

Das, Manob; Das, Arijit

Article

Dynamics of urbanization and its impact on Urban Ecosystem Services (UESs): A study of a medium size town of West Bengal, Eastern India

Journal of Urban Management

Provided in Cooperation with:

Chinese Association of Urban Management (CAUM), Taipei

Suggested Citation: Das, Manob; Das, Arijit (2019) : Dynamics of urbanization and its impact on Urban Ecosystem Services (UESs): A study of a medium size town of West Bengal, Eastern India, Journal of Urban Management, ISSN 2226-5856, Elsevier, Amsterdam, Vol. 8, Iss. 3, pp. 420-434, <https://doi.org/10.1016/j.jum.2019.03.002>

This Version is available at:

<https://hdl.handle.net/10419/271366>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by-nc-nd/4.0/>



Dynamics of Urbanization and its impact on Urban Ecosystem Services (UESs): A study of a medium size town of West Bengal, Eastern India



Manob Das*, Arijit Das

Department of Geography, University of Gour Banga, Malda, West Bengal 732103, India

ARTICLE INFO

Keywords:

Urban ecosystem
Ecosystem services
Medium size town
Sensitivity analysis
Urban sustainability

ABSTRACT

The continuous urban expansion changes the urban ecological landscape pattern and urban ecosystem functions that possess serious challenge before urban environmental and ecological management. In this context, assessing the relationship between rapid urban expansion and ecosystem services play an important role for the urban sustainability and development related to planning and policies. This study mainly focuses on the assessment of the dynamic nature of urbanization and its impact on urban ecosystem services through land use and land cover (LULC) changes of Old Malda Municipal town, Eastern India. The ecosystem service values (ESVs) are analyzed using Remote Sensing data and GIS techniques corresponding with the global Value Coefficient (VC) for four-time periods (1990, 2000, 2010 and 2017) to estimate total ecosystem service values (ESV_t) and individual ecosystem service function change. Coefficient of Sensitivity (CS) is also applied to test the reliability of the estimated VC used as proxies for each LULC categories. The result of the study landscape reveals that the ecosystem service values (ESVs) decreased by 25% from US\$ 1.33 million to US\$ 1.07 million because of losing cropland and vegetation cover by 34% and 35% respectively during 1990–2017. In case of individual ecosystem service functions, regulating services increased by 12% since 1990–2017 with highest contributing services of water regulation (57%), water supply (22%) and waste treatment (8%) respectively while maximum decline is recorded in soil formation (33.33%) followed by climatic regulation (31.82%) and nutrient cycling (31.25%). The decline in total and some individual ESV in the study landscape requires for urgent measures to be taken to enhance the urban ecosystem sustainability through effective planning and policies.

1. Introduction

Demand of urban land and concentration of urban population in urban areas are increasing over the period which brings massive changes of the loss of various natural capitals. Urban expansion is nothing but LULC change process which converts the natural land cover to built up urban (He, Zhang, Huang, & Zhao, 2016). Different type of natural land cover on the earth surface such as forest cover, crop land, water bodies which provide ecosystem services are largely affected by the process urban expansion. In fact as the natural or semi-natural land covers convert into impervious land surface (ILS), it affects the ecosystem function by altering the biogeochemical process and circulation pattern (Grimm et al., 2008; Zhang et al., 2009; Kaye, Groffman, Grimm, Baker & Pouyat, 2006) and cause loss of ecosystem services (ESs) (Foley et al., 2005; Lawler et al., 2014; Delphin, Escobedo, Abd-Elrahman & Cropper,

* Corresponding author.

E-mail addresses: dasmanob631@gmail.com (M. Das), arijit3333@gmail.com (A. Das).

<https://doi.org/10.1016/j.jum.2019.03.002>

Received 18 December 2018; Received in revised form 11 February 2019; Accepted 13 March 2019

Available online 25 April 2019

2226-5856/ © 2019 Zhejiang University and Chinese Association of Urban Management. Production and hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

2016; Eigenbrod et al., 2011). Apart from this, ecological processes and its functions are also influenced in variety of ways (Turner, Gardner, O'Neill & O'Neill, 2001; Weng, 2007) such as water quality, land quality (Su et al., 2011a,b; Su and Zhi et al., 2011; Tu, 2011), biological diversity (Turner, Gardner, O'Neill & O'Neill, 2001), habitat (Ng, Xie, & Yu, 2011), emission of GHGs (Matteucci & Morello, 2009) and so on. The rapid rate urbanization during the last few decades accelerated the demand of urban land and continuous replacement of different natural land cover types brought ceaseless substitution in urban land use pattern particularly in developing countries such as China, India and African countries (Seto, Güneralp & Hutrya, 2012) which leads to a decline of the ecosystem services gained from urban ecological land (UEL) in an urban areas (Bohnet & Pert, 2010; Güneralp & Seto, 2008; Huang, Wang & Budd, 2009; Jomaa, Auda, Saleh, Hamzé, & Safi, 2008; Li, Zhu, Sun & Wang, 2010; Pauleit, Ennos, & Golding, 2005; Su, Gu, Yang, Chen & Zhen, 2010; Sundell-Turner & Rodewald, 2008). About 50% of the world's total population is now residing in urban areas and which will reach to 60% by 2023 (Avelar, Zah, & Tavares-Corrêa, 2009). The impact of land use land cover changes either man made or natural is well documented and it brings concern about the ecosystem process and functions (Chase, Pielke Sr, Kittel, Nemani, & Running, 2000). Therefore, assessing as well as estimating losses of ecosystem services due to continuous urban built up expansion plays a significant role for sustainable urban development at regional scales and future planning for urban development.

The services gained from the ecosystem directly or indirectly to human well-being are defined as ecosystem services. Urban ecosystem services (UESs) are those services provided by urban ecological landscape (such as green space, park, water bodies etc.) and their corresponding components (Gómez-Baggethun & Barton, 2013). An urban environment provides a number of ecosystem services such as air purification, noise pollution reduction, regulation of climate (Bolund & Hunhammar, 1999; Jansson, 2013), food production or supply, waste treatment, local urban climate regulation, run off mitigation (Gómez-Baggethun & Barton, 2013). The rapid conversions of LULC in cities cause changes in biogeochemical cycle pattern, climate change and alteration in hydrological system and biodiversity (Alberti, 2005; Grimm et al., 2008). For this reason emphasis is being given on the changes of the urban ecological landscape UEL (urban ecological land) which provides ecosystem services to the urban environment from different open spaces such as forest cover, park, water bodies, and farmland. The ecosystem services like regulating, provisioning, supporting and cultural services are provided from such types of land uses which are inevitable for the existence of urban human life and urban quality of life. Urban ecological landscapes provide ecosystem services from a number of sources which can be broadly divided into two categories-green spaces (such as parks, urban forest, garden and yards, landfills etc.; and blue spaces (such as rivers, ponds, lakes, artificial swales etc.). There is a great demand or high intensity use of UES (Urban Ecosystem services) due to large number of urban receivers as compared to rural ecosystem services areas.

The present world experiences rapid rate of urbanization and it is becoming the hub of comprehensive development in socio-economic, cultural and other aspects characterized by shifting of rural population to urban areas. The unprecedented urbanization particularly in developing countries like India and China results gradual increase of population density in urban areas, the continuous expansion of urban land, rapid transformation of rural landscape into urban landscape, changes in economic activities from agricultural to non-agricultural economic activities (primary to secondary or tertiary economic activities) and the overall alteration in consumption behavior and living of standard in urban environment. Although many benefits (socio-economic, cultural) are attained by the process of urbanization among urban residents but a number of barriers are built in natural environment by transforming the urban landscape and affecting UAHB (Urban Atmosphere Hydrosphere and Biosphere). Recently, all around the world, rapid urbanization is one of the major cause of the global environmental and ecological changes and therefore, the projection of such changes is important for upcoming decades (Qu & Lu, 2015). The basic questions arising to the environmentalists and with which global world is concerned are (1) how to slim down the impact of rapid urbanization on the global ecological and environmental change? (2) how to achieve sustainable urban development through ecological planning (Breuste, Haase & Elmqvist, 2013; Breuste & Qureshi, 2011; Taylor & Hochuli, 2015) identifying the urbanization induced ecological problems? Therefore, in this context, effective environmental management is required for the proper understanding the relationship between urbanization and ecosystem services value in urban life. The measures of urban ecosystem services (UESs) are the important tools or indicator to quantify the quality of ecological environment and it has become a field of interest to the ecologists (Ahern, Cilliers & Niemelä, 2014; Costanza et al., 2014, 1997; Estoque & Murayama, 2013). A number of studies are performed to assess the impact of urbanization on ecosystem services (Alam, Dupras & Messier, 2016; Peng, Liu, Wu, Lv., & Hu, 2015; Wan et al., 2015) which aids to identify ecosystem services declined because of continuous urban expansion. Therefore, it is essential to examine the relationship between comprehensive urbanization and its impact on the urban ecosystem services.

In general context, Ecosystem Services (ESs) refers to benefits that human beings derive from ecosystems functions (De Groot, Wilson, & Boumans, 2002) or direct and indirect contributions from ecosystems. The concept of Ecosystem Services (ESs), here defined as "The conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (Daily, 1997). In Urban context, ESs refers to the dependency of urban population on goods and services provided by ecosystems (Elmqvist, , Fragkias, , Goodness, , & G, 2013; Gómez-Baggethun & Barton, 2013) and their components. The basic question that arises what does actually UESs (Urban ecosystem Services) mean? This question appears specially due to discrepancy (for both temporal and spatial) between boundary of an urban area and resource used within the urban area (Borgström, Elmqvist, Angelstam & Alfsen-Norodom, 2006; Ramalho & Hobbs, 2012). In this study Urban Ecosystem Services (UESs) are defined as those ecosystem services that directly provided by ecological landscape of an urban area (Gutman, 2007; Jansson, 2013). Pickett et al., (2001) documented that urban ecosystems are the built infrastructure covering a large area of land surface or area people living with high densities. Identification of clear boundary of urban ecosystem is very difficult because functions of urban ecosystems extend far beyond the physical boundary of urban area. Urban ecosystem not only includes ecological infrastructure (blue and green spaces) within the urban but also comprises urban hinterland that directly get affected from the core of city (in the form of materials and energy), suburban lands (Pickett et al., 2001) as well as city catchment and forests and cultivated lands of peri-urban areas (La Rosa &

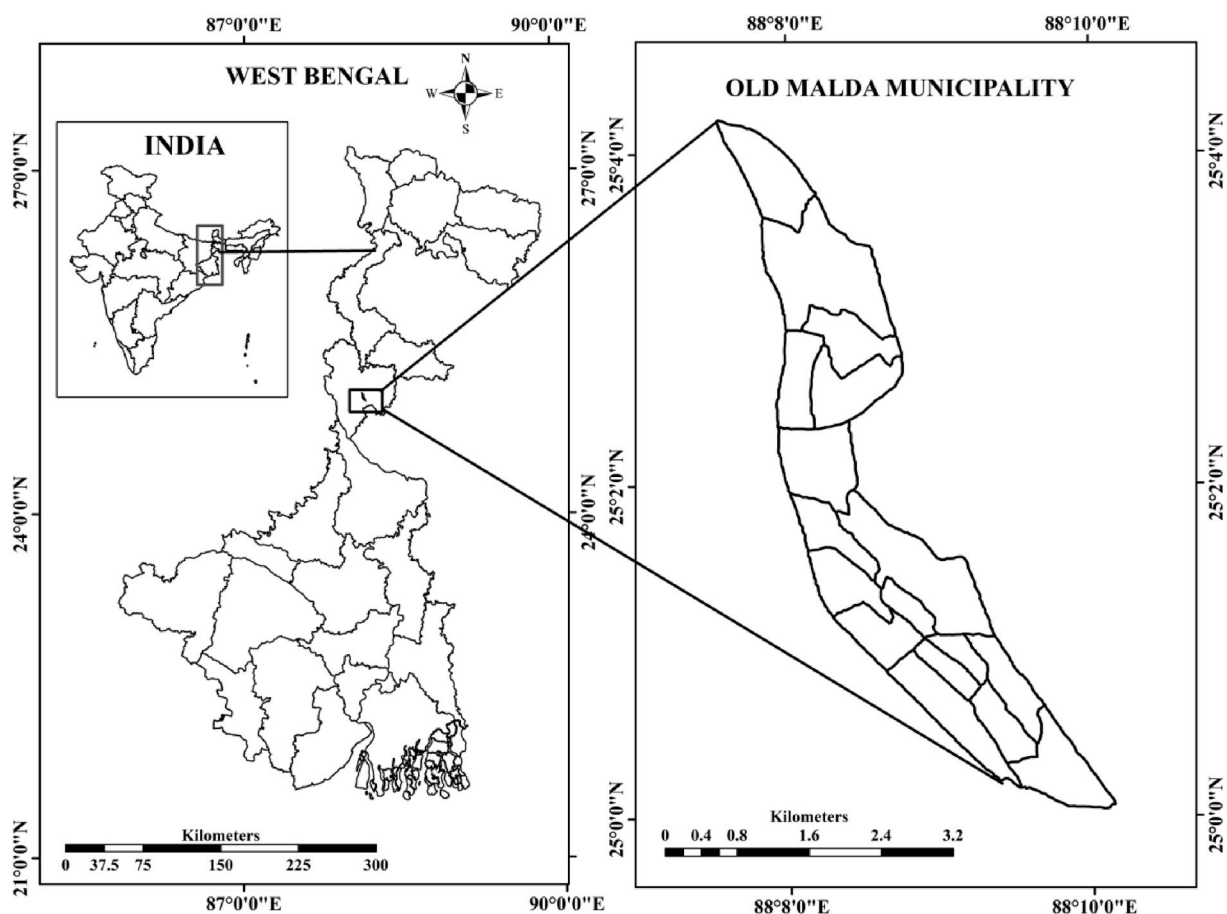


Fig. 1. Location map of the study landscape.

Privitera, 2013). Simply, Urban Ecosystem (UEs) means the services provided by urban ecological landscape within the physical boundary of an urban area. So practically urban ecosystem service mean those ecosystem services that are obtained from urban green or ecosystem products by urban population.

The urbanization process brings an impact on the changes of ecosystem services as the natural land covers are converted into artificial impervious surface because of high demand of urban land, space and resources. However, how do the ecosystem services change due to rapid expansion of urbanization? Are there any impact land use land cover (LULC) changes on ecosystem services? To investigate the answer of such questions, the present paper tries to establish the relationship between urbanization and ecosystem services provided by urban environment. The basic objectives of the study are to examine the dynamics of urbanization and its impact on the ecosystem services; and to assess the impact of the land use land cover changes on the ecosystem services since 1990 to 2017.

2. Materials and methods

2.1. Study area

The municipal town (Fig. 1), Old malda is a medium size town (population ranging from 20000 to less than 100000 according to the Census of India) located on the left bank of the river Mahanada and its confluence of Kalindri river which is a part of English Bazar Urban Agglomeration (EBUA) between 25°0' N to 25°4' N and 88°8' E to 88°10' E. It covers an area of approximately 9.54 sq. km. Old Malda has a subtropical monsoon climate with an average annual temperature of 30 °C. Physiographically Old malda is situated in Barind region which is characterized by ancient alluvial humps and old riverine flood plains.

Over the last 10 years, Old malda experienced rapid rate of urbanization which is leading factor for the changes of ecosystem services. In 1991, total urban population living in this town was 13021 which increased to 62959 and 84012 in 2001 and 2011 respectively. The most obvious results of this population increase are demand of land in urban areas for habitation and commercial purposes and rapid changes of land use/land cover (Gong and Xia, 2007). The environmental and ecological problems (such as air pollution, deterioration of the water quality, loss of habitation etc.) are associated with such changes of the land use/land cover (from natural to built up). These urban problems somehow create barriers in the quality of life for urban inhabitants. From this point of

view, assessment of the urban ecosystem services is very important.

2.2. Data used

In this study, cloud free multi-temporal landsat 5TM (Thematic Mapper-path/row 139/43; with spatial resolution 30 m) data of 1990, 2000 and 2010 and Landsat 8 OLI data of 2017 obtained from USGS (United Nation Geological Survey) have been used for Land use/land cover (LULC) classification (Shown in Table 1). The acquired landsat data are pre-georeferenced with UTM (Universal Transverse Mercator) coordinate system applying WGS 84 (World Geodetic System) datum. In this study supervised maximum likelihood algorithm is applied using ArcGIS 10.3 for the land use/land cover classification (LULC) as well as for the identification corresponding biomes (Shown in Tables 2 and 3).

Table 1

Landsat image used in this study.

Satellite images	Image ID	Acquisition date	Resolution (m)	Path/Row	Cloud cover (%)	Source
Landsat 5 TM	LT513904319900105BKT00	05/01/1990	30×30	143/39	<1010	USGS
	LT513904320000117BKT00	17/01/2000				
	LT513904320100128KHC00	28/01/2010				
Landsat 8 OLI	LC813904320170109LGN00	09/01/2017	30× 30 (15 m for band 8)			

2.3. Land use/land cover (LU/LC) classification and accuracy assessment

In this study landscape, land use/land cover classification has been prepared in Arc GIS software (version 10.3) using Supervised (Maximum likelihood) Image Classification Technique (SICS). More than 20–30 spectral signatures have been taken as representative signature for each land use/land cover type. For the accuracy assessment, Kappa Coefficient (KC) is computed for the classified images 1990, and 2017 respectively based on some representative reference points extracted from Google earth image. Total 112 and 103 reference points from Google earth image have been collected for the year 1990 and 2017 respectively. Kappa Coefficient is one the advanced measures for the better understanding of interclass discrimination rather than overall accuracy level of classification (Foody, Campbell, Trodd, & Wood, 1992; Ma & Redmond, 1995). The Kappa Coefficient value ranges from 0 to 1 where 0 represents least accuracy between field reality and classified images and the value > 0.85 indicates strong agreement between two sets of data (Monserud & Leemans, 1992). The Kappa Coefficient is calculated with help of following equation:

Table 2

Land use and land cover types used in this study area.

Land cover types	Description
built up	Land predominantly covered with houses,
Agricultural land	The area specially used for the production of agricultural crops
Vegetation	Area covered with
Water body	Area with open water including river, lakes and ponds

Table 3

Biome equivalent and corresponding Ecosystem Services value (as per as Costanza et al., 1997).

Land use types	Equivalent biomes	ESV coefficient (Million US\$ ha ⁻¹ yr ⁻¹)
built up	Urban	0
Agricultural land	Cropland	92
Vegetation	forest	969
Water body	River/lakes/ponds	8498

$$\text{Kappa Coefficient (KC)} = \frac{N \sum_{i=1}^r x_{ii} - \sum_{i=1}^r (x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^r (x_{i+} * x_{+i})}$$

Where, **KC** = Kappa Coefficient, **N** = total number of pixels; **r** = number of rows in matrix; **x_{ii}** = number of observation in row **i** and column **i**; **x_{i+}** and **x_{+i}** are the marginal for row **i** and column **i** respectively.

2.4. Estimation of ecosystem services (ESV)

Global VC (value coefficient) for 17 biomes was proposed by Costanza et al. (1997) to estimate the status of ecosystem services around the world. In this study to quantify the ESV (Ecosystem Service Value) for four land use categories, VC proposed by Costanza et al. (1997) is used. The most representative biomes are used as proxy for individual land use categories such as urban for settlement, river/lakes/ponds for water body, crop land for agricultural or cultivated land and forest for vegetation respectively.

The following equations are applied to quantify total ecosystem service value (ESV_t) and individual ecosystem service function (ESV_f) respectively:

$$ESV_k = A_k \times VC_k$$

Table 4

Ecosystem service Classification (Costanza et al., 1997).

Ecosystem services	Corresponding types (as per Costanza et al., 1997)
Provisioning	Food production, Raw materials etc.
Regulating	Gas regulation, Climate regulation, disturbance regulation, water regulation, water supply, water treatment etc.
Supporting	Soil formation, nutrient cycling, erosion control, pollination, biological control, habitat/Refugio, genetic resource
Cultural	Recreation, culture etc.

$$ESV_t = \sum A_k \times VC_k$$

$$ESV_f = \sum A_k \times VC_{kf}$$

Where, ESV_k , ESV_t and ESV_f is the ecosystem service value for individual land use categories, total ecosystem service value and individual ecosystem service function; A_k the area and VC_k is value coefficient (US\$ ha/year) for land use category k respectively. VC_{kf} is the value coefficient of function (US\$ ha/year) for land use category k.

After estimation of total ecosystem service values (ESVs) in the study landscape, the average Ecosystem service values (ESV_{avr}) is computed with the help of following equation:

$$ESV_{avr} = \frac{ESV_t}{U_a}$$

Where, ESV_{avr} is the average ecosystem service values (US\$/ha/year), ESV_t is the total ecosystem service value for a certain study year and U_a is the total geographical area of the urban area (ha).

2.5. Analysis of Sensitivity Index (SI)

In this study, the biomes are used as proxies for individual land use and land cover (LULC) types and they are not perfectly matched with the biomes proposed by Costanza et al. (1997, 2014), so an uncertainties exist in computing VC (value coefficient). Therefore, it is necessary to conduct the sensitivity analysis to determine the changes (%) of ecosystem service value on the changes (%) of value coefficient (VC). Using the concept of elasticity applied in economics, Coefficient of sensitivity (CS) has been performed with the help of following equation (Kreuter, Harris, Matlockm& Lacey, 2001):

$$CS = \frac{(ESV_j - ESV_i)/ESV_i}{(VC_{jk} - VC_{ik})/VC_{ik}}$$

Where, CS is the coefficient of sensitivity, ESV is the estimated ecosystem service value, VC is the value coefficient, i and j denotes the initial and adjusted values respectively and lastly k represents land use category. If the value of CS is greater than 1 (> 1) then the estimated ecosystem value is considered to be elastic (relatively high sensitive) in response to the VC and more attention needs to be paid in computing VC accurately but on the other hand if the value of CS is less than 1 (< 1) then the estimated ecosystem service value is inelastic (relatively low sensitive) with respect to VC and the resultant ecosystem service value is reliable.

3. Results

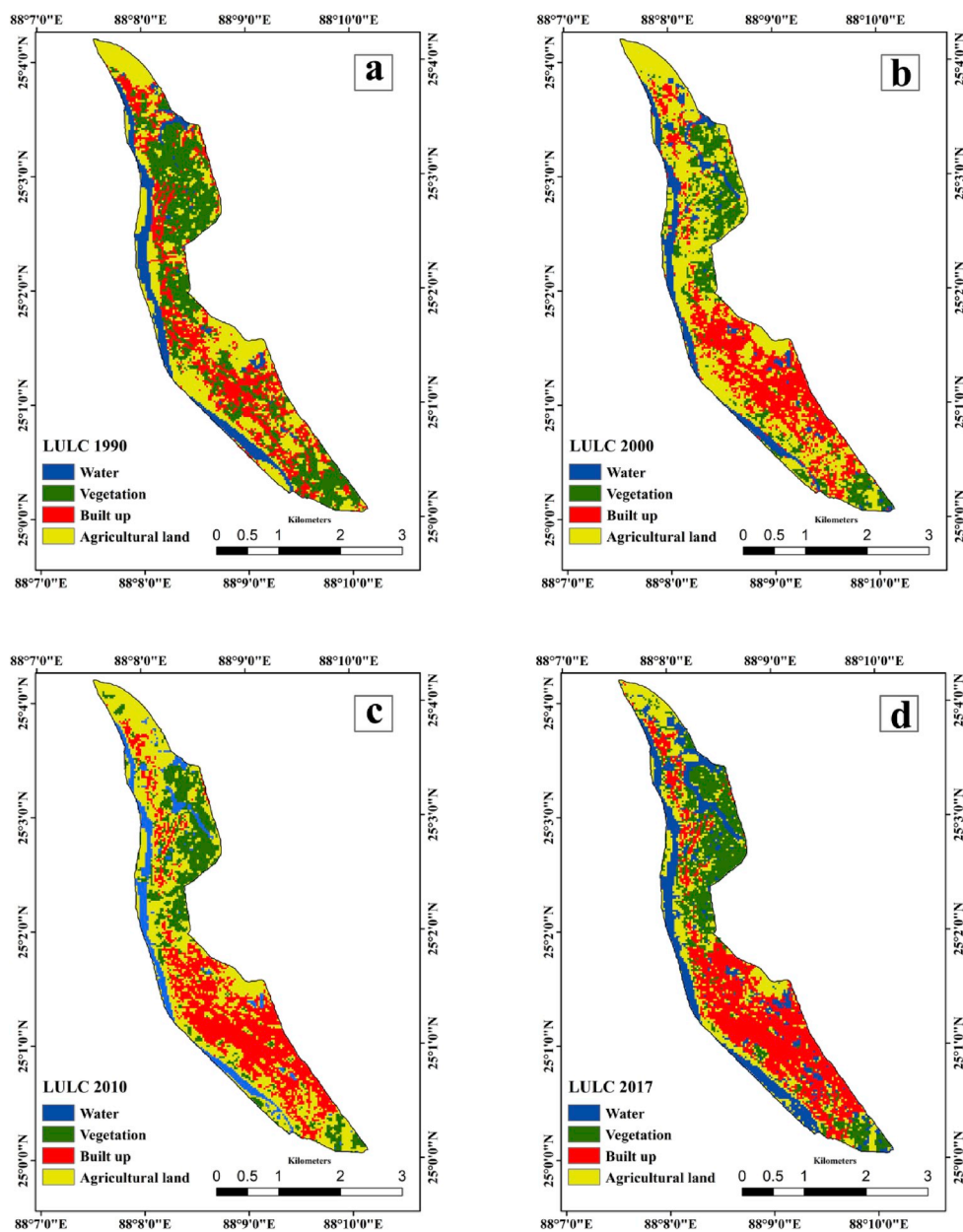
3.1. Urbanization pattern in the study landscape

Old malda municipality is a medium size town in malda district which experienced rapid rate of urbanization in recent year (Shown in Table 4). The urban built up of old malda municipality was 212 ha in 1990 and which increased to 313 ha in 2017 respectively. The urban land expanded by 47.64% from 1990 to 2017 with annual growth rate of 1.76%. The urban population also increased since 1991. According to the census of 1991, total urban population was 13021 which increased to 62944 (2001) ad 84012 (2011) respectively (Shown in Table 5).

Table 5

Pattern of built up and Population Growth (Census of India) in the study landscape.

Years	Growth of built up (%)	Years	Population Growth (%)
1990–2000	18.39	1991–2001	383.47
2000–2010	10.36	2001–2011	33.47
2010–2017	12.99	1991–2011	545.20
1990–2017	47.64	2011–2021	NA

**Fig. 2.** LULC maps of the study landscape (a) 1990 (b) 2000 (c) 2010 and (d) 2017.

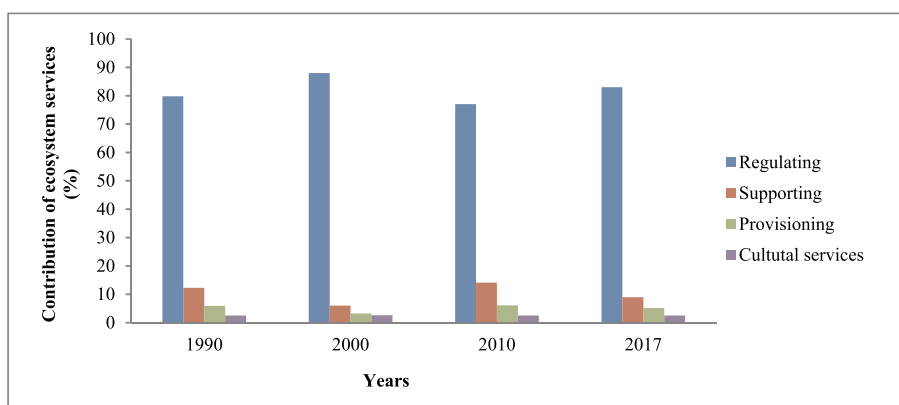


Fig. 3. Contribution of ecosystem services in the study landscape.

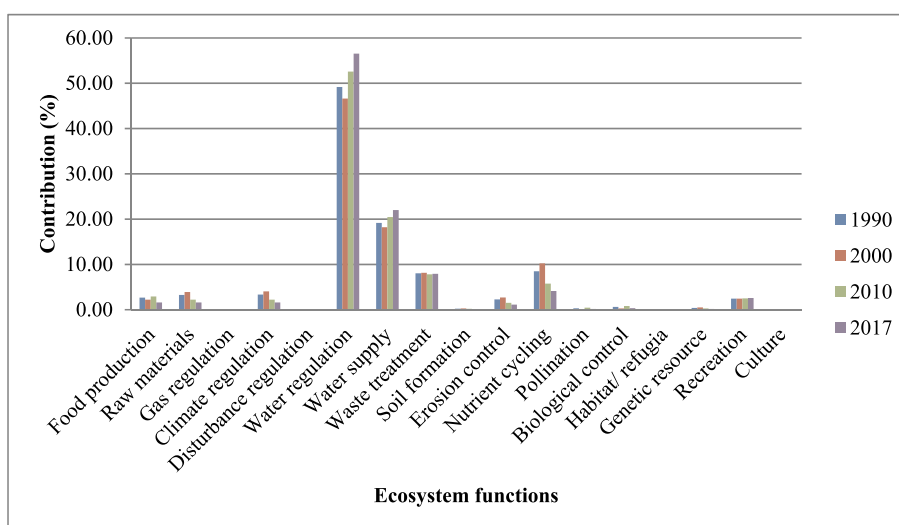


Fig. 4. Contribution of individual ecosystem service functions since 1990–2017.

3.2. Dynamics of LULC changes

In order to assess the dynamics of land use/land cover changes in the study landscape, change analysis of four LULC types are carried out based on LU/LC change maps from 1990 to 2017 (Shown in Fig. 2). The LU/LC change in the study landscape since 1990–2017 reveals that the areal coverage of each land use/land cover has changed substantially (Shown in Table 6 and Fig. 2). In 1990, agricultural land was the dominant land cover types (33% of the total area), followed by vegetation (32%), built up (22%) and water (12%) which replaced by built up (33%), agricultural land (25%), vegetation (22%) and water (20%) respectively. During the study period, highest increase in area is recorded in water (63.03%) followed by built up (47.64%) and highest decrease is examined in vegetation (– 30.74%) followed by agricultural land (– 25.40%) respectively. During the entire study period, water body and built up areas increased quickly from 119 ha to 194 ha and 212 ha–313 ha respectively. The rapid expansion of built up area is caused by

Table 6
LU/LC changes in the study landscape (1990–2017).

LULC classes	Area coverage (ha)				Changes in area (%)			
	1990	2000	2010	2017	1990–2000	2000–2010	2010–2017	1990–2017
Built up	212	251	277	313	18.39	10.36	12.99	47.64
Agricultural land	315	408	388	235	29.53	– 4.90	– 39.43	– 25.40
Vegetation	309	173	180	214	– 44.01	4.05	18.89	– 30.74
Water body	119	123	109	194	3.36	– 11.38	77.98	63.03
Total	955	955	955	955				

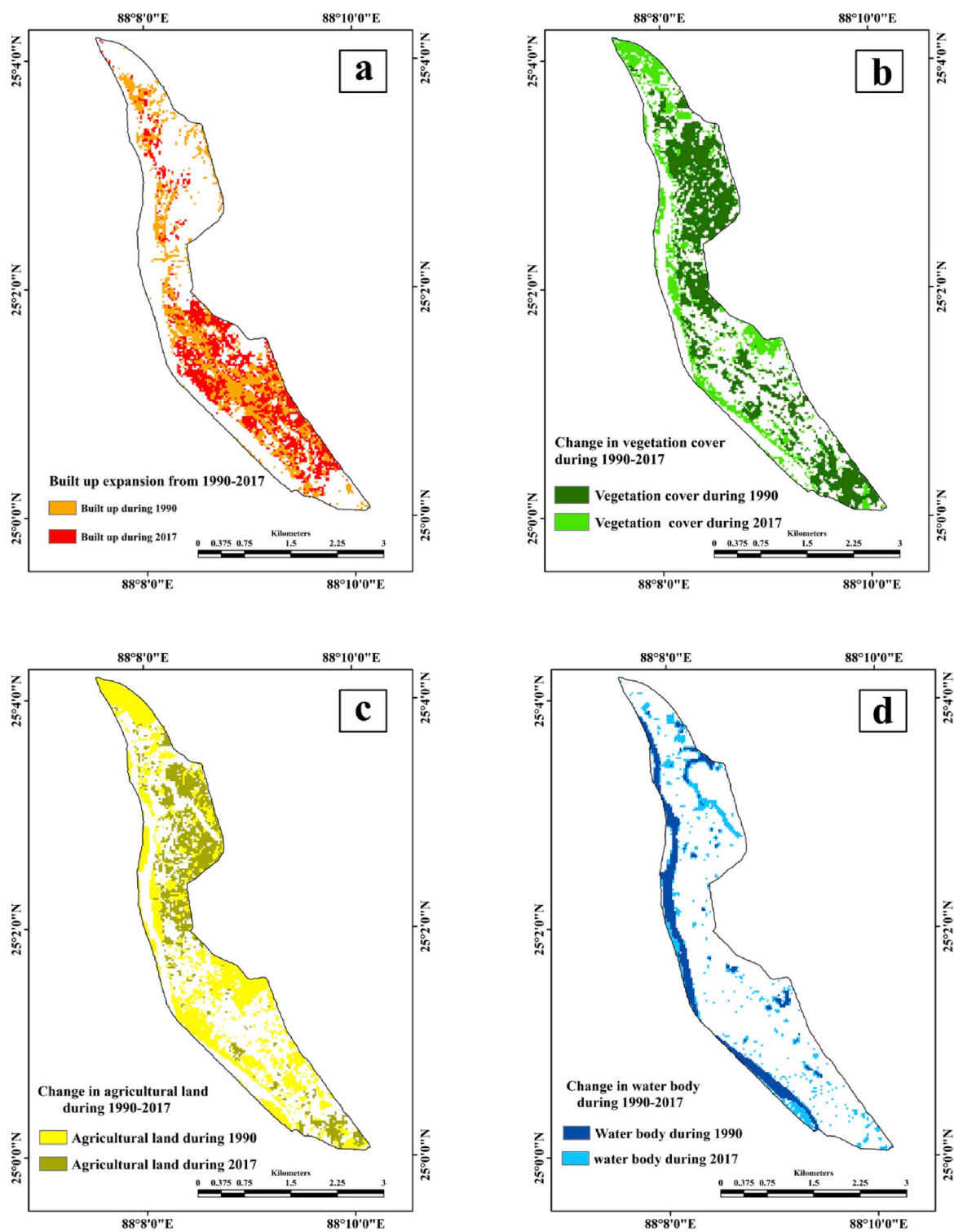


Fig. 5. Changes of corresponding biomes since 1990–2017 (a) urban (b) forest (c) crop land (d) water.

the mainly decrease of agricultural land and vegetation, with a decline from 315 ha to 235 ha (agricultural land) and 309 ha–214 ha (vegetation) respectively (Shown in [Tables 6 and 7](#), and [Fig. 3](#)).

3.3. Accuracy assessment

Accuracy assessment for the classified images of 1990 and 2017 based on 112 and 103 reference sites are carried out. The result shows that the overall accuracy level for year of 1990 and 2017 is 82% and 85% with Kappa coefficient value of 0.79 and 0.82 respectively.

3.4. Changes in total ESV in the study landscape

In this study, ecosystem service value for the each land use/land cover types as well as estimated loss of ESVs for the year 1990, 2000, 2010 and 2017 are computed applying value coefficient (VC) proposed by [Costanza et al. \(1997\)](#) (Shown in [Table 2](#)). Total ecosystem service value (ESV_t) increased in the first decade (1990–2000) by 9.09%. Since 2000–2010 and 2010–2017, total ecosystem service decreased by –21.52% and –1.77% respectively. Overall, the net decline in ecosystem service value is approximately –20.15% since 1990–2017 over the last 27 years of the study period due to decrease in vegetation and agricultural land. Water recorded highest ecosystem service value (ESVs) among four land use/land cover types because of highest value coefficient of water covering about 75% (1990) and 87% (2017) of total ESVs respectively. But although the agricultural land covers largest total area, the contribution (2% in 1990 and 1.12% in 2017 respectively) in total ESVs is relatively low because of lowest value coefficient (Shown in [Table 2](#)). In the study landscape water body and forest is the important ecosystem service provider accounting about 95% of the total ESVs (see [Fig. 4](#)).

Table 7

Annual value of ESV_f (US\$ million per year) for equivalent biomes.

Ecosystem services	Sub types	Crop land	Forest	Water	Urban
Provision	Food production	54	43	41	0
	Raw materials	–	138	–	0
Regulating	Gas regulation	–	–	–	0
	Climate regulation	–	141	–	0
	Disturbance regulation	–	2	–	0
	Water regulation	–	2	5445	0
	Water supply	–	3	2117	0
	Waste treatment	–	87	665	0
Supporting	Soil formation	–	10	–	0
	Erosion control	–	96	–	0
	Nutrient cycling	–	361	–	0
	Pollination	14	–	–	0
	Biological control	24	–	–	0
	Habitat/refugia	–	–	–	0
	Genetic resource	–	16	–	0
Cultural	Recreation	–	66	230	0
	Culture	–	2	–	0
Total		92	969	8498	0

Table 8

Total estimated ecosystem service values (ESVs) for LULC types and their changes during 1990–2017 ([Costanza et al., 1997](#)).

LULC types	ESV (US million/ha/yr)				ESV changes (based on 2007 US\$ million ha ^{−1} yr ^{−1})			
	1990	2000	2010	2017	1990–2000	2000–2010	2010–2017	1990–2017
Built up	0	0	0	0	0	0	0	0
Agricultural land	0.029	0.038	0.036	0.021	0.009	−0.002	−0.027	−0.008
Vegetation	0.299	0.167	0.174	0.207	−0.132	−0.007	0.033	−0.092
Water body	1.01	1.05	0.93	1.64	0.035	−0.119	0.008	0.630
Total	1.33	1.44	1.13	1.07	0.11	−0.32	0.74	−0.26

The contribution of individual ecosystem service functions (ESV_f) are shown in [Table 9](#). In the study landscape regulating services contributed highest ecosystem services (more than 80% in 1990 and 2017) followed by supporting (12.27% in 1990 and 5.99% in 2017), provisioning (5.91% in 1990 and 3.20% in 2017) and cultural services (2.50% in 1990 and 2.57% in 2017) respectively. The contribution of each ecosystem service value (ESVs) varied during the study period. The highest contribution of each ecosystem service function (ESV_f) to the total ESVs was recorded by water regulation and followed by water supply, nutrient cycling, and waste treatment (Shown in [Tables 10 and 11](#)).

Table 9Estimated ESV_f (US\$ million per year) in the study landscape (Costanza et al., 1997) for four representative equivalent biomes.

Ecosystem services		ESV _f (US\$ million per year)			ESV _f changes (%)				
		1990	2000	2010	2017	1990–2000	2000–2010	2010–2017	1990–2017
Provision	Food production	0.035	0.032	0.033	0.030	−0.003	0.001	−0.009	−0.005
	Raw materials	0.043	0.056	0.025	0.030	0.013	−0.031	−0.001	−0.013
Regulating	Gas regulation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Climate regulation	0.044	0.058	0.025	0.030	0.014	−0.033	−0.001	−0.014
	Disturbance regulation	0.001	0.001	0.00	0.00	0.00	0.00	0.00	0.00
	Water regulation	0.649	0.671	0.594	1.057	0.022	−0.077	0.005	0.408
	Water supply	0.253	0.262	0.231	0.411	0.009	−0.031	0.002	0.16
Supporting	Waste treatment	0.106	0.117	0.088	0.148	0.011	−0.029	0.00	0.005
	Soil formation	0.003	0.004	0.002	0.002	0.001	−0.002	0.002	−0.001
	Erosion control	0.030	0.039	0.017	0.021	0.009	−0.022	−0.001	−0.009
	Nutrient cycling	0.112	0.147	0.065	0.077	0.035	−0.082	−0.003	−0.035
	Pollination	0.004	0.002	0.005	0.003	−0.002	0.003	−0.002	−0.001
	Biological control	0.008	0.004	0.009	0.006	−0.004	0.003	−0.004	−0.002
	Habitat/refugia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Genetic resource	0.005	0.007	0.003	0.003	0.003	−0.004	0.00	−0.002
Cultural	Recreation	0.032	0.035	0.028	0.048	0.003	−0.007	0.00	−0.016
	Culture	0.001	0.001	0.00	0.00	0.00	0.00	0.00	0.00
Sum		1.32	1.44	1.13	1.07				

3.5. Impacts of land use/land cover changes on the ESV

Over the 27 years of the study period, a notable change in the contribution of area and ecosystem service value (ESVs) of individual land use/land cover types are recorded (Shown in Tables 6 and 8). Since 1990–2017, vegetation and agricultural land decreased by 30.74% and 25.40% respectively. On the other hand, the area of Built up consistently increased during the study period (1990–2017). In particular, built up covers 22.20% in 1990 which reached to 32.77% in 2017. Consequently, the total ESVs significantly declined since 1990–2017. For example, ecosystem service value crop land and forest decreased by 27.59% and 30.77% during the study period. The negative change of terrestrial ecosystem (crop land and vegetation cover) greatly influenced the total ESVs in the study landscape. The ecosystem service value (ESV_k) of crop land and forest deceased by US\$ 0.10 million while total ecosystem value (ESV_t) in the study area declined by US\$ 0.26 million (Shown in Table 8 and Figs. 5 and 6).

3.6. Analysis of ecosystem sensitivity

In this study, the coefficient of sensitivity (CS) for all the land use/land cover (LULC) types are less than 1 (< 1) which indicates that the estimated total ecosystem service values (ESV_t) were relatively low sensitive (inelastic) in response to the VC (value coefficient). The lower and higher value of Coefficient Sensitivity (CS) is recorded for crop land and water ranging from 0.01 to 0.02 to 0.78–0.88 respectively when the value coefficient for all the land use/land cover types are adjusted by 50% (Shown in Table 9). Relatively lower value of Coefficient Sensitivity (CS) indicates that the area of the concerned LULC types or the corresponding VC for that particular land use type is relatively low and vice versa. In the study landscape water and forest records the highest CS because of relatively large area (forest) and highest value coefficient (water). Coefficient of Sensitivity (CS) in case of water is relatively high (> 0.78) which indicates that more careful attention needs to be paid in considering the Value Coefficient (VC) in comparison to other components. Overall results shows that the coefficient sensitivity (CS) estimated in this study landscape is robust in spite of uncertainties exist in the value coefficient.

Table 10

ESVs after adjusting VC and coefficient of sensitivity (CS).

Change in VC	ESV		Change (1990–2017)	Effect of changing VC from original value			
	1990	2017		%	CS	%	CS
Forest + 50%	1.47	1.97	0.50	± 11.36	± 0.23	± 5.35	± 0.11
Forest − 50%	1.17	1.77	0.60				
Cropland + 50%	1.33	1.88	0.55	± 0.76	± 0.02	± 0.53	± 0.01
Cropland − 50%	1.31	1.86	0.550				
Water + 50%	1.83	2.69	0.86	± 38.6	± 0.78	± 43.85	± 0.88
Water − 50%	0.82	1.05	0.23				

4. Discussion

The study reveals that significant changes in the contribution of ESVs function are recorded during entire study period. The most significant positive changes have examined in ecosystem service value functions such as water regulation, water supply, nutrient cycling, and waste treatment which are the dominant contributors of total ecosystem service functions (specially regulating and supporting services). On the study of four time periods, (1990, 2000, 2010 and 2017) and the entire study from 1990 to 2017 revealed the fact that ecosystem service values (ESVs) has changed due to dynamics character of land use/land cover changes. Particularly, ecosystem service value declined over the last 27 years while the value coefficient of [Costanza et al. \(1997\)](#) was applied. In fact during last 27 years ecosystem service values (ESVs) of forest and crop land have declined with varied fraction due to conversion of these two land covers which are considered as the main sources of ecosystem services. The previous studies documented that change of LULC affects the corresponding ESs negatively. [Kreuter, Harris, Matlock, and Lacey \(2001\)](#) conducted a study and estimated the total loss of US\$ 6 million in San Antonio from 1976 to 1991. The ecosystem service values (ESVs) Pingbian country in China also showed a declining trend (25.4%) between the studies of 1974–2004 due to change of forest ecosystem ([Li et al., 2007](#)). [Leh, Matlock, Cummings, and Nalley \(2013\)](#) made attempts to quantify the ESVs in West Africa and concluded that ecosystem service values declined during the time periods of 2000–2009. The presents study also revealed a decline of ecosystem service values (ESVs) from US\$ 1.33 million to US\$ 1.07 million from 1990 to 2017 respectively as a result of decreasing forest and crop land ecosystems (see [Fig. 7](#)).

The contribution of individual ecosystem service functions (ESV_{*p*}) in the study landscape changed very slightly. The regulating services (79.78% in 1990; 83.01% in 2017) followed by supporting services (12.27% in 1990; 8.93% in 2017) are highest contributor of ecosystem service values (ESVs). But individually, the most five important contributor of ecosystem services functions are water regulation (56.52%) and followed by water supply (21.98%), waste treatment (7.91%), nutrient cycling (4.12%) and recreation (2.57%) respectively.

Table 11

Previous studies on loss of ESs due to urbanization.

Study Scale	Study landscapes	Research Periods	Loss of ESs	References
Global	world	2000–2015	Habitat for species (PSs), Biomass carbon storage (RSs)	Nelson et al., (2010)
Local	Massachusetts (USA)	2001–2011	Habitat Quality (SSs), Clean water (PSs),	Blumstein and Thompson (2015)
	Watershed in Florida (USA)	2003–2060	Timber volume (PSs), Carbon storage (RSs)	Delphin et al. (2016)
	Miyan reservoir watershed (China)	1990–2009	Fresh water (PSs), water purification (RSs)	Li et al., (2013a,2013b)

Losing of ecosystem services due to urban expansion are not local phenomena rather a common global issue. A number of studies have been performed throughout the world and this studies show that urban expansion led to the losses of ecosystem services namely regulating, supporting and provisioning services. [Seto, Güneralp, and Hutyra \(2012\)](#) and [Eigenbrod et al. \(2011\)](#) conducted a study at global scale and documented that habitat quality; food production will decline at global as well local scale within next 15 years due to urban expansion. A study was conducted by [Blumstein & Thompson \(2015\)](#) in Massachusetts, USA since 2001 to 2011 and found that WS (water supply) and FR (flood regulation) decreased because of rapid urban expansion. A similar kind of study was also performed by [Foley et al. \(2005\)](#) indicating that the ecosystem services reduced due to urban expansion. In this study landscape, ecosystem services such as soil formation, climatic regulation and nutrient cycling were decreased by more than 30%.

One of the main source of ecosystem services in this study area are crop land and forest area but due to continuous urban expansion – these ecosystem service providers were transformed into built up which is the main cause of ecosystem service losses. [Blumstein & Thompson \(2015\)](#) documented the same reason for the decline of ESs in Massachusetts since 2001–2011 where ESs services decreased because of the transformation crop land and forest into urban area. The conversion of forest into urban land led to the decline of timber production (11–21%) and carbon storage (16–26%) in Watershed in Florida, USA ([Delphin, Escobedo, Abd-Elrahman, & Cropper, 2016](#)). In this study, it is recorded that total ecosystem service value and individual ecosystem service value declined because loss of vegetation and crop land by 24% which shows consistency with the previous studies.

A number of research studies have been conducted on urbanization and its impact on the ecosystem services. Changes of the global ecological condition due to urbanization are ubiquitous and this global ecological condition likely to change in future ([Qu & Lu, 2015](#)). Simultaneous loss of ESs (supporting, provisioning and regulating) was recorded in a number of previous studies due to urban expansion ([Alam, Dupras, & Messier, 2016](#); [Peng, Liu, Wu, Lv., & Hu, 2015](#); [Wan et al., 2015](#)). [Wu, Ye, Qi, and Zhang \(2013\)](#) conducted a study on LULC changes and its relation with socio-economic development in Hangzhou metropolitan area (HMA) during 1978–2008 and study revealed that expansion of built up (169.85%) is one of the major cause of declining regional ES functions (decreased by 24.04%). [Zhang, Huang, He, and Wu \(2017\)](#) simulated the impact of urbanization on ecosystem services (ESs) in Beijing-Tianjin-Hebei urban agglomeration in China over the period of 2013–2040 and result showed that food production (1.34–3.16%), water retention (0.80–1.89%), carbon storage (1.68–1.60%), air purification (0.37–0.87%) will decline due to continuous expansion of urban land. In this region, ESs during 2013–2040 will decline by 83.66–97.11% due to conversion of cropland to urban built up.

In upcoming future, rapid urban expansion will lead to the loss of Ecosystem services because disordered and unplanned urban expansion (especially in developing country like India) and unplanned urbanization will capture adjacent forest cover and crop land

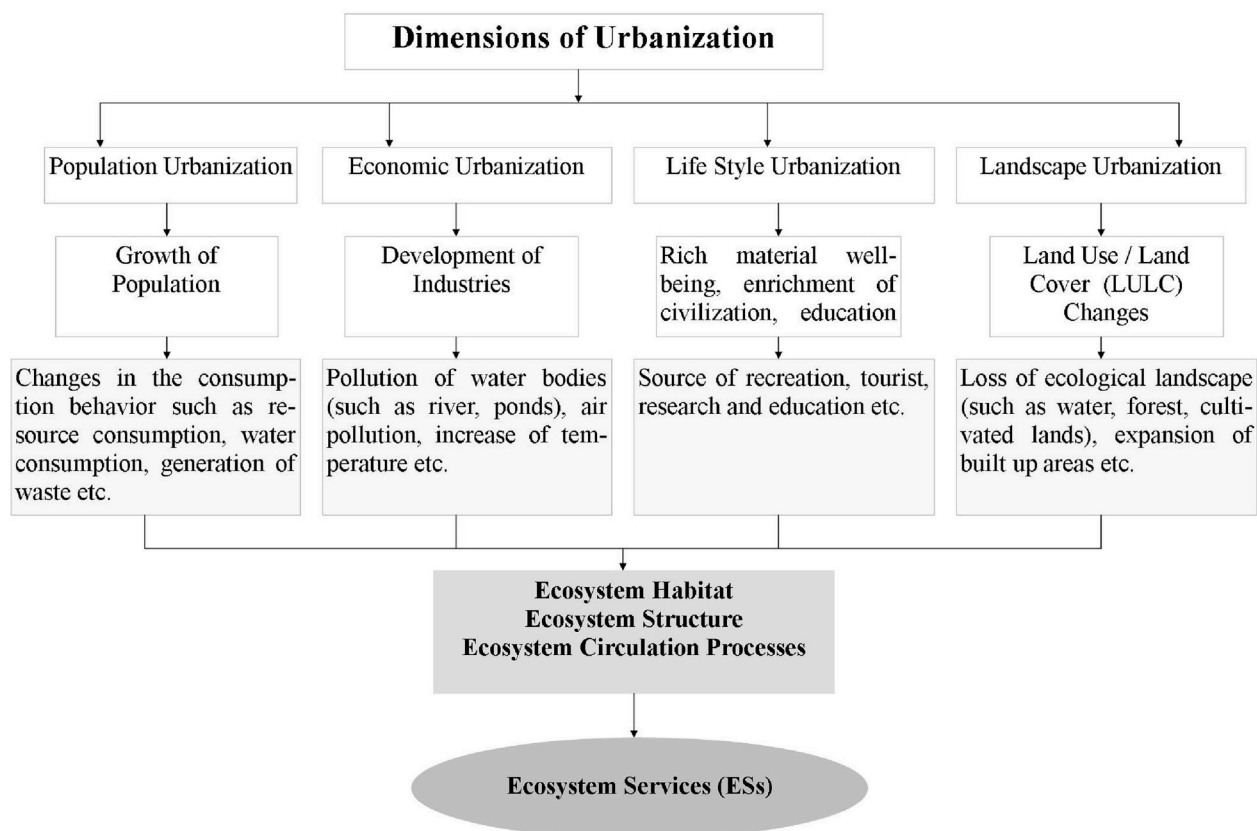


Fig. 6. Framework regarding impact of Urbanization on ESs.



Fig. 7. Examples of land use/land cover with their corresponding biomes and locations (A) Urban settlement near mangalari (National Highway 34) (Lat. 25°01'08" Long. 88°08' 50") (B) Agricultural land (Crop land) in north-eastern part (near bachamari) (Lat. 25°01'48" Long. 88°08' 38") (C) Water body near pal para (old malda road) (Lat. 25°01'38" Long. 88°08' 36") (D) Forests (specially mango trees) near old malda station road (Lat. 25°02'41" Long. 88°08' 38").

which provides a lot ecosystem services. In this context, effective and ecosystem protection oriented planning and policies should adopt for sustainable urban development. In developing country half of the urban land will take up from crop land by 2050 (Angel, Parent, Civco, Blei, & Potere, 2011) and significant loss of forest and crop land will o ESs negatively due to rapid urban expansion globally (Eigenbrod et al., 2011; Nowak & Walton, 2005; Seto, Güneralp & Hutrya, 2012). To diminish the loss of ecosystem services provided by biomes located in and around urban area, it is important to identify crop land and forest which are highly susceptible to urban expansion (Delphin et al., 2016).

4.1. Urban management policy and implications

The assessment of Ecosystem Service Valuation acts as tool which suggests how much direct and indirect benefits we can obtain from different terrestrial and aquatic ecosystems. Quantitative analysis of Ecosystem Services (ESs) and its various values can provide a strong foundation for urban ecosystem management (Tacconi, 2000). The Valuation of ESs will inspire the local administration and city planners to concern about limited natural resource and ecosystem loss. Particularly in developing country like India, various socio-economic planning is adopted for infrastructural development but it has observed that very little attention is paid in case ecological planning for the environmental sustainability. In Indian cities, continuous intrusion and transformation of ecological landscapes from grass lands, woodlands, water bodies into urban built up degrade ecosystems (Nagendra & Ostrom, 2012). Environmental degradation moves parallel with economic development and economic growth in Indian cities as such scale that it is impossible to remediate. In this context, urban development should be adjusted properly with natural ecological landscape to ensure a sustainable urban management. Therefore, assessing and monitoring the environmental sustainability through the proper application of urban management plays an important role for (1) betterment vulnerability of ESs (Cabral, Feger, Levrel, Chambolle & Basque, 2016) (2) effective decision making framework and identifying status of ESs (Costanza et al., 1997; Anaya-Romero, Muñoz-Rojas, Ibáñez & Marañón, 2016; Niquisse, Cabral, Rodrigues, & Augusto, 2017; Jacobs, Vaissiere, Bas & Calvet, 2016; Bartkowski, 2017).

Rapid urban expansion in Indian cities leads to a number of serious challenges on natural environment. Environmental degradation of India cities due to rapid expansion of urban area is a common phenomenon that needs an urgent implication of policy for sustainable urban development and effective urban management. Across the world, an innovative attempt has been made by local authorities to maintain the ecological landscape as an integral part of urban planning and strategies. The results of the study shows that ecosystem services (ESs) declined US\$ 1.33 million to US\$ 1.07 million due to conversion of agricultural land and vegetation into built up. The main cause of degradation of ecological landscape is unplanned and haphazard urban growth. No effective policies have been adopted to sustain the ecological landscape of this medium size town. In this context, scientific guidance will play a significant role to address ecological problems related to rapid rate of urbanization and it will assist the planner to implement sustainable urban management. The local administration should also pay attention to address the loss of natural capitals induced by urbanization. Local government should implement effective planning and policies for Old Malda Municipality (OMM.) such as:

- Promoting integrated spatial Ecological planning: Designing and promoting of spatial ecological planning can integrate of various LULC, urban green infrastructure development and improvement in local ecological governance. Such an effort is necessary to facilitate rational use of natural capital (land, urban greenery and water bodies) on sustained basis in the long-run.
- Management of urban greenery: Development and proper management of urban greenery have profound impact of ESs through its effects on natural cooling mechanism that increase evapotranspiration and it affects latent heating rather than sensible heating. It acts as sink for CO₂. This is also help in ground water recharge and conservation of soil.
- Conservation of wetlands and water bodies: urban waterscape plays a very crucial role in evaporation. The urban wetlands and water bodies absorb heat and thus the ambient air temperatures are likely to decrease. This is important to prevent day time urban heat island effect. Hence, water sensitive urban ecological planning is necessary to sustain urban climate and maintained sustained flow of urban ESs.
- Promoting sustainable groundwater management plan: Sustainable groundwater planning should be made with careful consideration of physical and socioeconomic characteristics of study landscape.

5. Conclusion

This paper deals with the land use/land cover dynamics and its impact on the ecosystem services during the time period from 1990 to 2017 using Remote Sensing data and GIS approach corresponding with global value coefficient (VC) proposed by Costanza et al. (1997). The level of urbanization in the study landscape has increased by 545.20% since 1991 to 2011 within the 20 years and changes of ecosystem service values (ESVs) indicates that urban expansion has an impact on the total ESVs as well as on the individual ecosystem service in Old Malda Municipal town. The agricultural land and vegetation cover which are the major contributors of ecosystem services declined caused by the rapid expansion of built up. The result shows that built up area has increased by 48% and crop land and vegetation declined by 35% and 34% over the last 27 years. In study landscape total ecosystem service values (ESV_t) decreased from US\$ 1.33 million to US\$ 1.07 million by 24.30% and individual ecosystem service changed due to losing of urban ecological land (UEls) especially conversion of cropland and vegetation into built up from 1990 to 2017. The continuous expansion of built up causes the degradation of natural land cover and losing of ecosystem services in the study landscape.

References

- Ahern, J., Cilliers, S., & Niemelä, J. (2014). The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. *Landscape and Urban Planning*, 125, 254–259.
- Alam, M., Dupras, J., & Messier, C. (2016). A framework towards a composite indicator for urban ecosystem services. *Ecological Indicators*, 60, 38–44.
- Alberti, M. (2005). The effects of urban patterns on ecosystem function. *International Regional Science Review*, 28(2), 168–192.
- Anaya-Romero, M., Muñoz-Rojas, M., Ibáñez, B., & Marañón, T. (2016). Evaluation of forest ecosystem services in Mediterranean areas. A regional case study in South Spain. *Ecosystem Services*, 20, 82–90.
- Angel, S., 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.
- Avelar, S., Zah, R., & Tavares-Corrêa, C. (2009). Linking socioeconomic classes and land cover data in Lima, Peru: Assessment through the application of remote sensing and GIS. *International Journal of Applied Earth Observation and Geoinformation*, 11(1), 27–37.
- Bartkowski, B. (2017). Are diverse ecosystems more valuable? Economic value of biodiversity as result of uncertainty and spatial interactions in ecosystem service provision. *Ecosystem Services*, 24, 50–57.
- Blumstein, M., & Thompson, J. R. (2015). Land-use impacts on the quantity and configuration of ecosystem service provisioning in Massachusetts, USA. *Journal of Applied Ecology*, 52(4), 1009–1019.
- Bohnet, I. C., & Pert, P. L. (2010). Patterns, drivers and impacts of urban growth—a study from Cairns, Queensland, Australia from 1952 to 2031. *Landscape and Urban Planning*, 97(4), 239–248.
- Bolund, P., & Hunhammar, S. (1999). Ecosystem services in urban areas. *Ecological Economics*, 29(2), 293–301.
- Borgström, S., Elmqvist, T., Angelstam, P., & Alfsen-Norodom, C. (2006). Scale mismatches in management of urban landscapes. *Ecology and Society*, 11(2).
- Breuste, J., Haase, D., & Elmqvist, T. (2013). Urban landscapes and ecosystem services. *Ecosystem Services in Agricultural and Urban Landscapes*, 83–104.
- Breuste, J., & Qureshi, S. (2011). Urban sustainability, urban ecology and the society for urban ecology (SURE). *Urban Ecosystems*, 14(3), 313.
- Cabral, P., Feger, C., Levrel, H., Chambolle, M., & Basque, D. (2016). Assessing the impact of land-cover changes on ecosystem services: A first step toward integrative planning in Bordeaux, France. *Ecosystem Services*, 22, 318–327.
- Chase, T. N., Pielke Sr, R. A., Kittel, T. G. F., Nemani, R. R., & Running, S. W. (2000). Simulated impacts of historical land cover changes on global climate in northern winter. *Climate Dynamics*, 16(2–3), 93–105.
- Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., & Raskin, R. G. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387(6630), 253.
- Costanza, R., de Groot, R., Sutton, P., Van der Ploeg, S., Anderson, S. J., Kubiszewski, I., & Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, 26, 152–158.
- Daily, G. C. (1997). *Nature's services*, Vol. 1997. Washington, DC: Island Press.
- De Groot, R. S., Wilson, M. A., & Boumans, R. M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, 41(3), 393–408.
- Delphin, S., Escobedo, F. J., Abd-Elrahman, A., & Cropper, W. P. (2016). Urbanization as a land use change driver of forest ecosystem services. *Land Use Policy*, 54, 188–199.
- Eigenbrod, F., Bell, V. A., Davies, H. N., Heinemeyer, A., Armsworth, P. R., & Gaston, K. J. (2011). The impact of projected increases in urbanization on ecosystem services. *Proceedings of the Royal Society B: Biological Sciences*, 278(1722), 3201–3208.
- Elmqvist, T., Fragkias, M., Goodness, J., Güneralp, B., Marcotullio, P. J., McDonald, R. I., & Wilkinson, C. (Eds.). (2013). *Urbanization, biodiversity and ecosystem services: Challenges and opportunities: A global assessment*. Springer.
- Estoque, R. C., & Murayama, Y. (2013). Landscape pattern and ecosystem service value changes: Implications for environmental sustainability planning for the rapidly urbanizing summer capital of the Philippines. *Landscape and Urban Planning*, 116, 60–72.
- Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., & Helkowski, J. H. (2005). Global consequences of land use. *Science*, 309(5734), 570–574.
- Foody, G. M., Campbell, N. A., Trodd, N. M., & Wood, T. F. (1992). Derivation and applications of probabilistic measures of class membership from the maximum-likelihood classification. *Photogrammetric Engineering and Remote Sensing*, 58(9), 1335–1341.
- Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics*, 86, 235–245.
- Gong, J., & Xia, B. (2007). Temporal-spatial grading diversification of land-cover at landscape level in guangzhou since 1990. *Acta Geographica Sinica*, 2.
- Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., et al. (2008). Global change and the ecology of cities. *Science*, 319(5864), 756–760.
- Güneralp, B., & Seto, K. C. (2008). Environmental impacts of urban growth from an integrated dynamic perspective: A case study of shenzhen, south China. *Global Environmental Change*, 18(4), 720–735.
- Gutman, P. (2007). Ecosystem services: Foundations for a new rural–urban compact. *Ecological Economics*, 62(3–4), 383–387.
- He, C., Zhang, D., Huang, Q., & Zhao, Y. (2016). Assessing the potential impacts of urban expansion on regional carbon storage by linking the LUSD-urban and INVEST models. *Environmental Modelling & Software*, 75, 44–58.
- Huang, S. L., Wang, S. H., & Budd, W. W. (2009). Sprawl in Taipei's peri-urban zone: Responses to spatial planning and implications for adapting global environmental change. *Landscape and Urban Planning*, 90(1–2), 20–32.
- Jacob, C., Vaissiere, A. C., Bas, A., & Calvet, C. (2016). Investigating the inclusion of ecosystem services in biodiversity offsetting. *Ecosystem Services*, 21, 92–102.
- Jansson, Å. (2013). Reaching for a sustainable, resilient urban future using the lens of ecosystem services. *Ecological Economics*, 86, 285–291.
- Jomaa, I., Auda, Y., Saleh, B. A., Hamzé, M., & Safi, S. (2008). Landscape spatial dynamics over 38 years under natural and anthropogenic pressures in Mount Lebanon. *Landscape and Urban Planning*, 87(1), 67–75.
- Kaye, J. P., Groffman, P. M., Grimm, N. B., Baker, L. A., & Pouyat, R. V. (2006). A distinct urban biogeochemistry? *Trends in Ecology & Evolution*, 21(4), 192–199.
- Kreuter, U. P., Harris, H. G., Matlock, M. D., & Lacey, R. E. (2001). Change in ecosystem service values in the San Antonio area, Texas. *Ecological Economics*, 39(3), 333–346.
- La Rosa, D., & Privitera, R. (2013). Characterization of non-urbanized areas for land-use planning of agricultural and green infrastructure in urban contexts. *Landscape and Urban Planning*, 109(1), 94–106.
- Lawler, J. J., Lewis, D. J., Nelson, E., Plantinga, A. J., Polasky, S., Withey, J. C., & Radeloff, V. C. (2014). Projected land-use change impacts on ecosystem services in the United States. *Proceedings of the National Academy of Sciences*, 111(20), 7492–7497.
- Leh, M. D., Matlock, M. D., Cummings, E. C., & Nalley, L. L. (2013). Quantifying and mapping multiple ecosystem services change in West Africa. *Agriculture, Ecosystems & Environment*, 165, 6–18.
- Li, R. Q., Dong, M., Cui, J. Y., Zhang, L. L., Cui, Q. G., & He, W. M. (2007). Quantification of the impact of land-use changes on ecosystem services: a case study in Pingbian County, China. *Environmental Monitoring and Assessment*, 128(1–3), 503–510.
- Li, Y., Zhu, X., Sun, X., & Wang, F. (2010). Landscape effects of environmental impact on bay-area wetlands under rapid urban expansion and development policy: A case study of Lianyungang, China. *Landscape and Urban Planning*, 94(3–4), 218–227.
- Ma, Z., & Redmond, R. L. (1995). Tau coefficients for accuracy assessment of classification of remote sensing data. *Photogrammetric Engineering & Remote Sensing*, 61(4), 435–439.
- Matteucci, S. D., & Morello, J. (2009). Environmental consequences of exurban expansion in an agricultural area: The case of the Argentinian Pampas ecoregion. *Urban Ecosystems*, 12(3), 287–310.
- Monserud, R. A., & Leemans, R. (1992). Comparing global vegetation maps with the Kappa statistic. *Ecological Modelling*, 62(4), 275–293.
- Nagendra, H., & Ostrom, E. (2012). Polycentric governance of multifunctional forested landscapes. *International Journal of the Commons*, 6(2), 104–133.
- Ng, C. N., Xie, Y. J., & Yu, X. J. (2011). Measuring the spatio-temporal variation of habitat isolation due to rapid urbanization: A case study of the shenzhen river cross-boundary catchment, China. *Landscape and Urban Planning*, 103(1), 44–54.

- Niquisse, S., Cabral, P., Rodrigues, Â., & Augusto, G. (2017). Ecosystem services and biodiversity trends in Mozambique as a consequence of land cover change. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 13(1), 297–311.
- Nowak, D. J., & Walton, J. T. (2005). Projected urban growth (2000–2050) and its estimated impact on the US forest resource. *Journal of Forestry*, 103(8), 383–389.
- Pauleit, S., Ennos, R., & Golding, Y. (2005). Modeling the environmental impacts of urban land use and land cover change—a study in Merseyside, UK. *Landscape and Urban Planning*, 71(2–4), 295–310.
- Peng, J., Liu, Y., Wu, J., Lv, H., & Hu, X. (2015). Linking ecosystem services and landscape patterns to assess urban ecosystem health: A case study in shenzhen city, China. *Landscape and Urban Planning*, 143, 56–68.
- Pickett, S. T., Cadenasso, M. L., Grove, J. M., Nilon, C. H., Pouyat, R. V., Zipperer, W. C., et al. (2001). Urban ecological systems: Linking terrestrial ecological, physical, and socioeconomic components of metropolitan areas. *Annual Review of Ecology and Systematics*, 32(1), 127–157.
- Qiu, Y., & Lu, Y. J. (2015, July). Risk factors analysis for logistics information integration based on the improved AHP-DEMATEL method. *2015 international conference on machine learning and cybernetics (ICMLC): Vol. 2*, (pp. 648–653). IEEE.
- Ramalho, C. E., & Hobbs, R. J. (2012). Time for a change: Dynamic urban ecology. *Trends in Ecology & Evolution*, 27(3), 179–188.
- Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences*, 109(40), 16083–16088.
- Su, W., Gu, C., Yang, G., Chen, S., & Zhen, F. (2010). Measuring the impact of urban sprawl on natural landscape pattern of the Western Taihu Lake watershed, China. *Landscape and Urban Planning*, 95(1–2), 61–67.
- Su, S., Li, D., Yu, X., Zhang, Z., Zhang, Q., Xiao, R., & Wu, J. (2011a). Assessing land ecological security in Shanghai (China) based on catastrophe theory. *Stochastic Environmental Research and Risk Assessment*, 25(6), 737–746.
- Sundell-Turner, N. M., & Rodewald, A. D. (2008). A comparison of landscape metrics for conservation planning. *Landscape and Urban Planning*, 86(3–4), 219–225.
- Su, S., Zhi, J., Lou, L., Huang, F., Chen, X., & Wu, J. (2011b). Spatio-temporal patterns and source apportionment of pollution in Qiantang River (China) using neural-based modeling and multivariate statistical techniques. *Physics and Chemistry of the Earth, Parts A/B/C*, 36(9–11), 379–386.
- Tacconi, L. (2000). *Biodiversity and ecological economics: Participation, values, and resource management*. Earthscan.
- Taylor, L., & Hochuli, D. F. (2015). Creating better cities: How biodiversity and ecosystem functioning enhance urban residents' wellbeing. *Urban Ecosystems*, 18(3), 747–762.
- Tu, J. (2011). Spatially varying relationships between land use and water quality across an urbanization gradient explored by geographically weighted regression. *Applied Geography*, 31(1), 376–392.
- Turner, M. G., Gardner, R. H., O'Neill, R. V., & O'Neill, R. V. (2001). *Landscape ecology in theory and practice*, Vol. 401. New York: Springer.
- Wan, L., Ye, X., Lee, J., Lu, X., Zheng, L., & Wu, K. (2015). Effects of urbanization on ecosystem service values in a mineral resource-based city. *Habitat International*, 46, 54–63.
- Weng, Y. C. (2007). Spatiotemporal changes of landscape pattern in response to urbanization. *Landscape and Urban Planning*, 81(4), 341–353.
- Wu, K. Y., Ye, X. Y., Qi, Z. F., & Zhang, H. (2013). Impacts of land use/land cover change and socioeconomic development on regional ecosystem services: The case of fast-growing Hangzhou metropolitan area, China. *Cities*, 31, 276–284.
- Zhang, C. L., Chen, F., Miao, S. G., Li, Q. C., Xia, X. A., & Xuan, C. Y. (2009). Impacts of urban expansion and future green planting on summer precipitation in the Beijing metropolitan area. *Journal of Geophysical Research: Atmosphere*, 114(D2).
- Zhang, D., Huang, Q., He, C., & Wu, J. (2017). Impacts of urban expansion on ecosystem services in the Beijing-Tianjin-Hebei urban agglomeration, China: A scenario analysis based on the shared socioeconomic pathways. *Resources, Conservation and Recycling*, 125, 115–130.