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REPORT

Measuring Sustainability Based Upon Various Perspectives: A Case Study of a Hill Station in Southeast Asia

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Abstract A hill station is a town or city situated in mountain regions in the tropics founded during the western colonization in the nineteenth and early twentieth centuries. Hill stations have moderate temperatures, and are known for their relatively good natural environments, which generate valuable ecosystem services that benefit the local population. However, rapid urbanization threatens the sustainability of these areas. This study evaluates the sustainability of the urbanization process of Baguio City, a hill station city in Southeast Asia and the summer capital of the Philippines, by determining the relationship between its velocity of urbanization and velocity of urban sustainability based upon various perspectives. From an equal weight perspective (of the triple bottom line of sustainability components, namely environmental, social, and economic) and a pro-economic perspective, the results revealed that the urbanization of Baguio City has been moving toward a "sustainable urbanization." However, from the environmental and eco-sustainable human development perspectives, the results indicated that it has been moving toward an "unsustainable urbanization." The paper discusses the implications of the findings for the planning of sustainable development for Baguio City, including some critical challenges in sustainability assessment and the applicability of the framework used for future sustainability assessments of the other hill stations in Southeast Asia.

Keywords Baguio · Hill station · Human–environment system · Sustainable development · Social–ecological system · Sustainable urbanization

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INTRODUCTION

Urbanization has brought improvements to social welfare and economic development, while cities have been playing important roles in our society, e.g., as a symbol of creativity, imagination and power of humanity, the cradles of innovation and knowledge creation, the heart of sociocultural transformations, and engines of economic growth (Wu 2010). Yet, urbanization is one of the many human activities that have a serious impact on the natural environment, both locally and globally (Grimm et al. 2008; Wu 2010; Seto et al. 2011). Urban areas now contain about half of the world's population; yet they cover less than 3 % of the earth's terrestrial surface, and are responsible for approximately 80 % of greenhouse gas emissions and 75 % of global energy consumption (MA 2005; UN 2010). This dualistic nature of urbanization (Wu 2010) should be balanced and must form part of the sustainability goal of humankind.

Poor urban development planning can lead to many negative socio-economic impacts (e.g., poor quality of life) (Bloom et al. 2008), while urbanization itself is arguably the most drastic form of land transformation that results in irreversible landscape changes. The three components of the triple bottom line of sustainability (TBLS), namely environmental, social, and economic, represent a nested hierarchy as societies cannot thrive without a functioning life-support system; and without functioning social structures and institutions, economies cannot flourish (Fischer et al. 2007; Mori and Christodoulou 2012). Based on these structural relationships, a sustainable city or community must achieve a balance among environmental protection, social well-being and economic development (PCSD 1997; Wu 2010). Proper landscape and urban planning might help in the attainment of sustainable urbanization.

Sustainable urbanization is an important component and an indispensable part of sustainable development (UN-Habitat/DFID 2002; Shen et al. 2012; Liu et al. 2013). It refers to the well-balanced relationship between environmental, social and economic aspects of society, and aims to achieve sustainable urban development (Drakakis-Smith 2000). In brief, sustainable urbanization is characterized by an urbanization process that satisfies the principles of sustainable development (Roy 2009). Sustainable development, also known as ecologically sustainable economic development, is a "…development that meets the needs of the present, without compromising the ability of future generations to meet their own needs" (WCED 1987, p. 43). However, critical challenges exist in achieving sustainable urbanization, including the divergence between: economic growth and environmental sustainability; economic sustainability and poverty reduction; inequity and exclusion; infrastructure deficiencies; agencies' inadequate governance capabilities; and a realization of the benefits of interdependence between rural and urban areas (UN-Habitat/DFID 2002).

Urban sustainability assessment plays an important role in proper landscape and urban planning toward sustainable urbanization. It evaluates the rate, direction and potential impact of urbanization on ecosystem conditions, ecological capacity and the socio-economic well-being of people. It can provide vital information to policy makers and planners in the pursuit of sustainable urbanization. The effects of sustainability policies and development plans on the urban environment can be revealed through indicators (Munier 2005). Therefore, indicators are important in the monitoring and evaluation process of the progress, direction and impacts of sustainability goals (Newman and Jennings 2008).

However, there exist critical challenges in measuring urban sustainability, including proper selection of relevant indicators and methods for measurement. The body of literature on coupled human–environment systems and sustainability science has grown very rapidly. Yet, there has been no standard that requires and specifies the indicators to be used for measuring urban sustainability. This is because different practices adopt different indicators according to their own purpose of evaluation and definition of sustainability (Alberti 1996; Singh et al. 2009; Shen et al. 2011). There is, however, a growing consensus that the environmental, social and economic components of the TBLS must be considered in the evaluation of urban sustainability, and therefore, indicators for each component are necessary (e.g., Alberti 1996; Zhang 2002; van Dijk and Zhang 2005; Scipioni et al. 2009; Singh et al. 2009; Shen et al. 2011; Liu et al. 2013).

"Despite the sustained economic growth of Asian economies in the recent decades, urban poverty, inequality, slums, poor urban environmental quality and liveability, worsening disaster risks and effects of climate change pose major development challenges" (Dahiya 2012, p. S44). At the same time, there has been a resurgence of interest in hill stations[1] for "quality environment" and other socio-economic development-related activities, resulting in the rapid urbanization of some, including Baguio City, the Philippines, and Bogor, Indonesia (Crossette 1999; Estoque and Murayama 2013a). Hill stations are known for their relatively good natural environments, which generate valuable ecosystem services that benefit the local population. However, rapid urbanization affects the fragile natural environment and threatens the sustainability of these areas.

There are still very few studies that assess the state and direction of urbanization in the hill stations of Southeast Asia within the context of sustainable development. Hence, this study evaluates the sustainability of the urbanization process of Baguio City, the Philippines. Once planned as a convalescence-cum-recreation center and a highland refuge to escape from "tropical fatigue," Baguio City is now a highly urbanized multifunctional city. Baguio City has been playing two major roles: (1) as a center that stimulates economic prosperity in the Cordillera Administrative Region (CAR) in Northern Philippines; and (2) as a niche with rich historical and cultural heritage, and an endangered natural landscape that is of national significance and which needs to be protected, preserved and developed in a sustainable manner. The ultimate challenge is how to fulfill these roles harmoniously. Recognizing the importance of these roles and with the aim of gaining comprehensive understanding of the state and direction of Baguio City's urbanization, this study measures urban sustainability based upon various perspectives.

MATERIALS AND METHODS

Study Area: Baguio City

Baguio City is situated in the mountainous area of CAR in Northern Philippines (Fig. 1). Although it is geographically located within the Province of Benguet, Baguio City has been functioning independently as a chartered city since 1909. Baguio is a relatively small city with an approximate land area of 57.5 km^2. It has a favorably cool climate owing to its elevation, which ranges from approximately 900 to 1600 m above sea level. Its average temperature is

[1] The term 'hill station' is commonly used to refer to a town or city in the tropics founded by a Western colonial power during the nineteenth and early twentieth centuries. Most hill stations are sited in mountain regions at an altitude between 1000 and 2500 m above sea level, and thus enjoy relatively moderate temperatures than those recorded in the surrounding lowlands.

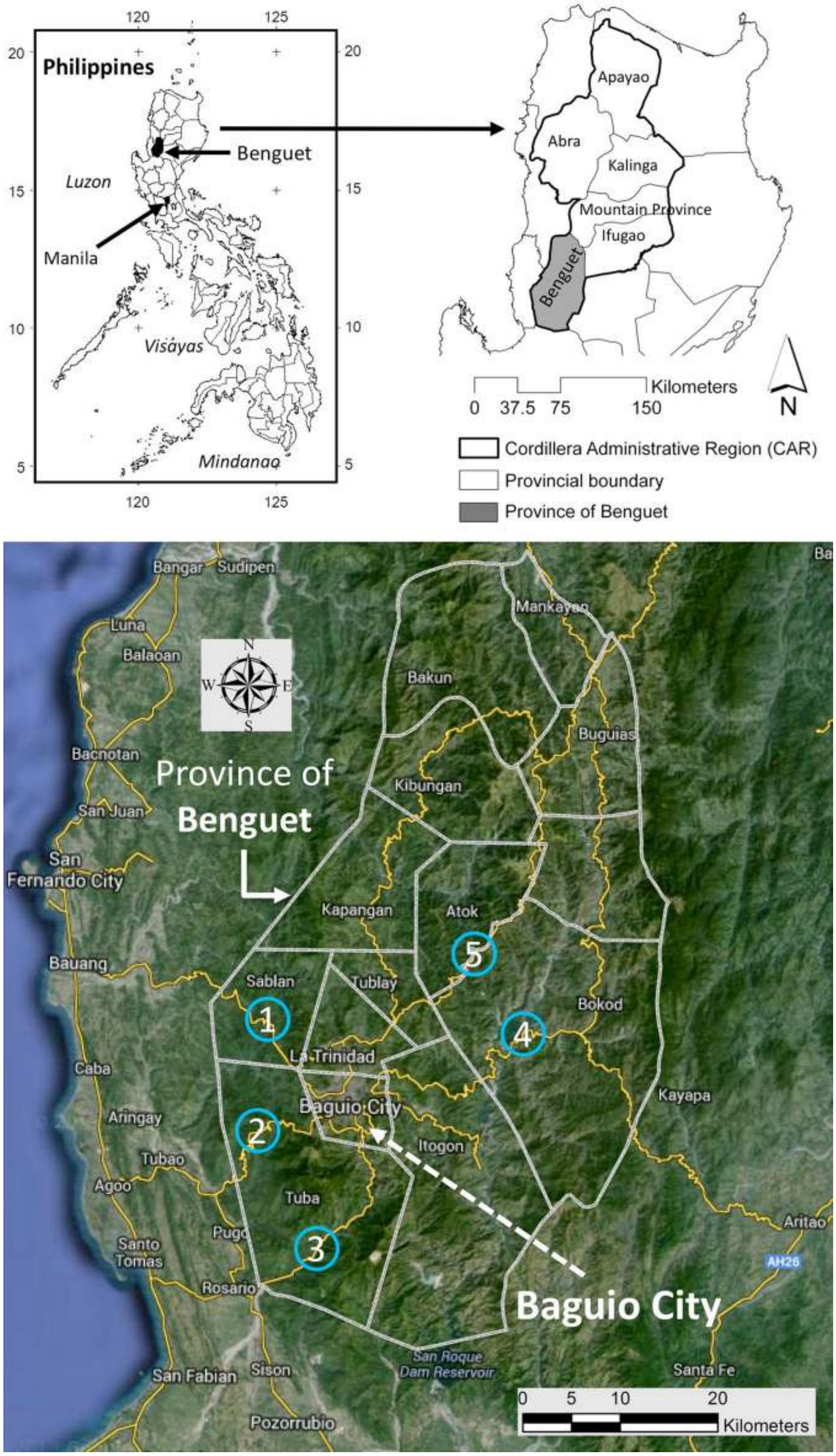

Fig. 1 Location of Baguio City. The *two maps above* show the geographic location of CAR and the Province of Benguet, where Baguio City is located. Access roads: (*1*) Naguilian Road (also known as Quirino Highway); (*2*) the Aspiras-Palispis Highway (formerly known as Marcos Highway); (*3*) Kennon Road (formerly known as Benguet Road); (*4*) Benguet–Nueva Vizcaya Road; and (5) Halsema Highway. *Background image source* (*bottom*): Google Maps

8 °C lower than that in the lowlands, and seldom exceeds the average annual maximum temperature of 26 °C (Saldivar-Sali and Einstein 2007). This characteristic and the once marginally disturbed natural landscape of the area make Baguio City the summer capital of the Philippines and one of the country's main tourist destinations. It is also the regional center of CAR, and the education and health services center north of Metro Manila.

In terms of accessibility, Baguio City can be reached from the western lowland areas via three national roads, and from the eastern part of the city via two other access roads (Fig. 1). In terms of demographic characteristics, the 2000 census reveals that the city has a very young population, with approximately 69 % below 30 years of age (NSO 2003). Baguio's annual population growth rate (APGR) has always been higher than the rate for the whole country. Surprisingly, however, people who are native to the province of Benguet, where Baguio City is situated, only account for approximately 16 % based on the "population by ethnicity" data (NSO 2003). Furthermore, only approximately 24 % of the population came from the whole CAR; instead the Ilocano group dominated the population (circa 45 %), followed by the Tagalog group (circa 21 %). This indicates that there has been a great deal of migration into the city over the past decades. Its accessibility (Fig. 1) might have played a vital role in its growth and development, establishing its centrality, influence and primacy all over Northern Philippines.

As of the 2010 census (NSO 2012), the population of Baguio City had increased from 119 669 to 318 676 since 1980 (Fig. 2). This shows that Baguio's population had grown almost threefold in the past three decades (1980–2010). It was during this period that the urban growth and development of Baguio City accelerated. The epoch considered in this study (i.e., 2000–2010) fall within this period, though there are also some analyses of future projections up to 2020.

Urban Sustainability Assessment

Singh et al. (2009) provide an overview of various sustainability indices applied in policy practice, including a review on sustainability indices formulation strategy, scaling, normalization, weighting, and aggregation methodology. They concluded that in most cases the focus of sustainability assessment is on one of the three aspects of the TBLS (environmental, social and economic). And although there have been many initiatives to measure sustainability, there are still few applications that implement an approach that is capable of integrating the three components of the TBLS (Singh et al. 2009). Shen et al. (2011) provide a comparative evaluation on the application of urban sustainability indicators into various practices. They concluded that "due to the differences between individual practices, the selection of indicators should be done with the clear understanding of the needs where these are going to be applied" (Shen et al. 2011, p. 26).

The assessment of urban sustainability can be initiated by focusing on the TBLS that takes environmental quality, social justice and economic prosperity into consideration (Elkington 1997; Pope et al. 2004). However, recent studies have argued that an indicator for an external environmental impact, called leakage effect, should also be included in the assessment in addition to the components of

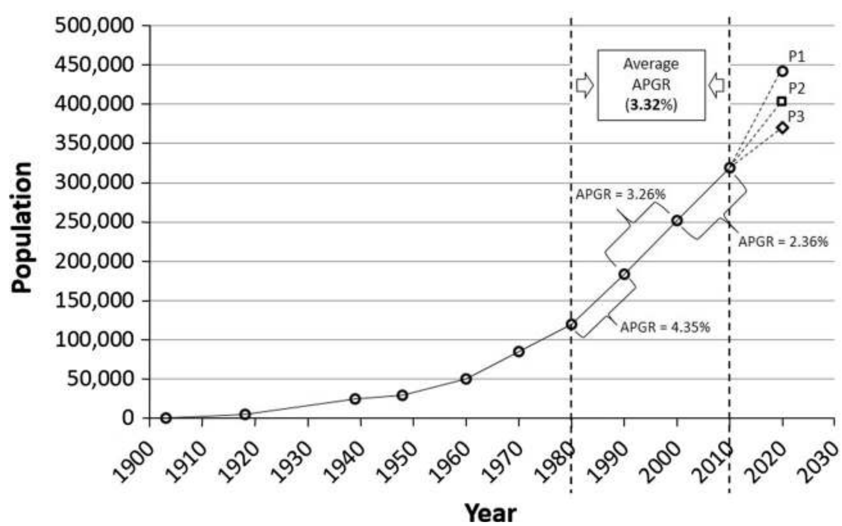

Fig. 2 Population growth of Baguio City. The data used for the indicators of the TBLS are within the 1980–2010 period (between the *two vertical broken lines*). *Note* P1—Projected 2020 population using 3.32 % APGR (1980–2010 average); P2—Projected 2020 population using 2.36 % APGR (most recent); and P3—Projected 2020 population using 1.52 % APGR (determined based on the APGR decrease rate from 1980 to 2010). *Data sources* Estoque and Murayama (2013a) and NSO (2012)

the TBLS (Mayer 2008; Mori and Christodoulou 2012). In their review, Mori and Christodoulou (2012) concluded that among the methods and indices for urban sustainability measurement they reviewed, no single method or index has the capability to simultaneously consider the components of the TBLS and leakage effect. They argued that there is a need for a new index. Shen et al. (2012) proposed a model for evaluating the sustainability of urbanization. The model considers both the velocity of urbanization and velocity of urban sustainability.

This current study recognizes the importance of leakage effect (Mayer 2008; Mori and Christodoulou 2012) and the potential of the concepts of the velocities of urbanization and urban sustainability (Shen et al. 2012) in sustainability assessment. It also argues that there is a need to explore different scenarios, for example, by using various perspectives (e.g., pro-economic and pro-environment), in order to gain a comprehensive understanding of the current state and future direction of the urbanization process. However, a sustainability assessment approach that can take all these aspects (leakage effect, velocities of urbanization and urban sustainability and scenario analysis, in addition to the three components of the TBLS) into consideration at the same time is still lacking. Therefore in this study, a framework for this purpose has been conceptualized and implemented. Using the framework, the sustainability of Baguio City has been assessed following these three steps: (1) determining its velocity of urbanization based on two different indicators, namely ratio of urban population and extent of impervious surface area; (2) determining its velocity of urban sustainability based on various perspectives that take into account leakage effect and the TBLS components; and (3) examining the relationship between its velocity of urbanization and velocity of urban sustainability. The details of each step, including technical definitions, are given in the next sections. The acronyms and abbreviations used in the following measurements are summarized in Table 1.

Table 1 Acronyms/abbreviations and their descriptions used in the measurement of urbanization rate, urban sustainability and their respective velocities

Acronyms/abbreviations	Descriptions
U_R	Urbanization rate
U_{R_1}	Based on urban population
U_{R_2}	Based on the extent of impervious surface area
U_S	Urban sustainability
$U_{S_{en}}$	Based on the environmental component
$U_{S_{so}}$	Based on the social component
$U_{S_{ec}}$	Based on the economic component
U_{S_1}	Based on perspective 1 (the environmental, social and economic components have equal weights)
U_{S_2}	Based on perspective 2 (pro-economic)
U_{S_3}	Based on perspective 3 (pro-environment)
U_{S_4}	Based on perspective 4 (pro-eco-sustainable human development index (E-SHDI))
Vu_R	Velocity of urbanization
Vu_{R_1}	Based on urban population (U_{R_1})
Vu_{R_2}	Based on the extent of impervious surface area (U_{R_2})
Vu_S	Velocity of urban sustainability
$Vu_{S_{en}}$	Based on the environmental component ($U_{S_{en}}$)
$Vu_{S_{so}}$	Based on the social component ($U_{S_{so}}$)
$Vu_{S_{ec}}$	Based on the economic component ($U_{S_{ec}}$)
Vu_{S_1}	Based on perspective 1 (U_{S_1})
Vu_{S_2}	Based on perspective 2 (U_{S_2})
Vu_{S_3}	Based on perspective 3 (U_{S_3})
Vu_{S_4}	Based on perspective 4 (U_{S_4})

Note the details of the four perspectives are given in Table 2

Measuring Urbanization Rate (U_R) and Velocity of Urbanization (Vu_R)

Urbanization is a dynamic process that involves various stages and is usually expressed with an urbanization rate (U_R) (Shen et al. 2012). U_R measures the degree or extent of urbanization at a certain point in time of the urbanization process. U_R therefore defines the stage of urbanization (Henderson and Wang 2004; Shen et al. 2012). It has been argued that the ratio of people living in urban areas to the total population of the study area can be used to measure U_R (Zhang and Song 2003; Shen et al. 2012; Liu et al. 2013). The various stages of the urbanization process include the initial stage, an acceleration stage and a terminal stage: the initial stage represents the earliest phase of the urbanization process until the ratio of the urban population reaches 30 %; the acceleration stage corresponds to the phase where the urbanization process is rapid; while the terminal stage represents the phase where the ratio of urban population is over 70 % (Northam 1975).

This study measured the U_R of Baguio City based on urban population (U_{R_1}) and extent of impervious surface area (U_{R_2}). In the 2000 census, the whole population of Baguio City was already considered to be an urban population (NSO 2003). Thus, for the purpose of measuring U_{R_1}, the ratio of Baguio's population to the whole population of CAR was used. Baguio is the regional center of CAR and the only city in the region before 2011.[2] To

[2] Tabuk, Kalinga is the region's second city. It was first declared as such in 2007, second in 2009, and third in 2011. The first two declarations were both followed by a Supreme Court decision, reverting Tabuk back to the status of a municipality.

Table 2 The building blocks and framework for an urban sustainability assessment of Baguio City

Components relative weights			Triple bottom line components	Indicators	Types	Sources
Perspective 1	Perspective 2	Perspective 3				
0.33	0.25	0.45	Environmental	Ecosystem service value	+	Estoque and Murayama (2012, 2013b)
				Human-to-ecosystem service value ratio	+	Estoque and Murayama (2012, 2013b)
				Ecological footprint (leakage effect[a])	–	Authors' own estimation
0.33	0.30	0.30	Social	Human development index–life expectancy index	+	HDN (2013)
				Human development index–education index	+	HDN (2013)
				Annual population growth rate[b]	−	Authors' own calculation
				Crime rate	−	www.nscb.gov.ph
0.33	0.45	0.25	Economic	Human development index–income index	+	HDN (2013)
				City internal revenue allotment	+	2002–2008 CLUP[c]; www.nscb.gov.ph
				Tourist arrivals	+	2002–2008 CLUP; www.nscb.gov.ph
				Incidence of poor families	−	2002–2008 CLUP; 2010–2020 CLUP

Perspective 4—based on the concept of eco-sustainable human development index (E-SHDI) (Ture 2013). The details of this perspective are given in Eq. (6) described in the "Materials and Methods" section of this paper

Note the details of the raw data are given in Fig. S1

[a] Potential external environmental impact

[b] The annual population growth rate (APGR) was considered to be inversely related with sustainability because Baguio City has already greatly surpassed its designed population ceiling of 25 000 people (Glorioso 2006; Cariño 2009; Estoque and Murayama 2013a). Baguio City already has a population density of 5543 people km^{-2}, and thus an increase in its APGR would exacerbate congestion

[c] Comprehensive Land Use Plan for Baguio City

measure U_{R_2}, this study used the extent of impervious surface area of Baguio City, which has been determined from remote sensing data (Estoque and Murayama 2011).

Each of the calculated U_R based on U_{R_1} and U_{R_2} for 2000 and 2010 represents a value that measures the degree or extent of urbanization at a certain stage in the urbanization process of Baguio City. Equation (1) was used to determine the velocity of urbanization (Vu_R), which measures the rate and direction of change in the urbanization of Baguio City from 2000 to 2010 based on U_{R_1} and U_{R_2}.

$$Vu_R = \frac{U_{R_{t_2}} - U_{R_{t_1}}}{t_2 - t_1}, \quad (1)$$

where $U_{R_{t_1}}$ and $U_{R_{t_2}}$ are the values of U_R (based on U_{R_1} and U_{R_2}) at time t_1 and t_2, respectively.

Measuring Urban Sustainability (U_S)

Indicators, Data Standardization, and Aggregation Procedures Urban sustainability (U_S) is a desirable state that can be achieved through the proper use of resources to guarantee a generational equity, protection of the natural environment, minimal use of non-renewable resources, economic vitality and diversity, community self-reliance, individual well-being and satisfaction of basic human needs (Hardoy et al. 1992; Choguill 1996; Shen et al. 2012). U_S can be used as a measure for assessing the extent to which a city has achieved a desirable state of sustainability (Banister 1998; Shen et al. 2012). Table 2 presents the building blocks and framework for the urban sustainability assessment of Baguio City. It contains all the U_S indicators used in this study, which have been grouped based on the three components of the TBLS, i.e., environmental, social, and economic. The sixth column defines the types of indicators, i.e., whether an indicator is directly (+) or inversely (−) related with sustainability. In the case of Baguio City, the indicators for each component (Table 2) were based on previous studies (Zhang 2002; Spiekermann and Wegener 2003; van Dijk and Zhang 2005; Scipioni et al. 2009; Singh et al. 2009; Shen et al. 2011; Moldan et al. 2012; SCI 2012; Axelsson et al. 2013; Rezvani et al. 2013; Liu et al. 2013), supplemented by the authors' "local knowledge" of the study area. The details of the indicators are given in Fig. S1.

One of the challenges in the aggregation of physical and socio-economic indicators is how to deal with their different dimensions. To overcome this, all the data collected were standardized to make aggregation possible. In this study, data standardization is aimed at generating a value for each indicator that ranges from 0 to 1, where 0 is low and 1 is high with reference to sustainability. Equations (2) and (3) present the standardization procedures. Theoretically, for an indicator that is directly related with sustainability ($I_{i(+)}$), when $x_i = a_i$, then the standardized value of the indicator is 1; however, when $x_i = b_i$, then the standardized value of the indicator is 0. For an indicator that is inversely related with sustainability ($I_{i(-)}$), when $x_i = b_i$, then the standardized value of the indicator is 1; but when $x_i = a_i$, then the standardized value of the indicator is 0.

$$I_{i(+)} = \frac{x_i - b_i}{a_i - b_i}, \quad (2)$$

$$I_{i(-)} = \frac{a_i - x_i}{a_i - b_i}, \quad (3)$$

where x_i is the original value of indicator I_i; a_i is the maximum value of indicator I_i; and b_i is the minimum value of I_i.

The standardized values of all the indicators for each of the three components of the TBLS that are either exactly or close to the years 2000 and 2000 were used in the analysis. The indicators for each component were all given equal relative weights. An aggregation procedure presented in Eq. (4) was used to measure the environmental ($U_{S_{en}}$), social ($U_{S_{so}}$), and economic ($U_{S_{ec}}$) sustainability of Baguio City. Theoretically, the individual sustainability index of the three components varies from 0 to 1. Values closer to 0 have lower sustainability, whereas values closer to 1 have higher sustainability (Table 3).

$$c_j = \sum_{i=1}^{n} x_i \times w_i, \quad (4)$$

where c_j is the sustainability index of component j; x_i is the standardized value of indicator i; w_i is the relative weight of indicator i; and n is the number of indicators for component j.

Table 3 Sustainability index scale

Index	Description
≥0.80	Very high
[0.60–0.80)	High
[0.40–0.60)	Medium
[0.20–0.40)	Low
<0.20	Very low

Note "[" means that the lower limit is inclusive, while ")" means that the upper limit is exclusive

Four Various Perspectives In Table 2, the first three columns on the left and the last row contain the four perspectives from which the U_S of Baguio City was based and measured upon: (1) an equal weight perspective (U_{S_1}); (2) a pro-economic perspective (U_{S_2}); (3) a pro-environment perspective (U_{S_3}); and a pro-eco-sustainable human development index (E-SHDI) perspective (U_{S_4}). U_{S_1} considers equal relative weights of the three components of the TBLS, while U_{S_2} considers a much higher relative weight for the economic component. U_{S_3} considers a much higher relative weight for the environmental component, whereas U_{S_4} integrates the human development index (HDI) with an ecological demand, i.e., ecological footprint (EF). HDI is a widely used index for measuring the level of human development, and covers three important socio-economic indicators, namely income, life expectancy and education level (Grimm 2008; UN 2011; HDN 2013). Alternatively, EF measures the total consumption of goods and services produced and the amount of waste assimilated by the global hectare (GHA) of bioproductive lands (Rees 1992; Rees and Wackernagel 1996; Wackernagel and Rees 1997). Equation (5) was used to calculate the U_S of Baguio City based on the first three perspectives, while Eq. (6) was used to calculate the U_S of the city based on the fourth perspective.

$$U_{S_{1,2,3}} = \sum_{j=1}^{n} c_j \times w_j, \quad (5)$$

where $U_{S_{1,2,3}}$ is the urban sustainability index based on perspectives 1, 2, and 3; c_j is the sustainability index of component j; w_j is the relative weight of component j; and n is the number of TBLS components.

$$U_{S_4}(\text{E-SHDI}) = \frac{\sqrt[3]{\text{LEI} \times \text{EI} \times \text{II}}}{\frac{(\text{C}) \times (\text{EQF})}{\text{GY}}} = \frac{\text{HDI}}{\text{EF}}, \quad (6)$$

where LEI is the life expectancy index, EI is the education index, II is the income index (see UNDP (2013) and HDN (2013) for details of these indices), while C is the consumption, EQF is the equivalence factor, and GY is the global yield (see Wackernagel and Rees (1997) for details of these parameters).

Kai et al. (1998) proposed a sustainable HDI (SHDI) by integrating HDI with the concept of total material requirement (TMR), which is derived from the material flow accounting method. SHDI has been used and compared with the HDI (Hammer and Hinterberger 2003). Recently, Ture (2013) argued and illustrated that EF can be used as a proxy measure for TMR, hence Eq. (6). In the case of Baguio City, EF was considered as one of the indicators under the environmental component (Table 2). This is in order to take into account the potential external environmental impact, called leakage effect (Mayer 2008; Mori and Christodoulou 2012), of Baguio's rapid urbanization.

As the EF of Baguio City was not yet known, Eq. (7) (Sutton et al. 2009) was used to estimate the EF values. Two sets of data were needed in the calculation, i.e., population and impervious surface area (ISA). For the population, the data for the 1990, 2000, and 2010 census dates (Fig. 2) were used. For the ISA, the remote sensing derived data for the years 1988, 1998, and 2009 (Estoque and Murayama 2011) were used, with the assumption that these were the most reliable data at the time of the study. Since there were mismatches on the dates between the two sets of data, one set had to be adjusted through extrapolation from the available data (in this case, the population). The city's EF for 2020 were also projected by: (1) projecting the ISA for 2020 (ISA_t) based on the 1988, 1998, and 2009 ISA data using Eq. (8); and (2) extrapolating the population for 2020 using three sets of APGR (see Fig. 2), also by following the logic of Eq. (8).

$$EF = -0.58258 + 0.0315935x, \quad (7)$$

where EF is the ecological footprint expressed as global hectare person^{-1} (GHA person^{-1}); and x is the impervious surface area (m^2) person^{-1} (ISA person^{-1}) (Sutton et al. 2009).

$$ISA_t = ISA_o \times \left(1 + \frac{i}{100}\right)^n, \quad (8)$$

where ISA_o is the impervious surface area of the base year of the projection (i.e., 2009); i is the average rate between the annual ISA expansion rate for 1988–1998 (x_1) and 1998–2009 (x_2), where x_1 and x_2 were individually determined ($x_{1,2} = (\sqrt[n]{\frac{ISA_{t_2}}{ISA_{t_1}}} - 1) \times 100$); and n is the number of years between the base year and end year of the projection.

Measuring the Velocity of Urban Sustainability (Vu_S)

The Vu_S defines the rate and direction of change in urban sustainability. Equation (9) was used to calculate Baguio City's Vu_S (i.e., $Vu_{S_{en}}$, $Vu_{S_{so}}$, and $Vu_{S_{ec}}$) based on the environmental ($U_{S_{en}}$), social ($U_{S_{so}}$) and economic ($U_{S_{ec}}$) components. The same equation was used to calculate the city's Vu_S (i.e., Vu_{S_1}, Vu_{S_2}, Vu_{S_3}, and Vu_{S_4}) under the four various perspectives (U_{S_1}, U_{S_2}, U_{S_3}, and U_{S_4}).

$$Vu_S = \frac{U_{S_{t_2}} - U_{S_{t_1}}}{t_2 - t_1}, \quad (9)$$

where $U_{S_{t_1}}$ and $U_{S_{t_2}}$ represent the sustainability indices (for each component and perspective) at time t_1 and t_2, respectively.

Examining the Relationship Between Vu_R and Vu_S

The relationship between urbanization and sustainability defines the state and direction of the urbanization process in a particular area: in this case, Baguio City. This relationship can be clarified through the evaluation of the sustainability of urbanization using both the velocity of urbanization (Vu_R) and velocity of urban sustainability (Vu_S).

This study adopted the methodology proposed by Shen et al. (2012), i.e., the Vu_R–Vu_S coordinate, or Cartesian plane (Fig. 3), which was also applied recently by Liu et al. (2013). The plane is divided into four quadrants (Fig. 3). In quadrant I, $Vu_R > 0$ and $Vu_S > 0$, where $Vu_R > 0$ indicates urbanization growth, while $Vu_S > 0$ suggests improvement of urban sustainability. Thus, quadrant I depicts a sustainable urbanization. In quadrant II, $Vu_R < 0$ and $Vu_S > 0$. This relationship denotes that although there is a counter-urbanization ($Vu_R < 0$), the practice is considered sustainable ($Vu_S > 0$). In this context, counter-urbanization may be necessary in order to improve urban sustainability. An example of this phenomenon is when socio-economic and ecological problems are alleviated or solved through an outward movement of urban people (decongestion) or a decrease in population growth (by birth or migration). In quadrant III, $Vu_R < 0$ and $Vu_S < 0$. This relationship denotes the process of counter-urbanization and a decline of urban sustainability during the urbanization process. In quadrant IV, $Vu_R > 0$ and $Vu_S < 0$. This relationship shows urbanization growth, but urban sustainability is declining.

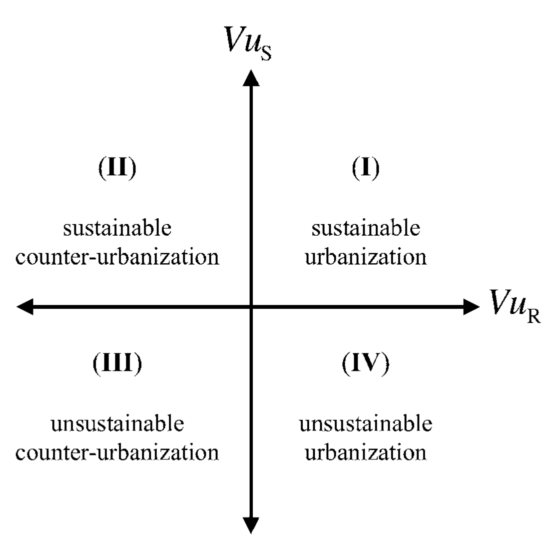

Fig. 3 The Vu_R–Vu_S Cartesian plane for evaluating sustainability of urbanization. *Source* adapted from Shen et al. (2012)

RESULTS

Velocity of Urbanization (Vu_R) in Baguio City

The results of the Vu_R measurement show that both U_{R_1} and U_{R_2} had a positive velocity (Vu_{R_1} and Vu_{R_2}), suggesting that the urbanization of Baguio City has been accelerating (Table 4a). The positive value of Vu_{R_1} shows that the relative proportion of the population of Baguio City to the population of CAR (U_{R_1}) in 2010 was higher than in 2000, indicating that Baguio City's population growth within this period was faster than the whole region. For Vu_{R_2}, its positive value was due to the substantial increase in the extent of impervious surface area of Baguio City (U_{R_2}) from 2000 and 2010. Between U_{R_1} and U_{R_2}, however, U_{R_2} had a much higher Vu_{R_2} (Table 4a). This suggests that the velocity of urbanization of Baguio City was faster if the extent of impervious surface area is used as an indicator than if ratio of urban population is used. The relationship between the APGR and per capita land consumption can help explain this trend. That is, although APGR was much lower during the 2000–2010 period than during the preceding period (Fig. 2), the per capita land consumption in Baguio City during the 2000–2010 period was slightly higher than during the preceding period (Table S1). Nevertheless, both indicators are useful as they both reflect the actual situation on the ground. They are independent from each other; for instance, it does not necessarily mean that if population growth was higher, the expansion of impervious surface area was also faster, and vice versa.

Table 4 The Vu_R and Vu_S and their components

	2000	2010	Velocity	
a. Urbanization rate				
Baguio–CAR population ratio (U_{R_1})	0.1848	0.1971	Vu_{R_1}	0.0012
Extent of impervious surface area in Baguio City (U_{R_2})	0.3431	0.5192	Vu_{R_2}	0.0160
b. Component sustainability index				
Environmental ($U_{S_{en}}$)	0.5124	0.2200	$Vu_{S_{en}}$	−0.0294
Social ($U_{S_{so}}$)	0.6302	0.7138	$Vu_{S_{so}}$	0.0084
Economic ($U_{S_{ec}}$)	0.4091	0.7856	$Vu_{S_{ec}}$	0.0377
c. Urban sustainability index				
Perspective 1 (U_{S_1})	0.5172	0.5731	Vu_{S_1}	0.0056
Perspective 2 (U_{S_2})	0.5012	0.6227	Vu_{S_2}	0.0121
Perspective 3 (U_{S_3})	0.5219	0.5095	Vu_{S_3}	−0.0012
Perspective 4 (U_{S_4})	0.3494	0.3425	Vu_{S_4}	−0.0007

Velocity of Urban Sustainability (Vu_S) in Baguio City

The results show that both the $Vu_{S_{so}}$ and $Vu_{S_{ec}}$ of Baguio City were positive, indicating that the sustainability of the social and economic components improved from 2000 to 2010 (Table 4b). Based on the sustainability index scale in Table 3, the sustainability index of the social component ($U_{S_{so}}$) in 2000 was already "high." This was largely due to the HDI values for the LEI and EI indices of the province of Benguet where Baguio City is located, which were relatively high during this period. In 1997, Benguet was ranked first in EI and seventh in LEI in the entire country (HDN 2013). In 2010, the $U_{S_{so}}$ of Baguio City increased, and this was again largely attributed to the improvement of the HDI components. In 2009, Benguet was ranked second for both EI and LEI. The increase in Baguio's $U_{S_{so}}$ was not however enough for its "high" sustainability to improve to "very high" sustainability. Meanwhile, the sustainability of Baguio's economic component ($U_{S_{ec}}$) in 2000 was only "medium," but this improved to "high" sustainability in 2010 (Table 4b). The increase in Baguio's $U_{S_{ec}}$ was due to the improvement of the HDI's II and internal revenue allotment, in addition to the decrease on the incidence of poor families. In 1997, Benguet's II was ranked fourth, and in 2009, it was ranked first in the entire country. In 2009, Benguet was also ranked first in the country in terms of the overall HDI (HDN 2013). In contrast, the results show that the $Vu_{S_{en}}$ of Baguio City was negative, indicating that the sustainability of the environmental component degraded from 2000 to 2010 (Table 4b). The sustainability of Baguio's environmental component ($U_{S_{en}}$) in 2000 was "medium," but this declined to "low" sustainability in 2010. The decline in Baguio's $U_{S_{en}}$ was due to the decrease in the ecosystem service value (ESV) and human-to-ESV ratio, coupled with the increase of EF.

The results also show that both the Vu_{S_1} and Vu_{S_2} were positive, indicating an improvement in Baguio's urban sustainability if it was to be measured from an equal weight perspective (of the TBLS components) and a pro-economic perspective, respectively (Table 4c). In 2000, Baguio's urban sustainability (U_{S_1}) was "high." This was maintained up to 2010 as the increase was not enough for the sustainability level to improve to "high" sustainability. Nevertheless, the increase in the city's U_{S_1} was due to the improvement in the $U_{S_{so}}$ and $U_{S_{ec}}$ from 2000 to 2010. Based on U_{S_2}, the city's urban sustainability in 2000 was "medium," but this improved to "high" sustainability in 2010 (Table 4c). This was due to higher relative weight given to the economic component ($U_{S_{ec}}$), which also demonstrated an improvement from 2000 to 2010.

In contrast, the results show that Vu_{S_3} was negative, indicating that the urban sustainability of Baguio City

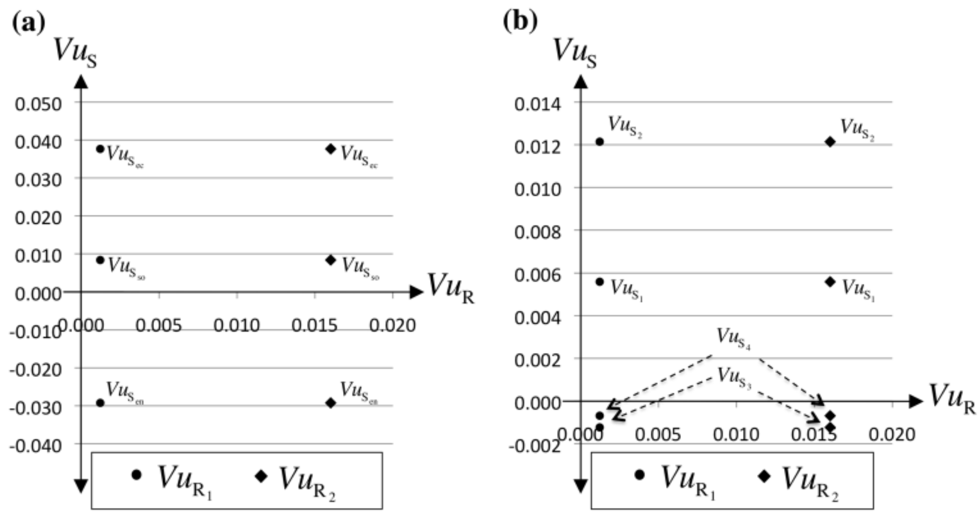

Fig. 4 Comparison of the sustainability of urbanization based on the two velocities of urbanization (Vu_{R_1} and Vu_{R_2}), and (**a**) the three velocities of urban sustainability of the environmental, social, and economic components ($Vu_{S_{en}}$, $Vu_{S_{so}}$, and $Vu_{S_{ec}}$); and (**b**) the four velocities of urban sustainability based on the four various perspectives (Vu_{S_1}, Vu_{S_2}, Vu_{S_3}, and Vu_{S_4})

had been declining if it was to be assessed from a pro-environment perspective (Table 4c). The decline in the city's U_{S_3} was due to the steep decline of the environmental component ($U_{S_{en}}$), which had also been given much higher relative weight. Nevertheless, the city's "medium" U_{S_3} was maintained up to 2010, despite the decrease in the value. Furthermore, the results also show that Vu_{S_4} was negative, indicating that from a pro-E-SHDI perspective the urban sustainability of Baguio City had also been declining (Table 4c). U_{S_4}, however, had a relatively lower decline compared with U_{S_3}. Compared with the other three measurements (U_{S_1}, U_{S_2}, and U_{S_3}), U_{S_4} values were much lower, which also have a sustainability description of "low" in 2000 and 2010. This was due to relatively high values of the EF, a sole indicator of the environmental component, in this iteration as a proxy measure for ecological demand. The decrease in the U_{S_4} values from 2000 to 2010 indicates that the increase in the HDI was relatively lower than the increase in the EF.

Relationship Between Vu_R and Vu_S of Baguio City

Figure 4 presents the evaluation of Baguio City's urbanization process in the context of sustainability based on the two velocities of urbanization (Vu_{R_1} and Vu_{R_2}), and (a) the three velocities of U_S based on the environmental, social and economic components ($Vu_{S_{en}}$, $Vu_{S_{so}}$, and $Vu_{S_{ec}}$); and (b) the four velocities of U_S based on the four perspectives (Vu_{S_1}, Vu_{S_2}, Vu_{S_3}, and Vu_{S_4}). Based on the Vu_R–Vu_S Cartesian plane (Fig. 3), the velocities of urbanization and urban sustainability for the individual TBLS components (Fig. 4a) and the four perspectives (Fig. 4b) are found in quadrants I (sustainable urbanization) and IV (unsustainable urbanization).

In particular, Fig. 4a shows that the $Vu_{S_{ec}}$ and $Vu_{S_{so}}$ were allocated in quadrant I, while the $Vu_{S_{en}}$ was allocated in quadrant IV. This indicates that the urbanization process of Baguio City was sustainable based on the social and economic components, but unsustainable based on the environmental component. Figure 4b shows that Baguio's urbanization process was sustainable based on an equal weight perspective (of the TBLS components) and a pro-economic perspective (Vu_{S_1} and Vu_{S_2}), but unsustainable based on the environmental and E-SHDI perspectives (Vu_{S_3} and Vu_{S_4}).

Human Ecological Footprint (EF) in Baguio City

Using the estimated values of ISA person^{-1} as inputted in Eq. (7), the resulting estimates for EF expressed in terms of GHA person^{-1} was 1.41 in 1988, 2.06 in 1998, and 2.48 in 2009 (Table S1). In terms of the future projections for 2020, at the same projected quantity of ISA, the EF under a much lower projected population (with much higher per capita land consumption) will have a much higher EF, and vice versa.

The increasing trend of the EF of Baguio City indicates that the potential external environmental impact (leakage effect) of its urbanization has been increasing. For comparison purposes, the EF of the Philippines in 2008 was 0.98, while its total biocapacity was only 0.62 GHA person^{-1} (WWF 2012). In the same year, the world's EF was 2.70, while the world's biocapacity was only 1.78 GHA person^{-1}. Thus, the estimated 2009 EF of Baguio City is far higher than the country's 2008 EF and biocapacity, and the world's 2008 biocapacity. If the current urban development trend continues, i.e., at the average expansion rate of impervious surface area (Table S1) and P3 APGR (Fig. 2), the EF of Baguio City in 2020 will greatly surpass both the Philippines' and world's current biocapacities (Table S1).

DISCUSSION

Proper selection of indicators is one of the critical challenges in urban sustainability assessment. Indicators might not be exactly the same across different cases, but what is important in the selection of indicators is that an indicator should be measurable over space and time and more importantly, has relevance to policy making and is usable in decision making (Alberti 1996; Astleithner et al. 2004). In this study, though there might be other indicators that were not included, the indicators used have relevance to policy and decision making. Moreover, they were able to capture the overall patterns of the three components of TBLS; patterns that are associated with the landscape changes and urbanization process of Baguio City, depicting the actual situation on the ground.

Highly connected with the selection of indicators is the issue on the sources of reliable data. At the country, regional and global levels, data for some important indicators, e.g., HDI and EF, are readily available (www.footprintnetwork.org; www.hdn.org.ph; www.undp.org; www.worldbank.org). Their availability helps facilitate a number of studies at these levels (e.g., Hammer and Hinterberger 2003; Siche et al. 2008; Sutton et al. 2009; Ture 2013). While there might be a much lesser concern on the availability of data in the developed countries, there is a much greater concern in the developing countries, especially at the local level. Consequently, some important data have to be derived from other studies using various techniques, as in the case of Baguio City. In cases where data are available, temporal inconsistency is another problem that deters the usability of such data for change detection analysis, which is vital for sustainability assessment. This issue on temporal inconsistency was also experienced in the case of Baguio City, which resulted in the exclusion of some other potentially relevant, more specific indicators like water consumption rate, waste generation rate, injury rate and public transport services (Zhang 2002; van Dijk and Zhang 2005; Scipioni et al. 2009; Shen et al. 2011), including fire incidence and annual per capita savings. Thus, if more specific indicators are to be used, there is a need to promote data awareness/consciousness, not only at the national level, but also at the local level.

The method for measuring U_S is another important issue. Several approaches for this purpose have been proposed in the literature (see Singh et al. 2009; Shen et al. 2011; Mori and Christodoulou 2012). In recent studies, Ture (2013) was able to calculate new rankings of countries based on the concept of E-SHDI (using the HDI and EF), while Liu et al. (2013) were able to measure the sustainability of the coastal Liaoning area in China, also by using HDI and EF. In the case of Baguio City, HDI and EF were also used, but in combination with other indicators. HDI considers only three socioeconomic indicators, thus it does not capture all facets of social and economic components (e.g., crime rate), and so does the EF in the case of the environmental component (see van den Bergh and Verbruggen 1999; van Kooten and Bulte 2000; Fiala 2008; Nourry 2008). In this study, EF was included mainly to estimate and monitor the potential external environmental impact or leakage effect of the urbanization of Baguio City. The actual degradation of the natural environment of Baguio City has been determined using the changes in ESV as proxy measures. Interesting as they are, a full review of sustainability assessment approaches was not tackled in this article. However, the reader is referred to Singh et al. (2009), Shen et al. (2011), and Mori and Christodoulou (2012) for more examples and reviews.

This study estimated the EF of Baguio City as a proxy measure for leakage effect and integrated it with the environmental component of the TBLS. The integration of EF in the measurement of urban sustainability stresses the need to take into consideration not only internal, but also external environmental impact when evaluating Baguio's urban sustainability. This is essential because the effects of Baguio's urban systems on the region's natural capital and ecosystem services go beyond the city's urban boundaries. A city may appear sustainable owing to the inflows of the needed resources from other areas, but the continuous depletion of resources in those other areas might lead to their own "unsustainability" (Mayer 2008). While Baguio focuses on economic development within its jurisdiction, it also depends on other areas for its imports of ecosystem goods (supply of resources and food) and exports of environmental impact (disposition of waste, emission of pollutants and indirect usage of ecosystem services). Therefore, Baguio City's dependence on other areas and consequent potential leakage effects also need to be considered when planning for its sustainable development.

This study shows that U_R and Vu_R can vary depending on what or which indicators are used in the assessment. The use of the extent of impervious surface area as an indicator, in addition to the proportion of urban population, adds to the existing approaches in measuring rate and velocity of urbanization. The proposed indicator takes advantage of the continuous advancement of remote sensing technologies, which enables rapid mapping and change detection analysis of impervious surface areas. This study also shows that U_S and Vu_S can vary depending on or from which perspective sustainability is measured. Nonetheless, it is important that the different objectives, interests and perspectives of the varying “actors” in a coupled human–environment system are represented, explored, analyzed and taken into consideration in any sustainability assessment. This study might be one of the few, if not the first, to measure sustainability in a single case study area based upon various perspectives and techniques, especially in a hill station that really needs ecologically sustainable economic development. This type of measurement is useful, considering that a hill station-based urban ecosystem has arguably a more complex social–ecological or human–environment system that requires inter-disciplinary, multidimensional approaches.

The sustainability assessment for Baguio City has been very challenging. There are some caveats that need to be considered whenever the results are to be used: (1) temporal inconsistencies of the data—some of the data (indicators) used do not fall exactly on the period considered; (2) the estimation of the EF was based on a proxy measure; and (3) the data collected from other studies (see Tables 2 and S1) also have some limitations. These limitations are mostly data-related, so the increasing availability of data might help address these limitations in future studies. As this study has used Baguio City's major indicators of sustainability, it can still provide valuable insights about the current state and direction of the urbanization process of this highly valued hill station, vital in planning for its future sustainable development.

CONCLUSIONS

Based on the empirical results and subsequent analyses, this study concludes that:

- urbanization rate (U_R) and velocity of urbanization (Vu_R) can vary depending on the indicators used. For Baguio City, however, although the U_R based on urban population and extent of impervious surface area were not the same, their respective Vu_R have indicated that the city's urbanization has accelerated;
- the social ($U_{S_{so}}$) and economic ($U_{S_{ec}}$) sustainability of Baguio City have improved, but its environmental ($U_{S_{en}}$) sustainability has declined; and
- urban sustainability (U_S) and velocity of urban sustainability (Vu_S) can vary depending on or from which perspective they are measured. From an equal weight perspective (of the TBLS components) (Vu_{S_1}) and a pro-economic perspective (Vu_{S_2}), the results have indicated that the urbanization process of Baguio City has been moving toward a “sustainable urbanization.” However, from the environmental perspective (Vu_{S_3}) and E-SHDI perspective (Vu_{S_4}), the results have indicated that it has been moving toward an “unsustainable urbanization.”

These findings show an evident divergence between socio-economic growth and environmental sustainability in the case of Baguio City, and this poses critical challenges toward its sustainable urbanization. In the recent past, the environmental component has not received the attention it really deserves. Therefore, it is vital for the Philippine national and local government to reassess Baguio City's carrying capacity. It is important that Baguio's remaining natural resources should not be taxed beyond their limits so that the future quality of living condition in the city will not be compromised. There is a need to advance ecologically sustainable economic development in order for Baguio City to be able to promote an acceptable living standard in the future, and ensure the availability of natural resources, the life-support systems, not only for the present, but also for future generations.

The huge imbalance between the socio-economic and environmental components raises doubts on Baguio City's overall sustainability. It is in this context that sustainability assessments/measurements based upon various perspectives must be considered in policy debates to help shed light on how to balance the dualistic nature of Baguio City's urbanization. This study further concludes that:

- the integration of velocity of urbanization (Vu_R) based on two different indicators and velocity of urban sustainability (Vu_S) under four various perspectives has provided a type of sustainability assessment that has never been attempted before; and
- the framework implemented in this study allows different perspectives for exploratory analysis, and is able to integrate a measurement index that can take leakage effect into account.

The approach introduced in this study contributes to the field of sustainability science in particular, and to the advancement of coupled human–environment systems studies in general. This study also provides a basis for other sustainability assessments in the future. It can be reproduced in other hill stations of Southeast Asia, for example in Bogor (Indonesia), Dalat (Vietnam), and Pyin Oo Lwin (formerly Maymyo) (Myanmar). The same set of indicators can be used for these hill stations, and in case where data for the indicators used in this study are not available, the framework's flexibility allows other indicators to be used. Comparative studies might help advance our understanding of the current state and future directions of the urbanization process in these areas in the context of sustainable development.

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