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Conceptualizing Peri-Urban-Rural Landscape Change for Sustainable Management

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CONCEPTUALIZING PERI-URBAN-RURAL LANDSCAPE CHANGE FOR SUSTAINABLE MANAGEMENT

Mrinalini Goswami*

Abstract

Urbanization has been a spontaneous phenomenon resulting from economic activities for the well-being of society, with consequent adverse impacts. In 2010, more than half of the global population lived in cities, and urban population will be 70% by 2050. (WHO, 2010).In countries like India, the alteration of villages into urban centre is very rapid, transforming demographic, economic and biophysical characteristics of the landscape. In this process of transformation, eco-sensitive areas and rural population dependent on natural resources are threatened in many ways, including their livelihoods, socio-ecological and cultural settings. The transitional peri-urban areas have been recognized in spatial and economic terms in Indian context with regard to commodity flow, housing, peri-urban agriculture and pollution in recent years. An integrated approach to identify the peri-urban concerns and evolve a landscape level management strategy is still missing. This paper examines the existing research in this area to look into an effective and viable approach for the assessment of peri-urban landscape change to develop a sustainable landscape management strategy.

Introduction

Although half of the world population is urban, Redman and Jones (2005) estimates that the cities occupy only 4% of the terrestrial area; but that population consumes 3/4th of natural resources and generate equal share of pollution and waste worldwide. Based on current trends, urban land cover will increase by 1.2 million km^2 by 2030, nearly tripling global urban land area between 2000 and 2030 (UNDP, 2016). According to World Urbanization Prospects (UNDESA, 2017), from 2017 to 2050, it is expected that just nine countries will accommodate 50% of the world's population and among those, and in terms of global urban growth India will top the list. During the last three decades in India, the link between urbanization and environment has emerged as a major issue (Maiti and Agrawal, 2005) as modern cities have grown in a haphazard and unplanned manner due to fast industrialization (Jaysawal and Saha, 2014). A large proportion of India's urban population is currently concentrated in the six most developed states, namely Maharashtra, Gujarat, Tamil Nadu, Karnataka, Punjab and West Bengal, accounting for about half of the country's urban population (Kundu, 2011). The Tier-1 cities in India have already faced environmental problems which are evident from their poor assimilative capacity (higher levels of pollutants), supportive capacity and lack of basic infrastructure (Ramachandra and Aithal, 2013); these have been able to attract attention for appropriate environmental planning and

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This paper is not in the framework of empirical research, but based on literature reviewed as a part of PhD research. Hence, it is structured as a conceptual framework for addressing the problems of a peri-urban landscape.

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management. On the other hand, a high level of urbanization has been noticed in economically backward states too (Kundu, 2011).

With the increasing urbanization, concerns for peri-urban interface have emerged widely. Such areas are characterized by higher residential, commercial and industrial density than the average for rural and urban areas, as well as higher rates of population growth and more dynamic processes of land conversion. In India, peri-urban areas are largely neglected in policy and practice (Randhawa and Marshall, 2014), for the particular reason of these areas being at the borders, ignored as a specific area in the study of urbanization (Shaw and Das, 2017), also neglected by both urban and rural administration as the delineation of borders of urban areas are blurred when it comes to population movement and resource use from rural areas. Master plans for cities legitimize the peripheries, but at the same time they have left them “intentionally” unregulated in a “fuzzy zone” (Roy, 2002).Simon (2008) emphasized on the importance and widespread nature of peri-urban interface with differing significance and importance according to various factors, including land tenure systems, rate and scale of urbanization, availability of employment, standards of living and median incomes, resources, and the capacity of local governance institutions etc. With such complexity of factors playing an active role in the transition zone, it is essential to assess the landscape in a holistic way.

To formulate policy that promotes economic growth and sustainable urban development while minimizing environmental impacts, decision-makers must understand the factors that drive urban expansion. Changes in urban fringe areas need to be observed through scientific examination which would include widespread developments as a process and has the capability to predict the pattern of possible landscape change. The comparison of different land use maps (based on remotely sensed data) over a temporal dimension helps to see the trend of the changes that have occurred in the landscape and through an integrated analysis with socio-economic parameters and urban development policies, future changes can be foreseen.

Concept of Peri-urban Area as a Landscape

Urbanization can be defined as a process of intensification of human settlement and their activities. The definition of ‘urban’ varies from country to country, and over time, the definitions differ in the same country which makes comparison challenging. All countries have independent definition to distinguish urban and rural population, and in sometimes the definition even changes within a country over years (Cohen, 2006). “Urban” is defined as a complex which makes up the characteristic mode of life in cities, on the other hand urbanization is the development and extension of these urban factors. According to Gerald (1969), urbanism and urbanization in newly developing countries are enormously complex subjects. India has been experiencing a steady growth of urban population (17% in 19961 to 31% in 2011; Census of India) contributed by formation of new urban areas and rural to urban migration and inclusion of rural areas according to new urban definition (Kundu, 2006). It is characterised by substantial contribution to national income (63% of GDP in 2014), higher level of inequality and lower extent of poverty (Tripathi, 2013). During 2001-2011, the decadal urban population growth rate was 31.8% which is almost two times more than national population growth rate. The proportion of rural populations declined from 72.19 per cent in 2001 to 68.84 per cent in 2011 (Census of India, 2011).

With the increase of urbanization, the concerns for managing heterogeneous peri-urban areas also intensify.

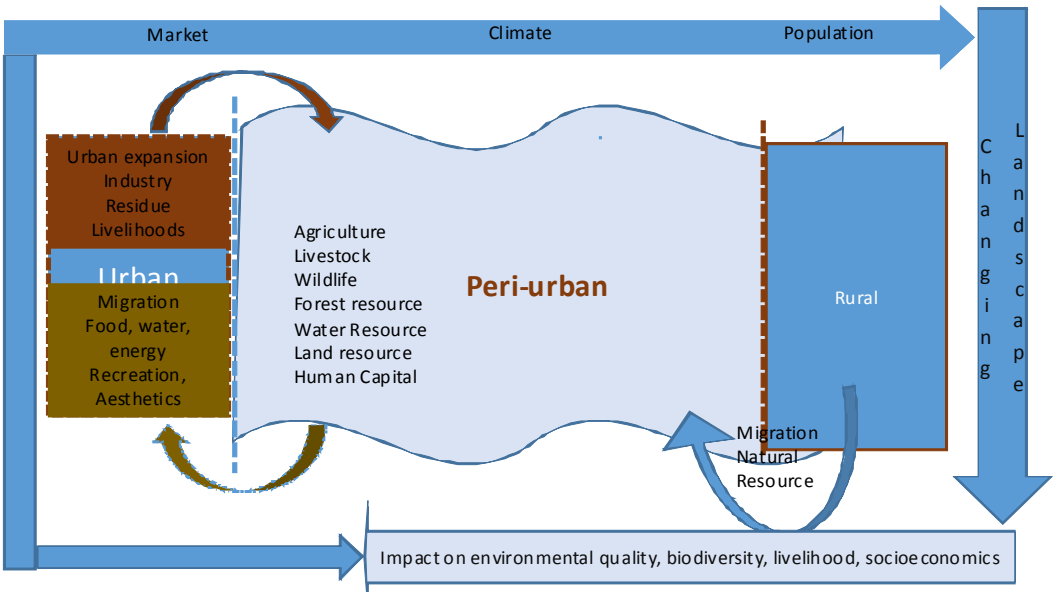
The term peri-urban is used frequently in the literature, but the definition of the term is context specific and it hardly makes for any understanding of what constitutes a peri-urban area. This point was made by the Organisation for Economic Co-operation and Development (OECD) in its report on peri-urban agriculture (OECD, 2003) which states:

> *The term "peri-urban area", cannot be easily defined or delimited through unambiguous criteria. It is a name given to the grey area which is neither entirely urban nor purely rural in the traditional sense; it is at most the partly urbanized rural area. Whatever definition may be given to it, it cannot eliminate some degree of arbitrariness.*

A peri-urban area is the most active zone of urbanization that is affected by the urban core (Douglas, 2012; Frenkel & Ashkenazi, 2008) being a zone of interaction between urban and rural (Huang *et al,* 2011). A peri-urban area refers to a transition or interaction zone, where urban and rural activities are juxtaposed (Iaquinta, 2001), and landscape features are dynamic, subject to rapid modifications, induced by human activities (Douglas, 2012), defined by population, built-up areas, infrastructure, administrative boundary etc. (Tacoli, 1998) and home to a range of functions from agricultural production to attractive residential alternatives and recreational areas (Busck, 2006). The type fringes are also determined by the size and function of the bordering city and the services (agricultural produce, forest produce, labour, water, recreational) and resources it is providing to the city.

OECD (1979) states for defining peri-urban areas: The impacts of economic growth and physical expansion of the urban area are not confined within urban boundaries; they reach into much wider areas surrounding urban centres, creating so-called *"rurban areas",* "*urban fringe areas*", or "*peri-urban areas*". There have been a number of terminologies used to describe this transition zone between urban and rural areas, which is a part of future urban limit. Some of those terms are: *urban fringe, suburb, inner* and *outer urban fringe, rural-urban fringe, urban periphery, rurban area, peri-urban area etc.* Because of the dynamism of such areas and the ever-shifting urban boundary, it is important to include more areas from the rural administrative boundary into the conglomeration that is called as rural-peri-urban landscape for the purpose of this research.

Figure 1: Defining Peri-urban-rural Landscape (Source: Author's Interpretation)



The definition of peri-urban concept should be provisional that can be useful in certain cases but not in others (Adell, 1999), that suggests each time with a context-specific working definition. Scholars have been trying to define and classify (Iaquinta, 2001; Wilfgang, 2008) such urban peripheral areas with vague boundary and explain the distinctive features (Allen, 2003; Tacoli, 1998; Douglas, 2012). Specifically, Iaquinta and Drescher (2000) identify five peri-urban (PU) types: village PU, diffuse PU, chain PU, in-place PU and absorbed PU. The typology derives from underlying sociodemographic processes, especially migration (Fazal, 2012).Although rural-urban fringe areas accommodate both urban and rural characteristics, they don't have a pure resemblance with urban or rural features. These areas develop special characteristics which are specific to such transition zones.

Overall, however, the word "peri-urban" is used in three different ways, that is, to denote a place, a concept or a process (Narain and Nischal, 2007). It could perhaps be understood as a concept that allows us to look at the relationships between rural and urban linkages and institutions and can be seen as a landscape rather than looking for administrative boundary. To understand the changes, it is essential to analyse the functions and structures of social, economic and ecological systems. Nevertheless, the transitional peri-urban areas develop their own socio-economic features with the changing demography; these areas can never be isolated from their rural and urban seams. Both the boundaries are pervious, allowing two-directional material and energy flows (Figure1). There are several external driving forces (e.g. market, climate, population) exerting pressure on peri-urban landscapes which lead to changes in biophysical as well as socio-economic changes.

Definitions of landscape invariably include an area of land containing a mosaic of patches or landscape elements. Landscape is a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in a similar form throughout (Forman and Godron, 1986) and has at least one factor of interest (Turner *et al,* 2001). Peri-urban areas often lie outside the legal jurisdiction of the city (Shaw, 2005) and are very difficult to be delineated as places with a boundary. Thus a peri-urban

area can be roughly delineated as a landscape by identifying the land area with special features specific to that zone.

From an environmental perspective, the peri-urban interface can be characterized as a heterogeneous mosaic of “natural” ecosystems, “productive” or “agro-” ecosystems, and “urban” ecosystems affected by the material and energy flows demanded by urban and rural systems (Allen *et al,* 1999). This approach opens up the understanding of biological, physical, chemical and socio-economic components and their interactions in the change prone zone. An environmental conceptualization of the peri-urban interface is crucial with several implications for its analysis and for policy interventions.

Impact and Challenges of Peri-urbanization, Worldwide and in India

Along with the dynamic land use pattern, the demography of peri-urban areas is also highly dynamic as they offer better residential alternatives for the urban workers at a low cost and accessibility to new urban livelihoods. The peripheral areas undergo multiple transformations (physical, morphological, socio-demographic, cultural, economic and functional) with consequences like an uncertain and complicated pattern of land use and land cover change which may be undesirable for ecological as well as social sustainability. Developmental activities and managing strategies in sustaining biodiversity in peri-urban areas shows landscape alteration as the major factor threatening biodiversity (Oka, 2009).

In older industrial countries, the peri-urban is a zone of social and economic change and spatial restructuring, while in newer industrializing countries, and most of the developing world, the peri-urban is often a zone of chaotic urbanization leading to sprawl (Nilsson *et al,* 2013) and has a higher dependence on rural activities for wealth and employment (in agriculture, mining and fisheries) than developed countries (Lynch, 2004), thereby exerting a greater pressure on the biophysical landscape. The major concerns listed include the rate and scale of land use and land cover change, loss of agricultural land, intensive market-oriented farming of high value crops, unsustainable use and depletion of both renewable and non-renewable resources, detrimental health and environmental impacts of wastes, particularly landfills. Some of the dynamic characteristics of rural-peri-urban landscape can be listed as:

- Environmental vulnerability
- Unplanned growth
- Land use land cover alteration
- Shifting of livelihoods
- Alteration of social structure
- Migration
- Neglect by administration
- Lack of special policy

Peri-urban areas are with new and dynamic urban land uses. Sridhar (2010) put forward an explanation for the demographic pressure to land use change that regulation of land use is more relaxed in the periphery of cities, with the result that the migrant population finds it less difficult to

reside there. Non-agricultural and market oriented activities are imposed and adopted by communities, often after losing their existing natural-resource based livelihoods or out of a desire to get better income. It is not only a rapid land transition zone, but also affected by residual dumping and all kinds of environmental pollution. As an aggregate, it becomes a market-related zone which is under pressure to exploit the agricultural and natural resources in an unsustainable manner if not regulated in time. With an interminable number of problem areas, the peri-urban landscapes are also offering benefits to the developing society. Nilsson *et al* (2013) identified the positive effects of peri-urbanization, such as: 1. Fulfilment of people's living preferences; 2. Under smart growth- attractive and competitive urban environments; 3. Proximity to consumers for local producers and potential for eco-friendly lifestyles; 4. More economic development of rural communities. These areas, being at the borders, have been neglected by both urban and rural administrations. In such a situation, conservation and development activities impose limits on the property rights and access of the local people on common property resources like lake and grazing lands.

Urbanization produces a variety of unprecedented and intense "experimental manipulations", and potentially undermine the capacity of the ecosystem to sustain production and maintain the resources (Foley *et al,* 2005).This leads to intensive use of resources to serve the growing urban demand, for instance, small area of land would be used for intensive cultivation for crops with market demand, instead of subsistence farming. Studies demonstrate farmers are dependent and threatened by the dynamics of broader urban economy (Friedberg, 2001). The pressures of urbanization have been felt more by agricultural land than natural land. This may be because of the cost of conversion in terms of clearing of forests, filling up of water bodies and so on. Conversion of natural land is higher than that of agricultural land because of the drive to conserve natural areas(Kumar, 2009) and further affect on land ownership, property rights regime and land tenure (Wehrmann, 2008).

Indian peri-urban areas have weak basic services, and metropolitan peripheries fare poorly on access and quality (World Bank, 2013) and failing to generate any of the gains in income, happiness, and mobility that the US, Brazil and China have experienced (Chauvin, 2017). The unsatisfactory state of the environmental situation in most peri-urban areas is largely due to official neglect and non-recognition of these areas as deserving of urban civic status (Saxena and Sharma, 2015). These areas are fraught with institutional ambiguity, unplanned growth, poor infrastructure and environmental degradation (Randhawa and Marshal, 2014).The World Bank's report (2013) looks at whether public policy is amplifying or dampening the potential productivity gains from urbanization—focusing on policies for land management (Vishwanath *et al*, 2013).It suggests that integrated improvement of land policy, infrastructure and connectivity can help in reaping benefits from the expanding urban areas in India.

Literature in Indian Context

Projections for the year 2030state that about 600 million Indians will reside in urban areas, an increase of over 200 million in just 20 years (GoI, 2011). Massive peri-urbanization happens when a country approaches advanced stages of development. India's early suburbanization suggests that the overall stagnancy of metropolitan areas is partly because of land management practices that push firms and

workers out of the cores (Vishwanath *et al,* 2013). As a result, there is proliferation of industries, expansion of urban areas with conversion of agricultural land (Pandey and Seto, 2015; Moghadam and Helbich, 2013, Mallupattu *et al,* 2013; Fazal, 2000) and change in the livelihood patterns of peri-urban communities (Narain, 2009). In the Indian context, before the era of extensive LULC research, detailed studies were conducted with special reference to urban growth or economic development.

The rural-urban fringe in India, however, differs from that of developed countries. In developed nations, it is largely due to the diffusion of urban population, whereas in India, it is the result of the growing impact of cities on the villages nearby. In the Indian context, the formation of peri-urban areas is assumed to be related to 'push factors', such as a deteriorating environment, creating a strong influence on these areas beyond the traditional city limits (Thirumurthy, 2005). The peri-urban boundary is forever shifting, followed by extending urban areas engulfing the interface in route (Dutta, 2012), affecting social systems of rural communities near urban agglomerations (Bryant, 1992), and urban values and lifestyles are encroaching upon agricultural areas (Antrop, 2000).

Shaw (2005) discussed the environmental dimension of spreading urbanization. The findings included the problem of increased environmental vulnerability due to solid wastes in the peri-urban areas of India and examined the role of governance and local initiatives and their capacities to manage the impacts. Many of the cities report the emergence of satellite towns in their vicinity that eventually become part of the city agglomeration. The fringe villages of urban areas try to retain their characteristics, yet react to the urban situation by altering their socio-ecological and cultural structures.

The sluggish growth in manufacturing employment in urban areas can be attributed also to the shifting of large manufacturing industries outside the city limits as a concern for environmental pollution. This is facilitated by the easier availability of land and access to unorganized labour markets, as well as lesser awareness or less stringent implementation of environmental regulations in rural settlements in the urban periphery (Kundu, 2011). Often, large industrial units tend to get located or pushed out of the municipal limits due to environmental concerns incorporated in the City Master Plans. The poor migrants are able to build shelters in these "degenerated peripheries" and find jobs in the industries located therein or commute to the central city for work (Kundu *et al*, 1999; Kundu *et al,* 2002).

Bunting, (2007); Jacobi *et al* (2009); Agrawal *et al* (2003); Brook *et al* (2001), Bhupal *et al* (2002) and others have focused on studies related to peri-urban agriculture in India with special reference to waste water use in agriculture and aquaculture, pollutant residues in food products, impact of air pollution, food security and livelihood enhancement in peri-urban areas of various cities in India. A study in fringe areas of Delhi reveals that although the villagers have been exposed to prolonged urban influences, land continues to be an integral part of their lives, specially in terms of acquiring their livelihoods (Mallik and Sen, 2011). It is increasingly being accepted that peri-urban areas of sprawling cities experience significant land transformation due to the expansion of the urban core contained within their boundaries. The rural-urban interaction in fringe villages is more intense not merely because of their physical proximity but because of a greater flow of resources with the city, and their function as engines of economic, social and cultural transformation. The studies also reveal different processes and levels of urban influence and also manifest a significant social impact with prominent temporal variation.

Research shows (Purushothaman *et al,* 2016) empirical studies on Indian peri-urban areas do not imply a clear direction or a gradient from rural to urban in any indicators except in terms of environmental externalities. The underlying factors for peri-urbanization and rural-urban linkages vary from one to another peri-urban area which set the mandate to recognize diversity of sustainability issues in the peri-urban landscapes. Ramachandra (2012), Ramachandra and Aithal (2013), Reddy and Reddy (2007), Goel (2011), Hackenbroch and Woiwode(2016), Vij and Narain (2016), Dupont (2007), Narain and Nischal (2007), Narain (2009) and Dutta (2012) studied peri-urban areas in different Indian contexts. Those studies include a range of issues- spatio-temporal dynamics of urbanizing landscape, top down policy and planning focus, population dynamics, urban edge expansion and envelopment at the cost of permanent crops and pastures, material and service flow livelihood enhancement etc. The available studies reiterate the need for integration of various sectors and advocate a bottom-up approach for urban expansion planning, where the opinions of various stakeholders would be taken into account.

Approaches in Peri-urban Research; Identification of Gaps

Various approaches have been adopted to study peri-urban areas ranging from spatial and temporal land use change assessment, flow of material and energy, relocation of underprivileged settlements and polluting industries, waste disposal, peri-urban agriculture, livelihood assessment framework and sustainability modelling. Contemporary urban theories rooted in western developed country contexts are of limited use for understanding the pace, scale, and complexity of urbanization in India (Tiwari *et al*, 2015).DFID studies have confirmed the lack of attention given directly to peri-urban areas of developing countries (Phillips *et al*, 1999). Studies have been conducted in peri-urban landscapes for assessing the land use change using different models and documented sources (Orenstein *et al*, 2014; Pontius *et al,* 2004 etc). Photo-interpretation techniques using aerial photographs and satellite images have been applied to investigate land use and land cover change due to urban expansion. With the availability of high resolution satellite data to study the past changes and advancement of modelling exercises for future urban developments, it has become advantageous to bring change monitoring at multiple scales. In global peri-urban research, along with linking of social and economic systems, studies have been conducted to monitor change for multiple periods to understand the complex drivers of urban morphology through space and time, and to forecast future land use trends (Seto & Kaufmann, 2003).

Table 1: Matrix Showing Availability of Literature

Research aspects	Global	General	Integrated	Micro Scale	Trend/ status	Projection/ management
		Indian context				
Ecological/landscape sustainability	✓	✓	X	✓	✓	✓
Livelihood (NR) assessment	✓	✓	✓	✓	✓	--
Landscape sustainability for peri-urban area	--	X	--	--	--	--
Biodiversity	✓	✓	✓	✓	✓	✓
Environmental quality	✓	✓	✓	✓	✓	✓
Development of indicators	✓	✓	✓	X	X	X
Sustainability assessment through (spatio-temporal) modelling	✓	✓	X	X	✓	X

Table 1 shows the availability of literature on peri-urban landscape and various aspects related to the dynamic characters of the landscape.

Most of the research into peri-urban landscape so far has been done on a rather general scale; we lack information about what is happening in those "vast monotonous bedrooms that surround the cities" (Palang *et al,* 2011).Analysis in Indian context (Report by Asia Pacific Network for Global Change Research, 2009), has investigated effects from urbanization on the loss of agricultural land and water bodies. Subsequent investigations could focus on the consequences for such features as fragmentation of habitat, degradation and changes in vegetation and other environmental changes measurable through remote sensing and related techniques. It would be especially useful to investigate these consequences not just on the immediate urban periphery alone, but in the wider region surrounding expanding cities through a holistic system approach.

Need of the hour: Integrated Landscape Approach

(a) Integrating the disciplines

Apart from the richness in biodiversity, culture and tradition, India is also competing economically with other nations and hence there is proliferation of industries and expansion of urban areas which make landscape planning crucial. Peri-urban research should take an overtly interdisciplinary approach, a sensitivity for local contexts and the integration of the city with the larger eco-region (Adelina *et al*, 2015).

Models help to understand the complex human-ecological system and specially the spatial dynamics and processes over temporal scale. Patterns of sprawl and spatio-temporal changes could be identified and analysed cost effectively and efficiently with the help of remote sensing and geographic

information systems (GIS) along with ground knowledge (Bhatta, 2009; Barnes *et al,* 2001) which can be further used in models to envisage the future landscape change. Modelling land-use, land-cover and environmental change is a field of increasing importance and a broad range of models has been developed for this discipline (Haase and Richter, 1983; Schaldach and Priess, 2008). The integrated land use model provides a link between the human dimension of global LUC (including economic drivers) with global scale simulations of climate, water cycle, biodiversity risk and other global change processes and issues (Schaldach *et al*, 2011).

(b) Large temporal scale for micro-spatial assessment

Having realised the importance of landscape modelling, two major dimensions of modelling are identified- space and time. Models of biophysical and/or human processes operate in a temporal context, a spatial context, or both (Agarwal *et al,* 2002). The 'space' dimension refers to the geographical extent, a micro-scale which in peri-urban India would be a cluster of a few villages, a wetland with a surrounding socio-ecologically dependent area, a protected area etc. Secondly, the time dimension is to be considered in terms of the assessment of future socio-ecological consequences of land use policies based on the past pattern of landscape change (both biophysical and socio-economic) which will be useful for supporting decisions about where and how to progress with our economic activities. It is important to integrate spatially explicit land-use change models with socio-economic and bio-physical variables. Such models can be more efficiently used for the projection of suitable future development alternatives and for conducting experiments to enhance the understanding of key processes in land-use changes (Verburg *et al,* 2004).The comparison of different land use maps (based on remotely sensed data) over a temporal dimension helps to see the past trend of the changes that have occurred in the landscape. Such integration of approaches helps in formulating an efficient set of strategies for the sustainable development of a peri-urban landscape.

(c) Integrated modelling and scenarios for future prediction

Satellite images can often be used to detect land use change through observations of the biophysical characteristics of the land and empirical data from socio-economic surveys can be integrated to assess the role of those factors. Reviews of existing models (Upadhyay *et al,* 2006; Agarwal *et al,* 2002) include different categories of land use change models, economic models, conceptual models, empirical regression models, linear and non-linear programming, and simulation models, and have been assessed in terms ranging from temporal dynamics and spatial interaction to human decision making. The findings suggest the need for improvements in scale dimensions (ecological systems and decision making have differences in scale), integrating multiple disciplines and the relative significance of different drivers.

Land SHIFT is a model with intermediate complexity. Land SHIFT is a dynamic and spatially explicit land-use and land-cover change model (Schaldach *et al,* 2011) that can be used to quantify potential changes in land-use and land-cover with respect to future socio-economic changes. Several research studies have applied the model for impact assessments under varied conditions (Alcamo *et al*, 2011; Schaldach *et al*, 2011) adjusted to the South-East Asian study region. Land SHIFT provides a

framework for the combination of biophysical and socio-economic information with geographical information on land use and land cover, and integrates the information, generated in different modelling approaches. To apply Land SHIFT at a smaller spatial scale than it has been used, in managing landscape at landscape level, efficient sustainable peri-urban planning would require technical modification.

The model has been authenticated to use in Indian conditions (Schaldach *et al*, 2011; Gupta, 2009) and has the potential to modify for finer spatial resolution which can be served with empirical data to study landscapes with more specified characteristics. In a pilot study, Schaldach *et al* (2011) used the Land SHIFT model to assess the impact of biofuel production on land-use change in India up to the year 2030. The case study aimed at the simulation of land-use change and its relation to other global change processes. It explicitly states the competition among land-use activities such as human settlement, biofuel production, wood production and food production and the resulting effects on the spatial extent of natural land, which show immense potential for peri-urban landscape study.

Agent-based models have emerged in land and environmental science as a way to better capture the complex system characteristics of a coupled socio-ecological system. ABMs for socio-economic systems have evolved as extensions of other modelling techniques, including analytical and statistical modelling, cellular automata, artificial learning and others (Tatiana *et al.,* 2013). An agent-based model of land use/cover change (ABM-LUCC) is an effective tool for exploring agent diversity and landscape heterogeneity within a spatially explicit structure (Evans and Kelly, 2004). To develop an efficient framework for landscape planning, the following steps need to be considered.

1. Select a computationally feasible model for spatio-temporal land use change modelling
2. Robust estimation by controlling parameters which will be context specific (e.g. urban, protected area, farm)
3. Integrate an Agent Based Module to the spatially explicit model
4. Further development of a model for scenario analysis with most effective use of computational model for strategy formulation for sustainable development.

Several studies (Alberti, 2003; Peterson *et al,* 2003; Reed, 2006) argue that humans must be explicitly incorporated into all aspects of ecological analysis, because humans have been changing the structure and functions of ecosystems at every possible spatial and temporal scale. There has been involvement of humans as various stakeholders of the landscape in scenario analysis. Mapping socio-economic scenarios for land use change and consequent changes in the ecosystem is an important aspect of an integrated ecological study for robust decision making.

(d) Best chosen indicator framework

A key challenge of ecosystem management is determining how to manage multiple ecosystem services across a landscape (Hearne *et al,* 2010). To respond to rapid landscape change, it is important to assess the ecosystem services at multiple scales- space and time, particularly at regional scale (Paetzold *et al,* 2010) and understand feedbacks to human behaviour (Carpenter *et al,* 2007). Dale and Beyeler (2001) stated that indicators can be used to assess the condition of the environment to provide an early

warning signal of changes in the environment or to diagnose the cause of an environmental problem. The United Nations defines indicators as not datasets but rather as models which simplify a complex subject to a few numbers that are easy to understand and grasp by policy makers (UNCSD, 1996).

Indicators are an essential component in the overall assessment of the progress towards sustainable development (Gallopin, 1996) and have been given immense importance in recent years. There are many methodological frameworks (Scoones, 1998; Gunderson, 2001; Turner *et al*, 2003) proposed to develop sustainability indicators at a local scale; Reed (2006) proposed a learning process that integrates best practices for a stakeholder-led local sustainability assessment framework. To study such dynamic socio-ecological systems, rural-peri-urban areas are to be analysed in terms of specially developed indicator frameworks. Many scholars have adopted livelihood and peri-urban agriculture to assess the transformations in city peripheries. Perhaps the best understanding of the importance of rural-urban linkages and their significance for economic, social and cultural change in low-income nations comes from a detailed analysis of the livelihood strategies for various economic classes (Tacoli, 2006).

Several frameworks have been developed for livelihood and landscape research and are successfully implemented in practice. All these frameworks, being context specific, don't correspond entirely with the objectives of studying complex peri-urban areas. Hence it is preferable to work with a specifically developed set of indicators for peri-urban areas. Table 2 gives an overview of several indicator frameworks for studying livelihoods and landscape is given. The definition of sustainability for the purpose of this research should involve environmental sustainability, that would include effective biodiversity conservation and maintenance of ecosystem integrity, and livelihood sustainability that would entail achievement of poverty alleviation, food security and equity without harming the environmental support system.

Table 2: Indicator Frameworks for Studying Livelihood and Landscape in Peri-urban Context

Developer	Focus	Conceptual framework
DFID (1999)	rural poor's livelihood sustainability	5 capitals
CIFOR multi-disciplinary landscape assessment (Sheil *et al*, 2002)	landscape for project design	hazards, vegetation types, prices, natural products, five capitals
EC handbook for trade sustainability impact assessment (EC, 2016)	policy assessment	economic, social and environmental indicators
FAO/ILO (2009) livelihood assessment tools	livelihood baseline and hazards impact	SLF, capabilities, assets, activities
OECD strategic environmental assessment (Sadler and Dalal, 2012)	policy assessment to integrate environment	5 capitals
WB PSIA (The World Bank, 2003)	policy assessment	well-being-income and non-income based: assets, access, employment
WWF- protected areas benefits assessment (2009)	PA benefits	subsistence, economics, cultural, environmental services, political
WWF-landscape outcome assessment methodology (Aldrich, 2007)	landscape change	5 capitals
IFAD (2011)		5 capitals
CITES (2015)	trade prohibition, conservation policy livelihood impact	social and economic impact
IUCN- integrated wetland assessment toolkit (Springate-Baginski *et al,* 2009)	biodiversity, economic valuation and livelihood assessment	conservation and development trade offs
CARE- Household livelihood security assessment, (Frankenberger *et al,* 2002)	strategy, security, rights	6 capitals

There have been various functional sets of indicator frameworks for environmental sustainability ranging from protected area and conservation oriented (CIFOR forest product trade; IUCN- integrated wetland assessment toolkit), policy and development project assessment (CIFOR multi-disciplinary landscape assessment; EC handbook for trade sustainability impact assessment; WB-PSIA; OECD strategic environmental assessment), livelihood sustainability (DFID, 1999; CITES,2015; IFAD, 2011; FAO/ILO livelihood assessment tools, 2009; CARE-Household livelihood security assessment, 2002), landscape sustainability(WWF-landscape outcome assessment methodology) etc.

As a part of an integrated approach for peri-urban research, sets of indicators from both livelihood and landscape frameworks could be listed to assess the relevance and significance of indicators for a particular peri-urban landscape. Both livelihoods and land use change are interdependent (McCusker, 2006) and in a bi-directional loop; considering that, the proposed research should look into the natural resources dependence of livelihoods, its trends and status with respect to

the changing landscape to assess the ecosystem's sustainability. Thus amalgamated indicator frameworks including both selected landscape and livelihood indicators would work as an effective tool for the management of the peri-urban interface.

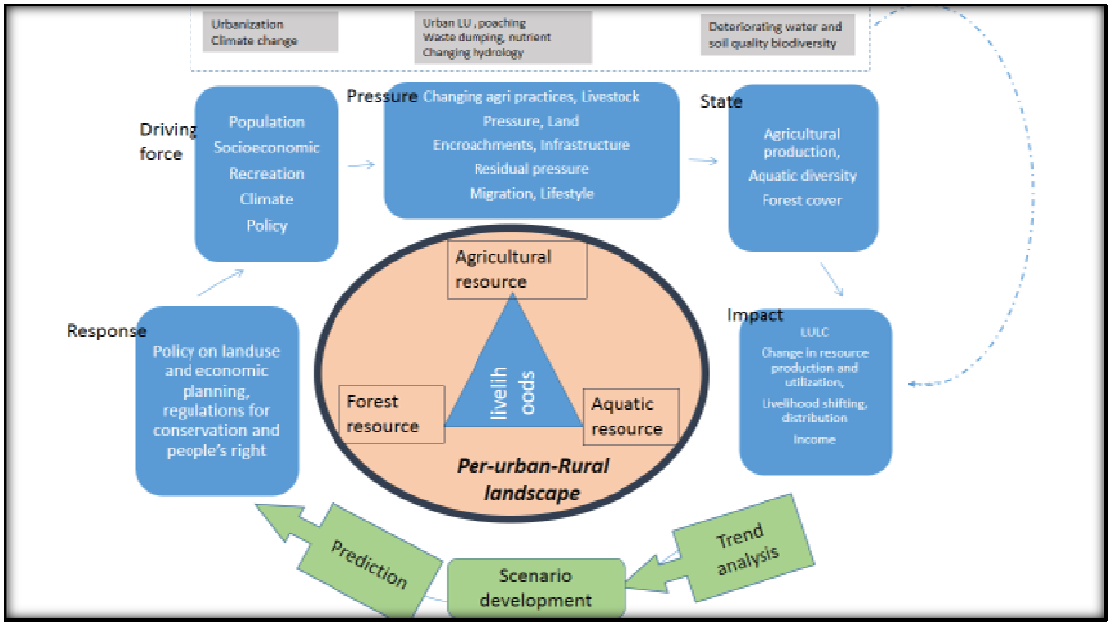
Conceptual Modelling Framework for Peri-urban Landscape

Modelling land use and land cover dynamics in the context of developing countries like India will rely on micro scale data since the drivers of change in these countries are individual agents with distinct characteristics (Elias *et al,* 2012). These drivers vary widely because of a highly heterogeneous bio-physical and socio-economic environment and unequal development within the country. The emergence of multiple anthropogenic environmental change and rapid transition of land use and land cover cannot be distinguished from socio-economic agents of change. In developing countries like India, land use activities largely decide the land cover rather than environmental determinants (e.g: soil quality, climate etc.) of land cover, for e.g: land use activities associated with logging leads to a deforested land cover (Lambin, 1997).The linkage between human and environment sub-systems is influenced by several driving forces including population growth, economic growth, technological change, political and economic institutions and cultural attitudes and beliefs. Land use planning at landscape scale is essential for striking a balance between economic growth, conservation of biodiversity and safeguarding of cultural heritage.

To recognize the importance of multidisciplinary research for assessing, monitoring, forecasting and managing the integrity of the socio-ecological landscape, various methods have been developed, especially with the use of an indicator framework. The complexity of ecological systems has led to model-based approaches for examining their components and interactions, and for predicting management outcomes (Jakeman, 2006). The biophysical and socio-economic factors are accounted for in global environmental change research; the linkages and historical dissimilarities should be acknowledged at landscape level planning for two reasons, primarily, the characteristics of driving forces for land use change vary at different spatial scales and second, decisions for land management are to be taken at individual stakeholder's level (for e.g.-farmer). Nautiyal *et al* (2010) emphasized that it would be imperative to analyze the complexity of the human and ecosystem interaction and consequently proposed a tool that would be helpful in understanding the science behind sustainable landscape management.

An efficient set of indicators based on the conceptual framework (as in Figure2) can show the linkages of human system to natural environment and the impacts of driving forces and pressures on the resources that provide livelihood to the people. This broadly follows the DPSIR (driving force, pressure, impact and response) framework for the indicator system. This is a conceptual framework which can also be viewed as qualitative or quantitative statements of the hypothesis.

Figure 2: Conceptual Framework for the Research



The response will help in building landscape management strategies. A detailed process in the framework can be divided under the following steps.

i. Understanding on rural-urban linkages to define the peri-urban area
ii. Identification and assessment of resources
iii. Approach formation
iv. Issue identification
v. Description of criteria for identification of indicators.
vi. Development of context relevant indicator framework (based on both livelihood and landscape frameworks)
vii. Measuring and analyzing the indicators
viii. Sustainability evaluation
ix. Formulation of sustainable development recommendations from scenario analysis

An outline for developing policy for management plan can be developed under five modules. Each of the modules needs to be further planned under four categories viz., Ecological, Technical, Institutional, Financial and Social sub-modules.

Module I: Ensure Ecological Sustainability

Module II: Ensure Economic Sustainability

Module III: Land Use Regulation

Module IV: Sustainable Hydrologic Regime

Module V: Residual Management

The identification and delineation of urban fringe should be taken up as one of the primary activities in the process of formulation of the development plan. The process of delineation should be exclusively technical and should not be affected by the interests of political parties and the real estate sector. A statutory authority for the administration of the fringe should be set up which coordinates

between both rural and urban development authorities, and enables the community's voice to be heard in land use planning. The underlying dilemma for the inclusion of villages in urban limits should be tackled by defining the ecological and social basis. It is crucial to adopt a scientific basis for identification and integration of villages in the new administrative limits to be practiced as a regular system.

Successful implementation of a management plan for sustainable peri-urban landscape development would require sound technical basis, adequate financial resources, active participation of urban institutions and interest of both government and local communities. Active and focused local civil society organization and interest of higher level political functionaries have been found to be effective in managing peri-urban solid waste in Chennai (Shaw, 2005), reviving a water body in Pamal (Narain *et al*, 2007). Decentralized administration community development in Hubli Dharwad (Brook *et al,* 2008) and citizen participation in Visakhapatnam (NIUA, 2007) etc have been documented as successful initiatives, yet the concerns are dealt with in a piecemeal approach.

Conclusion

The peri-urban-rural interfaces always undergo increasing economic pressure for the construction of infrastructure like transportation, residential, industrial and commercial with tangible damage to the natural ecosystem. To avoid undesired landscape change, a multi-sectoral policy has to be formulated or restructured wherever necessary. Being a highly vulnerable area with multi-dimensional environmental problems, looking solely into sustainability in a piecemeal manner cannot manage the peri-urban interface efficiently. The externalities of environmental planning, management responses and political processes are to be assimilated in sustainability planning. The implementation of such a strategy for sustainable landscape development with enhanced livelihood opportunities would require proper planning for physical and financial infrastructure, environmental health and safety, communities' behavioral change and political will.

Understanding of the social-ecological system in terms of the multi-functionality of the ecosystem to provide environmental and human welfare needs a contextual indicator framework. The negative externalities due to urban expansion and vulnerability and adaptation capacity of the local community need to be quantified to manage the peri-urban environment. This kind of analysis will provide a way to understand the complex relationship between anthropogenic drivers and metrics of ecosystem health.

At continental and regional scale, models like Land SHIFT have been proved to be an integrated approach which provides the framework for the combination of bio-physical and socio-economic information with geographical information on land use and land cover, and integrate this information, generated with different modelling approaches. The Land SHIFT model offers flexibility in integrating sub-modules (biophysical, socio-economic and land use change)use of input data and scenario formulation. Further modification of the model to make it apt for applying in landscape level analysis will augment its suitability in micro scale peri-urban landscape planning in the Indian context. Exploration of the scope for the integration of Agent Based Modelling would be significant in the context of representing human-decision making in socioecological system models.

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