

Impact of Population Dynamics on Water and Forestry Resources in Gem Subcounty, Kenya

^{1*}Ruth N. Wamwana, ²Ahmed Maalim, ³David Karienyee, ⁴Nelson Mbithi

**Corresponding author*

^{1,3}Department of Arts and Social Sciences, Garissa University, P.O Box 1801-70100, Kenya,
School of Education

^{2,4}Department of Mathematics and Natural Sciences, Garissa University, P.O Box 1801-70100, Kenya,
School of Education

Abstract: The relationship between population dynamics and natural resources has garnered increasing attention due to its continuous effects to the environment and the well-being of the people. The consumption of natural resources is higher than their replenishing rate and the major cause of this is the population pressure. The specific objectives of this study were to examine the impacts of changes in population size on water and forestry resources, assess the impact of population distribution on water and forestry resources in Gem Sub county, Kenya specifically in Yala Township and Central Gem Wards between 1998-2023. This study adopted mixed research design. Simple random sampling was used to select 273 households and purposive sampling was used to select two key informants. Primary data was collected through administration of 273 semi structured questionnaires and in-depth interviews to the key informants. Secondary data was obtained from online sources to obtain population data, ARCGIS Pro software was used to obtain land use and land cover maps. Quantitative data was analyzed using Microsoft Excel while qualitative data was analyzed into themes. This study established that changes in population size had influenced the consumption of water and forestry resources, high consumption of these resources was because of high demand. The population growth of the study area had changed over the years. Data from Kenya Population and Housing Census indicates that there was a rapid growth rate (1.9%) between 1999-2009 and slow growth rate (0.52%) between 2009-2019. This study found out that population distribution was sparse in 1999 but the population increased from 2009 to 2023. Due to the hard economy and low wages, the working age population migrated from towns to rural areas to cultivate their lands. With no jobs, life become difficult where they end up over exploiting tree resources. The results show that people living near rivers and streams don't consider hygiene and sanitation, the streams and rivers acted as their waste disposal thus contamination of water sources. Data from land-use and land-cover maps show that over the years trees have reduced, built up areas have increased and water points have increased to cater for the increasing population. Water and forestry resources authority need to look on how these resources can be used sustainably by putting strict measures and adhering to them.

Keywords: Population dynamics, Water resources, Forestry resources

Introduction

Population dynamics involve the study of human population size, distribution and composition over a given period of time. Population is composed of different elements which are, but not limited to; age, sex, ethnicity, distribution and density, wealth, education, marital status and fertility. These elements determine how human population consumes resources. Population dynamics helps understanding the existence of resource competition (Ngoc & Tien, 2023). Natural resources are assets in the natural environment that are useful to human beings. World dynamics of population growth is at a higher rate which is a worry to human life because it will lead to factors such as shortage of water for drinking, clearing of trees, corrosion of soil, arable land reduction, shortage of food and diseases (Sadigov, 2022). These limitations will be more rampant in continents like Africa and Asia if no action is taken. Almulhim & Abubakar, (2023) noted that water is one of the resources for life sustainability and people need to conserve and use it efficiently. They further reported that ensuring water management and availability is one of the SDGs but still an approximate 2.2billion people consume unsafe water. Ground water is highly dependent for household use in SSA (Gevera et al., 2022). Governments at local level have failed to curb the increasing water demand for their people, they therefore adopt using water resources in unregulated way to meet the consumer needs. Furthermore, using wells and dams which are unprotected and untreated puts the health of people at risk. Kenya WRMA reports that the increasing population which is accompanied by increased demand is the major challenge in water resources (Okello et al., 2015).

The demand of water in countries and regions which are water stressed is continuously rising to cater for the increasing population. Increased demand of water and its scarcity have become a major challenge to people's lives (Baggio et al., 2021, Mulwa et al., 2021). They also report that pollution of water, growth of population

and water resources being managed poorly increases the crisis of water. Degradation of the environment is proportionate to the size of population. Kenya is facing a population growth at rate 2.2% (KNBS 2019, Kogo *et al.*, 2021). The continuously growing population is affecting forest resources (Ochola, 2018). Forests play an important role in the environment among them being helping in biodiversity conservation, reducing the impact caused by soil chemicals as well as the amount of carbon (iv) oxide in the environment (Njora & Yilmaz, 2022). Kenyan forests are shrinking despite the efforts put in place for protection and conservation. Forest cover depletion is connected to making charcoal, logging intensively, growth of population and agricultural land expansion (Chidumayo & Gumbo, 2013). Water and forestry resources in Siaya County just like all the other counties bordering Lake Victoria is at a risk of degradation, putting millions in danger of water and wood insecurity and associated poverty and famine (Varunghese & Shyam, 2022). Unsustainable land management, inappropriate agricultural practices, and high population growth and density is contributing to resource degradation.

This paper focuses on how population dynamics factors affect the natural resources and the steps that can be put forward to prevent extinction of these resources in Gem Sub County of Siaya County, Kenya.

Objectives of the Study

The study's specific objectives were to;

- Examine the impact of changes in population size on water and forestry resources between 1998 - 2023 in Gem Sub County, Kenya
- Assess the impact of population distribution on water and forestry resources between 1998-2023 in Gem Sub County, Kenya

Method and Materials

Description of the study area

This study was conducted in Gem Sub County, Siaya County. The Sub county lies between latitude 0.04°N and longitude 34.45°E (ARC GIS PRO). It covers an area of 405.2Km^2 . The study majored in two wards; Yala Township and Central Gem with ten sub locations, the wards lie between latitude 0.04°N and longitude 34.34°E , latitude 0.02°N and longitude 34.26°E (ARC GIS PRO) respectively.

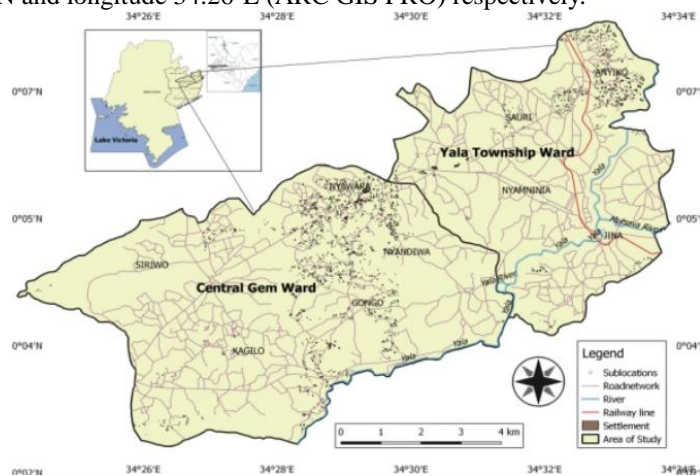


Figure 1: Map of the study area

Study Design

This study adopted mixed research design to evaluate the impact of population dynamics on water and forestry resources from 1998 to 2023. KNBS (2019) reports that the total households in the study area were 14578; 6426 in Central Gem and 8152 in Yala Township. Simple random sampling was used to obtain 250 respondents as sample size using Yamane's formula. Purposive sampling was used to obtain two key informants. Both primary and secondary sources were used in data collection. Questionnaires were used to capture data from 250 household heads on how population size and population distribution have affected water and forestry resources. In-depth interviews were administered to the forester and water management officer of Gem Sub county to identify if their responses correspond to those of the household heads. Population data of 1999, 2009 and 2019 was obtained from KNBS online reports. Satellite imageries of 1999 and 2009 were obtained from USGS while those of 2019 and 2023 were obtained from ESRI.

Limitation of the study

There was no specific data on the area covered by the forest and water of the years 1999, 2009, 2019 and 2023. Population estimates of 2023 was also not available therefore the data from satellite imageries was assumed to represent the forest cover, water and the population estimates of 2023 (built-up areas).

Results and Discussion

Population dynamics was evaluated using three elements; population size, population distribution and age-sex structure while natural resources considered water and forestry resources. The study period was from 1998 to 2023 which comprised of census reports of 1999, 2009 and 2019. Data from Landsat 7 and sentinel 2 imageries was used to analyze changes in land use and land-cover (built-up areas, trees and water).

Changes in population size and resource demand

Changes in population size

Population depends on fertility rates, trends in migration and death rates (Gu *et al.*, 2021). Slightly over thirty nine percent of the respondents described the rate of population growth as rapidly increasing, 44% as slowly increasing, 6.8% as stable and 10% as declining. The rapidly increasing population (39.2%) was due to teenagers giving birth at a very young age (18 years and below), people migrating from other communities to buy land in the community while others rent for work. Slowly increasing population (44%) was due to women on family planning. Family planning is the paramount determining factor of decline in fertility to reduce both high pregnancy and birth rates (Bongaarts, 2020). Moreover, many people have been dying and a smaller number is replacing the deceased population. The stable population (6.8%) was due to the death rates being the same as the birth rates, so those who are being born replace those who are dying at the same rate. The declining population (10%) was due to the death rates being higher than the birth rates.

These findings correspond with the Kenya population housing and census data of 1999, 2009 and 2019. There was rapid increase from 1999 to 2009 whereby the rate of population growth was 1.9% which substantiates the study of (Gu *et al.*, 2021) that decline in fertility has been registered in developing countries but not the case in SSA Gem Sub county included, from 2009 to 2019 there was a relatively slow increase of 0.52%. In some sub-locations like Nyamninia, Anyiko and Gongo there was decline in population of 0.2%, 0.04% and 0.02% respectively from 2009 to 2019. From the data below it can be said that in the coming years the population will either be stable or continuously declining especially in Yala Township because two of its sub-locations have registered a decline in population. With reduced number of people water and forestry resources will be easily managed and used sustainably.

$$r = \frac{\frac{(P_f - P_i)}{P_i} \times 100\%}{\text{Number of Years}}$$

Where;

r

is rate of population growth

P_f is the final population

P_i is the initial population

Rate of population growth of Central Gem and Yala Township between 1999 and 2009

Total population of 1999= 46256

Total population of 2009= 55035

Change in No. Of years= 2009-1999

$$r = \frac{(55035 - 46256 \times 100\%) / 46256}{10} = 1.9\%$$

Rate of population growth of Central Gem and Yala Township between 2009 and 2019

Total population of 2009= 55035

Total population of 2019= 57912

Change in No. Of years= 2019-2009

$$r = \frac{(57912 - 55035 \times 100\%) / 55035}{10} = 0.52\%$$

Total population of Central Gem and Yala Township from 1999-2019

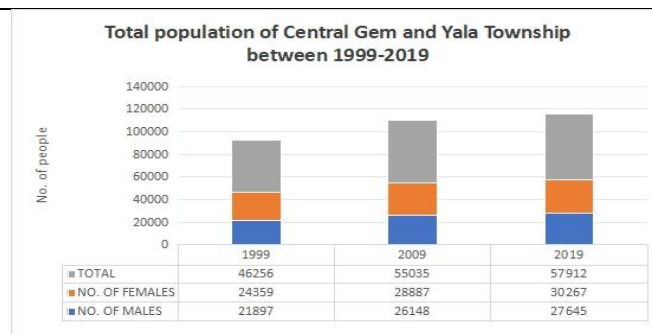


Figure 1: Total population of Central Gem and Yala Township from 1999 to 2019

Source (KNBS 1999, 2009 & 2019)

Resource demand and consumption

Mulwa et al., (2021) noted that water demand was likely to be more than supply in developing countries. High population pressure and continuous subdivision of land affects forested areas as noted by Habel *et al.*, (2017) which was the case in this study where water and forestry resources were highly consumed by people because the demand was also high.

Resource extraction and depletion

The increasing population of the study area implies increase in the demand of food, clean water, housing and fuel thus resulting to deforestation and continuous extraction of ground water as noted by Mishra, (2023). Tree cover have been cleared for settlements, that is, construction of new homes and other structures and land for farming, firewood for cooking, making furniture and charcoal burning. Furthermore, some people cut down trees to sell them since they lack other means of income. Polygamy and poverty are factors resulting to deforestation according to Oko et al., (2022). As families continue to grow, more land is needed especially as the boys in the household become off age. The land needed is the forested area, these trees are therefore cut down to create room for them to settle while the same trees are used to build their houses. The remaining land is utilized in cultivation leaving no land for tree planting.

More construction is executed during the December holidays when the men in the families come back from urban centers to construct their houses which was being called (go dala). Trees were also being cut down because of the monkeys which were commonly referred as ong'er by the local people. 68.4% being farmers had a challenge in producing good yields from their farms especially maize, bananas and fruits like avocado, guavas and mangoes because the monkeys had made their planted forests home. The ripe yields would become their feast, additionally these monkeys would even join them during meal time. The assistant forester in Gem Sub County notes that many people have visited her with the issue of the monkey inhabiting their homes but the problem is the people themselves destroyed their habitats so they have no other place to go. Besides, during burial ceremonies a lot of firewood is required. To cater for this at least two trees would be cut down.

Clearing of trees have had a great impact on water resources, during drought periods water scarcity is rampant. Trees act as water catchment areas but deforestation results to insufficient amount of water as noted by Rodrigues et al., (2022). During droughts, water from springs reduces in its flowage (Plate 4.1). All the spring water points were protected and had chlorine dispensers to provide people with chlorine after fetching water, this made people to queue to wait to get clean and treated water. High demand of water made people who can afford to buy water to use their money to get water since one spring was shared by many people in the community so rather than wasting time queuing for water they preferred buying it.

The increasing population leads to diversion of more stream water to help them irrigate their cultivated land especially during drought seasons. Sometimes these stream water dry up because other people also collect them for other purposes like water for household use and feeding of livestock. The diversion of stream water sometimes bring conflicts among the community members during these drought seasons. Stream owners water their plants mostly vegetables during morning hours and evening hours. After watering the plants in the morning the stream water will reduce, they wait until evening for the water to regenerate again so that they can water their plants again. They therefore do not expect other people who have been fetching water during normal seasons to fetch that water.

Some of water sourced from rivers for domestic use had chlorine dispensers while most of them lacked the dispensers (Plate 4.2). Generally, the study area had rugged terrain and steep slopes. This landscape made people to do most of the activities like bathing, livestock feeding and washing their clothes near the water points or in the water points to make work easier since carrying water to the homestead was very far and tiresome

(Smiley & Stoler, 2020). People washing near water points contribute to water contamination, in their perspective they were washing away from the streams but the soapy water poured after washing entered the stream water thus resulting to contamination. People cultivating along rivers and streams encouraged continuous siltation of these water points. During rainy seasons the soil washed away from the cultivated land entered the water. Continuous piling of the soil reduces the amount of water since the soil hold a lot of water. In the case of stream water, the soil is removed from the water, this makes the water to become dirty. Since people cannot fetch dirty water, they have to wait for the water to settle and become clear and clean. On the other hand, the rivers (Yala, Musuthuthu, Mala and Msure) are reducing in size and the quality of water is also reducing as also noted by Mondal & Palit, (2022) that water bodies mainly lakes and rivers were shrinking and losing their quality due to the population pressure. Furthermore, the residents noted that sometimes when they use the river water to bath they scratch themselves.

People who used the stream flowing into River Msure in Nyandiwa Sublocation (Nango village) have had cases of cholera. Most of the residents in this area lacked toilets in their households in the past years, the area surrounding the river being bushy was used by many people as bush toilets. During rainy seasons the waste is washed into the stream. This stream didn't have a chlorine dispenser, people consumed unprotected water. If they wanted water for drinking they fetched it during morning hours since its was clear and clean, during day time the water was usually dirty because of people bathing inside the water, livestock drinking the water directly and the people washing clothes. With the help of community health promoters (CHPs) some toilets had been built in households and also residents were being given chlorine tablets to put in the water to reduce cases of cholera.



Plate 1: a) Spring water point and b) a chlorine dispense



Plate 2: Stream water point with a chlorine dispenser

Population distribution and water and forestry resources

All the respondents (250) in the study area suggested that there was change in population distribution whereby in the past years the population was sparsely populated but in the recent years the population have become evenly distributed. These findings are different from that of (Higo & Khan, 2015) because the global population is uneven therefore differs with the result from this study. As the population continues to increase, it becomes densely distributed resulting to the need for more of the already scarce and finite resource that does not increase land and land is just constant it cannot increase with increasing population (Maja & Ayano, 2021).

Influence of population distribution on water resources

The even population distribution is affecting both trees and water resources. Continuous cutting down of trees is also contributing to climate change in the study area. People were over-extracting ground water, they have dug ditches everywhere in search of stream water to help them during drought period. Some people had gone to an extent of settling near the water points especially the rivers and streams. All the waste materials from

their households were dumped into the water points which results to contamination and poor hygiene. Furthermore, people practiced fishing in the rivers, sometimes they over-fish. The residents near rivers had a suggestion that the government should allow them to have their own fish ponds using the river water so that they can stop over-exploiting the fish. This distribution is also a reason why many children drown in the river water as a result of fishing. Those people near the springs are said to be protecting the water, they plant trees like Eucalyptus near the water springs whose roots require a lot of water thereby competing with the population mostly during drought periods.

Influence of population distribution on forestry resources

People were migrating from urban to rural areas especially males because of the hard economy. This finding opposes that of Ampaire *et al.*, (2020) who noted that cutting down of trees is accelerated by men who migrate to urban areas. Those having jobs are given peanut pay which cannot cater for their families so the only option is to return to their villages to cultivate their lands (Oyvat, C., & wa Githinji, 2020). Children were dropping out of schools since the household heads were not able to pay their school fees, heads who sometimes gave up leaving mothers to take care of the family. The mothers can only struggle to acquire what the family will eat. Due to school dropouts the population becomes idle and only over-exploit the tree resources for charcoal burning, burning bricks, selling the trees and other ways majorly for income since everyone is struggling to survive in the household. Additionally, the trees planted for income which sometimes lack the buyers are cut down with no replacement for charcoal production. The idle population puts the fathers in a difficult position. Boys of the family require land for them to start their families at a young age. After being given the land, they start selling the land because of the difficult life. They sell until they have no place to stay hence turning to their parents or their brothers which result to continuous conflicts and disputes.

Land use and land cover (LULC) maps of Central Gem and Yala Township of years 1999, 2009, 2019 and 2023

The land use and land cover maps were classified into three classes, that is, built up areas which indicates the areas occupied by the population, water which represents the water bodies and trees which represents the tree cover of the two wards. Built up areas are represented by the red colour, water by the blue colour and trees by the green colour. Change in land cover is mainly linked to rapidly increasing population which results to encroachment of agricultural land and cutting down of trees as Sang *et al.*, (2023) notes. KPHC report indicates that in 1999 the population was 46256, in 2009 (55035) and in 2019 (57912). There was a rapid population increase from 1999 to 2009 of 1.9% and a slow increase from 2009 to 2019 of 0.52%. In 1999, the built-up areas covered 8.42%, tree cover was 90.60% and the water covered 0.97% (Figure 2). In 2009, built-up areas covered 20.52%, tree cover was 78.43% and water covered 1.037% (Figure 3). Figure 3 shows that trees have occupied a larger area compared to built-up areas and water. Although the tree cover occupied a larger area, it reduced by 12.17% from 1999 whereas built-up areas and water increased by 12.11% and 0.06% respectively. In 2019, the built up areas covered 30.03%, tree cover was 68.93% and water covered 1.038% (Figure 4). as indicated in Figure 4, tree cover still occupied a larger area compared to built up areas and water. Despite trees occupying a larger area, they reduced their cover to 9.5% from 2009 whereas built-up areas and water increased by 9.5% and 0.001%. In 2023, the built up areas covered 65.35%, tree cover was 27.41% and water covered 7.24% (Figure 5). From Figure 5, built up areas occupied a larger area surpassing tree cover which had been occupying a larger area since 1999 to 2019. Additionally, the area covered by water also increased at a higher rate compared to other years. Built-up areas and water increased by 35.32% and 6.2% respectively while tree cover reduced by 6.2% from 2019.

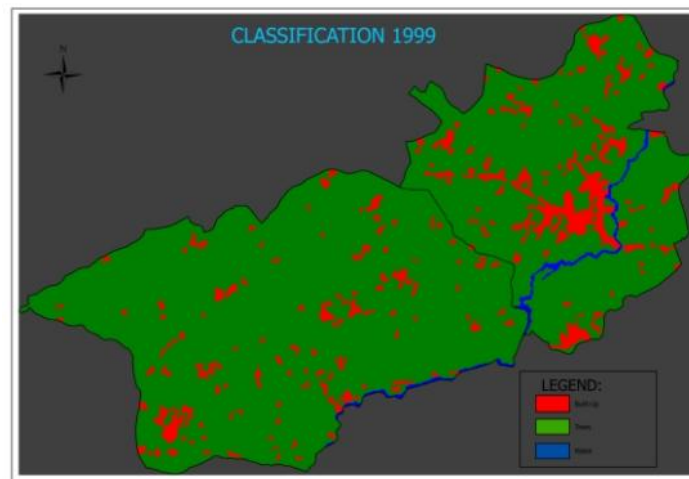


Figure 2: 1999 Land-use and land-cover map of Central Gem and Yala Township

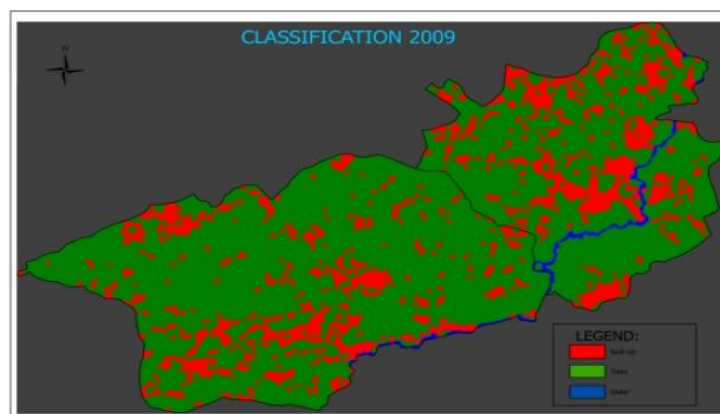


Figure 3: 2009 Land-use and land-cover map of Central Gem and Yala Township

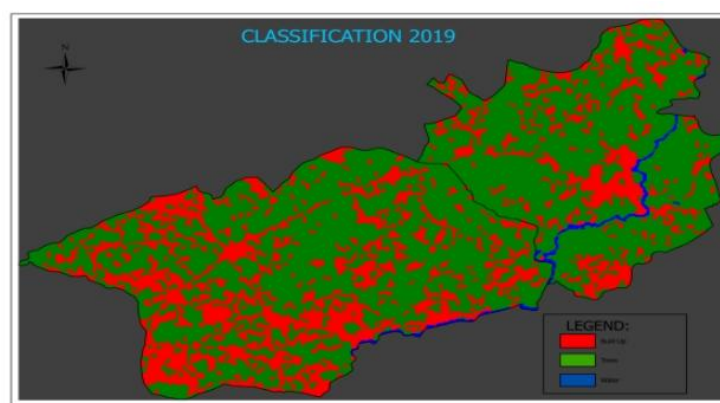


Figure 4: 2019 Land-use and land-cover map of Central Gem and Yala Township

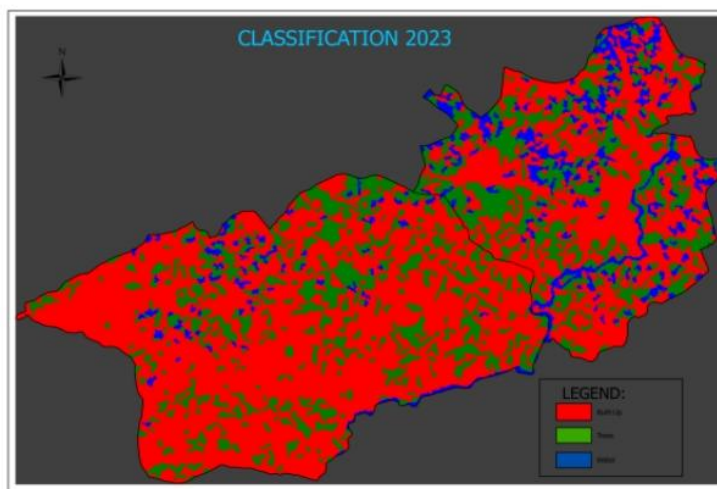


Figure 5: 2023 Land-use and land-cover map of Central Gem and Yala Township

It is evident that the built-up areas and water bodies have been increasing their cover while the tree cover have been decreasing from 1999 to 2023. These data indicates that deforestation rates are extremely high and should this trend continue, the region will be ranked among the ASAL regions in the coming years. These findings oppose that of Rotich & Ojwang', (2021) who reported that despite growth of population there was decline in built-up areas, water and forest cover. From LULC, in 1999 the population was sparsely distributed, in 2009 some areas were sparsely distributed and others were evenly distributed and in 2019 it was evenly distributed. The LULC maps also indicate that the areas which had tree cover in 1999 have been occupied by the population in 2009, 2019 and 2023 which is the main cause of tree cover reduction and an increase in water coverage mainly to cater for the increasing population thus supplementing the data collected from the field.

Table 1: Landuse coverage of 1999, 2009, 2019 and 2023

YEAR	LANDUSE	AREA (Ha)	% AREA	POPULATION (KPHC)
1999	Built-up areas	728.73	8.42	46256
	Trees	7839.63	90.60	
	Water	84.24	0.97	
	Total	8652.6	100	
2009	Built-up areas	1769.76	20.52	55035
	Trees	6760.53	78.43	
	Water	89.37	1.037	
	Total	8619.66	100	
2019	Built-up areas	2588.85	30.08	57912
	Trees	5941.35	68.93	
	Water	89.46	1.038	
	Total	8619.66	100	
2023	Built-up areas	5632.56	65.35	
	Trees	2363.04	27.41	
	Water	624.06	7.24	
	Total	8619.66	100	

Conclusion

From the above findings it was concluded that the population of the study area was slowly increasing by 0.52% as the rate of population grew from 2009 to 2019. The increasing population consumes a lot of water and there was also high demand for forest products, land-use and land-cover maps of 1999 to 2023 also shows that the population and water bodies have been increasing whereas tree cover has been degrading. Trees help in modifying the microclimate of an area or a region but since there was continuous tree clearing the population was greatly affected during drought seasons whereby some streams dry up and the springs reduce their water flow. Some residents (20.8%) were trying to plant more trees but deforestation rates still remained higher. Both the foresters and water resource authority (WRA) were trying to develop new forests and construct new water points but the problem is the population. Sometimes construction of springs takes a lot of time, people destruct

the unfinished constructed springs which makes it difficult for the construction to carry on. The residents had a perspective that if any activity like planting trees in a certain area or constructing any water point in an area, the government was trying to take their lands. Moreover, those whose lands had the springs thought they rightfully own those springs. The hard economy was making people to return to their villages only to destroy what was there in the name of family sustainability. Although some people were trying to sustainably use these resources a large number were destroying them therefore the management need to look on how these resources can be used sustainably by putting strict measures and ensuring people of Gem Sub county adhere to them.

Recommendation

The Subcounty government of Gem to;

Educate the community on the importance of planting trees and construction of springs which are majorly in people's land so that they can perceive that those activities are helping them. Construct more springs and boreholes since its water is protected so that people can move from using river and stream water. Giving out incentives, generally Siaya County is considered to have the lowest forest cover (0.23ha) Gem being one of its sub county, the foresters are trying to develop forests but they are failing. By giving the community incentives, new forests can be developed to increase the forest cover if they remain with the notion that the government want to grab their lands. Advise and promote the local community to use different products for construction. Gem Sub county is rich in rocks, people can use them for construction so as to reduce tree clearing. Create job opportunities to those who don't have the jobs and pay them better wages so that they stop over relying on tree resources to make the ends meet. Further research needs to be done on human-wildlife conflict on the community in the Gem Sub county.

References

- [1]. Almulhim, A. I., & Abubakar, I. R. (2023). Developing a sustainable water conservation strategy for Saudi Arabian cities. *Groundwater for Sustainable Development*, 23, 101040.
- [2]. Ampaire, E. L., Acosta, M., Huyer, S., Kigonya, R., Muchunguzi, P., Muna, R., & Jassogne, L. (2020). Gender in climate change, agriculture, and natural resource policies: insights from East Africa. *Climatic Change*, 158(1), 43-60.
- [3]. Baggio, G., Qadir, M., & Smakhtin, V. (2021). Freshwater availability status across countries for human and ecosystem needs. *Science of the Total Environment*, 792, 148230.
- [4]. Bongaarts, J. (2020). Trends in fertility and fertility preferences in sub-Saharan Africa: the roles of education and family planning programs. *Genus*, 76(1), 32.
- [5]. Chidumayo, E.N., & Gumbo, D.J. (2013). The environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis. *Energy for Sustainable Development*, 17(2), 86-94.
- [6]. Gevera, P. K., Dowling, K., Gikuma-Njuru, P., & Mouri, H. (2022). Public knowledge and perception of drinking water quality and its health implications: an example from the Makueni County, South-Eastern Kenya. *International Journal of Environmental Research and Public Health*, 19(8), 4530.
- [7]. Gu, D., Andreev, K., & Dupre, M. E. (2021). Major trends in population growth around the world. *China CDC weekly*, 3(28), 604.
- [8]. Habel, J. C., Casanova, I. C. C., Zamora, C., Teucher, M., Hornetz, B., Shauri, H., ... & Lens, L. (2017). East African coastal forest under pressure. *Biodiversity and Conservation*, 26, 2751-2758.
- [9]. Higo, M., & Khan, H. T. (2015). Global population aging: Unequal distribution of risks in later life between developed and developing countries. *Global Social Policy*, 15(2), 146-166.
- [10]. KNBS (1999). 1999 Kenya Population and Housing Census.
- [11]. KNBS (2009). 2009 Kenya Population and Housing Census.
- [12]. KNBS (2019). 2019 Kenya Population and Housing Census.
- [13]. Kogo, B. K., Kumar, L., & Koech, R. (2021). Climate change and variability in Kenya: a review of impacts on agriculture and food security. *Environment, Development and Sustainability*, 23, 23-43.
- [14]. Maja, M. M., & Ayano, S. F. (2021). the impact of population growth on natural resources and farmers' capacity to adapt to climate change in low-income countries. *earth systems and environment*, 5, 271-283.
- [15]. Mishra, R. K. (2023). Fresh water availability and its global challenge. *British Journal of Multidisciplinary and Advanced Studies*, 4(3), 1-78.
- [16]. Mondal, S., & Palit, D. (2022). Challenges in natural resource management for ecological sustainability. In *Natural Resources Conservation and Advances for Sustainability* (pp. 29-59). Elsevier.
- [17]. Mulwa, F., Li, Z., & Fangninou, F. F. (2021). Water scarcity in Kenya: current status, challenges and future solutions. *Open Access Library Journal*, 8(1), 1-15.
- [18]. Ngoc, N.M., & Tien, N.H. (2023). Solutions for Development of High-Quality Human Resource in Bing Duong Industrial Province of Vietnam. *International journal of business and globalisation*, 4(1), 28-39

- [19]. Njora, B., & Yılmaz, H. (2022). analysis of the effects of deforestation on the environment and agriculture in Kenya. *International Journal of Water Management and Diplomacy*, 1(4), 91-110.
- [20]. Ochola, G. O. (2018). Natural resource use dilemma: a review of effects of population growth on natural resources in Kenya. *Int. J. Environ. Sci. Nat. Resour*, 13, 555867.
- [21]. Okello, C., Tomasello, B., Greggio, N., Wambiji, N., & Antonellini, M. (2015). Impact of population growth and climate change on the freshwater resources of Lamu Island, Kenya. *Water*, 7(3), 1264-1290.
- [22]. Oko, P. E., Odey, D. U., & Anake, C. B. (2022). Impact of population growth on biodiversity loss in Boki agro-ecological rainforests, Cross River State, Nigeria. *Global Journal of Pure and Applied Sciences*, 28, 99-105.
- [23]. Oyvatt, C., & wa Githinji, M. (2020). Migration in Kenya: beyond Harris-Todaro. *International Review of Applied Economics*, 34(1), 4-35.
- [24]. Rodrigues, A. A., Macedo, M. N., Silvério, D. V., Maracahipes, L., Coe, M. T., Brando, P. M., ... & Bustamante, M. M. (2022). Cerrado deforestation threatens regional climate and water availability for agriculture and ecosystems. *Global Change Biology*, 28(22), 6807-6822.
- [25]. Rotich, B., & Ojwang, D. (2021). Trends and drivers of forest cover change in the Cherangany hills forest ecosystem, western Kenya. *Global Ecology and Conservation*, 30, e01755.
- [26]. Sadigov, R. (2022). Rapid growth of the world population and its socioeconomic results. *The Scientific World Journal*, 2022(1), 8110229.
- [27]. Sang, C. C., Olago, D. O., & Ongeru, Z. J. (2023). The factors driving land cover transitions and land degradation and the potential impacts of the proposed developments in the Isiolo dam watershed, LAPSSSET corridor, Kenya. *Discover Sustainability*, 4(1), 9.
- [28]. Smiley, S. L., & Stoler, J. (2020). Socio-environmental confounders of safe water interventions. *Wiley Interdisciplinary Reviews: Water*, 7(3), e1438.
- [29]. Varughese, A., & Shyam, B. (2022). Protecting Lake Victoria for a green, resilient, and inclusive future: Sustainable communities and nutrition concerns in Homabay, Kenya. World Bank