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Geospatial assessment on land-use changes of Home Gardens in Upper Mahaweli Catchment in Sri Lanka

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ABSTRACT

Land use changes are altering the hydrologic regimes in a catchment and have potentially large impacts on its water resources. Tree rich Home Gardens (HGs)in the Upper Mahaweli Catchment (UMC) play a vital role in catchment protection while providing other ecological services especially in areas where lack of forest cover. The main objective of this research study was to assess land-use changes of HGs in UMC and to analyze determinants for changes. An integrated approach was adopted for the methodology by integrating geo-spatial technologies with socio-economic modeling. Multi-temporal satellite imagery taken in 1990, 2005 and 2017 used for spatial assessment. Socioeconomic assessment was carried out to assess determinants for changes by developing a Binary logistic regression model using spatial, biophysical, and socio-economic determinants as predictor variables. According to spatial assessment a significant change has been revealed in Nuwara Eliya District of the UMC from 1990 to 2017. The most prominent changes have been occurred during 1990-2005 compared with to 2005 - 2017. During these periods HG land use has been increased by 14.85 % and 5.25%. In contrast, the distinct land use change was the increment of annual crop-based land use by 44.95% during 1990-2005 period. Spatial determinants were positively influenced for the conversion of HGs into other land uses. All other socio-economic determinants except age of the household head were significant for land use changes. Since conversion of HGs into annual crop-based land use would induce reduce tree cover of the UMC which lead to hinder ecological services of catchment protection function derived from HGs, policy strategies should focus on providing sufficient incentives to enhance tree cover of the HGs to control the conversion and to restore ecological services.

1. Introduction

Land use is the result of the number of interactions between humans and their environment on the land. Fundamentally land use changes influence both human and natural systems at different temporal and spatial scales (Foley et al, 2005; Turner et al. 2007; Vitousek et al, 1997). These changes are of significance in the heterogenous large scale landscapes like catchments (Turner, 2003; Lambin et al, 2001). Stonestrome (2009) emphasized that such changes are altering the hydrology of the system and have potentially large impacts on water resources. According to Gobin et al, (2002), there are a number of socio-economic and biophysical drivers or determinants responsible for land use changes in the catchment. Therefore, it is required to assess those drivers using an appropriate model reflecting all these determinants responsible for land use changes. Turner (2003) highlighted that quantifying changes in the prominent landscape level is very important to understand the spatial and structural variability in land use and their associated ecological effects. Land-use change models have been developed to delineate land-use driving factors that influence land-use changes, and precisely predict land-use change patterns and variations in space and time. Different land-use change models, such as stochastic models, optimization models, dynamic process-based simulation models and empirical models, have been used to explore land-use changes (Agrawal et al, 2002). An interdisciplinary approach, integrating the social and natural sciences has been proposed (Lambin et al, 1999) as the best way to analyze land use changes (Van der Veen and Otter, 2001).

Home gardens are one of the predominant land uses in Upper Mahaweli Catchment (UMC) and contribute to the catchment protection while providing an array of other ecosystem services as a small patch of forest do. UMC located in the central highlands of Sri Lanka is known as the heart of the country not only due to the location, but also ecological and socio-economic significance to the country. The natural forest cover of the UMC has gradually decreased during the last two centuries due to the large- scale deforestation for plantation agriculture (Hevawasam, 2010). Subsequently, the forest cover in the hill country which protects the UMC has been reduced further to a few isolate patches in order to meet the demand for agriculture, development activities and human settlements. Well maintained Home Gardens (HGs) are one of the best substitutes for compensating the loss of forest cover in the catchment since tree rich HGs are analogue to a forest patch which provide number of ecosystem services (Ariyadasa, 2002). HGs located in the UMC play a vital role to maintain the sustainability of watershed functions while providing other various ecosystem services to the society.

However, HGs presence in the UMC have been subjected to numerous changes over past decades due to various factors. The quality of home gardens has been degraded due to fragmentation and changing the species composition. In addition, historical changes of species composition and dynamism of Home Gardens in Sri Lanka are little studied. Hence, evidence is scanty (Pushpakumara et al, 2012). Relatively little attention has been paid on studies related to the dynamics of Home gardens under the influence of possible biophysical and socio-economic factors. The ultimate results would be reduced environmental and socio-economic benefits derived from Homegadens. It will also affect the hydrological functions of the UMC.

Due to lack of scientific data and information and relevant analysis on spatial distribution of home gardens, their changes are not known. Reasons for changes are not scientifically analyzed. Distribution of home gardens with respect to sensitivity of the watershed is not known. In addition, home gardens that are vulnerable to change are not identified.

There is an immense body of literature on land use changes across countries all over the world taking into consideration different aspects for analysis following various methodologies. However, the research focus highlighted in this study as far as concerning in Sri Lankan context is sparse. Hence, this study is important to fill the research gap in Sri Lanka in addition to generating scientific information to set proper policy decisions on catchment protection. Due to the information gap, relevant policy makers face challenges in setting appropriate policy strategies to check shrinking, fragmenting of home gardens to maintain the sustainability of environmental and socio-economic benefits derived from the UMC of Sri Lanka. To generate meaningful scientific information, integration of spatial assessments with socio-economic analysis is essential regarding such complex landscapes like catchments.

Against such a background, this study intended to answer several research questions regarding the spatial distribution of land uses in recent time and the past in the UMC, the magnitude of spatial and temporal changes and what factors are responsible for such change. The main objective of this research was to assess land-use changes of Home Gardens in UMC by integrating Geographic Information System, Remote Sensing and Socio-Economic Modeling. Specific objectives were to assess and quantify spatial distribution of land uses including home gardens in multi temporal scale, assess spatial and temporal changes of land uses and to analyze spatial, biophysical, and socio-economic determinants for the changes of land uses in the UMC.

2. Materials and Methods

2.1. Study area

Upper Mahaweli Catchment (UMC) is located in the central highlands of Sri Lanka. Total surface area is 3110.81 Km2 with the sub-catchments of Kotmale, Victoria, Randenigala and Rantembe. The Mahaweli takes in the largest volume of water amounting to one seventh of Sri Lanka's total runoff and has a catchment area that covers 15 % of the land in the country (Hewavisenthi,1997). Several multipurpose reservoirs have been impounded in the UMC which generates 40-50 % of the hydropower production in the country and divert water to major irrigation systems located in the dry zone of the country. During the past few decades, land use and land cover changes have occurred in the catchment due to various reasons. Among them deforestation was predominant. Deforestation in the last two centuries has resulted in the removal of a large part of forest cover for agricultural usage. At present, natural forest patches have been preserved only on hilltops of the UMC above the 1500 m contour. UMC is covered by the main three districts in the country which are Kandy, Nuwara *Eliya* and Badulla district. Two Divisional Secretariat Divisions of Nuwara *Eliya* district namely, Hanguranketha and Walapane were selected as the study area by considering factors such as distribution of HGs biophysical and socio-economic significance to the catchment (Figure 1). Total population of Hanguranketha and Walapane DSD is 94,943 and 111,633 (Department of Census and Statistics, 2012). Nearly 67.4% of people in these areas are engaged in agriculture as an economic activity and only 10.8% are engaged in the industry sector, whereas 21.8 % are involved in the service sector (Environmental Profile of Nuwara *Eliya* district).

2.2. Data sources and analysis methods

2.2.1. Spatial assessment using Geographic Information System (GIS) and Remote Sensing technique.

Remote sensing and GIS technique have been used extensively to provide accurate and timely information for assessing land use and land cover changes over time (Afera et al, 2018). It explores new ways to detect, characterize and monitor land use changes specially for large scale landscape coverage such as watersheds. Change detection analysis, employing both GIS and remotely sensed data, has been also used to assess land use changes over time (Soni et al, 2015; Halefom et al, 2018). Spatial assessment in this study was carried out using the following steps.

Step 1: Acquisition of image data

Freely downloadable images (Landsat series) were utilized covering two Divisional Secretariate Divisions of the Nuwala *Eliya* district located in the catchment area taken as the sample area to represent catchment. Other spatial data sources such as aerial photographs, land use maps and 1:50,000 topographic maps prepared by survey department were used as ancillary data. In addition, data from secondary sources was collected from relevant institutions. Satellite data specifications are given in Table 2.1.

Step 2: Pre-processing of images

Pre-processing of satellite images before detection of changes is essential to build a more direct association between the biophysical phenomena on the ground and the acquired data. Preprocessing is also needed to establish direct linkage between data and biophysical phenomena (Coppin et al, 2004). The standard image processing techniques of extraction, layer stacking, geometric correction/ geo referencing, and change detection were performed on the three Landsat TM images (Table 1) obtained on different years. Data was pre-processed in ERDAS imagine for geo-referencing and sub-setting of the image based on Area of Interest (AOI).

Step 3: Image classification and preparation of land use maps

The image classification is performed to place all pixels in an image into land use classes to draw out useful thematic information (Boakye et al, 2008). Image classification was done to assign different spectral signatures from the LANDSAT datasets to different land use land cover classes. Land cover classes are typically mapped from digital remotely sensed data through the process of a supervised digital image classification (Campbell, 1987; Thomas, Benning, & Ching, 1987). ERDAS IMAGINE 2014 software was used in this research study to run the image classification. Supervised classification system was adopted using maximum likelihood algorithm. Google images, land use maps published by the Survey Department of Sri Lanka, and GPS data collected during field work were served as reference data to obtain ground control points for the preparation of land use map in 2017. To obtain the training samples for the preparation of land use maps for 1990 and 2005 using Landsat images, topographic maps prepared by the Survey Department of Sri Lanka were used. Field observation was not possible for that period. Google images were also not available, and geo referenced aerial photographs were also not available to take as reference. Therefore, 1:50,000 topographic map prepared by the Survey Department of Sri Lanka was used to identify ground control points and training samples. Google images and topographic maps were utilized as ancillary data for the preparation of land use map for 2005. Due to the unavailability of a standard classification system to classify land cover classes in Sri Lanka, most prominent cover classes distributed in the catchment were selected which consist of eight cover classes (Table 2).

Step 4: Accuracy assessment

Accuracy assessment is one of the most important steps in image classification. Accuracy assessment is the process of estimating how accurate the land cover data are in terms of thematic categories, in order to determine whether the product meets the requirements of the intended application. Accuracy assessment can provide a comparison on a category by-category basis of classification results vs. known reference data. In this study, to conduct accuracy assessment to prepare land use maps for

1990 and 2005 ground truth cannot be verified by field observations. Therefore, alternative approaches were adopted (Wagner et al, 2013). For the accuracy assessment of 1990, classified image 110 training samples were obtained as stratified and randomized points from the topographic map prepared by the Survey Department of Sri Lanka to represent each cover classes. In addition, google images were used as ancillary data for the accuracy assessment of 2005 image to follow the same methodology. Field observations were carried out for the accuracy assessment of 2017 classified image. GPS data was from 110 stratified and randomized reference sample locations representing each cover classes were obtained. Error Matrix was produced following a standard procedure (Ziboon et al, 2013).

Step 5: Post Classification Change Detection

Change detection has been defined as a "process of identifying differences in the state of an object or phenomenon by observing it in different times" (Singh 1989). This is considered an important process in monitoring LULCC because it provides quantitative analysis of the spatial distribution of the relevant attributes of interest and this makes LULC study a topic of interest in remote sensing applications (Song et al, 2001; Pinilla, 2004). The post-classification comparison has been proven to be the most popular approach in change detection analysis (Foody, 2002b). Change detection analyses describes and quantifies differences between images of the same scene at different times.

In this analysis classified images of 1990, 2005 and 2017 were used to detect changes. The post-classification comparison has been proven to be the most popular approach in change detection analysis (Foody 2002). The methodology followed in this study to detect changes was the "Post classification comparison" (Jensen et al, 1987; Dimyati et al, 1996; Ward et al, 2000).

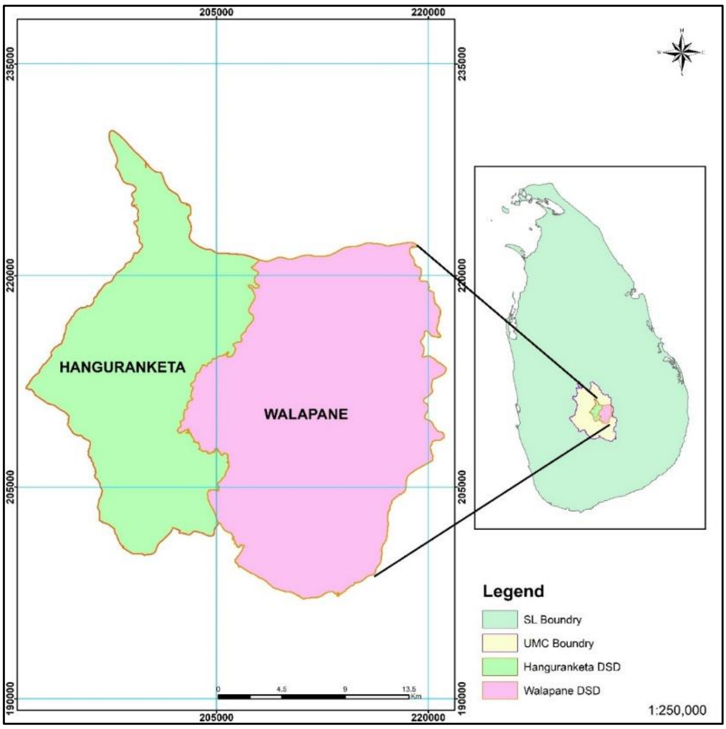

Figure 1. Map of the study area

Table 1. Satellite data specifications

Data	Sensor	Year of Acquisition	Bands	Resolution (m)	Source
Landsat_5	TM	1990	Multispectral	30X30	USGS
Landsat_5	TM	2005	Multispectral	30X30	USGS
Landsat_8	OLI_TIRS	2017	Multispectral	30X30	USGS

Table 2. Description of Land use/ Land cover classes

Classes	Description
Forest & shrubs	Dense Forests, spars forests, forest plantations and shrubs
Home Gardens	Home Garden clusters with tree components
Tea	Tea plantations
Paddy	Paddy fields
Annual crop-based	Agricultural areas with annual crop based Agro-forestry systems
Bare land	Bare ground, Vacant lands, open area, and fallow lands including grasslands
Water body	Reservoirs, rivers, streams and lakes

2.2.2. Socio-economic model to analyze determinants of land use changes.

In regional as well as local scale land use/ land cover change is one of those major challenges that affect the natural landscape. Land-use/cover change (LUCC) analysis is a complex process that includes actors and factors at different social and spatial levels. Understanding the relationship between Land Use Change and its driving forces is one of the vital parts of current environmental research and is achieved by analyzing the driving forces through applying models, statistical methods, and conceptual framework approaches (Zhang et al, 2017). A number of stochastic models are extensively used recently in spatial analysis, specially within the GIS and RS environment to explain interactions of spatially explicit variables with a number of socio-economic variables to generate more realistic information. Often times, an interdisciplinary approach, integrating the social and natural sciences have been proposed (Lambin et al, 1997) in many land use change studies (Van der Veen & Otter, 2001). The use of regression equations and models has been extensive and valuable (Victor et al, 2011). Land use and land cover change in UMC has been influenced by a number of natural and anthropogenic activities. In this study, Binary Logistic Regression Model was used as one of the best econometric models to assess the spatial and non- spatial or socio-economic determinants for land use change of the study area.

Model parameters of the Binary Logistic Regression model

The model has been designed based on the hypothesis that there is a significant change in Home Garden land use along with other land uses and a number of drives responsible for the change.

The model and the model parameters configured as in the following equation (i).

Based on the review of literature regarding the common determinants of land use changes and availability of data, selected variables within spatial context as well as the socio-economic perspective are described as following.

$$P_{ij} = a + bdist^{uc}_{ij} + cdist^{road}_{ij} + dang_{ij} + edem_{ij} + ftemp_{ij} + gRF_{ij} + hpop_{ij} + idem_{ij} \ldots\ldots) \quad \ldots\ldots \text{(i)}$$

Change of HG will be determined by the binary dependent variable Y. If HG is changed to other land use Y= 1 otherwise Zero.

where, p_{ij}= probability of HGs change into other land uses

Descriptions of each model variable are illustrated in table 3.

Table 3. Descriptions of the Variables

Variable	Meaning	Data Extraction
distc^{uc}	Distance to the HG from the nearest urban centre	Measured in GIS from the urban centres data layer
dist^{road}	Distance to main roads	Measured in GIS from the transportation network data layer
dem	Land elevation	Extracted from the DEM
temp	Mean annual temperature	Extracted from Temperature layer
RF	Mean Annual rainfall	Extracted from Rainfall layer
popd	Population density	Extracted from population density layer
ac	Size of the HG	Household survey
ahh	Age of the household head (years)	Household survey
ahg	Age of the Home garden(years)	Household survey
inc	Average income of the household head	Household survey
edu	Education level	Household survey
expf	Farming experience (years)	Household survey
asub	Agriculture subsidies	Household survey
a	Stochastic error	Generated randomly from the Equation

2.3. Primary Data collection for socio-economic assessment

Primary data was collected by employing household survey using a structured questionnaire for 100 households/Home Garden Owners from Nuwara *Eliya* district. Two DSDs from Nuwara-*Eliya* district were selected for data collecting sample locations for the household level survey using 100 home Garden owners using random sampling technique. The questionnaire prepared for household survey was pretested followed by modification to make some of the unclear questions more focused and clearer before being administered to the selected households. Both quantitative and qualitative data were analyzed during this study. Quantitative and qualitative data obtained through the household questionnaire survey were coded and entered to the STATA 11.2 Econometrics software for descriptive statistical analysis using the binary logistic regression model which has been described above.

3. Results and Discussion

3.1. Temporal and spatial distribution of Land Uses in Nuwara Eliya district

Based on the classified images obtained from 1990, 2005 and 2017 land use maps were prepared for the same years for *Hanguranketha* and *Walapane* DSDs in *Nuwara Eliya* district which are located within the Upper Mahaweli Catchment (Figure 2). The results of the accuracy assessment carried out to validate classification results for each cover classes of the classified images are illustrated in table 4. The producer's accuracy, user's accuracy, overall accuracy of the four classified images data are shown in Table 4. To generate accuracy assessment 110 reference points were taken.

Areas of each land use and land cover categories classes were estimated from land use maps prepared for 1990, 2005 and 2017 using Arc GIS. Temporal distribution pattern of land use/land cover classes in selected DSDs in *Nuwara Eliya* district is depicted graphically in Figure 3. From 1990 land use and land cover classes, 30.11% of the study area in *Nuwara Eliya* district was Home gardens whereas Forests and shrubs, Tea, Paddy, Other Agricultural lands, Bare lands, water bodies and Urban areas shared 26.81%, 17.96%, 6.04%, 8.35%, 5.84%, 4.88%0 and 0.01% respectively.

Table 4. Results of accuracy assessment for land use land cover classes.

Cover Classes	1990		2005		2017	
	User Accuracy	**Producer Accuracy**	**User Accuracy**	**Producer Accuracy**	**User Accuracy**	**Producer Accuracy**
Forest	87.6	82	92.3	88.6	93.5	92.5
Home Gardens	85.3	81.6	89.8	82.5	88.6	85.3
Tea	82.6	80.3	85.2	81.4	86.5	82.5
Paddy	87.8	85.9	87.4	83.9	81.5	80.2
Other Agric. Crops	82.4	78.3	82.6	79.2	75.6	73.5
Bare Land	88.6	75.5	78.6	75.6	71.5	63.5
Water	98.7	95.8	100	100	100	100
Urban	93	89.5	96.5	94.5	93.5	92.3
Overall Accuracy (%)	87.5		89.3		90.1	
Kappa Coefficient (K)	0.82		0.85		0.87	

In 2005, 34.58% of the study area of Nuwara *Eliya* district was covered by home gardens. Other land use land covers as Forests and shrubs, Tea, Paddy, Other Agricultural lands, Bare lands, water bodies and Urban areas represented 22.26%, 15.36%, 6.57%, 12.11%, 5.13%, 3.98% and 0.02%. of the total area. Regarding 2017 land use and land covers, 36.39% was Home Gardens whereas Forests and shrubs, Tea, Paddy, Other Agricultural lands, Bare lands, water bodies and Urban areas shared 21.08%, 14.30%, 6.51%, 13.22%, 4.49%, 3.98% and 0.03% proportionately.

3.2. Multi-temporal Land Use Changes

Multi -temporal data obtained from Remote Sensing and Geographic Information System is highly useful in analyzing the land cover changes in a catchment. Change analyses describes and quantifies differences between images of the same scene at different time periods. The classified images prepared for different time periods, 1990, 2005 and 017 were used to calculate the area of different land cover and observe the changes that are taking place in the span of data by comparing and overlaying land use land cover map prepared for different time periods and using the Dissolve function of the GIS, the position and the percent of different land uses and changes areas can be identified. The summary statistics of changes of land use/ land cover classes and the change detection maps prepared for the study areas Nuwara *Eliya* district are presented in this section.

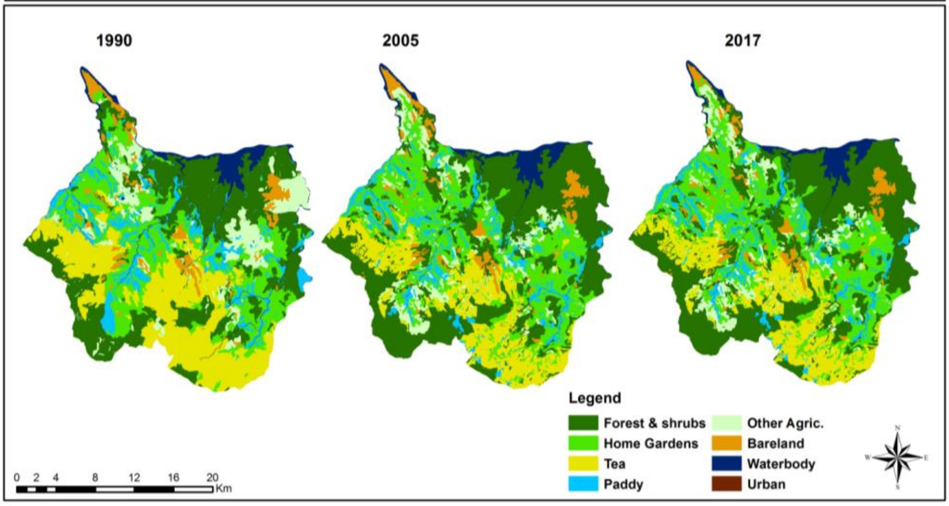

Figure 2. Temporal and spatial distribution pattern of land use/land cover classes in selected DSDs in *Nuwara Eliya* district from 1990-2017

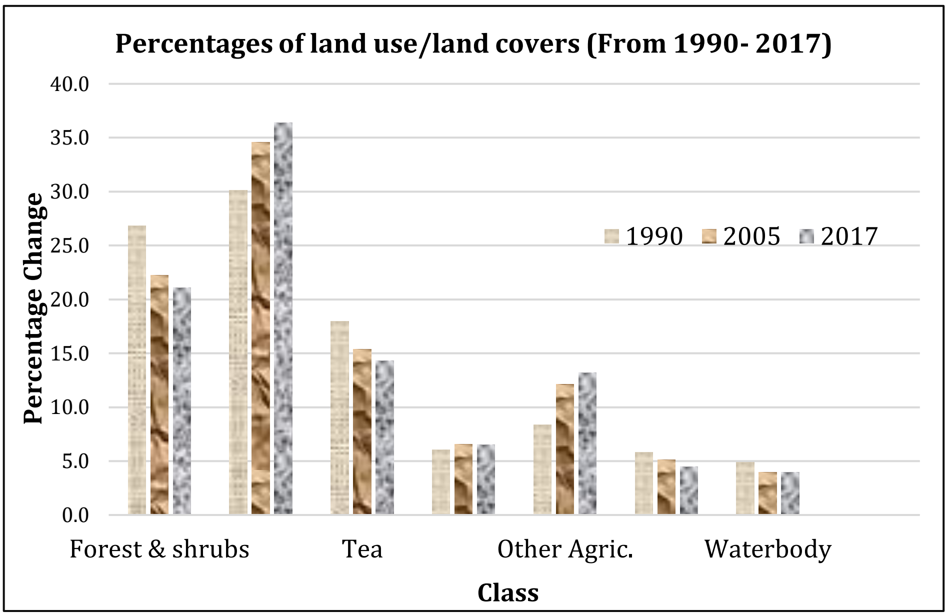

Figure 3. Percentages of temporal and spatial distribution of Land use/ land cover classes in selected DSDs in *Nuwara Eliya* district from 1990-2017

Table 5. Summary statistics of Land Use Land Cover Changes in *Nuwara Eliya* District -1990- 2017

Class	1990 Area(Ha)	%	2005 Area(Ha)	%	2017 Area(Ha)	%	% Change 1995-2005	% Change 2005-2017
Forest & shrubs	14705.2	26.81	12206.20	22.26	11560.50	21.08	16.99	5.29
Home Gardens	16512.5	30.11	18965.21	34.58	19960.21	36.39	-14.85	-5.25
Tea	9850.2	17.96	8424.30	15.36	7842.50	14.3	14.48	6.91
Paddy	3310.2	6.04	3602.20	6.57	3572.20	6.51	-8.82	0.83
Other Agric.	4581.8	8.35	6640.20	12.11	7250.20	13.22	-44.93	-9.19
Bare land	3203.9	5.84	2815.90	5.13	2462.60	4.49	12.11	12.55
Waterbody	2674.26	4.88	2182.30	3.98	2183.36	3.89	18.40	0.06
Urban	8.2	0.01	10.50	0.02	15.30	0.03	-28.05	-45.71
Total	**54864.26**	**100**	**54846.64**	**100**	**54846.91**	**100**	**0.00**	**0.00**

Note: Negative values imply an increment

Percentage change (Y) is calculated using the following equation.

$$y = \frac{a_{i\,1990} - a_{i\,2017}}{a_{i\,1990}} \times 100$$

Where,

a_{i1992} = land area of i^{th} land use class in 1990
a_{i2017} = land area of i^{th} land use class in 2017
α, β are coefficients, x_i; explanatory variables aggregated to GNDs.

According to the Table 5 the results revealed that percentage change of HGs and urban sectors have got increment and accounted for 14.85% and 28.0511% in the Nuwara *Eliya* district from 1990-2005. The most prominent change during the same period is increment of other agriculture lands by 44.93%. This change is not favorable for the catchment protection since annual cash crops and vegetable-based agriculture expansion bring a lot of negative environmental consequences such as increase in soil erosion, siltation of reservoirs and aggravation of land slide hazards in the study area (Wickkramagamage, 1990; Hewavasam, 2010). However, percentage change of HGs and other agriculture land uses during 2005 - 2017 have shown fairly low increments of 5.25% and 9.19% respectively. Moreover, percentage of urban land uses have been maintained increasing trend from 1990-2005 as well as 2005-2017. Percentage change of land use/land cover classes in Selected DSDs in Nuwara *Eliya* district- from 1990 to 2017 is illustrated in figure 3.3. Forest & shrubs, Tea, Paddy, Bare lands and water bodies have decreased during both time periods. Fairly low percentage increment of land use and land cover changes have been shown in Home garden and other agriculture land use categories from 2005-2017. However, urban land use has increased significantly during this period by 45.72%.

3.3. Results of the Socio-economic assessment

3.3.1 Determinants for Land Use Changes

Land use and land cover change (LULCC) are the results of changes and/or the modification in the intensity of an existing land use and cover type due to natural factors and anthropogenic activities (Emiru et al, 2018). Therefore, selection of the best fitted model and model parameters is a crucial issue. One of the most important requirements of a realistic model to assess the determinants for land use changes is incorporation of spatial variables in addition to socio-economic variables since land use changes are highly location specific (Lambin,1997). Considering those factors, the logistic regression model has been developed for this research as the best fitted model by taking relevant variables within the availability of data. The outcomes of the logistic multiple regression analysis to explore the determinants for changes of land use are listed in the table 6.

Table 6. Statistical parameters generated by the Logistic Regression model

Variables	Coefficient	Standard Error	t-test	Probability
Distance to the HG from the nearest urban center (km)	1.52**	0.78	2.39	0.4
Distance to main roads(m)	1.23*	1.06	3.2	0.25
Land elevation (m)	0.06**	0.17	1.28	0.16
Mean annual temperature (^{0}C)	1.62*	0.9	0.82	0.19
Mean Annual rainfall (mm)	1.05**	0.078	3.75	0.28
Population density	0.05*	0.07	2.08	0.32
Size of the HG (ha)	0.02**	1.03	1.75	0.43
Average income from the main Occupation of the household heads (Rs)	0.56**	1.2	1.04	-0.21
Average income from agriculture crops (Rs)	0.7*	0.25	0.65	0.27
Education level	0.15**	0.3	1.03	0.19
Farming experience (years)	0.32**	1.02	1.02	0.35
Constant	1.25	2.05	1.02	0.08

LR Chi square
Log Likelihood
R-squared
Adj-R-squared
Number of observations- 300
*significant ($p<0.05$) **significant ($p<0.01$)

The results of the logistic regression model indicated that the model was statistically significant at the 0.1% level based on the F test. R2 value 0.55 implies the model is reasonably acceptable in its prediction power. According to the results of the study, as far as the spatial variables are concerned such as distance to the nearest urban center and distance to the main road; a unit of increase of these spatial variables increase the probability of conversion of Home Garden land use into other land use changes by 40% and 25% respectively (S.E. =0.78, t=3.29, p=0.01; S.E. =1.06, t=3.2, p=0.01). Field observations confirmed that changes are basically due to commercialization and urbanization. Abelairas & Astorkiza (2012) mentioned that, conversion of agricultural land to housing in rural areas that are closer to the city resulted in increased land prices.

Results revealed that in case of a unit increase in size of the Home garden, probability of conversion to another landform is likely to increase by 43%. As size of the HG increases, plenty of land is available for change into other land uses such as cash crops and vegetable-based agriculture land uses which are commonly practice in the study area. As far as socio-economic determinants are concerned, when population density decreases by one unit, there is a 30% probability of HGs converting into another land use. The negative relationship implies that, as population density increases, demand of lands for settlement purposes also increases. It implies that people need to keep the land as HGs for their residential purpose. According to Dutta et. al. (2016) the increase in population in these zones has led to high demand for other land uses against agriculture land use. This has increased conversion of agricultural lands into other land uses.

According to the results, a unit increase in average income of the household head decreases the land use conversion probability of HGs to decrease by 21% (S.E.=1.2, t=-1.04, p=0.05) . The negative relationship is due to the fact that as average income of the household increases there is no reason to convert HG into any other land for the sake of income generation. Increasing income is an incentive for farmers to intensify their crop production (Lambin et al, 2010; Anisa et al, 2017). This would be the reason to increase other agriculture-based land use during 1990-2005 rapidly since land shortage was not a serious issue during that period in the study area. This conversion is not favorable for the catchment since it is directly related to decrease in the tree cover of the catchment.

Similarly, results showed that a unit increase in Education level, decreases the land use conversion probability of HGs likely to decrease by 19% (S.E.=0.3, t=-1.03, p=0.05). As people get more educated, HG owners can raise their income from other employments off-farm sources without converting the HG into agriculture. On the other hand, those who transfer into the agricultural sector are less motivated to invest in education (Berry & Glaeser, 2005; Guo & Li, 2009).

According to the results, a unit increase in Farming experience of the household head increases the land use conversion probability of HGs likely to increase by 35% (S.E.=1.02, t=1.23, p=0.05). Under such circumstances there is a tendency to convert HGs into agriculture land uses. As farming experience increases of the household heads, they use HGs to grow more crops to get income mainly from cash crops and vegetable (Other agriculture land use) cultivation in the study area. The survey results revealed that, as far as policy related determinant is concerned, a unit increment in Agriculture input subsidies received by the household head is also likely to increase the probability of conversion by 18% of HGs to agriculture land use, specially to tea and pepper cultivation (S.E.=1.25, t=1.45, p=0.05) based on field observations. These determinants would affect the reduction of permeant tree cover in the catchment due to conversion of Homegarden land uses into other unsustainable land uses. On the other hand, it leads directly to the loss of ecosystem services which are derived from Home Gardens, especially catchment protection functions. However, all biophysical determinants such as Land elevation, Mean annual temperature, Mean Annual rainfall, and social variables such as Age of the household head which are likely to be responsible for the conversion of HGs were not explained by the model statically.

4. Conclusion and Recommendations

HGs contribute to the sustainability of the Upper Mahaweli Catchment by providing number of catchment protection functions in areas where lack of natural forest cover in the catchment area. Maintaining of tree rich HGs in the catchment while converting into other land uses is a crucial issue. For long-term sustainability of the catchment, land use changes should be analysed taking long time periods. Number of drivers responsible for land use changes in catchments including spatial, biophysical and socio-economic determinants. Therefore, this research was carried out as integrated assessment combining spatial assessment using GIS and Remote Sensing coupled with socio-economic assessment.

Based on the results, this study concluded that selected Divisional Secretariat Divisions in Nuwara *Eliya* district experienced predominant spatial and temporal changes in land uses with the conversion of Home garden land use into other land uses during the past 27 years. Increasing trend of Home Gardens during the same period would bring positive impacts to the catchment. It basically depends on the quality of Home Gardens in terms of tree density and tree diversity. However, the most prominent feature of increasing other annual crop based land use at a higher percentage which consist of cash crops and vegetables would continue negative environmental impacts in the catchment further. Urban land use has also acquired a greater area due to rapid urbanization in Nuwara *Eliya* district. Spatial and socio-economic drivers were responsible for changes such as Distance to the HG from the nearest urban center, Distance to main road. Size of the HG whereas socioeconomic drivers of Population density, Average income of the household head, Education level, Farming experience, Agriculture subsidies were also responsible for changes.

Since tree rich Home Gardens play an indispensable role in catchment protection especially in areas where there is a lack of forest cover, to compensate for this lack of forest cover, proper incentives should be provided to enhance tree cover in Home Gardens in the catchment area. HG owners as well as relevant authorities should take appropriate measures to enhance the quality of Home gardens to augment ecosystem services from them mainly to maintain the sustainability of the catchment protection functions.

Based on the findings, this study suggests several recommendations. The tree cover of Homegardens should be increased to enhance the catchment protection function. Sufficient incentives can be provided to HG owners to increase tree cover by the relevant authorities and they should be income generating incentives. As far as Home garden owners are concerned, if they are able to earn sufficient income from tree components of the HGs, they are willing to plant timber trees sustainably. Such policies are more appropriate for large size home gardens located in the catchment to discourage conversion to monoculture plantation crops and other annual agriculture crops. In addition, sustainable agro-forestry systems with more tree component can be introduced through the Department of Agriculture. Conversion of Home gardens due to a monoculture agriculture or low income generating short term crop cultivation can be reduced through that policy. It is recommended that continuous technical and advisory support should be provided for Home garden owners to tackle silvicultural problems encountered during maintenance of trees. Therefore, a technical and advisory support package should be attached to all tree planting programs in order to maintain sustainable tree cover in the Home gardens located within the catchment.

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