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Assessing the Effect of Land-Use and Land-Cover Change on Groundwater Recharge in Akaki Catchment, Central Ethiopia.

Mearg Belay Shibeshi, N.Rao Cheepurupalli, K.V. Suryabahagavan, Dessie Nedaw

Abstract: ***Land-Use and Land-cover (LU/LC) changes are the major factors influencing catchment hydrology. Thus, understanding the impact of LU/LC on recharge is important for management of water resources. The present study area is located in the central Ethiopian highlands of the Main Ethiopian Rift. The main objective of this study was to determine the LU/LC change of Akaki catchment between the year1986−2015 G.C and to evaluate the impact of these changes on recharge. To analyze the changes in area over the time, a satellite image was obtained for the years 1986, 2000 and 2015. The methodology consists three steps. First land-cover (LC) maps of the year 1986, 2000 and 2015 were compiled. Secondly, the relationship between hydro meteorological elements and recharge has investigated. Finally, WetSpass modeling was applied to estimate the seasonal and annual ground water recharge. The model was run for the three different years LC maps keeping the other parameters constant. Hence, the result reflects impact of LULC change on recharge. The simulated results of the model indicates that the mean annual recharge was decreasing from 268.6 mm/y for land–use(LU) map of 1986 to 264.9 mm/y and 260 mm/y for LU maps of 2000 and 2015, respectively. The Study outputs indicated that recharge in the catchment did not change significantly. However, LULC had remarkable variation in the period between1986 and 2015. This result provides a better understanding of the spreading situation of Akaki catchment which would support decision making process to control the ground water conditions.***

Keywords: ***Akaki catchment, GIS, Groundwater recharge, WetSpass.***

I. INTRODUCTION

Understanding impacts of land-use/land-cover (LU/LC) change on the hydrologic cycle is needed for optimal management of natural resources. Impacts of LU/LC change on atmospheric components of the hydrologic cycle (regional and global climate) are increasingly recognized [1]. Unlike surface water where, the impact of land-use and land-cover change on subsurface components of the hydrologic cycle, the saturated and unsaturated zone are less well recognized, in particularly groundwater recharge. However, the potential scale of subsurface impacts is large. So far, impacts of LU/LC change on ground water resource particularly ground water recharges are less well recognized. Therefore, to estimate and understand the impact of LU/LC change on ground water recharge, it is also important to accurately assess the type and direction of changes occurring within the watershed. Thus, land use changes have to be evaluated properly using conventional and latest geospatial techniques like Remote Sensing and geographic information system (GIS). For the sustainable management of groundwater resources, the amount of recharge received by an aquifer is by far the most important figure required. Yet this figure is usually the least well-known quantity in hydrogeology, especially in arid and semi-arid environments [2]. Unfortunately, it cannot be measured directly on any reasonable spatial scale. That so many years of effort have failed to find a single, reliable method for measuring groundwater recharge is due to the complexity of this phenomenon and the large variety of situations encountered. However, estimation of groundwater recharge is of great importance in water resources management, especially for areas in which groundwater is vital for the local water supply. Exact estimation of regional groundwater recharge requires a good understanding of the hydrological processes in the area, which could be greatly altered by global change and human activities [3]. It is also important to understand how LU/LC change impacts ground water recharge, especially in regions that are undergoing rapid urbanization. Therefore, this study focused on the analysis of hydrological processes and recharge ability of various land–use types in the Akaki catchment, central Ethiopia. This can be accomplished through change detection analysis of multi-temporal remotely sensed imagery. Correlating historical LU/ LC practices with recharge can be used to assess the impact of changes on ground water recharge. A specific modeling tool to estimate recharge that should be mentioned in depth, as it was used in this research project, is the WetSpass modeling. The WetSpass model calculates the water balance of a grid cell while considering the fractions of vegetation, bare soil, open water and impervious area; therefore, it provides a good choice for estimation of long-term average spatial patterns of groundwater recharge [4]-[6]. For this study the WetSpass model is to be applied with a focus on how hydrological processes respond to land use change, and what affect various land uses have on groundwater recharge.

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*Correspondence Author
Mearg Belay Shibeshi*, Department of Geology, School of Mines, Aksum University, Ethiopia. Email: meargbly@gmail.com
N.Rao Cheepurupalli, Department of Mineral Processing Engineering, School of Mines, Aksum University, Ethiopia. Email: nraocheepurupalli@gmail.com
K.V. Suryabahagavan, School of Earth sciences, Addis Ababa University, Ethiopia. Email: drsuryabhagavan@gmail.com
Dessie Nedaw, School of Earth sciences, Addis Ababa University, Ethiopia. Email : dessienedaw@yahoo.com

A. Wetspass Model

WetSpass is an acronym for Water and Energy Transfer between Soil, Plants and Atmosphere under quasi-Steady State and it was built as a physically based methodology for estimation of the long-term average, spatially varying,

water balance components: surface runoff, actual evapotranspiration and groundwater recharge. It is especially suited for studying long-term effects of land use changes on the water regime in a watershed. The model is completely integrated with GIS ArcView (3.x) as a raster model coded in Avenue, the programming language of ArcView. Parameters such as land use and soil types are connected to the model as attribute tables of land use and soil raster maps, which allow new definitions of climatic as well as land use and soil types [5].

WetSpass requires spatially-distributed input data for land cover, soil texture, topography, precipitation, wind speed, groundwater depth and potential evapotranspiration at any meters resolution. However, precipitation and soil inputs are the drivers. In this study, the different land cover maps were resampled to a spatial resolution of 30x30 meters. In addition, the model needs a series of model parameters that describe the model's behavior. The model uses seasonal (summer and winter) geographical information systems (GIS) input grids of the mentioned inputs to estimate annual and seasonal groundwater recharge values:

$$R = P - S - ET \qquad \text{Equation (1)}$$

Where, R is the groundwater recharge, P is the precipitation, S is surface runoff and ET is evapotranspiration, with mm units for all parameters. The surface runoff depends on the land-use, soil, and slope and precipitation intensity in relation to infiltration capacity of the soil. It is calculated using the classical rational formula:

$$S = CHOR\ C\ (P - I) \qquad \text{Equation (2)}$$

Where, CHOR is a coefficient that parameterizes the part of the seasonal precipitation that actually contributes to runoff, C is a runoff coefficient based on the rational formula and I is the interception (mm). Evapotranspiration is calculated as a sum of evaporation, transpiration and interception. In this research study, ground water recharge of the catchment under different land use scenarios was estimated using the WetSpass modeling methods. WetSpass gives various hydrologic outputs on a yearly and seasonal (summer and winter) basis. Even though the model was originally developed to compute the long-term spatially distributed recharge of a basin. It also simulates runoff, evapotranspiration, interception, transpiration, soil evaporation and errors in water balance. This model has been used in many instances to estimate groundwater recharge. To assess the effect of land-use and land-cover change on the ground water recharge of the catchment, the WetSpass model was run for the three different time land-use and land-cover grid maps keeping the other impute parameter constant

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II. MATERIALS AND METHODS

A. Description of the study area

The Akaki catchment is located in the central Ethiopian highlands at the western margin of the Main Ethiopian Rift (MER). The catchment is situated at the northwestern Awash River basin between latitude 456616.37−503051.3N and longitude 988157.06−1019420.7 E covering a total area of the catchment about 1,466.56 km^2 Fig.1. The watershed boundary of the study area is characterized by large central volcanoes and a well-developed morphology.

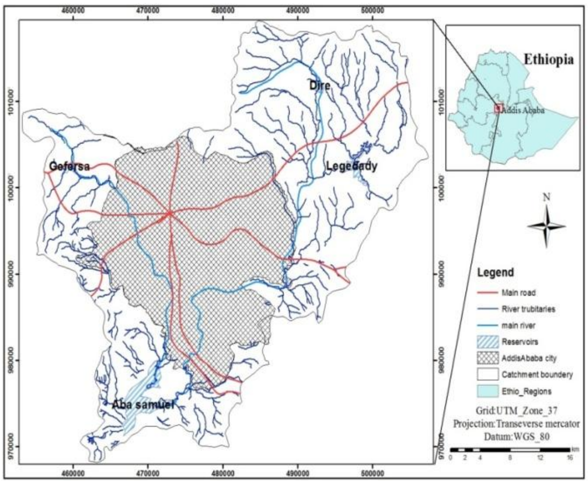

Fig. 1. Location map of the study area

It is surrounded by high rising mountain systems in all directions and the center of the catchment lies on an undulating topography with some flat land areas. Intotomountain ridge forms the northern boundary of the city following the East-West trending Ambo - Kassam major fault system. The elevation of this ridge ranges from 2,600 to 3,200 masl forming the main recharge area. The volcanic mountains, Mt. Wechecha in the west, Mt. Furi in the south–west, and Mt. Yerer in the south–east are the high massive volcanic centers Fig. 2.

B. Climate

In order to understand the environment and the possible impact of human activity on it, a basic knowledge of weather and climate is required. Since the mid-twentieth century, carbon dioxide levels in the atmosphere have been steadily rising. If this phenomenon continues, many researchers believe that the global and local climate characteristics will be significantly altered in the coming decades [6],[7]. This trend has been termed climate change, and would likely have large effects on the hydrologic cycle around the world. The climate of the study area is typically characterized by two distinct seasonal weather patterns: the wet season, which extends from June to September, contributing for about 73.7% of the annual rainfall, and the dry season which covers the period from October to May, with intermittent rainfall in the rest of the months [8]. The maximum mean monthly temperature of Akaki catchment ranges between 21.1^{o}C (wet season) to 29^{o}C (dry season), while the minimum falls between 7^{o}C–12^{o}C [9]. The wind flow pattern is influenced by the seasonal variation of the Inter Tropical Convergence Zone.

The mean annual wind speed is 0.68 m/s. Sunshine hours vary from a daily mean of 9.66 hours in December to 2.18 hours in July. The monthly variation closely follows the rainfall pattern as would be expected with more sunshine hours in the dry months than in the wet months. At a station in Akaki catchment relative humidity has been measured four times a day since 2013. The Relative humidity records show the average annual relative humidity value of 51.2% with average minimum monthly of 39.8% in December and reaches maximum 72% in August [9].

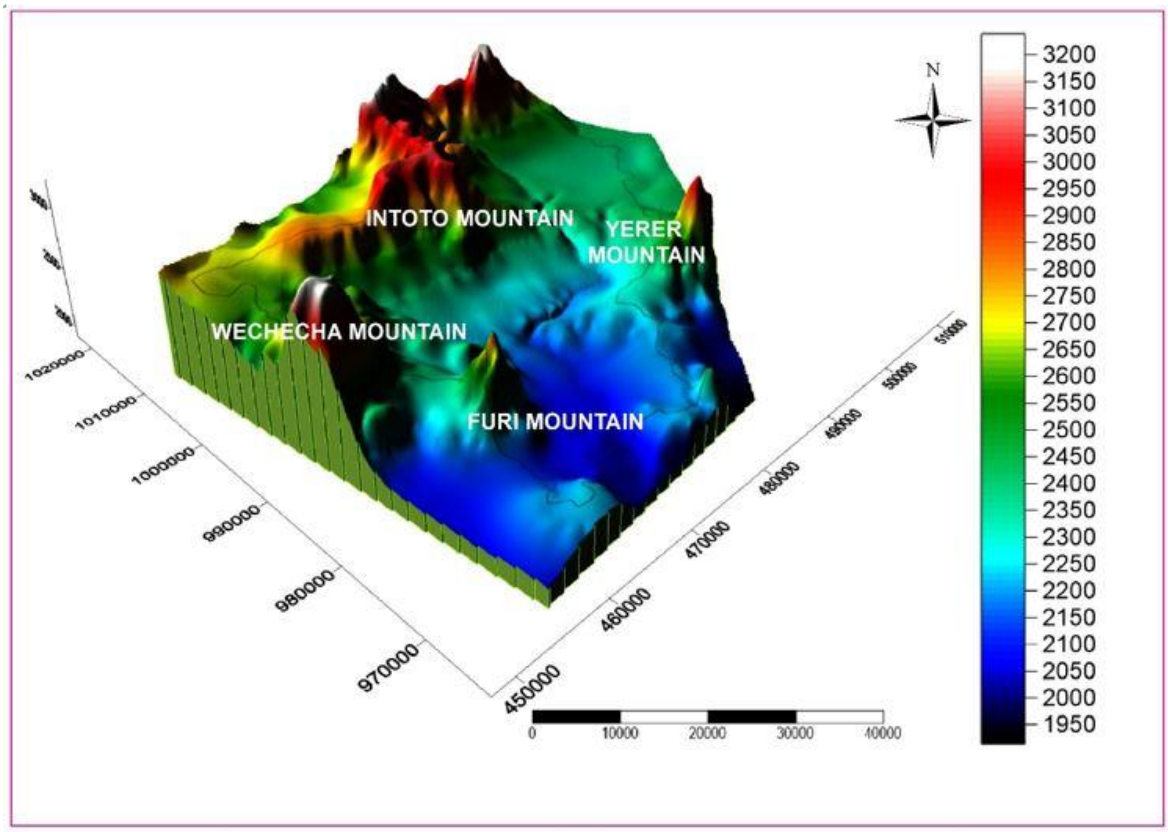

Fig. 2. Physiographic map of Akaki catchment

C. Geology of the StudyIarea

Because of its physiographic position the geological history of the study area is an integral part of the evolution and the development of the Ethiopian plateau and the rift system. Many researchers have conducted the geological and stereo graphic sequences of the Akaki catchment [10], [11]. Based on field investigation, satellite image interpretation and previous geological studies a simplified geological map was established in Fig. 3. According to reference [12], the following lithostratigraphic units can be identified in the catchment younging to the south.

Alaji Formation

In this part of the escarpment, the Alaji group volcanic rocks (Alaji rhyolite and IntotoSilicics) were outpoured from the end of Oligocene until middle Miocene [13]. This unit is dominant in the northern part of the study area and it extends from the crest of Intoto (ridge bordering the northern parts of Addis Ababa) towards the north [11]. The main rock types in this unit includes rhyolites, trachytes, tuff, agglomerate, and aphanitic basalt. The EntotoSilicics represents massive Oligocene fissure-basalt, rhyolites, and trachytes with minor welded tuff and obsidian [10].

Addis Ababa Basalts

Stratigraphically, this unit is underlain by the Entotosilicics and overlain by lower welded tuff of the Nazareth group. It is porphyritic in texture and mainly present in the central part of the city [11], and covers the central and southern part of Addis Ababa. Olivine porphyritic basalts outcrop around Merkato, Teklehamanote and Sidest Kilo with a varying thickness. The Lower Welded tuff overlies Olivine porphyritic basalt near by the building college, the kolfe Police School, the KokebeTsebah School and Yeka Mariam church. On the other hand, only in the gorge of the Ketchene stream the olivine porphyritic basalt is overlain by the plagioclase porphyritic basalt [14].

Younger Volcanics (Nazaret Group and Bishoftu Formations)

The units identified in the Nazaret group denoted as lower welded tuff, aphanitic basalt and upper welded tuff. The Nazaret group is underlain by Addis Ababa basalt and overlain by Bofa basalts. Bofa Basalts outcrop south ward from Akaki River where they appear in the form of boulders reaching a thickness of 10m. They are restricted and dominated in the south eastern part of the city. This rock is characterized by big vesicles that are filled by calcite. This basalt is underlain by the tuffs which cover the welded tuff. The rock outcrops mainly south of Filowha fault and extends towards Nazaret. They are composed of aphanitic basalts, welded tuffs, ignimbrites, trachytes, and rhyolites. The Bishoftu formation consists of olivine porphyritic basalt, scoria, vesicular and scoriaceous basalt, and locally trachy-basalt lava flows [15].

They are localized in the south and are 20 to 40 m thick in the Akaki well field. Locally, it is overlain by scoria, tuff, sand, and gravel. This unit forms the major aquifer of the region [15].

Recent Deposits

These include alluvial, residual, and lacustrine deposits. The thickness varies between 5m and 50m near river banks in the south [16]. It is overlain by dark younger black cotton clayed soils. Alluvial deposits are found in some places along the little and Big Akaki rivers, particularly south and south west of Addis Ababa. Residual soils are located in the central, south east, northeast, and western flat plains.

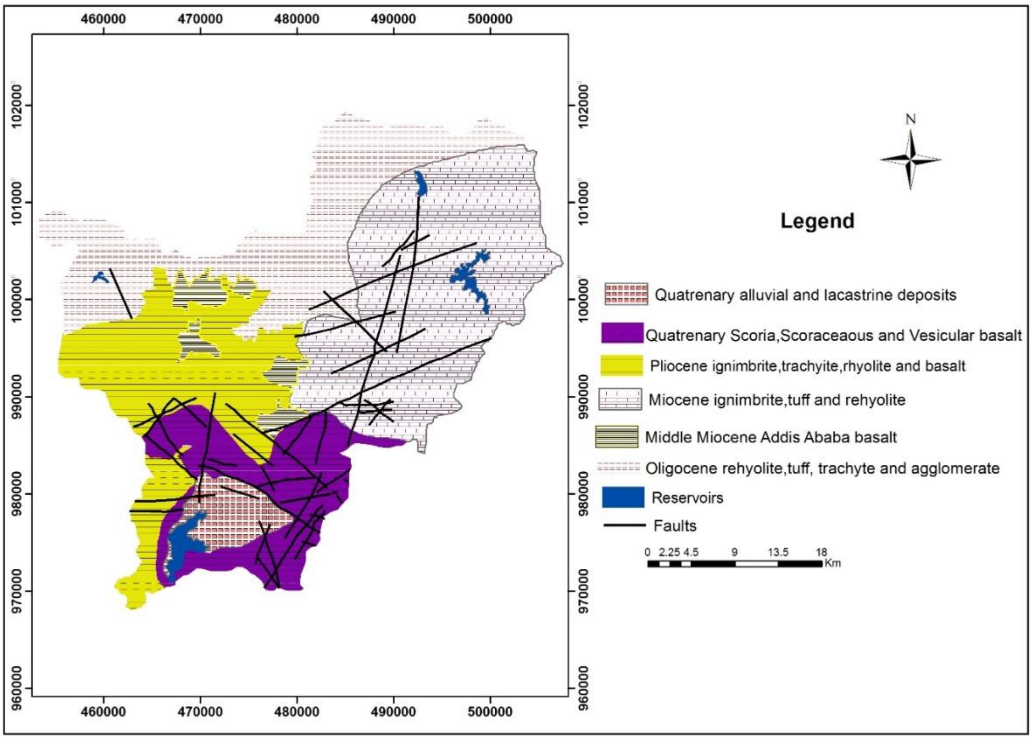

Fig. 3. Geological map of the study area

D. Methods

This study was conducted using data collected from literature, secondary data collected from office, primary data gathered from field survey and laboratory analysis of remote sensing imageries. The methodology used for this study was given below in the form of a flow chart in Fig. 4.

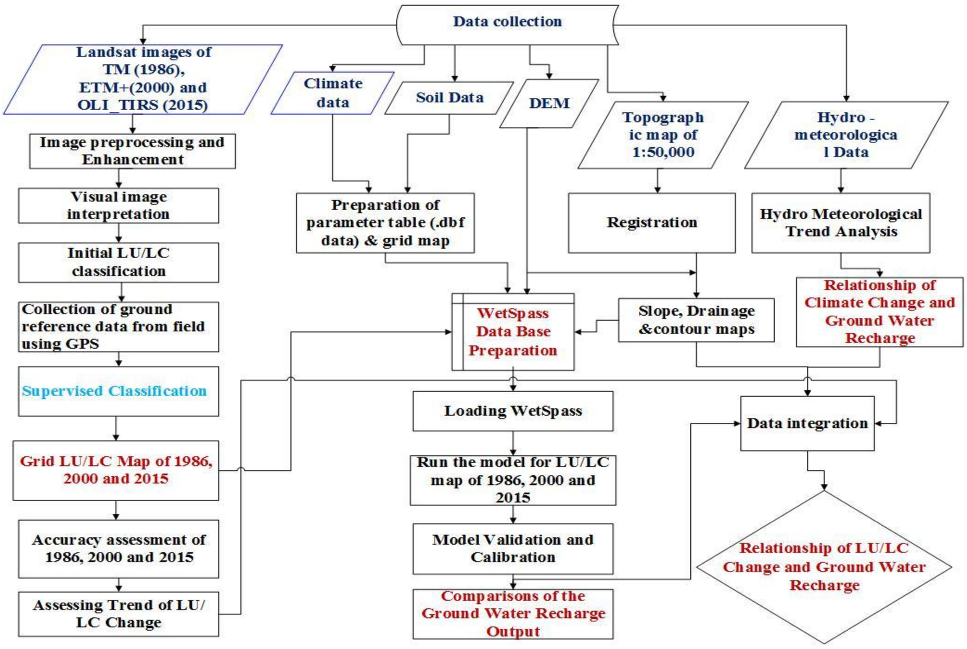

Fig. 4. Flow chart showing the general frame work of the study.

III. RESULTS AND DISCUSSION

A. Land-Use and land-Cover change detection

The land–use maps for 1986, 2000, and 2015 for Akaki catchment are presented in Fig.5. Comparison of classification results suggest that the principal land–cover changes observed in the study area between 1986 and 2015 are the urban settlement, grass land, forest and cultivated lands. The area and percentage coverage of these five land–use classes during the three intervals are presented in Table I.

It shows that the urban settlement and cultivated land areas were increased while that of forest and grass land declined continuously from 1986 till 2015.

Table- I: Land-use/ land-cover categories in the study area during 1986, 2000 and 2015

Land-use classes	1986		2000		2015	
	Area in (ha)	Area in (%)	Area in (ha)	Area in (%)	Area in (ha)	Area in (%)
Water body	1552.62	1.059	1734.94	1.18	1624	1.1
Urban settlement	16005.8	10.91	22899.8	15.61	32052.1	21.86
Grass land	37708.3	25.71	31136.25	21.23	21512.2	14.67
Forest land	19886.26	13.56	18501.95	12.62	14563.1	9.9
Cultivated land	71502.9	48.76	72383	49.36	76904.5	52.44
Total	146656	100	146656	100	146656	100

Table I shows the spatial distribution of land-use/land-cover categories of the study area during the three years 1986, 2000 and 2015 in the Akaki catchment. For the year 1986, the land cover map is shown in Fig. 5a. The percentage coverage of each class is shown in Table I and indicates that the highest area of the catchment is covered with cultivated land (48.97%), while forest, grass land, urban settlement and water covered 13.56%, 25.71%, 10.9% and 1.06%, respectively.

For land-use/land-cover map of 2000 as shown in Fig. 5b, the areal coverage of cultivated land, urban settlement and water body was increased to 49.36%, 15.61% and 1.18%, respectively, while the areal coverage of forest land and grass land was decreased to 12.62% and 21.23%, respectively.

The LU/LC map for 2015 of the Akaki catchment is presented in Fig. 5c, in which the cultivated land is covered for about 52.44% of the areal extent of Akaki catchment. Whereas forest land, grass land, urban settlement and water body covered 9.9%, 14.67%, 21.86% and 1.1% of the areal coverage of the study area, respectively.

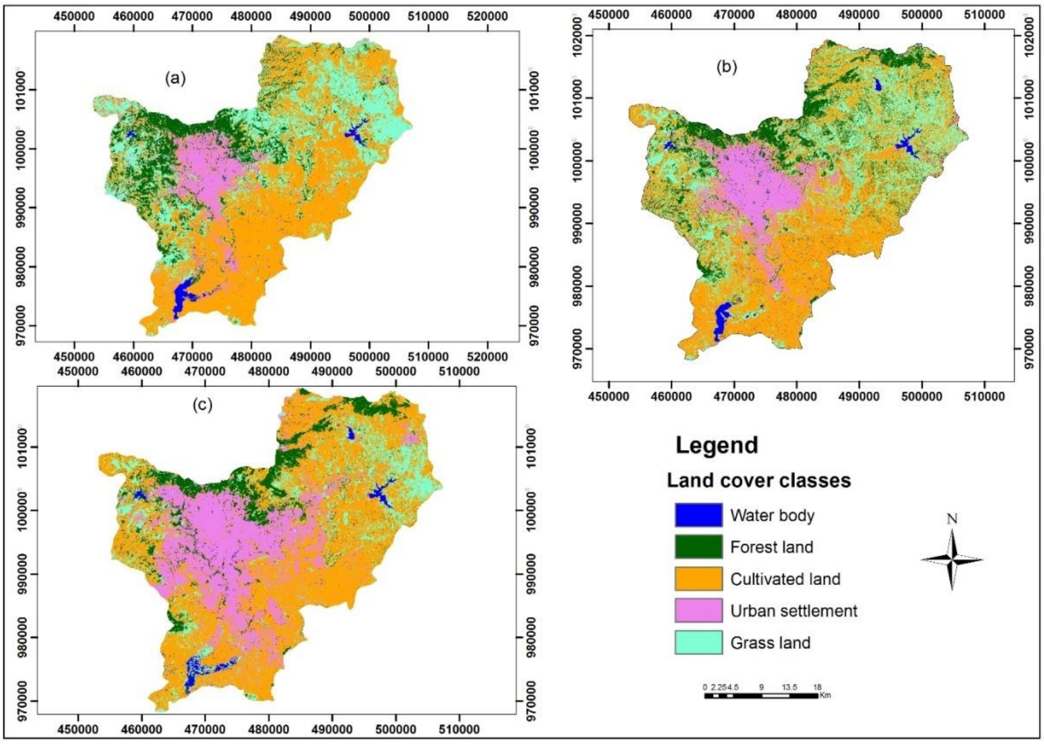

Fig .5. Land–use map of the years 1986 (a), 2000 (b) and 2015(c)

B. WetSpass model

WetSpass gives various hydrologic output grids on a yearly and seasonal (summer and winter) basis. Even though the model was originally developed to compute the long-term spatially distributed recharge of a basin, it also simulates runoff, evapotranspiration, interception, transpiration, soil evaporation and errors in water balance.

The results of the modeling are given by digital grid maps of the spatial distribution of annual average values of actual evapotranspiration, surface runoff and groundwater recharge for the 29 years period from 1986 to 2015 under different land use scenarios.

a. Groundwater recharge under different land–uses scenarios

The WetSpass model was applied for the three different land–use maps to assess the impact of land–use and land–cover change on water balance of the catchment especially ground water recharge. It estimates seasonal and annual long-term spatial distribution amounts of groundwater recharge by subtracting the seasonal and annual surface runoff and evapotranspiration from the seasonal and annual precipitation respectively. A simulated result of WetSpass modeling for groundwater recharge was summarized for each period as an average map Fig. 6. The results indicated that the total annual ground water recharge for Akaki catchment was changed insignificantly from time to time with change in land–use and land–cover. The model estimates the simulated total annual ground water recharge of the catchment for land–use and land–cover maps of 1986, 2000 and 2015 to be 9,622,050.3 mm/y, 9,490,260.5 mm/y and 9,315,814.2 mm/y respectively.

Table II shows the simulation results of WetSpass modeling for ground water recharge under different land–use and land–cover scenarios and season (summer and winter). It also shows both the annual and seasonal ground water recharge of the catchment was slightly decreasing with changing in land–use and land–cover.

Table- II: Comparison of ground water recharge under different land use and land cover scenarios

Year	Average Annual ground water recharge (mm/y)	Total annual ground water recharge (mm/y)	Average summer ground water recharge (mm)	Average winter ground water recharge (mm)	Annual Std. deviation
1986	268.55	9,622,050.3	248	20.6	205
2000	264.9	9,490,260.5	247	17.9	197
2015	260	9,315,814.2	243	16.9	197

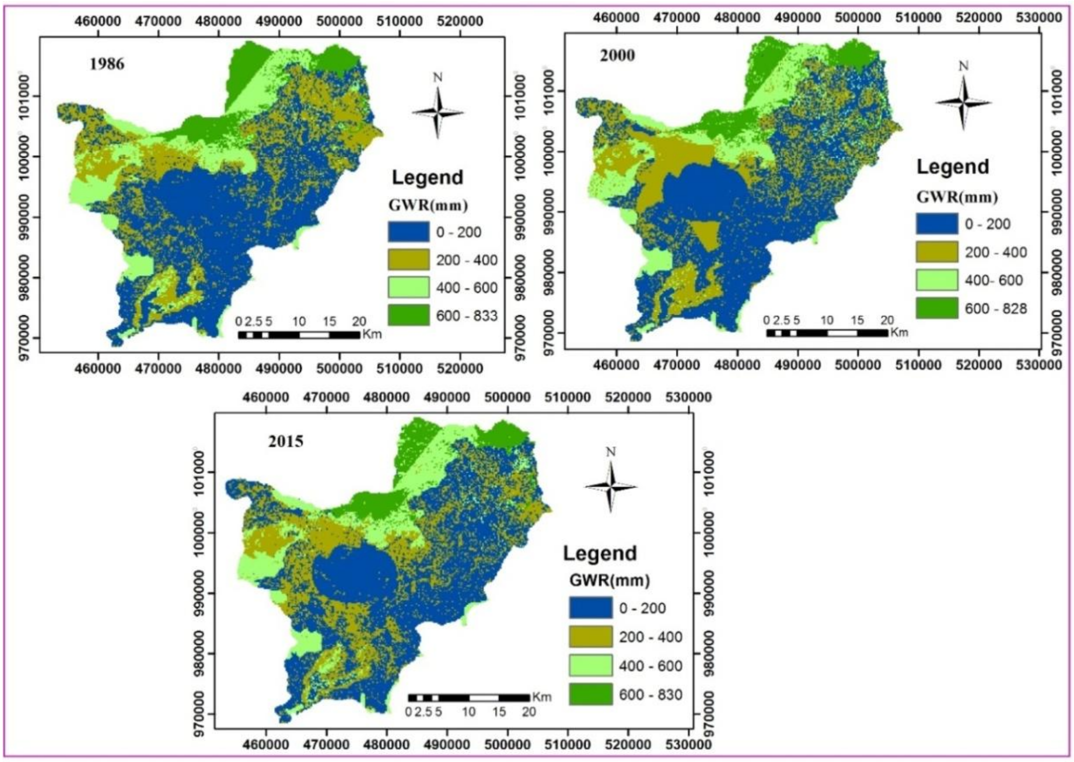

Fig. 6. Annual ground water recharge maps of the years (a) 1986, (b) 2000 and (c) 2015

C. Discussion

a. Impact of land–use change on groundwater recharge

Based on three different periods of remote sensing and the longterm observed hydro-meteorological data from the 1986 to 2015, the impacts of land use changes in the groundwater system in the Akaki catchment were analyzed by estimating of groundwater recharge. Land-use and land-cover changes like urban settlement expansion and change of grass land and forest land in to cultivated land are found to be the major changes in the catchment. From the land–use land–cover classification result maps for the periods of 1986, 2000 and 2015, it has been observed that grass land and forest land have changed negatively during 1986 to 2015 change detection phase by -16,196.1 ha and -5,323.16 ha area while urban settlement, cultivated land and water body area have changed positively by 16,046.3 ha, 5,401.6 ha and 71.38ha respectively.

Such dramatic change was caused by the uncontrolled expansion of urbanization, industrialization and increase of population. It has been reported that in many parts of the world the water table is declining at the rate of 1–2 meter/year as a result of population increase and land–use and land–cover changes particularly urban expansion and deforestation [17]. The effects of uncontrolled population growth are obvious such as forest destruction, pressure on land–and other natural resources, unsustainable pattern of land–use for agriculture, degradation of land–and depletion of resources.

These environmental consequences in turn lead to other problems. For instance, vegetation destruction increases surface runoff by doing that it affects the ground water recharge. The above change also highly affects infiltration condition of rain water which supply to the ground water by increasing surface runoff due to the reduction of forest cover which serves one as a barrier for reducing the speed of the runoff and also it reduces evaporation by increasing the humidity of the surrounding environment which have a great influence on the ground water recharge condition of the catchment. The distribution of the different land-use and land-cover classes in the catchment can affects the groundwater recharge quantity. Beside the areal coverage and type of land– use classes in the catchment, the distribution and location of these classes can affect the groundwater recharge quantity. This situation was also found in some other studies like [18] that considered land–cover change as a factor for reduction of ground water recharge quantity. For example, despite the increase in urban settlement area and decrease in forest area, the values of groundwater recharge by the period of 2015 have decreased compared with the value of ground water recharge by the year 1986.

According to [19], most of the impacted are on a global scale can be expected from large-scale removal or planting of forests, which may have an impact on potential and actual evapotranspiration and on precipitation patterns and amounts. Similarly, the decrease in groundwater recharge of the catchment in this study is a result of the fast expansion of urban settlement in the areas of high recharge values (the high altitude areas of the central to northern parts) and a decrease of the forest cover in the northern and north western parts of the catchment. This situation was also found in some other studies like [20] that considered urban land to be impervious areas that promote surface runoff and prohibit infiltration. Some previous works that make effort to estimate ground water recharge are available in the Akaki catchment such as the one published by [21], [16] and [22]. The model results for this research were continuously verified by the previous model results and independent runoff data. According to [21] estimates ground water recharge of the Akaki catchment by using the chloride mass balance (CMB) method and he was calculated the annual ground water recharge of the catchment to be 265 mm, which amounts to 23% of the weighted mean annual areal precipitation of the catchment. Comparison of this value with the present simulated model result appears to be in a good agreement. On the other hand, reference [22] estimates the average recharge of the catchment by using empirical model known as DRASTIC and GIS. However, this study appears to overestimate the recharge values estimated by [21], [16] and [22]. The variation in the estimated values of ground water recharge by different methods indicates the requirements of relatively high quality methods of recharge estimation. Hence, for successful estimation of groundwater recharge utilization of a variety of exhaustive and accurate independent methods is mandatory. The present investigation has demonstrated that the estimation of groundwater recharge using WetSpass is in good agreement with those obtained by other studies. Agreement of the WetSpass model result with some research studies indicates the validity of the simulated recharge.

IV. CONCLUSION

Humans have exerted large–scale changes on the terrestrial biosphere, primarily through the land-use/land-cover changing. However, the impacts of such changes on the hydrologic cycle particularly groundwater recharge are poorly understood. Hence, groundwater recharge estimations under different land–use scenarios are essential for the management of groundwater aquifers. The objective of this study was firstly to use RS imageries to see the changes on LU/LC of the catchment for the past 29 years. Secondly, to map areas of recharge and understand how land management practices could affect recharge through recharge estimation. In this study, a geospatial analysis approach based on RS-GIS technology and the seasonal steady-state water balance model, WetSpass, was implemented for the estimation of groundwater recharge in Akaki catchment under different LU/LC scenarios. Comparison of classification results suggests that the principal LU/LC changes in the study area between 1986 and 2015 are the urban settlement, grass land, cultivated lands and forest reduction. It indicates that the water body, urban settlement and cultivated land areal coverage from 1986 to 2015 increases form 1,552.6 hectare, 16,005.8 hectare and 71,502.9 hectare to 1,624 hectare, 32,052.1 hectare and 76,904.5 hectare respectively. While forest and grass lands are decreased from 19,886.26 hectare and 37,708.3 hectare to 14,563.1 hectare and 21,512.2 hectare respectively. Results from the WetSpass model are in good agreement with some of the recent previous studies and indicates the validity of the simulated recharge.

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REFERENCES

1. IPCC, Climate change, "The physical science basis.10thSession of working Group I of the IPCC", Paris. France. 2007.

2. W. Kinzelbach, W. Aeschbach, C. Alberich, B.GoniI, U. Beyerle, P. Brunner, W.H. Chiang, J.Rueedi, and K.iZoellmann, ”A Survey of Methods for Groundwater Recharge in Arid and Semi-arid regions. Early Warning and Assessment Report Series”, UNEP/DEWA/RS.02-2. United Nations Environment Programme, Nairobi, Kenya. 2002.
3. B.T. Nolan, R.W. Healy, and P. E. Taber,”Factors influencing ground-water recharge in the eastern United States”. Journal of Hydrology, 332: 2007, pp: 187–205.
4. O. Batelaan, and F. DeSmedt, ”WetSpass: a flexible, GIS based, distributed recharge methodology for regional groundwater modeling”, Proceedings of a symposium held during the Sixth IAHS Scientific Assembly at Maastricht, The Netherlands, IAHS Publication. 269, 2001, pp: 117.
5. O. Batelaan, F. DeSmedt, and L. Triest, ”Regional groundwater discharge: Phreatophyte mapping, groundwater modeling and impact analysis of landuse change”, Journal of Hydrology. **275**: 2003, pp: 86–108.
6. O. Batelaan, F. DeSmedt, ”GIS based recharge estimation by coupling surface subsurface water balance”, Journal of hydrology. 337, 2007, pp: 337–355.
7. P, Ranjan, S, Kazama, and M. Sawamoto, "Effects of climate change on coastal fresh groundwater resources." Global Environmental Change. 16: 2006, pp: 388-399.
8. NMSA, “Initial National Communication of Ethiopia to the United Nations Framework Convention on Climate Change (UNFCCC)”, National Meteorological Service Agency, Addis Ababa, Ethiopia. 2001.
9. E. Oljira,”Numerical ground water flow simulation of Akaki river catchment.”, Unpublished MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia, 2006.
10. W.H. Morton, D.C. Rex, J.G. Mitchell, and P.A. Mohr, “Rift ward younging of volcanic rocks in the Addis Ababa region, Ethiopian Rift valley”, Nature, 280: 1979, pp: 284–288.
11. H. Girmay, and G. Assefa, ”Addis Ababa-Nazareth Volcanic: A Miocene-Pleistocene Volcanic Succession in Ethiopian Rift, Ethiopian,” Journal of Science, Addis Ababa, Ethiopia. 1989, pp: 163. http://earthexplorer.usgs.gov/
12. Addis Ababa Water and Sewerage Authority (AAWSA) Addis Ababa water supply project stage III, detail report, and ground water resource. Addis Ababa Water and Sewerage Authority, Addis Ababa, Ethiopia, 1991.
13. B. Zanettin, and E. Justin-Visentin, ”The volcanic succession in central Ethiopia: The volcanics of the western Afar and the Ethiopian Rift margins”, Mem Ist Geol Miner Univ. Padova. 31: 1974, pp: 1–19.
14. A. Vernier, G. Assefa, and H. Girmay, “Lithostratigraphy of the volcanic rocks of Addis Ababa”, Atti. Della Fac. Ing. 26: 1985, pp: 235–249.
15. T. Ayenew, M. Demlie, and S. Wohnlich, ”Application of Numerical Modeling for Groundwater Flow System Analysis in the Akaki Catchment, Central Ethiopia”, Math Geosci. 40: 2008, 887–906.
16. Addis Ababa Water and Sewerage Authority (AAWSA), Addis Ababa water supply project. Stage-III A groundwater-phase I , 2000.
17. R. B. Singh, D. Kumar, and A. Kumar, “Groundwater Situation in India: Problems and Perspective”. 2010, pp:563-580.
18. M. Albhaisi, L. Brendonck, and O. Batelaan, ”Predicted impacts of land use change on groundwater recharge of the upper Berg catchment”, South Africa, 2013, 39(2).
19. Y. B, Liu, S. Gebremeskel, F. deSmedt, L. Hoffman, and L. Pfister, ”Predicting storm runoff from different land-use classes using a geographical information system-based distributed model”, Hydrological Processes. 20: 2006, pp:533–548.
20. M.K.. Jat, D. Khare, P.K. Garg, “Urbanization and its impact on groundwater: A remote sensing and GIS-based assessment approach.” Environmentalist. 29(1), 2009, pp: 17– 32.
21. M. Demlie, S. Wohnlich, B. Gizaw, and W. Stichler, “Groundwater recharge in the Akaki catchment, Central Ethiopia: Evidence from environmental isotopes (δ18O, δ2H and 3H) and chloride mass balance”, Journal of Hydrology Process, 2006.
22. D. Nigussa, “GIS based groundwater vulnerability assessment in the Akaki rive catchment (Addis Ababa), central Ethiopia”, MSc Thesis, School of Graduate Studies, Addis Ababa University, Addis Ababa, 163 , 2003.

AUTHORS PROFILE

Mr. Mearg BelayShibeshi, MSc in Earth science specialization in Remote Sensing and GIS from Addis Ababa University, Ethiopia. Currently he is serving as dean for school of mines Aksum University, Ethiopia. He actively participated in research and community services in national and international level. He is the principal investigator of ESIA project for the establishment of iron Ore Mining and Steel Making Plant at indasillase, Tigray, Ethiopia. He has published more than 3 papers in national and international journals of repute. He has presented papers at different places in the conferences and seminars.

Dr. N. Rao Cheepurupalli, is working as an Assistant professor in the department of Mineral processing Engineering, School of mines at the Aksum University, Ethiopia. He has more than 6 years of teaching experience in the field of Mining and Mineral Processing Engineering. He is one of the Member of ESIA report for the establishment of Iron Ore Mining and Steel Making Plant at Indasillase, Tigray, Ethiopia. He has published more than 10 papers in national and International journals of repute. He has presented more than 8 papers at different places in the conferences and seminars.

Dr. K.V. Suryabahagavan is working as an associate Professor in Remote Sensing and GIS in the School of Earth sciences at the Addis Ababa University, Ethiopia. He has published more than 24 papers in international journals of repute. He has presented more papers at different places in the conferences and seminars.

Dr. Dessie Nedaw is working as an associate Professor in Hydrogeology in the School of Earth sciences at the Addis Ababa University, Ethiopia. He has published more papers in international journals of repute. He has also presented more papers at different places in the conferences and seminars.