Modelling LULC for the period 2010-2030 using GIS and Remote sensing: a case study of Tikrit, Iraq

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Abstract. This study extends upon the results of [1] to include the modeling of Land use/ Land cover (LULC). This study looks at the changes that occurred from 2010 to 2030 in Tikrit district, Iraq by predicting LULC for the year target 2030 by using the classified images for two points of time (2000 – 2010) as a foundation for the modeling process. The projected map, in comparison with 2010 LULC map, shows a significant decrease in vegetation area (45.11 km2) which must be regulated in order to maintain a green environment, and increase in the urban area (58.42 km2) which should be monitored to have sustainable development and control the eco-environment degradation. Also, in this study, it is shown clearly that the use of Geographic Information System (GIS) and remote sensing (specially IDRISI software) in modeling LULC is a suitable approach to understand the future pattern.

1. Introduction

One of the most important concerns of the world, nowadays, is the change in eco-environment that are caused by human exploitation and regional climate especially in arid and semiarid areas. Also, There are many ways of anthropogenic in changing the landscape of the world such as agriculture, deforestation, expanding farmland, and urban centres [1].

Degradation in the eco-environment has become one of the problems that affects Iraq, particularly the middle and southern part of it [1]. One million hectares is the estimated area that can be affected by this degradation [2]. Sand dunes, misuse of the cover of the plant, overgrazing were identified by Al-Janabi et al. (1988) as the causes of land degradation and cover changes. Important factors were added to these causes by Dougrameji (1999) these are the use of unsustainable practices continuously in addition to the deterioration and the poor maintenance of the infrastructure that was deteriorated because of the sanctions between 1990 and 2003. In last three to four decades, starting by the Iraq-Iran war and ending by the American invasion, Iraq has been involved in several wars. In particular, after 2003 the demography of Iraq has been changed due to the invasion dramatically, hence, the urban growth has been severely changed [1].

Modelling of land use and land cover is a scientific field that is growing rapidly because of its importance in identifying the effects of the humans on the environment. In view of this importance, scientists have constituted an international organization named Land use and Cover Change (LUCC) organization that is connected with the International Geosphere Biosphere Program and the International Human Dimensions of Global Change Program [5]. Furthermore, many algorithms and methods have been developed for modelling land use and cover.

One of the approaches that have been developed for forecasting Land use/ Land cover (LULC) is Cellular Automata (CA) which is defined as a dynamical discrete system in space and time that works by specific rules on a uniform grid based space [6]. CA involves cells and transition rules that are used to identify the state of a certain cell. It is especially interesting for land use and land cover modelling because of its ability to represent a complex system by a small set of rules and states with spatio-temporal behaviour (Figure 1). CA was successfully compiled in one of the models in the IDRISI software that, hence, gives this model power and easiness for performing modelling LULC.

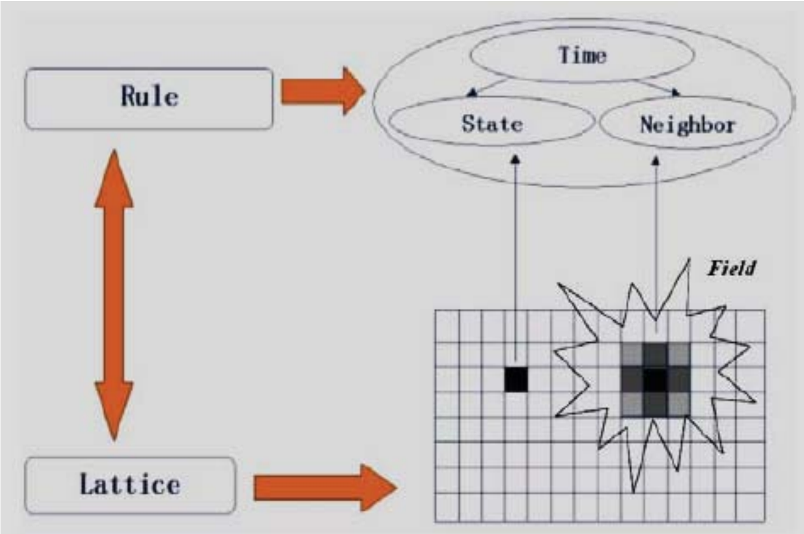

Figure 1. The components of CA and their relation (adopted from [7]).

CA_Markov is a model in the DRISI software. This model is a powerful tool for modelling and predicting land use and land cover change. It is a methodology that has been used widely in LULC modelling as it takes into consideration spatial interaction and stimulates multi LULC types [8]. In this research, an approach of detecting the change and predicting the change of a specific year is applied. This approach is an integrated method of remote sensing, GIS, and modelling (CA method), as the RS and GIS is used for detecting the change and providing basis data for CA model, the latter is used to predict the future LULC map.

In Iraq, there is a phenomenon called Desertification (i.e. A land losing its bodies of water till becomes dry) in addition to significant unmonitored Land use / Land cover (LULC) change due to several reasons such as the climate change around the world, the wars that Iraq has been involved, and the reduction in the amount of the water in the river that passes from Iraq [1]. The LULC change and desertification of the last four decades 1972-2010 and the factors that affected these changes were studied by [1].
This study aims at forecast in the future (i.e. 2030) pattern of land use and land cover in the area on the basis of the past and current situation and compare the result (by a change detection process) with the latest existing classified image (i.e. 2010).

2. Study area

Tikrit city that is located in Salahaldin province in Iraq was chosen due to the big number of immigrants that moved to Baghdad, in addition many people moved from Baghdad to Tikrit particularly because of the invasion in 2003. Another reason of choosing it is the importance of it as an administrative and economical centre of Salahaldin province. Tikrit is located 155 km from Baghdad the capital of Iraq. Also, it is the centre of Salahaldin province. Its population is 172,119 in 2007. The study area extends between

43°07'37.69" and 44°6'15.02" east and approximately between 34°26'20.41" and 35°4'1.96" north. Its area is about 2554.8 km^2 (Figure 2).

3. Data and methods

In this study, three types of software were used:

a) ArcGIS- was used for creating slope constraint and providing the administrative shapefile.
b) ENVI- was used for change detection analysis.
c) IDRISI Taiga- was used for presenting change detection graphs and for modeling land use and land cover.

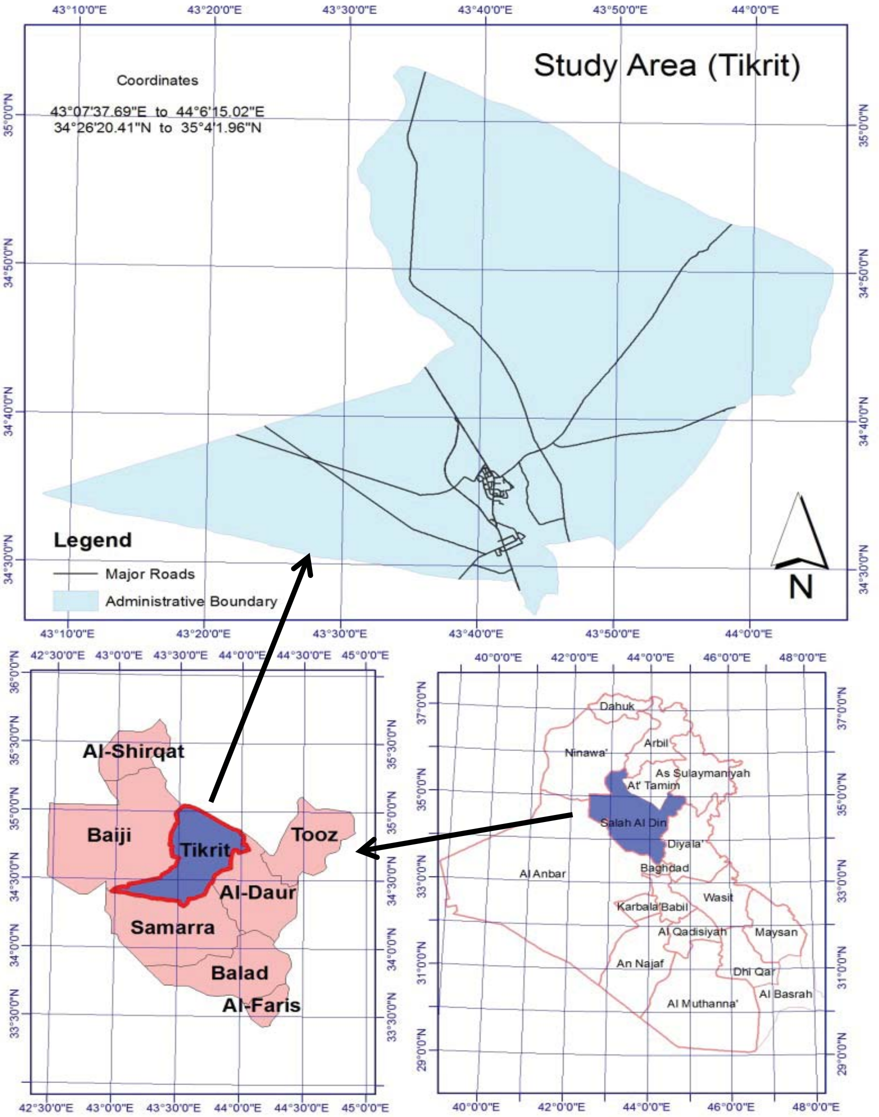

Figure 2. Study area.

The data that are used in the research are shown in table 1 and the detail of raw data are not going to be clarified as the detail can be seen in [1]. The studied data included thematic maps of 2000 and 2010 that were extracted from Landsat imagery for the two time epochs by using Maximum likelihood supervised classification. This step was done because for the process of modelling needs transition data that gives the pattern of changing to the model. This transition file was extracted by comparing the 2000 and 2010 classified maps. However, ancillary data were used in this research such as GIS map that were useful for deriving some of the restriction areas (i.e. areas cannot be developed or changed for example urban cannot be changed to water).

Table 1. Summary of data used for the study.

No.	Data Type	Acquisition Date	Source
1	Thematic Map	2000	[1].
2	Thematic Map	2010	[1].
3	Administrative and local government Map	2011	SAD Province
4	GIS Map for Iraq (UN)	2003	SAD Province
5	ASTER Global Digital Elevation Model V002 (DEM)	2011-03-16	NASA

The practical and theoretical aspects of land use and land cover change analysis and modeling implemented in this study involve several steps (Figure 3).

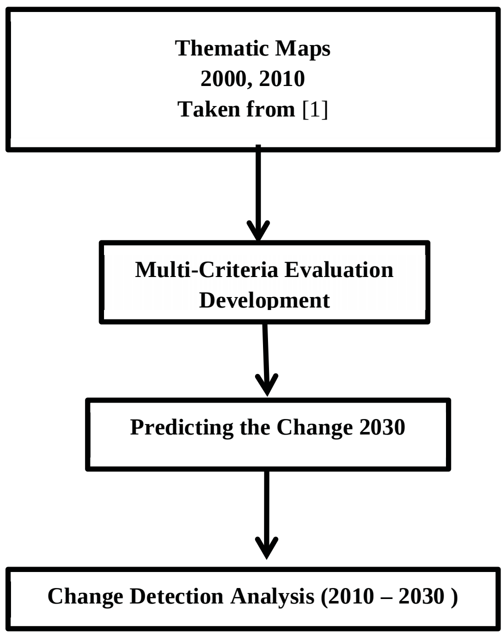

Figure 3. The methodology used in this study.

In order to predict land use and land cover changes for 2030, CA_Markov was performed in the environment of IDRISI Taiga software. As the name suggests, it is a combination of two components: Cellular Automata and Markov transition probabilities.

To perform CA_markov, preparing some inputs is required: Basic Land Cover map which was extracted by classifying a satellite image, Markov transition area file that was created by the use of Markov model in IDRISI and transition suitability image collection which is a collection of suitability images created by using MCE (Multi-Criteria Evaluation) model.

The first requirement was created in [1]. The second which is Markov Transition Area file was extracted by using Markov Module in IDRISI. The output will be a text file that contains the number of pixels, which are supposed and expected to change from one land cover type to the other through certain time units. The third requirement is the collection of suitability images that can be obtained by utilizing MCE module.

4. Criteria development

In the use of CA_Markov, criteria must be created, as they are the basis of making a measured and evaluated decision. Criteria consist of two types: Constraints and Factors.

4.1. Constraints

Constraints are used to limit the alternatives under consideration. Basically, it identifies the areas in a class that can be used for change from other classes to this class, and the areas that cannot be changed. They are represented as Boolean (Logical) maps. This means areas included in the consideration have the value 1 and the areas not included in the consideration have the value 0. These constraint images were created by using Reclass module to change them for 0 and 1 images. In this study, for each class there are constraints (Table 2).

It is worth mentioning that one of the constraints was created using ArcGIS. A DEM image which was obtained from NASA was first converted to a TIN (triangulated irregular network) image. Then the slope was created. Next, the areas with slope over 13^o were extracted from the slope raster. This was used as a constraint for urban areas as they cannot be built in the areas with more than 13^o slope.

4.2. Factors

Factors are commonly continuous images (measured in a continuous scale) defining the suitability area for the alternatives of the change. Simply put, they are images with measure of the change suitability by a continuous scale (e.g. 0 to 255). A fuzzy module is provided. The selection of the Fuzzy module parameters is based on the knowledge and the experience of the analyst. The standardization of a map is from 0 (least suitable) to 255 (most suitable).

After adding the constraints to the Decision wizard and creating the fuzzy map (considered as factor), the wizard asks to choose a method of weighting the factors and constraints. In this step, an equal weight method was chosen as there was no need for weighting the factors because they were weighted through the process of fuzzy module. The constraints were all given 0 values as they were not to be used for any change. So, the value of 1 was given to the factor layer which was created by the fuzzy module. Table 2 shows the factors and constraints and how they were considered.

Table 2. Classes' constraint and factors

Class	Constraints	Factors
Water	Non Water class	No factor
Vegetation	Urban, Water	Vegetation, Soil, Barren Land
Barren Land	Urban, Water	Barren Land, Soil, Vegetation
Soil	Urban, Water	Soil, Vegetation, Barren Land
Urban	Water, Slope	Urban, Soil, Vegetation, Barren Land

These steps were followed for each class based on 5 classes that were used (Table 2) in the maps which means they were done five times to create 5 suitability maps. Finally, gathering the five classes' suitability maps in one raster group file created the suitability map.

5. Modelling in CA_Markov

The requirements of the CA_Markov module were added to the module one by one: basic land cover which is the map of 2010 as the 2030 map had to be predicted, Markov transition areas file which was created using the 2000 and 2010 maps and a transition suitability image collection which was obtained by the decision support wizard. Then, the number of iterations was set to 20 with one iteration for each year (2010 to 2030). Finally, the module gave LULC image for 2030 as a predicted LULC.

6. Model validation

In order to ensure that the model is reliable in predicting an LULC for a specific project year, it must be validated using existing datasets. Therefore, the used model was validated by using two maps: the first one is the real land use and land cover of the year 2010, and the second map is a predicted (simulated) 2010 map. The latter was simulated by using the model and the same procedure that was implemented in predicting 2030 land use and land cover map, but, in this case, the 1990 and 2000 maps (Taken from [1]) were used for simulating 2010 maps. The validate module in IDRISI Taiga was used for validating the model by producing several parameters: Kno, Klocation, and Kstandard that are used to identify the accuracy of the model. Table 3 shows the result of the validation module.

Table 3. Kappa index result of the model validation.

Parameter	Value
Kno	0.7918
Klocation	1.0000
Kstandard	0.0157

For all of the Kappa statistics, 0% indicates that the level of agreement is equal to the agreement due to chance and 100% indicates perfect agreement. In comparing the reality map (classified) with the predicted map, the most important parameter is Kno which should be used to evaluate the overall success of the simulation or the model [9]. Klocation should be used to evaluate the ability of the simulation to identify location [9]. In this model, the value of Klocation indicates the model is perfect in specifying location. Kstandard shows almost no useful information because it compounds the location error with quantification error. So, it fails in being used for evaluating a model [9]. Hence, this value that is 0.0157 is neglected.

In addition, the CROSSTAB module was used for the same reason of validating the model that was used in simulating 2030 LULC map. It was utilized due its ability to produce Kappa index of agreement between the simulated and real map for the same time point for each class in addition to the overall Kappa coefficient.

CROSSTAB output provides many of the statistics that can be used by the user in order to separate between location error and quantification error. Location errors happen in case of there is a difference in the location of a category in a map from the location of the same category in the other map. Moreover, quantification errors happen in case of there is a difference in the quantity of cells in a specific category in a map from the quantity of the same category in the other map. Kappa Index of Agreement contains these two types of errors [9].

A real 2010 maps was taken from [1] as a classified map while a simulated 2010 was extracted in the same way of 2030. 1990 and 2000 classified maps were used in order to simulate (modelling) 2010; hence, real (classified) and simulated (modelled) were used in this module. Table 4 represents the values of the Kappa index agreement between the simulated and real 2010. In addition, the overall Kappa confident of the agreement was extracted and its value was 0.8404.

Table 4. Kappa index of agreement between the predicted and real 2010 maps.

Class	**Kappa Index of Agreement (KIA)**
NoData	0.9996
Water	0.8548
Vegetation	0.9175
Barren Land	0.7098
Soil	0.7253
Urban	0.4203

7. Result and discussion

Figure 4 shows the projected land cover/use for the year 2030. By visual examination and comparison with 2010 Land cover map (Figure 5), it can be seen that there is a significant increase in the urban areas, and this increase is of three types: one of them is in-fill urban expansion which occurs within existing urban areas; the second is extension of existing urban areas and the third is termed ‘leap frog’ expansion, which refers to dispersed urban area growth that is disconnected from existing urban areas.

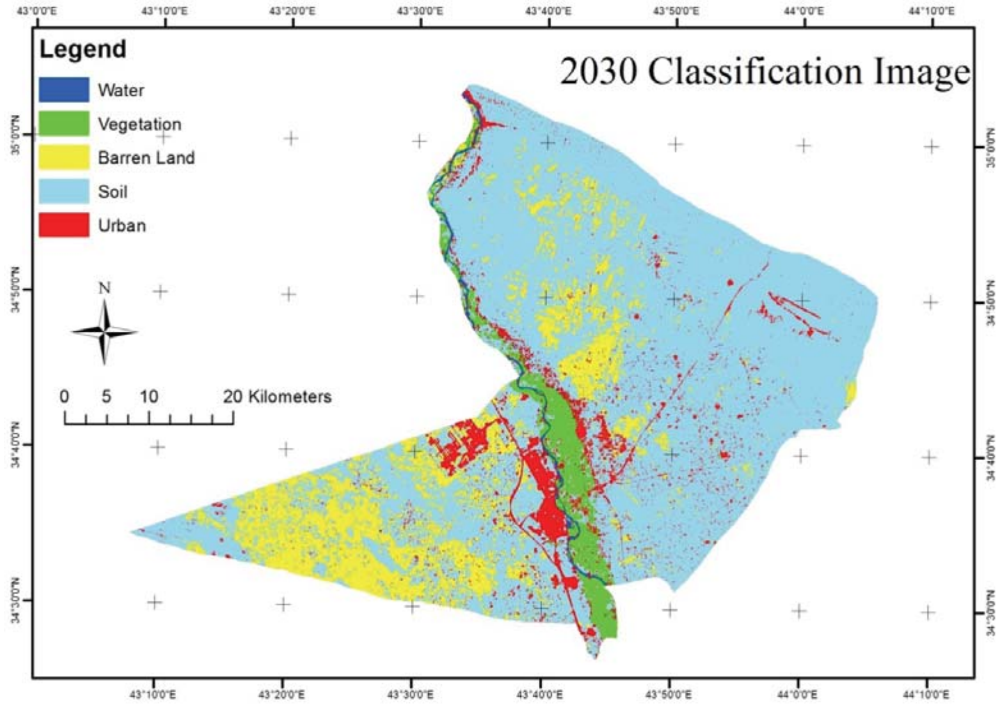

Figure 4. Projected Map of the year 2030.

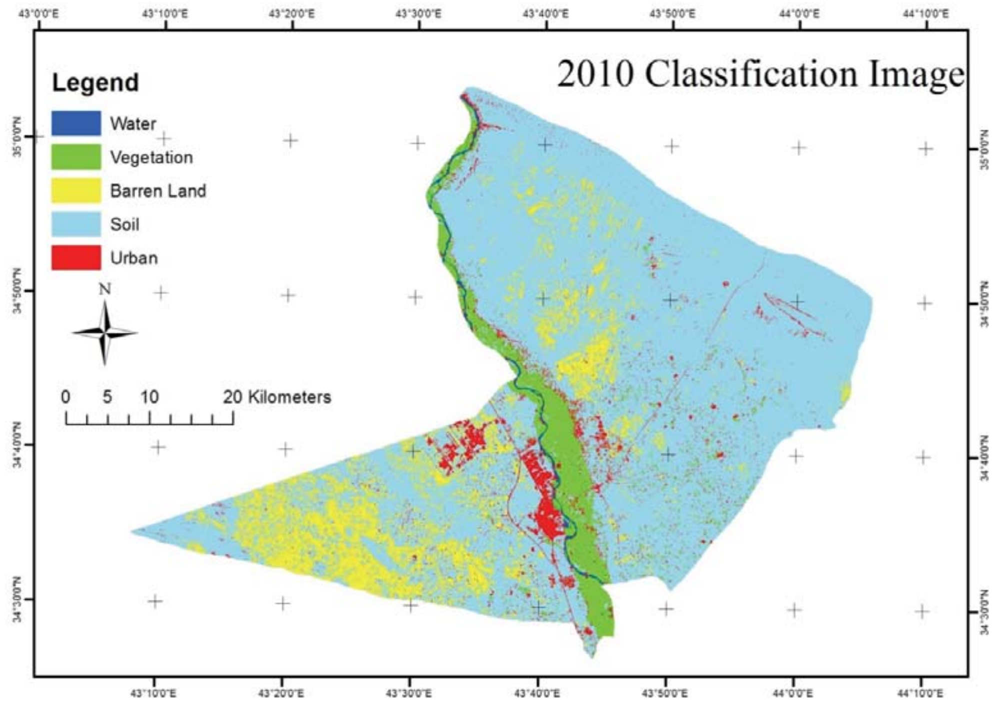

Figure 5. Projected Map of the year 2010.

Table 5 shows the areas of land covers that were calculated from the map that was predicted for the targeted year 2030.

Table 5. Areas of land covers in 2030 measured in km^2

No.	Land Cover	Area km2
1	Water	18.50
2	Vegetation	103.55
3	Barren Land	391.03
4	Soil	1866.37
5	Urban	175.24

Based on table 6 and figure 6, the most identifiable change that should be taken into consideration is the increase in the area of urban land cover by 58.42 km^2 with a percentage of 50.01% with no area loss through the period between 2010 and the prediction year 2030. As mentioned earlier, if a new planned base map is not used to regulate the growth, an urban sprawl threatens to appear in the city. Vegetation area is predicted to decrease in 2030 by 45.11 km^2 with a percentage of 30.34%, which is a large reduction that can significantly contribute to eco-environment degradation. A plan needs to be put in place to control this degradation by methods such as planting trees around the city to increase the green cover that can act as a dam for dust that comes from the west of Iraq to Tikrit city. The plan could incorporate irrigation projects in the soil area, which decreased by 111.51 km2 with a percentage of 5.64%, and the barren land which increased by 94.24 km^2 with a percentage of 31.75%. These projects can be used by farmers to increase their production and can be used by the government for starting new plantation projects.

Table 6. Losses and Gains in land covers/uses areas between 2010 and 2030 measured in km^2.

	Loss	Gain	Net Change	% of Change
Water	0	3.95	3.95	27.16
Vegetation	-45.44	0.33	-45.11	30.34
Barren Land	-8.62	102.86	94.24	31.75
Soil	-154.78	43.27	-111.51	5.64
Urban	0	58.42	58.42	50.01

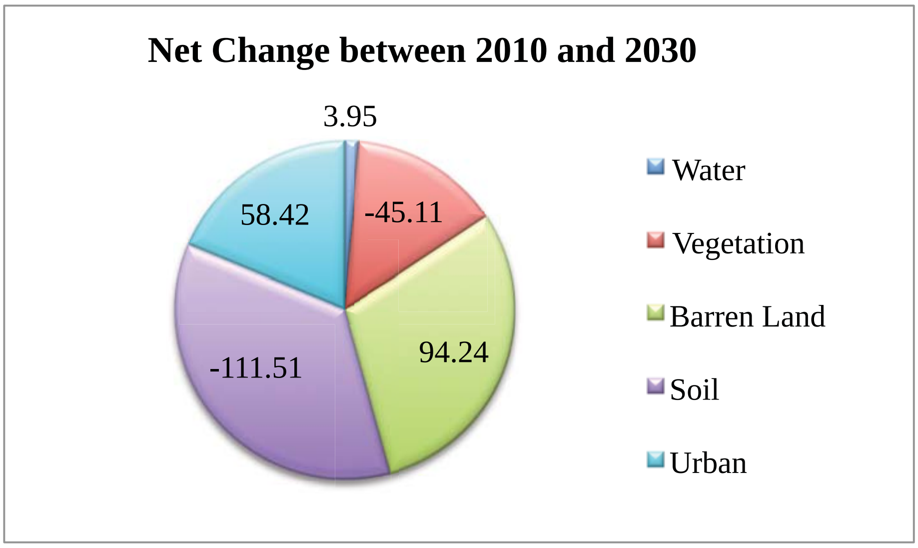

Figure 6. Net changes on the area of Land cover/use types in 2010-2030.

8. Conclusions

In the projected image for 2030, it is found that the vegetation will decrease by a great amount, which must be regulated in order to maintain a green environment. Also, three modes of urban expansion are expected to occur quite dramatically, which need to be monitored and controlled by a base map accompanied by strong laws to implement it. The most viable solution for such problems is building dams in the river in order to store the water, building some irrigation channels around the city and directing water to them so it reaches the largest possible area.

Moreover, by using different remote sensing datasets, satellite image, GIS vector maps, and hard copy maps, it is demonstrated that GIS and remote sensing are excellent ways of identifying the changes that take place in land cover and land use because of their ability to provide data for different times that facilitates decision making. Also, these tools are instrumental in modeling future land cover/ use.
Finally, predicting land use/land cover changes and identifying their consequences is based on the capability of understanding the drivers (past, current) of land use and land cover change.

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