# *Implications of urban expansion on land use and land cover: towards sustainable development of Mega Manila, Philippines*

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# Implications of urban expansion on land use and land cover: towards sustainable development of Mega Manila, Philippines

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**Abstract** Planning of land use and infrastructure in advance for a population that is projected to grow rapidly is highly important for its sustainable development. A correlative approach of land use shifts and infrastructure design is perhaps the best sustainable urban development option that can be made at present. This paper is aimed at suggesting policy foresight, in terms of infrastructure and land use management of Mega Manila. Using Land Change Modeller, this study assessed landscape pattern, change process and future scenario of land changes in the study area. The land use/landscape change pattern, with vulnerability analysis and predicting 2030 land use maps, enabled us to understand impacts of urban expansion on different land use sectors. Overall analysis of gains and losses in different land use categories across different sectors between 1989 and 2010 indicated that built-up area experienced the highest net gain of 90.96%. Two future scenario maps were projected to indicate the potential effects of urban expansion on forested areas near study area. Urban expansion was predicted to expand by 897.16 sq. km (36% gain) with protected area scenario. Contributions to this gain were projected to come from agricultural land of 274.94 sq. km, identified as one of the major contributors to urban expansion. Following the analysis, the paper argues that land use management plan should be revised in the Mega Manila city to reduce the loss of protected areas and anthropogenic impacts.

**Keywords** Land use change · Vulnerability · Urban planning · Manila

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## Introduction

Considering the spatio-temporal scale of its effect, urbanization is assumed as biggest anthropogenic alteration on earth and its environment (Patra et al. 2018). According to the World Economic and Social survey report (2013), about 2.5 billion people were added to the global urban population between 1950 and 2010. This included a net addition of 1.3 billion people to small urban centres, 632 million people to medium urban centres, and 570 million people to large urban centres. Since the declaration of human rights in 1948, cities and towns are believed to be a basis of

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primary living standards because of the many benefits city spaces provide to the improvement of human wellbeing (Human Development Report 2016). The United Nations Population Division marked 2007 as a year when the number of people living in urban areas became more than half of the world's total population. The global urban population has further been predicted to exceed 70% by 2050, estimated to be 6.25 billion, and about 80% of this figure has been projected to live in developing nations and highly concentrated in Africa and Asia (UNDESA 2014). Ismail (2014) reported that at regional level, over the past decades, the south-east Asian region has seen progressive increase in both the geographic and population size of its cities, with a doubling period of 25 years (760 million in 1985, to 1.6 billion by 2010). However, rapid but unplanned urbanization results into serious environmental consequences such as loss of crop production areas, loss of biodiversity, increase in water scarcity, increase in environmental pollution, reduced food security, and deterioration in people's living standard among others. Rapid urbanization also, however has positive impacts such as rise in land value, job opportunities. Henceforth Rapid urbanization deserve better and pro-active attention (Mundhe and Jaybhaye 2014; Wang et al. 2016).

City planning designs that are believed to support anthropogenic impacts on earth's natural systems is reported largely lacking in comparison to high rate of population growth. However, if global utilisation of natural resources is to evolve into efficient consumption patterns, urban sustainability has to be a priority. However, achieving urban sustainability in rapidly expanding cities with little or no control from local authorities is a real challenge in today's world. Shlomo et al. (2011) and Bren d'Amou (2017), reported that based on current density decline rates for the past decade, the world population is still expected to double in 43 years, and urban land use land cover will double in only 19 years. Considering this rapid expansion of urban land use research and actions toward building urban resilience for complex mega-cities (the capacity of the city to function so that its inhabitants, particularly the poor and vulnerable, survive and thrive no matter what stresses or shocks they encounter) is urgently needed.

For this reason, achieving urban sustainability or transforming city designs into sustainable cities concept by 2030 requires an integrative assessment approach. According to Helming et al. (2008), sustainability impact assessments (SIA) is inherently difficult because they often require researchers and policy advisors to compare things that are not easily compared. It is argued that understanding cities' sustainability includes social and economic development, environmental management and urban governance. Several studies have explained that a high population density and compact urban design require walkable neighbourhoods and mass transit alternatives (Kenworthy 2019).

Sustainable city design considers the environmental land use patterns' impacts, accepting that the people living in any city minimise their inputs of energy, water, food and waste output, air pollution (carbon emissions) and water pollution. In 2013, the United Nations Department of Economic and Social Affairs reported that the land use patterns and urbanisation have been diverse within developing countries and between developing and developed countries. Urban expansion in developing countries has followed a rapid pace and concentrated in capital cities. Seto et al. (2010) argued that concentrated populations can save land for agriculture, wildlife and habitat by using less land for urban development. However, the trade-offs between urban opportunity, urban sustainability, urban governance and environmental challenges of the 21st century such as climate change and unsustainable land use shifts being fuelled by the high rates of regional population growth and demand for natural resources have become difficult to foresee. This trade-off between population growth and demand for natural resources are evolving with time and achieving sustainability across all national sectors strongly depends on how regional authorities respond by wisely managing land uses, including expansion of urban areas, and natural resource consumption patterns. McDonald et al. (2008) reported that the transformation of contemporary patterns of urbanisation: footloose international capital, urban governance and institutional structures, and agglomeration forces the distance between protected areas and cities to shrink dramatically in some regions. McDonald et al. (2008) also reported that the median distance from a protected area to a city in Eastern Asia was predicted to fall from 43 to 23 km by 2030. Most of the protected areas are likely to be impacted by the new urban growth from low to moderate-income nations, where there are institutional limits to support the capacity to adapt to anthropogenic and climate change impacts of urban expansion on land use change and forestry (LUCF).

Therefore, as urban expansion occurs in any regional or global city, it adversely affects the carbon sink areas such as forest and vegetation lands within and beyond the city. Seto et al. (2010) explained that urbanisation creates heavily human-dominated landscapes and drives local and regional environmental changes by transforming land use land cover (LULC), hydrological systems and biogeochemistry. For example, Philippines Forest Management Bureau of the Department of Environment and Natural Resources (FMB-DENR) report (2013) suggests that, the forest cover of the Philippines decreased by 3286.82 sq. km or 4.59% from 71,684 sq km in 2003 to 68,397.18 sq km in 2010 at an annual rate of change in the area of 469.54 sq. km. Over a long-term perspective between 1990 and 2010, the annual rate of loss increases to 547.5 sq. km/year. According to Hansen et al. (2013) annual rate of loss of forest cover in the Philippines is 514 sq. km/year, which is slightly lower than the national figure i.e. 1353 sq. km/year. Unfortunately, national level data does not provide a very tangible argument to formulate downscaled database to develop local city level strategic urban plans for sustainable city design.

Saatchi et al. (2011) emphasise the importance of forestland in the Philippines through a conscience study that forests stores 663 million metric tonnes of carbon in living forest biomass. Protected areas are home to the estimated 1196 known species of amphibians, birds, mammals and reptiles. Unfortunately, 14.7% are threatened towards extinction (World Conservation Monitoring Centre 2004). The biodiversity in forest and vegetation lands of the Philippines are home to at least 8931 flora species of vascular plants, of which 39.2% share are endemic and about 5.1% are protected under IUCN categories I–V.

Value for average carbon density for 10%, 20% and 30% tree cover is 111, 118 and 120 tC/ha respectively as shown in Table 1. The Philippines' widespread logging industry has always been termed responsible for forest depletion. In 1980s and early 1990s, considering severe flooding at that time due to excessive deforestation, the government banned timber harvesting so that incidences of frequent flooding could be reduced. Considering only about 5% of the Philippines national forests exist in some form of protected area, Government's efforts to curb deforestation due to timber smuggling was reported largely ineffective Deforestation of Philippines' forests come from both legal and illegal mining operations. Several studies have linked deforestation to soil erosion, river siltation, flooding and drought. In order to fully understand the link between forest land loss and urban expansion, this study was conducted through modelling the land use changes to generate policy strategies for building sustainable resilient Mega Manila city by the year 2030.

This paper tries to analyse the impact of urban expansion through the proposed transport infrastructure under Mega Manila dream plan on land use change and forestry (LUCF) around in the Mega-Manila region. Transport infrastructure has been identified as one of the most potent factors that leads to urban expansion as they affect mobility of people (Cheng and Masser 2003; Gao and Li 2011; Iizuka et al. 2017). This paper provides results for (a) actual changes between 1989 and 2010, and (b) projected changes from 2010 to 2030. Using ArcGIS Land Change Modeler (LCM 2.0), implicational scenarios for planned 2030 transport infrastructure were assessed to predict the impact of the ongoing road and mass transit rail systems projects on the land use sectors patterns. Projection of future land use maps without constraint (protected area) and with constraint (protected area) layers for 2030 were generated and used to support the analysis of the impacts of urban expansion on land use change and forestry (LUCF). The use of integrative approach through the use of constraints, distance from major roads, proximity to the rail line, slope and aspect were used. The use of static and dynamic variables improved the accuracy of results and also, enabled consideration of Philippines Government laws and regulations in the modelling analysis. United Nations Framework Convention on Climate Change, National Statistical Office (NSO) and United Nations Department of Economic and Social Affairs (UNDESA) reports were reviewed for analyzing carbon emissions and population data. Finally, conscience implicational scenario analysis of these land use changes were carried out to understand the study area landscape pattern, change analysis and change process techniques. The land use maps of recent past and future (2030) were generated and used to explain the change analysis for the impacts of urban expansion.

**Table 1** Average carbon density of Philippines forest cover Adapted from Saatchi et al. (2011)

| Forest definition (canopy cover %) | 10% tree cover | 25% tree cover | 30% tree cover |
|---|---|---|---|
| Forest area (Million ha) | 21 | 13 | 11 |
| Aboveground forest carbon (Mt C) | 1810 | 1176 | 1068 |
| Belowground forest carbon (Mt C) | 502 | 324 | 293 |
| Total forest carbon (Mt C) | 2312 | 1500 | 1361 |
| Average carbon density (t C/ha) | 111 | 118 | 120 |

## Study area and data

The study area, Mega Manila consists of 5 provinces including National capital Region (NCR) of Metropolitan Manila, Bulacan, Rizal, Laguna and Cavite (Fig. 1). Bulacan is the largest in terms of spatial form while Metropolitan Manila or NCR is the economic powerhouse of the Philippines republic.

The total population of the Mega Manila has increased to 24,889,000 in 2016 from 12,934,000 in 1989. Urban expansion is expected to continue in the city.Population estimates revealed that half of total urban population of Philippines are concentrated in Mega Manila. Out of total urban population of 59,220,000 of Philippines, Mega Manila is predicted to have 29,390,000 by the year 2030 (Fig. 2). Static and dynamic driver variables for land change modeling is shown in Fig. 3. The road network is compact in middle (Metro Manila) of the city and leads to ports and out to other provinces. The rail line network cuts through the middle of the city connecting the north to the south. Most of the city is established along river


**Fig. 1** Study area location *Sources*: NEDA and JICA 2014

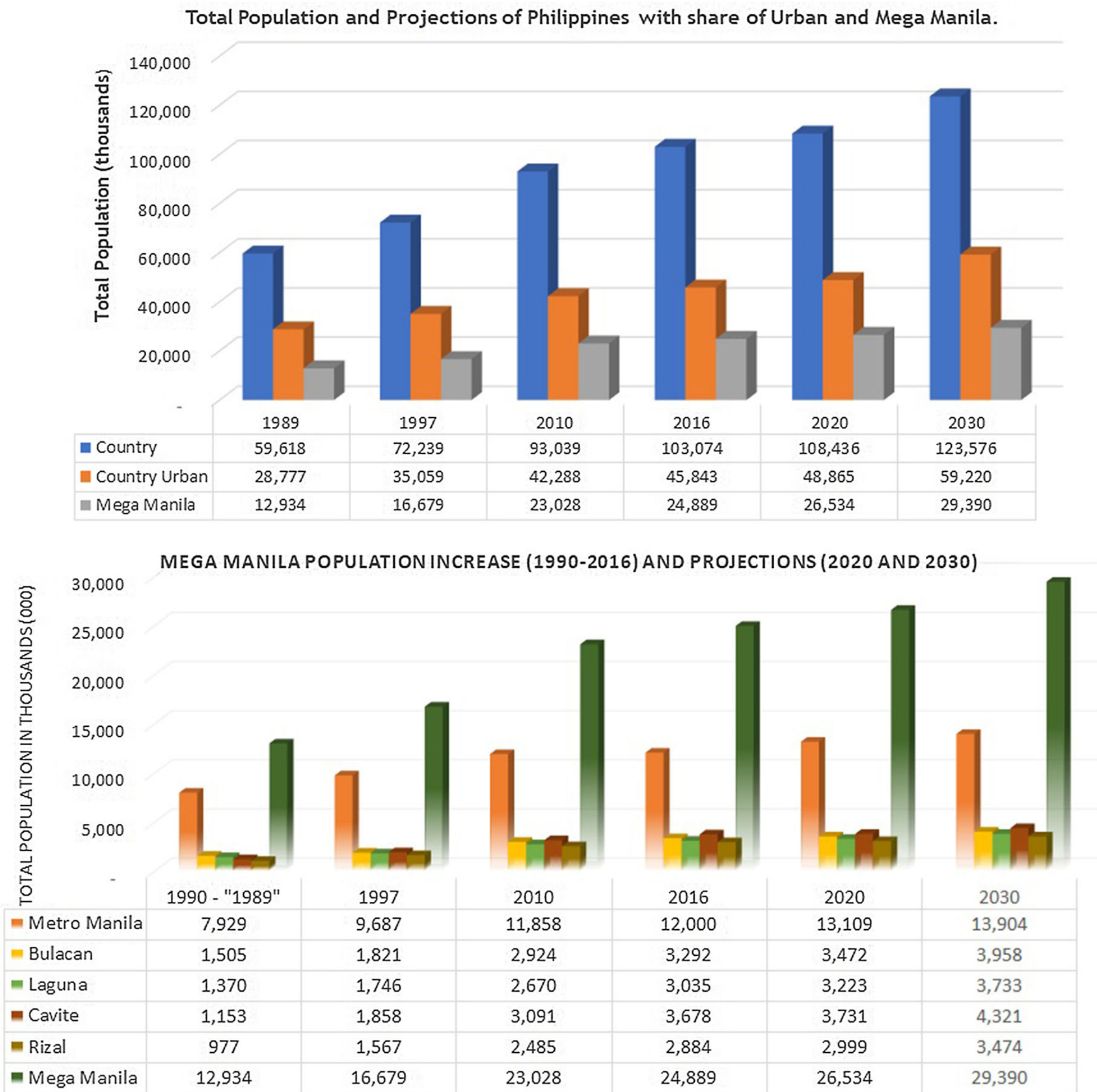


**Fig. 2** Graphs illustrating population of provinces in, total urban population, and percent share of Mega Manila

systems Urban expansion is reaching even high slope land area as shown in Fig. 3.

## Methods

Flowchart for Land Change Modelling (LCM) is shown in Fig. 4. It covers following steps:

### Image classification

Land use land cover maps were prepared using Landsat satellite images. The image classification process used supervised classification method. Land use/land cover map for years 1989 and 2010, which were used as input for modelling, is shown in Fig. 5.

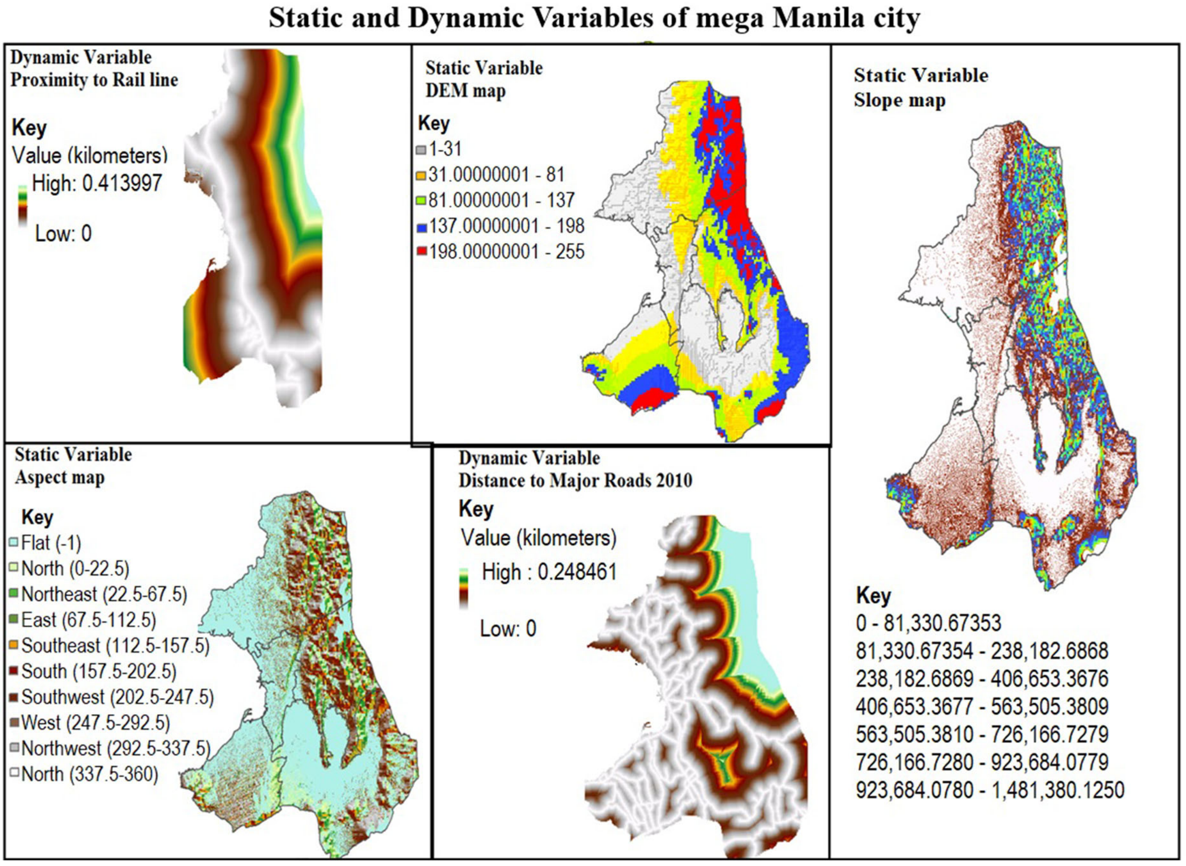


**Fig. 3** Dynamic and Static driver variables as input for land change model (LCM)

Land change modeler for arc GIS 2.0

To understand the extent of urban area expansion from 1989 to 2010, a change analysis using land change modeller was carried out. More data were acquired and prepared for the modelling process using Arc GIS. As shown in Fig. 4, static driver variables of land use change included digital elevation model, aspect and slope of the terrain. Dynamic variables included distance to major roads in 2010 and proximity to the rail line. Thereafter, prediction process was carried out to provide how possible urban expansion might impact on the land use change and forestry (LUCF) between 2017 and 2030.

*Change prediction*

As first step, land use map and driver variables data preparation was done and matched spatially. As indicated in the Fig. 4, land use maps of 1989 and 2010 were the first inputs for the modelling process. Thereafter, the model was used to generate transitional potentials through the use of Multi-Layer Perceptron neural network option tool in LCM model. Using the LCM model, a 2030 land use map was generated. However, since this study focuses on understanding the impact of urban expansion on forestry sector, two scenario models were carried out including planned transport infrastructure network as envisioned in the Philippines authorities transport infrastructure dream plan 2030. A digitized map indicating a rail network of 75 km subway from San Jose Del Monte to Dasmannas, NLEX-SLEX express roads connecting ports, 91 km elevated North–South Commuter rail with modern high capacity train from Malolos through Tutuban to Calamba planned infrastructure for 2030 was used as input for change prediction (NEDA and JICA 2014). Thereafter, two scenarios were

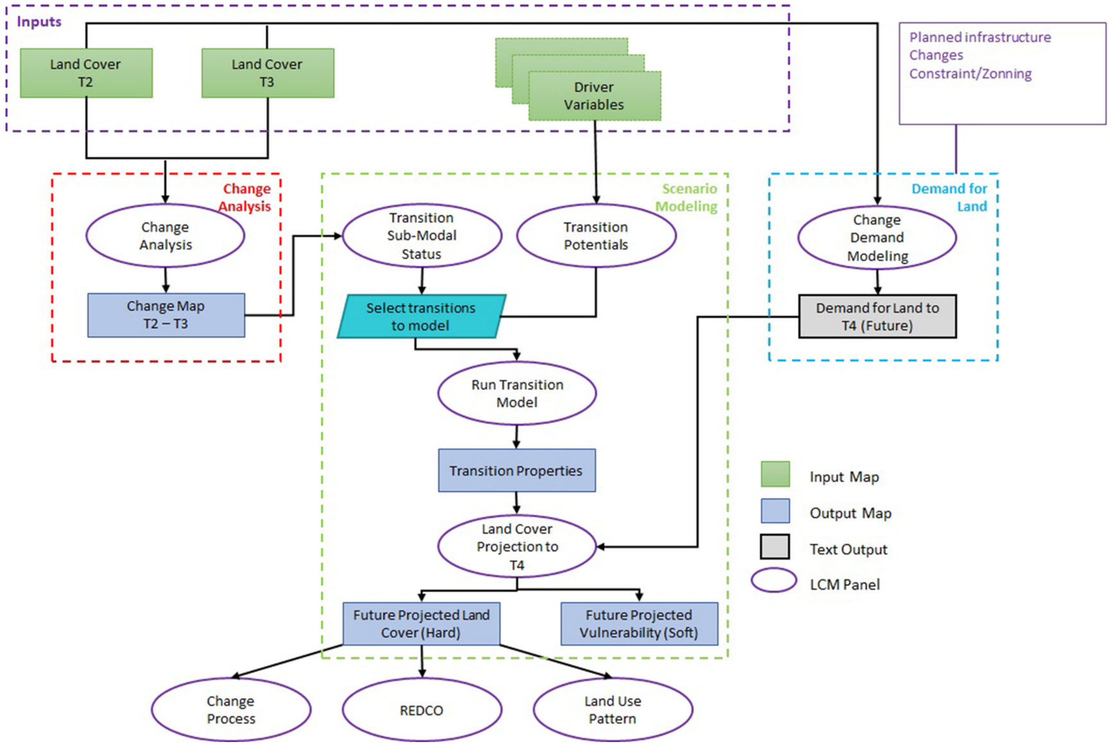


**Fig. 4** LCM modelling flow chart

developed, first one without protected areas (constraint) layer and the other was carried out with constraint layer. Using the constraint layer during the model represents the national designated protected lands within the city borders. The protected areas zones or constraint zoning model input layer included three forest reserves namely Angat, Angat Pilot Project, Dona Remedios Trinidad-General Tinio, and Marikana; one protected landscape/Seascape namely Pamitinan; and four National Parks namely, Mount Banahaw-San Cristobal, Mount Palay–Palay, Mount Makiling, Biak-na-Bato and Hinulugang Taktak.

One of the limitations of the study was the accurate identification of which land was agricultural or vegetation-land use sectors. Because this might have been affected by the agricultural season across the city and type of crop grown during the period the satellite image was captured. However, since the study focused on how much built-up area land increased and gained from other land use sectors including vegetation and agriculture. Having vegetation or agricultural land could not affect the accuracy result of urban area expansion.

*Land use pattern analysis*

Cover and Thomas (2006), explains that in statistics and information theory a maximum entropy probability distribution has an entropy that is at least as great as that of all other members of specified class of probability distributions. According to the principle of maximum entropy, if nothing is known about a distribution except that it belongs to a certain class (usually defined in terms of specified properties or measures), then the distribution with the largest entropy should be chosen as the least-informative default. Cover and Thomas (2006) further explains that the motivation is twofold: first, maximising entropy minimises the amount of prior information built into the distribution; second, many physical systems tend to move towards maximal entropy configurations over time.

For this study, a Normalised Entropy method was used to understand the land use pattern analysis. According to Clark's lab, it is Shannon's Entropy measure normalised by the maximum entropy for the number of land cover classes involved. Another

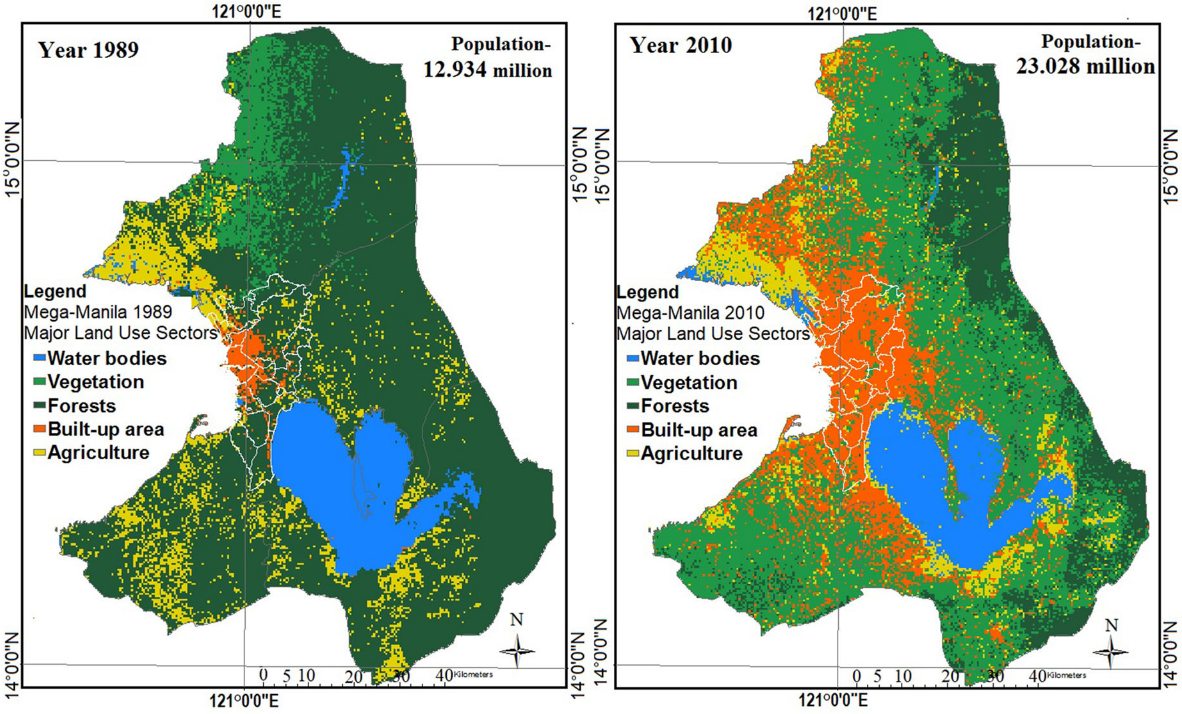


**Fig. 5** Land use maps were generated as input for Land Change Modeller (LCM)

common term for this measure is Diversity. It is calculated over the local neighbourhood of each pixel, defined as either a 3 × 3, 5 × 5 or 7 × 7 neighbourhood. The formula is as follows:

$$E = -\sum (p * \ln(p)) / \ln(\mathrm{n})$$

where $p$ is the proportion of each class within the neighbourhood, ln is the natural logarithm and n is the number of classes. The result is an index that ranges from 0 to 1 where 0 indicates a case where the land cover is uniform within the neighbourhood and 1 indicates maximum diversity possible of land covers within the neighbourhood.

*Change process analysis*

Bogaert et al. (2004), describes the change process as an option that compares the earlier and later land cover maps and measures the nature of the change underway within each land cover class. It is an optional step in the implications platform of land change model software. It does this by using a decision tree procedure that compares the number of land cover patches present within each class between the 1989 and 2030 periods to changes in their areas and perimeters. The output change process map where each land cover class is assigned the category of change that it is experiencing: deformation, shift, perforation, shrinkage, enlargement, attrition, aggregation, creation, dissection, and fragmentation. However, that while the output is in the form of a map, it is not spatially explicit—i.e., the process attributed to a land cover category is uniform over the entire Mega Manila city.

## Results and discussion

### Change analysis between 1989 and 2010

Land use land cover maps for year 1989 and 2010 were prepared as input for land change modeller process. Accuracy assessment was carried out using Google Earth pro and Arc GIS. Result indicated that 2010 Land use land cover map has a 72% accuracy rate with a Cohen's kappa value of 0.907. The 1989 land use map on the other hand indicated 89% accuracy rate

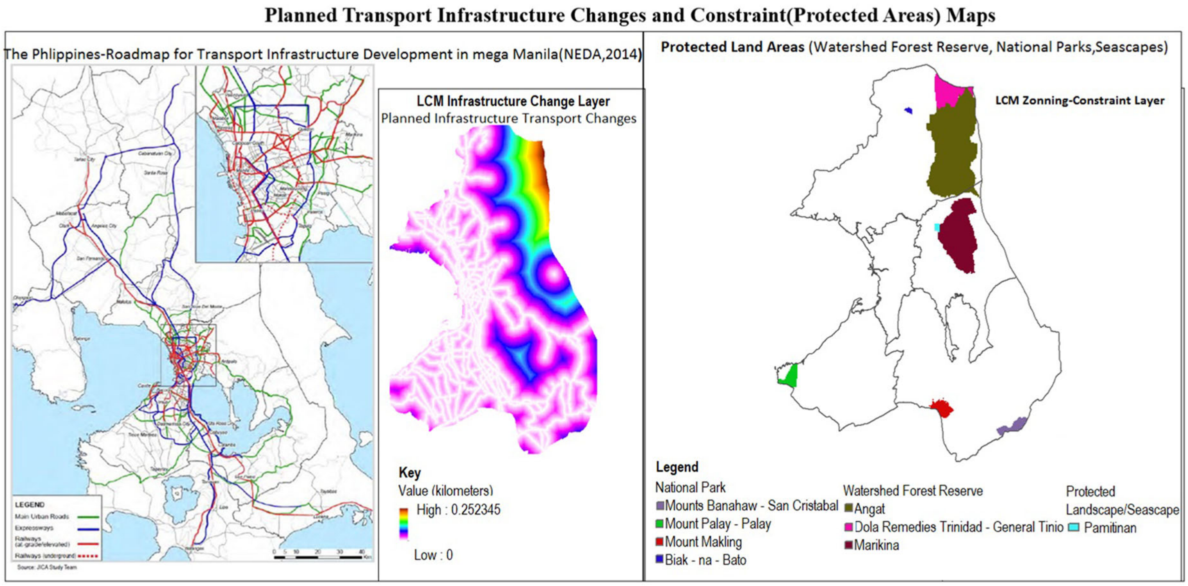


**Fig. 6** Change prediction incorporated protected and planned transport by 2030 layers

and a Cohen's kappa value of 0.866. Figure 6 illustrates the supervised classification process outcome; and the planned digitised Euclidean distance transport infrastructure map and protected area lands in the city.

Our results show that there has been a wide range of forest land changing to other land use sectors between 1989 and 2010 (Fig. 6). Based on these changes, a resulting 2030 land use map was also generated to indicate how much forestland might be there by 2030 (Fig. 7). Transitioning of land from forest sector to other land use sectors indicated a rapid change between the years 1989–2010 (Fig. 8). Here, Fig. 8a shows gains and loss across different land use sectors, while Fig. 8b shows net land use change across sectors, between 1989 and 2010. With a total net loss of forest land of 4389.30 sq. km in 21 years, actual land use shifts from forest land were gained by agriculture, vegetation and built-up area. A net gain for vegetation land and build-up area from 1989 to 2010 was found 3228.68 and 1446.63 sq. km respectively. Overall analysis of gains and loss across sectors indicated that built-up area experienced the highest net gain of 90.96% followed by vegetation with 84.75%. Agriculture experienced a net loss of − 25% (194 sq. km) because despite gaining 66.97% of agricultural land, it lost more land at a rate of 73.61% to 571.22 sq. km. of land use. Vegetation land experienced a significant land loss at 33.68% change. Transitioning change map was generated to understand which land use sector gained more land from the forestland. As shown in Fig. 9, vegetation gained 2938.36 sq. km of land from forests, built-up area 1124.43 sq. km, agriculture gained 300.63 sq. km and water bodies 25. 88 sq. km.

## Land vulnerability and future scenario maps

Since the continuity and connectivity of landscape and mixed land use patterns undergoes a change process and follows a certain landscape pattern; a landscape pattern and change process analysis were carried out in order to understand the probabilities of future change. This analysis was carried out because the connectivity of landscape and mixed land use can change the provision of ecosystem services, affecting sustainability conditions. As shown in Fig. 10, a landscape change pattern map indicated an overall probability of 0.27–0.54 chance that land changes across sectors in Manila will continue to shift across sectors. Land change map indicated that there is more chance that the forest land remaining in Mega Manila city would shift to the built-up (urban) area as indicated in green colour on the change process map below. It also indicated that vegetation land will undergo dissection. Vegetation land area has a high chance to form

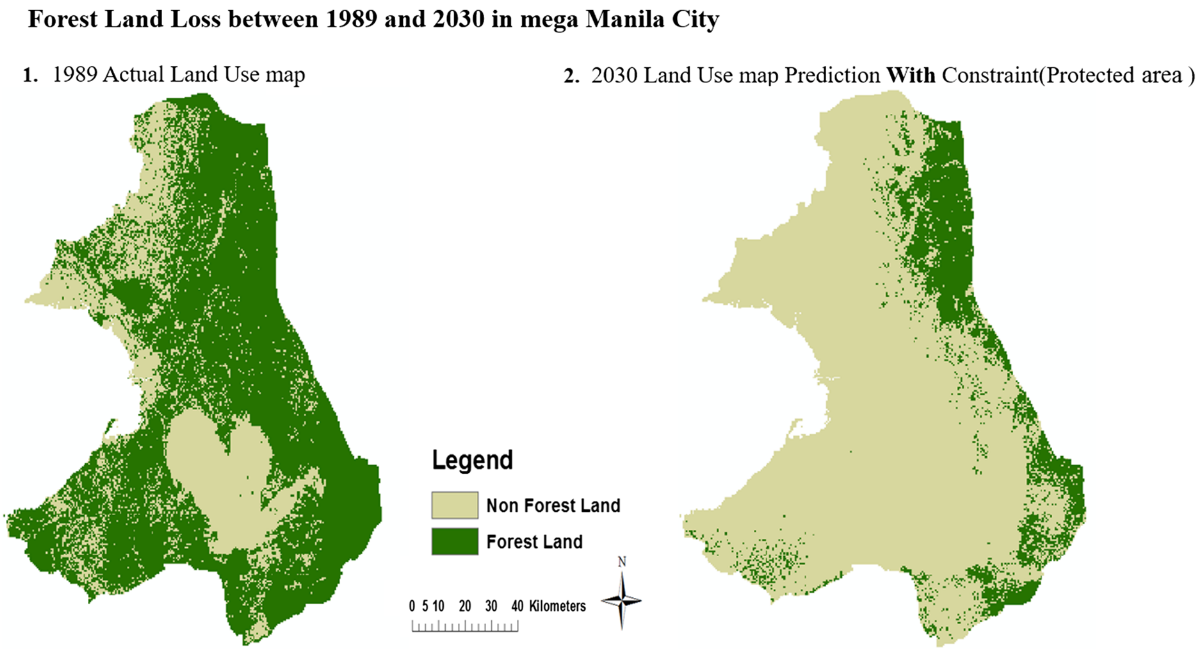


**Fig. 7** Visual spatial extent of forest land cover depletion by 2030 in Mega Manila City

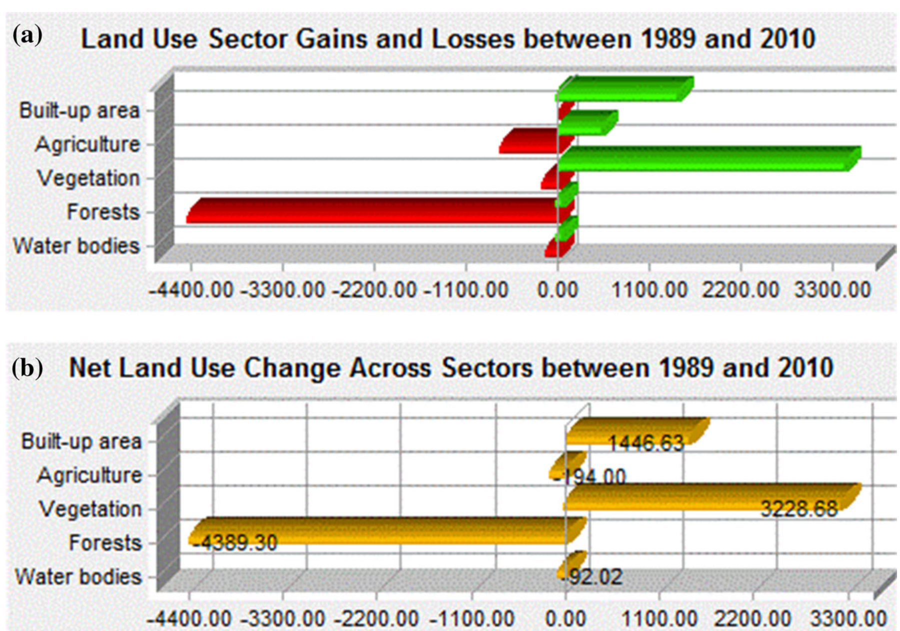


**Fig. 8** **a** Gains and loss across different land use sectors, **b** Net land use change across sectors, between 1989 and 2010

into another land use sector. On the other hand, agriculture pixels indicated a high attrition, which meant that they are weakening their resistance to change. Therefore, agriculture land sector indicated affinity to change because it was experiencing a reduction in its persistence rate of change.

Thereafter, a land vulnerability map generated based on the actual changes that occurred between 1989 and 2010, indicated the same result that forest land has a high creation rate of pixels with a high vulnerability matrices between 151. 68 and 242.68, which is shown in red colour on map 3 in Fig. 10.

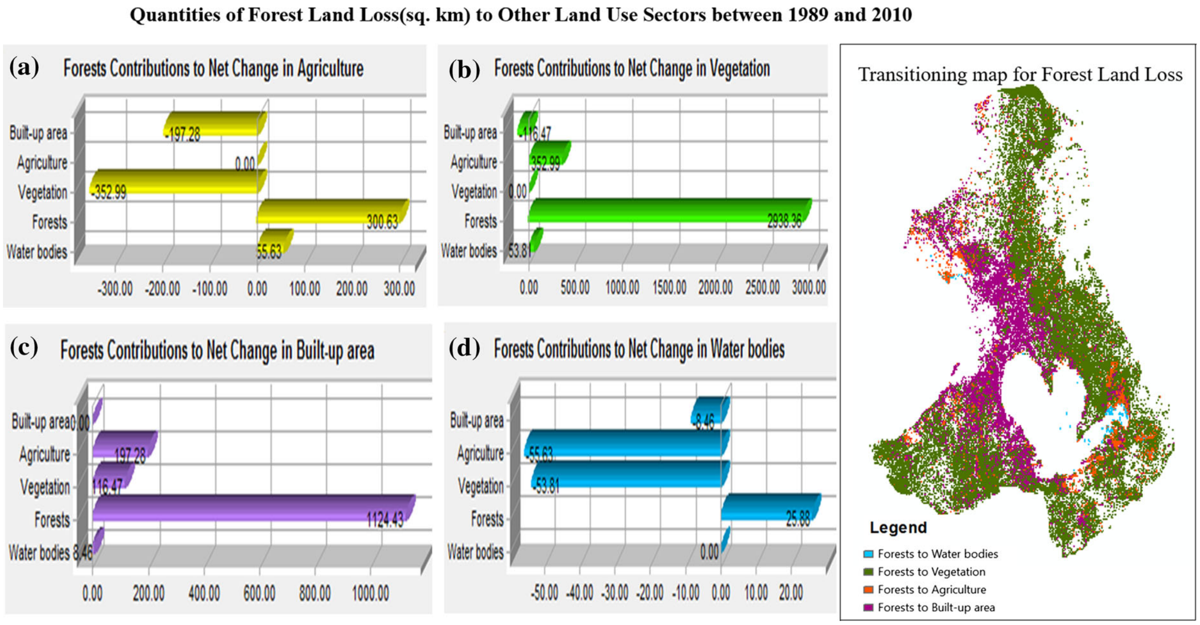


**Fig. 9** Quantities of forest land loss in Mega Manila between 1989 and 2010

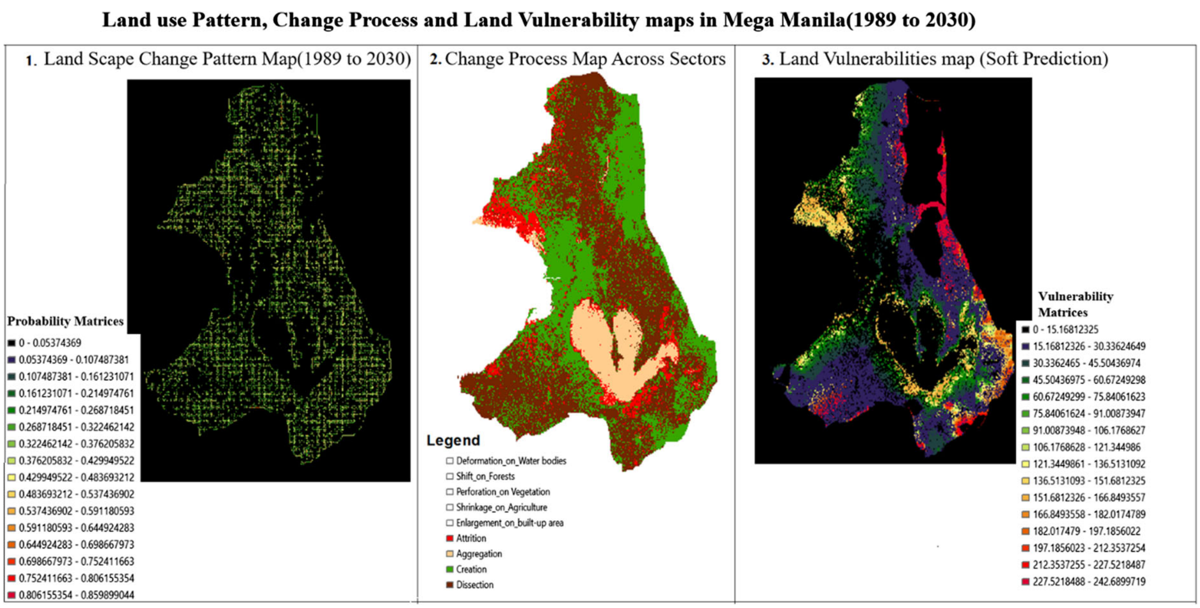


**Fig. 10** Maps indicating probability of future land use shifts in Mega Manila

Note that the protected areas land from Fig. 7 since the modelling process used a constraint layer. However, two future scenario maps were predicted to indicate the probability effects of how urban expansion if not managed might contribute to the depletion of forest land by 2030.

## The 2030 scenario analysis with and without protected area layer

The 2030 scenario map was produced to show the importance of protected area on the forested landscapes. The first scenario map for 2030 showed that the use of a continuous enforcement of protected area on the forest reserves, watersheds and seascapes in Mega Manila is among the best pathways to prevent the depletion of forest land due to urban expansion. As indicated in Fig. 11 below, in the 2030 land use map 3 forest reserves namely Angat-(Angat Pilot Project), Dona Remedios Trinidad-General Tinio and Marikina might experience less change to urban expansion. Unfortunately, in the south of Mega Manila national parks namely Mount Banahaw-San Cristobal, Mount Palay–Palay and Mount Makiling would be the forest land that can be affected by the urban expansion during the first scenario that incorporated protected area lands.

The second scenario prediction of the 2030 map that did not incorporate the protected area layer during the modelling. Clearly indicated a total expansion of built area across all the national parks, forest watershed reserves and the seascape land areas. As indicated in map 2 in Fig. 11. The actual quantity predictions that might occur were reported in terms of how much built-area land would gain by the year 2030. No contributions indicated from water bodies and forests to the built-up area in the with constraint scenario impact analysis. SE Asia shows that forests are the primary source for a much higher percentage of new agricultural land than any other region on earth (Gibbs et al. 2010), with fruits orchards, palm oil farming, tea, rubber, pulp, fire, paper tree plantations etc. agro-forestry plantations.

As indicated in Fig. 12, the amount of land that has been projected to increase the built-up area by 2030 was observed to be 879 sq. km with constraint and 1921 sq. km without constraint scenario. However, this clearly shows that in both scenarios, built-up area sector was projected to experience more net gain than any other land use sector in Mega Manila. With the rate of change of 36% built-up area gain. Again, most of it has been projected to shift to 622 sq. km from vegetation at a rate of change loss of 20% and a 275.02sq. km from agriculture also at change loss of 56% between the years 2010 and 2030 under a with constraint scenario.

On the other hand, without constraint impact scenario indicated a high continuous loss of forest land, which clearly indicates the possibility if no continuous enforcement of the protected area zone law is ensured. As shown in Fig. 12 map-2a the total gain in the urban expansion (built-up area) in spatial form was predicted to 1921.53 sq km at a rate change of 54.71% gain. Contributions to this gain were predicted

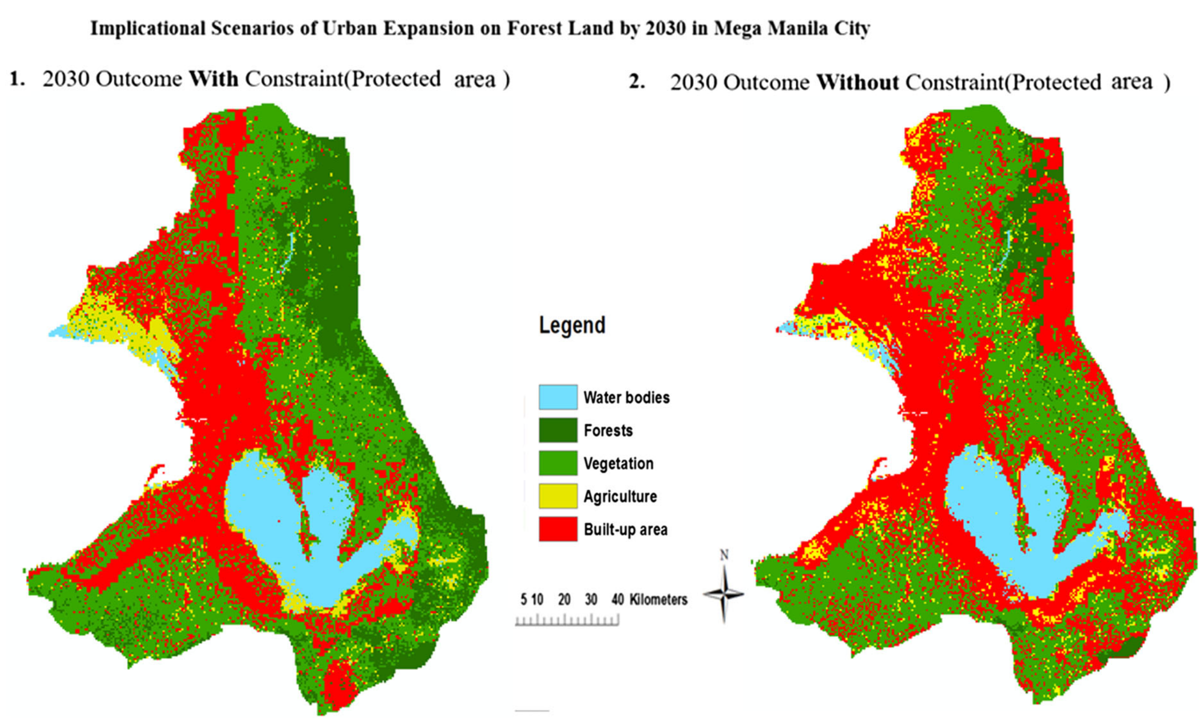


**Fig. 11** Implicational scenarios of urban expansion on forest land by 2030 in Mega Manila

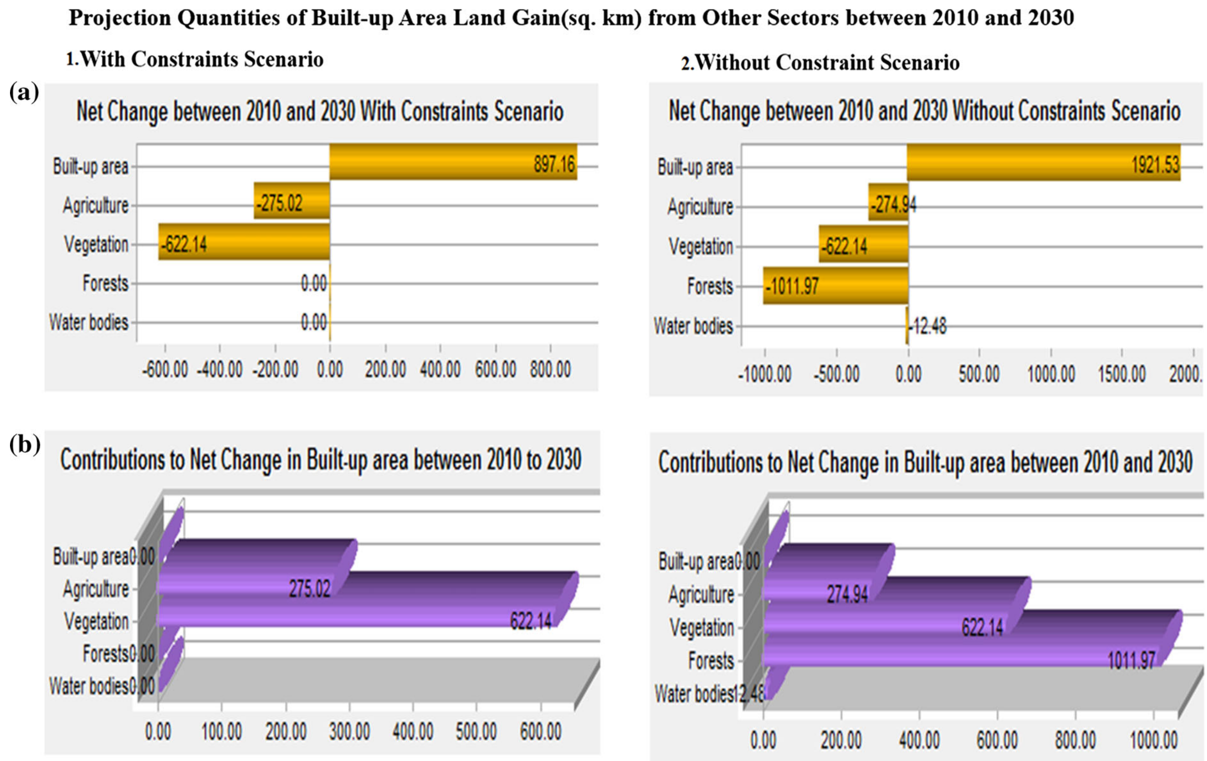


**Fig. 12** Projection quantities scenarios of built-up area land gain

to come from agriculture land, 274.94 sq. km and was identified as one of the major contributors to urban expansion at a rate of 35.72% of its total land use shift. Vegetation indicated a higher resistance to change than agriculture with a rate of change loss of 16.33% but contributing a high value in spatial form with 622.14 sq. km. forest land also contributed to the rate of change of 2.92% but a high value in the spatial form of 1011.97 sq. km that cover most of the forest reserve lands of Angat-(Angat Pilot Project), Dona Remedios Trinidad-General Tinio and Marikana and completely transforming Biak-na-Bako National Parks into built-up area.

However, for this study which concentrated mainly on how other land use sector transitioning to the built-up area and its impacts on the forest land loss. These shifts between vegetation to agriculture and agriculture to vegetation were found not valid to affect result on how much land become built-up area between 1989 to 2030. Since, vegetation to built-up area, agriculture to built-up area quantities are not affected by the time the satellite data was collected.

## Implications of the findings in Philippines and beyond

Our results are similar to the arguments of Afroz et al. (2014), Wells et al. (2014), and Hughes (2017), who evidenced that the high rate of built-area land expansion, if not managed, might come with adverse effects on remaining natural ecosystems. Expansion of built-area land can lead to normal biotic consequences of deforestation, increase in pollution, surface run-off, as well as in due course can become a source of stable populations of invasive species. Defries et al. (2010), further explains that though most studies theorise that urbanisation takes pressure off rural areas, the opposite has been found to be the case, with increasing rates of deforestation correlated with progressive urbanisation in 41 tropical region nations.

At the national level in the Philippines, Myers et al. (2000), Brooks et al. (2006) reports that deforestation has already removed 93% of the original forest cover, which is a tragedy in one of the two regions considered a biodiversity hotspot. According to the WWF Greater Mekong 2013 report it is a similar situation in most

Southeast Asian countries, where the forest is 2–4% for Thailand, Vietnam, Myanmar, and specific values for Lao PDR that has lost 5.29% of forest, Cambodia 6.97%, Indonesia 8.73% and Malaysia 14.5%. This forest loss becomes eminent because it does not only include encroachment (Pearce 2007; Hughes 2017), but also in worst-case scenario the entire denudation of a protected area may take place, for example, in Riau National Park in Indonesia, only 2.63 sq. km of the 157.83 sq. km of forest present in 1986 remained in 2006.

Typically, Sundaland, Wallacea, Indochina and the Philippines, represent some of the most biologically diverse regions on earth and the continuous reduction of forest land leads to degradation of remaining biodiversity hotspots. Fox et al. 2014 explains that the implications of little or no law enforcement leads to increased erosion, increased environmental risk of landslides and reducing emissions from deforestation and forest degradation (REDD) is among the examples of global initiatives that is always being criticized and improved though it has the potential to facilitate forest water reserves, national parks, and seascape preservation from humanity inhabitant occupation impacts.

Hughes (2017) reported that at global level Southeast Asia experiences the highest deforestation rates, with major threats to biodiversity being anthropogenic activities such as mining in the tropics, the greatest number of hydropower dams under construction, and a consumption of species for traditional medicines. Miettinen et al. (2011) estimated that around 14.5% of regional forest cover loss in the last 15 years at an average rate of 1% loss annually, and of the 73% of land covered by forest in 1973, only 51% existed by 2009.

Furthermore, in global analysis, the expansion of urban areas in East and SE Asia was found to potentially disproportionately impact on protected areas, with more protected areas projected to become within 10 km of a city by 2030 in SE Asia than in any other region (McDonald et al. 2008), driving a direct loss in biodiversity in areas directly converted, increases in accessibility and potential disturbance to surrounding regions and increasing demands for conversion of surrounding regions to support the needs of urban expansion and inhabitants.

Hughes (2017) mentioned that tree plantations and deforestation represents one of the most imminent drivers of land use change in cities, and some countries have already lost over half their original forest cover (i.e., the Philippines, parts of Indonesia), with projections of as much as 98% loss for some regions in the coming decade. Deforestation is mainly supported by activities such as mining, through the construction all the infrastructure needed to facilitate production and the cost of this to biodiversity is not only through the direct loss of areas for mines, but also through the development of roads that further fragment the landscape.

## Conclusion

It is claimed that that SE Asian protected areas were performing comparatively well relative to other parts of the world in terms of protecting forests (Hughes 2017; Heino et al. 2015). However, on closer scrutiny, protected areas only perform 1.5% better than forest outside protected areas in terms of preventing deforestation, and in a number of countries (i.e., the Philippines), protected areas actually have higher rates of deforestation than unprotected areas (3.14% vs. 2.86%), and the majority of countries show under 1% difference between the two.

In our study, urban expansion through transport infrastructure, together with industrial structure developments, contribute to adversely affect ecological sustainability. These factors are continuously fed by high demand of natural resource use in Mega Manila city. Urban expansion has been projected to expand by 897.16 sq. km (36% land gain) with 275.02 sq. km (19.52% land loss) to be gained from agriculture sector and 622.14 sq. km (55.59% land loss) to be gained from vegetation-land use sector. Land use activities such as timber industry or urban expansion can change surface reflectance and local precipitation patterns. It eventually affects the hydrological cycle, carbon cycle hence contributing to climate change related events at a local city level. In conclusion, land use changes across sectors followed a landscape pattern change process from forest to vegetation, vegetation to agriculture and then agriculture to built-up area, vegetation to built-up area between 1989 and 2010. The same simultaneous land sector shift patterns have been observed to continue for the coming years from 2010 to 2030. There is a continuous exchange between vegetation and agriculture land sectors.

Based on the findings of this study, considerable urban expansion is projected in due course to wipe out the forest lands of Mega Manila city by 2030. Global, Private Sector and community resilience initiatives such as UNREDD, REDD+ etc. enforced by both local, external and government can be supported by our study for protection of remaining forests and their biodiversity near urban areas.

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**Compliance with ethical standards**

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## References

Afroz, R., Masud, M. M., Akhtar, R., & Duasa, J. B. (2014). Water pollution challenges and future direction for water resource management policies in Malaysia. *Environment and Urbanization Asia, 5*(1), 63–81.

Bogaert, J., Ceulemans, R., & Salvador-Van Eysenrode, D. (2004). Decision tree algorithm for detection of spatial processes in landscape transformation. *Environmental Management, 33*(1), 62–73.

Bren d'Amour, C. B., Reitsma, F., Baiocchi, G., Barthel, S., Güneralp, B., Erb, K.-H., Haberl, H., Creutzig, F., & Seto, K. C. (2017). Future urban land expansion and implications for global croplands. In *Proceedings of the National Academy of Sciences of the United States of America*.

Brooks, T. M., Mittermeier, R. A., daFonseca, G. A., Gerlach, J., Hoffmann, M., Lamoreux, J. F., et al. (2006). Global biodiversity conservation priorities. *Science, 313,* 58–61.

Cheng, J., & Masser, I. (2003). Urban growth pattern modeling: a case study of Wuhan City, PR China. *Landscape and Urban Planning, 62*(4), 199–217. https://doi.org/10.1016/S0169-2046(02)00150-0.

Cover, T. M., & Thomas, J. A. (2006). Chapter 12, maximum entropy. Elements of information theory, 2edn. Wiley. ISBN 0471241954.

DeFries, R. S., Rudel, T., Uriarte, M., & Hansen, M. (2010). Deforestation driven by urban population growth and agricultural trade in the twenty-first century. *Nature Geoscience, 3*(3), 178–181.

Fox, J., Castella, J. C., Ziegler, A. D., & Westley, S. B. (2014). Rubber plantations expand in mountainous Southeast Asia: What are the consequences for the environment? *AsiaPacific Issues, 114*(4), 1–8.

Gao, J., & Li, S. (2011). Detecting spatially non-stationary and scale-dependent relationships between urban landscape fragmentation and related factors using Geographically Weighted Regression. *Applied Geography, 31*(1), 292–302. https://doi.org/10.1016/j.apgeog.2010.06.003.

Gibbs, H. K., Ruesch, A. S., Achard, F., Clayton, M. K., Holmgren, P., Ramankutty, N., et al. (2010). Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. *Proceedings of the National Academy of Sciences USA, 107*(38), 16732–16737.

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., et al. (2013). High resolution global maps of 21st Century forest cover change. *American Association for the Advancement of Science, 342*, 6160.

Heino, M., Kummu, M., Makkonen, M., Mulligan, M., Verburg, P. H., Jalava, M., et al. (2015). Forest loss in protected areas and intact forest landscapes: A global analysis. *PLoS ONE, 10,* e0138918.

Helming, K., Marta, P.-S., & Paul, T. (2008). *Sustainability impact assessment of land use changes*, ISBN 978-3-540-78647-4. Springer, Berlin, Heidelberg, New York.

Hughes, A. C. (2017). Understanding the drivers of Southeast Asian biodiversity loss. *Ecosphere, 8*(1), 01624. https://doi.org/10.1002/ecs2.1624.

Human Development Report. (2016). Human development for everyone, United Nations Development Programme, USA, pp. 286. ISBN: 978-92-1-126413-5.

Iizuka, K., Johnson, B. A., Onishi, A., Magcale-Macandog, D. B., Endo, I., & Bragais, M. (2017). Modeling future urban sprawl and landscape change in the Laguna de Bay Area, Philippines. *Land, 6*(2), 26. https://doi.org/10.3390/land6020026.

IPCC. (2014). Climate change 2014: Synthesis report. *The contribution of working groups I, II and III to the Fifth assessment report of the intergovernmental panel on climate change*. (80 pp, 4.2 M, About PDF) EXIT [Core Writing Team, R.K. Pachauri and L.A. Meyer (Eds.)]. IPCC, Geneva, Switzerland, 151 pp.

IPCC. (2014). Climate Change 2014: Mitigation of climate change. *EXIT contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (Intergovernmental Panel on Climate Change). (2008). Climate change 2007. Synthesis report. *Contribution of working groups I, II and III to the fourth assessment report*. In: R. K. Pachauri, A. Reisinger (Eds.) Intergovernmental Panel on Climate Change (IPCC), Geneva-Switzerland, p.104.

Ismail, R. (2014). South-east Asian urbanisation and the challenge to sustainability: implications for the environment and health. *Environmental Policy and Law, 44*(1), 55.

Japan International Cooperation Agency (JICA) And National Economic Development Authority (NEDA). (2014).

*Roadmap for transport infrastructure development for metro manila and its surrounding areas (Region III & Region IV-A)*, Final Report Summary, Almec Corporation.

Kenworthy, J. R. (2019). Urban transport and eco-tourism: A global comparative study of cities with a special focus on five larger Swedish urban regions. *Urban Science, 3,* 25. https://doi.org/10.3390/urbansci3010025.

McDonald, R. I., Kareiva, P., & Forman, R. T. (2008). The implications of current and future urbanisation for global protected areas and biodiversity conservation. *Biological Conservation, 141*(6), 1695–1703.

Miettinen, J., Shi, C., & Liew, S. C. (2011). Deforestation rates in insular Southeast Asia between 2000 and 2010. *Global Change Biology, 17*(7), 2261–2270.

Mundhe, N. N., & Jaybhaye, R. G. (2014). Impact of urbanization on land use/land covers change using Geo-spatial techniques. *International journal of Geomatics and Geosciences, 5*(1), 50–60.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., DaFonseca, G. A., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature, 403*(67722), 853–858.

Patra, S., Sahoo, S., Mishra, P., & Mahapatra, S. C. (2018). Impacts of urbanization on land use/cover changes and its probable implications on local climate and groundwater level. *Journal of urban management, 7*(2), 70–84.

Pearce, F. (2007). Bog barons: Indonesia's carbon catastrophe. *New Scientist, 196*(4), 50–53.

Saatchi, S., et al. (2011). *Benchmark map of forest carbon stocks in tropical regions across three continents*. PNAS June 3, 2011.

Seto, K. C., Sánchez-Rodríguez, R., & Fragkias, M. (2010). The new geography of contemporary urbanisation and the environment. *Annual Review of Environment and Resources, 35*(1), 167–194.

Shlomo, A., Parent, J., Civco, D. L., Blei, A., & Potere, D. (2011). The dimensions of global urban expansion: Estimates and projections for all countries, 2000–2050. *Progress in Planning, 75*(2), 53–107.

The 2004 IUCN Red List of Threatened Species

The Food And Agriculture Organization Of The United Nations's Global Forest Resources Assessment. (2015). Country Report, the Philippines, Prepared as a contribution to the FAO publication, The Philippines report, FAO as official government documents. http://www.fao.org/3/a-au190e.pdf.

United Nations, Department of Economic and Social Affairs, Population Division (UN DESA), World Urbanization Prospects: the 2014 Revision, ST/ESA/SER.A/366, 2015, p. 517.

United Nations Environment Programme—World Conservation Monitoring Centre (UNEP-WCMC). (2004). *Protected Areas, Plant and animal biodiversity*—World Database on Protected Areas.

United Nations, World Economic and Social Survey 2013. Sustainable Development Challenges. E/2013/50/Rev. 1. ST/ESA/344. Department of Economic and Social Affairs. ISBN-13: 978-9211091670

Wang, Z., Chai, J., & Li, B. (2016). The impacts of land use change on resident's living based on urban metabolism: a case study in Yangzhou city of Jiangsu province China. *Sustainability, 8,* 1004. https://doi.org/10.3390/su8101004.

Wells, K., Lakim, M. B., & O'Hara, R. B. (2014). Shifts from native to invasive small mammals across gradients from tropical forest to urban habitat in Borneo. *Biodiversity and Conservation, 23*(2), 2289–2303.

WWF-Greater Mekong. 2013. *Ecosystems in the Greater Mekong: past trends, current status, possible futures*. wwf.panda.org/greatermekong.