CHANGING PATTERNS OF LAND USE AND LAND COVER AND THE POTENTIALITY OF BIOECONOMY IN SUSTAINABLE LAND MANAGEMENT IN KERALA, INDIA

by

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THESIS

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DECLARATION

I, Akshara, T. (2016 – 20 – 019) hereby declare that this thesis entitled **"Changing Patterns of Land Use and Land Cover and the Potentiality of Bioeconomy in Sustainable Land Management in Kerala, India"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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SYMBOLS AND ABBREVIATIONS

CAP	Common Agricultural Policy
CFP	Common Fisheries Policy
DBT	Direct Benefit Transfer
EAGGF	European Agricultural Guarantee and Guidance Fund
GEP	Google Earth Pro
KETs	Key Enabling Technologies
kml	Keyhole Markup Language
LU/LC	Land use/land cover
SDGs	Sustainable Development Goals

CHAPTER 1

INTRODUCTION

Complex interaction between man and the encompassing physical environment is the essential factor which contribute towards land use/land cover (LU/LC) change which is basically the transition of various land use types. A major portion of the earth's land surface has undergone drastic LU/LC change (Liping *et al.,* 2018; Rawat and Kumar, 2015). When seen from a global perspective, LULC change has a major impact on the functioning of the earth system. Anthropogenic contribution towards the change in land use is the most significant one (Lambin *et al.*, 2001; Song *et al.*, 2018). This is predominantly seen in developing countries than in developed countries now. There are various social, demographic, economic, cultural, institutional, technological and meteorological factors playing a significant role in the LU/LC change. Each of these factors are in one way or the other interrelated to one another. Of these factors, the socio-economic factors have greater contribution towards the change (Geist and Lambin, 2002; Oslon *et al.,* 2004; Vidal-Macuaa *et al.,* 2018).

A significant result of LULC change is carbon emissions identified with anthropogenic activities and is a global concern (Zhu *et al.,* 2019). Human induced LU/LC change have reduced the capacity of soil to store carbon, increasing soil bulk density (Sasmito *et al.,* 2019) and leading to global warming through enhanced greenhouse gas emission (Muñoz-Rojas *et al.,* 2012). Alteration in the energy balance of earth and biogeochemical cycles results due to changes in LU/LC which in turn contribute towards climate change having a significant impact on ecosystem services (Song *et al.,* 2018). These impacts vary with space and time (Tolessa *et al.,* 2017). Alterations in the pattern of land use change results in soil erosion as well as soil pollution which was noticeably seen when forest areas were transformed for other land use activities like agriculture resulting in an increase of 0.61 Pg yr-1 of soil erosion (Borrelli *et al.*, 2013). The largest increase in the annual

temperature was witnessed following the conversion of evergreen forests by 5.7 K (Fu and Weng, 2016). Other adverse ecological consequences of LU/LC change include soil and water quality degradation, biodiversity loss, changes in regional weather patterns and so on (Zhao *et al.,* 2006; Allan *et al.,* 2015). When seen from a global perspective, 62% of land changes in Asia is associated to the changing land use activities (Song *et al.,* 2018). Similarly, the conversion of lands in association with urbanisation and industrialization have led to land scarcity for agriculture, thereby posing serious threat in the path of food security, affecting the existence of the population adversely (Chen, 2007; Pandey and Seto, 2015).

LU/LC change can be in the form of either land use intensification or fallowing or abandoning of lands. Both intensification and fallowing can have adverse effects on the society as well as environment. According to Knoema world data atlas (2018), 107.31 million hectares of land has been left fallow around the world with the highest being in India, despite India being an agrarian nation. Land abandonment can be a significant deterrent attaining Sustainable Development Goals (SDGs) primarily SDG 1, 2, 3, 5, 8, 13 and 15 (Hobbs and Cramer, 2007; Plieninger *et al.,* 2014; Filho *et al.,* 2016; Mbow *et al.,* 2019)

The concept of bioeconomy was used for the first time during 1960s for representing an economic term that helps in identifying the components having biological origin primarily in relation to commercial activities (Bonaiuti, 2014; Birner, 2018;). It was since 2000s, bioeconomy gained immense popularity which led to it being adopted by various nations with the prominent one being European Union (Aguilar, 2019). Majority of policies and strategies were implemented in the fields of biotechnology as well as renewable resources (Birner, 2018).

The European commission (2012) defines bioeconomy as "*bioeconomy encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy [and] includes the sectors of agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries".* With the adoption of

bioeconomy, every nation aims to solve the critical societal issues which hinder the development of a nation. Thus, five major objectives are identified as a part of bioeconomy which include food security, sustainable natural resource management, climate change mitigation and adaptation, reduced dependence on non-renewable resources and increment in employment opportunities (Scarlat *et al.,* 2015; Székács 2017). Bioeconomy also include three major visions which are closely interlinked, namely, biotechnology vision, bioresource vision and bioecology vision (Bugge *et al.,* 2016). While the biotechnology and bioresource vision has a close inclination towards scientific and technological aspects, the bioecology vision gives more prominent thought for the environmental perspective, making it the most important of all visions while considering the current environmental condition (Pfau *et al.,* 2014; Bugge *et al.,* 2016; El-Chichakli *et al.*, 2016). The accomplishment of SDGs can be effectively made a reality by the adoption of bioeconomy, as 12 of the 17 SDGs have a close association with the major objectives of bioeconomy (Bracco *et al.,* 2018; UNDP, 2020). Of the various SDGs, the ones that require earnest consideration are the eradication of poverty and mitigation of climate change which are among the basic aims of bioeconomy.

Proper integration and availability of biomass, biorefinery and biotechnology, which are considered the pillars of strength of bioeconomy are highly necessary for making it a successful and sustainable economic pathway (Sillanpää and Ncibi 2017; Lewandowski, 2015). The major sectors which play a critical role in the development and flourishment of bioeconomy are agriculture, fishery and forestry as they are the most important sources of biomass along with the industrial sector (Scarlat *et al.,* 2015; Sillanpää and Ncibi, 2017). Appropriate policies and strategies in these sectors can increase the pace of economic development as well as sustainable management of natural resources. Prior to the adoption and implementation of bioeconomy, it is necessary to make sure that all the basic requirements for its development are present (Székács, 2017). For determining the suitability of bioeconomy in a particular region, further research will have to be carried out considering all the critical factors influencing it. Subsequently, for attaining the complete benefit of bioeconomy, there is a necessity of appropriate

policy framework and close collaboration between the private and public sector by taking into consideration environmental, economic, social, institutional and technological challenges (McCormick and Kautto, 2013).

Natural resources are being over exploited at an alarming rate which will have deteriorating effect on the future generation and their survival. Consequently, it is the obligation of present generation to use resources judiciously and to conserve them for the coming generations. LU/LC change studies are very important for proper planning and utilization of natural resources and their effective management. The determination of LU/LC change in an area will help in understanding the economic, environmental and social impacts it will possess and to authoritize links between policy decisions, regulatory actions and the resulting LU/LC activities. It is additionally imperative to resolve the underlying factors which contribute towards the change for analyzing its effect, in order to mitigate the adverse impacts of LU/LC change. Kerala is one such state where rapid LU/LC change have been taking place since decades, making it important to contemplate the rate of change alongside the factors responsible for it. While considering the agricultural scenario in Kerala, it has undergone drastic changes over the years, with greater reduction in the area available for cultivation, leading to the transformation of the state from an agrarian economy to a modern economy concentrating on the service sector. With the help of studies, appropriate strategies and policies can be developed to ensure sustainable utilization of resources. One such approach is the adoption of bioeconomy which is basically a sustainable economic pathway. Implementation of bioeconomy will help to tackle the critical societal issues as they are founded ideally on renewable resources which has the potential to accommodate sustainable economic growth along with eco-friendly activities. Bioeconomy even has the potential to enhance the agricultural sector of the state through appropriate strategies and interventions alongside the possibility to accomplish numerous SDGs.

The general objective of the study is to assess the potentiality of bioeconomy in sustainable land management in the context of changing patterns of land use and land cover. The specific objectives are:

(1) To elucidate and evaluate the land use and land cover changes in the urban, suburban and rural areas of Kerala for the last two decades.

(2) To determine the factors that lead to the changes in land use in terms of both land use intensification and fallowing of lands.

(3) To explore the possibility of introducing bioeconomy framework in the study area for sustainable management of land through appropriate land use activities.

CHAPTER 2

REVIEW OF LITERATURE

2.1 KERALA- AN OVERVIEW

Kerala is an Indian state located in the south western end of the Indian subcontinent lying as a narrow strip of land between the Arabian sea and the Western Ghats in the west and east respectively (Dutt *et al.,* 2015). Kerala is divided into three parts in the east-west direction, namely, highland, mid-plains and coastal areas. In and around the Western Ghats, the area is primarily composed of hilly and thick evergreen forests with majority of rivers of Kerala originating from these highlands. The coastal belts are aligned parallely to the Western Ghats in the west. Mid-lands is present in between the highland and coastal plain, consisting of a combination of hills and valleys. Kerala is a water rich land mass due to 41 west flowing and 3 east flowing rivers alongside numerous lakes and backwaters (Government of Kerala, 2021). Fisheries, agriculture and forestry are the three distinct natural resource-based productive sectors that is distributed all through the state and provide a diversified resource base at the microlevel (Dutt *et al.,* 2015; Government of Kerala, 2021).

2.2 AGRICULTURE IN KERALA AND ASSOCIATED ASPECTS

The agriculture in Kerala is characterised by cultivation in small size land holdings which forms one among the lowest in the country (Fox *et al.,* 2017). Over the years, Kerala economy has undergone drastic changes in its productive sectors as well as other aspects of economy primarily in the form of a transition from a traditional backward agrarian economy to modern flourishing economy (Shinoj, 2015). Such a transition has possessed a hindrance in the path of agricultural development, at such a time when there is huge shortage for labour as well profits. As of now, the major problems faced by the agricultural sector in Kerala comprises

of decrease in land available for cultivation, increase in the number of small and fragmented land holdings (Kunze and Momsen, 2015; Thaickavil, 2020), lower productivity per unit of labour and abhorrence of agricultural sector by young generation due to uncertainty in income and profit (Krishnan and Firoz, 2021). The structural transformation undergone by the state comprises of four characteristics which involve reduced share of agriculture in employment generation and economic development, enhanced share of industries and other sectors in economy, increased rural to urban migration in search of jobs (Shinoj, 2015) and a demographic transition in the rates of birth and death leading to an increase in population prior to arriving at an equilibrium state (Sanitha, 2015).

2.2.1. Food security

Kerala is one such State that relies upon neighbouring states for 85% of its food requirements (Masiero, 2015) and is known as a 'food deficit' State in India on account of the wide gap in the consumption and production of food grains particularly rice. The political economy of the decrease in rice cultivation is firmly identified with the economic advancement in Kerala where the farmers have started cultivation of remunerative crops like coconut, banana, rubber etc (Subhash, 2020) which are more profitable and require less labour (Kannan, 2000; Karunakaran, 2014; Nair and Dhanuraj, 2016). During early 1960s, the area used for the cultivation of food crops and cash crops were 45% and 37 % respectively. However, by 2013-14, the area devoted for the cultivation food crops diminished drastically to 10% while the area for cash crops expanded to 62% (Kumar and Pradeep, 2017). A projected land use pattern of Kerala exhibited a drastic reduction in the land under net sown area, which is highly likely to create an adverse effect on the economic as well as food stability of the state (Sreya and Vidhyavathi, 2018). As per the data from the State Planning Board, between 1980 and 2007, 5,00,000 ha of paddy fields were lost and a significant reduction in the harvest was additionally noticed. This created a huge gap in the requirement and production of rice in the state, i.e., an increase from 50% in 1960s to 85% in 2007-2008. Thus,

in order to meet the grain requirements of the population, the state depends on centre and other neighbouring states like Tamil Nadu, Andhra Pradesh and so forth (Shinoj, 2015). On the off chance that this pattern is to proceed further, there is high likelihood that Kerala would turn into the most food insecure state in the country. During this period, the area of land under fallow other than current fallow and current fallow recorded a positive growth rate (Government of Kerala, 2016). Thus, it can be presumed that the decrease in cropped area has a significant impact on food crops over non-food crops. As a result, the changing cropping pattern not only poses threat for food security but also for ecological stability of the state (Rejula and Singh, 2015).

2.2.2. Unemployment

Agriculture is a primary source of employment and income for a large number of people especially those from disadvantaged communities and women, thereby, making it necessary to have meaningful progress of this sector in order to fulfil the goal of inclusive and faster economic growth as specified in the 12th five-year plan. Yet, the circumstance in Kerala is marginally debilitating. Though land reforms were embraced by the state since early 1950s, post reform, the performance exhibited by the agricultural sector was poor and they have been supplanted by the service sector to a greater extend (Harilal and Eswaran, 2018). This possesses huge threat to the people who rely primarily on agriculture as a source of living. As per the census of 2011, the work participation of women in the agricultural sector have decreased radically which can be attributed to the shift from the cultivation of food crops to cash crops. This was principally a direct result of higher preferance for men over ladies for the cultivation of cash crops which prompted enormous number of ladies being jobless. While considering the cropping system in Kerala, it can be classified into four, namely, paddy based low land cropping system, monocrop plantations, coconut based mixed cropping system and homestead based mixed cropping system. Of these, higher participation of women was seen in the first and last cropping system. But with time there occurred a severe decline in this cropping

system, resulting in the downturn of involvement of women in agriculture (Kumar and Pradeep, 2017).

From a societal perspective, employment is not only seen as a source of income yet in addition as a means to evaluate the social status and contact of an individual with others, subsequently having considerable contribution towards the subjective well-being of the individual. Researchers have found that individuals having a permanent job and a steady income have high levels of subjective well-being than those without an employment (Meer, 2014). The most critical policy concern for developed as well as developing nations is the existing scenario of unemployment, consequently making it the priority while considering the objectives of development. A major reason for unemployment for both educated as well as uneducated youth is the perishing of production sector. While considering the case of Kerala, educated unemployment is the core problem (Arun, 2017), which is the same for India as well (Bairagya, 2015). As per the national statistics of 2019, the unemployment rate of the state (9.53%) is above the national (6.1%) rate. It was found that of the total educated employed individuals, only three-fifth were in regular employment with some certainity in their income. The number of women who are employed is likewise low (Singh *et al.,* 2019) and had a clear preferance for public sector job (Arun, 2017). The prominent reason for Kerala's high rate of unemployment is the huge gap in the demand and supply components of labour. The demand and the supply component comprise of the available employment opportunities and the education system existing in the economy respectively (Bhalla and Meher, 2019). Unemployment rates have always been high in Kerala since 1990 regardless of having high literacy rates. The major reason for this can be ascribed to the declining and stagnant nature of primary and secondary sector while the tertiary sector contributing actively to the state domestic product. (Ramanathaiyer and MacPherson, 2018).

2.2.3. Migration

In Kerala, the migration of individuals, both in and out of the state is very high and conspicuous. As per the report of Kerala Migration Survey (2011), more than 3 million people live outside the state, which is nearly 10% of the total population of the state (Bhagat, 2011). The economic upsurge of Middle East Asia in 1970's and 80's attracted large scale migration of Keralites to this region (Viswanathan, 2014). It has brought economic freedom and high living standards in Kerala who slowly moved into a consumer society rather than a production society. Kerala at large presently depends on its neighbouring states for rice, vegetables, and other staple foods. The economic rise also resulted in high educational standards, and the development of highly skilled human resources (Azeez and Begum, 2009). The opportunities for permanent settlement, and obtaining citizenship in Middle East was slim which triggered the highly skilled migrants to choose alternative destinations such as United States, United Kingdom, Australia etc. Presently, a good portion of young generation lives in these countries as permanent residents or citizens giving up Indian citizenship. Unlike Middle East migration, the present migration is not a booster up for Kerala economy, pumping out the money to those countries by selling their land properties in Kerala.

2.2.4. Environment and climate change

Disregarding the state's richness, there are various environmental issues in the form of tree cover loss, overexploitation of resources, soil erosion, depletion of groundwater table, deterioration of water quality and water pollution (Gopakumar, 2011). The situation is additionally convoluted by the expanding population of the state. Occurrence of frequent flash floods, landslides and silting of reservoirs, became a common phenomenon due to the changes in the land use pattern and deforestation resulting serious ecological and environmental problems (Kumar, 2005; Dutt *et al.,* 2015). Rainfall patterns have been exhibiting uncertainities in the state since past few years. According to the report submitted by the Indian Network

for Climate Change Assessment (INCCA) (2010) to the government of India, titled 'Impact of climate change in four regions of the country', it was found that increasing temperature, decreasing rainfall and flooding related to sea level are part of the climate change scenario for Western Ghats as well as Kerala. Wetlands are an important part of the ecosystems of Kerala which comprises of both natural and human-made waterbodies like mangroves, paddy fields, lakes, rivers, kole land and so on. But these wetlands are declining at a disturbing rate due to anthropogenic activities (Abraham, 2015) which might be a reason for frequent floods and droughts in the state recently (Gopakumar,2011). A projected emission of greenhouse gases showed an increase in monsoon seasonal mean surface temperature and rainfall of the order of about 1.5^{o}C and 2 mm per day in the decade 2040–2049 with respect to the 1980s (Saseendran *et al.,* 2000). All the above factors have gravely influenced the agricultural sector, leading to its stagnant condition.

2.2.5. Land use/land cover change

The demographic transition undergone by the state is profoundly relatable to numerous Western countries yet while considering the economic development, it is exceptionally low. The state is known as the demographic sweet thump of India. During the 2001 census, it was found that the population density of the state was 819 persons per square kilometre, which increased to 860 by 2011. The population is further expected to increase from 3.3 million to 3.6 million during a period from 2011 to 2036, thereby elevating the population density from 860 to 951 persons per square kilometre (Government of Kerala, 2021). The rate at which the population is increasing is alarming and have significant impact on various societal components, the prominent one being the impact on land use pattern. Increasing population is likely to lead to agricultural land expansion and intensification and later on leading to abandonment of these lands and their conversion into industrial and residential areas (Devi and Kumar, 2011)

The LU/LC change undergone by Kerala is a remarkable one over all these years. Land use infers the activities carried out on land while land cover is the natural

features that cover the surface of the land which is viewed as the most important local anthropogenic disturbance to the ecosystem (Sheeja *et al.*, 2011). The predominant form of land use in Kerala during 2006-2007 was found to be agriculture, having occupied an area of nearly 55%, followed by forests (28%), while land not under agricultural use was found to be only 11%. While considering the land use pattern during 2019-2020, total cultivated area was 66.64% and the net sown area was 52.13% which had undergone a decrease over the years. Forests occupied 27.83% of the total area and the land used for non-agricultural use rose to 11.73% (ENVIS Centre: Kerala State of Environment and Related Issues, 2021). Two divergent trends are being observed in the recent land use history of Kerala. The first one is an intensification of human activities, and the sprawling of urban centres, and the second one is the fallowing and abandonment of land (Sreya and Vidhyavathi, 2018). The urban features in the *urban-rural* continuum are growing quite fast reducing the distances among them. This urban sprawling creates congestion of roads without proper ease of traffic. Similarly, the air quality and supply of water are being challenged in such areas (Aravindan and Prasanth, 2018). During early 2000s, Cochin urban agglomeration was the only city having more than a million population of the 18 urban agglomerations, but by 2011, it increased to 7 cities, namely, Kozhikode, Thrissur, Malappuram, Thiruvananthapuram, Kannur and Kollam. During a period from 2001 to 2011, Kerala has shown an exceptional expansion in the level of urbanisation (Pradhan, 2017). A peculiar feature of the state is that the identification of exact demarcation of rural-urban area is difficult due to the scattered pattern of cities and moderate population density. The urbanisation witnessed in Kerala is different from other parts of the country as it is characterised not just by the migration of rural population to urban areas (Bhagat, 2011) yet additionally a decrease in the area of agricultural fields and their conversion for other economic activities (Thomas, 2017). Between 2001 and 2011, there has been a dramatic increase in the urban population owing to the reclassification of numerous rural areas to urban, i.e., into census towns (Thaickavil, 2020). According to 2011 census, there has been rapid increment of census towns from 99 in 2001 to 461 in 2011, i.e., an increase of almost 366%. A

major reason for this is due to the shift of male working group away from the agricultural sector (Kuruvilla, 2013).

On the other hand, the absence of human labours and the increase in the labour cost leaves much of the marginal lands to the process of fallowing and abandonment. Though various laws were introduced to enhance the agricultural sector, it was found beneficial only to rich and influential farmers leaving behind marginal farmers, forcing them to leave the land fallow (Viswanathan, 2014). Poor mechanisation and irrigation management practices have exacerbated the situation (Nair and Dhanuraj, 2016). Land treated as an economic power force traditionally is not being considered anymore and is also losing its relevance as an investment option except in certain business pockets. The societal and lifestyle changes also largely contribute to the pace of urbanization. The aspirant young populations migrate to metro cities and major towns in search of white- and blue-collar jobs kept no human resources available at the rural areas to continue the legacy of cultivation (Jose and Padmanabhan, 2015). Consequently, there was a surging of labour costs in the rural areas which resulted an influx of low skilled migrants from other States in India such as Bengal, Odisha, Uttar Pradesh and so on (Kumar, 2011; Reja and Das, 2019; Kumar, 2020), primarily undertaken by the marginalised people who depend on agriculture as an income source. Climate change have significant impact on agriculture which increases the risk faced by these marginalised agricultural dependent population, thereby acting as an impetus that pace up the migration of individuals in search of better living conditions and job (Hari *et al*., 2021). Globalisation is a primary driving force responsible for migration of individuals which play a significant role in the expansion as well as contraction of economic opportunities. The high pace of internal migration occurring in India is a result of urbanisation, as people in rural areas migrate to urban areas in search of a steady pay job, contributing significantly towards the increase in urban population (Brahma and Paul, 2018). The increasing rate of urbanisation and the abandonment of agricultural lands have dire impact on the ecosystem and the environmental quality. Higher the rate of conversion of land cover to land use types suitable to

meet the needs of human beings, higher will be the negative impact possessed by this change in LULC on the environmental quality (Krishnan and Firoz, 2021).

2.3 BIOECONOMY – A NOVEL APPROACH TOWARDS SUSTAINABILITY

Birner (2018) said that, as per Bonaiuti (2014), the use of the term "bioeconomics" can be followed back to Zeman, who during the late 1960s used it to represent an economic term which identifies the components of biological origin in most of the commercial activities. Adding to it, Bonaiuti said that for Georgescu-Roegen, the usage of "bioeconomics" meant that compatibility issues are most likely to arise when indefinite growth and nature's fundamental laws are considered. Thus, "bioeconomics" is basically different from "bioeconomy". For von Braun (2014), two geneticists Juan Enriquez Cabot and Rodrigo Martinezthe were the first to define bioeconomy. According to the paper published by Enriquez in the Science magazine in 1998 named as "Genomics and the World's Economy", a change in the world's economy will take place when the discoveries related to genomics are applied, prompting a reorientation of the industry's role in it. He likewise laid out the formation of a new economic sector, the life sciences in that paper (Enriquez, 1998). Though there isn't a direct usage of "bioeconomy" in his paper, it represents origin of the bioeconomy concept, that is, transformation of many industrial production processes due to progressions in the biological sciences and in biotechnology are likely to occur.

Since, the early 2000s, the concept of bioeconomy has been promoted in various regions of the world and not alone in European Union and each of these nations have published bioeconomy related policies and strategies. The bioeconomy term was presumably initially used in 1997 at a meeting held by AAAS (American Association for the Advancement of Science). In December 2015, Berlin witnessed the first Global Bioeconomy Summit, organized by the Bioeconomy Council of Germany in a joint effort with an International advisory committee. Over 700 bioeconomy specialists from more than 80 nations were

brought together. The evolution of bioeconomy as a universal notion can be seen in the scientific literature as well (Birner, 2018).

2.4 BIOECONOMY AS AN ALTERNATIVE DEVELOPMENTAL PATHWAY

Bioeconomy has the potential to solve critical societal issues including unemployment, food insecurity, climate change, overexploitation of resources and so on which form the major objectives of bioeconomy.

2.4.1. Unemployment

Unemployment is one of the major societal issues that every nation experiences. According to Statista (2020), the global rate of unemployment amounted to 5.4 percent in 2019. The unemployment rates are increasing despite having high literacy rates in many countries. A significant portion of the population, mainly the educated youth of developing countries are migrating to developed countries in search of new jobs and for a better living condition. When such migrations take place, it is likely to have a negative impact on the economy of that country. The adoption of bioeconomy has a major effect on employment. The base of bioeconomy is determined by agriculture-based industries as well as industries related to biomass, chemicals, food and feed ingredients used. In order for these industries to develop, efficient and technically skilled workforce will be necessary thereby increasing the employment opportunities (Deshar, 2016). With the adoption of bioeconomy, changes in employment rates are likely to occur in both rural and urban areas creating full time equivalent jobs and thus improving job quality. It can become a new income source for rural and coastal communities whose major income source is from agriculture and fisheries as the biomass production is mainly from these sectors (Ronzon and M'Barek, 2018). Production of locally available crop varieties can be more useful to local farmers as the conditions necessary for their growth can be provided without much ecological issues. When these local varieties are used, dependence on imported varieties can

be reduced and the burden on family budget of farmers can also be minimized. Growing bioeconomy rises the demand for the feedstocks used and the products produced which in turn change the prices related commodities and thus increased economic benefits for producers of these commodities. The changing production processes, market systems and income have positive effects on health and employment. Thus, the quality of life will get enhanced. The youth can get employed in their own country rather than moving abroad in search of jobs and thereby increasing the economy of one's own nation (Hasenheit *et al.,* 2016). However, the changing prices of bioeconomy products can turn out to be a burden for the lower- or middle-class consumers as they may not be able to afford such high prices and they may also be forced to buy goods at a higher price. Also, necessary arrangements should be made in order to help the consumers adapt to the new concept of economy.

2.4.2. Food security

The total populace will keep on expanding by over 30% in the coming 40 years from 7 billion in 2012 to in excess of 9 billion by 2050 as assessed by United Nations Population Fund in 2013. As per *World Population Prospects: the 2019 Revision* report, the medium-variant projection shows that the worldwide populace is probably going to develop to around 8.5 billion by 2030, 9.7 billion by 2050, and 10.9 billion by 2100 (UN, 2019). 47 least developed countries are among the world's fastest growing and the population is likely to double between 2019 and 2050 in many of these countries thereby, affecting its natural resources as well as policies aiming to achieve the Sustainable Development Goals. Thus, obviously leading to increased food consumption along with the demand for various products (Deshar, 2016; FAO and OECD, 2018). So as to cope up with the increased food consumption demand, the food production needs to be expanded. Yet, because of various reasons like adverse weather conditions, plant pathogens and diseases, agriculture is not being able to deliver the desired output. When the food consumption demand is not met, it will lead to food insecurity, a major challenge

for the nation. Adoption of bioeconomy through the use of biotechnology process can solve the challenge to a greater extend. With the evolution of green biotechnology, massive changes have taken place in the agricultural sectors by immensely contributing to various high yielding resistant varieties (Clarke and Zhang, 2013).

2.4.3 Environment and climate change

In order to meet the requirements of the ever-increasing population, the natural resources are being exploited in a ruthless manner, prompting its over exploitation and depletion. This will adversely affect the environment, disrupting the balance of nature (Crist *et al.,* 2017). Over exploitation of non-renewable resources will prompt its exhaustion without leaving any chance for its recovery. All these years, there has been an expanded reliance on fossil fuel resources which is also a non-renewable resource for major economic activities. The utilization of these resources also has various environmental impacts in the form of greenhouse gas emissions contributing to a great extent towards global climate change (Gilfillan *et al.,* 2019). The changing land use patterns also had a major role to play when carbon emissions are considered (Hansis *et al.,* 2015; Houghton and Nassikas, 2017). Considering the emission scenario, the theory of exploiting energy from renewable sources like wind, sun, waves etc and also the utilization of bioenergy or biofuel is gaining immense value. (Deshar, 2016). Thus, for combating climate change as well reducing the overexploitation of resources, a transition from a fossil based to bio-based economy is necessary. The major positive impact of bioeconomy when the environmental aspect is considered is the reduced consumption of fossil resources and thus reduced greenhouse gas emissions (Hasenheit *et al.*, 2016). Like any other economy, even bioeconomy has certain adverse effects on the environment, but with advancement in technology and proper planning, bioeconomy can prove to be fruitful.

2.5 BIOECONOMY – A SECTORAL APPROACH

Major sectors which contribute enormously towards the development and advancement of bioeconomy and associated activities are agriculture, fisheries, forestry and industries. All these sectors are interlinked and require dynamic connection among them to accomplish the goal of a bioeconomy based economic development.

2.5.1. Agriculture

Earlier the basic agenda of every nation was to utilize all the resources that were available to feed the population that was increasing which prompted agricultural practices that were unsustainable, deteriorating the quality of resources. The primary repercussions include arable land shortages, water pollution, and soil erosion, affecting the environment as well as agriculture. Therefore, its high time that a sustainable form of agriculture be adopted. The primary objective is thus to ensure adequate measure of good quality food having least negative effect on the environment. A sustainable bioeconomy by adopting sustainable land and water management, and cultivation practices are necessary to combat the current issues with the aim to increase agricultural productivity; to provide food at an affordable price; to ensure food security; to ensure a fair standard of living for farmers and to stabilise markets (Jordan *et al.,* 2007; Scarlat *et al.,* 2015).

2.5.2 Fishery

Overfishing is considered to be one of the major reasons that contribute towards the decline of various fish, shellfish and other living marine resources around the world. Environmental and climate change, pollution, habitat loss and so on too has an effect on these resources but overexploitation has a greater effect. When this is to continue further, severe losses in the economic as well as social sectors are likely to take place (Rosenberg, 2003). A biobased economy could contribute towards the management of the fisheries sector with the development of appropriate policies. The Common Fisheries Policy (CFP) was developed by the

European Union as a part of the bioeconomy for managing aquaculture and fishing. To guarantee the exploitation of resources at a sustainable rate and to maintain a balance between fishing and the resources, various regulations were laid upon fishing and related activities. The CFP also ensures that the health and safety of the producers or fishermen are satisfactory and help them get a fair price in the market. Thus, the aquaculture and the seafood processing industry can possibly become the "marine pillar" of bioeconomy, opening up new markets for aquatic biomass-based products (Scarlat *et al.,* 2015).

2.5.3 Forestry

When the forestry sector is considered in relation to bioeconomy, it has greater potential to be a pillar of strength for bioeconomy. Three of its major benefits that could be pointed out are its enormous biomass production potential, zero competence with the agricultural sector and finally the contribution to climate change mitigation through carbon sequestration. As far as the conservation of biodiversity and environment is considered, the role of forests in it is commendable (Ollikainen, 2014). In spite of the fact that the services provided by forests are essential for a sustainable environment, they aren't appropriately valued and are excluded from the market, it is recommended by scientists to introduce payments for them that would urge private landowners to manage their forests sustainably. With the development of bioeconomy, the forestry sector could be made more economical alongside environment conservation, thereby enhancing the global competitiveness of forest products (Scarlat *et al.,* 2015; Sillanpää and Ncibi, 2017).

2.5.4. Industry

The existence of many industries can be attributable to fossil fuel resources like coal, petroleum etc. which are non-renewable in nature. Despite the shortage in fossil supplies, there is increased dependence on these resources and unless the renewable resources become cheaper and accessible for its exploitation, this

dependency on fossil sources are going to increase. For a sustainable future, a renewable and environment friendly raw material must be looked upon. Hence, so as to have the strategic energy sector, sustainable bioeconomy has to be adopted (Sillanpää and Ncibi, 2017) using renewable resources as feedstocks and biobased industries. Biotechnology has been recognized as one of the key enabling technologies (KETs) for driving the bioeconomy. The main strategy goals are focusing on research and innovation on KETs. With the utilization of biotechnology in the industrial sector, various products can be developed that has a biomass origin and less inclined to cause a negative impact on the environment. Biopharmaceuticals have already gained popularity, now it is time for the acceptance of biochemicals and bioplastics (Scarlat *et al.,* 2015).

2.6 BIOECONOMY – A GLOBAL PERSPECTIVE IN RELATION TO AGRICULTURE

Though agriculture is an inevitable part of nearly all bioeconomy strategies, the attention given to it as well as the manner in which it is shrouded in, vary across nations. Countries like European Union, United States and Sweden have developed strategies explicit to agriculture while Italy, Germany and Spain have developed strategies considering the contribution of bioeconomy to the agro-food system for developing bioeconomy value chains (Motola *et al.,* 2018). Major agricultural development can be achieved basically through an increase in research and innovation and the adoption of new technologies and methods. Similarly, research and development in climate smart and sustainable precision agriculture is likewise proved promising in many nations like Italy, Norway, Germany, Spain and France (Diakosavvas and Frezal, 2019).

While contemplating the case of developing countries, they exhibit substantial reliance on biobased primary sectors like agriculture, fisheries and forestry (Börner *et al.,* 2017). Developing countries have taken efforts to progress towards bioeconomy by adopting appropriate strategies. South Africa prioritised

the application of Indigenous Knowledge System in primarily three sectors, namely, agriculture, industry and environment with the expectation that it will contribute immensely towards development of biobased industries and thereby increasing the nation's Gross Domestic Product (FAO, 2018). In any case, the contribution of agriculture towards the development of bioeconomy chain in developing nations are sparce contrasted with developed and industrialised nations (Börner *et al.,* 2017). Argentina sees bioeconomy as a tool towards sustainability, requiring adequate availability of biomass and technology alongside consistent support from public and private institutions for promoting innovation (FAO, 2018). In India, bioeconomy is firmly aligned towards biotechnology applications in sectors like pharmaceuticals, agriculture and biobased industries. It has been found that bioeconomy has been a success in the country but is in its early stages and thus require more research and innovation to flourish (Biotechnology Industry Research Assistane Council, 2020). When the development of bioeconomy in China is thought of, it is synonymous to green revolution and has seen an ascent in the usage of the term bioindustries during the 12th five-year plan (Wang *et al.,* 2018; Sillanpää and Ncibi, 2017). Bioeconomy is in its infancy in many of the developing countries, hence these nations are attempting to sort out its prospects and consequences on the nation's economy and development.

2.7 AGRICULTURE, FALLOWING AND BIOECONOMY

Bioeconomy can be treated as a way to slow down and avert the process of fallowing or farmland abandonment and ultimately lead to advancement of the agricultural sector. Bioeconomy is gaining enormous relevance across the globe and many nations have adopted numerous strategies in sectors like agriculture, forestry, fisheries etc. for developing bioeconomy with the ultimate aim to increase competence in the global market and to accomplish sustainability (Besi and McCormick, 2015; Sillanpää and Ncibi, 2017; Meyer, 2017; FAO, 2018). Bioeconomy has been a huge success in the European Union (EU) both economically as well as environmentally, attributable mainly to the strategies and

policies developed. According to the Bioeconomy Report of EU (2017), while considering employment, bioeconomy was able to generate 18.6 million jobs in various sectors with the highest being in the agricultural sector contributing to almost 9.6 million jobs. When turnover is considered, 2.2 trillion Euro was generated, with the highest being in the food, beverages and tobacco sector contributing to 1.17 trillion Euro. The significant sectors that contributed to the economic growth are agriculture, forestry, fisheries, food and beverages, biobased textiles, wood products and furniture, paper, biobased chemicals, pharmaceuticals, plastics and rubber, bioelectricity and biofuels. In association with the Common Agricultural Policy (CAP), farmers are provided with direct payments through the European Agricultural Guarantee and Guidance Fund (EAGGF) on the off chance that they satisfy certain conditions such as good maintenance of lands, meeting the food safety standards, protection of environment and animal welfare. The financial incentives provided substantially reduced land abandonment and encouraged cultivation on the lands. In Poland, the abandoned farmland diminished from 1.9 million ha in 2002 to 0.7 million ha in 2010 (Sroka *et al.,* 2019).

Agriculture is considered as the core of bioeconomy development as it is a primary source of bioeconomy feedstock (Lewandowski *et al.,* 2018). It has been found that bioeconomy has numerous applications in agriculture including developing crops having high yield and productivity, high water and fertiliser use efficiency and disease resistance. Accordingly, the development of bioeconomy implies bringing with it new fortuities in the agriculture sector. It includes, enhanced employment opportunities and income source through the opening of new markets and other business sectors (Ronzon *et al.,* 2017). Reducing the risks associated with the fluctuations in the policies and prices of commodities by developing a more resource efficient economic model and transforming agriculture thereby establishing new links with other sectors of economy are all significant contributors towards agriculture development (Diakosavvas and Frezal, 2019). Apart from these, it is profoundly important to know the role of ecosystem in the fixation of water and nutrients and its circulation in plants. Bioeconomy strategies concur on the necessity to encourage sustainable management of soil for greater

productivity in agriculture (Helming *et al.,* 2018). The strategies developed by the European Union features the capability of research in soil management for a sustainable agriculture. Efficient utilization of water in agriculture is likewise considered as a need, particularly with regards to climate change. The German strategies alludes to the significance of irrigation and utilization of water and thus the need for advanced technologies to fulfil these needs which can moreover lessen energy utilization (Staffas *et al.,* 2013).

While considering the existing scenario in Kerala corresponding to fallowing of agricultural lands and associated issues like food insecurity, unemployment, land use land cover change and unsustainable land use practices, bioeconomy can turn out to be the best solution for bringing out a change in the current system. It can possibly contribute towards the sustainable management of land by forestalling or reducing fallowing and promoting agriculture through the adoption of appropriate interventions benefitting all the individuals economically, socially and ecologically.

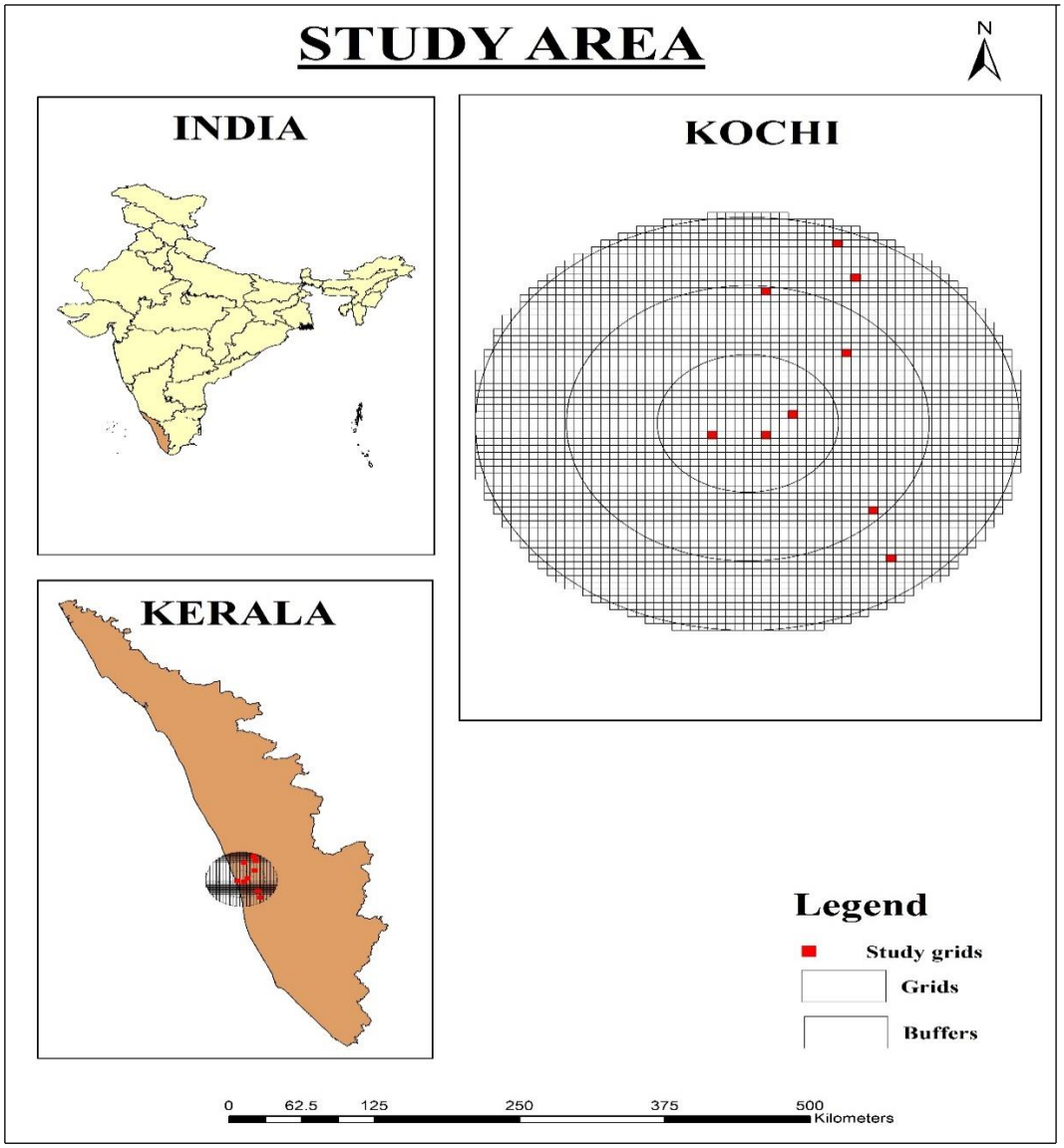
CHAPTER 3

MATERIALS AND METHODS

3.1 STUDY AREA

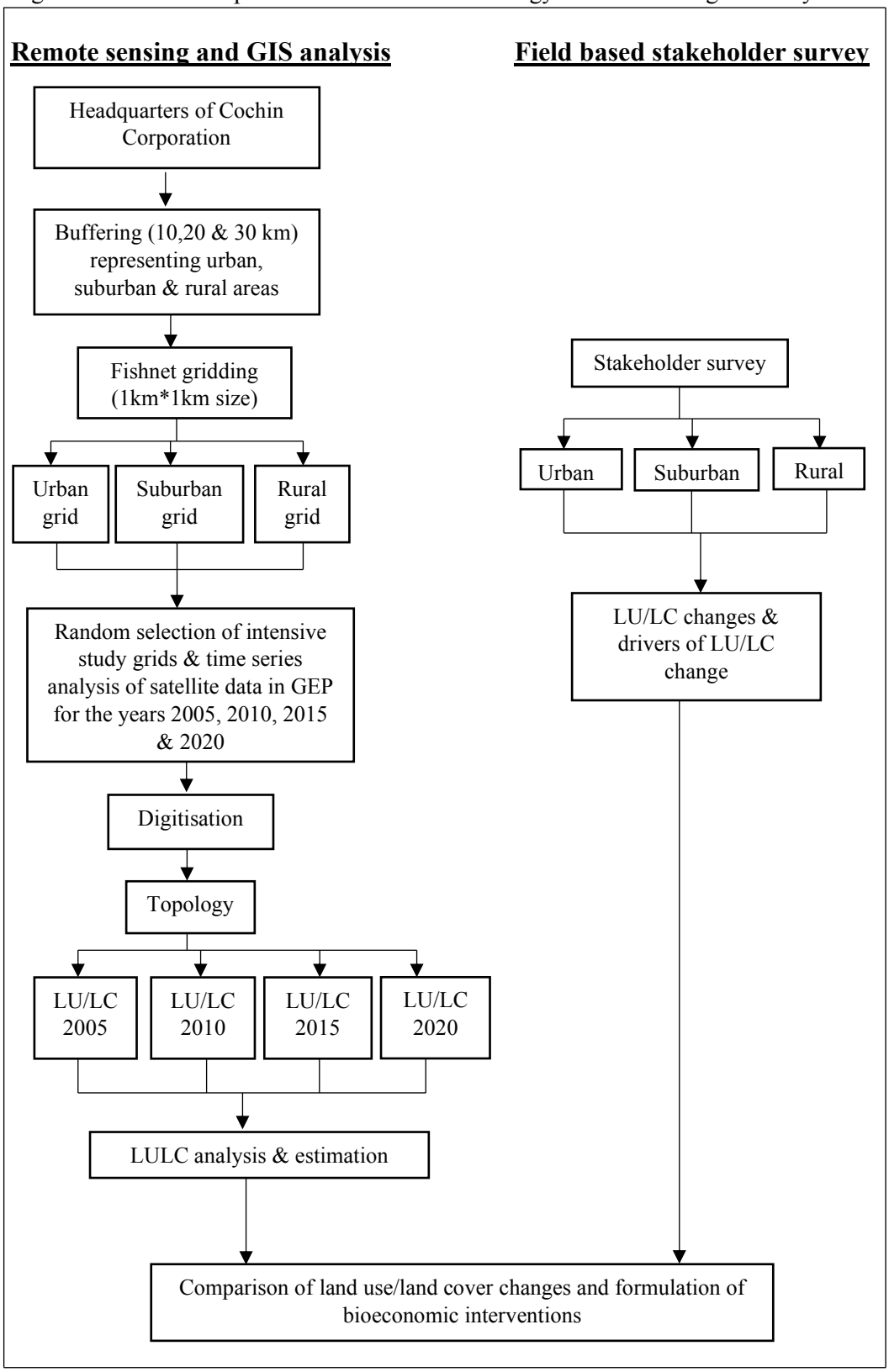
The study was carried out in the most populous metropolitan area in Kerala, i.e., Kochi, also known as the industrial, financial and economic capital of Kerala. Kochi, having the latitude and longitude of 9º 58'N and 76º 14' E respectively, is considered the core of Ernakulam district, globally known as "The queen of Arabian sea" with an area of 95 sq km. It is considered Tier II city by the Government of India. Kochi being a coastal city is partly surrounded from one side by the Vembanad lake and partly from the other side by the Arabian sea itself (George and Rajan, 2015). The population density of the region is the highest in the state with a value of 859 per sq. km. The urban agglomeration population marked tremendous growth with the number rising from 8.24 to 21.12 lakh from the year 1981 to 2011. The region has a flat elevation with a warm and humid climate (Murali and Kumar, 2015). The average annual rainfall is 3100 mm with 132 average annual rainy days. The economic growth of the city began with the economic reforms brought about by the Central government during early 1990s. The service sector played a central role in boosting the economy with the establishment of numerous IT parks and port-based infrastructures which triggered the constructional and developmental boom in the city. Kochi witnessed rapid commercialisation over the years and has now developed into the commercial hub of Kerala (Ernakulam district administration, 2021) primarily because of an all-weather harbour, good quality water and access to cheap hydro-electric power (George and Rajan, 2015).

Figure 1. Location map of the study area



3.2 METHODS

Figure 2. Schematic representation of the methodology followed during the study



3.2.1 Data collection

Headquarters of the Cochin corporation was taken as the center point of the study. This point was located in the Google Earth Pro (GEP). Google Earth Pro is the current standard version of Google Earth which is basically a computer program that provides 3D representation of earth based on satellite images. The point was then exported to ArcGIS Desktop 10.5 for creating buffers around this point. The 10, 20 and 30km buffers were created to represent urban, suburban and rural areas respectively. The buffered area was then gridded into 1km grids using fishnet grid from cartography tool of ArcToolbox. The shapefile was then exported to GEP for further procedure. From GEP, 3 random grids from each of urban, suburban and rural areas were selected for the time series satellite image analysis (Fig. 1). Particular care was given to opt data which are cloud free, clear and geometrical registration error is less than one pixel. The years pertaining to 2005, 2010, 2015 and 2020 were selected, and months were from January to March.

3.2.2. Digitization and Image classification

Manual digitization was done in these grids for the years 2005, 2010, 2015 and 2020 by fixing the scale to 50m. For digitizing the data, various classes like buildings, mixed orchard, waterbody, tarred roads, muddy roads, railway tracks, barren area, fallow lands and paddy fields were considered depending on the respective grid. Appropriate colours were provided for each class with a specific name for their identification. Digitization was done using the polygon feature for all the classes, even for roads, for determining the area afterwards. Initially, 2005 was digitized by taking into consideration necessary classes and the data was saved in .kml extension (Keyhole Markup Language), which is the file type used by Google Earth to display map information. Then 2005 data served as the base map for 2010 and the changes occurred were digitized. Similarly, 2010 and 2015 served as base map for 2015 and 2020 respectively.

3.2.3. Image processing and change detection

The digitized data was then brought to ArcGIS, however, preceding any further analysis, the kml file was converted to shapefile using the conversion tools of ArcToolbox. As the digitization was done manually, the chances of occurrence of errors were high, thus topology was run. Topology is generally used to display topological relationships, exceptions and errors. Permissible spatial relationship between features is characterized using topology rules. The errors that were present were primarily in the form of overlaps and gaps between features. Topology was validated by comparing the feature geometry against all topology rules defined. Projected Coordinate System, WGS 1984 UTM Zone 43N was defined for the study area.

Post error correction, Query was defined by selecting "name" as the field id and afterward these features were merged into one single class. For instance, all the features identified with buildings were merged into one class named "building". From symbology of layer properties, appropriate colours were given for each class. For calculating the area, a new field was added to the attribute table named as "Area". Then area was calculated using calculate geometry in SI unit, ha and the rate of change in urban, sub urban and rural areas were determined. Finally, maps were prepared by adding necessary details including title, north arrow, scale bar, legend etc.

3.2.4. Ground truthing and stakeholder survey

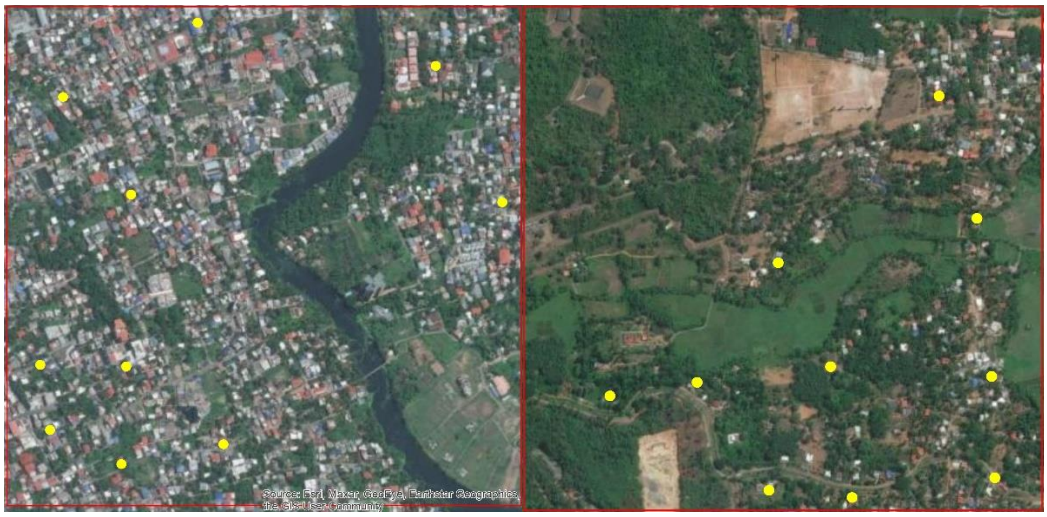
Ground truthing and stakeholder survey was carried out to validate whether the changes detected over the years in the thematic maps generated and the information derived from the images during the study is accurate or not. It involves the comparison of the features on a remote sensing image to those on the ground reality for the verification of the features on the image. Subsequently, a field visit was conducted to selected grids in urban, suburban and rural areas which had gone through substantial changes over the years. In the urban, suburban and rural areas,

visit was made to grids pertaining to Vyttila, Edathala and Nedumbasserry. These were the places where drastic changes had taken place as far as intensification of buildings, fallowing of lands, decrement of mixed orchards, paddy fields and so on were taken into consideration. The GPS points of these regions were noted to validate the changes by comparing it with the map obtained from the study. The GPS points were procured using GARMIN-Etrex-30x GPS of 5m accuracy.

A stakeholder survey was conducted among households to elucidate the land use history. The possibility to reintroduce agriculture in the area along with the possible interventions for the same were also discussed during the survey. Households were selected based on the criteria of how long they have been living in that region. Only those households were surveyed who have been residing in the region for as far back as 20 years or more. This was done in order to get vital information in regards to the LU/LC change as well as to determine the factors contributing to change for supporting the results obtained from the study. 10 households from each of urban, suburban and rural areas were surveyed randomly. The questionnaire was divided into 4 sections. The first section consisted of general details like the questionnaire number, date, name of the surveyor, name of the panchayat or municipality, ward number and GPS points of the location. The second section constituted of the personal details of the respondent such as the name, age, gender, address, occupation, phone number and the number of family members of the respondent. The third section comprised of the questions identified with the LU/LC change in the area during 2005, 2010, 2015 and 2020, driving forces behind the change, constraints related to the revamping of the agricultural sector and the possible interventions for the same. Primarily, changes in the classes like buildings, mixed orchards, fallow lands, paddy cultivation, roads, railways, etc. and waterbodies were analysed in percentage. For the reasons behind the change, a numerical ranking system based on a 10-point scale was used with the most important one getting the highest score and thereafter in the descending order. The final section was for providing any additional remarks of the area, viewpoint and suggestions of people. The questionnaire involved yes/no questions, multiple choice questions and rank based questions (The questionnaire is appended in

Annexure 1). The responses obtained were then entered in Microsoft Excel for further analysis and graph preparation. The overall methodology is summarized in Figure 2. Figure 3 represents the location of households from where the surveys were conducted.

Figure 3. GPS points of various survey locations (a) GPS points of survey location taken from urban area; (b) GPS points of survey location taken from suburban area; (c) GPS points of survey location taken from rural area



(a) **(b)**

(c)

Location of survey points

CHAPTER 4

RESULTS

4.1 LAND USE/LAND COVER CHANGE

The LU/LC change in the study area is presented in the tables given below. Maps of the grids pertaining to urban, suburban and rural areas is given below which represent the changes in LU/LC during 2005, 2010, 2015 and 2020.

Table 1. Land use/ land cover in urban area from 2005-2020, ha

YEAR/ CLASS	2005	2010	2015	2020
Barren area	6	6	4.4	5
Building	124	140	159	174
Mixed orchard	145	128	108.6	93
Muddy road	1	1	-	-
Railway track	1	1	1	1
Tarred road	14	16	19	19
Waterbody	9	8	8	8
TOTAL	**300**	**300**	**300**	**300**

Table 2. Land use/ land cover in suburban area from 2005-2020, ha

YEAR/ CLASS	2005	2010	2015	2020
Barren area	2	1	3	2
Building	7	11	17	25
Fallow land	-	8	10	12
Mixed orchard	199.6	203.4	196.86	189.4
Muddy road	2	0.2	0.14	0.2
Paddy field	85	70	67	63
Tarred road	4	5	5	8
Waterbody	0.4	0.4	1	0.4
TOTAL	**300**	**300**	**300**	**300**

Table 3. Land use/ land cover in rural area from 2005-2020, ha

YEAR/ CLASS	2005	2010	2015	2020
Barren area	4	3	3	4
Building	8	16	22	28
Fallow land	-	9	7	17
Mixed orchard	202.5	194	194.8	184.9
Muddy road	0.5	1	0.2	0.1
Paddy field	70	61	57	48
Railway track	2	2	2	2
Tarred road	2	4	4	6
Waterbody	11	10	10	10
TOTAL	**300**	**300**	**300**	**300**

Figure 4. LU/LC map representing changes in the urban area 1 from 2005-2020

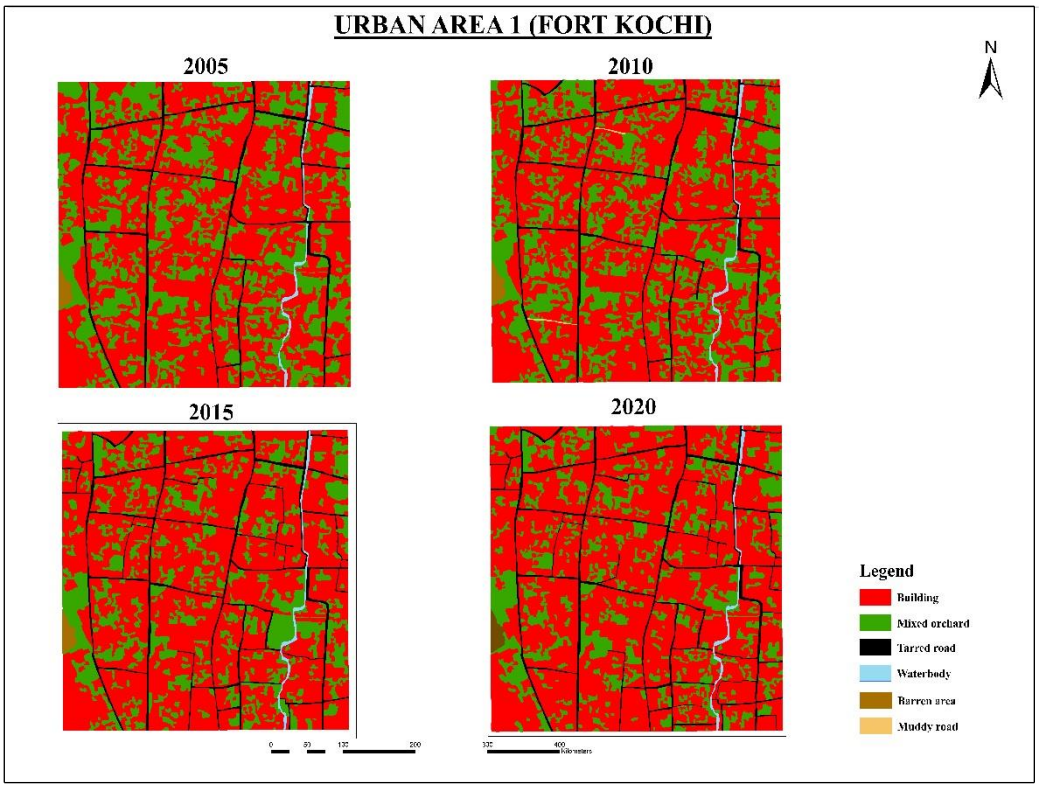


Figure 5. LU/LC map representing changes in the urban area 2 from 2005-2020

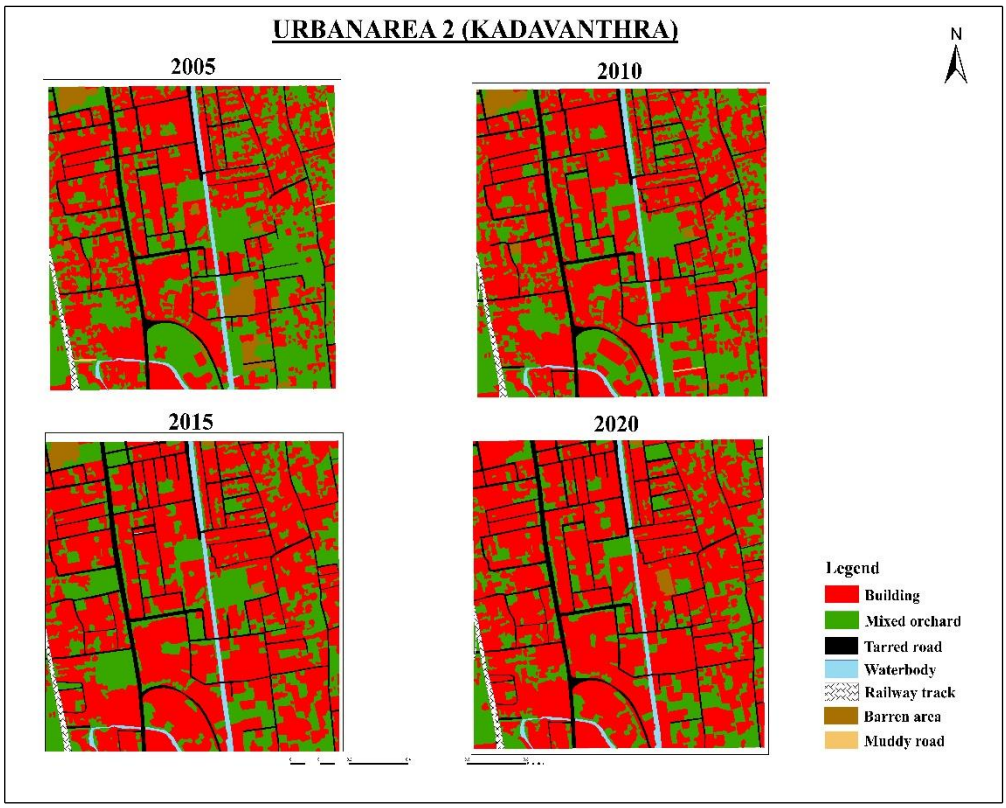


Figure 6. LU/LC map representing changes in the urban area 3 from 2005-2020

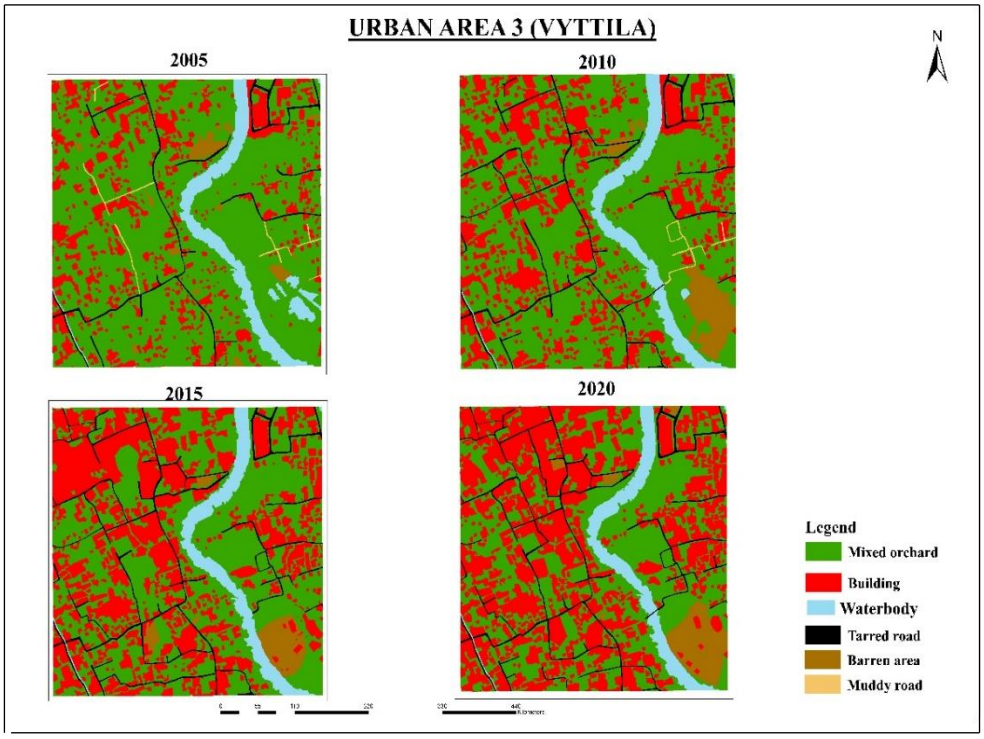


Figure 7. LU/LC map representing changes in the suburban area 1 from 2005-2020

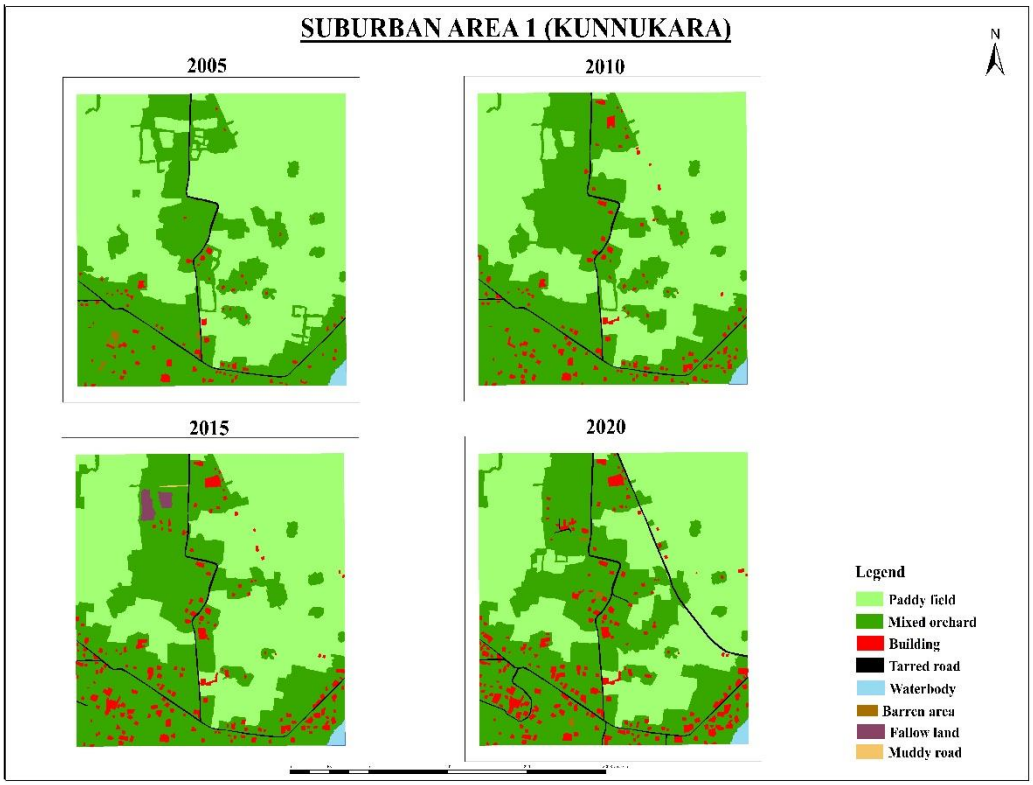


Figure 8. LU/LC map representing changes in the suburban area 2 from 2005-2020

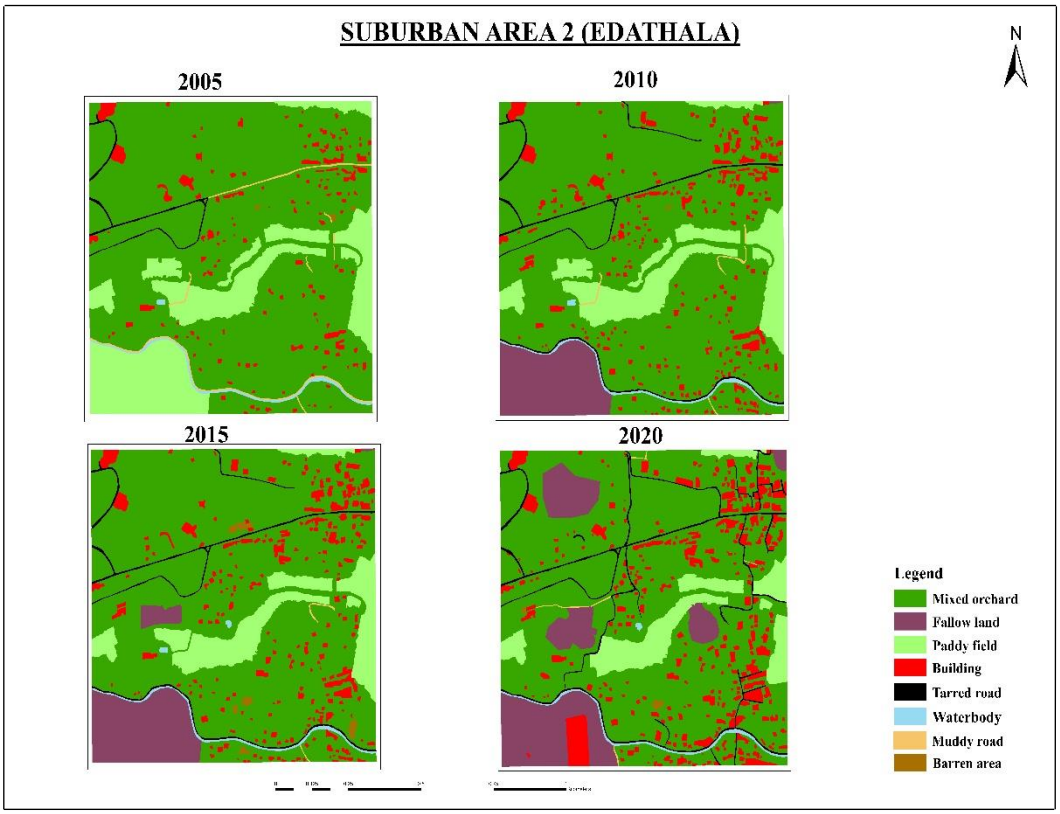


Figure 9. LU/LC map representing changes in the suburban area 3 from 2005-2020

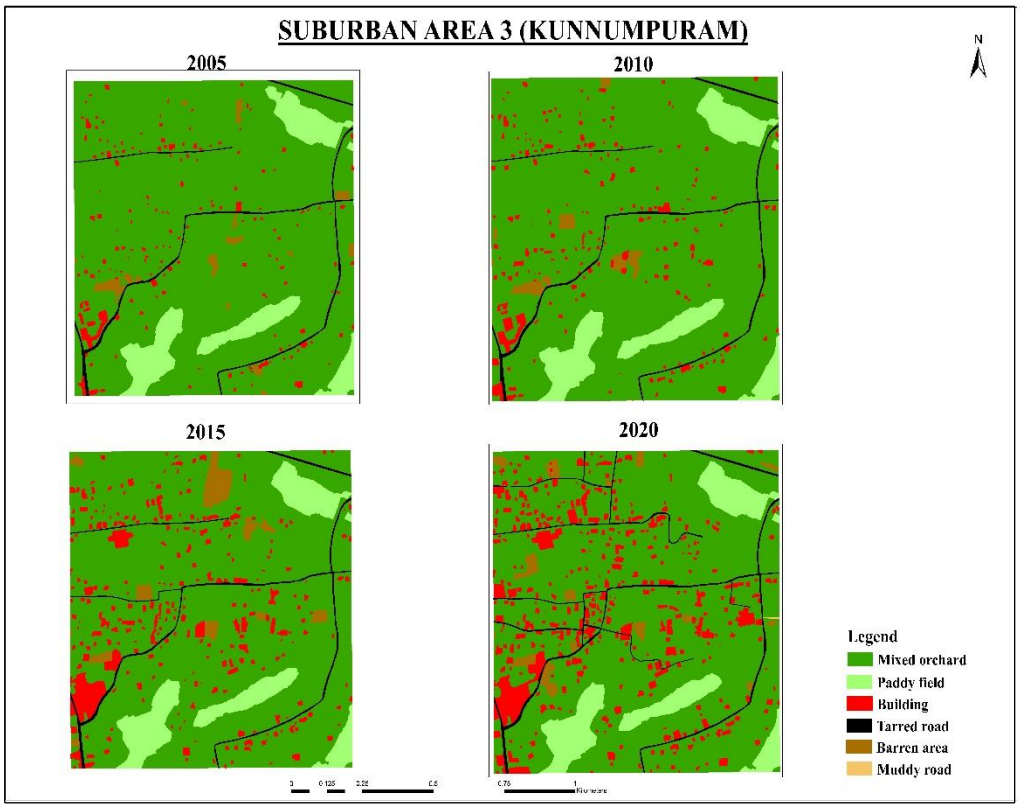


Figure 10. LU/LC map representing changes in the rural area 1 from 2005-2020

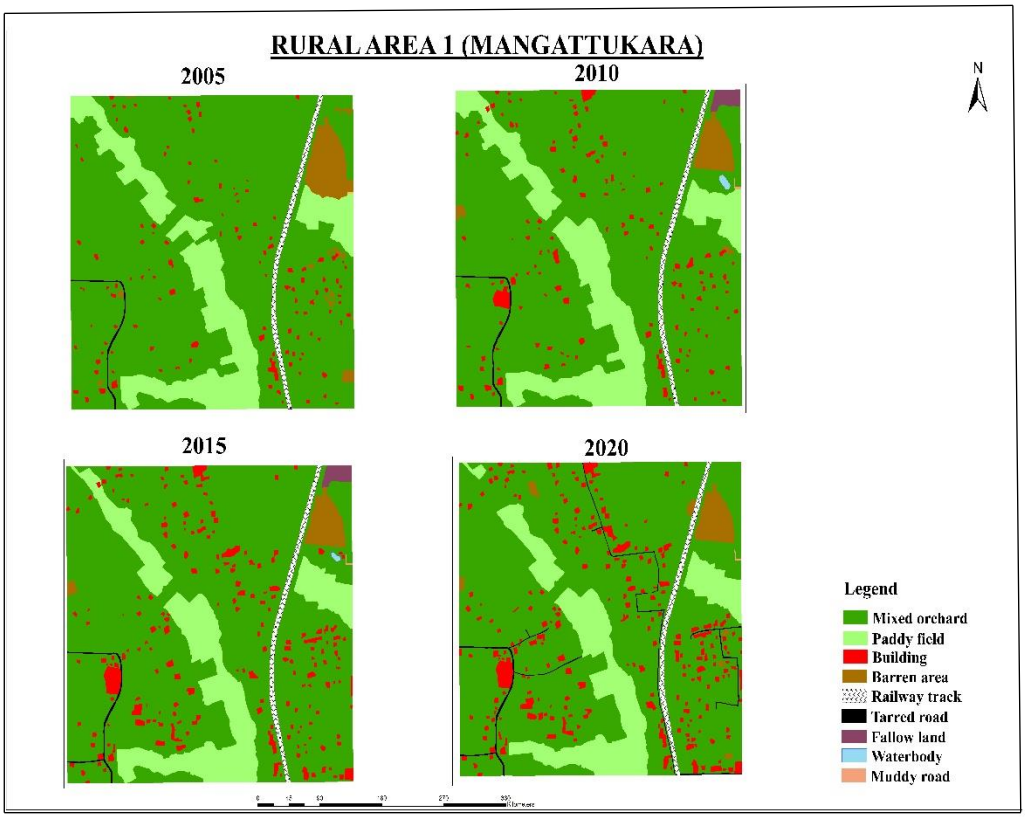


Figure 11. LU/LC map representing changes in the rural area 2 from 2005-2020

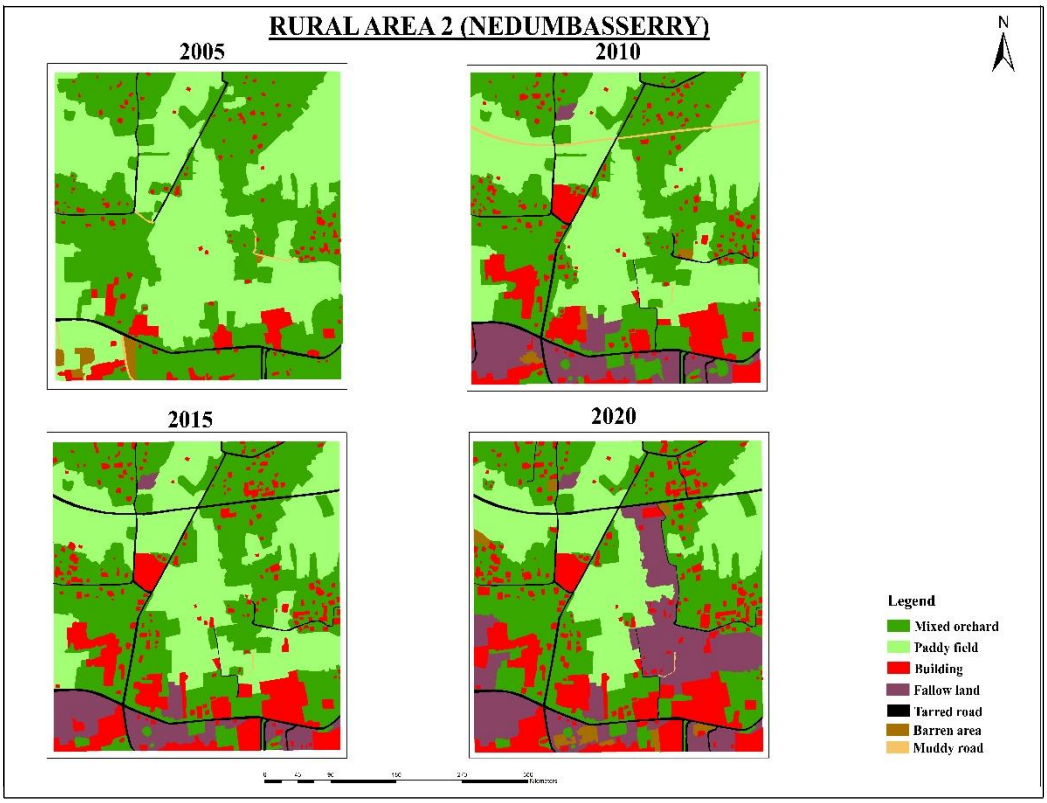
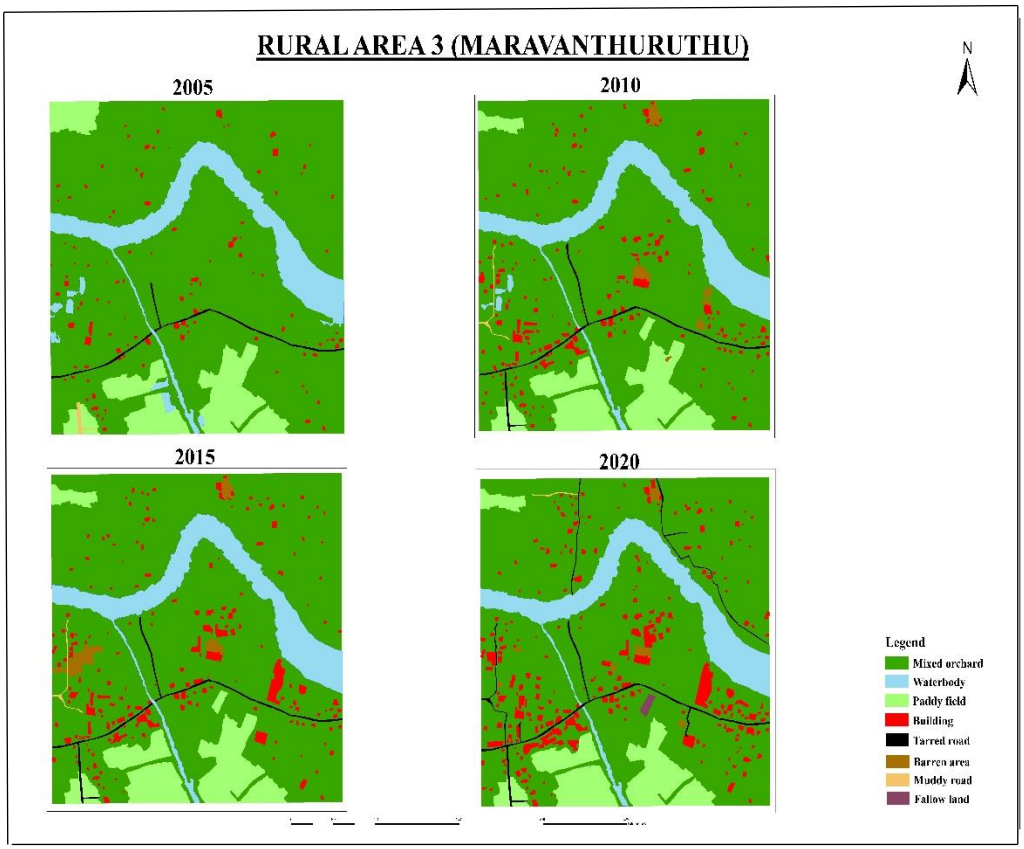


Figure 12. LU/LC map representing changes in the rural area 3 from 2005-2020



4.1.1 LU/LC change in urban area

While considering the case of urban area, of the total area of 300 ha, 124 ha of land were occupied by buildings in 2005 which expanded to 174 ha by 2020, i.e., an increment of almost 16.6%. Mixed orchards occupied an area of 145 ha in 2005 which decreased to 93 ha by 2020, a reduction of 17.3% while the waterbodies decreased from 9 ha to 8 ha by 2010 and thereafter remained the same until 2020. The urban area witnessed an expansion of tarred roads from 14 ha in 2005 to 19 ha by 2020, almost an increment of 1.6%. During initial years, 1ha of land were muddy roads, which reduced to zero by 2020 as all the muddy roads got converted to tarred roads as a part of urban development. As far as barren areas are thought of, 6 ha was the total area occupied by them which remained the same during 2010 as well. However, by 2015, it decreased to 4.4 ha and later on expanded to 5 ha by 2020. Railway tracks in urban areas haven't endured any change in the last two decades. It occupied only 0.3% of the total urban area. In urban areas, major changes had taken place in the classes namely, buildings, mixed orchards and tarred roads, with drastic changes occurring in the Vyttila grid.

4.1.2 LU/LC change in suburban area

On account of the suburban area, the land area occupied by buildings were only 7 ha in 2005 which increased to 25 ha by 2020, having an increase of 6%. It was found that the area of mixed orchards increased from 199.6 ha in 2005 to 203.4 ha by 2010. But later on, there happened a shrinkage in its area reaching a value of 189.4 ha by 2020. In the suburban area, paddy cultivation exhibited a diminishing pattern over the last two decades. In 2005, 85 ha of land were devoted for paddy which declined to 63 ha by 2020, having undergone a change of nearly 7.3%. During 2010, 8 ha of land was left fallow which expanded to 12 ha by 2020, an increment of 1.3%. There occurred no change in area occupied by waterbodies and remained constant over the years. Tarred roads had undergone an escalation from 4 ha to 8 ha during 2005 to 2020. In 2005, 2 ha of muddy roads were found which

gradually decreased to 0.2 ha by 2020. The suburban area had shown an abating trend at first in the case of barren areas which increased during the next year, i.e., by 2015 and finally diminished by 2020 to 2 ha, coinciding with the value found during 2005. Classes like buildings, mixed orchards, paddy fields and fallow lands had witnessed major changes in terms of area of occupancy, primarily in the grid pertaining to Edathala which was once an agrarian region.

4.1.3 LU/LC change in rural area

A positive trend in the area of buildings were witnessed in the rural areas. The buildings expanded to 28 ha by 2020 from 8 ha in 2005, i.e., an expansion of 6.6%. Mixed orchards portrayed an interesting trend in rural areas. Initially a decreasing trend was witnessed from 2005 to 2010, i.e., an abatement from 202.5 ha to 194 ha. In any case, by 2015, it increased to 194.8 ha and afterward diminishing to 184.9 ha by 2020. A drastic decline in area of paddy fields occurred from a period of 2005 to 2020, i.e., a decrease from 70 ha to 48 ha, close to 7.3% contrast in area, especially in the grid pertaining to Nedumbasserry. The situation of fallow lands is somewhat critical where, even during 2010, 9 ha of lands were left fallow which accounts for 3% of the total rural area, later on shrinking to 7 ha by 2015. However, by 2020, the fallow land increased drastically to 17 ha which is almost an increase of 3.4% within 5 years of time, indicating serious consequences on the agricultural sector. The area of waterbody diminished at first and thereafter remained consistent for the rest of the years. Tarred roads expanded from 2 ha to 6 ha during 2005 to 2020. Rural areas witnessed a curtailing trend in the area of muddy roads besides in 2010 which expanded from 0.5 ha to 1ha during a period from 2005 to 2010 and subsequently curbing for the rest of the years. During 2005, 4 ha of land were barren which remained the same in area during 2020 as well, however decreased during 2010 to 2015. Railway tracks were found in a particular grid of rural area which occupied only 0.7% of the total rural area and remained the same over the years. Critical changes had taken place in the case of paddy fields, fallow lands, mixed orchards and buildings. Nedumbasserry is one

such rural region which went through humongous changes over the last two decades in terms of increase in fallow lands and decrease of paddy fields and mixed orchards.

4.2 LAND USE CHANGE BASED ON SURVEY

Figure 13. Change in land use based on survey respondents in urban area

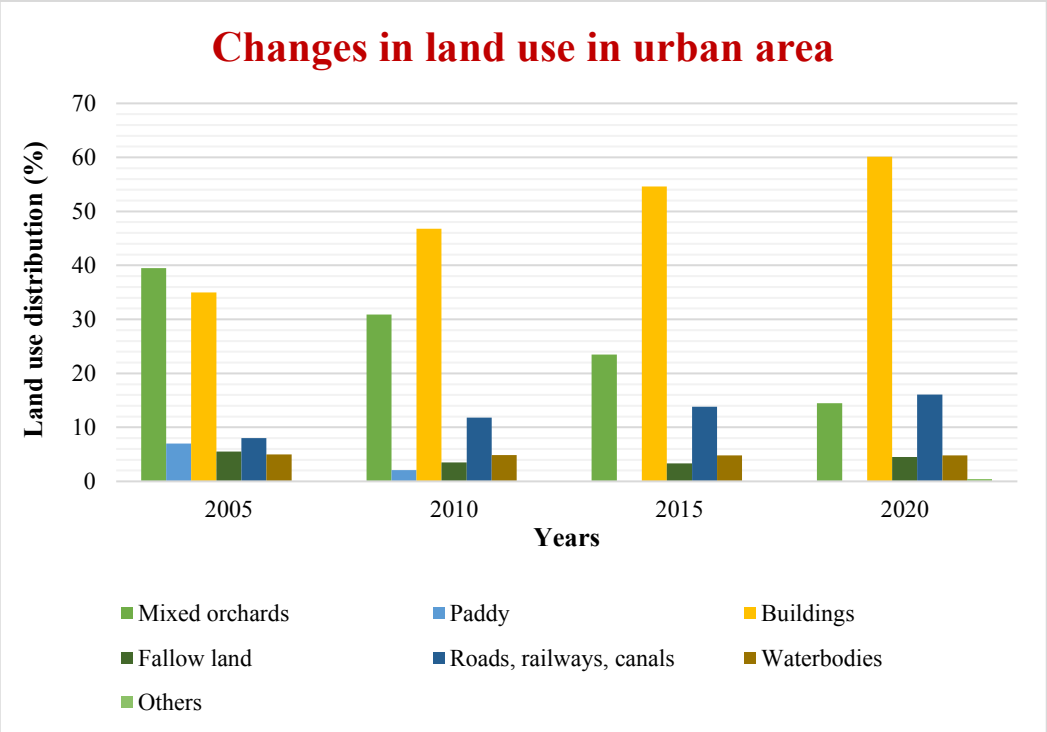


Figure 14. Change in land use based on survey respondents in suburban area

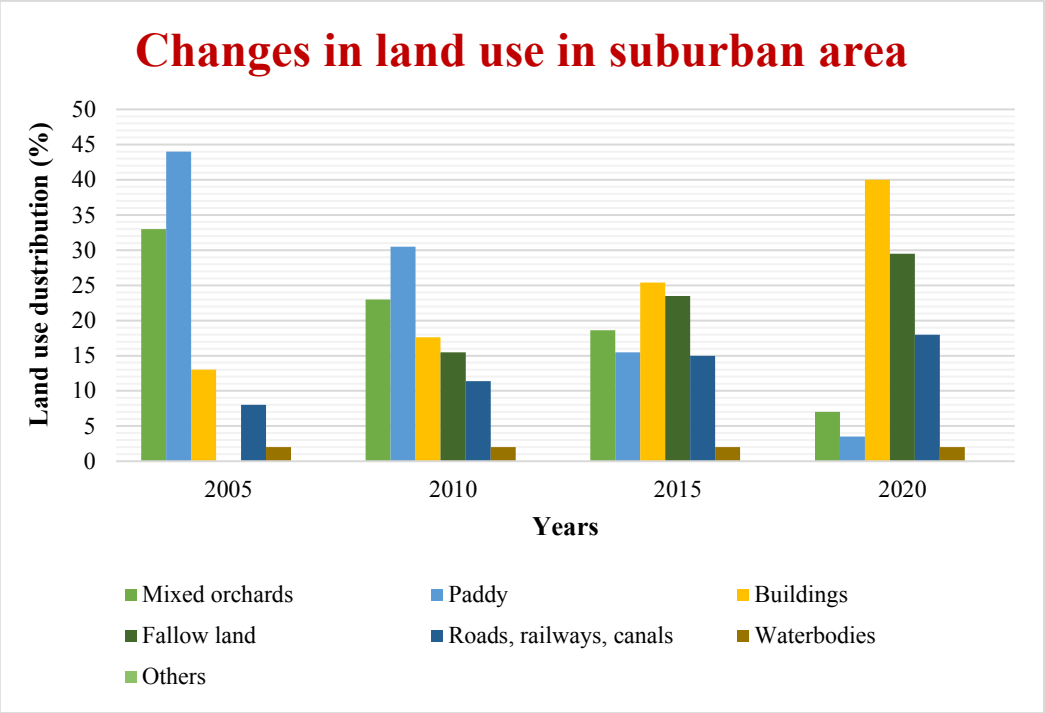
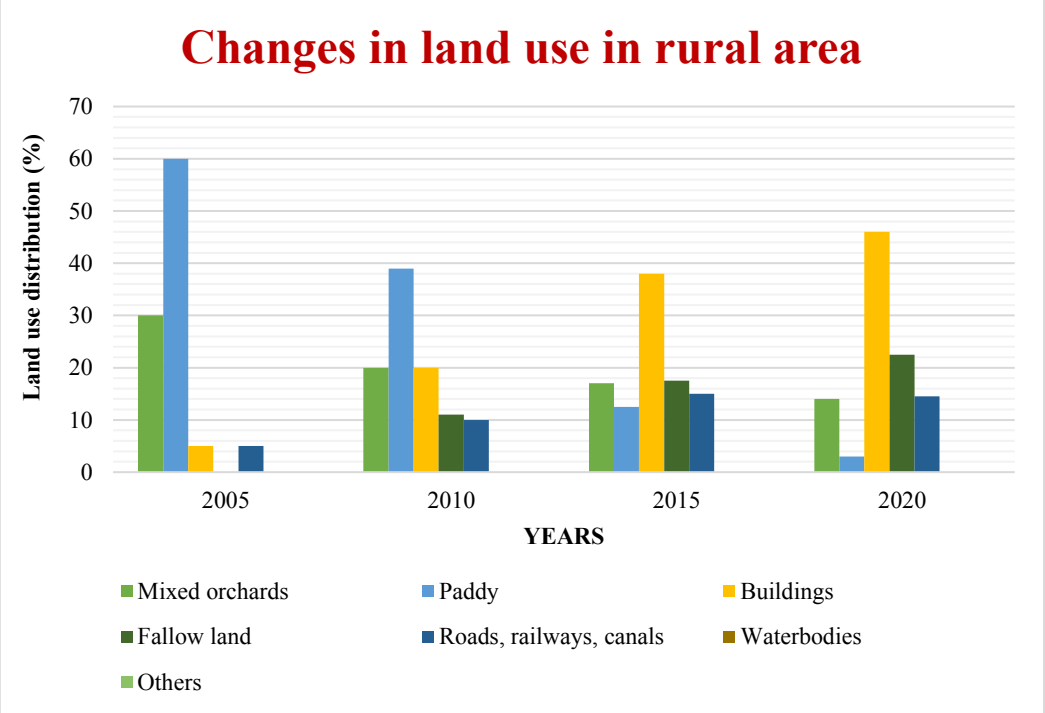


Figure 15. Change in land use based on survey respondents in rural area



Figures 13 to 15 address the responses of the inhabitants of the study area on the basis of the survey which depict the changes observed by them over the years. In the urban area (figure 13), drastic changes had taken place while considering buildings and mixed orchards. The area of occupancy of buildings increased from 35% in 2005 to 60% by 2020 while for the mixed orchards, a reverse trend was observed with the area decreasing from nearly 40% to 14% over the last two decades. The paddy cultivation which was found during 2005, disappeared by 2015. Almost a consistent trend was observed in the case of fallow lands with its distribution remaining less than 5%. By 2020, a new land use feature was seen in the area, i.e., barren land which occupied less than 1% of the area. The water bodies stayed pretty much consistent over the course of the years with an abatement of only 0.1 to 0.2%. Roads and other infrastructures nearly multiplied by 2020.

While thinking about the suburban area (figure 14), mixed orchards, paddy cultivation and buildings had undergone tremendous changes in terms of their area. The situation is highly critical in the case of paddy as the area occupied by them diminished from 44% to nearly less than 5% by 2020. The situation is similar in the case of mixed orchards as well with the value having undergone a decrement of nearly 26%. The area occupied by buildings expanded from 13% to 40% by 2020. Fallow lands consistently portrayed an increasing trend, with the area increasing over the years and having an occupancy of 30% by 2020. Roads, railways, canals and so forth expanded from 8% in 2005 to 18% by 2020. The waterbodies remained the same over the years.

The case of rural area (figure 15) is similar to that of suburban region with the area occupied by paddy and mixed orchards decreasing exceptionally, having gone through a reduction of nearly 57% and 16% respectively by 2020. The decrement of the area occupied by paddy is a matter of atmost concern. The fallow lands increased from 11% to 22% by 2020, nearly double the value found in 2005. The change in the area distribution of buildings is an astounding one, having expanded from 5% to 46% over the last two decades. Roads, as usual, depicted an expanding trend with noteworthy changes happened between 2005 and 2015.

4.3 LU/LC CHANGE AND DRIVING FACTORS

Figure 16. Major factors which contributed towards the LU/LC change in urban area from 2005 to 2020

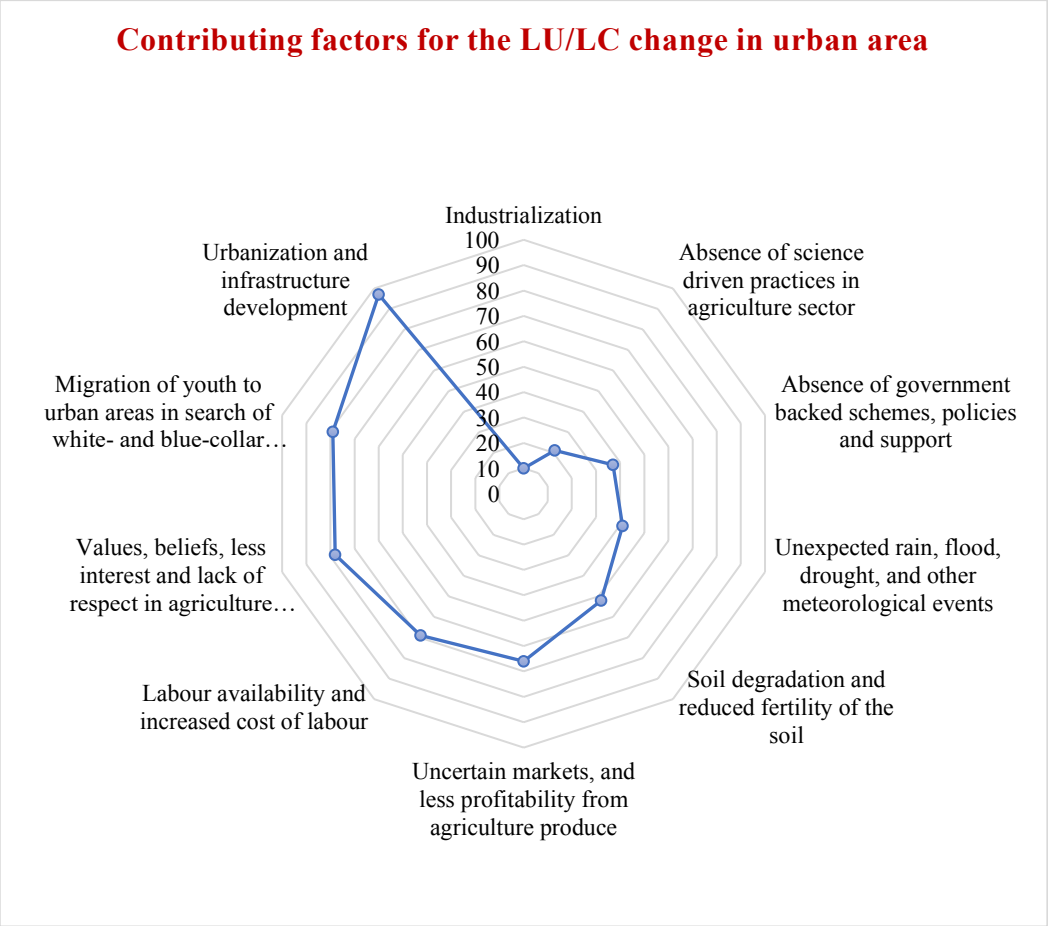


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Figure 17. Major factors which contributed towards the LU/LC change in suburban area from 2005 to 2020

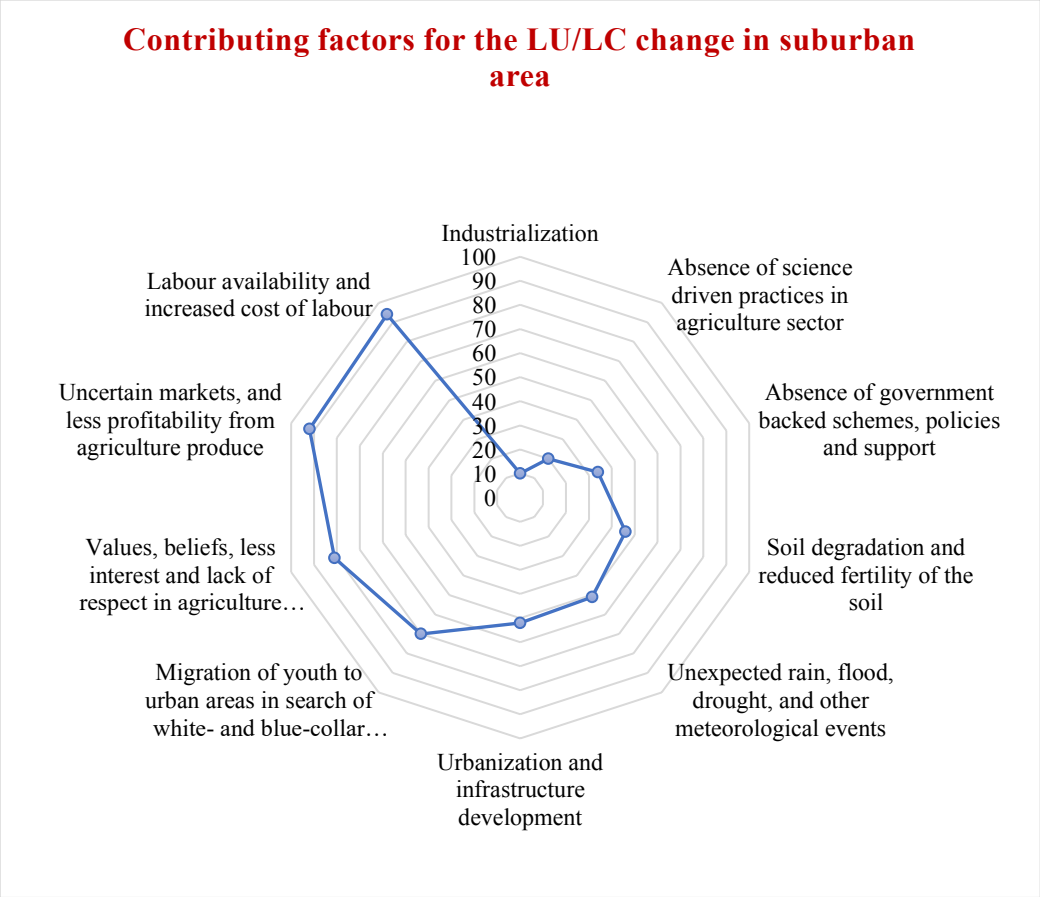
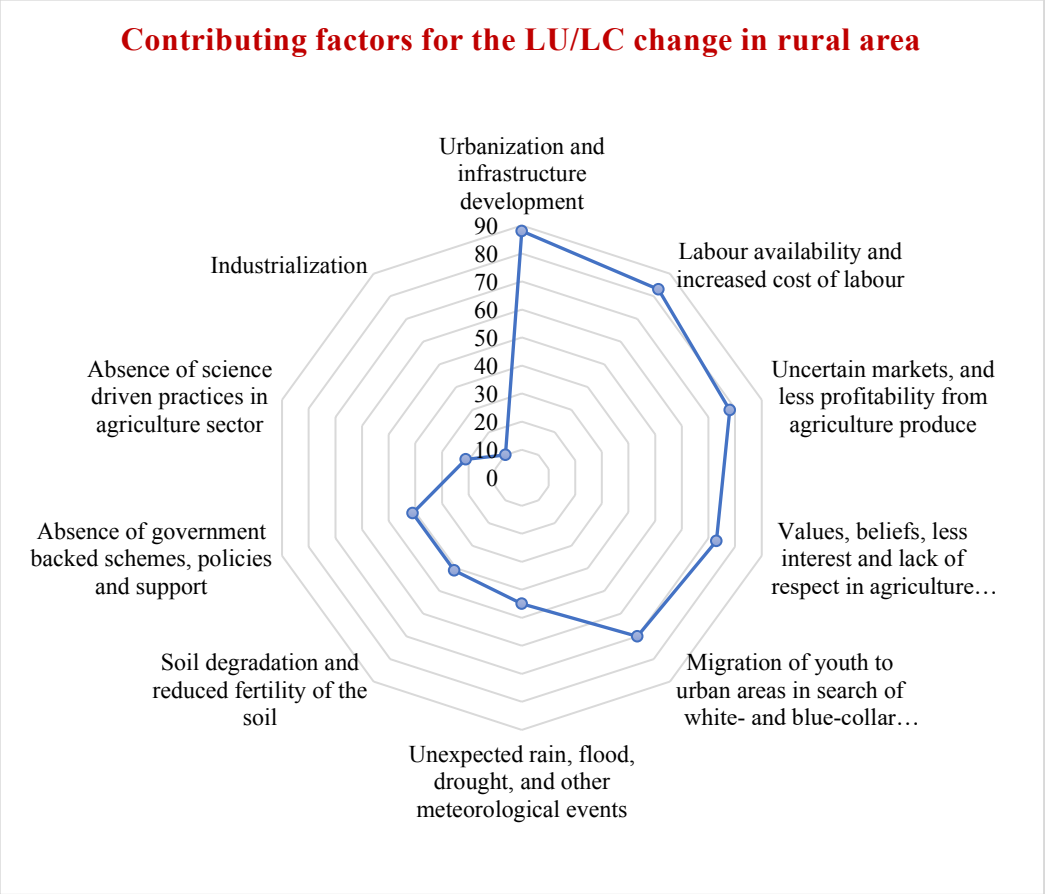


Figure 18. Major factors which contributed towards the LU/LC change in rural area from 2005 to 2020



In the urban area, the major factor which contributed towards LU/LC change during 2005 to 2020 was urbanisation and infrastructure development which got the highest ranking followed by the migration of youth in search of white- and blue-collar jobs. A sectoral transition from agriculture to other professions occurred as a result of lack of interest and changing values and believes of the youth. This in turn led to shortage of labour and increased labour cost, thereby deteriorating the agricultural sector of the region. Uncertain markets and reduced profitability from agricultural produce further aggravated the situation, having received fifth ranking during the survey. Soil condition of the region was not found a reason for the change along with the meteorological factors. All the respondents were of the opinion that the policies developed by the government had nothing to do with the stagnation of the agricultural sector. None were aware of the science driven practices; hence it received the second last ranking, denoting its least significance. The factor that received the lowest ranking was industrialisation, which is clearly visible from figure 16, indicating that no industrial development took place in the region over the last two decades.

While considering the case of suburban area, the prominent factor which led to LU/LC change was labour availability and increased cost of labour. The second ranking was secured by the factor related to uncertain markets and less profitability from agricultural produce. These two factors had a massive role in the conversion of paddy fields and other agricultural lands into fallow lands and for other purposes. Lack of interest, changing values, believes and lack of respect for agriculture as a job led to the large-scale migration of individuals to urban areas in search of white- and blue-collar jobs, which were the other two factors that got next highest ranking. Urbanisation and infrastructural development received fifth ranking, representing its relevance in the suburban region, slowing undergoing a shift from a suburban to an urban region. Similar to urban area, factors related to the quality of soil, meteorological parameters, government policies and science driven practices obtained lower ranks. Industrialisation was the least prominent factor that led to the change in the suburban area, represented in figure 17.

In the rural area, the factors contributing towards the change had similarities with factors that led to change in urban as well as suburban area. The most critical factor of change was urbanisation and infrastructure development followed by labour availability and increased cost of labour. Uncertain markets and reduced profit led to fallowing of agricultural lands as the economic output obtained was less than the input given, prompting huge losses to the farmers. The youth lost interest in agriculture as a profession and it resulted in their migration to urban centres for a better income and living conditions. Agriculture lost its value as a source of income and thus couldn't attract the youth towards it. Similar to urban and suburban areas, all other factors got lower ranks. The least dominant factor was industrialisation which was the same in the case of urban as well as suburban area, clearly depicted in figure 18.

Factors such as absence of science driven practices and government backed agricultural policies were of least concern for the people residing in those regions, representing their diminishing relevance in LU/LC change in the study area. Many were ignorant of the science driven practices. The situation in the case of suburban and rural areas are quite similar to each other in terms of fallowing of lands. Lack of labour availability and reduced profit from agriculture were supported by many as the notable reasons for fallowing of lands, thereby transforming the agrarian region for other land uses. Migration of individuals to urban centres led to higher rate of infrastructural development in those regions. Industrialisation received the lowest rank in all the 3 regions.

4.4 BIOECONOMY INTERVENTIONS

Figure 19. Bioeconomy interventions proposed by the respondents during survey in urban area

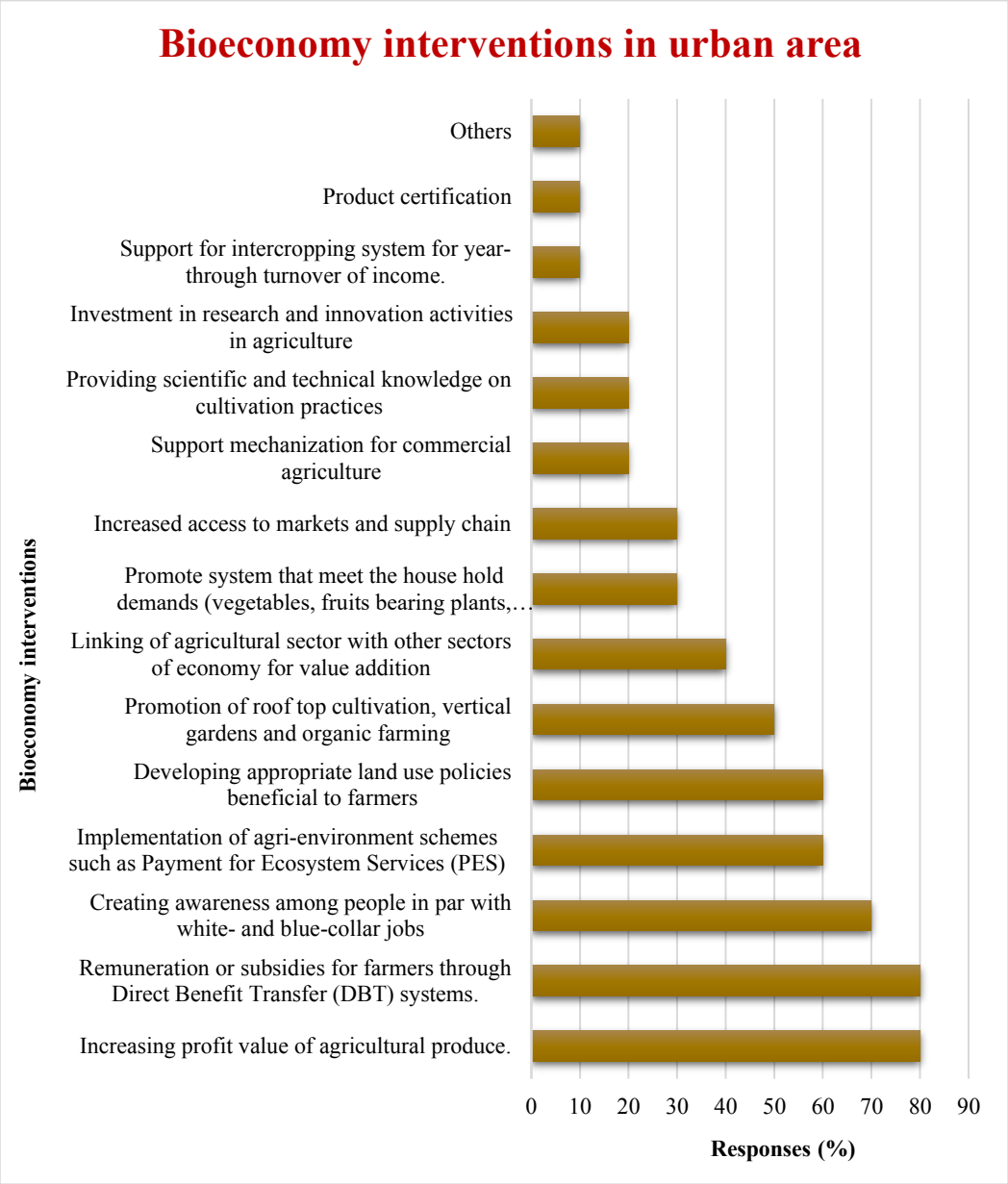


Figure 20. Bioeconomy interventions proposed by the respondents during survey in suburban area

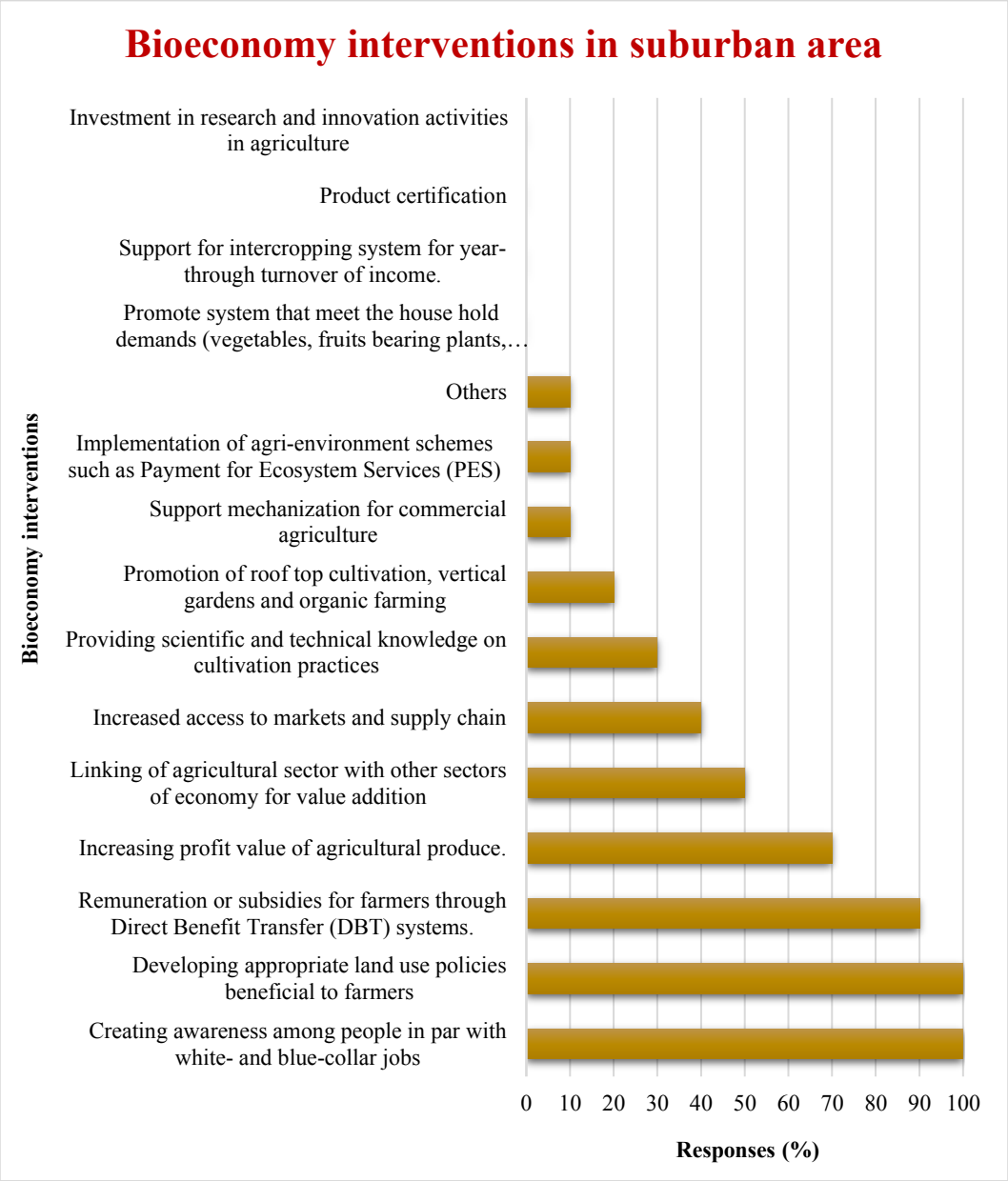
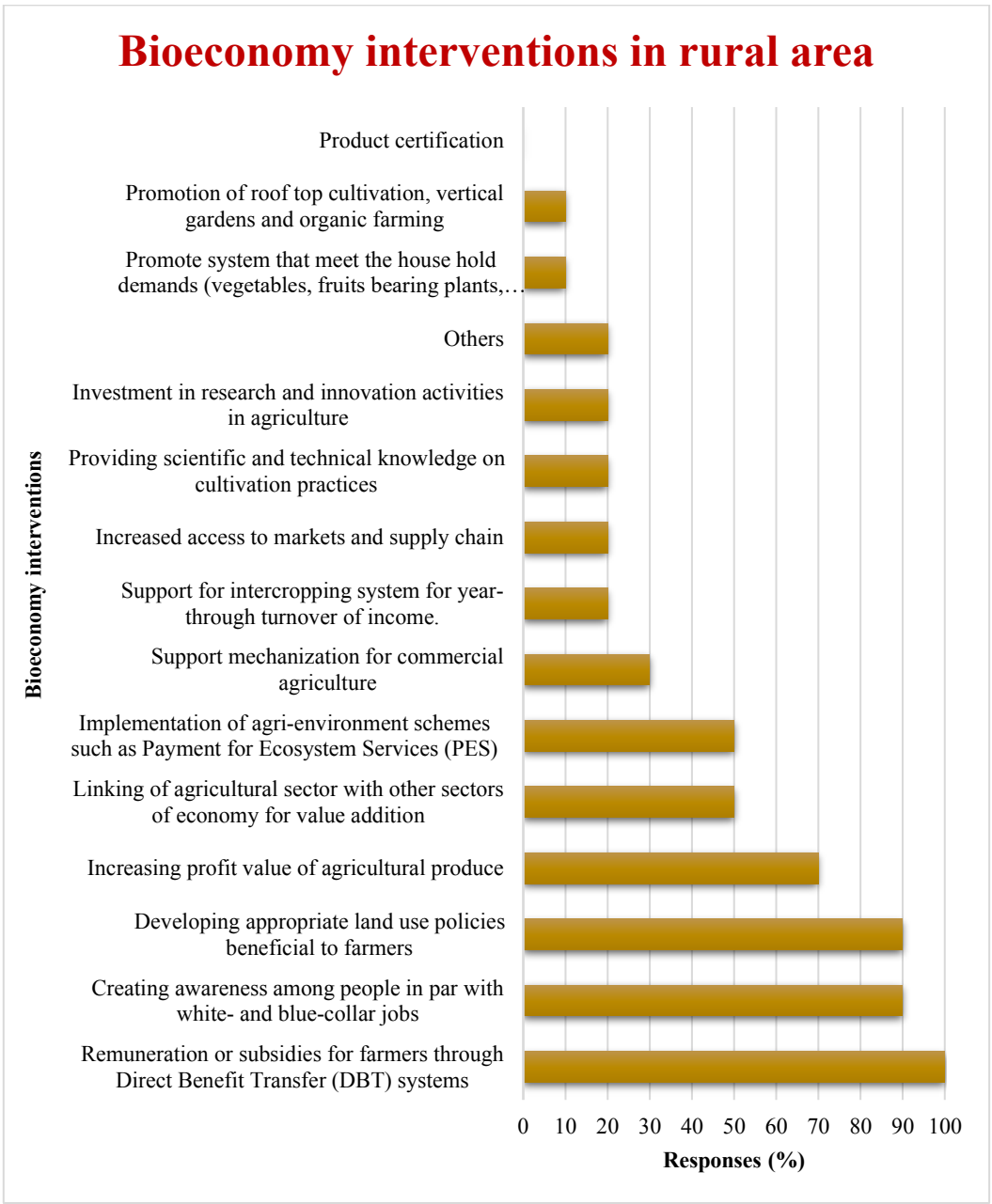


Figure 21. Bioeconomy interventions proposed by the respondents during survey in rural area



The bioeconomy interventions to re-establish cultivation on lands as well as to enhance the agricultural sector were proposed by the respondents based on the survey and is represented in the figures 19, 20 and 21. In the urban area (figure 19), highest responses were obtained for providing remuneration or subsidies for farmers through Direct Benefit Transfer (DBT) systems alongside to increase the profit value of agricultural produce. Almost, 80% of the respondents were in favour of these interventions. 70% were of the opinion of the necessity to create awareness among people in par with white- and blue-collar jobs while 60% stressed on the relevance of appropriate land use policies beneficial to farmers as well the implementation of agri-environmental schemes. Promotion of roof top cultivation, vertical gardens and organic farming were supported by 50% of the respondents. All other interventions, namely, linking of agricultural sector with other sectors, promotion of a system to meet household demands and increased access to market and supply chain, support mechanization for commercial agriculture, providing scientific and technical knowledge on cultivation practices and investment in research and innovation activities in agriculture and support for intercropping and product certification attained less than 50% support. One of the respondents even proposed to foster an intervention in relation to improving the quality of land.

On account of the suburban area (figure 20), all the respondents were in equal support for the necessity to create awareness among people in par with white- and blue-collar jobs alongside the development of appropriate land use policies beneficial to farmers, with both of them receiving 100% positive responses. 90% of the respondents supported the idea of providing remuneration or subsidies for farmers through Direct Benefit Transfer while 70% stressed on the relevance of increasing the profit value of agricultural produce. Only 50% were in support of linking agricultural sector with other sectors. All other interventions received less than 50% responses, with investment in research and innovation activities in agriculture, support for intercropping, promotion of a system to meet household demands and product certification receiving zero responses. One of the respondents recommended to provide land to those who are in need of it or might want to do cultivation on the land.

The case of rural area is very similar to that of the suburban area (figure 21), with all the respondents showing their support for the intervention related to provide remuneration or subsidies for farmers. The necessity to create awareness among people in par with white- and blue-collar jobs along with the development of appropriate land use policies beneficial to farmers were supported by 90% of the respondents. 70% showed their support for increasing the profit value of agricultural produce while 50% upheld the relevance of linking agricultural sector with other sectors alongside the implementation of agri-environmental schemes. All the other interventions received less than 50% responses with product certification receiving none. One of the respondents, recommended to incorporate agriculture as a part of educational curriculum to improve the knowledge of students regarding its relevance and to motivate them to be a part of its development. Another respondent was of the opinion to improve the irrigation facilities of the region as it was a major obstruction for the agricultural sector to prosper.

Among all the interventions, highly supported ones were creating awareness among people in par with white- and blue-collar jobs, development of appropriate land use policies beneficial to farmers, providing remuneration or subsidies for farmers through Direct Benefit Transfer and increasing the profit value of agricultural produce. 80 to 100% of the respondents supported these interventions while the least support was obtained for product certification probably due to the lack of information or knowledge about it.

CHAPTER 5

DISCUSSION

5.1 LU/LC CHANGES IN TERMS OF LAND USE INTENSIFICATION AND FALLOWING AND THE DRIVERS OF CHANGE

Momentous changes have taken place in the LU/LC in the study area over the years in terms of land use intensification as well as fallowing of agricultural lands. The rate of intensification was the highest in urban areas, with the value reaching nearly 65% by 2020. Initially, during 2005, the intensification rate was only 47%, which had undergone an escalation close to 20% during a period of 20 years, owing to urbanisation and infrastructural development. While for the years 2010 and 2015, the rates were nearly 53% and 60% respectively. No fallowing was observed in the urban regions. The rate of land use intensification in suburban and rural areas is highly similar, with the 2005 rate being 4% and increasing to nearly 12% by 2020, almost three times the initial value. Though, not a drastic increase for the years 2010 and 2015, there was an increasing trend with the values being 5% and 7% respectively for the suburban areas. The case of rural areas was also similar, with 2010 rate being close to 8% and 2015 rate undergoing an increase of 1%, i.e., nearly 9%. While considering rate of fallowing, it increased immensely in both suburban and rural areas. By 2020, the fallowing reached a value of 4% and 6% in suburban and rural areas respectively. The principal reasons for this can be attributed to less profit and decreased availability of labour. In the case of the suburban areas, the rate of fallowing was 2.6% during 2020, which rose to nearly 3% by 2015. For the rural regions, 3% of land was left fallow during 2010, but it shrunk to 2% by 2015. There have happened noteworthy changes in the area of buildings, mixed orchards, paddy fields and fallow lands which is prominently evident from the LU/LC maps as well as the graphs obtained from the data of the stakeholder survey.

In general, buildings have shown an increasing trend in all the 3 regions especially in the urban area. While considering mixed orchards, they have portrayed a decreasing trend, particularly in urban area as a result of development in the area occupied by buildings. The case of paddy fields is similar to that of mixed orchards in terms of the decrease in area with the change being highly critical in certain suburban and rural areas. When fallow lands are taken into consideration, they have shown an increasing trend with a significant change in rural areas as well as certain regions of suburban areas. In certain regions the area occupied by fallow lands were higher than that of mixed orchards and paddy, signifying the rate of fallowing occurring in the state along with it stressing on the impact it is likely to have on food security as well the financial stability of farmers. While meeting the basic necessity of the requirement of a shelter, the other pivotal factor for the survival of human beings is put at stake, i.e., agriculture and other cultivations. When considering the LU/LC change, socio-economic factors were the conspicuous one that contributed towards the change alongside agricultural factors to some extent. Environmental factors and climatic factors were not found to be major factors of change. The socio-economic factors primarily consist of uncertain markets, less profitability, urbanization, infrastructural expansion, migration of rural population to urban areas, lack of enough employment in rural areas and attitudes, values, beliefs and individual perceptions of people (Oslon *et al.,* 2004; Benayas *et al.,* 2007; Lasanta *et al.,* 2017; Ranganathan and Pandey, 2018; Castro *et al.,* 2020; Chaudhary *et al.,* 2020) which have overwhelming impact in contributing towards fallowing of lands and their subsequent abandonment. While agricultural factors like the availability of labour, cost of labour, price and profit volatility additionally assume a significant part in LU/LC change (Sulieman & Buchroithner, 2009).

Cochin urban agglomeration is one of the biggest and the fastest growing urban agglomeration in the state. The rate at which urbanisation as well as infrastructural development is taking place in the city is surprisingly high which is evidently the reason for land use intensification in urban areas. Though paddy

cultivation was practiced in some urban regions during 90's, the condition now is entirely different. All the paddy fields got converted primarily into settlement areas especially for flats and apartments. Large scale migration of individuals to urban centres from rural and suburban areas further enhanced the intensification process. As the migration rate increases, the land use in urban areas intensify which ultimately lead to the conversion of all available land for meeting the prerequisites of the growing population. The growth of urban consumer class has close relationship with land use change which is greatly influenced by the globalized flow of people, capital, commodities and so on (Meyfroidt *et al.,* 2013).

During early 2000s, agriculture was a major source of income for individuals dwelling in suburban and rural areas. A major portion of the land in these regions were devoted for paddy cultivation along with the cultivation of other crops like rubber, coconut, nutmeg and so on. Over the years, agriculture lost its worth as a source of living which prompted its abandonment and conversion to fallow lands and for settlements or other purposes. In a grid pertaining to rural area, i.e., Nedumbasserry, significant changes in land use have occurred post the arrival of airport. It elicited a situation where the paddy fields lost their agricultural value, arousing their abandonment. The development of roads and other infrastructures further aggravated the situation. As of now, only a small portion of the land is utilised for paddy cultivation which is also under the phase of fallowing due to lack of proper irrigation facilities. People likewise lost interest in agriculture due to abridged profit from agricultural produce alongside uncertain markets which ultimately led to their migration to urban agglomerations in search of white- and blue-collar jobs.

Agriculture is gradually losing its aesthetic as well as economic value across the state persuading increased dependence on neighbouring states for meeting the dietary requirements. A large portion of people in suburban as well as rural regions are unable to do cultivation on their lands due to reduced availability of labour as well as increased labour cost even after having the desire to do cultivation. This trend is actually forcing them to leave their land fallow which accounts for large

hectares of agricultural lands (Figure 22). A greater number of farmers gave it their best attempt to continue cultivation on their land yet continuous yield and profit loss constrained them to refrain from cultivation.

Likewise, with the development of corporate jobs with higher pay and living standards, the youth got attracted to it, losing interest in cultivation, leaving behind agriculture as a source of income and consequently permitting their land to fallow. This additionally prompted the migration of suburban and rural population to cities for a better standard of living and thus posing a serious problem in the agri-labour market in Kerala. Despite the fact that there was large scale migration of immigrants from other Indian states, they weren't found fit to do cultivation on these lands as they came from an entirely different cultural and linguistic background (Priya *et al.,* 2018). Though institutional factors like lack of appropriate land use policies were considered insignificant factors in LU/LC change, there were situations which depicted its inability to forestall the fallowing of lands. The farmers were left with no choice except to abandon their land and convert it for other purposes reluctantly with the hope that at least it could give them a stable income.

Regardless of the acknowledgement of significance of agriculture in guaranteeing food security of the state, absence of labour, land and good quality agricultural practices pose a deterrent in its formative pathway. The study found that the older generation is as yet keen on returning to the older tradition of cultivation if provided with prominent support from the government primarily in the form of appropriate land use policies, financial support and other beneficial social and agricultural interventions. It was additionally found that some were of the opinion of promoting cultivation in their own households which involve the practice of roof top cultivation, vertical gardening etc. that could be beneficial for at least meeting the food requirements of that specific household.

Figure 22. Fallow lands found in various locations (a) Fallow land in a suburban area (Edathala); (b) Fallow land in a rural area (Nedumbasserry); (c) A land which was once used for cultivation got converted for settlement purpose in an urban area (Vyttila)

(a)

(b)

(c)

5.2 BIOECONOMY INTERVENTIONS IN FALLOW AND ABANDONED LANDS

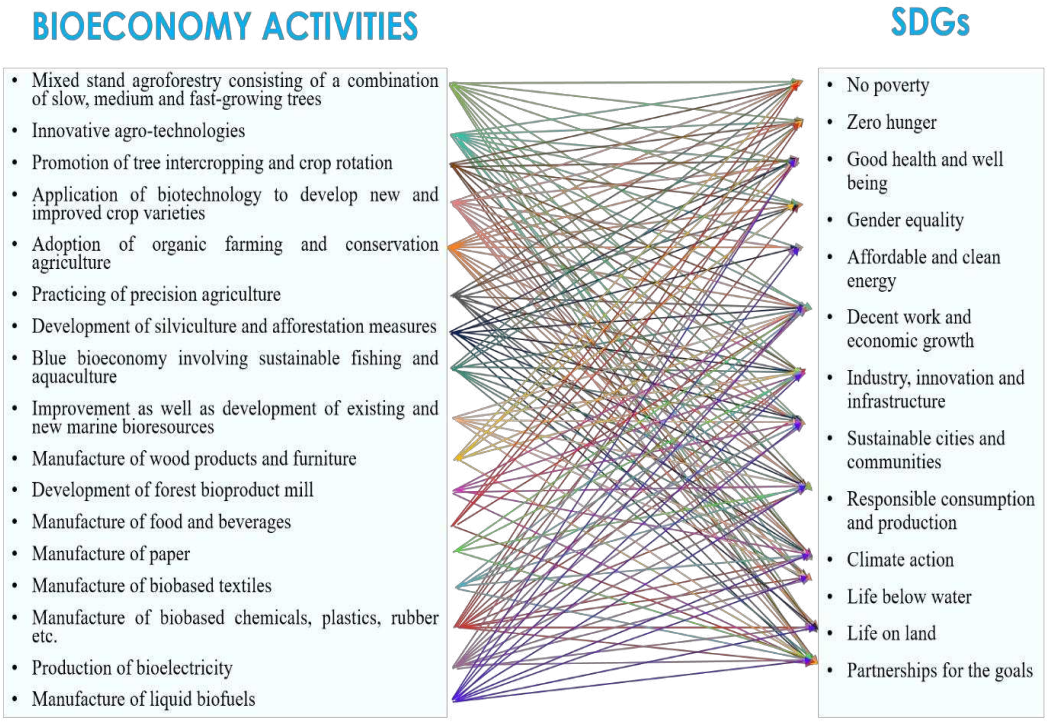
Bioeconomy interventions involve actions that are intentionally carried out in order to improve the current land use patterns and prevent its further degradation thus, leading to the development of bioeconomy as well as agricultural sector. These interventions can be developed considering various aspects of the

environment and society. For this purpose, three basic interventions namely, institutional, economic and social and demographic have to be adopted and each one of them has an association with one another. The stakeholder survey revealed the relevance of these interventions in the enhancement of the agricultural sector and how they could be beneficial to the ones depending on it. Development and proper implementation of agri-environmental schemes can bring about economic benefits to farmers in the form of incentives, better produce and thus increased economic value of the produce. Increased income from farming means a better social status through employment opportunities and better standard of living, thereby encouraging others to opt for agriculture as a source of livelihood. Similarly, increased awareness programmes and utilisation of traditional knowledge along with advanced technologies can lead to the betterment of agricultural sector as a whole which subsequently result in reduced fallowing and reinforcement of agriculture. Restoration of farming on abandoned lands can pave path for the development of various bioeconomy sectors which has the potential to contribute towards economic growth alongside the improvement of numerous societal aspects including reduced poverty, ample availability of food and feed, employment opportunities and so on. These societal aspects are an essential part of discrete SDGs.

Various bioeconomy activities in accordance to restoration of agriculture can possibly aid the accomplishment of numerous SDGs which is addressed in Figure 23. The captious one among them is the primary goal of no poverty. Bioeconomy activities like agriculture, forestry, fishing and aquaculture, manufacture of food and beverages, manufacture of wood products and furniture, paper, manufacture of biobased textiles and biobased chemicals, plastics, rubber etc can significantly contribute towards the eradication of poverty by providing employment opportunities for the poor and marginal farmers, consequently expanding their income and subsequently providing a poverty free lifestyle. Next goal of zero hunger is firmly identified with the first goal; when there is no poverty, there won't be hunger as well, as there is a proper income to meet the nutritious and dietary needs of a family. Similarly, the manufacture of food and beverages, organic

farming, fishing and aquaculture can likewise provide enough food for the population in a sustainable manner. Good health and well-being, which frames the third goal of the SDGs has close association to the first two. Conservation agriculture, organic farming, manufacture of food and beverages and sustainable fishing and aquaculture can provide nutritious food in adequate quantity thereby guaranteeing food security and hence good health. Health condition can also be improved by improving the manufacturing process as well as by the production of biobased products which cause less harm to the environment and furthermore for humans and other living organisms.

Figure 23. The contributions of bioeconomy activities to Sustainable Development Goals



The goal of gender equality can be achieved by distinct bioeconomy activities like agroforestry, intercropping and crop rotation, organic farming, silvicultural activities and biobased industries by providing equal job opportunities for men and women along with the assurance of active participation of women in all fields of economy. With the adoption of farming in small scale agricultural lands, give more opportunity for women in taking suitable decisions regarding the requirements and

its composition. Production of clean and affordable biobased fuel and bioelectricity alongside the active contribution of blue bioeconomy can essentially help towards the attainment of yet another goal; decreasing the harmful effects on the environment. Increased adoption and incorporation of bioeconomy activities have the potential to contribute towards increased employment opportunities and thus largely towards economic growth of the nation. The new job opportunities can become an income source for them and thus better living condition in their hometown, in this manner reducing the rate of migration of rural population to cities and towns. Innovation is the basic building block of bioeconomy development, without which bioeconomy related activities can never prosper. Manufacture of liquid biofuels, biobased textiles, production of bioelectricity and advanced agricultural practices are all innovative activities developed as a result of innovation in the field of bioeconomy. Moreover, providing standards and labels for the bioeconomy products and activities will upsurge the likelihood of its procurement by individuals, thereby reinforcing bioeconomy development.

The goal to accomplish sustainable cities and communities can be considered a fundamental aim of bioeconomy. All the bioeconomy activities and processes are sustainable in nature which involves organic farming, precision farming, conservation agriculture, manufacture of biobased chemicals, plastics, rubber etc, biobased textiles, liquid biofuels and production of bioelectricity. Each one of these activities are eco-friendly and in this way cause very less harm to environment in the form of reduced exploitation of resources as well as conservation of natural resources, consequently having close relationship to the following goal of responsible production and consumption. It includes the utilization of renewable resources, thus reducing the dependence on fossil resources which detrimentally affect the environment and organisms. Under the current scenario of global warming, the SDG of climate action require atmost importance. With the development of bioeconomy activities, it is easier to achieve the goal as bioeconomy follows the path of sustainability and reduced emission of greenhouse gases. Sustainable agriculture involving precision farming, conservation agriculture, organic farming, incorporation of innovative biotechnological

applications, sustainable silviculture and afforestation measures, conservation of existing marine resources and development of new ones are the most significant ones along with the manufacture of biobased chemicals, plastics, rubber, biobased textiles, liquid biofuels and the production of bioelectricity. These activities generously reduce the emission of greenhouse gases as it involves the utilization of renewable biobased resources and not fossil fuels. The fulfilment of this goal has close association to various national and international treaties and agreements like the Paris agreement.

The 13th and 14th goal of life below water and life on land can likewise be attained by the adoption of appropriate sustainable bioeconomy activities. On account of conservation of life below water, bioeconomy has effectively evolved various policies to limit the overexploitation of fishes and protection of aquaculture resources with the development of a blue bioeconomy. Similarly, the production of bioelectricity and liquid biofuels from terrestrial crops additionally reduce the reliance on hydropower generated electricity which possess immense threat to the aquatic ecosystem. Manufacture of biobased products like plastics, rubber, chemicals likewise cause less harm to these life forms when they reach their habitat. In case of life forms on earth, adoption of organic farming which involves reduced usage of synthetic chemicals, helps in the conservation of soil microorganisms as well as improve the environmental conditions, accordingly improving the health of organisms on land. Practice of sustainable forestry involving silviculture ad afforestation measures can also improve the habitat of wildlife and hence increasing their rate of survival. Moreover, the usage of biobased products will diminish the harmful effects of synthetic products on organisms. The last and final goal of partnerships for the goals can be achieved by efficient collaboration between nations in the form of economic support and equitable sharing of resources. Transfer of knowledge and technologies can play a significant role in the sustainable development of developing as well as least developed countries. It aims to increase the cooperation between North-South and South-South by increasing trade and hence economic growth to achieve all the targets. However, all these goals can only be accomplished with the availability of appropriate lands and by

efficient utilization of land. Consequently, exhibiting how important it is to restore lands for providing raw materials for carrying out bioeconomy activities. With proper interventions and bioeconomy activities, it is conceivable to resolve 13 of the SDGs including the most critical goal of no poverty alongside climate action.

There are other conceivable bioeconomic interventions other than the agricultural ones that can be carried out to forestall abandonment of lands and promote agriculture. Economic, institutional and social and demographic interventions assume a similarly significant role in the accomplishment of the goal of restoration of agriculture in fallow lands. Alluring results may be achieved by the legitimate execution of these interventions at the right time at the right place. All these interventions have close linkages to each other and thus have to be executed efficiently.

Economic interventions

- Remuneration for farmers for the environmental benefits they provide, thereby encouraging them to cultivate more crops rather than leaving the land fallow.
- Investment in research and innovation activities in agriculture.
- Promotion of bioeconomy value chains, i.e., agro-food system development.
- Increasing profit value of agricultural produce.
- Linking of agricultural sector with other sectors of economy.
- Development of economic sectors allied to agriculture sector like the food, feed and beverages sector.
- Setting up of standards and labels for products to enhance the market uptake.

Institutional interventions

- Development of appropriate land use policies beneficial to farmers.

- Proper implementation of policies.
- Development of policies and strategies to integrate various sectors of economy.
- Setting up of standards and labels for bioeconomy products and activities.
- Implementation of agri-environment schemes whose major characteristic is that they provide compensation to the farmers for the losses occurred as result of the implementation of the prescribed measures adopted to benefit environment.

Social and demographic interventions

- Creating awareness among people on the relevance of agriculture to prevent fallowing and to understand the importance of bioeconomy in sustainable development.
- Increasing employment opportunities in agricultural sector to reduce the migration of youth to cities in search of job.
- Appropriate utilisation of the local and traditional knowledge of farmers and indigenous communities regarding agriculture and farming land which in turn can benefit bioeconomy development.
- Promotion of a system to meet household demands and encouraging organic farming, roof top cultivation, vertical gardening, etc.
- Providing scientific and technical knowledge on cultivation practices.

CHAPTER 7

SUMMARY

Kerala has witnessed sensational changes in LU/LC pattern over the last two decades. The study was carried out in the most popular and quickest developing urban agglomeration of the state, i.e., Kochi. The study area was delineated into urban, suburban and rural areas by considering 10, 20 and 30km buffer from headquarters of Cochin corporation. Grids were arbitrarily chosen from each of these areas for doing the digitisation and for understanding the LU/LC changes. Manual digitisation was done using Google Earth Pro involving various classes like buildings, barren areas, paddy fields, mixed orchards, fallow lands, waterbodies, tarred roads, muddy roads and railway tracks. Digitisation was done for the years 2005, 2010, 2015 and 2020. Further analysis pertaining to these grids were done in ArcGIS software. The rate of land use intensification and fallowing were high in all the three regions of the study area. Significant changes in the areas occupied by buildings, mixed orchards, paddy fields and fallow lands were observed. Both buildings and fallow lands depicted an expanding trend while paddy fields and mixed orchards represented a diminishing trend. These changes were more less similar in urban, suburban and rural areas.

A stakeholder survey was conducted to determine the drivers of change in terms of land use intensification and fallowing of lands. The survey also aimed to elucidate the land use history of the study area. From the survey, it was found that the changes observed were exceptionally similar to that obtained through digitisation. The major reasons for land use intensification were found to be urbanisation and infrastructural development alongside the migration of rural population to urban areas in search of jobs. While the major factors that contributed towards fallowing of lands were found to be lack of labour availability, increased cost of labour, reduced profitability from agricultural produce and migration of youth to urban centres. Lack of interest of youth in agriculture was a transcendent

factor in fallowing of lands and their subsequent abandonment. The survey also consisted of a section of questions that dealt with the interventions people anticipate from the side of government and related organisations for the flourishment of agricultural sector and to impede fallowing of lands. The study found that bioeconomic interventions can play a critical role in the re-establishment of the agricultural sector along with the accomplishment of numerous SDGs, zero hunger, no poverty, climate action, sustainable economic development and so on to name a few. In order to attain the ultimate goal of sustainability, bioeconomy is the most imperative and plausible economic pathway. It can bring along with it various economic, social and environmental prosperity.

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ABSTRACT

The LU/LC change undergone in the state of Kerala is an exceptional one as far as land use intensification and fallowing of lands are taken into consideration. Kerala is under the threat of various societal issues like the decline of the agricultural sector, food security, unemployment and climate change. It is high time that a sustainable economic pathway has to be embraced for the future generations. Kochi was taken as the area of study due to its expanding pace of urbanisation. The aim of the study was to assess the potentiality of bioeconomy in sustainable land management in the context of changing patterns of land use and land cover. The methodology involved the digitisation in Google Earth Pro to determine the land processes over the last two decades and further analysis in ArcGIS software. A stakeholder survey was conducted to determine the factors of change and to discuss the possible bioeconomy interventions for the improvement of the agricultural sector. The study found that major LU/LC changes had occurred in the study area, essentially in the form of increase in the area of buildings and fallow lands and decrease of paddy fields and mixed orchards. Intensification of land use was for the most part witnessed in urban centres while fallowing was noticeably seen in certain regions of suburban and rural areas. The compelling drivers of change were found to be urbanisation and infrastructural development alongside the lack of availability of labour and increased rate of migration of individuals in search of jobs. Thus, for sustainable management of land, a bioeconomic pathway was proposed with possible social, economic and institutional interventions to re-establish the agricultural sector as well as to enhance the economic, environmental and societal scenario of the state.

ANNEXURE 1

KERALA UNIVERSITY OF FISHERIES AND OCEAN STUDIES

(DEPARTMENT OF CLIMATE VARIABILITY AND AQUATIC ECOSYSTEMS)

&

KERALA AGRICULTURAL UNIVERSITY

(COLLEGE OF CLIMATE CHANGE AND ENVIRONMENTAL SCIENCE)

QUESTIONNAIRE ON AGROECOSYSTEMS AND LAND SYSTEM DYNAMICS IN URBAN TRANSITION CENTRES IN ERNAKULAM

Instructions

1. Introduce yourself.
2. Explain why we are doing this research.
3. Explain the objective of the study.
4. Explain the outcome of the study.
5. Explain the guarantees of anonymity and confidentiality.
6. Ask for consent to conduct the interview.

GENERAL DETAILS

Questionnaire No:	Date:
Name of Surveyor: Ms. Akshara T	Panchayat/Municipality:
Ward/Landmark:	GPS points:

PERSONAL DETAILS

Name:	Age:
Gender:	Address:

Occupation:	Phone number:
Number of family members:	

1. How long have you been living here?

☐ *For the last 20 years*

☐ *Less than 20 years (No need to continue survey)*

2. How much land you own now?

3. What was the percentage contribution of land use in your land parcel in 2005?

No.	Land cover/use	Percentage	Comments, if any
1.	Land based crops cultivation (mixed orchards)		
2.	Paddy based cultivation		
3.	Buildings		
4.	Land not used for any purpose (Fallow land)		
5.	Roads, Railways, Canals		
6.	Water bodies		
7.	Any other land use:		

4. Were there any changes in land use in the next five years (i.e., 2010)? If yes, how the land use changed in percentage?

No.	Land cover/use	Percentage	Comments, if any
1.	Land based crops cultivation (mixed orchards)		
2.	Paddy based cultivation		
3.	Buildings		
4.	Land not used for any purpose (Fallow land)		
5.	Roads, Railways, Canals		
6.	Water bodies		
7.	Any other land use:		

5. From 2010 to 2015, how the land use is changed with percentage contribution in your land parcel?

No.	Land cover/use	Percentage	Comments, if any
1.	Land based crops cultivation (mixed orchards)		
2.	Paddy based cultivation		
3.	Buildings		
4.	Land not used for any purpose (Fallow land)		
5.	Roads, Railways, Canals		
6.	Water bodies		
7.	Any other land use:		

6. What is the current land use practices (2020) in terms of percentage contribution to the overall land holding?

No.	Land cover/use	Percentage	Comments, if any
1.	Land based crops cultivation (mixed orchards)		
2.	Paddy based cultivation		
3.	Buildings		
4.	Land not used for any purpose (Fallow land)		
5.	Roads, Railways, Canals		
6.	Water bodies		
7.	Any other land use:		

7. What are the major changes you observed in the last 15 years in your area? (Please tick the points)

i. Increase in the housing complexes, and urbanization.
ii. Roads, Canals, Railway, and other infrastructure development.
iii. Development of small scale and large-scale industries.
iv. Conversion of mixed orchards to monocrops such as rubber, banana, coconut etc.
v. Conversion of paddy fields to other land use.
vi. Landfilling of water bodies
vii. Leaving the land to fallow since agriculture is not profitable.

8. What were the major reasons for the changes in land use in your area? (Rank on a 10-point scale where the important factors will get high score, and thereafter descending order).

Variable	Rank	Comments, if any
Urbanization and infrastructure development		
Industrialization		
Uncertain markets, and less profitability from agriculture produce		
Labour availability and increased cost of labour		
Soil degradation and reduced fertility of the soil		
Values, beliefs, less interest and lack of respect in agriculture as a profession		
Migration of youth to urban areas in search of white- and blue-collar jobs.		
Unexpected rain, flood, drought, and other meteorological events		
Absence of government backed schemes, policies and support		
Absence of science driven practices in agriculture sector		

9. What are the constraints in revamping the agriculture in your area? (Please tick the points)

   i. Absence of land
   ii. Absence of labour
   iii. Unavailability of seed materials
   iv. Absence of technical knowledge with cultivation practices
   v. Limitations in finding the right markets to sell the products
   vi. Absence of proper directions from the government authorities and institutions

10. Do you think that a revamping of our agriculture sector will helps in ensuring the food security?

☐ Yes

☐ No

11. If yes, what interventions you propose for the rejuvenation of agriculture sector? (Please tick on the appropriate boxes).

☐ Increasing profit value of agricultural produce.

☐ Remuneration or subsidies for farmers through Direct Benefit Transfer (DBT) systems.

☐ Promote system that meet the house hold demands (vegetables, fruits bearing plants, tuber crops etc).

☐ Promotion of roof top cultivation, vertical gardens and organic farming

☐ Support mechanization for commercial agriculture

☐ Support for intercropping system for year-through turnover of income.

☐ Product certification

☐ Increased access to markets and supply chain

☐ Linking of agricultural sector with other sectors of economy for value addition

☐ Implementation of agri-environment schemes such as Payment for Ecosystem Services (PES)

☐ Creating awareness among people in par with white- and blue-collar jobs

☐ Developing appropriate land use policies beneficial to farmers

☐ Providing scientific and technical knowledge on cultivation practices

☐ Investment in research and innovation activities in agriculture

☐ Others

Say thanks and appreciate their co-operation.

Remarks:

ANNEXURE 2

Published a paper based on the thesis in the journal 'Climate Change and Environmental Sustainability'

Thekkeyil, A., George, A. and Joseph, S. 2020. The prospects of bioeconomy in transition economies, *Clim. Change Environ. Sustain.* 8: 160–170. http://dx.doi.org/10.5958/2320-642X.2020.00016.2