the receptors (Martin, 2015).

The risk of natural disaster (take flood as an example) can be defined as the summation of the total damage under a single event (H*E*V) multiple by its occurrence probability for all the probable evens in a specific period (e.g. a year).

$$Risk=SUM(H*E*V*Pr.) \ldots\ldots\ldots\ldots (1)$$

Where:
Risk: Expected annual loss (in $)
H: Hazard potential (inundation depth in flood)
E: Exposure (number of household, or acreage)
V: Vulnerability (Loss/Depth/unit household)
Pr: occurrence probability of the event

The above equation may be applied to a designated spatial unit, e.g. county, township, or unit grid in a mesh system, and the results from each unit in the region collectively produce a map showing the spatial distribution of the flood risk.

Exposures

As shown in equation (1), the flood risks are estimated from hazard (flood depth), exposure (socio-economic activities) with the loss functions (vulnerability). The flood hazard maps, generated from hydraulic model with hydrological and morphological data, are the most available data in most of the countries. The exposure data are another vital data for risk analysis. As stated in the talk of RohiniSwaminathan, she said "There is nothing natural about disaster."(Swaminathan,2016) Nature causes extreme events (usually called "hazards" when they threaten people), but people create disasters. So the exposure can be identified as the most important data in the process of risk analysis, since there will be no harm from a huge hazard if there is not any socio-economic activities at the site.

The "exposure" is defined by ISO as "the extent to which an organization and/or stakeholder is subject to an event". This includes all kind of socio-economic activities, and most of them can usually be linked with different land use: such as residential, commercial, industry, agriculture, husbandry, also life lines and public work (infrastructures).

Residential

All the socio-economic activities are developed by human and demographic data will be the most basic ones. Residential data of different living styles need to be established as the first batch in the exposure database. The residential data were separated into two major categories: Single Family and Multiple Family. As shown in Figure 2(a), single household in a single building is Single Family. A building used by multiple households as shown in Figure 2(b) is multiple family. These two living styles have very different characteristics. The single family may suffer to less loss than multiple family under same flooding depth, because valuables or people may be moved to higher floor.

Figure 2. Residential Styles

Commercial

The commercial activities may be classified into three categories according to their loss characteristics from flooding: Retail, Wholesale, and Service. As shown in Figure 3, the wholesalers will pile their goods up to the ceiling while the retailers won't. And the service stores, like banks have no merchandizes other than office equipment.

Figure 3 Wholesaler, Retailer and Services

Industry

This category includes all the factories and manufacturing activities. The flooding loss features are the most complicated ones for modeling. The flooding losses may be dependent on the time of flooding and the kinds of the manufacturing activities. Even the same industry may be different from each other due to their manufacturing technology and equipment. There may be raw material, semi-finished products or products ready for shipping at the time of flooding.

Agriculture

The agriculture land use can be diversifies and have frequent variations from time to time. The flooding losses of perennial orchard and short term crops may be quite different. Some crops (e.g. peanuts) may be more sensitive to inundation than the others (e.g. sugarcane).

Husbandry/Aquaculture

Husbandry and aquaculture may be important activities in rural area. Different Livestock and poultry breeds, growth stages, and feeing methods may also have different loss features from flooding.Facilities like barn and stable may also be considered in damage assessments.

Infrastructures

Publicworkincluding transportations, life lines, schools and parks may be suffered from flooding loss and need to be considers as exposures in flooding risk analysis.

Data availability

From above discussions, it is complicated for an exposure database establishment. Many assumptions or approximations may have to be made depending on the data availability. This paper reports the Taiwanese experiences in constructing the exposure database for natural disaster risk management.

Census

The Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Taiwan conducts three major censuses periodically, i.e. Population and housing Census (every 10 years);Agriculture, Forestry, Fishery and Animal Husbandry Census (every 5 years); and Industry and Service Census(every 5 years). The data are published aggregately based on spatial unit with different levels of aggregation for privacy concern.

Registries

The government kept a very efficient registry system for different kind of socioeconomic activities for management and taxes collection purposed. These include household and residence (for registered population), real estate properties, cars, business, and manufactories. All these registries linked with street addresses or cadastral IDs'. A geocoding system has been implemented for every single street addresses in Taiwan, so all the registered socioeconomic activities are GIS ready for further spatial analysis. Figure 4 shows a map of Taichung City at the central part of the Island with all the street addresses. The points shown in Fig.4 may have more than one point stacked together at a x-y coordinate since there maybe more than one street address in an apartment or high-rise building.

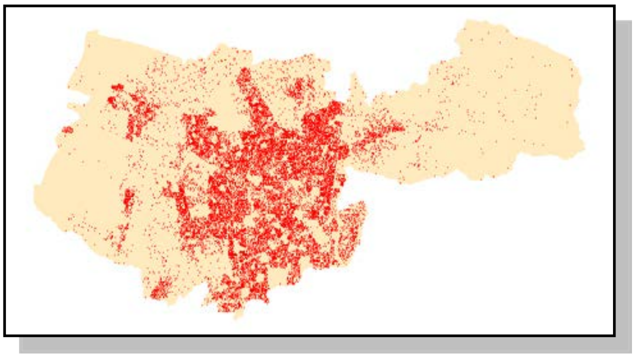

Figure 4. Street Address Geocoding in Taichung City, Taiwan

Land use survey

A land use survey was also done for the whole country and was corrected/adjusted as necessary from time to time. A sample map is shown in Figure 5. The Land Uses are categorized into three hierarchical levels. For example:

01: Agriculture;
0101: Crop;
010101: Paddy; 010103: Orchard;
0102: Aquaculture;
0103: Livestock;.

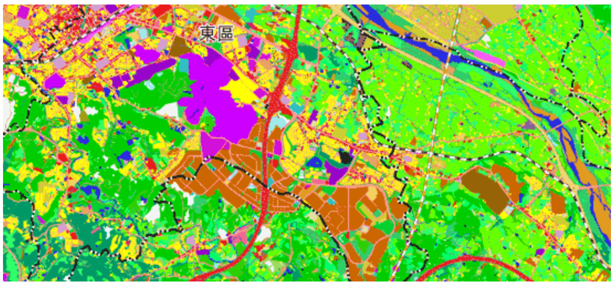

Figure 5. Sample Map of National Land Use Survey, Taiwan

Data Statistical System

The socioeconomic data are related to persons and have privacy concerns. Most of the socioeconomic data usually disseminate after aggregation to some specific spatial administration units (e.g. city, county) for privacy protection. But this spatial aggregation may create problems distorting the spatial distribution patterns known as Modifiable Areal Unit Problem (MAUP). The spatial distribution pattern distortions may create problems of inequity or under/over designs in regional planning for public work, public health and safety. A Geographical Statistical Classification System, as shown in Fig. 6, was established for mitigation of MAUP in spatial aggregation for socioeconomic data disseminations.

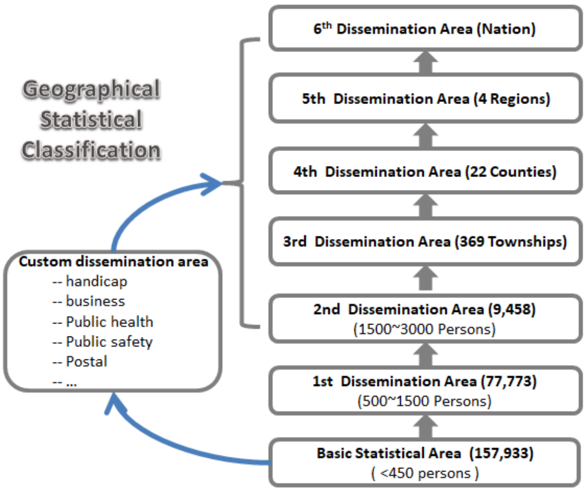

Figure 6. Geographical Statistical Classification System

Grid-based database

All these exposure data will be overlaid with the hazard maps in flood risk analysis as shown in Figure 7. Since most of the flood simulation models are grid-based, the grid-base spatial data model is used for this exposure database implementation. A grid system with resolution of 40 meters is used to host all the related socioeconomic data in the exposure database system.

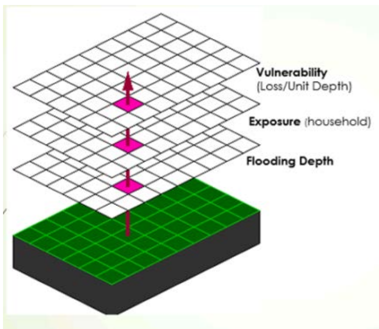

Figure 7. Grid-based Flood Risk Estimations

Most of the socioeconomic data available in Taiwan are spatially aggregated to the selected level in Geographical Statistical System that is usually much larger than the 40m by 40m cell-system used in this paper, The multi-layer and multi-class Dasymetric model, as shown in eq.(1) (Su, et.al., 2010) andFigure 8.was used to redistribute the published aggregated socioeconomic data into the grid cell in our database, as shown in Figure 9.

$$\ldots\ldots\ldots\ldots D_{ij} = \frac{P_i \times (A_{ij}W_j)}{\sum_{j=1}^{m} A_{ij}W_j}$$

Where i and j are the subscripts for areal unit and subclasses respectively, m is the number of the subclasse, Dij are the population density, Pi is the population in areal unit i, Wj is the weighting factor for subclass j and Aij is the area of subclass j in unit i.

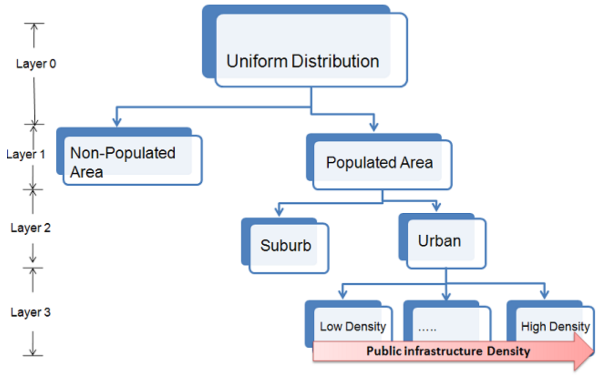

Figure 8. Multi-layered dasymetric framework for population desegregation.(Lin and Su, 2009)

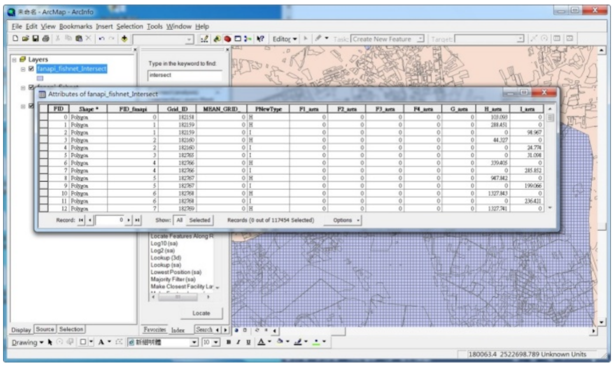

Figure 9. Grid-based Socioeconomic Database

Summary

Exposure data are one of the most important data for flood risk management. Exposure is the extent to which an organization and/or stakeholder is subject to an event. This includes all kind of socio-economic activities. This paper presents a grid-based GIS database with a resolution of 40m by 40m integrating necessary socioeconomic data that are vital for flood risk analysis.

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