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Benoît Otjacques
Patrik Hitzelberger
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From Science to Society

New Trends in Environmental Informatics

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New Trends in Environmental Informatics

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Editors
Benoît Otjacques
Environmental Research and Innovation
Luxembourg Institute of Science and Technology
Esch/Alzette
Luxembourg

Patrik Hitzelberger
Environmental Research and Innovation
Luxembourg Institute of Science and Technology
Esch/Alzette
Luxembourg

Stefan Naumann
Institut für Softwaresysteme in Wirtschaft, Umwelt und Verwaltung
Hochschule Trier - Umwelt-Campus Birkenfeld
Birkenfeld
Germany

Volker Wohlgemuth
Environmental Informatics
University of Applied Sciences
Berlin
Germany

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Preface

This book presents the main research results of the 31st edition of the long-standing and established international and interdisciplinary conference series on environmental information and communication technologies (EnviroInfo 2017).

The conference was held on 13–15 September 2017 at the Neumünster Abbey in Luxembourg, organized by the Luxembourg Institute of Science and Technology (LIST), under the patronage of the Technical Committee on Environmental Informatics of the German Informatics Society.

The tag line of this year's conference was "From Science to Society: The Bridge provided by Environmental Informatics". It underlines that Environmental Informatics has its roots in applied research and that it is not an ivory tower discipline. Environmental research at the local organizer LIST, a research and technology organization, is a clear example of this focus on doing research that has a high impact on the society. At the same time, the location Luxembourg truly exemplifies some of the complex research topics for Environmental Informatics today. For example, due to its size and geographical situation, the country is specifically challenged by environmental issues that cross borders such as the impact of environmental disasters, emissions caused by the cross-border mobility due to the international workforce in the country, or the interoperability of environmental decision systems in general.

The articles in this book give some innovative answers to these and other questions that are relevant for Environmental Informatics research, such as semantic interoperability modelling used for disaster management, sustainable mobility solutions, approaches for energy-aware software-engineering, and land-use planning.

The editors would like to thank all the contributors to the conference and these conference proceedings. Special thanks also go to the members of the programme and organizing committees. In particular, we would like to thank all those involved at the local organizer, LIST. Last, but not least, a warm thank you to our sponsors that supported the conference.

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June 2017

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Part I
Applications of Geographical Information Systems and Disaster Management

Forecasting the Spatial Distribution of Buildings that Will Remain in the Future

Toshihiro Osaragi and Maki Kishimoto

Abstract Changes in land use in established city areas generally arise when older style buildings are demolished and replaced by contemporary buildings. The direction and the speed of land use change are dependent on the possibility and probability that buildings will be demolished or will remain in the future. Hence, various studies about the life span of buildings have been carried out, and proposed statistical models that could estimate the value of probability that buildings would be demolished or would remain in a specific time interval, based on the age of buildings. However, in general it is not easy to acquire the necessary information about the age of buildings. In order to extend the application of the proposed model to these cases, we propose a method for estimating the number of buildings that will remain in the future when data about the age of buildings cannot be obtained.

Keywords Interval probability function of remainder · Age of building · Life span · Disaster prevention planning · Land use model · Tokyo

1 Introduction

A basic unit of land use change is a building lot owned by a landowner or business proprietor. Land use changes generally arise when older style buildings are demolished and replaced by contemporary buildings. Such phenomena are often observed in established high-density areas. Hence the direction and the speed of land use change are dependent on the possibility and probability that buildings will be demolished or will remain (Osaragi and Nishimatsu 2013). This is quite different

T. Osaragi (✉) · M. Kishimoto
Department of Architecture and Building Engineering, School of Environment and Society, Tokyo Institute of Technology, Tokyo, Japan
e-mail: osaragi.t.aa@m.titech.ac.jp

M. Kishimoto
e-mail: kishimoto.m.ac@m.titech.ac.jp

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from land use change in suburban areas, where a major concern is “change of land-use classification, for example, change from field/forest to residential area”.

In respect of the field of disaster prevention planning, conversion of building structures or materials to an incombustible state is one of the most important issues (Osaragi 2013). Although research regarding the provision of fire-fighting services is of relevance to these disasters (Adrian et al. 1983, Richard et al. 1990; Wallace 1993), we should discuss fire prevention rather than control in order to comprehensively address the problem of multiple uncontrolled fires following a large earthquake (Wallace 1991). The process of conversion of cities to an incombustible state has not thus far been strongly promoted, because of the large amount of resources necessary for rebuilding. Conversion of buildings to an incombustible state is generally achieved when older style buildings are demolished and replaced with contemporary buildings. The speed at which building structures or materials may be changed is thus dependent also on the possibility and probability that buildings will be demolished.

Various studies about the life span of buildings have been carried out (Kaplan and Meier 1958), since the life span of buildings is one of the basic concerns in various fields including urban economics and management, land use, and disaster prevention planning. Reliability theory has been applied in many studies, and they, in turn, proposed methods for assessing the probability that buildings will be demolished or remain in the future (Komatsu 1992; Osaragi et al. 2002). However, most of these studies have considered the case that the life span of buildings is a simple, single-variable function dependent only on the age of the building. Given this background, Osaragi (2004) proposed a statistical model that can evaluate characteristics of buildings and location, which in turn affect the life span of buildings. In particular, he examined characteristics of buildings (age of building, construction materials, building type, etc.) and characteristics of locations (land use zoning, building area to plot ratio, accessibility to railway stations, etc.), and evaluated how these factors affected the life span of buildings. Furthermore, he proposed a mathematical model, referred to as the “interval probability function of remainder”, that can stably estimate the probability that buildings will be demolished or will remain within a time interval (Osaragi 2005). That is, if information about the age of each building is acquired, the demolished/remaining probability can be estimated and applied in a variety of micro-simulation models.

However, in the general use of the model, the age of each building must be known in order to estimate the value of the probability. This requirement is an impediment to the application of the proposed model to actual urban data. In this article, in order to modify this disadvantage and extend applications of the model, an alternative method of the model is proposed using the concept of the “average decrepitude of buildings”, which can be estimated from time series digital maps of cities. The average decrepitude of buildings can be considered as a quasi-average-age of buildings in an area, which can be calculated from the number of buildings that remain in a time interval. The utility and the efficiency of the alternative method are examined by consideration of numerical examples based on actual data taken from densely built-up areas of the Tokyo metropolitan area.

2 Modeling of the Probability Function of Remainder

The age of buildings is denoted by t ($t \geq 0$), and the category of buildings or locations (construction materials, building type, land use zoning, building area to plot ratio, accessibility to railway station, etc.) is denoted by j (j = 1, 2, …, m). The probability that a building of category j exists at age t is expressed by $P_j(t)$. This function is labeled the "probability function of remainder". It is assumed that derivative of $P_j(t)$ with respect to age t can be obtained. Moreover, "the density function of life span" is expressed by $f_j(t)$, and "the demolition function" which expresses the ratio of buildings being demolished is denoted by $h_j(t)$. The following relations exist between the above variables,

$$f_j(t) = \frac{-dP_j(t)}{dt}, \tag{1}$$

$$h_j(t) = \frac{f_j(t)}{P_j(t)}. \tag{2}$$

On the substitution of the expression for $f_j(t)$ derived from Eq. (2) for $f_j(t)$ in Eq. (1), we obtain

$$P_j(t) = \exp\left[-\int_0^t h_j(x)dx\right]. \tag{3}$$

Although it is important to investigate the characteristics of demolition function $h_j(t)$, for the present purposes it is assumed that $h_j(t)$ can be expressed by the following equation using Taylor's expansion,

$$h_j(t) = \sum_{k=0}^{K-1} \frac{h_j^{(k)}(a)}{k!}(t-a)^k, \tag{4}$$

where $h_j^{(k)}(a)$ is the derivative of $h_j(t)$ with respect to time at the age $t = a$, and K is a constant sufficiently large to ensure a satisfactory approximation. Expressing the demolition function $h_j(t)$ as a polynomial of age t in this way, Eq. (3) can be rewritten as follows,

$$P_j(t) = \exp\left[-\sum_{k=1}^{K} a_{jk}t^k\right], \tag{5}$$

where a_{jk} is a constant coefficient corresponding to the coefficients k of the powers of t in Eq. (4). Specifically, the demolition function, $h_j(t)$, can be expressed using the coefficients a_{jk} as follows:

$$h_j(t) = \sum_{k=1}^{K} k a_{jk} t^{k-1}. \tag{6}$$

The probability that a building, which has survived to age t, continues to survive to age $t + \Delta t$ ($\Delta t > 0$) is expressed by $P_j(t + \Delta t|t)$. This function is hereafter called "the interval probability function of remainder". Since $P_j(t + \Delta t|t)$ is a conditional probability of $P_j(t)$, it has the following relationship with the probability function of remainder, $P_j(t)$,

$$\begin{aligned} P_j(t + \Delta t|t) &= \frac{P_j(t + \Delta t)}{P_j(t)} \\ &= \exp\left[-\sum_{k=1}^{K} a_{jk}\{(t + \Delta t)^k - t^k\}\right]. \end{aligned} \tag{7}$$

Thus, the values of $P_j(t)$ and $P_j(t + \Delta t|t)$ can be obtained and applied to a variety of simulation models, if the coefficients a_{jk} are estimated.

The values of a_{jk} can be estimated as maximum likelihood estimators by applying the undetermined multipliers method of Lagrange. Due to the limitation of pages, we omit the detailed description for the estimation method, which shows that the Lagrange function is a convex function of the coefficients a_{jk}. That means, a local minimum solution, which is a typical problem in optimization by the Hill-climbing method, does not exist for the present problem.

3 Methods for Estimating the Number of Buildings that Will Remain

We describe four methods, shown in Fig. 1, for predicting the number of buildings that will remain in through a time interval. First, if information about ages of buildings is acquired, the following two methods are available, which use the probability function of remainder directly.

Method (1): Substituting the age of each building for the variable t in $P_j(t + \Delta t|t)$, the value of the interval probability of remainder is then predicted for each building. This method thus requires detailed information about building ages to be effective in predicting the demolished/remaining status of each building, one by one.

Method (2): Substituting the mean value of buildings age $\bar{t}$ in a study area for the variable t in $P_j(t + \Delta t|t)$, the average value of the interval probability function of remainder is then derived. This method can be used in situations where not all of the ages of the buildings are known, but the mean value of the ages of buildings in the study area is known. It differs from method (1) in that the value of the interval probability function of remainder is therefore assumed to be the same constant value for all buildings of the same type in the area. Accuracy is thus expected to

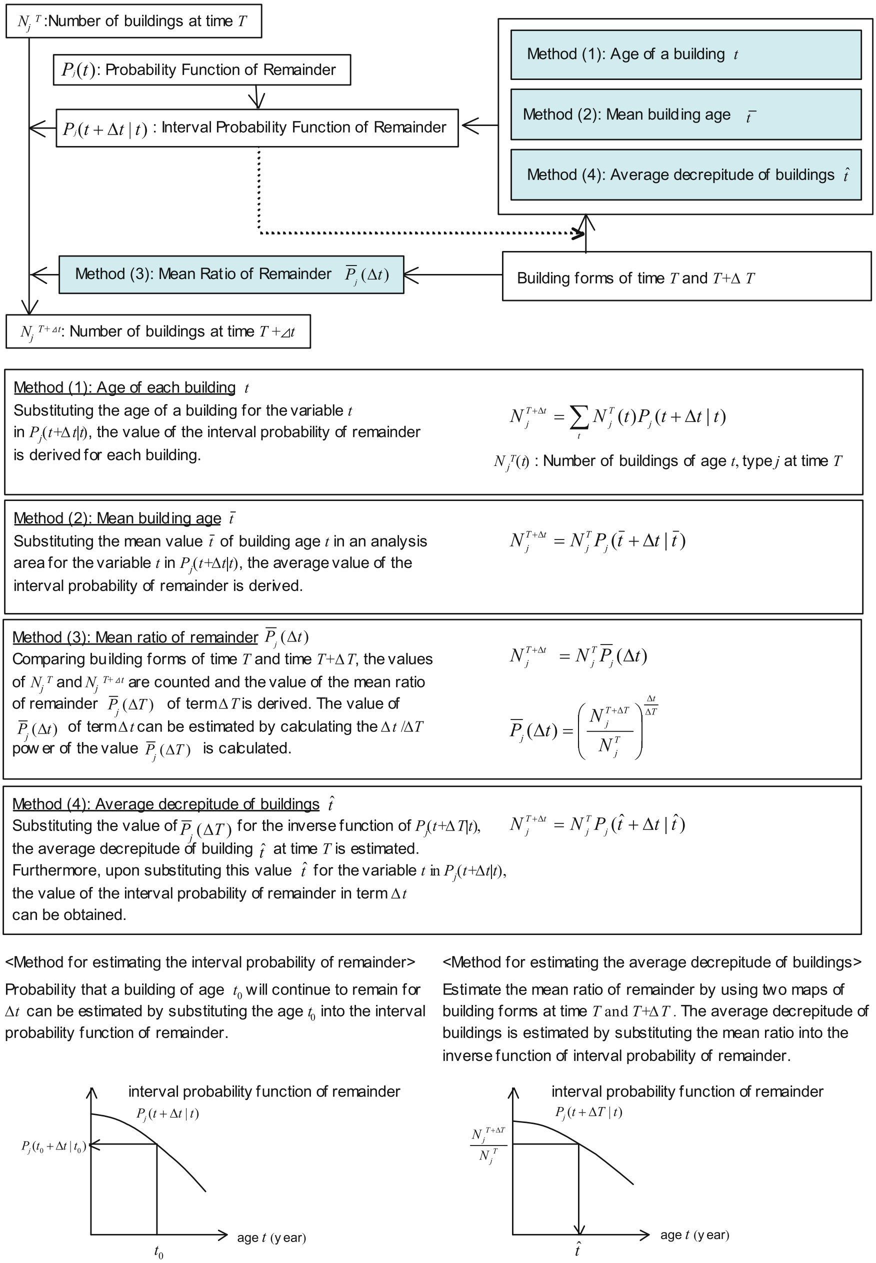


Fig. 1 Methods for estimating the number of buildings that will remain

diminish when the actual age of a building differs significantly from the mean value of building age in the study area.

If no information about ages of buildings is available, the following two methods can be applied by using digital maps of building forms at the two points in time.

Method (3): By comparing building forms at time T and time $T + \Delta T$ on geographic information systems (GIS), we can extract data for the number of buildings in existence at time T, N_j^T, and at time $T + \Delta T$, $N_j^{T+\Delta T}$. From these two values, the value of the mean ratio of remainder $\bar{P}_j(\Delta T)$ of term ΔT can be derived. Furthermore, the value of the mean ratio of remainder $\bar{P}_j(\Delta t)$ of term Δt can also be estimated by calculating the $\Delta t/\Delta T$ power of the value $\bar{P}_j(\Delta T)$. However, since the value of the mean ratio of remainder is assumed constant across any given interval, this method is not therefore considered to be suitable for long-term predictions.

Method (4): Substituting the value of $\bar{P}_j(\Delta T)$ for the inverse function of $P_j(t + \Delta t|t)$, the average decrepitude of building $\hat{t}$ at time T can be estimated. The average decrepitude of buildings $\hat{t}$ is considered as a quasi-mean-age of buildings in the area. Note that the value $\hat{t}$ may be larger or smaller than the actual mean age of the building. Substituting this value $\hat{t}$ for the variable t of $P_j(t + \Delta t|t)$, the value of the interval probability function of remainder in term Δt will be obtained.

4 Validation of Methods

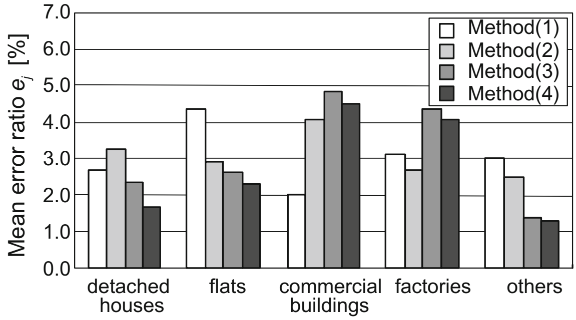
Using the data for Mitaka city in Tokyo, the number of buildings that remain in given specific time intervals is estimated using the four methods, and their accuracy is examined. The interval probability function of remainder according to building type is constructed using data from 1994 and 1996. Then, the number of buildings existing in 1994 that are expected to remain 4 years later (in 1998), is estimated by the four methods. Estimated values according to the building type for each town (the number of towns is 11) are compared with the actual observed values. Here, the accuracy of the estimates is evaluated by the following absolute error rates,

$$e_i = \frac{1}{M}\sum_{j=1}^{M}\left|\frac{N_{ij} - \hat{N}_{ij}}{N_{ij}}\right| \times 100\ [\%], \tag{8}$$

where a suffix j (j = 1, 2, …, M) denotes a building type and a suffix i denotes a town ID number. The value N_{ij} is the actual observed value, while $\hat{N}_{ij}$ is the corresponding estimated value.

The absolute error rate of the number of remaining buildings estimated by each method is shown in Fig. 2. For “commercial buildings”, the estimation accuracy of method (1) is superior to that of the other methods. Before performing this analysis, we expected that method (1), using the age of each building, would offer the highest stability and accuracy for all building types. However, the results show that these

Fig. 2 Accuracy of estimates obtained by the four methods



expectations are not fulfilled. With this method, the same interval probability function of remainder is assumed across the whole area for buildings of the same type. In a small area like a town, however, the influence of the regional gap of demolition characteristics should not be ignored. Therefore, the estimation accuracy is not as high as was expected, even if detailed information of buildings' ages is used in the estimation. That is, we can conclude that the study area should be divided into sub areas in order to estimate the interval probability function of remainder more accurately if the demolition characteristics of building type are strongly dependent on local characteristics.

According to the results of "detached houses", "flats", and "others", the estimation accuracy of method (4) is higher than methods (1) and (2). As described in the above paragraph, the average decrepitude of buildings in each area used in method (4) reflects the demolition characteristics in the object area. Therefore, even if an area includes many comparatively new buildings, in practice, if the rate of demolition is high in the area, the degree of demolition might also be relatively high. Consequently, even if the same interval probability function of remainder is used, the estimate of method (4) may be of higher accuracy than methods (1) or (2), which do not incorporate the local characteristics of locations.

Next, the correspondence between the estimated values of the number of demolition buildings and the actual observed values are examined. The results are shown in Fig. 3. Each point in Fig. 3 corresponds to one town. Although some

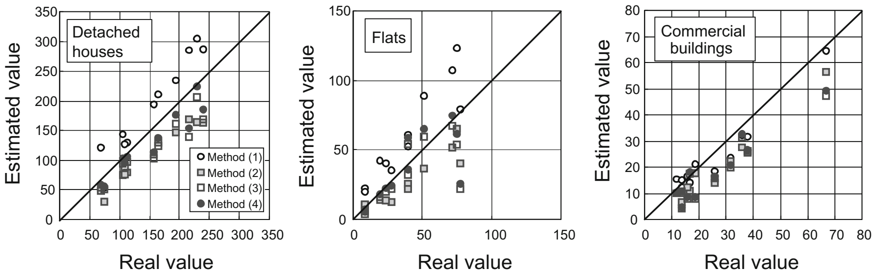


Fig. 3 Accuracy of estimates of the number of buildings demolished obtained by the four methods (Each point corresponds to a single towns in Mitaka city)

towns show large estimation errors, overall the estimated values and the actual observed values correspond well.

Next, we consider here the flexibility of application of the method of the interval probability function of remainder. The number of remaining buildings in Tokyo's Setagaya ward is estimated by method (4) using the interval probability function of remainder of Mitaka city. A corresponding estimate is also derived from method (3), and then the estimation accuracies of these two methods are compared. That is, the estimation accuracy is examined for the case when the ages of the buildings are unknown. By overlaying the building forms of 1991 and 1996 using the Tokyo GIS data, information of whether buildings are demolished or remain is obtained.

The number of buildings of remaining for 10 years (i.e. to 2001) is estimated, considering 1991 as the initial year. Specifically, since the mean ratio of remainder for 10 years is required to apply method (3), the squared value of the mean ratio of remainder for 5 years is estimated. In the process of applying method (4), first, the average decrepitude of buildings $\hat{t}$ in 1991 for each town is estimated by using the interval probability function of remainder. By substituting this value $\hat{t}$ for the interval probability function of remainder $P_j(t{+}10|t)$, the probability that each building will continue to remain after 10 years is estimated. The rate of the mean absolute error is calculated by Eq. (3), and the results are shown in Fig. 4. It is shown that the rate of the mean error of method (4) is smaller than that of method (3). For detached houses, flats, and commercial buildings, the rate of the mean error is around 5 percent or less. Since the study area is different from the area from which the parameters are estimated, the results are inferior to those shown in Fig. 2. However, the results shown in Fig. 4 are sufficiently accurate for practical purposes. For longer estimations, estimation accuracy will diminish, since method (3) assumes constancy of the mean ratio of remainder. On the other hand, since method (4) uses the average decrepitude of buildings, it is possible to describe the probability of remaining precisely, using an expression that varies with time. Therefore, method (4) shows a higher accuracy than method (3).

Next, in order to examine the estimation accuracy of method (4), the actual and estimated values of the number of demolition buildings for each town are compared (the number of towns in Setagaya ward is 62). The results are shown in Fig. 5. For

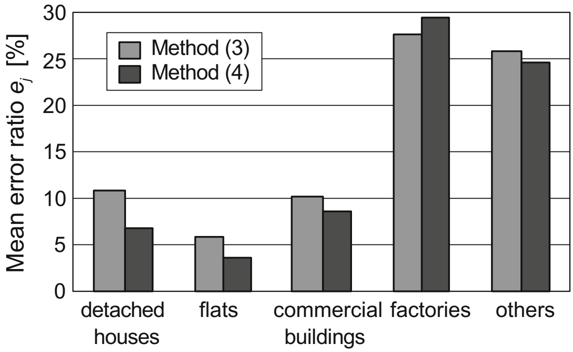


Fig. 4 Accuracy of estimates of the number of buildings that will remain obtained by methods (3) and (4) (Setagaya Ward)

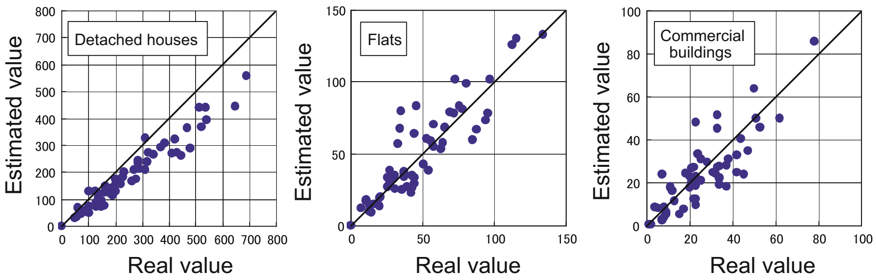


Fig. 5 Accuracy of estimates of the number of buildings demolished obtained by method (4) (Each point corresponds to a town in Setagaya Ward)

the case of detached houses, since the actual values of the demolition rate in 1991–1996 are lower than those of 1997–2001, the estimated values are a little small in many towns. We can say, however, that overall there is good agreement between the estimated and actual values.

5 Summary and Conclusions

In this research, a method for extending the application of the interval probability function of remainder is proposed, in order to facilitate the incorporation of this function into micro-simulation models, such as land use models and disaster prevention planning for established city areas. In particular, it is shown that the average decrepitude of buildings can be calculated if the data of building forms at two points in time can be obtained, even if information about the age of buildings is not available. Moreover it is shown that the number of remaining buildings can be estimated to a high degree of accuracy (the rate of error is about 1–4%) in a comparatively small spatial unit like a town. Furthermore, by using the interval probability function of remainder and the average decrepitude of buildings, estimations of the number of demolished/remaining buildings in the future can be achieved to a high accuracy.

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Research on the Potential Environmental Zonation of Red Flesh Dragon Fruit in Vinh Phuc Province

Minh Nhat Thi Doan, Cong Thien Dao, Nam Ta Nguyen, Hang Thanh Thi Nguyen, Hang Le Thi Tran, Son Thanh Le and Manh Van Vu

Abstract Red flesh dragon fruit (Hylocereus polyrhizus) or pitaya is well-known as an excellent source of antioxidants and high content of nutrients. The Red flesh dragon fruit is a hybrid of the white flesh dragon fruit Hylocereus undatus and a native Hylocereus costaricensis from Middle and North America. It brings high economic efficiency and currently being developed in the province of Vinh Phuc. The main objective of the study is to create a model, which help to determine the suitability in developing dragon fruit cultivation in Vinh Phuc province in order to support local agricultural and land use planning. The model is built based on the application of Geographic Information System (GIS), Kriging interpolation method, Multi-Criteria Decision Analysis (MCDA) method, Fuzzy Set Theory and Analytic Hierarchy Process (AHP) to evaluate and map the area suitable zonation for farming.

Keywords Hylocereus polyrhizus · GIS · MCDA · AHP

M.N.T. Doan (✉) · C.T. Dao · N.T. Nguyen · H.T.T. Nguyen · H.L.T. Tran · S.T. Le · M.V. Vu
VNU University of Science, 334 Nguyen Trai, Thanh Xuan, Hanoi, Vietnam
e-mail: dtnminh.2410@gmail.com

C.T. Dao
e-mail: dtcong2104@gmail.com

N.T. Nguyen
e-mail: namnguyenkhtn@gmail.com

H.T.T. Nguyen
e-mail: thanhhang0283@gmail.com

H.L.T. Tran
e-mail: hangtrancoste@gmail.com

M.V. Vu
e-mail: vuvanmanh@hus.edu.vn

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1 Introduction

Vinh Phuc is located in Red River Delta. It is one of the seven provinces of the Northern key economic zone. Vinh Phuc province is bordered to the North by Thai Nguyen and Tuyen Quang, to the west by Phu Tho, to the south by Hanoi, to the east by 2 districts: Soc Son and Dong Anh of Hanoi city. The province has 9 administrative units: Vinh Yen City, Phuc Yen town and the districts: Binh Xuyen, Lap Thach, Song Lo, Tam Duong, Tam Đao, Vinh Tuong, Yen Lac (Fig. 1).

Vinh Phuc is one of the provinces that have the highest level of GDP growth rate of the entire country. In order to ensure the sustainable development, the province has identified the direction of developing the service industry to re-invest in agriculture, mobilizing investment capital for production development and construction of agricultural infrastructure (Vinh Phuc Provincial People's Committee 2011). In planning the agricultural development of the province, the red flesh dragon fruit was added to the list of crops with high economic value. However, until now, this crop has not been studied for the zonation developed in accordance with the environmental conditions of the province.

Red flesh dragon fruit is hybrid between white flesh dragon fruit Hylocereus undatus and Hylocereus costaricensis, a native breed originated in Central and North America. Red flesh dragon fruit is one of the fruit plants which bring high economic efficiency in both developed North and South Vietnam, most concentrated in Binh Thuan. Dragon fruit can grow and develop in different soil types such

Fig. 1 Vinh Phuc administrative map

as sandy soil, gray soil, alkaline soil to alluvial soil, red soil bazan, soil. The temperature suitable for the red dragon fruit growth and development ranges from 15 to 35 °C (Van Ke 1998), in which the most appropriate temperature ranges from 21 to 26 °C (Liaotrakoon 2013). The weather conditions of light frost, even for a short time will also affect red dragon fruit growth. The demand of precipitation for crops ranges from 800 to 2000 mm/year (Van Ke 1998). A good drainage system can reduce the influence of precipitation on the flowering, fruiting of trees. The red dragon fruit is photophilic plants, suitable for cultivation in areas where there are lots of light. In addition, it can be planted in the low slope area in (Truong Thi Dep 2000).

2 Methodology

The research applied a series of criteria in order to find potential development of the red dragon fruit tree planting. The criteria include temperature, precipitation, distance to the irrigation source, distance to roads, slope.

2.1 Impact Factors for the Suitability of Growing Dragon Fruit

Temperature

Temperature is a factor that greatly affects plant growth. Plants can grow in a wide temperature range, but different types of plants have different minimum and maximum temperature points. The minimum temperature and the maximum temperature for the growth of the plant are the temperature points at which the plant stops growing. Limits of temperatures growth change with the adaptation of plants in different ecological zones. To evaluate the regions having potential for the growth and development of dragon fruit, research based on the field examinations, using the Linear Regression with 2 variables: elevation and temperature to find the relationship between temperature and elevation, thereby construct the map of temperature for the target area. With 10 data points observed in fieldtrip, the research obtained.

Equation of variability of temperature depending upon elevation in the winter:

$$y = -0.006x + 18{,}769$$

Equation of variability of temperature depending upon elevation in the summer:

$$y = -0.0054x + 32.517$$

where: y is temperature (°C); x is elevation (m).

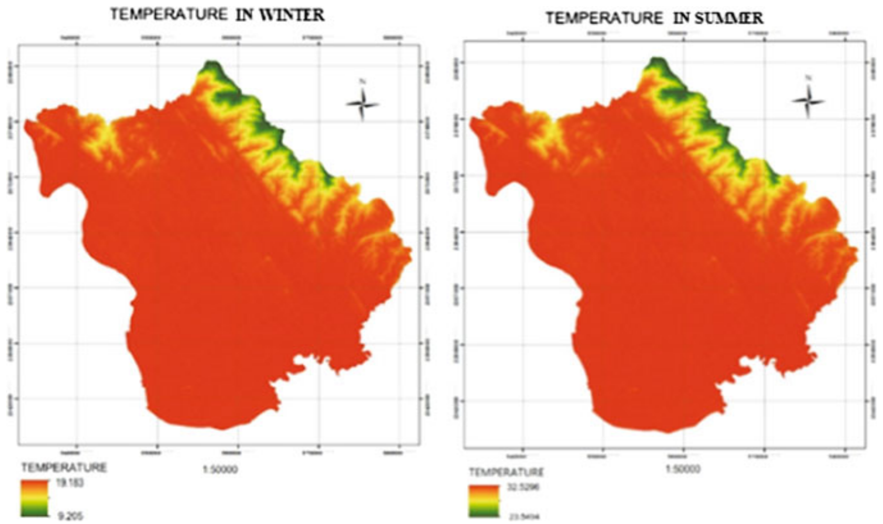

Fig. 2 Map of temperature in summer and winter

By the result of study about relationship between temperature and elevation, using DEM for Vinh phuc province, the research created temperature map for this area in the winter and summer (Fig. 2).

Precipitation

The research used the data of rain capacity monitored from monitor stations on the locality of Vinh Phuc province, as well as international monitoring data shared by Globalweather (NCEP). The precipitation map of the study area was interpolated by

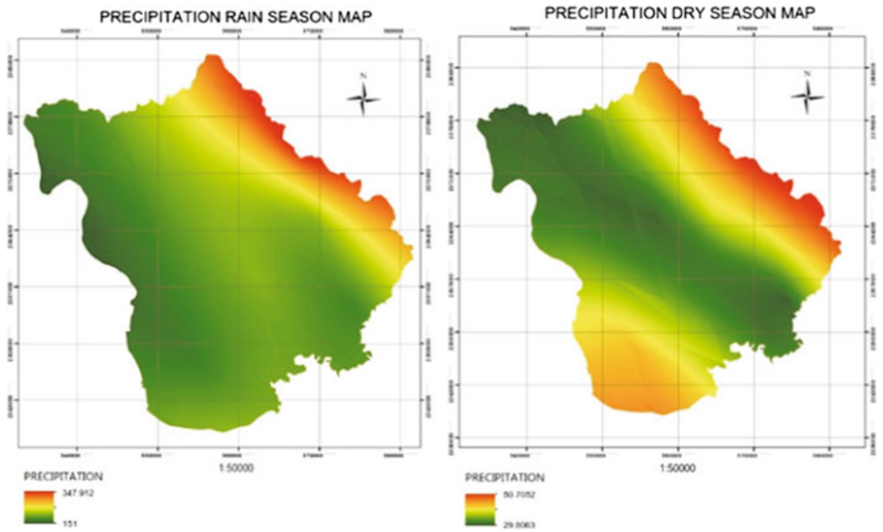

Fig. 3 Map of precipitation in rain and dry season

Ordinary Kriging from the average monitoring data of two seasons: rainy season (from April to September) and dry season (from October to March) (Fig. 3).

Slope

Slope is also an important factor in assessing suitability for selection of crop. Sloping land is often subjected to erosion, which leads to land degradation, soil degradation, poor nutrient, structural failure, pH reduction, increase of levels of soil toxicants and it can make the soil die biologically. Most of sloping lands are degraded and sour, many areas were deserted due to loss of agricultural and forestry production ability. For dragon fruit, the lower the slope, the more suitable for cultivation. In this study, the slope map was created based on the DEM of Vinh Phuc (Fig. 4).

Distance to Irritation Source, Distance to the Road

The distance to the irritation source is also taken into account in determining the suitability of cultivation. Based on the map of Red river in Vinh Phuc province, the study used the IDRISI tool to calculate the raster map showing the distance to

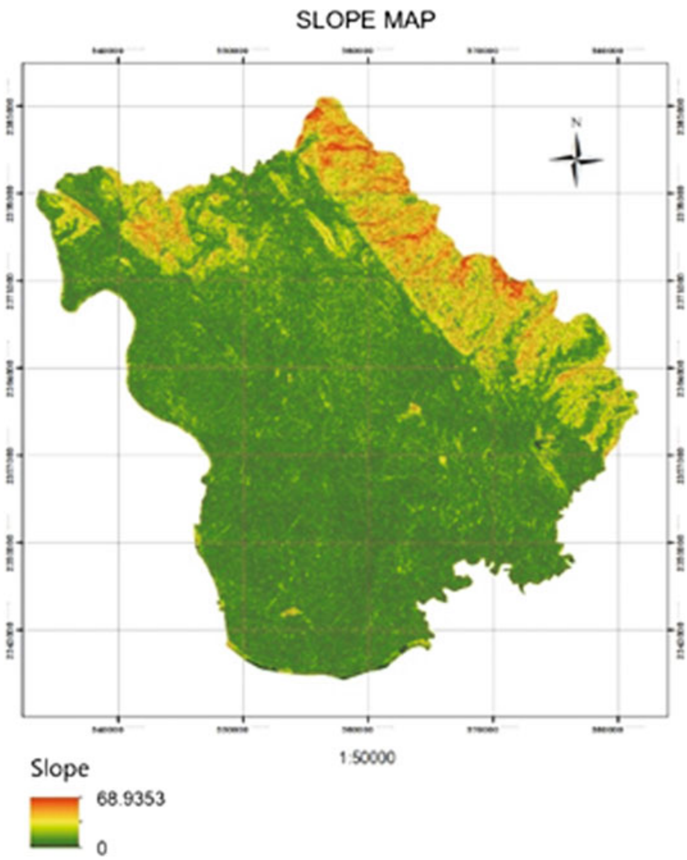

Fig. 4 Map of slope

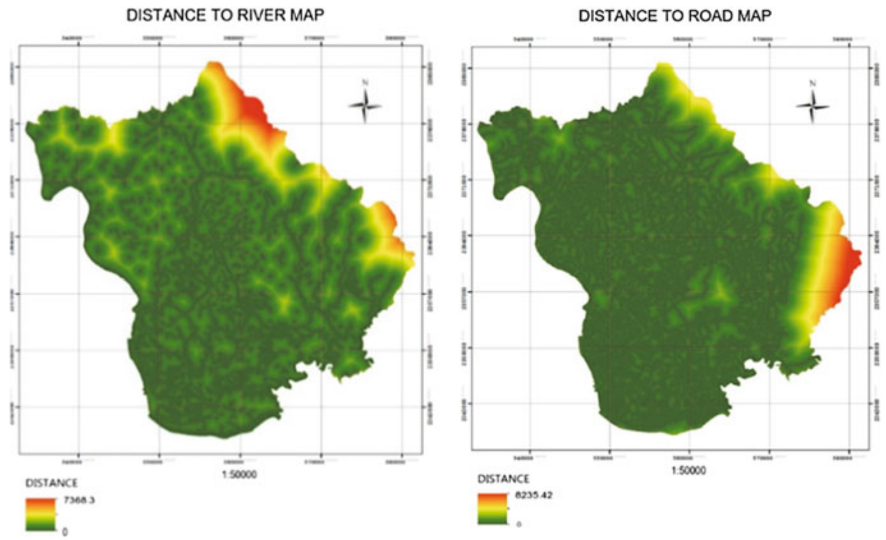

Fig. 5 Distance to the road and distance to irritation source

the irrigation source for each location. The distance to the irritation source for growing the dragon fruit should range from 20 m to 100 m. If the distance is less than 10 m, the location is not suitable for growing dragon fruit because it can be influenced by flooding and landslide. A distance of more than 100 m is also considered inappropriate due to the difficulty of water supply for irrigation.

For the purpose of harvesting, transporting products, the distance to roads is also included as an indicator to assess the suitability of dragon fruit cultivation. Research used optimal distance to the road from 20 to 100 m, over 5000 m is considered inappropriate (Fig. 5).

2.2 *Evaluate, Synthesize and Analyze Data*

Multiple-criteria decision analysis (MCDA)

Multiple-criteria decision analysis (MCDA) is a sub-discipline of operative research that explicitly evaluates multiple conflicting criteria in decision making. MCDA methods can be divided into 2 types: (i) multi-objective decision making (MODM) and (ii) multi-attribute utility theory (MAUT). This stage includes standardization, expert work, weighting calculation, and summary analysis of all criteria considered in the decision-making process

Standardize the evaluation factors

Since the datas collected are measured on different scales, the first step of MCDA is to standardize all data sets and comparable units. There are a large number of approaches that can be used to create attribute classes of comparable criteria. Based on the researches and experiences of the experts, in this study, the fuzzy set theory