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Development of an Innovative Land Valuation Model (iLVM) for Mass Appraisal Application in Sub-Urban Areas Using AHP: An Integration of Theoretical and Practical Approaches

Jannet C. Bencure [1,*], Nitin K. Tripathi [1], Hiroyuki Miyazaki [1], Sarawut Ninsawat [1] and Sohee Minsun Kim [2]

1 Remote Sensing and Geographic Information System, School of Engineering Technology, Asian Institute of Technology, 58 Moo 9, Klong Luang, Pathumthani 12120, Thailand
2 Department of Development and Sustainability, School of Environment, Resources and Development, Asian Institute of Technology, 58 Moo 9, Klong Luang, Pathumthani 12120, Thailand
* Correspondence: jcbencure@gmail.com

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Abstract: Land development in sub-urban areas is more frequent than in highly urbanized cities, causing land prices to increase abruptly and making it harder for valuers to update land values in timely manner. Apart from this, the non-availability of sufficient reliable market values forces valuers to use alternatives and subjective judgement. Land value is critical not only for private individuals but also for government agencies in their day-to-day land dealings. Thus, mass appraisal is necessary. In other words, despite the importance of reliable land value in all aspects of land administration, valuation remains disorganized, with unregulated undertakings that lack concrete scientific, legal, and practical foundations. A holistic and objective way of weighing geospatial factors through expert consultation, legal reviews, and evidence (i.e., news) will provide more realistic results than a regression-based method that does not comprehend valuation factors (i.e., physical, social, economic, environmental, and legal aspects). The analytic hierarchy process (AHP) enables these factors to be included in the model, hence providing a realistic result. The innovative land valuation model (iLVM), developed in this study, is an inclusive approach wherein experts are involved in the selection and weighing of 15 factors through the AHP. The model was validated using root mean squared error (RMSE) and compared with multiple regression analysis (MRA) through a case study in Baybay City, Philippines. Based on the results, the iLVM (RMSE = 0.526) outperformed MRA (RMSE = 1.953).

Keywords: land valuation; mass appraisal; real estate; analytic hierarchy process (AHP); multiple regression analysis (MRA); geographic information system (GIS)

1. Introduction

Fast and updated land valuation has become part of the economic agenda [1] recently, especially in government land-related transactions such as taxation, expropriation, fragmentation, reallocation, and consolidation [2], or even in land administration and management [3]. Land value is important for people in the agricultural, financial, and business sectors since it determines their position in lending institution in terms of borrowing capacity [4].

Land is the most precious and limited non-renewable resource [5]; yet, it is one of the most exploited and undervalued natural resources [6]. In addition, rapid population growth and urbanization increase demands for land; hence, it is essential for government to adopt a more meaningful and practical way for land use planning and administration to have a more sustainable community, that is, by incorporating land value in such activity. Land use management could be easier if land were assigned value [1]. The recession of the property market in the United Kingdom (1980s), Japan (1990s), Germany (1994), and the United States (2007) provides concrete evidence on the effects of land value and how significant it is in the land administration system [3]. In 2016, the 2030 agenda for sustainable development, known as Global Goals, linked the importance of improved land use planning, administration, and management in achieving their goals. The value of land depends on the physical, economic, social, environmental, and legal factors [5]. Nevertheless, defining a precise and perfect valuation model remains difficult due to variations of such factors [7] and valuers' perceptions; hence, value is most often perceived as inconsistent and biased. This type of situation is no big issue for single and one-time pass land valuation. In contrast, regular and massive valuation, for example through mass appraisal for taxation, expropriations, land administration, and other similar purposes, requires updated and high levels of consistency and transparency.

Land valuation is the process of estimating the absolute [8–11] or relative value [12] value of land. Regardless of the purpose or extent of the area, valuation can be done manually or automatically. The latter involves collection of market values that serve as sample values, from which empirical analysis and calibration is performed to derive numerical valuation model for the area. The used of an automatic valuation model (AVM) has been popular for more than ten years in developed countries like Sweden, Canada, and the United States, and is becoming popular worldwide [2].

The most popular AVM approaches are based on regression analysis, ranging from simple to hybrid regression, such as multiple regression analysis [2], valuation method based on the two cumulative distribution functions (VMTCDF)by Ballestero of 1971 [13], spatial Bayesian [14], geographically weighted regression [15,16], and ridge regression [17], among others. Artificial intelligence (AI) techniques like artificial neural networks [10], genetic algorithms [11,17], case-based reasoning [18], and random forest [19] are becoming popular. Moreover, a factor-weighting approach like multi-criteria decision analysis (MCDA), has been also utilized by several studies [7,20–23]. The MCDA-based approach estimates relative land value that is most often expressed as an index (i.e., rank) with equivalent qualitative descriptions such as high or low value. The Storie Index, a well-known and accepted method in California of valuating agricultural land based on soil characteristics [22,23], is an example of a factor-weighting approach. Meanwhile, few have performed interpolation techniques such as those in the study of [24].

One of the significant limitations of regression-based and AI techniques is that they do not comprehend the real-world valuation factors [20,25] because they are data-dependent. For example, in an attempt to establish a relationship between land value and elevation and road proximity made using data from areas that are all or mostly located at relatively similar elevations, elevation will obviously appear to be more significant than road proximity when employing this technique, which is not the real case. In contrast, MCDA enables us to select, rank, and weigh factors based on experts who often perform value judgement; hence, the result is more realistic. Moreover, a model is holistic when it considers both the negative and positive influence of geospatial factors (i.e., physical, environmental, economic, social, and legal) to the land. These factors can be considered when MCDA is employed. Another weakness of the former methods is that they require significant land value data to achieve desirable results [12]. Data that involve money are most often confidential and not publicly available, although sometimes they are available but not reliable. For example, a technical report by the Philippines Land Administration and Management Project (2002) mentioned that sellers or buyers incorrectly declared the selling price to avoid paying higher transfer tax. Obviously, when data are not available, valuers may be forced to use alternatives, like adopting sales from other district and then making an adjustment—this makes the valuation inconsistent.

Therefore, to overcome the above-mentioned limitations, the current study aimed at developing the innovative land valuation model (iLVM) for mass appraisal applications utilizing the MCDA technique, particularly the analytic hierarchy process (AHP) in geographic information systems (GIS), and generating a land value map. The geospatial factors were identified and ranked based on survey, interview, news, existing laws and standards, and related studies. The 15 valuation factors considered in the study are: proximity to roads (three types), schools (two types), hospitals, central business district (CBD), industry, river/lake, coastline, active fault line, land use, slope, aspect, and elevation. These were grouped into five main categories: physical, social, economic, legal, and environmental. The performance of the developed iLVM was validated using root mean squared error (RMSE) and compared with MRA through a case study of Baybay City, Philippines. The legal factors were based on the existing laws of the Philippines (e.g., the Water Code of the Philippines and the Philippine Disaster Risk Reduction and Management Act of 2010, among others) since the model is tested in Baybay City. Sub-urban cities like Baybay City are perfect for the study because horizontal development is more frequent than highly urbanized development. These infrastructure developments caused land prices to peak more abruptly than normal, making more difficult for appraisers to update land values. Also, Baybay City has been employing a manual method in valuation undertakings despite its cityhood status. The advantage of this method is that it overcomes the limitations of regression-based and its applicability at a larger scale. It is still subjective yet less biased, and is transparent and flexible enough to be applied based on the condition of locality or country in a theoretical, logical, and realistic manner.

The paper is arranged as follows: Section 2 presents the theories, framework, and methods employed in developing the model; Section 3 describes the data used, study area, and developed iLVM wherein the model performance is implemented and validated through a case study; Section 4 presents the results; Section 5 discusses the results; and Section 6 presents a summary and conclusion and pinpoints the strengths and drawbacks of the iLVM.

2. Methodology

The study is GIS-based, wherein 15 geospatial factors are considered in the development of the iLVM. The goal is to develop an innovative land valuation model by involving the experts of real estate such as assessors and appraisers, and government officials concerned with land resources in the different phases of development through a survey questionnaire and in-depth interview. The residents were also asked through separate field questionnaires which factors mattered to them. Moreover, the existing laws of the Philippines (e.g., the Water Code of the Philippines, the National Building Code of the Philippines, and the Philippine Disaster Risk Reduction and Management Act of 2010, among others), principles on valuation standards (i.e., International Valuation Standards, and RICS Valuation-Global Standards), and previous literature also aided in the development process.

The analytic hierarchy process (AHP) was employed because of its accuracy, simplicity, and theoretically robust capability for handling both numerical and non-numerical measurements [26], as well as its ability to embrace real-world factors in the model. The common problem with valuation, especially in developing countries, is limited or non-availability of land value data [23] that could affect MRA results. Hence, the AHP is used in the current study instead of MRA. The spatial layers are stored in the database and processed in GIS software, while Python scripting is used to automate geoprocessing task, thus minimizing human intervention. The overall workflow of iLVM development is presented in Figure 1.

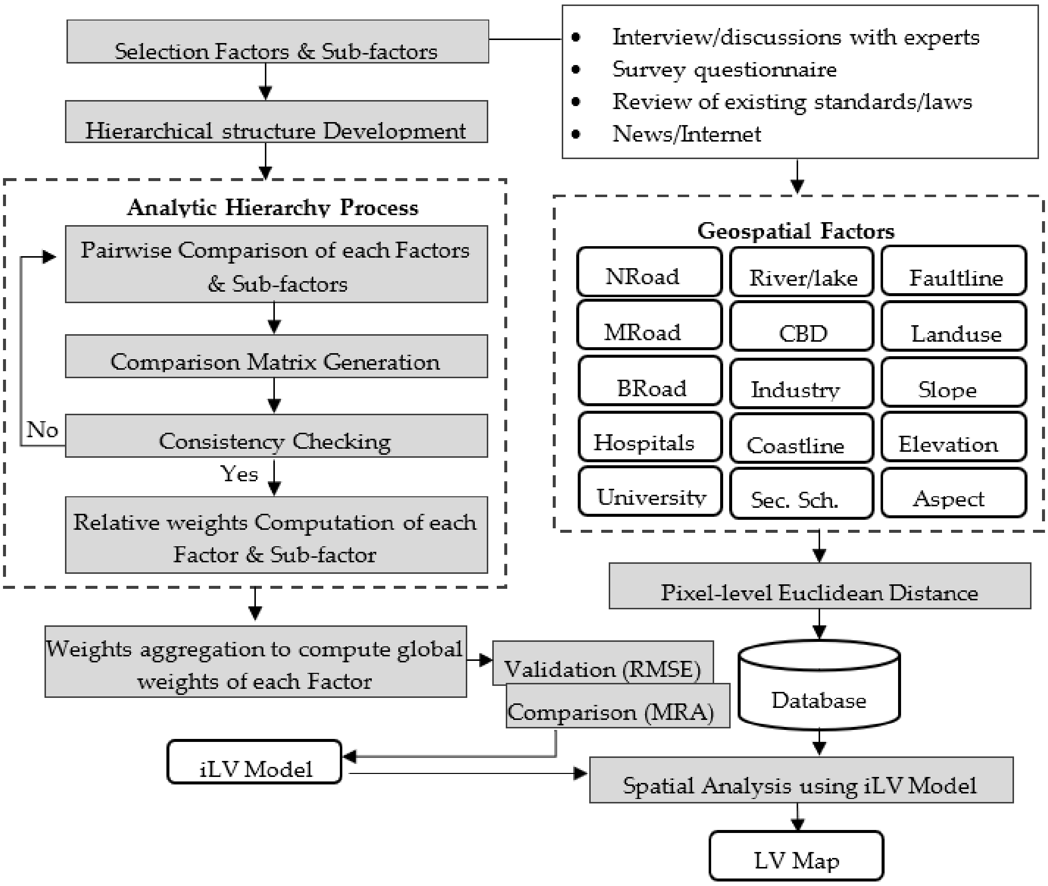


Figure 1. Overall workflow of the innovative land valuation model (iLVM) development. NRoad: national road; MRoad: municipal/city road; Broad: barangay road; CBD: central business district; Sec. Sch.: secondary school; RMSE: root mean square error; MRA: multiple regression analysis; LV Map: land value map.

In the scenarios of the Philippines, national roads (highways) form the main land transportation system that connects the country's three major island and provides access to major population centers. These roads are further complemented with provincial roads, municipal or city roads, and barangay roads that respectively provide interconnectivity among cities and municipalities (not traversed by national roads), within a municipality or city, and on interior barangays or villages [27].

2.1. Analytic Hierarchy Process

The analytic hierarchy process is the most popular multicriteria decision-making method that quantitatively measures the expert's opinion in the form of weights [26]. The AHP process initially involves a pair-wise comparison matrix wherein the relative dominance of each factor (or sub-factor) is compared with respect to the common variable. The consistency of derived weights (eigenvectors) is checked by calculating consistency ratio [20].

Despite criticism pinpointed by other scholars, the AHP remains the commonly used in many research fields and practical applications [28]. This is because the AHP: (1) overcomes human difficulty in making simultaneous judgment among factors to be considered in the model; (2) is relatively simple as compared to other MCDA methods; (3) is flexible to be integrated in various techniques such as programming, fuzzy logic, etc.; and (4) has the ability to check consistency in judgement [26].

2.2. Geospatial Land Valuation Factors for iLVM Development

The 15 factors finally selected during survey, interview, and review of existing standards and literature, were grouped as physical, social, economic, environmental, and legal accordingly to a developed hierarchical structure (Figure 2). The physical factors refer to the physical attributes of land such as elevation, slope, aspect, and land use. Environmental factors describe the susceptibility of land to hazards such as flood (proximity to river), earthquake (nearness to the active fault zone), air pollution (proximity to industry), and storm surge (proximity to coastline). Social factors are the benefits for the society the land may bring due to its location relative to roads, hospitals, schools, and rivers (amenity benefits). Economic factors are economic benefits of the land due to its nearness to the shopping centers, factory/industry, and coastline. Legal factors are the legal constraints of the land such as permitted land use, salvage zone and other restrictions. The coastline is categorized as economic because of the business establishments are found along the beach area. In each factor, the raster layer of 2-m pixel resolution is generated using the Euclidean distance tool.

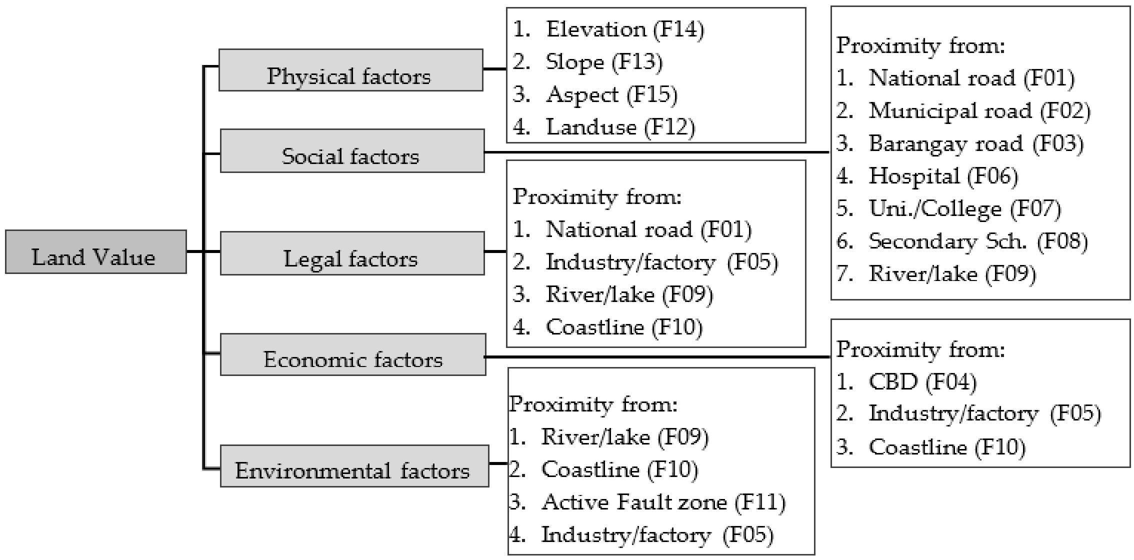


Figure 2. Geospatial factors included in the iLVM development. CBD: central business district.

2.3. Hierarchical Modelling

After the 15 factors were identified and categorized as mentioned in the previous section, assigning of relative weights of the first hierarchy (i.e., physical, social, economic, environmental, and legal) was then performed (Figure 3). In a similar manner, the relative weights of the second hierarchy (i.e., 15 subfactors) in each factor-category were also computed. In both processes, the AHP was used to derive the relative weights of each factor-category and subfactor.

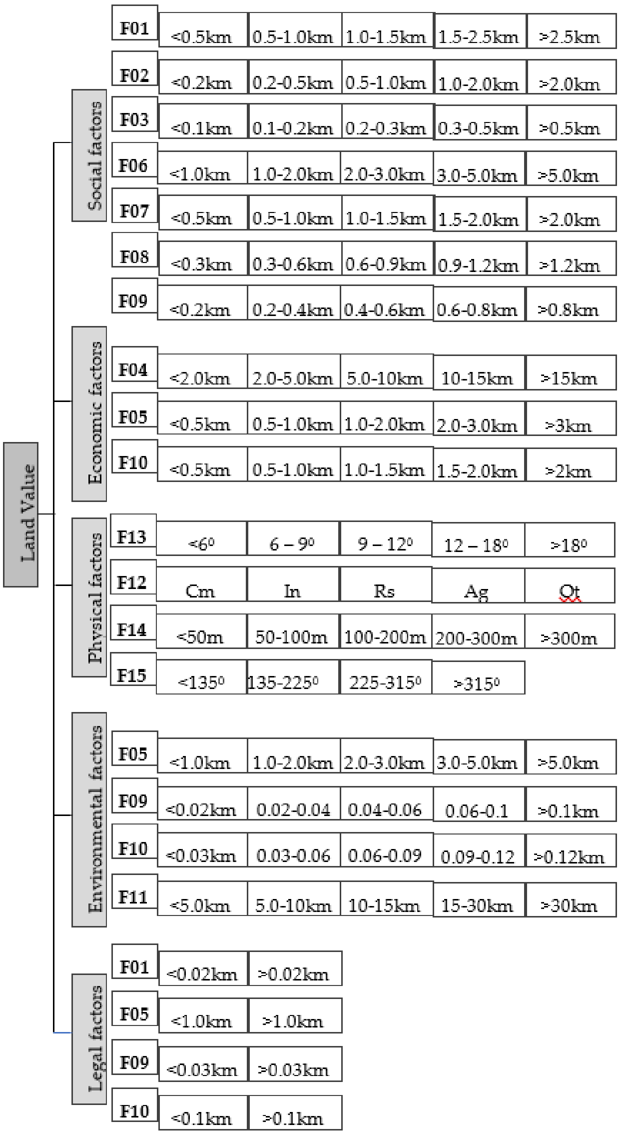


Figure 3. Hierarchical structure of land valuation geospatial factors and sub-factors. F01: national road; F02: municipal/city road; F03: barangay road; F04: CBD; F05: industry; F06: hospitals; F07: university; F08: secondary school; F09: freshwater; F10: coastline; F11: faultzone; F12: landuse; F13: slope; F14: elevation; F15: aspect; Cm: commercial; In: industrial; Rs: residential; Ag: agricultural; Ot: other land uses such as forests, open space, etc.

2.4. Scoring of Sub-Factors

Each sub-factor was classified and assigned score of 0 to 5, with 5 being highest effect on land value and 0 meaning no effect (Table 1). The classifications (i.e., distances, elevation threshold, etc.) are based on the expert's advice (i.e., for economic and social factors), existing laws and standards (i.e., legal factors), and news (i.e., for environmental factors).

Table 1. Scores of land valuation sub-factors.

Land Value	Code	Name	Unit	SCORE 5	4	3	2	1	0
Social	F01	National Road	km	<0.5	0.5-1.0	1.0-1.5	1.5-2.5	2.5-3.0	>3.0
Social	F02	Mun/City Road	km	<0.2	0.2-0.5	0.5-1.0	1.0-2.0	2.0-2.5	>2.5
Social	F03	Barangay Road	km	<0.01	0.1-0.2	0.2-0.3	0.3-0.5	0.5-1.0	>1.0
Social	F06	Hospitals	km	<1.0	1.0-2.0	2.0-3.0	3.0-5.0	5.0-5.5	>5.5
Social	F07	University	km	<0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	>2.5
Social	F08	Secondary Sch.	km	<0.3	0.3-0.6	0.6-0.9	0.9-1.2	1.2-1.5	>1.5
Social	F09	Freshwater	km	<0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	>1.0
Economic	F04	CBD	km	<2.0	2.0-5.0	5-10.0	10-15.0	15-20.0	>20.0
Economic	F05	Industry	km	<0.5	0.5-1.0	1.0-2.0	2.0-3.0	3.0-3.5	>3.5
Economic	F10	Coastline	km	<0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	>2.5
Physical	F12	Landuse	-	Cm	In	Rs	Ag	Ot	-
Physical	F13	Slope	°	<6	6-9	9-12	12-18	>18	-
Physical	F14	Elevation	m	<50	50-100	100-200	200-300	300-500	-
Physical	F15	Aspect	°	<135	-	135-225	225-315	>315	-
Environmental	F05	Industry	km	>5.0	3.0-5.0	2.0-3.0	1.0-2.0	<1.0	-
Environmental	F09	Freshwater	km	>0.1	0.06-0.1	0.04-0.06	0.02-0.04	<0.02	-
Environmental	F10	Coastline	km	>0.12	0.09-0.12	0.06-0.09	0.03-0.06	<0.03	-
Environmental	F11	Faultzone[1]	km	>30	15-30.0	10-15.0	5.0-10	<5.0	-
Legal	F01	National Road	km	>0.02	-	-	-	<0.02	-
Legal	F05	Industry	km	>1.0	-	-	-	<1.0	-
Legal	F09	Freshwater	km	>0.03	-	-	-	<0.03	-
Legal	F10	Coastline	km	>0.1	-	-	-	<0.1	-

[1] 100-m (both side) from active Faultline, based on [29] study.

2.5. Evaluation of Judgement Consistency and Validation of iLVM Performance

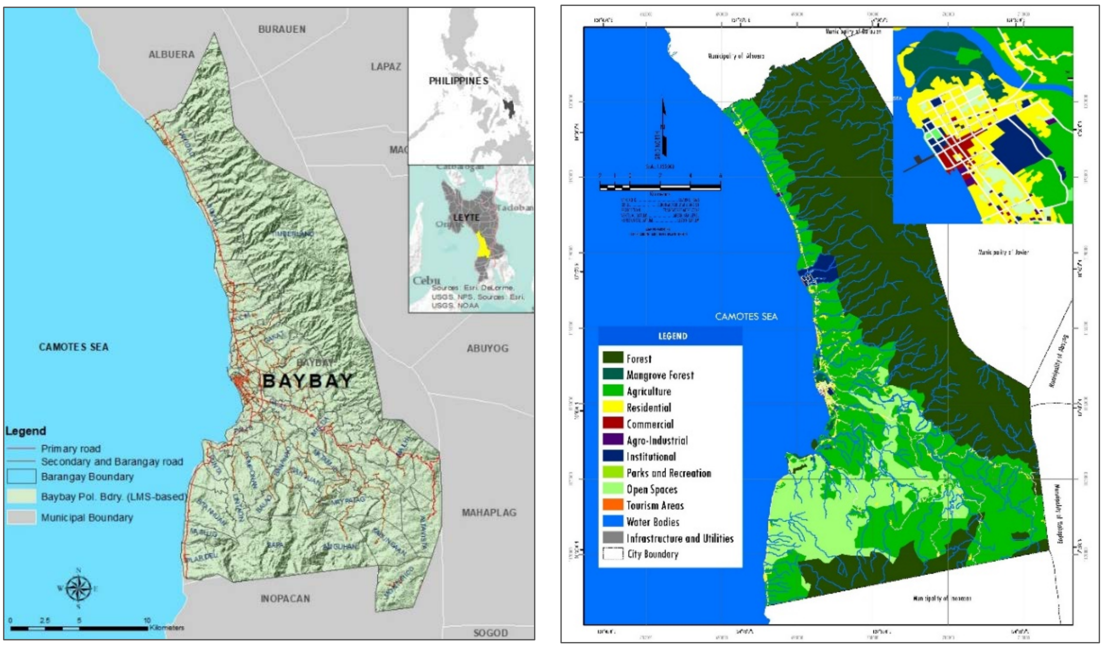
The consistencies of the judgement are checked if it meets the allowable limit, that is, 0.1 or less [30]. On the other hand, the validation involves two steps: (1) conversion of weights into monetary unit (i.e., Philippine currency), and (2) RMSE computation. The numerical values derived from AHP are still relative index, ranging from 1 to 5. Hence, it is necessary to convert these values into monetary terms to compare it with the market values. The transformed values, that represent the land market value in Philippine currency (i.e., PhP), were then compared to 118 collected samples, from which the RMSE was determined. Performance of the developed iLVM was further compared to MRA, a well-known valuation method.

3. Data and Case Study

3.1. Study Area: Baybay City, Philippines

Philippines is one of the developing countries in Southeast Asia. The country is further administratively divided into 17 regions, with each region composed of provinces. Each province is divided into cities and municipalities (or towns), and municipalities into barangays. Baybay City is the second largest city and largest town in the province of Leyte in terms of area and population. It is a coastal municipality in the province, consisting of 92 barangays, 10 of which are urban barangays, and the remaining 82 are rural. According to the 2015 census, there were 109,432 inhabitants [31]. Its GIS-based computed area is 40,375 hectares as per Political Survey, Land Management Bureau record, of which approximately 40% are alienable and disposable (Figure 4). Most of the areas are described as undulating to steep slopes, while the remaining flat areas are dominantly located in coastal areas. In terms of economy, agriculture is the common livelihood however, large portion of the city's revenue were derived from business establishments [32].

In the context of mass appraisal, more than 75% of the provinces and at least 80% of the cities are still using outdated land market values [32]. Lack of sales data that delays the valuation process and absence of standards are among the pinpointed reasons. In fact, most municipalities are adopting manual valuation despite their awareness on the inconsistency and lack of transparency of such method. Baybay City was chosen to be the case study area because of four reasons: (1) it is a sub-urban area, (2) as a newly established city, Baybay has undergone rapid infrastructure development, making it more difficult to update land values, (3) it is one of the 80% of cities that are still using outdated market land values, and (4) assessors are still employing the manual valuation method.



(**a**) (**b**)

Figure 4. Map of Baybay City, Philippines. (**a**) The location of Leyte Province and Baybay City per DENR-LMB record. (**b**) The existing land use map of Baybay City, Philippines as per Baybay City Local Government Unit, 2010.

3.2. Data and Preprocessing

Most of the secondary data were collected from Philippine government agencies (Table 2). There are 9070 cadastral parcels, in local coordinate system. For uniformity, all spatial data were transformed into the Philippine Reference System 1992 (PRS92) coordinate system. In addition, the coastline was extracted from Landsat OLI using McFeeters (1996) Normalized Difference Water Index.

The primary data and other relevant information were gathered in four phases. First, an initial in-depth interview with the agencies involved in land valuation was conducted to aid in the composition of survey questionnaire. Second, in-person and online discussions with real estate appraisers, assessors, and environmentalist were also performed to seek advice on both classification and scoring of sub-factors. Next, another survey questionnaire was prepared for residents that aimed to supplement sales data and determine land market value in their locality. Lastly, existing laws and standards, newspapers, and the Internet were reviewed as well to acquire relevant information related to environment and legal aspects.

Table 2. Description and sources of secondary data used in the study.

Data Description	Sources	Format
1. Landuse based on the LU Plan	Local Government Unit, Baybay City	Map
2. IfSAR DEM [1]	Dept. of Science and Technology, Philippines	Raster
3. Hospital location	Dept. of Health, Philippines (www.doh.gov.ph) Google maps	Shp [2]
4. Road network	Dept. of Public Works and Highways, Philippines Local Government Unit, Baybay City; Local Government Unit, Baybay City; Open Street Map; Google Satellite Image	Shp [2]
5. Schools	Commission on Higher Education, Philippines (www.ched.gov.ph); www.gov.ph; Google maps	List/Shp
6. Freshwater	PhilGIS (www.philgis.org)	Shp [2]
7. Center Business Center	Local Government Unit, Baybay City	Map
8. Industries	Local Government Unit, Baybay City;	Map
	Open Street Map, Google Satellite Image	Shp [2]
9. Landsat OLI8, P113/R52-53	https://earthexplorer.usgs.gov/ (for coastline)	Raster
10. Active Fault Line	PHIVOLCS http://faultfinder.phivolcs.dost.gov.ph/	Shp [2]
11. Sales data (2013–2015)	Local Government Unit, Baybay City	List
12. Cadastral Lot	DENR-Land Management Bureau, Philippines	CAD

[1] IfSAR DEM: Interferometric Synthetic Aperture Radar Digital Elevation Model; [2] Shp—shapefile.

4. Results

4.1. Weights of Main Factors and Sub-factors

The current study identified 15 factors in the LVM development. These factors were grouped into five categories and each category was assigned weights using the AHP method with the aid of expert advice. Further, sub-factor of each category was weighted also with the AHP. The pair-wise comparison and weights of the main factors (Table 3) and sub-factors (Table 4) are shown along with the respective consistency ratio (CR) value. In all cases, CR value is less than 0.10; this implies judgements are consistent and hence weights are acceptable.

Table 3. Pair-wise comparison and weights of main factors.

	Physical	Social	Economic	Environment	Legal	Weights
Physical	1	1/3	1/2	2	4	0.184
Social	3	1	3	3	5	0.432
Economic	2	1/3	1	2	2	0.201
Environment	1/2	1/3	1/2	1	1	0.101
Legal	1/4	1/5	1/2	1	1	0.082
			CR = 0.06			

Table 4. Pair-wise comparison and weights of sub-factors.

a. Physical factors

	F13	F14	F15	F12	Weights
F13	1	2	3	1/3	0.237
F14	1/2	1	2	1/3	0.151
F15	1/3	1/2	1	1/6	0.080
F12	3	3	6	1	0.532
			CR = 0.02		

b. Legal factors

	F01	F05	F09	F10	Weights
F01	1	1	3	1/2	0.265
F05	1	1	2	1	0.275
F09	1/3	1/2	1	1/2	0.128
F10	2	1	2	1	0.332
			CR = 0.05		

c. Social factors

	F01	F02	F03	F06	F07	F08	F09	Weights
F01	1	2	3	1	2	1	5	0.223
F02	1/2	1	1	1/2	1/3	1	4	0.113
F03	1/3	1	1	1	2	1	4	0.145
F06	1	2	1	1	3	2	5	0.220
F07	1/2	3	1/2	1/3	1	1/2	3	0.119
F08	1	1	1	1/2	2	1	2	0.139
F09	1/5	1/4	1/4	1/5	1/3	1/2	1	0.041
				CR = 0.07				

d. Economic factors

	F04	F05	F10	Weights
F04	1	3	2	0.539
F05	1/3	1	1/2	0.164
F10	1/2	2	1	0.297
		CR = 0.01		

e. Environmental factors

	F05	F09	F11	F10	Weights
F05	1	1	1/2	1	0.204
F09	1	1	1/2	1	0.204
F11	2	2	1	1	0.346
F10	1	1	1	1	0.246
			CR = 0.02		

4.2. The Developed iLVM and Its Perfomance

With the computed weights, the LVM′ general Equation (1) was derived to produce a single layer necessary to produce a land value map. Since the numerical values computed from Equation (2) have no physical unit except that they only show the relative land values in the study area, these values were further converted into market values for proper validation and comparison. There were 118 items of market data (min = 1.50; max = 35,000) used to evaluate the developed model. Market data that represent land value (in the current study) were transformed into logarithmic form (base 10) to address skewed data [33]. Then, a linear relationship between AHP and market values was assumed [34], initially with an RMSE of 0.547. It was found out that errors occurred at extreme AHP values (i.e., upper ends); then the model was further improved into a more complex expression presented in Equation (2) with an improved RMSE of 0.526.

$$LVM' = W_P \sum Wi_p Fi_p + W_S \sum Wi_S Fi_S + W_E \sum Wi_E Fi_E + W_R \sum Wi_R Fi_R + W_L \sum Wi_L Fi_L \quad (1)$$

where W_P, W_S, W_E, W_R, and W_L are the respective main weights of the physical, social, economic, environmental, and legal factors; W_i represents the weights of ith sub-factors F_i.

$$LVM = \begin{cases} 10^{-0.5335 + 1.2023 LVM'} ; & LVM' \leq 2.0 \\ 10^{-0.1858 + 3.012 ln(LVM')} ; & LVM' > 2.0 \end{cases} \quad (2)$$

where LVM is the land value per square meter in the Philippine Peso (PhP). LVM′ is computed using Equation (1).

The model is evaluated with root-mean-square error (RMSE) and compared with MRA. Figure 5 shows the visual representation of the model performance, with (a) being the fitted line plot between the actual and predicted value, and (b) being residual plot of the predicted value. Table 5 presents the statistics summary of the model in comparison to MRA.

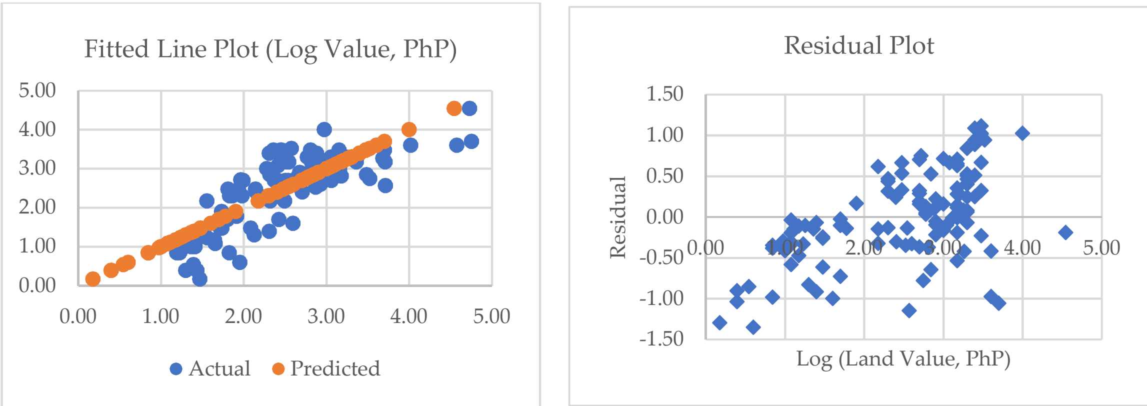


Figure 5. (**a**) The fitted line plot of log land value, and (**b**) the residual plot of log value (Philippine Peso, PhP).

Table 5. Model statistics summary and significant valuation factors of iLVM and multiple regression analysis (MRA). RMSE: root mean square error.

Model	RMSE	Significant factors
iLVM	0.526	All considered
MRA	1.953	F11, F13, F14, F12 [1]

[1] Significant at $p < 0.05$ level of significance.

4.3. LV Map of Baybay City, Leyte

Raster layers (2-m resolution) of the 15 factors (Figure 6) were generated using Euclidean distance tool. The LV map was generated through arithmetic operations in accordance with Equation (1) and Equation (2) to merge 15 layers into a single layer. In order to derive parcel-level value, the shapefile of 9072 cadastral lots was superimposed over the generated pixel-level map, from which zonal statistics by mean were then determined. The final LV map, shown in Figure 7(a), shows the seven classes of land values for straightforward analysis, and was compared with the barangay category map (Figure 7(b)). Figure 6(a) indicates the 9072 parcels, 984 of which are inside urban barangays, and 2209 of which have rural high population density. The rest have a rural low population density.

5. Discussions

The relative importance or weights of the five main factors is indicated by the real estate experts in the Philippines. It is apparent (Table 3) that the social aspect (weight 0.432) is the most important factor that influences land value, while economic and physical factors are moderately important (Weight ~ 0.2) in valuing land. This indicates that accessibility nevertheless matters above all in valuing land, as also reported by previous studies (e.g., [2] and [35]). It is important to note here that the social factor comprises other factors that give benefits to society, such as accessibility to road and basic amenities. The economic factor represents benefits brought by factors due to the proximity to economic development like business centers. The physical factor refers to physical attributes

(Section 2.2). In other words, these top three factors are regarded as positive influence. On the other hand, the environment (weight ~ 0.1) is a comparatively less important factor in valuing land. This is quite realistic because in general, people in the economic industry do not focus much on negative externalities but rather on accessibility and economic benefits. One study [36], for example, reported that closeness to a fault line is not considered in the valuing of land near the West Valley Fault System in Philippines. Also, the legal aspect is regarded as the least important factor affecting land value, perhaps due to lack of law enforcement.

The most influential sub-factors (Table 4) for the physical, legal, social, economic, and environmental factors are F12 (land use, weight 0.532), F10 (coastline, weight 0.332), F01 (national road, weight 0.223), F04 (CBD, weight 0.539), and F11 (fault zone, weight 0.346), respectively (Table 4). As shown, there is huge disparity of weights among sub-factors under the physical and economic factors, while the weights are nearly evenly distributed for legal, environmental, and social sub-factors.

In terms of final model performance, the RMSE of the developed model when compared to actual data was found to be 0.526, which outperformed the MRA (RMSE = 1.953). The significant factors as identified by MRA are active faultlines (F11), slope (F13), elevation (F14), and land use (F12). The MRA result, in the current study, contradicts the generally accepted principle that accessibility affects land value [2,37] among all factors. On the other hand, the statistics summary of the iLVM, that is, low RMSE, Adj.R^2 = 0.673 and zero average residuals, indicates good fits without bias, and that around 67% of the variability is explained in the model (Figure 5(a)). However, large residuals ($e > |1.0|$) are noticeable, causing the predicted value to be under or over predicted (Figure 5(b)). When examined further, some commercial areas are overvalued because a linear relationship between AHP points and market value was assumed. In any case, the developed LVM is acceptable.

Visual inspection was also performed to check distribution of high and low values by using the generated land value (LV) map from the iLVM. After analysis, it was found out that there were 928 parcels with an estimated value of ≥PhP 10,000 per square meters, around 45% of which fell inside the urban barangay, while there was a large number (~43%) of parcels coinciding under rural high population density (i.e., ~300 persons/ha) areas. According to the Comprehensive Land Use Plan of Baybay City, such a high population density barangay must be classified as an urban area. In general, the result shows that about 85% of high-valued parcels are commercial establishments and service industries, while low values are found for agricultural areas.

The result implies that the developed iLVM is acceptable. It is objective, i.e., transparent, consistent, and flexible to update with respect to time and locality conditions. However, caution must be also exercised when employing the AHP since the model accuracy is highly dependent on the secondary data (i.e., geospatial factors). In any case, with the advent of free publicly spatial data such as Open Street Map, Google Map, and Google Satellite images, updating these data is no longer an issue. It is therefore safe to say at this point that multi-decision criteria analysis with the AHP can be a perfect tool for improved land valuation processes.

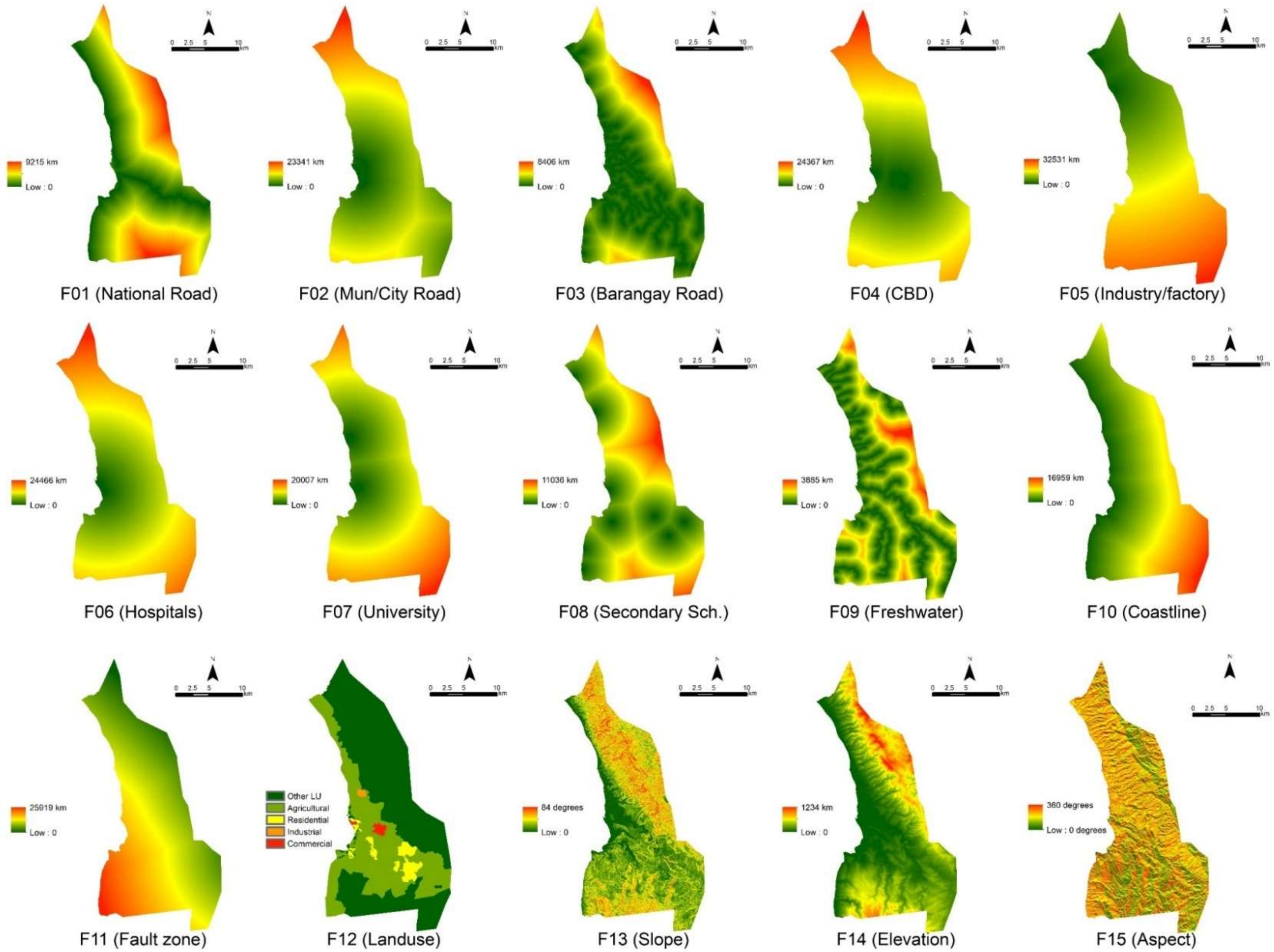


Figure 6. Raster layers of 15 geospatial factors considered in the iLVM development.

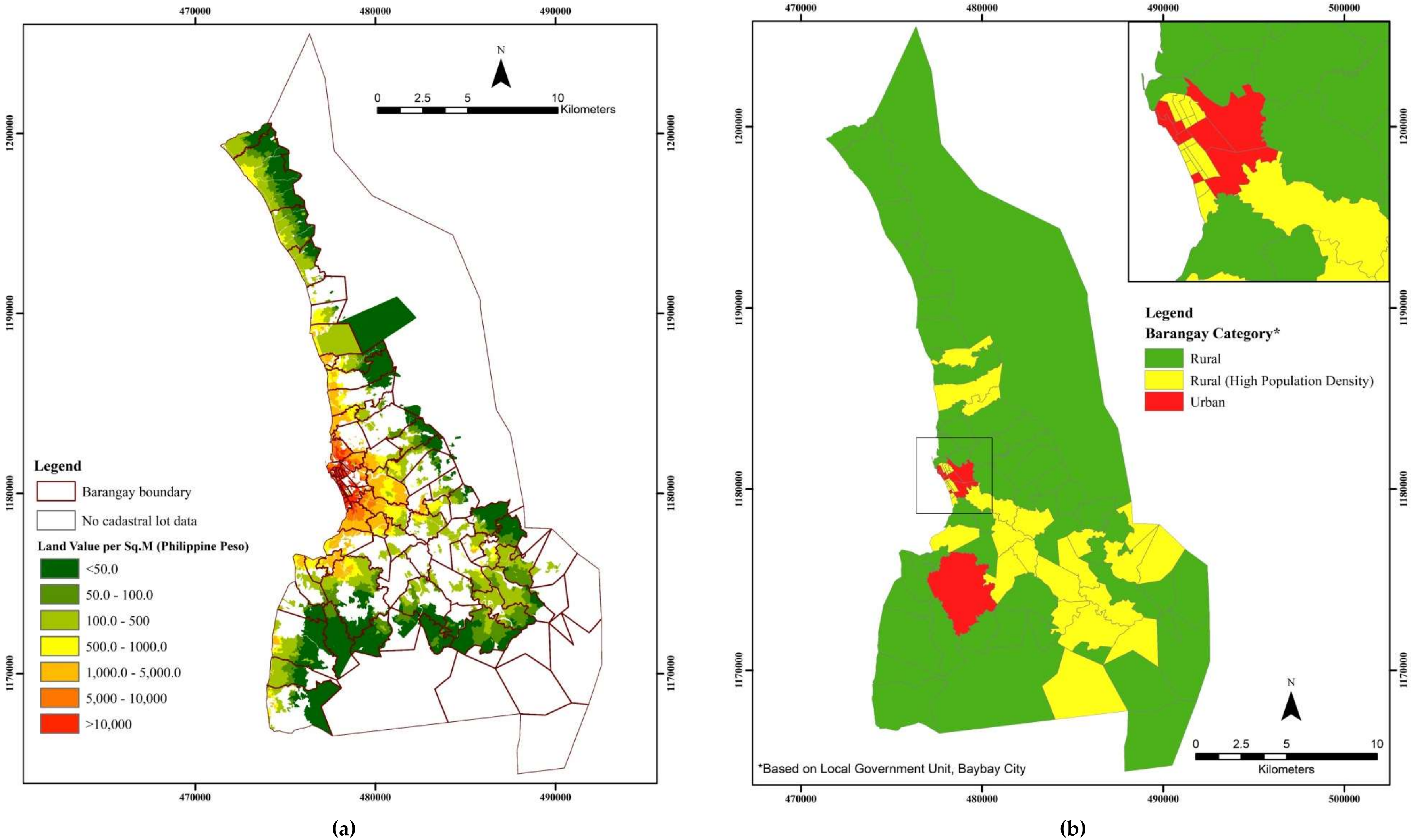


Figure 7. (**a**) Land value map of Baybay City at parcel-level. (**b**) Barangay map categorized as rural, rural (high population density), and urban per Baybay City Plan.

6. Summary and Conclusions

The need for consistent, transparent, realistic, and updated land valuation is essential in all aspects of land administration, especially when it involves numerous land parcels. The goal of the current study is to involve experts in various development phases of the innovative land valuation model (iLVM). The initial stage of the study involved interview with different land-related agencies to identify valuation factors and to assist in drafting of the survey questionnaire. Next, in-person and online discussions with land and environment experts were conducted to seek advice on both classification and scoring of 15 factors. Then, another survey questionnaire was prepared for residents that aimed to supplement sales data and determine land market value in their locality. Lastly, existing laws and standards, newspapers, and the Internet were reviewed to acquire relevant information related to environment and legal aspects.

The characteristics of land in terms of its proximity to national road, municipal road, barangay road, hospital, university, secondary school, CBD, industry/factory, freshwater, coastline, land use, and an active fault zone as well as its internal features such as land use, elevation, slope, and aspect were extracted through Python scripting and passed to spreadsheets for analysis. In addition, further spatial statistical analysis and preparation of final value map were performed in ArcGIS. These factors are gathered in groups as economic, physical, social, environmental, and legal factors, wherein the former three are considered as positive while the remaining two as negative with respect to their influence on land value. The analytic hierarchy process was employed to weigh the 15 factors in terms of their influence on land value. Actual market values were used to validate the model through a case study in Baybay City, Leyte. The root mean square error was used to compare model performance with MRA (RMSE = 1.953).

The result shows that iLVM outperformed (RMSE = 0.526, Adj. R^2 = 0.673) the MRA. The RMSE was used to evaluate because it reports the absolute fit of the model to the data or the closeness of the actual value with the predicted values. In other words, the RMSE is absolute measure of fit, while the R-squared is relative measure. As shown, the iLVM performance is comparable to other methods such as the MRA [2] (Adj. R^2 0.80), GWR [15] (Adj. R^2 0.541), and the spatial Bayesian [14] (Adj. R^2 0.652), among others. It is also evident in the final LV map of Baybay City that parcels with high values are distributed in urban areas where commercial establishment are present, while low-valued parcels are in agricultural/or forested areas. This implies that iLVM is acceptable. Apart from better accuracy, other strengths of this approach over existing methods (e.g., [2]) are: (1) the involvement of several land experts in various phases of development (it is logical, transparent, and realistic); (2) factors are assigned weights in objective way and are hence consistent; and (3) the technique needs little market data, which is the usual valuation problem [13] and is hence practical.

The drawback of the current approach is that it is less objective than the regression-based technique (e.g., [38,39], etc.) but this could be a good alternative of asset valuation [20] especially when there is necessity for a high level of transparency and consistency such as land-related government transactions [2], and when it involved numerous parcels (i.e., mass appraisal). Therefore, the study concluded that AHP could be a perfect tool for property valuation, and that the performance of AHP-based valuation can be well-supplemented with existing free publicly data (valuation factors) to achieve desirable results.

The developed model can be applied in other sub-urban areas of the Philippines with few adjustments on transforming AHP points to market value. Since the legal factors or conditions set in this study were based on the laws of Philippines, the iLVM may be modified slightly for application in other sub-urban areas.

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