Sustainable Management Strategies for Chepkoilel-Sergoit Catchment (CSC): Linking Environmental, Water, and Food Security

Chibole, O. K.[1]*, Odenyo, V. A.[2], Mwasi, S.[1], Ucakuwun, E. K.[1], & Ngode, L.[3]

[1]*Department of Environmental Sciences, University of Eldoret, Kenya*

[2]*Department of Environmental Planning, Sustainability and Geoinformatics, University of Eldoret, Kenya*

[3]*Department of Seed Crop and Horticultural Science, University of Eldoret, Kenya*

**Corresponding author: chibole.kudenyo@uoeld.ac.ke*

https://doi.org/10.62049/jkncu.v5i2.291

Abstract

Due to rapidly increasing population, CSC has undergone unprecedented land use and land cover (LULC) transformations in the last three decades. This study carried out an integrated analysis of selected environmental, water, and food security parameters in the Catchment in order to identify management strategies that would optimize its sustainable management. The catchment was subdivided into three zones based on LU/LC and topography. The geology, LU/LC changes, soils, hydrology, and river ecosystem health were assessed. LU/LC changes were examined and quantified using supervised classification of Landsat imagery of 1995, 2014 and 2020 in ArcGIS 3.2, and ground-truthing. Soil study was carried out through review of existing published studies, study area reconnaissance visits, and close observation of exposed soil profiles. Hydro-meteorological data was analysed using hydrological time series, and selected water quality parameters were analysed. The LU/LC study showed that the catchment had lost 69% of its forest cover, while farmland increased by 44%, settlement increased by 261% and wetland declined by 64% during the period. Nitosols and Ferralsols were found to be predominant soils. The river ecosystem health of the whole catchment was found to be degraded with the degradation extent increasing from the upper to the lower zone. The study concluded that the catchment requires sustainable management strategy.

Keywords: Environmental Security, CSWC, Water Catchment, Sustainable Management, River Ecosystem Health; Food Security

Introduction

Chepkoilel-Sergoit Water Catchment (CSWC) is bounded by 00°27'N and 00°43'N; 35°30'E and 35°34'E), and drained by Chepkoilel and Sergoit rivers. Rivers Chepkoilel, Sergoit and Sosiani form the upper catchment of River Kipkaren, which is part of the larger Nzoia catchment, one of the major catchments of Lake Victoria. The northern periphery of Eldoret City lies within the CSWC. Due to the steadily increasing population in the catchment and Eldoret City, CSWC has undergone unprecedented land use and land cover transformations (Chibole, 2013). The catchment also supports steadily expanding agricultural production characterised by small scale, medium and large-scale farming activities that include cereals (maize, wheat), horticulture (vegetables, flowers and fruits) and livestock farming (dairy and poultry), with increasing use of surface water and well-water for irrigation. The rapidly increasing population in the City is also experiencing widespread expansion in the use of well-water for their household needs. It is therefore urgent that solutions linking land/water and water/biodiversity systems in an integrated catchment-based approach be sought to encourage sustainable development of the catchment.

Materials And Methods

Materials

The catchment extends for approximately 85 kilometers from its source in the Elgeyo escarpment, Elgeyo Marakwet County at an altitude of more than 2,700 meters above sea level to its end at Turbo in Uasin Gishu County at an altitude of approximately 1,900 meters above sea level. Here, the Chepkoilel/Sergoit River joins Kipkaren River. The catchment occupies an area of 714 km^2, and is characterized by steep slopes and swiftly flowing streams in the upper section, which slow down progressively as the slopes become gentler downstream. The slopes are particularly gentle in the middle zone of the catchment, which has resulted in the development of wetlands, the largest of which is the Marula wetland located in the northern reaches of Eldoret City. Further downstream the gradient increases slightly, enabling swifter flow of the river in its lower zone (Figure 1).

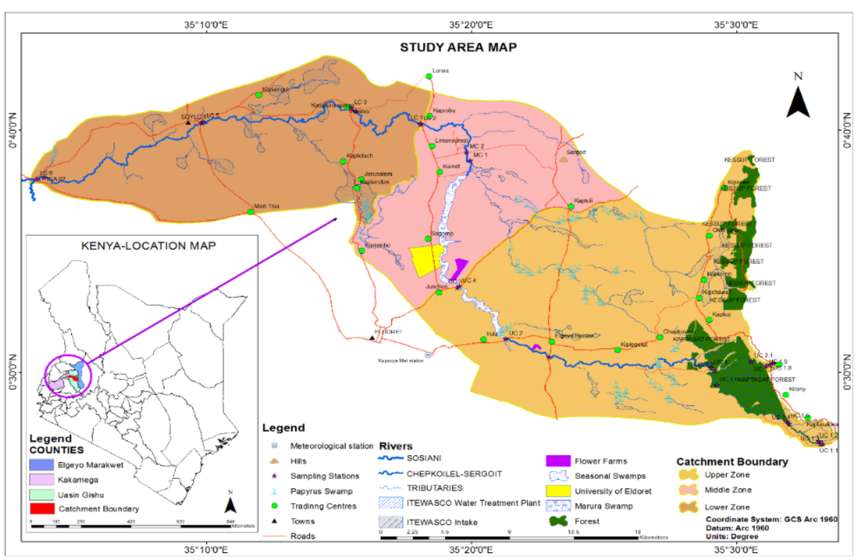

Figure 1: Chepkoilel-Sergoit Catchment, subdivided into Upper Zone, Middle Zone and Lower Zone. Key sampling points are identified

Methods

The study covered five major environmental areas: Geology, Land use and Land cover, Soils, the catchment hydrology, and river ecosystem health.

Geology

The geological study involved desk study, field observations, sample collections and laboratory analysis

i) Desk study

A review of the regional and local geology of the study area (Sanders, 1963) from literature was done to understand the nature of the basement complex and the Lower- and Upper Uasin Gishu phonolites, which are the main rock types that underlie the study area.

ii) Field observation, sample collections and Laboratory analysis

Exposures of the different rocks were observed in the field and their characteristics recorded. The characteristics of interest were mainly the rock structure, i.e. massiveness, fractures and joints, and weathering. Due to the sporadic occurrence of the exposures, fresh rock samples were taken at convenient points in a random manner. Similarly, water samples were collected at spaced but convenient locations along the river course as indicated on the map. The whole rock analysis using X-ray fluorescence spectrometer analysis method was done at the Geology and Petroleum Department in Nairobi for major and selected trace elements. The water samples were analyzed for Fluoride, Iron (Fe), Copper (Cu), and Zinc (Zn).

Land Use/Land Cover

Land use and Land cover changes in the catchment were examined and quantified using supervised classification of medium-resolution, dry-season Landsat 5 TM 30m, Landsat 8 OLI- 30m and 15m imagery of January 1995, 2014 and 2020 in ArcGIS **3.2**, and ground-truthing undertaken to verify the results. Cover types and relevant details were identified and recorded in the field. Land use activities and changes were discussed in the field with randomly selected members of the community who freely elaborated on their observations and experiences. The LU/LC were classified into five categories as shown in Table 1.

Table 1: Land cover classification scheme

No.	Land cover	Description
1.	Farmland	Farms with crops, those under cultivation and those where crops had been harvested
2.	Forest	Natural and planted
3.	Settlement	Human constructed structures and other impervious surfaces including rocky surfaces
4.	Wetland	Natural
5.	Water	Rivers, dams and any natural surface water

Soils

Soil study was undertaken to understand the soil-related factors impacting stability of river/ stream base flow, to understand the soil-related factors impacting year-round availability of water in the catchment and the seasonal fluctuations in available water in wells in the mid and lower zones of the catchment. The research was carried out through review of existing published studies (Sanders, 1963; Lomurut, 2014; Jaetzold, 1987), reconnaissance visits of the study area, and close observation of exposed soil profiles such as road cuts, quarries, river channel cuts and photography.

Hydrology

Hydro-meteorological data spanning three decades was analysed using hydrological time series. The river discharges at key strategic sampling points were gauged using current meter, and selected water quality parameters: Dissolved Oxygen (DO), pH, Total Dissolved Solids (TDS), Turbidity, and Conductivity were measured in situ on a weekly basis for a period of nine months to cover both dry and wet seasons. Grab samples for macronutrients were analysed in the university of Eldoret laboratory. The Brucine method was used for nitrates analysis, while Vanadomolybdophosphoric acid colorimetric method was used to determine phosphate levels. Analysis data results were subjected to frequency distribution analysis and found to be parametric. SPSS was employed for regression analysis and computation of Water Quality Index (WQI). WQI was then used to characterize water quality in the three zones. DO, with its weight factor of 0.22, was used as the key indicator parameter.

River Ecosystem Health

The ecosystem health of River Chepkoilel-Sergoit was assessed based on its riparian vegetation condition and physical condition indicators; 50 m line transects were randomly constructed along the riverbanks. Ten sampling points were selected at random along each transect. At each sampling point, a perpendicular projection across the river was estimated from either corresponding opposite banks. This projection served as the basis for data collection. Riparian vegetation condition (vegetation intactness and extent of vegetation degradation) and physical condition (extent of soil erosion and water clarity) at each sampling point were visually scored. Scores were categorized into 5 Likert scales of each magnitude of degradation for each parameter: 0%, 1-25%, 26-50%, 51-75%, 76-100% and their sum computed for each zone (lower, middle and upper) of the catchment.

Results And Discussion

Catchment Characteristics

The catchment occupies an area of approximately 714 km^2, with an average slope of 0.01. The slopes are generally steep in the Upper Zone, very gentle in the Middle Zone, and medium in the Lower Zone. It has a total of 15 streams, and the length of the mainstream is approximately 85 kilometers (Table 2).

Table 2: Chepkoilel-Sergoit key catchment characteristics

S. No	Zone/Parameter	Area
1.	Upper Zone	329.4 km^2
2.	Middle Zone	158.7 km^2
3.	Lower Zone	230.4 km^2
4.	Catchment Total	718.5 km^2
5.	Total no. of streams	15
6.	Total length of mainstream	85 Km
7	Stream order	2

Geology

The Upper zone is underlain mostly by the Upper Uasin Gishu phonolites, which are generally massive in structure and therefore impervious and hence poor in aquifer formation. Middle and Lower zone is underlain by the Lower Uasin Gishu phonolites and Basement Complex (Fig. 2). These formations are less massive and form aquifers where they are intensely fractured and weathered to depths up to 30 m. The fractured areas constitute good unconfined aquifers during the rainy season and rapidly drain when the dry season sets in.

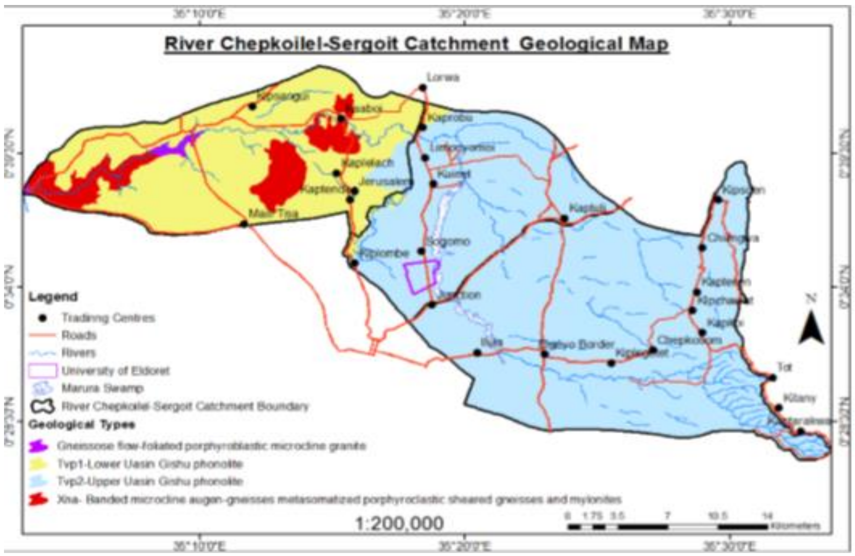

Figure 2: General geology of CSC

Land Use/Land Cover

Land use and land cover were classified into farmland, forest, settlement, swamp and water (Fig. 3 and Table 1). Results of the Land-use/Land-cover study showed that, over the three decades, the catchment had lost 69% of its forest cover (Fig. 3), while farmland increased by 44%; settlement in the catchment increased by 261% and wetland declined by 64%. Significantly, the upper zone, the main source of the water supply in the catchment, lost 46% of its forest cover during the period (Table 3), (Odhiambo & Odenyo, 2022; Kemboi *et.al*, 2022). The Upper zone is the mainstay of the flow of the river, receiving an average of 1,700 mm of rainfall in a year, and therefore, the rapid loss of vegetation cover needs to be reversed urgently for future water availability.

Table 3: LU/LC change with time

Land Cover	Area Km^2 (1995)	Area Km^2 (2014)	Area Km^2 (2020)
Farmland	368.875	492.186	531.976
Forest	115.173	78.770	34.912
Settlement	20.489	31.285	74.041
Wetland	212.700	115.589	77.486
Water	0.903	0.565	0.567
Total area	718.140	718.395	718.982

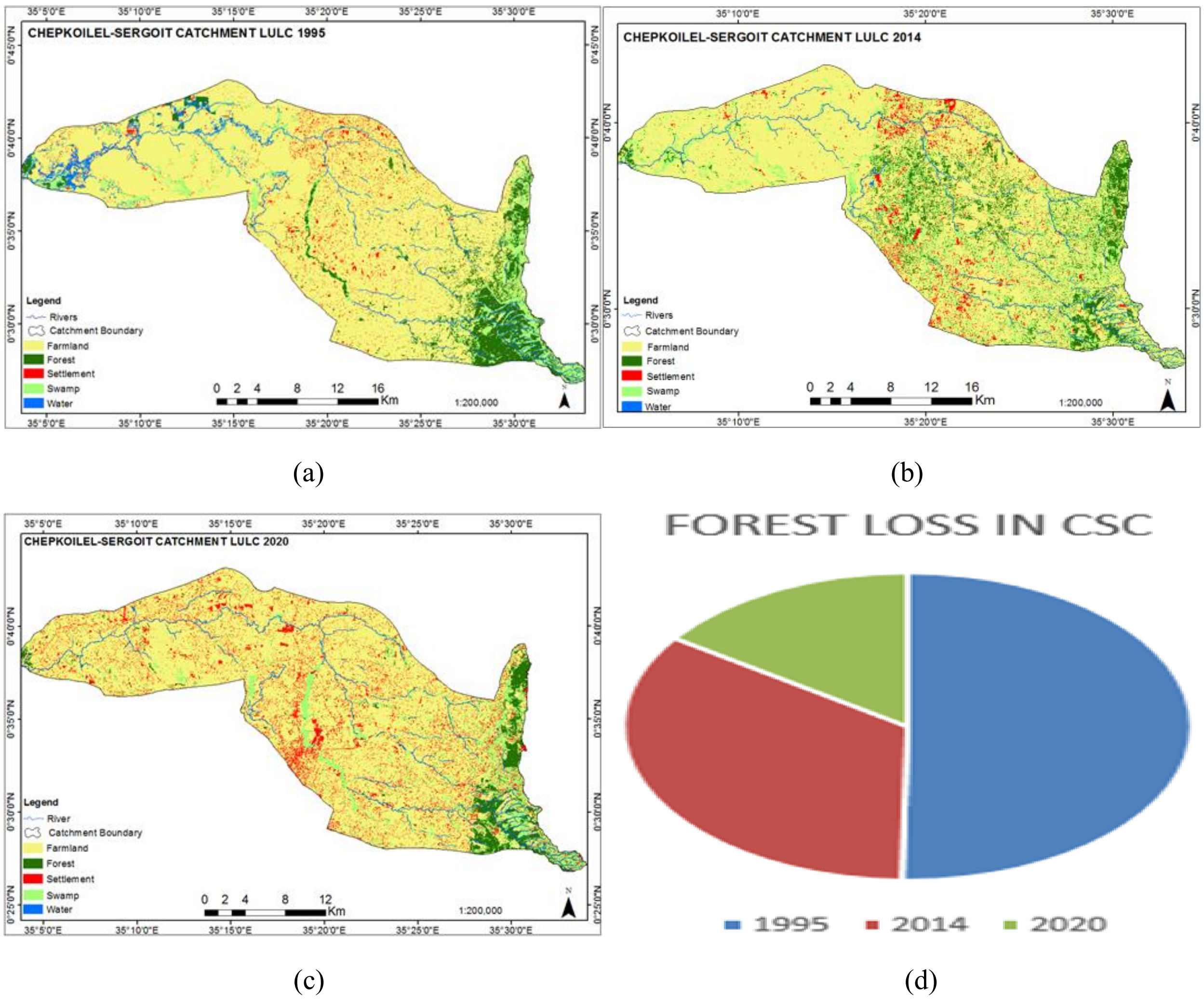

Figure 3: (a) LULC in 1994, (b) 2014, (c) 2020, and (d) Proportion of forest loss over the years between 1995 – 2020.

Soils

Well-developed Nitosols, with deep, well-drained profiles (1.5 m) in gentle slopes dominate UC. These are red, tropical soils, which are developed under high rainfall and dense vegetation, with blocky and well aggregated structure which allow steady infiltration and percolation of rainwater. In the Upper Zone, they are responsible for the base flow of the river and keep the streams and springs in the upper catchment flowing year-round. In the Middle Zone and Lower Zone, the predominant soils are Ferralsols, red and yellow strongly weathered soils with high content of aluminum and iron oxides (Figure 4). In the MZ they have a depth of up to 90 cm, thinning out to 20 cm in LZ. In areas which have been repeatedly cultivated they are much less than 20 cm, partly because they are easily eroded due to their granular structure. In both zones, the ferralsols are underlain by laterites, a slightly-to-very slightly permeable layer of partially decomposed rock that is typical of tropical zones with wet and dry season. In the upper areas of MZ, the laterites appear to be slightly permeable, as evidenced by the thicker soil profile above them. In the lower section of this zone the soil above the laterite becomes progressively thinner and less permeable as evidenced by shallower soil profiles and proliferation of seasonal wetlands. This is the factor that occasions dry riverbeds during extended dry seasons, as well as the drying up of shallow wells.

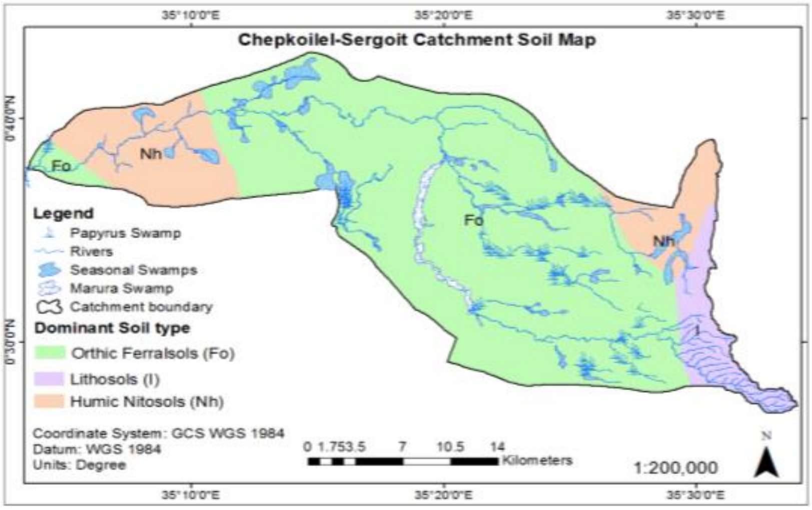

Figure 4: General soil map of CSWC

Hydrology

The catchment potamology is characterised by stream density of 0.02, most of it in the upper zone of the catchment. The rainfall regime is bimodal with an annual average of 1200 mm, with a minimum of 900 mm and maximum of 1700 mm, and with exceedance probability of 0.9 and 0.05, respectively (Figures 5 and 6). The Upper Zone has a mean wet discharge of 17 and dry season water discharge of 0.5 m^3s^{-1}. The corresponding figures for middle zone are 20 and 0.7 m^3s^{-1}, while discharge in lower zone range from 1.7 to 34 m^3s^{-1} during dry and wet season, respectively (Table 4). Phosphate levels are generally low (< 10 μgL^{-1}), there is an elevated level of nitrates, however, in the middle and lower zones during wet season (> 4 mgL^{-1}). The upper zone has a generally good water quality, with a Water Quality Index rating (70 – 80). The middle zone WQI rating ranges from poor to medium (30 – 60), while lower zone has generally poor WQI (25 – 50), (Figure 7).

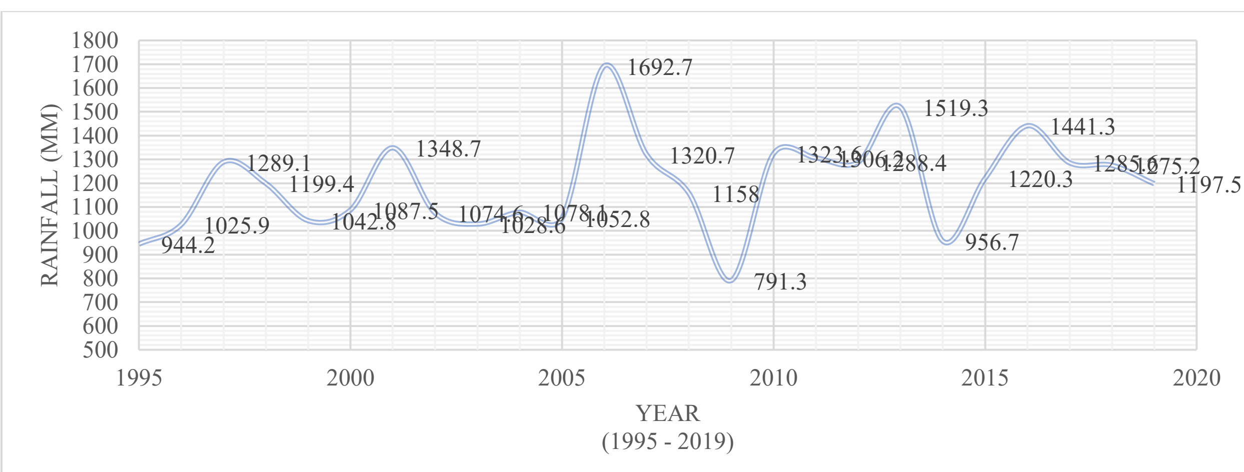

Figure 5: Rainfall variability in the catchment

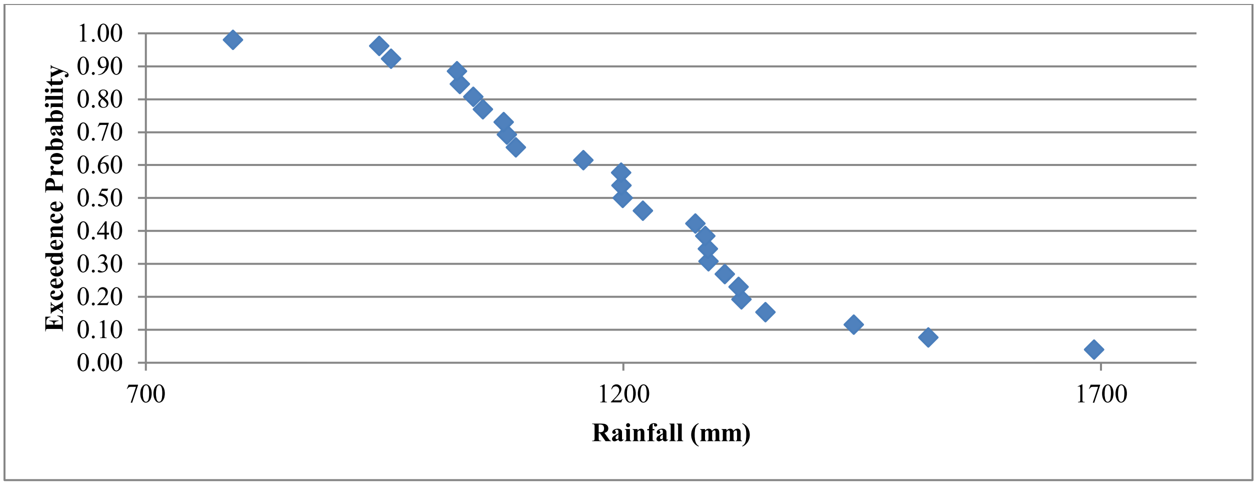

Figure 6: Rainfall exceedance probability in the catchment

Table 4: Average River discharge during dry and wet seasons

S/No	Zone	Season m^3s^{-1}	
		Dry	Wet
1.	Upper	0.5	17
2.	Middle	0.7	20
3	Lower	1.7	34

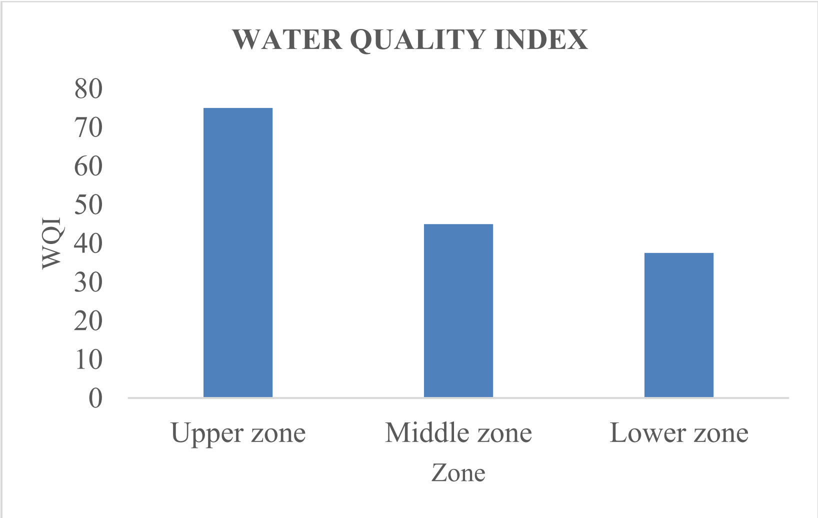

Figure 7: Mean Values of Water Quality Index (WQI) in the Catchment

River Ecosystem Health

Overall combined river Chepkoilel-Sergoit condition (health indicator) assessment showed that (i) the lowest extent of degradation (0%) was observed at upper zone (=48.44%), (ii) the highest extent of degradation (76-100%) was observed at lower zone (28.97%), followed by middle zone (21.37%). There was no difference in the combined extent of degradation among the zones. All the zos were found to be degraded.

Conclusion

Environmental security of CSWC is threatened and by extension water and food security are increasingly coming under threat as indicated, by i) the loss of 46% of the forest cover in the upper zone, the mainstay of the flow of the river, ii) poor ecosystem health of the river, iii) medium to poor WQI in the middle and lower zone, and iv) the loss in wetland cover respectively. Linking environmental security to water, food security and river ecosystem health as one of remedial measures will go a long way in meeting human demand for ecosystems services and, therefore, enhance sustainable development in catchment.

Recommendations

The study recommends the institution of conservation measures in the catchment to reduce the deterioration of the catchment. These should include water conservation measures in the Upper catchment to increase rainfall infiltration, reduction of cultivation to the stream water's edge throughout the catchment, and the introduction of agro-forestry throughout the catchment to increase tree cover, selecting suitable species for the various catchment zones.

Acknowledgement

The research was funded by a University of Eldoret-Annual Research Grant 2020-UoE/D/DVPRE/DRIV/NACO/074.

References

Chibole, O. K. (2013). Modeling River Sosiani's water quality to assess human impact on water resources at the catchment scale. *Journal of Ecohydrology & Hydrobiology, 13*, 241–245.

Jaetzold, R., Schmidt, H., Hornetz, B., & Shisanya, C. (1987). *Description of the first priority sites in the districts, District No. 11 – Uasin Gishu*. Ministry of Agriculture, National Agricultural Laboratories, Fertilizer Use Recommendation Project (Phase X). Government of Kenya.

Kemboi, G., Odenyo, V. A. O., & Odhiambo, S. (2022). Human activities impacting potable water availability and quality in Chepkoilel-Sergoit catchment and awareness of stakeholders, Uasin Gishu County, Kenya. *[Unpublished manuscript]*.

Lomurut, J. A. (2014). *A first-generation digital soil map of a portion of the Uasin Gishu Plateau, Kenya* (Master's thesis, Purdue University). Purdue University, Indiana, USA. https://docs.lib.purdue.edu/open_access_theses/649

Odhiambo, S., Odenyo, V. A. O., & Kemboi, G. (2022). Assessing land cover and land use changes in the Chepkoilel/Sergoit river catchment, Uasin Gishu County, Kenya. *African Journal of Science, Technology and Engineering, 4*(1), [page range if available].

Sanders, D. L. C. (1963). *Geology of the Eldoret area, Degree Sheet 34, N.W. Quarter* (Report No. 64). Geological Survey of Kenya, Ministry of Natural Resources, Government of Kenya.