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# Analysis and Prediction of Land-use and Land-cover Changes and Driving Forces by using GIS and Remote Sensing in the Coka Watershed, Southern Ethiopia

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## ABSTRACT

**Background:** Land-use and land-cover (LULC) change is among the dynamic environmental and ecological factors for monitoring and facilitating the developmental strategies to balance conservation and conflict of resource uses. This study aimed to analyze LULC changes that have occurred during 1988-2018 and its prediction for 2040-2060 periods.

**Methods:** LULC changes were analyzed using geographic information system Landsat and predicted by CA-Markov model.

**Result:** The results of this study confirmed that cultivated-land and rural-settlement, bare-land, built-up-area and waterbody have increased at an annual rate of 23.1, 2.2, 0.8 and 1.1 ha/year but forestland, bushland and grassland have decreased at an annual rate of 14.4, 4.1 and 8.7 ha/year, respectively. It is projected that the increase in cultivated-land, bare-land, built-up-area and waterbody but decreases the forestland, grassland and bushland. Expansion of agriculture and deforestation showed increasing trend on both previous and predicted LULC changes with upcoming expansion of bare-land due to major driving factor of population growth. Thus, well integrated landscape planning and reliable predictions for future LULC are needed to reduce the deterioration of environment.

**Key words:** Degradation, Environment, Land-use and land-cover, Projection, Watershed.

## INTRODUCTION

Land-use-cover (LULC) change is a non-linear transformation of one land-use type to another where human activities influence the ecosystem. An intersection of natural and anthropogenic factors like climate changes, policy adjustments, population growth and decrease in productivity of land are among the major drivers for LULC changes (Lambin and Meyfroidt, 2011; Nanda *et al.*, 2014). Although, the LULC changes vary greatly in intensity, degree and patterns across the regions (Lambin and Meyfroidt, 2011).

Some studies on LULC dynamics revealed that some land use types expanded at the expense of others (Agidew and Singh, 2017). As reported by Temesgen *et al.* (2017), cultivated-land and built-up areas expanded at the expense of forest, bush and grasslands in Ethiopia. Whereas, drastic expansion of urban built-up area at the expense of cultivated-land is observed in the northeastern and northern Ethiopia (Gebrelibanos and Assen, 2013). According to Assefa and Bork (2016), grassland reduced due to rapid population growth and agricultural expansion, southern Ethiopia. The Ethiopian Biodiversity Institute report showed that forestland decreased by 27.5% (EBI, 2014). Different researchers argue that LULC change could be the reason for the reduction of the soil value by exposing the land to soil erosion in Ethiopia (Birhan and Assefa, 2018).

However, information on LULC changes and its causes, consequences and impacts on environment for policy makers and researchers in the last long periods of years in and around Coka watershed is very limited. This study has been investigated and documented to fulfill this gap by assessing and evaluating the LULC changes and their driving forces which have occurred over the past three decades during 1988-2018 and predicting LULC changes for coming four decades 2018-2060 in Coka watershed, southern Ethiopia.

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## MATERIALS AND METHODS

Coka Watershed is located at the geographic bounders of 7°12′10″N - 7°18′20″N latitude and 37°31′0″E - 37°34′25″E longitude in the southern Ethiopia (Fig 1). The total area of the watershed is about 3731 ha. Its altitude ranges from 772 to 2524 m.a.s.l. with slope gradients varying between gently to very steep, mean annual rainfall (1267.13 mm), with minimum (12.2°C) and maximum (26.3°C) temperature.

Land-use and land-cover changes analysis were assessed using remote sensing data from satellite images

(Landsat-5 TM for 1988 and 1998, Landsat-7 ETM$^+$ for 2008 and Landsat-8 OLI-TIRS for 2018) with 30 m* 30 m spatial resolution and path/row of 169/55 were used as data sources. Satellite data were downloaded from open access U.S. Geological survey (USGS) Center for Earth Resources Observation and Science (EROS) (https://earthexplorer.usgs.gov/). ASTERGDEM with 30 m cell size was obtained from Aster Global Digital Elevation Map (http://gdex.cr.usgs.gov/gdex/).

The images were acquired in the same season to avoid the effect of seasonal variations and to avoid could effect. 50-75 random GPS ground points per land-use class were collected for accuracy assessment and land-use type classification. All the datasets were projected to the Universal Transverse Mercator (UTM) map projection system zone 37 N and datum of World Geodetic System 84 (WGS84), ensuring consistency between datasets during analysis. The major causes of LULC changes were explored by using key informant interviews (KII) and focus group discussions (FGD) with local communities from six kebeles for additional information.

The four Landsat images were performed to identify useful thematic information to investigate the LULC changes. Pre-processing activities like geometric and radiometric corrections were applied before image classification. Sub-setting and layer stacking were performed before commencement of the actual classiûcation. Moreover, all the acquired satellite images were enhanced using histogram equalization to improve image quality. The hybrid classification technique was applied for satellite image classification which combines both unsupervised and supervised classification techniques as (Solomon *et al.*, 2014). Projection of LULC for the periods 2040 and 2060 were done with Cellular Automata Markov (CA-Markov) model in TerrSet software as (Li *et al.*, 2017). Next, the classified images were compared with the reference images by means of error matrix.

Overall accuracy (Congalton 2005) was calculated by Eq.1 as: -

$$\text{Overall (OA)} = \frac{x}{y} \qquad (1)$$

Where,
OA is overall accuracy, X is number of corrected values in the diagonals of the matrix and Y is total number of values taken as a reference point.

Kappa coefficient (Congalton, 1991) was calculated using Eq. 2: -

$$K= \frac{N\sum_{i=1}^{r} xii - \sum_{i=1}^{r}(xi + * x+i)}{N^2 - \sum_{i=1}^{r}(xi + * x+i)} \qquad (2)$$

Where,
K is Kappa coefficient, r is the number of rows in the matrix, xii is the number of observations in row i and column i, xi+ are the marginal totals of row i, x+i are the marginal totals column i and N is the total number of observations.

LULC change detection was made using Eq 3 and 4:

$$\text{LULC change (\%)} = \frac{x-y}{y} \times 100 \qquad (3)$$

$$\text{Rate of LULC change (ha/year)} = \frac{x-y}{z} \qquad (4)$$

Where,
X is area in time-2, Y is area in time-1, Z is time interval between X and Y in years.

## RESULTS AND DISCUSSION

### Land-use and land-cover (LULC) change trends

An overall accuracy of 87, 85, 88 and 91% and a kappa coefficient of 0.84, 0.83, 0.87 and 0.89 were obtained for

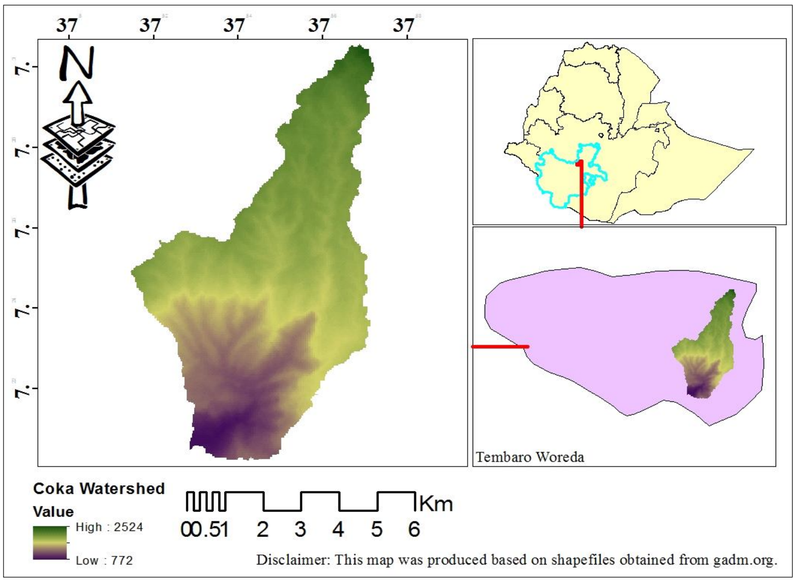


**Fig 1:** Map of the Coka watershed.

the classified images of 1988, 1998, 2008 and 2018 years, respectively. Hence, the results indicated strong agreement of the classified image with ground truths. According to Solomon *et al.* (2018) accuracy rating, the study result is reasonably high accuracies range of LULC changes classification with ground truth.

Cultivated-land and rural-settlement-land (CLRS) has expanded by rate of change 93.4% during 1988-2018 periods (Fig 2 and 3). The highest gain was observed in CLRS 1107 ha (38.3%) of which the highest area was from grassland 550 ha (49.7%) followed by forestland 333 ha (30.1%) (Table 1 and 2). Conversely, the total loss from CLRS to other land types was 414 ha (14.3%) (Table 2). Majority of CLRS was converted to forestland 329 ha (79.5%) followed by grassland 39 ha (9.4%) (Table 2). According to FGD and KII the driving force for expansion of CLRS was associated to an increment of population size demanding for food and deforestation. This reveals that expansions of CLRS were occurred due to growth of population and deforestation. This finding is in agreement with studies found by (Solomon *et al.* 2014; Anjan and Arun, 2019), cultivated-land expansion was found in most part of worldwide including Ethiopia.

Forestland reduced with annual diminishing rate of 14.4 ha/year between 1988-2018 periods, respectively (Fig 2 and 3). It gained much land from CLRS (53.4%) followed by grassland (29.7%) and the total gain of forestland is 616 ha (21.3%) (Table 1 and 2). Divergently, the highest loss of forestland was observed in the study watershed which was 1048 ha (36.2%). FGD made clear that this reduction of forestland is due to expansion of cultivated land, fuel, charcoal and construction. This indicates that forestland is under considerable pressure due to increasing population, expanding agricultural, urbanization and deforestation. It may lead to climate change, biodiversity loss, soil fertility loss and hydrological disturbance the study area. This finding is supported by FAO, (2015) and Ebrahim and Mohammed (2017), poverty, population growth, agricultural expansion, urbanization, deforestation and lack of policy implementation are various causes for forest deterioration.

Bushland diminished by rate of 4.1 ha/year during 1988-2018 periods (Fig 2 and 3). The major gain was from forestland (90.6%) with total gain of 522 ha (18.0%) (Table 2). The highest bushland converted was to grassland (45%) followed by cultivated-land (34.8%) with total loss of 644 ha (22.3%) (Table 1 and 2). According to KII the reduction of bushland was linked to high demand of grazing and cultivated-lands. This result shows that more bushlands to grassland and cultivated is one kind of environmental degradation. This agrees with Hailemariam *et al.* (2016), bushland converted into cultivated-land during 1985-2016, Bale Mountain, Ethiopia.

Grassland was decreased by 8.7 ha/year among 1988-2018 years (Fig 2 and 3). The majority gain occurred was from bushland 290 ha (55.1%) followed by forestland 197 ha (37.5%) whose total gain is 526 ha (18.2) (Table 2). In reverse, the largest area of grassland 550 ha (70%) transformed to CLRS followed by forestland 183 ha (23.3%) and the total loss from the grassland is 786 ha (27.2%)

**Table 1:** Description of land-use and land-cover classes according to FAO (2010).

| Land use types | Description |
|---|---|
| Cultivated and rural-settlement | Areas currently under crop, fallow land and scattered rural settlements |
| Bare-land | Land surface without vegetation cover, or with rocky land. |
| Built-up area | Urban housing area (Mudulla Town and Ambukuna kebele center) |
| Bushland | Land covered by small trees, bushes |
| Grassland | Land covered by grass with scattered shrubs |
| Forestland | Area dominated by high and dense natural and plantation forest |
| Waterbody | Back flow water of Gilgal gibe 3 dam |

**Table 2:** LULC change matrix in Coka watershed.

| | LULC types in Year 2 (2018) | | | | | | | Year1 | Loss in | Loss in |
|---|---|---|---|---|---|---|---|---|---|---|
| Year 1 (1988) | Forest land | Bush land | CL and RS | Grass land | Built up | Bare land | Water body | Total (Ha) | 1988 (Ha) | 1988 (%) |
| Forest land | 243 | 473 | 333 | 197 | 6 | 20 | 19 | 1291 | 1048 | 36.2 |
| Bush land | 104 | 163 | 224 | 290 | 3 | 14 | 9 | 807 | 644 | 22.3 |
| CLRSL | 329 | 27 | 328 | 39 | 8 | 11 | 0 | 742 | 414 | 14.3 |
| Grass land | 183 | 22 | 550 | 105 | 6 | 21 | 4 | 891 | 786 | 27.2 |
| Built up area | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Bare land | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Water body | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Year 2 Total (Ha) | 859 | 685 | 1435 | 631 | 23 | 66 | 32 | 3731 | | |
| Gain (Ha) in 2018 | 616 | 522 | 1107 | 526 | 23 | 66 | 32 | | 2892 | |
| Gain (%) in 2018 | 21.3 | 18.0 | 38.3 | 18.2 | 0.8 | 2.3 | 1.1 | | | 100 |

(Table 1 and 2). This might reveal the presences land degradation. This is supported by Asmamaw *et al.*, (2011) and Hagos, (2014) argued that conversion of grassland to cultivated-land is common, Ethiopia.

Bare-land was expanded by rate of 2.3% during 1988-2018 periods (Fig 2 and 3). It gained the highest amount of land from grassland (32%) with total gain of 66 ha (2.3%) (Table 1 and 2). This could divulge the presence of environmental degradation and reduce ecosystem services in the study area. As Hagos, (2014) and Birhan and Assefa, (2018), expansion of bar-land minimizes the productivity of soil, Ethiopia.

Built-up area expanded with rate of 0.8 ha/year 1988-2018 periods (Fig 2 and 3). The highest conversion from cultivated land (34.8%) and the total gain of built-up area is 23 ha (0.8%) (Table 1 and 2). FGD elucidated that major cause for the expansion of built-up area due to migration of people from rural to urban. This finding agrees with Temesgen *et al.* (2017). similarly, the growth of built-up area was by 0.008%, India (Anjan and Arun, 2019). Urbanizations are linked to demographic factors mostly in developing countries (Riad *et al.*, 2020).

Waterbody was with rate of increment during 1988-2018 periods 1.1 ha/year (Fig 2 and 3). It was gained from bush (9 ha), grassland (3 ha) and forest land (19 ha) (Table 2). KII confirmed that the waterbody was increased during this period because of back flow of Gilgal gibe 3 dam accumulations at the bottom (outlet point) part. This finding is in line with Gebremicael *et al.*, (2013), the increase of waterbody is due to the construction of dams.

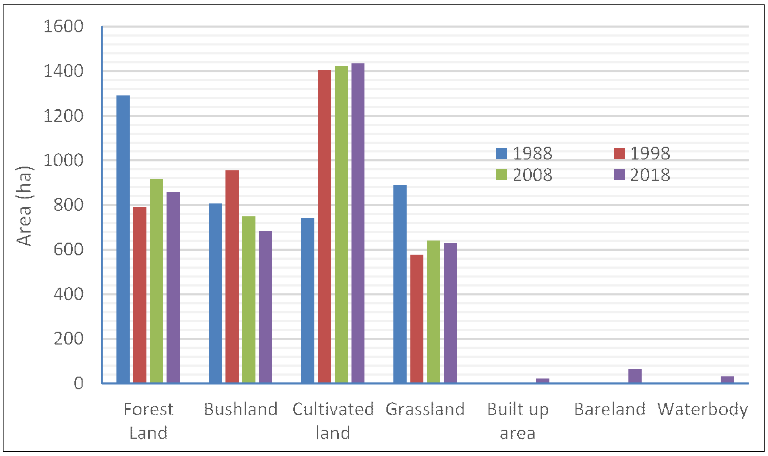


**Fig 2:** Summary of LULC changes trend.

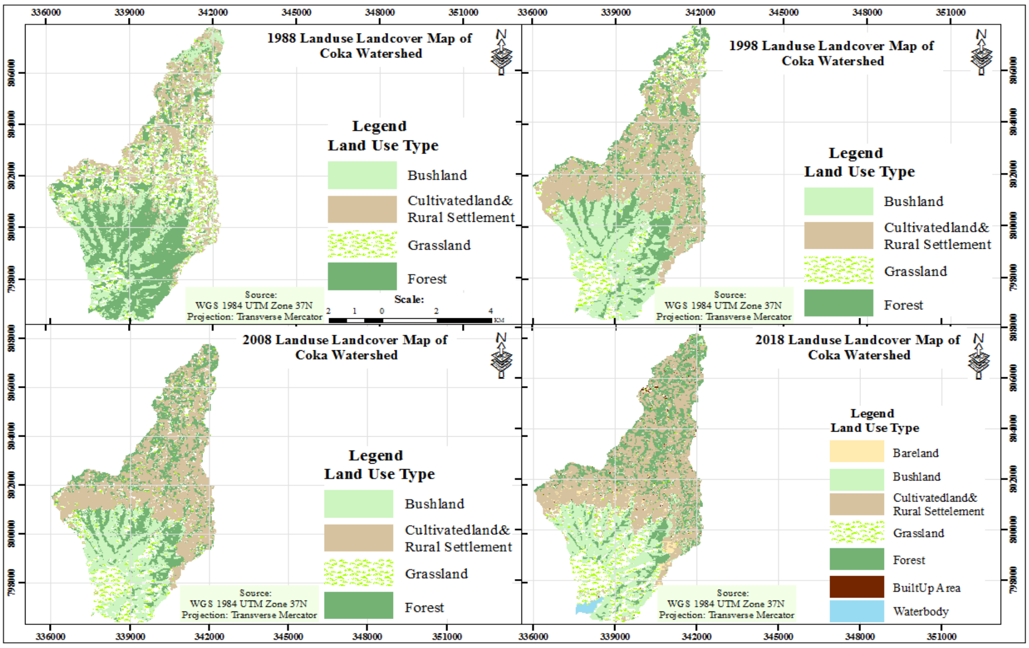


**Fig 3:** LULC change map in Coka watershed.

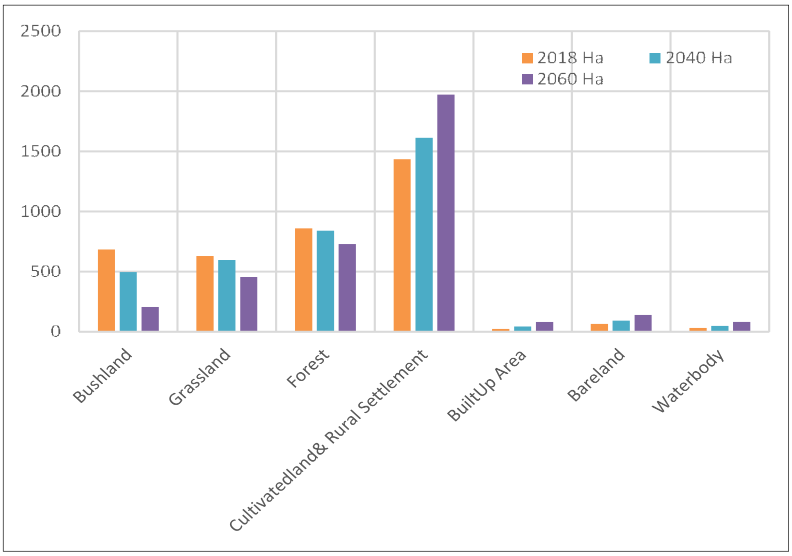


**Fig 4:** The predicted LULC changes in Coka watershed.

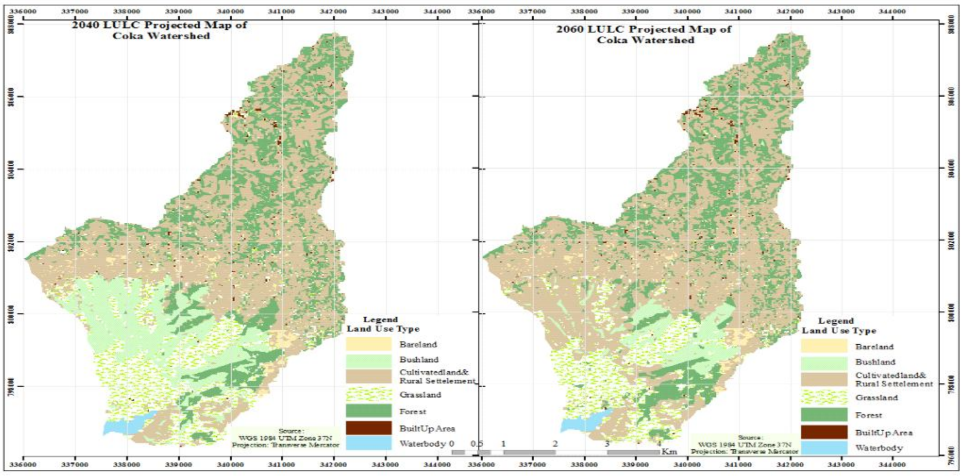


**Fig 5:** Projected LULC change map.

## Future LULC changes

A continuous raise of CLRS is projected with rate of 12.2 ha/year during 2018-2060, which indicates high expansion of CLRS for projection periods (Fig 4 and 5). Majority of its gain is from forestland (41.4%) followed by bushland (31.9%) with total gain of 53% is predicted to be transformed to CLRS (Table 3). In reverse, its' total loss will be 27.8% (Table 3). This result was approved by Temesgen *et al.* (2017), cultivated-land will be expanded by 99.5 ha/year during 2030-2045, Ethiopia.

The projected forestland showed a decrement trend by 3.1 ha/year during 2018-2060 (Fig 4 and 5). It is projected that total of 19.7% will be transformed to forestland (Table 3). Conversely, its' total loss of 25.9% which projected decrement of forest could be directly connected with $CO_2$ emission that may contribute to environmental degradation in study area. This finding agrees with Muhammad and Han (2019) in Indonesia during 2050-2070.

Bushland will be transformed by rate of 61.9% decrement during 2018-2060 (Fig 4 and 5). Total gain of bushland will be 153 ha (7.2%). Reversely, total loss of bushland (27.1%) will be converted to other land use types (Table 3). This result agrees with Temesgen *et al.* (2017), decrement in bushland will happen in Andassa watershed, Ethiopia.

A decrement of grassland is predicted by 3.8 ha/year during 2018-2060 (Fig 4 and 5). Total gain of grassland 11.7% will be transformed from other land use types (Table 3). In opposite, the total loss of grassland will be 409 ha (19.2%) in the mentioned periods. This reveals that expansion of CLRS will be high at the expense of grassland if not protected. This projection is supported by Temesgen *et al.* (2017).

Built-up area will increase from by rate of increment 1.4 ha/year during 2018-2060 (Fig 4 and 5). Total of 2.7% will be changed to built-up area (Fig 4). This was also true

**Table 3:** LULC conversion matrix between 2018 and 2060.

| LULC in | LULC in 2060 (Ha) | | | | | | | Total in | Loss | Loss (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2018 (Ha) | Bush land | Grass land | Forest land | CL and RS | Built Up | Bare land | Water body | 2018 | (Ha) | in 2018 |
| Bush land | 108 | 125 | 65 | 360 | 5 | 6 | 16 | 685 | 577 | 27.1 |
| Grass land | 63 | 222 | 12 | 301 | 6 | 12 | 15 | 631 | 409 | 19.2 |
| Forest land | 51 | 0 | 309 | 466 | 10 | 4 | 19 | 859 | 550 | 25.9 |
| CL and RS | 39 | 123 | 342 | 844 | 36 | 51 | 0 | 1435 | 591 | 27.8 |
| Built Up | 0 | 0 | 0 | 0 | 23 | 0 | 0 | 23 | 0 | 0 |
| Bare land | 0 | 0 | 0 | 0 | 0 | 66 | 0 | 66 | 0 | 0 |
| Waterbody | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 32 | 0 | 0 |
| Total in 2060 | 261 | 470 | 728 | 1971 | 80 | 139 | 82 | 3731 | | |
| Gain in 2060 | 153 | 248 | 419 | 1127 | 57 | 73 | 50 | | **2127** | |
| Gain (%) | 7.2 | 11.7 | 19.7 | 53.0 | 2.7 | 3.4 | 2.3 | | | 100 |

for Temesgen *et al.* (2017), it will be increased in 2045 by 188%.

Bare-land will increase by 1.7 ha/year during 2018-2060 (Fig 4 and 5). Total of 73 ha (3.4%) other land use types will be transformed to bare-land. This result is in agreement with Sinan *et al.* (2014), bare-land will be raised in 2030 by 31.75%, Iraq.

An increment in waterbody will be by rate of 1.2 ha/ year 2018-2060 periods (Fig 4 and 5). In this regard, its total gain from other land use types will be 50 ha (2.3%) (Fig 4). This finding divulges that it could be opportunity for harvesting fishes but it might cause for biodiversity loss.

## CONCLUSION

The spatial and temporal analysis of land-use and land-cover (LULC) change of Coka watershed clearly indicates the prevalence of serious environmental degradation and related problems the area will face in the near future. During 1988-2018, LCRS, built-up-area, bare-land and waterbody were increased but forestland, grassland and bushland were decreased. It is also similar that the pattern of increasing and decreasing for projected LULC change during 2040-2060. Major driving forces of LULC changes in study area are population growth, fuel and construction material need, expansion of cultivated land, socioeconomic factors, institution and urbanization. Thus, detailed investigations of household mechanisms for adaptation of the changes observed are essential for future action and a multilevel stakeholder approach to sustainable land management is needed. Therefore, existing biophysical, socio-economic, land policy and institution strategies should be given high priority, at least to prevent existing potential from further deteriorating.

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**Conflict of interest:** None.

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