Estimating the Effects of Urban Forests on House Prices: A Geographically Weighted Regression (GWR) Approach

Menganggarkan Kesan Hutan Bandar ke atas Harga Rumah: Satu Pendekatan Geographically Weighted Regression (GWR)

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Abstract

This study estimates the premiums added to the price of a house by nearby urban forests using Geographically Weighted Regression (GWR). Housing properties located in Wangsa Maju in the north-east of Kuala Lumpur, Malaysia was chosen as the case study. The outcome of this study showed a positive relationship between the existence of urban forests and house prices. In other words, the proximity of a property to the nearest urban forests uplifts the expected selling price of a house. More importantly this study reveals that the relationship between house price and urban forest are varied over geographical space. In other words, the relationship between house price and urban forest indicates that locational externalities generated by urban forests have a positive impact on house price in some areas but negative or no impact on the others. The magnitude of the effect was also found to be varied; the capitalisation in house prices is found greater in some areas but less on the others. The use of GWR allows such spatially varying relationships to be revealed, therefore leading to a better understanding of the relationship between the existence of urban forests and house prices. Moreover, the positive relationship between the existence of urban forests and house prices found in this study was the reason for urban forests to be preserved and future developments that may involve these precious resources need to be well planned.

Keywords

House price, urban forests, Hedonic House Price (HPM), Geographically Weighted Regression (GWR), Wangsa Maju

Abstrak

Kajian ini menganggarkan premium yang ditambah ke atas harga rumah yang terletak berdekatan dengan hutan bandar menggunakan teknik yang agak baru; *geographically weighted regression* (GWR). Hartanah perumahan yang terletak di Wangsa Maju iaitu di timur laut Kuala Lumpur, Malaysia dipilih sebagai kajian kes dalam kajian ini. Hasil kajian ini menunjukkan terdapat hubungan yang positif antara kewujudan hutan bandar dan harga rumah. Dalam erti kata lain,

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kehampiran satu unit hartanah dengan hutan bandar meningkatkan harga jualan jangkaan harga rumah. Lebih penting lagi ialah kajian ini menunjukkan bahawa hubungan antara harga rumah dan hutan bandar berbeza-beza mengikut ruang geografi. Dalam erti kata lain, hubungan antara harga rumah dan hutan bandar menunjukkan bahawa *locational externalities* yang dihasilkan oleh hutan bandar mempunyai impak positif ke atas harga rumah di sesetengah kawasan tetapi memberi impak negatif atau tiada impak pada kawasan yang lain. Magnitud impak ini juga didapati berbeza-beza; manfaat ke atas harga rumah yang lebih besar terdapat di sesetengah kawasan tetapi kurang pada kawasan yang lain. Penggunaan GWR membolehkan hubungan ruangan yang berbeza-beza ini dapat ditunjukkan, oleh itu membawa kepada pemahaman yang lebih baik tentang hubungan antara kewujudan hutan bandar dan harga rumah. Selain itu, hubungan positif antara kewujudan hutan bandar dan harga rumah yang ditemui dalam kajian ini adalah satu sebab mengapa hutan bandar perlu dipelihara dan pembangunan masa depan yang mungkin melibatkan sumber berharga seperti ini perlu dirancang dengan baik.

Kata kunci
Harga rumah, hutan bandar, Harga rumah hedonik (HRH), *Geographically weighed regression* (GWR), Wangsa Maju

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Introduction

Urbanisation process that occurs rapidly brings great pressure on land and other natural resources. If we look at the most part of the world an urban area is a common feature in a country. In other words, the majority of the population lives in an urban environment. In 1900, only nine per cent of the global population live in urban areas. However, this figure had increased to 40 per cent in 1980, 50 per cent in 2000 and in 2007, for the first time in the history of mankind, the global urban population surpassed the rural population: more than three billion individuals now live in cities (McIntyre *et al*., 2000; Crespo and Grêt-Regamey, 2013). Furthermore, it is expected that in 2025 more than 60 per cent of the global population will be living in cities (McIntyre *et al*., 2000).

Meanwhile, in more developed countries such as Japan, North America and Europe the number of people living in cities had achieved 80 to 90 per cent. In Malaysia, there was nearly 60 per cent of population lived in urban areas in the year 2000, compared to only 37.6 per cent in 1975 and current planning projection suggested that by the year 2020, 70 per cent of the population will be living in urban areas (Jaafar, 2004). Yet, in more developed region such as the Klang Valley, an urbanisation level had exceeding 80 per cent. This phenomenon is associated with the migration of young people from rural to industrial urban areas such as in the Klang Valley (Jaafar, 2004). Unfortunately, this enormous and complex urbanisation process has many consequences for our societies at the social, economic, environmental, and cultural levels (UNESCO, 2011). In the case of environmental problems for instance, a high population growth rate along with urban development potentially leads to an exploitation of the nature such as urban forests, resulting in an unhealthy ecology.

The Klang Valley region has been the most rapidly growing region in Malaysia during the past few decades. The early growth of this region concentrated primarily in the Federal Territory of Kuala Lumpur. The rapid growth of the population, employment, economic activities and services, particularly in Kuala Lumpur and the Klang Valley in general has resulted in a demand boom for housing, primarily within easy commuting distance to and from Kuala Lumpur city centre such as in Wangsa Maju-Maluri, Sentul-Manjalara, Damansara-Penchala, Bukit Jalil-Seputeh, Bandar Tun Razak-Sungai Besi, Hulu Langat, Gombak and Petaling Jaya. For instance, in Kuala Lumpur, residential area encompasses about 23 per cent or 5,490 hectare of the total available land in year 2000, and it is projected to become about 31 per cent or 7,424 hectare in the year 2020 (The Federal Territory Development and the Klang Valley Planning Division, 2004).

Table 1 shows total projected number of housing unit needed in the year 2020. In line with this, there have been increasing pressures on the region's remaining forests to be converted for residential uses. So far, most of the lowland forest in the Klang Valley has been down-sizing with the gradual encroachment from the residential area (Hung, 2010). For example, the Sungai Buloh Forest Reserve which is located in the midst of Petaling Jaya, once sprawling over 6,590 hectare, has shrunk steadily over the years, where now only 321.7 hectare is left. Parcel by parcel of forest land had been first converted into rubber plantations, and then into oil palm estates. While in the last 15 years, those parcels are mainly for the development of residential houses. To date, newly developed residential areas, such as Damansara Perdana, Damansara Damai, Sunway Damansara, Damansara Indah and Kota Damansara, were all once part of the Sungai Buloh Forest Reserve.

Another typical example is the Ayer Hitam Forest Reserve located in Subang Jaya – a residential town in the Petaling district, where hectares of land from the forest reserve has been gradually converted into different uses since 1970 (Table 2). Following the

Table 1 Total projected number of housing unit needed in 2020

Strategic zone	Housing unit needs by type			Total
	Low cost housing	Medium cost housing	High cost housing	
Kuala Lumpur City Centre	10,496	20,992	38,486	69,975
Wangsa Maju-Maluri	31,604	42,981	51,830	126,414
Sentul-Manjalara	36,768	32,965	57,055	126,788
Damansara-Penchala	5,167	28,048	40,596	73,812
Bukit Jalil-Seputeh	35,713	30,422	66,136	132,271
Bandar Tun Razak-Sungai Besi	38,823	25,235	32,999	97,057
Total	158,571	180,643	287,101	626,315

Source: The Federal Territory Development and the Klang Valley Planning Division, (2004) major housing boom in the last two decades, the main conversion is for the residential use (Hung, 2010). Another remaining forest's in the region which also under great pressure to be converted into residential use is Wangsa Maju Forest Reserve which is located 10 kilometres away from Kuala Lumpur city centre. In 2012, for example, residents of Section 10, Wangsa Maju had protested against the construction of three 26-storey condominiums blocks consisting of 721 units with a five-storey car park podium (Zhin, 2012). It is believe that they will be more housing projects in Wangsa Maju to be implemented in the near future since the projected number of housing unit needed to be developed in 2020 was estimated at 126,414 units (see Table 1).

Table 2 Conversions of Ayer Hitam Forest Reserve to other uses

Year	Used for	Area (hectare)
1970	Grazing	62.70
1973	Agriculture	240.00
1988	Agriculture	623.40
1989	Agriculture	658.00
1989	Agriculture	148.00
1993	Dumping site	58.00
1994	Settlement	11.30
1994	Recreational/residential	222.60
1995	Residential	324.20
1995	Residential	112.00
1995	Residential	447.20
Total		2907.40

Source: Hung (2010)

The question is why this region's remaining forests are important and need to be preserved? Urban forests are always being regarded as the most prominent elements of urban nature and producing a number of benefits. These benefits can be categorised into two; direct and indirect benefits. The direct benefits of urban forests are defined in terms of their commercial value such as source of timber. Alongside these direct benefits, the existence of urban forests has also contributed for pleasant landscape, clean air, peace and quiet as well as potential source of recreational amenity (Tyrväinen, 1997; Powe *et al.,*1997; Garrod and Willis, 1992) to surrounding residents. In rapidly growing urban and suburban areas, any preserved forests can offer relief from congestion and other negative effects of development.

Other indirect benefits include reduced wind velocity, balance micro-climate, shading and erosion control. Unlike more conventional forests products such as timber, the benefits attached with landscape and recreational amenity cannot conveniently be estimated as they do not usually attract a market price and in the past the economic value related to forests has largely been ignored (Powe *et al.,* 1997). Therefore, many municipalities have not specified their urban forest policies and many forested areas are considers as left over areas waiting for more intensive use (Löfström, 1998 cited by Tyrväinen, 1997).

However, in countries such as the United Kingdom (UK) and North America today, non-market benefits associated with forests has been taken into account when making decisions likely to lead to changes in environmental quality. As has been argued by Powe *et al*., (1997) and Garrod and Willis (1992), the existence of forests especially in an urban area has potentially to increase local property values. It has been argued further by Powe *et al,*. (1997) since urban forests are important landscape and source of recreational amenity, house buyers may pay a premium to be located nearby urban forests. Tyrväinen (1997) have arrived at the same argument where she highlighted that many qualitative surveys (e.g. contingent valuation methods) showed that urban forests are an appreciated characteristic in the home environment.

As landscape and recreational amenity are not directly traded, a number of techniques are available to estimate the non-market benefits of urban forests. The literature has shown that there are two broad categories of non-market techniques: stated preference techniques on the one hand and revealed preference techniques on the other. In the case of stated preference techniques, contingent valuation methods (CVM) can be used to estimate how much the public willing to pay (WTP) for the preservation or an improvement of urban forests quality. Revealed preference techniques such as the travel cost method (TCM) can also be used in estimation of recreational benefits offered by urban forests. However, this method has limited applicability in an urban settings because there is often no travel or similar expense involved in accessing the area (Tyrväinen, 1997).

In the context of this study, another revealed preference techniques namely hedonic pricing is used to estimate the effects of urban forests on house prices. The hedonic price method (HPM) is a well-established method used to analyse a market for a single commodity with many attributes, in particular that of housing. In other words, HPM is based on the idea that properties are not homogeneous and can differ in respect to a variety of attributes. These various attributes will determine the value of the house. For example, since urban forest is an important source of recreational amenity and pleasant landscape of the neighbourhood, house buyers may pay a premium in order to be located nearby urban forests. As a result, price differentials should develop among the neighbourhoods due to differences in distance from urban forests. These price differentials are signals about the value that residents place on living in a neighbourhood where urban forests exist. HPM will capture the value of recreational amenity and pleasant landscape generated by urban forests only if the benefits from the accounts for those houses that are located nearby urban forests.

However, producing a hedonic price model is best suited to non-spatial commodities. It is unlikely to sufficiently capture the spatial context and variation within which properties are located. Thus a relatively new spatial econometric technique known

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as Geographically Weighted Regression (GWR) which addresses the issue of spatial heterogeneity is also used to estimate the effects of urban forests on house prices in this study. By using GWR, it allows local rather than global parameters to be estimated, and thus provides a way of accommodating the local geography of the relationship between house price and urban forests. Moreover, it is used to verify the heterogeneity of the relations, which in turn can indicate the degree of misspecification in the global model.

Housing properties located in Wangsa Maju of the north-east of Kuala Lumpur, Malaysia was chosen as a case study. Wangsa Maju is always known for its hilly and green forest character. This area has thirteen housing estates namely Setiawangsa, Wangsa Maju, Wangsa Melawati, Desa Setapak, Setapak Jaya, Setapak Permai, Taman Sri Rampai, Danau Kota, Taman Bunga Raya, Taman Setapak Inn, Taman Ibu Kota, Medan Idaman and Taman Setapak. Figure 1 shows the satellite view of the study area taken from Google Earth whilst Figure 2 shows the location of study area in the Federal Territory of Kuala Lumpur.

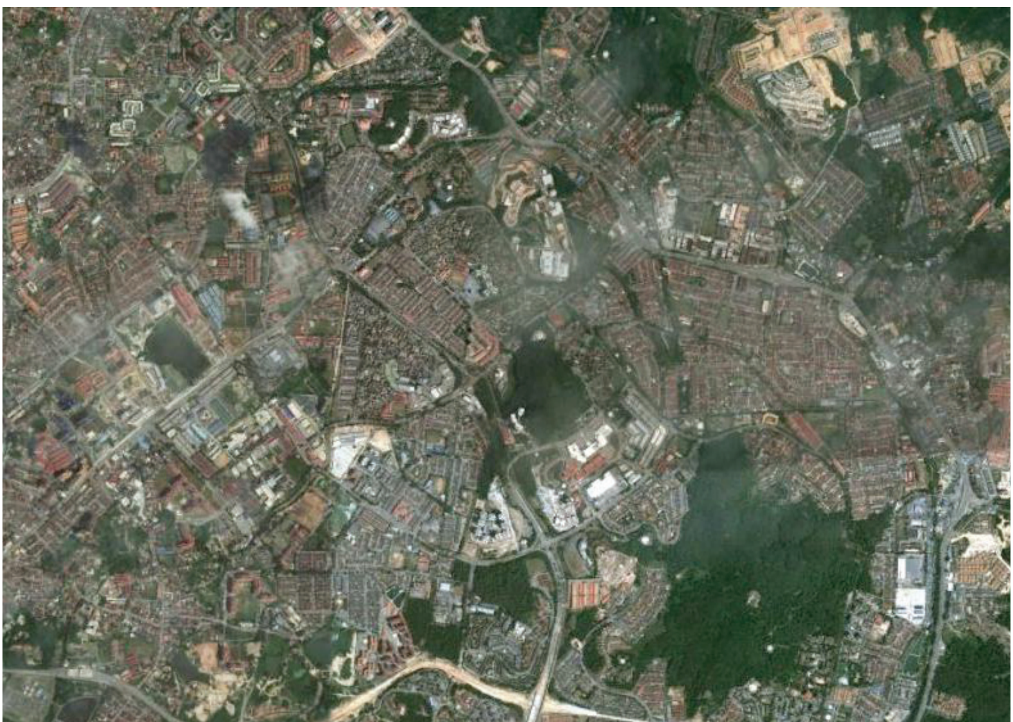

Figure 1 Satellite view of the study area
Source: Google Earth (2013)

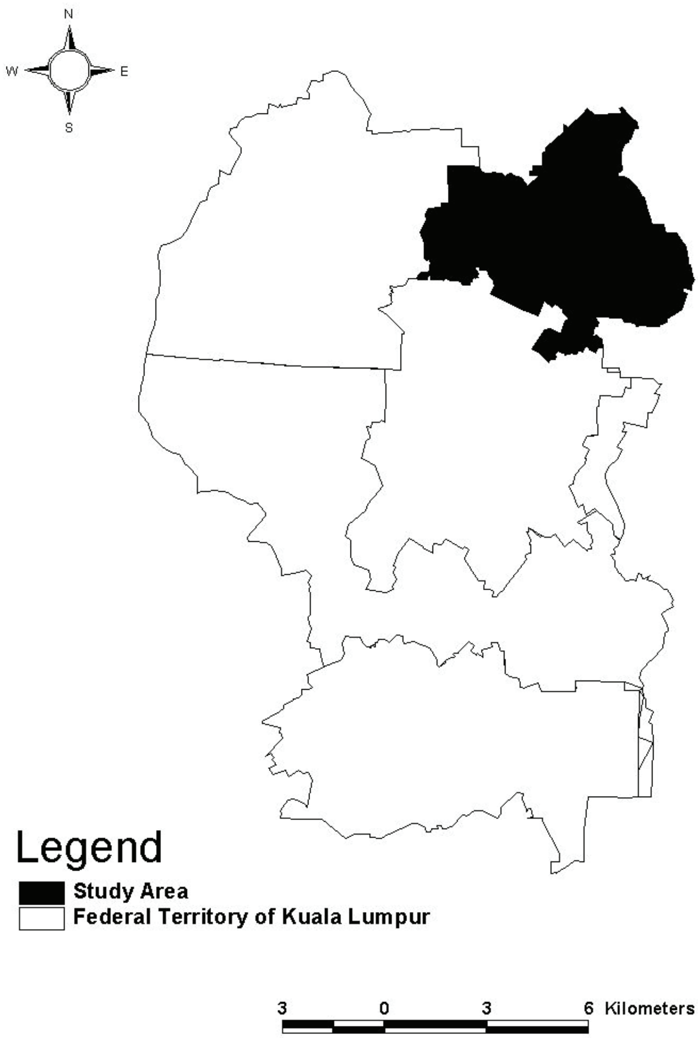

Figure 2 The location of Wangsa Maju in Federal Territory of Kuala Lumpur
Source: The Federal Territory Development and the Klang Valley Planning Division (2004)

Existing Research and Implications for This Study

Many studies found in scientific publications since the 1990s provide forests researchers with sufficient evidence to observe how forests, in particular urban forests affect real estate markets. In general, most studies suggest that proximity to forests area increases property values but with varying magnitude. For instance, study carried out by Garrod and Willis (1992a) in rural areas of England found that residential property were sold at a higher price when more than 20 per cent of the land surrounding the residential property (in a one-kilometre square) is woodland areas. Interestingly, in the same study Garrod and Willis also found having a woodland view tends to reduce residential property values. However, no explanation for these differing results was given by authors. In contrast, a study carried out by Tyrväinen and Miettinen (2000) in Finland indicate that having a forest view increased residential property values.

In another study, Garrod and Willis (1992b) estimate the effects of percentage of three types of forested lands in a one-kilometer square grid on residential property values, and these three are broadleaved trees, Scots pine and Corsican pine planted before 1920, and conifers planted before 1940. The results of their estimation suggest that the greater the percentage of land covered by broadleaved trees, the higher the value of residential property. In the case of Scots pine and Corsican pine planted before 1920, their effects on residential property values were found to be none. For conifers planted before 1940, the results suggest its effect on residential property values were found to be negative. In other words, residential properties located nearby this forest were sold at a lower price.

A study conducted by Tyrväinen (1997) in Finland for a sample of 1006 apartment sales indicate that urban forests are an appreciated environmental characteristic and that their benefits are reflected in the residential property values. She concluded that proximity of watercourses and wooded recreation areas as well as increasing proportion of total forested area in the housing district had a positive influence on apartment price. In a study of proximity to woodland and its effects on the house prices of Southampton, Powe *et al*., (1997) found that house value increase is associated both with locating in close proximity to woodland and within easy access of larger areas of woodland.

Dombrow *et al.,* (2000) conducted a study of 269 single-family residential property sales with an average price of $93,272, and they found that the presence of mature trees contributed about two percent to the value of residential property. Subsequent study carried out by Tyrväinen and Miettinen (2000) suggest that housing district located nearby large forested area increase in value. However, the negative effects were found for those residential properties that are located nearby forest preserve. Tyrväinen and Miettinen (2000) attribute this negative effect to the closeness of the residential properties from forest preserve, and many of these residential properties had mature conifers right next to them. In Finland, due to the long winters, light can be extremely valuable, and the shed provided by these trees has made the properties less valuable. Yet, a study carried out by Thorsnes (2002) in Michigan show that residential properties were sold at a premium of 19 per cent to 35 per cent for those located nearby forest preserve.

The Estimation Methods

The discussion in this section is focussing on the methods used to estimate the effects of urban forests on house prices. As stated above, this study was using the GWR to estimate the effects of urban forests on house prices. The GWR is based on a global regression model (a hedonic price model) which is then modified by GWR to calibrate local regression parameters by weighting the distance between one data point and another through the coordinates of data.

The Hedonic Price Model

The general form of a hedonic pricing model can be presented as:

$$P_i = f\ (F, S, L,) + \varepsilon \qquad (1)$$

where,

P_i = the market price of property *i*,
R = a vector of the urban forest attribute in the neighbourhood,
S and L = the vectors of structural and locational variables,
ε = a vector of random error terms.

Variables used in this study were divided into two categories; focus and free variables. Focus variables were those variables of particular interest and it may vary from one study to another, and in this case consisted of the urban forest attribute contained in vector *F*. Free variables were defined as those that are known to affect house prices, though are of no special interest in the study, and in this case such as structural and locational attributes contained in vector *S* and *L*. It has to be noted that the free variables were selected on the basis of their inclusion in previous studies (see, for example, Powe *et al*., 1997; Garrod and Willis, 1992b; Nicholson and Willis, 1991), and most importantly, on the basis of their availability.

The next stage of estimation process using hedonic price model is to choose the functional form which best portrays the relationship between a property's market price and each of the variables describing its characteristics. In other words, the functional form is the exact nature of the relationship between the dependent variable (a vector of house) and the explanatory variables (such as structural and locational attributes). There were four common functional forms used in hedonic price model; linear, semi-log, double-log and Box-Cox linear (Garrod and Willis, 1992b; Cropper *et al.,* 1988; Palmquist, 1984). Unfortunately, economic theory does not generally give clear guidelines on how to choose a particular functional form for property attributes (Tu, 2000; Garrod and Willis, 1992b). However, Cropper *et al*., (1988) suggest that linear, semi-log, double-log and Box-Cox linear perform best, with quadratic forms, including the quadratic Box-Cox, was not be able to meet the expectations.

Geographically Weighted Regression (GWR) Model

One of the main problems in studying property values or specifically house prices is how to handle and integrate the spatial dimension. As mentioned previously, the problem with the HPM is the parameter estimates are assumed to apply constantly over the whole geographical space. In other words, the relationships being measured are assumed to be 'stationary' over geographical space. Hence a technique known as Geographically Weighted Regression (GWR) which addresses the issue of spatial heterogeneity is used to estimate the effects of urban forests on house prices in this study. Fotheringham *et al.,* (1998) have pointed out that this spatial heterogeneity if not carefully handle may cause problems for the interpretation of parameter estimates from a global regression model.

It was argued in the literature that any relationship that is not stationary over geographical space will not be represented well by a global regression model. Fotheringham *et al.,* (2002) have argued further that, failing to address issues related to spatial heterogeneity may cause the estimated parameter produced by a global regression model misleading locally (Fotheringham *et al*., 2002). The GWR on the other hand has the capability in dealing with spatial heterogeneity that is by taking into account of coordinates in estimated parameter. The GWR model can be mathematically expressed at location *i* in space as follows (Crespo and Grêt-Regamey, 2013: p. 667):

$$P_i = \beta_0 (u_i, v_i) + \sum \beta_k (u_i, v_i)\, x_{ik} + \varepsilon_i,\ i = 1, \ldots, n, ;k=1 \quad (2)$$

where,

P_i	= the response variable at point *i*,
u_i, v_i	= the spatial coordinates of point *i*,
$\beta_0 (u_i, v_i)$	= the location-specific intercept term parameter,
$\beta_k (u_i, v_i)$	= the *k*th location-specific parameter,
p	= the number of unknown local parameters to be estimated (excluding the intercept term),
x_{ik}	= the k^{th} explanatory variable associated with $\beta_{k,}$
ε_i	= a random component assumed to be independently and identically distributed,
n	= the number of observations

Based on equation 2 above, location-specific parameters $\beta_k (u_i, v_i)$ are estimated using weighted least squares and can be expressed as follows (Crespo and Grêt-Regamey, 2013: p. 667-668):

$$\beta (u_i, v_i) = [X^T W_i X]^{-1} X^T W_{iy},\ i = 1, \ldots, n, \quad (3)$$

where,

$\beta (u_i, v_i)$	= a (*p* x 1) vector parameter estimates at location *i*,
X	= an (*n* x *p*) matrix of observed explanatory variables,
W_i	= a distance decay (*n* x *n*) matrix,
y	= an (*n* x 1) vector of observed response variables.

Note that *p* and *i* are as defined in the equation 2 above. Location *i* is also denoted as the regression point; the point at which parameters are being estimated. As expressed in the equation above, the weighting of an observation is done through a distance decay matrix (W_i) so that observations located near to the point in space are weighted more than observations located further away. By this geographically weighted calibration, continuous and smooth surfaces of local parameter estimates can be mapped over geographical area. Another advantage of using GWR in comparison to other spatial methods such as multilevel modeling is that each observation is treated as an individual observation at a specific geographic point. Thus, the maps produced will not be limited within an artificially bounded geographical area such as political or administrative boundaries as normally required when modeling spatial data (Du and Mulley, 2011; Crespo and Grêt-Regamey, 2013).

Data Collection

To estimate the effects of urban forests on house prices, sufficient and accurate data are essential particularly for the purpose of conducting statistical analysis to generate statistically significant result. For the purpose of this study, house price transaction together with structural and location data is required. This section describes the data collection process for this study.

House price transaction and structural data

In house price related data analysis, house price transaction data are normally collected. In this study, house price transactions for 2005 were chosen to be the sample. The selling price of an individual house and its structural attributes were collected from the Department of Valuation and Property Services, Malaysia. In total, 1457 units of housing selling prices were collected.

Location data

The data on the base map, land parcel and location attributes (type of land use) were obtained from the Department of Survey and Mapping of Malaysia, Centre of Spatial Analysis, Science University of Malaysia, Kuala Lumpur City Hall and Department of Agriculture of Malaysia. Land use or location attributes data were collected for the year of 2005.

In order to measure the distance to location attributes from a given house, the Geographical Information Systems (GIS) was used in this study. GIS was used to organise and manage large spatial datasets (that is, units of houses) and of course their structural and location attributes too, and most importantly GIS was used to position each observation and location attribute accurately on a local map by using the geographical coordinates. Moreover, the combination between GIS and spatial analysis has been particularly useful in this study in which the distance and proximity were measured accurately by measuring the distance from one point to another using network distance.

Empirical Results

The results of the hedonic price and GWR models using the above specification are presented below in two stages. The first part shows the results from the hedonic price model and the second part shows the results from the GWR model.

The Hedonic Price Model

Based on the advice given by Cropper et al. (1988), double-log specification was used to estimate the effects of urban forests on house prices in this study. The model is regressed on a set of determinants as follows:

$$lnP_i = \beta_0 + \beta_1 lnFOREST_i + \beta_2 lnDIST500_i + \beta_3 lnFLRAREA_i + \beta_4 TYPTRRDi + \beta_5 TYPSEMID_i + \beta_6 TYPDETCH_i + \beta_7 LRTSTN_i + \beta_8 lnPRIMARYSCH_i + \beta_9 lnSECONDARYSCH_i + \beta_{10} lnINDUSTRY_i + \beta_{11} lnMJJROAD_i + \beta_{12} lnCOMMERCIAL_i + \beta_{13} lnSHOPMALL_i + \varepsilon \quad (4)$$

where *i* is the subscript denoting each property; P_i is the price of property *i* in Malaysia Ringgit (MYR); ln is natural logarithm; FOREST is the network-distance from the property to forest area measured in metres; DIST500 is the property located within 500 metres from forest area; FLRAREA is the floor area of the property in square foot; TYPxxx is a set of dummy variables that illustrate the type of house which are further described as follows:

TYPTRRD is 1 if the property is terraced, 0 otherwise;
TYPSEMID is 1 if the property is semi-detached, 0 otherwise;
TYPDETACH is 1 if the property is detached, 0 otherwise;

LRTSTN, PRIMARYSCH, SECONDARYSCH, INDUSTRY, MJRROAD, COMMERCIAL and SHOPMALL are the network-distance from the property to the nearest LRT station, primary schools, secondary schools, industrial areas, major road, commercial areas and shopping mall respectively. These variables are all measured in metres. Finally, $\beta_0,...,\beta_{17}$ denotes a set of parameters to be estimated associated with the explanatory variables (including the intercept term), and ε denotes standard error of the estimation, which is assumed to be independently and identically distributed. The descriptive statistics of the model's variables are shown in Table 3.

Table 4 shows the coefficient values associated with the 'best' model for double-log specification together with a Monte Carlo significance test procedure for the GWR model. Within the final model all of the explanatory variables were significant at the 99 per cent level, and 83.2 per cent of the variation in the dependent variable was explained.

Table 3 Descriptive statistics of the model's variables

Variable	Type[a]	Description	Units	Minimum	Maximum	Mean
Dependent variable						
SELLING	C	House price transactions	Malaysia Ringgits (MYR)	60000	1450000	239965.15
Explanatory variables						
Focus variables						
FOREST	C	Proximity to forest area	Metre	10	2265.46	742.84
DIST500	D	Location within 500 metre	Dummy (0 or 1)	0	1	
Housing property variables						
FLRAREA	C	Floor area in	Square foot	55	364	102.83
TYPTRRD	D	Terraced house	Dummy (0 or 1)	0	1	
TYPSEMID	D	Semi-detached house	Dummy (0 or 1)	0	1	
TYPDETCH	D	Detached house	Dummy (0 or 1)	0	1	
Locational variables						
LRTSTN	C	Proximity to LRT station	Metre	76.64	2901.09	1317.33
PRIMARYSCH	C	Proximity to primary school	Metre	18.69	1827.12	404.12
SECONDARYSCH	C	Proximity to secondary school	Metre	20.67	1122.69	456.44
INDUSTRY	C	Proximity to industrial area	Metre	21.54	2552.31	1219.77
MJRROAD	C	Proximity to major road	Metre	25.19	1014.78	437.12
COMMERCIAL	C	Proximity to commercial area	Metre	10	1756.49	382.06
SHOPMALL	C	Proximity to shopping mall	Metre	53.90	3373.59	1156.12

[a]C = continuous; D = binary

Table 4 The results of hedonic price and GWR models

	Hedonic price model (HPM)			GWR Model
	Coefficient	t-ratio	Implicit price (MYR 2005)	*P*-value (Monte Carlo)
Intercept	6.903	41.630		0.000***
Focus Variable				
FOREST	-0.029	-4.102	-9.70	0.000***
DIST500	-0.080	-5.060	-19197.21	0.010**
Structural Variables				
FLRAREA	0.977	40.704		0.000***
TYPTRRD	0.529	22.864		0.000***
TYPSEMID	0.748	17.546		0.000***
TYPDETACH	0.679	9.439		0.000***
Locational Variables				
LRTSTN	-0.064	-4.643	-11.66	0.000***
PRIMARYSCH	0.033	3.843	19.60	0.000***
SECONDARYSCH	-0.060	-6.725	-31.54	0.000***
INDUSTRY	0.119	9.603	23.42	0.000***
MJRROAD	-0.049	-5.299	-26.89	0.000***
COMMERCIAL	0.058	6.573	36.43	0.000***
SHOPMALL	0.051	4.860	1799.74	0.000***
Summary Statistics				
No of observations = 1457				
Dependent mean = 239965.15				
R^2 (adjusted) (HPM: 83.2; GWR: 88.3)				
Akaike Information Criterion (HPM: -557.57 ; GWR: -989.21)				
ANOVA	*Sum of squares*	*Degrees of freedom*		*F value*
OLS residuals	57.0	14.0		
GWR improvement	18.6	67.2		
GWR residuals	38.4	1375.8		9.9

*** = significant at 0.1% level

** = significant at 1% level

Focus and free variables were incorporated in the final model on the basis of significant coefficient values. In the case of focus variables, there were only two of the four focus variables, FOREST and DIST500, included in the final model. Another two variables was shown not to have a significant coefficient value and was therefore eliminated from the final model.

The implicit prices of all the explanatory variables were calculated by holding all other variables at their mean level. Hence, for the variable FOREST the implicit price was estimated at MYR9.70. This means that for every metre away from urban forests, reduced the expected selling price of a house by MYR9.70. In the case of the variable DIST500, the location of a property within 500 metres of urban forests adds a premium of approximately MYR19, 197.21 to house price.

With respect to the structural attributes of free variables, the variable FLRAREA was found to be the most dominant factor in determining the house price. For every square-foot increase in the floor area, the expected selling price of a house increased by MYR2, 279.94. The greater magnitude of the effect of the variable FLRAREA was expected since floor areas are always associated with the size of the property – this is consistent with the most of the hedonic house price literature. In the case of property-type attribute, its role was only to indicate the price for different types of housing in the study area. Thus, the implicit prices for variables TYPDETACH and TYPSEMID was expected to be higher than a TYPTRRD. After examining the results in the final model, there were significant differences in price between different types of housing. In other words, the implicit prices of the TYPDETACH (MYR162, 936.34), TYPSEMID (MYR179, 493.93), and TYPTRRD (MYR126, 941.56) should all have reflected some value-added by the attributes that they possess.

In terms of the locational attributes of free variables, the importance of their role in determining the selling price of a house was confirmed by the analysis. Among locational variables of the house, proximity to nearest industrial area (INDUSTRIAL) was found to be the most statistically significant in determining house prices with the anticipated signs. The implicit price for proximity to the nearest industrial area was estimated at MYR23.42. This indicated that for every metre away from the nearest industrial area had increased the expected selling price of a house by MYR23.42. Meanwhile, the least statistically significant locational variable in determining house prices in this study was proximity to the nearest primary school (PRIMARYSCH) together with the unexpected signs. It clearly shows that on average, for every metre away from the nearest primary school had increased the expected selling price of a house at the rate of MYR19.60. The discussion in the next section is focuses on the local geography of the effects of urban forests on house prices.

Geographically Weighted Regression (GWR) Model

As widely recognised, the main contribution of the GWR technique is the ability to produce the spatial variability of the estimated parameter from explanatory variables in the model. Therefore, explanatory variables found to be significant in the HPM but may vary significantly over geographical space and be revealed by the GWR modelling. The analysis using GWR software presents two diagnostic information; the information for the HPM and GWR model – including general information on the model and an ANOVA (it can be used to tests the null hypothesis that the GWR model has no improvement over the HPM). The Monte Carlo test calibrated for the GWR model found that all explanatory variables displayed significant spatial variation over geographical space (see, Table 4). Moreover, from the summary statistics in Table 4, the adjusted R^2 had increased from 83.2 per cent in the HPM to 88.3 per cent in the GWR model.

Another test that is available in the GWR model is the F-test. According to Brusndon *et al*., (1996) the F-test is used to test whether the GWR model offers an improvement over, and describes the relationship significantly better than the HPM. As shown in Table 1 above the F-value was estimated at 9.9 and this can be considered as high F-value. High F-value suggesting that the GWR model has a significant improvement over the HPM in determining the relationship between house price and housing attributes. Therefore, the assumption that the GWR model has no improvement over the HPM can be rejected. In addition, the Akaike Information Criterion (AIC) of the GWR model (-989.21) is less than the one the HPM (-557.57) indicated that GWR model performs better than the HPM. After considering degrees of freedom, the conclusion that can be made is; the GWR model provided a better explanation of the

Figure 3 Housing estates in Wangsa Maju

relationship between house price and housing attributes in this study, particularly by addressing spatial variation of the relationship over geographical space.

All the local parameter estimates can be mapped but due to space limitations, this paper concentrates on FOREST variable only. This estimated parameter was mapped in Figures 3 by using Inverse Distance Weighted (IDW) interpolation that is available in ArcView software. According to Du and Mulley (2006) the best interpretation comes from maps of local estimated parameter alongside the maps of local *t*-ratio since the local *t*-ratio maps exhibit the local significance that accounts for the local varying estimate errors. The data range, including estimated parameter and *t*-ratio, was classified into classes of equal extent, an appropriate colour scheme that in turn gives a clear picture of local spatial variation, and estimated parameter and *t*-ratio can be mapped in a single choropleth map in order to reduce the number of maps in the text. To assist the readers with the place names mentioned in text, various housing estates regions that are included in the sample of this study is labelled on Figure 3.

Figure 4 show the local estimated parameter as different colour points with both the darkest and lightest areas were significant with *t*-ratio greater than -2 and +2. It is clear

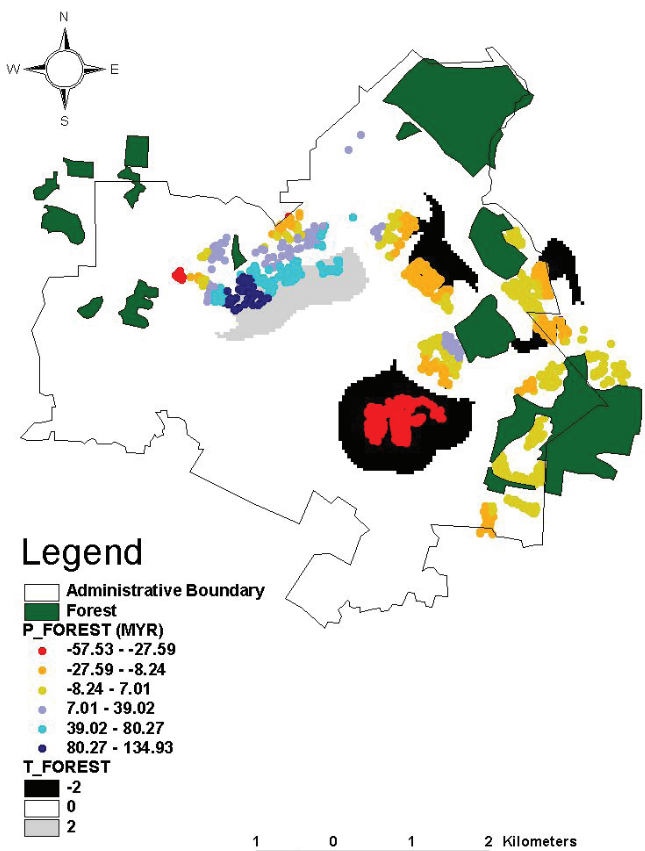

Figure 4 Map of the local parameter estimates associated with variable proximity to urban forests

from the maps that the estimated parameter exhibit considerable local spatial variation over geographical space and this spatial variation of course completely unobserved in the global model.

The expected selling price of a house was estimated by the HPM to reduce by MYR9.70 for every metre away from urban forests. By plotting the estimated parameter and *t*-ratio from the GWR model, the effect of urban forest on house prices in Wangsa Maju were found to be greater than it was estimated by the HPM. For example, the expected selling price of a house located in Desa Setapak, some residential properties in Taman Bunga Raya, Taman Setapak Inn Wangsa Melawati, Wangsa Maju, Taman Setiawangsa, Taman Seri Rampai, Medan Idaman, Setapak Jaya and Setapak Permai housing estates reduced by MYR8.24 to MYR57.53 (orange and red dots) for every metre away from forest area. Although, majority of the expected selling price of a house reduced for every metre away from urban forests in most of the area, yet, the statistically significant local estimated parameter only covers some parts of the area and these areas are Setapak Jaya, Setapak Permai, Desa Setapak and some residential properties in Desa Melawati housing estates.

The main reason why the majorities of house buyers in Wangsa Maju value the existence of forests around their residential area and are willing to pay more is due to the forests are important landscape and source of recreational amenity for residents, in particular where Wangsa Maju Forest Reserve is among very few remaining forest's in the region. The result of the GWR also reveals the expected selling price of a residential property located too close to the forest has decreased in value. This is indeed in accordance with the findings of Tyrväinen and Miettinen (2000) in Finland, who claim that property values decreased where residential properties located too close to the forest. The reason is that residents tend to avoid negative locational externalities that may generate by the forest such as erosion, forest fire and wild animals, particularly wild monkey.

However, the literature identifies significant issues of multicollinearity in all regression based analysis. Since the GWR technique follows a similar principal, it is sensible to expect the presence of multicollinearity among variables that was estimated in the GWR model. According to Wheeler and Tiefelsdorf (2005) and Du (2006), multicollinearity is more likely to be found in GWR models than the HPM. Wheeler and Tiefelsdorf (2005: 163) argue further that 'evaluating data in GWR for local multicollinearities and pair-wise correlations between sets of local coefficients is even more important than in the traditional global regression model due to the increased complexities of the GWR estimation procedure that potentially induces interrelationships among the local estimates'. These issues was raised and explored by Wheeler and Tiefelsdorf (2005) and later by Du (2006). It is important to note that, ignoring this issue would mislead the interpretations of the local parameter estimates.

Wheeler and Tiefelsdorf (2005) have listed five multicollinearity detection measures for the GWR model; scatter plots between the local parameter estimates, histograms of local parameter correlations, maps of the local parameter correlations or the local variance inflation factors, scatter plots of correlation between two local kernel weighted independent variables and the local parameter correlations. It has been argued by Du (2006) that the last two approaches require specialised computational procedures. To detect the presence of multicollinearity among transport variables in the GWR model of her study, Du employed scatter plots between the local parameter estimates incorporated into correlation matrix, together with a check of local standard errors. The scatter plots between the local estimated parameter approaches seem to be more convenient and proved to be effective to use as demonstrated by Du, and so was employed in this study. The result from this procedure shows that there was little evidence of multicollinearity among local estimated parameters in this dataset.

Conclusion

As noted above, the purpose of this study was to estimate the effects of urban forests on house prices by using GWR technique, but, the basis of explaining variation in the dependent variable was provided by the HPM. Unfortunately, the HPM was not able to capture spatial variability over geographical space. The spatial variation of the explanatory variables included in the final model, however, has clearly been addressed by employing GWR in this study. The maps of two focus variables demonstrated the expected selling price of a house reduced for every metre away from urban forests.

By using the GWR in this study, we were able to identify there are great numbers of buyers place a high value on pleasant landscape and source of recreational amenity generated by urban forests, and therefore willing to pay marginally more of a house by nearby urban forests. Thus, it is reasonable to suggest that this group of buyers are more likely to compete through the pricing system in the property market to enjoy positive externalities that may generated by urban forests, and may also become involved in political actions in order to protect their valuable forest from being demolishing that may cause their property prices to decrease, since locational externalities such as forest represent a larger investment in the price of their property. Evidently, in 2012 for example residents of Section 10, Wangsa Maju had protested against the clearance of forest land for the construction of three 26-storey condominiums blocks consisting of 721 units with a five-storey car park podium. This is due to the fact that, Wangsa Maju Forest Reserve is a very few remaining forest’s in the region which also under great pressure to be converted into residential use.

Given that this study has shown there is a positive relationship between house prices and urban forests hence it is the responsibility of the municipal, corporate and private citizens to preserving, maintaining and managing urban forests. This goal can be achieved by having policies such as Urban Forest Management (UFM) policy. Strategies in a UFM policy that potentially be implemented includes tree inventory, deployment of qualified/trained staff, memorial and commemorative trees, hardy species, succession planting, and planting and care of school grounds. In addition, it is the responsibility of the municipal to carry out Forest Impact Assessment (FIA) not just in social and biodiversity terms, but most importantly in monetary/economic terms before any project involving urban forests can be implemented.

This study has indeed contributed to the literature on the positive relationship between house price and urban forests by providing more accurate, robust, reliable and most importantly meaningful empirical evidence that is by addressing spatially varying relationship between house price and urban forests.

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