IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 17, Issue 11 Ser. 1 (November 2023), PP 08-19
www.iosrjournals.org

Influence ofAnthropogenicdisturbance on ecosystem health status of River Sironko catchment, on the slopes of Mount Elgon, Uganda

Remigio Turyahabwe[1], Caroline Mulinya[2]Andama Edward[3]
William Aino Shivoga[4]

[1]Department of Geography, Faculty of Science and Education, Busitema University, Tororo, Uganda.
[2]Department of Geography, Kaimosi Friends University College, MasindeMuliro University of Science and Technology, Kakamega, Kenya. [3]Department of BiologyFaculty of Science and Education, Busitema University, Tororo, Uganda, (corresponding author) [4]Department of Biological Sciences, School of Natural Sciences, MasindeMuliro University of Science and Technology, Kakamega, Kenya

Abstract
Habitat quality and resident macroinvertebrates were used to assess the influence of different anthropogenic disturbances (land uses) on ecosystem health status of River Sironko catchment. The study was carried out at different land use sites (natural forest, pastureland, planted forest, mixed agriculture, banana plantation, urban and sugarcane plantation) from November 2019 to April 2020 during wet and dry seasons. A total of 3,944 macroinvertebrate individuals were identified consisting of 30 families with different levels of tolerance to pollution: 8 were sensitive to pollution and 10 were tolerant while the majority 12 were moderately sensitive. Based on SASS-ASPT, the overall ecosystem health ranged from fair to good and natural. Integrated Habitat Quality Score (IHAS) ranged between 46±0.82percent in urban site to 65±0.82% in forested sites. There was a statistical significant difference in SASS among natural and planted forest, mixed agriculture, banana plantation and sugarcane agriculture, Makuyu urban and sand mining (ANOVA at $p \leq 0.05$). There was a highly significant positive correlation between SASS (macroinvertebrates) scores and riparian vegetation ($r = 0.77$, $p \leq 0.01$), stream condition ($r=0.59$, $p \leq 0.01$) and IHAS totals($r=0.46$, $p \leq 0.01$) (habitat). Based on this finding, we concluded that land use influences physico-chemical habitat quality which in turn influences macroinvertebrate assemblage and therefore the ecosystem health status.

Key words: *Ecosystem health, Macroinvertebrate assemblage, Habitat quality, Sensitive and tolerant taxa.*

Date of Submission: 24-10-2023 Date of Acceptance: 04-11-2023

I. INTRODUCTION

Freshwater resources are composite assets that provide a variety of goods and services for consumptive and productive activities of human beings (Chikodzi*et al.*, 2017). In the aquatic environment, it acts as an 'arena' of aquatic ecosystems which requires constant monitoring if ideal ecosystem health and sustainability are to be maintained. According to Karr (1999),river ecosystem health is synonymous with ecosystem integrity which he defined as, "The ability of aquatic ecosystem to support and maintain key ecological processes and community of organisms with a species composition, diversity, and functional organisation as comparable as possible to that of undisturbed habitats within the region". Catchment and riparian degradation has continued to cause declining ecosystem integrity of streams in many African countries. Many studies on river health evaluation have been conducted in order to prevent river ecosystem from further deterioration. For example, Chikodzi*et al., (*2017) used Water quality and biotic indices to assess river health conditions and results showed that if care was not taken early enough, the rate of ecosystem health deterioration was higher than it could be restored as evidenced by poor Physico-chemical conditions matching poor macroinvertebrate assemblage. In East Africa, Raburu*et al.*, (2009) examined the impact of agro-industrial activities on water quality of RiverNyando, in lake Victoria basin in Kenya and found that, of all anthropogenic sources, agricultural land use was the major contributor to the changes in water quality, especially the nutrient loads of phosphorous and Nitrogen that increased downstream from tea plantation zone deteriorating the quality of water.Previously, rivers in Uganda had good health status evidenced by their exceptional biodiversity (Plumptre*et al.*, 2003) but have declined due to the intensifying anthropogenic disturbances in the catchment areas with very little direct measurements available about their current health status (Kasangaki*et al.*, 2008,Bagalwa*et al.*, 2014). For example, Van Butsel*et al.*, (2017) found out that the chemical and biological water quality in Fort portal municipality streams were lowered by certain urban (municipal) pressures like waste disposal in river Mpanga but agriculture did not seriously impair macroinvertebrates apart from a few locations.River Sironko provides significance ecological services and socio-economic benefits in the region but how this is affected by the anthropogenic disturbancesby man which measured. Most attempts made to find out the impact of land use on ecosystems of few rivers in western Ugandahave used only the Physicochemical water quality parameters and not physical habitat assessment which is insufficient indicator of river ecological health conditions. In this study, both abiotic and biotic indicators were used to measure anthropogenic influence on river Sironko ecosystem health.

II. MATERIALS AND METHODS

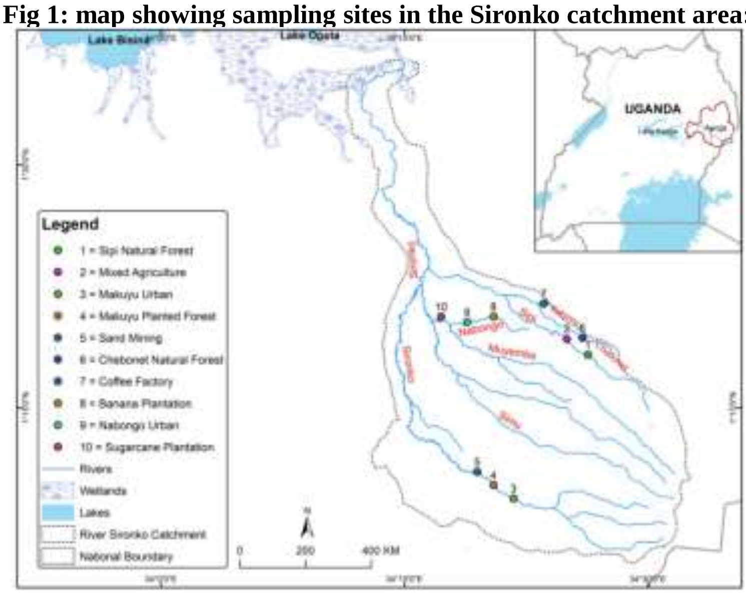
Study area:

River Sironko catchment is located in Eastern Uganda stretching between 33.5 ^{0} – 36^0 E and 1^0 – 5^0 N. It drains into Lake Opeta-Kyoga basin. The catchment covers a surface area of approximately 710.96 KM^2, with its waters flowing over a distance of approximately 97.10Km. River Sironko headwaters originate from the slopes of the northern part of the Mount Elgon National Park (approximately 3300 m a.s.l.) a natural tropical forest in its headwaters. The biggest part of relief is mountainous with interceptions of gentle slopes westwards. The river and its tributaries flows south west wards, crossing several urban centers such as Makuyu, Budadiri, Sironko, Simu corner and Muyembe-Nabbongo. River Sironko crosses cultivated steep slopes where annual and perennial crops are grown, animal grazing and a regional coffee collection centre that also hosts a coffee processing factory at the same site. In the middle, it crosses both perennial and some annual crop gardens, sand mines as well as residential areas and some urban centres at levels of town boards and town councils while the lower reaches are dominated by both annual and perennial crop gardens of banana and sugar cane plantations and wetlands, part of which is used for animal raring. The catchment comprises a variety of climatologically and ecologically different regions, ranging from a year-round wet climate at the source area inMount Elgon National Park (2000-3000 mm annual rainfall), over a wet climate with two short dry seasons per year (1400 mm annual rainfall) in the mid-range regions of the system, to the drier downstream region (1000 mm annual rainfall) with pronounced dry and wet seasons. Depending on altitude and season, mean temperatures from source to mouth areas may vary from below 10 °C to over 22 °C. (Turyahabwe*et al.,* 2020; 2023).

Sampling design:

The study applied stratified sampling design which used purposive identification https://www.scribbr.com/methodology/systematic-sampling/of different land uses in River Sironko Catchment. The different land uses selected were the natural forest, planted forest, pasture, sand mining, banana plantation, mixed agriculture, sugarcane plantation and urban land uses in the River Sironko Catchment. Each land use in the catchment was categorized into strata and each stratum was randomly sampled independently. We also sampled stations on the basis of at the ‘beginning, inside and at the end of landuse’ types. The sampling sitesare indicated on the map shown in Fig. 1. Data collection lasted for six months from November 2019 – April 2020.

Fig 1: map showing sampling sites in the Sironko catchment area:



The characteristics of sampling points in the fig.1 above were summarized in the Table 1.

Table 1: Geographical characteristics of sampling stations in the Sironko catchment area:

Site	Easting	Northing	Altitude (M.A.S.L)
Chebonet natural forest	656859.87mE	146166.49mN	2130
Sipi natural forest	657645.81mE	147303.15 mN	2072
Sipi mixed agriculture	656711.65 mE	147895.56 mN	2047
Kawacom coffee factory	654476.13 mE	150153.09 mN	1780
Makuyu urban	651526.07 mE	127791.08 mN	1287
Makuyu planted forest	651009.41 mE	128231.00 mN	1303
Budadiri sand mining	649005.72 mE	129659.75 mN	1229
Nabongo banana plantation	644978.70 mE	147820.11 mN	1090
Nabongo urban	644391.39 mE	147735.40 mN	1080
Muyembe sugarcane plantation	643074.95 mE	1436996.64mN	1084

Data collection:

Measurementof habitat qualityfor macroinvertebrates

At each sampling site, on each sampling occasion, an assessment of the diversity and quality of the habitat available for aquatic macroinvertebrates was undertaken using the Integrated Habitat Assessment System (IHAS) score sheet(McMillan, 1998). The various invertebrate habitat quality parameters that were scored on each site included Stone InCurrent(SIC) scored out of 20%, Vegetation (Vg) scored out of 15%,Other Habitat (OH) scored out of 20% and stream condition (SC) scored out of 45%.These were computed where the total maximum score is 100%. Results from these scores were interpreted in line with the method guidelines set by McMillan(1998) as; 100% represents "ideal" habitat availability/quality while other Scores are described as >75 Very Good, 65 – 74 Good, 55 – 64 Fair/Adequate, < 55 Poor quality habitats.

Supplementary data on habitat quality assessment that was collected included;water quality parameters like EC,TDS,pH and temperature measured using Hanna Combined Ec/TDS/pH and Temperature meter (model HANNA Hi 991300)**,**and D.O was measured using multi - parameter analyzer (model Consort C3010/C3030 dual channel), while velocity was obtained by introducing andtiming buoyant dry sticks in the river over a 5-m stretch (Gore, 1996).Discharge was obtained from the product of velocity, wet depth and wet width of the channel, while the wet width and wet depth of the channel were measured using a wading rod and a tape measure. Water transparency was measured using a 25 cm Secchi disc colored black and white. GPS coordinates were recorded using GPS- *Germin Oregon e-60* type.

Macroinvertebrate sampling

Macroinvertebrates were sampled using method of 'kick and sweep sampling', using a standard collection net of 1 000 µm mesh size (Dickens and Graham 2002) in triplicates (before, inside and at the end of the land use) considering runs, riffles, pools and riparian vegetation. Macroinvertebrate sampling was done for standard 3 minutes by disturbing 1m^{2}areas for each micro habitat. Samples were sorted live on a white sorting tray and then put in sample bottles and preserved with 70% ethanol. The samples were then pooled together to make one sample for a site which were later taken to Busitema University Biology laboratory for further processing. While in the laboratory, samples were identified up to the family level following the procedures of Graham and Dickens (2002).Each macroinvertebrate family was assigned a tolerance score called SASS5 score, indicating its tolerance towards pollution. The scores ranged from 1 (high tolerance, low sensitivity) to 15 (low tolerance, highly sensitive). Per site, the SASS scores of all present taxa were summed up and divided by the number of taxa obtainedon the site. This gave us the average score per taxon (ASPT) and represented the average tolerance of the biological community at each site. In absence of a national-specific reference conditions, default quality classes adopted from Rossouw (2004) were assigned to values of the ASPT as; ASPT <5 = poor quality health, 5-6 = moderate health and 7^+ = natural or good quality.

Measurement of other macroinvertebrate metrics

The macroinvertebrate species diversity, richness and evenness were determined at each site using Shannon Weaver's Diversity Index (Shannon and Weaver, 1949) to compare macroinvertebrate diversity between various habitats associated with anthropogenic stressors (land uses) and was calculated as follows:

$$\boldsymbol{H} = \sum_{\boldsymbol{i}=\boldsymbol{1}}^{\boldsymbol{n}} \left(\frac{\boldsymbol{n_1}}{\boldsymbol{N}} \; [\, \boldsymbol{log2} \,] \; \left(\frac{\boldsymbol{n_1}}{\boldsymbol{N}} \right) \right)$$

Where,

H= Shannon Wiener index of diversity,

$n_{i=}$ Total No. of individuals of a species, N= Total No. of individuals of all species.

Relative Abundance (RA) was also calculated as; R.A =Number of individuals of one taxon/Total number ofindividuals in a sitex100. Ecosystem health condition categories were computed by comparing our study resultsof ASPT with standard ASPT valuesset byRossouw (2004) ecosystem health categories, while habitat quality was categorized based on IHAS standards set by McMillan (1998).

Analysis:

The data on macroinvertebrate metrics from different landuses were compared with the habitat quality parameters from the same stations to determine the relationship between habitat quality and macroinvertebrate assemblage from different landuses using a Spearman's rank correlation generated from STATA version 14. This was done by comparing macroinvertebrate assemblage metrics (SASS5, ASPT, diversity, richness, evenness and relative abundance)with habitat quality parameters (SIC, OH, SC, Vg, IHAS totals, EC, TDS, pH, D.O,transparency, temperature, discharge).To compare the differences in distribution of macroinvertebrate assemblage metrics and macroinvertebrate habitat quality parameters in different land uses, a one-way Analysis Of Variance (ANOVA) was used. Before the comparison, a normality test using Shapiro-Wilk was applied to macroinvertebrate assemblage metrics andinvertebrate habitat quality variables. Where allvariableshaving passed thenormality test, one-way ANOVA was performed to assess the differences between means of dependent variables from the different land uses. A post hoc test using Least Significant Difference (LSD) test was done to comparethe distribution of macroinvertebrate assemblage and habitat quality characteristics from different land uses.

III. RESULTS

Influence of land use on macroinvertebrate assemblages in River Sironko catchment

Table 2 shows macroinvertebrate community found in the River Sironko catchment area arising from the different land uses.

Table 2: Influence of land use onmacroinvertebrate assemblagein the R.Sironko catchment area

Order	Families in each order	Sensitivity – Tolerance to pollution	Distribution of individuals of each family in each land use											
			Forestry			Agriculture			Urban land ude		Sand	Factory		
			Chebonet Natural forest	Sipi natural forest	Makuyu planted forest	Nabongo banana Plantation	Muyembe Sugarcane	Sipi mixed agriculture	Makuyu urban	Nabongo urban	Budadiri sand mining	Kabiriro coffee Factory	Total No. of individuals in each family	%age of total number in Sironko catchment area
Crustacea	Potamonautidae	T	166	79	-	-	-	13	-	-	-	-	258	6.5
	Palaemonidae	M	8	-	-	-	-	20	-	-	-	-	28	0.7
Trichoptera	Hydropsychidae	T	59	46	45	218	83	45	14	48	87	379	1024	26
	Hydrophilidae	M	24	-	8	-	-	-	84	-	-	62	178	4.5
	Glossosomatidae	S	-	-	-	-	-	-	-	-	28	-	28	0.7
	Philopotamidae	M	-	-	-	-	37	-	-	-	-	-	37	0.9
Gastropoda	Hydrobiidae	T	-	-	-	-	-	-	-	-	-	6	6	0.2
Ephemeroptera	Ephemerelidae	S	289	35	-	25	-	18	-	-	-	24	391	9.9
	Oligoneuridae	S	244	154	-	35	-	-	-	-	-	36	469	11.9
	Heptagenidae	S	-	-	48	-	-	-	57	-	115	-	220	5.6
	Trycorithidae	M	-	-	-	-	-	-	10	-	-	-	10	0.3
	Peltoper	S	-	-	14	-	-	-	-	-	-	-	14	0.4

	idae													
Plecoptera	Perlodidae	S	-	3	-	-	-	-	-	-	-	-	3	0.1
Diptera	Tipulidae	M	17	-	-	46	12	-	26	-	-	-	101	2.6
	Chironomidae	T	-	71	-	-	17	55	216	77	-	-	436	11.1
	Simulidae	M	-	-	-	-	-	-	105	-	-	26	131	3.3
Hemiptera	Naucoridae	M	12	5	-	-	-	36	-	-	-	26	79	2
	Belostomadidae	T	-	3	-	-	-		-	-	-	4	7	0.2
	Nepidae	T	-	-	-	-	-	-	-	-	-	7	7	0.2
Odonata	Libellulidae	T	12	-	-	45	-	-	-	12	-	-	69	1.7
	Calopterygidae	S	-	3	-	8	-		-	-	-	11	22	0.6
	Coenagrionidae	T	-	-	15	-	-	-	-	-	-	140	155	3.9
	Aeshnidae	M	-	-	-	19	-	-	10	6	11	8	54	1.4
	Corydalidae	M	-	-	-	-	22	-	-	-	-	-	22	0.6
Annelida	Oligochaeta	T	-	-	9	-	-	-	35	-	9	-	53	1.3
	Leeches	T	-	-	-	-	-	-	13	18	-	-	31	0.8
Coleoptera	Gyrinidae	M	-	-	-	-	-	-	-	-	-	7	7	0.2
	Elmidae	M	-	-	31	8	-	-	-	-	-	-	39	1
Lepidoptera	Perlidae	S	-	-	21	-	-	-	-	-	-	-	21	0.5
Pelecypoda	Carbiculidae	M	-	-	-	35	9	-	-	-	-	-	44	1.1
Total 12	30	T=10, M=12, S=8	831	399	191	439	180	187	570	161	250	736	3944	100
Percentage composition of individuals in the whole catchment area			21.1	10.1	4.8	11.1	4.6	4.7	14.5	4.1	6.3	18.7		100

Note: S=Highly sensitive to pollution, M= Moderately sensitive to pollution, T= Tolerant to pollution.

From Table2,we retrieved a total of 3944 individual animals from theRiver Sironko catchment area. This population was composed of 12 orders dominated by Ephemeroptera and Odonata with each represented by five families accounting for 16.7% each of the whole order population. These were followed by Trichoptera represented by four families accounting for 13.3%. Diptera and Hemiptera had equal number of families each represented by three, while Coleopteran, Crustacean and Annelida were each represented by two families. The least represented orders were Plecoptera, Gastropoda, Lepidoptera and Pelecypoda each represented by one family hence accounting for 3.3% each of the whole population.

The 3944 individuals were counted from thirty (30) families with different levels of tolerance to pollution. Out of the 30 families, only eight (8) were sensitive to pollution and ten (10)were tolerant while the majority (12) were moderately sensitive. Implying that the ecosystem health has moved from natural state and the biggest part of it is in the modified state and thus already been polluted.

Based on the family distribution,the majority of the individual animal species in the catchment belonged to the Hydropsychidae family with 1024individuals accounting for 26% of the total population. This family was found on every sampling point in the whole catchment hence a habitat generalist.This was followed by Oligoneuridae, Chironomidaeand Ephemerelidaeeach with469, 436 and 391 individuals accounting for 11.9%, 11.1% and 9.9% respectively of the total population. The smallest family was Perlodidae with only 3 individuals accounting for 0.1%.

A total of 1,411 individual macroinvertebrates consisting of 19 families were identified in the forested land use sites along River Sironko Catchment during the study (Table2).Most of the macroinvertebrate (1221) individuals were identified in the natural forest while only 191 were in the planted forest. Thus, the natural forest inhabited over 86% of the macroinvertebrate population in forested sites compared to only 13% found inthe planted forest. The most dominant families of macroinvertebrates identified in the natural forested sites were Potamonautidae, Hydropsychidae, Ephemerelidae, Oligoneuridae and Chironomidae. On the other hand, the planted forest sites were dominated by the families Hydropsychidae, Heptagenidae, Elmidae and Perlidae.Out of the 19 families identified during the study, only seven (7) were sensitive to pollution and seven (7) were tolerant while five (5) were moderately sensitive. The natural forest had a greater number of sensitive macroinvertebrate families (4) compared to the planted forest that had only three (3). The majority of the macroinvertebrate individuals identified in the forested sites belonged to the Oligoneuridae family with 389 individuals accounting for 27.6% of the total population found in the forest land use. This was followed by Ephemerelidae with 324 individuals accounting for 23% of the total population in forest sites. These two dominating sensitive macroinvertebrate families were only found in the natural forest. The rarest families were Perlodidae and Belostomatidae each with only 3 individuals and accounting for 0.2%. These two rarest and sensitive families were only habited in the natural forest and not found in the planted forest.

A total of 806 individuals of macroinvertebrates belonging to 7 orders and 15 families were identified in agricultural land usesites of River Sironko (Table 2).Four hundred and thirty nine (439) macroinvertebrate individuals were recorded in banana plantation, 180 in sugarcane plantation while only 187 were observed in mixed agriculture land use type. Thus, the majority of macroinvertebrate individuals (54%) were identified in the banana plantation part of the river, followed by 23% in mixed agriculture and 22% in sugarcane plantation. Results in Table2 show that the banana plantation was richest of all the agricultural land uses with 439 individual macroinvertebrates represented by 9 families dominated by Hydropsychidae (49.7%) and Tipulidae (10.5%).

The macroinvertebrate families of Hydropsychidae and Chironomidae, which are tolerant to pollution and Naucoridae, which is moderately tolerant, dominated the stream in mixed agriculture land use (Table 2). The stream in banana plantation land use was dominated by Hydropsychidae (tolerant to pollution), Oligoneuridae (sensitive), Tipulidae (moderately sensitive), Libellulidae (toelerant) and Carbiculidae (moderately sensitive). In the sugarcane land use, the river was dominated by two macroinvertebrate families: Hydropsychidae (tolerant to pollution) and Philopotamidae (moderately tolerant). Based on the results of pollution sensitivity of macroinvertebrate families, mixed agriculture sites of the river had the most poor water quality, followed by the banana plantation and the least polluted sites were in the sugarcane plantation land use.

In the urban land use sites, a total of 731 individual macroinvertebrates belonging to 5 orders and 11 families were recorded in the river at Makuyu and Nabongo Urban centres (Table 2). Makuyu Urban recorded the highest number (78%) dominated by Chironomidae (tolerant), Simulidae (moderately sensitive), Hydrophilidae (moderately sensitive) and Heptagenidae (sensitive). Nabongo Urban accounted for 22% of the identified macroinvertebrates dominated by Chironomidae which is tolerant to pollution. In general the urban land use sites of the river were dominated by Chironomidae and Simulidae Families, which are pollution tolerant and moderately sensitive to pollution, respectively. This indicates poor water quality or ecosystem health of the river as it flows through the urban land use sites in River Sironko Catchment.

At factoryland use site,a total of 736 individual macroinvertebrates consisting of 13 families were collected in the river at Kabiriro Coffee factory. These were dominated by pollution tolerantfamilies of Hydropsychidae(51%) and Coenagrionidae (19%). These two families can survive in poor water quality conditions, indicating that the effluents from the coffee factory negatively affected the ecosystem health of the river.

At the sand mining site, a total of 250 individual macroinvertebrate were identified in samples at Budadiri Sand Mining (Table 2). They were dominated by the pollution sensitive Heptagenidae Family (46%) and pollution tolerant Hydropsychidae Family (35%).This indicates that this land use has limited pollution potential only that sand mining disturbed the habitat thereby not allowing macroinvertebrates to settle as a result of constant dredging especially at the end of the wet season when the sand mining activity was at its peak. The number of individual macroinvertebrates reduces in the middle of the land use but increased at the downstream of the sand mining area.

Assessment of river ecosystem health at different land uses sites in River Sironko Catchment using the South African Scoring System (SASS)

Results in Table 3 show the variation in total mean SASS, total mean of macroinvertebrate families, mean ASPT and ecosystem health class with land uses in River Sironko Catchment.

Table3: Variation in total mean SASS, total mean of macroinvertebrate families, mean ASPT and ecosystem health class with land uses in River Sironko Catchment.

Site and Land use	Mean SASS Score per site	Mean number of macroinvertebrate	Mean ASPT per site	Ecosystem health class per Site	Mean ASPT per land use	Average Ecosystem health class per land use

		families per site				
Forestry						
Inside Chebonet Natural forest	69	9	7.6	Natural	7.7	Natural
End of Chebonet Natural Forest	61	7	8.7	Natural		
Inside Sipi Natural Forest	49	5	9.8	Natural		
End of Sipi Natural Forest	59	8	7.4	Natural		
Start of Makuyu Planted Forest	26	5	5.2	Fair		
Inside Makuyu Planted Forest	50	6	8.3	Natural		
End of Makuyu Planted Forest	34	5	6.8	Good		
Agriculture						
Start of Sipi Mixed Agriculture	59	8	7.4	Natural	7.2	Natural
Inside Sipi Mixed Agriculture	39	5	7.8	Natural		
Start of Muyembe Sugarcane Plantation	16	4	4	Poor		
Inside Muyembe Sugarcane Plantation	30	4	7.5	Natural		
Start of Nabongo Banana Plantation	14	3	4.7	Poor		
Inside Nabongo Banana Plantation	56	5	11.2	Natural		
End of Nabongo Banana Plantation	49	6	8.2	Natural		
Urbanization						
Start ofMakuyu Urban	37	6	6.2	Good	5.4	Fair/ moderate
Inside MakuyuUrban	44	5	4.3	Poor		
End of MakuyuUrban	26	5	5.2	Fair		
Start of Nabongo Urban	49	6	8.2	Natural		
Inside Nabongo Urban	28	6	4.7	Poor		
End of Nabongo Urban	13	3	4.3	Poor		
Coffee Factory and Sand Mining						
Start of Coffee Factory	75	10	8.8	Natural	6.8	Good
End of Coffee Factory	57	12	4.8	Poor		
Before Budadiri Sand Mining	28	3	9.3	Natural	6.9	Good
Inside Budadiri Sand Mining	5	2	2.5	Poor		
End of Budadiri Sand mining	36	4	9	Natural		

Results in table 3 show that natural forest sites were associated with the highest mean ASPT per land use with 7.7 making it natural ecosystem health class while the mean ASPT per site in the same land use ranged between 5.2 in the planted forest to 9.8 in the natural forest. In the same way, the mean SASS score per site ranged between 26 in the planted forest to 69 in the natural forest.

Agriculture was associated with natural ecosystem health class with the Average Ecosystem health class per land use of 7.2. Its mean ASPT per site ranged between 11.2 (inside banana plantation) to 4.2 (at the start of the banana plantation). The mean SASS score per site in the agricultural land use ranged between 14 (at the start of banana) to 59 (at the start of mixed agriculture). Conversely, the mean number of families ranged between 8 at the start of mixed agriculture to 3 at a site at the start of banana plantation (Table 3).Based on the ecosystem health classes per site, seven (7) sites (28%) were poor, 14 sites (56%) were natural, 2 sites (8%) were fair while 2 sites (8%) were good (Table 3). Based on the average ecosystem health per land use, forestry and agriculture maintained natural ecosystem health class, urban land use had a fair /moderate ecosystem health class while coffee factory and sand mining sustained a good ecosystem health category. The mean ASPT per site in the urban land use sites ranged between 8.2 at the start Nabongo urban to as low as 4.3 at the end of Nabongo urban centre site, while the number of taxa followed the same order with 6 families at the start of Nabongo urban land use reducing to only 3 at the end of Nabongo urban. The mean SASS score also followed the same order reducing from 49 at the start of Nabongo urban to only 13 at the end of Nabongo urban centre. Sand mining and coffee factory recorded good ecosystem health class.

Influence of land use on macroinvertebrate assemblage metrics in the River Sironko Catchment

Results of ANOVA test of macroinvertebrate metrics in different land uses in River Sironko catchment are shown in Table 4. There was a statistically significant difference in SASS among natural and planted forest, mixed agriculture, banana plantation and sugarcane agriculture, Makuyu urban and sand mining (ANOVA at $p \leq 0.05$). ASPT showed a significant difference among planted forest, mixed agriculture, banana and sugarcane plantations, Makuyu urban, coffee factory and sand mining (Table 4). There was statistically significant difference in species richness among all land uses except planted forest, Nabongo urban and sand mining. Species diversity showed significant difference among all land uses except sand mining (ANOVA at $p \leq 0.05$).

There was a significant difference in species evenness among natural forest, banana plantation and sugarcane plantation, Makuyu and Nabongo Urban centres.

Distribution of SASS was similar in sugarcane plantation, urban land use and in sand mining at Budadiri but differing significantly from the rest of the sites. Sipi natural forest had the highest ASPT of 8.6±0.79 while Nabongo urban had the lowest at 5.2±0.73 (Table 4, ANOVA at $p \leq 0.05$). Nabongo urban and Muyembe sugarcane plantation did not only have the lowest ASPT but also had a similar ASPT distribution which differed significantly from the rest of the sites at ($p \leq 0.05$). The highest species richness was recorded in Makuyu planted forest at 7±0.82 while the lowest was recorded at Budadiri sand mining with 3±0.41species richness. Distribution of species richness at Budadiri sand mining was not only significantly different from that of Makuyu planted forest but also significantly differed from the rest of the sites ($p \leq 0.05$).

Table 4: ANOVA of macroinvertebrate metrics in different land uses in River Sironko Catchment

Land use	SASS	ASPT	Richness	Diversity	Evenness	Relative Abundance
Forestry						
Chebonet Natural Forest	64.5 ± 2.25^{a}	8.15 ± 0.74^{a}	5 ± 0.41^{abc}	1.59 ± 0.11^{abc}	0.72 ± 0.02^{ab}	20.1 ± 2.88^{a}
Sipi Natural Forest	54 ± 1.63^{ab}	8.6 ± 0.79^{a}	5 ± 0.41^{abc}	1.62 ± 0.12^{abc}	0.74 ± 0.07^{ab}	10.1 ± 1.94^{bc}
Planted Forest	37 ± 3.67^{cd}	6.9 ± 0.76^{abc}	7 ± 0.82^{a}	1.89 ± 0.45^{a}	0.91 ± 0.08^{a}	4.8 ± 0.43^{c}
Agriculture						
MixedAgriculture	49.25 ± 2.87^{bc}	7.6 ± 0.74^{ab}	5 ± 0.08^{abc}	1.54 ± 0.12^{abc}	0.95 ± 0.12^{a}	4.45 ± 0.61^{c}
Banana Plantation	40 ± 4.55^{bc}	7.6 ± 0.63^{ab}	5 ± 0.1^{abc}	1.67 ± 0.19^{abc}	0.76 ± 0.09^{ab}	11.1 ± 1.42^{abc}
Sugarcane Plantation	23.25 ± 2.06^{de}	5.8 ± 0.88^{bc}	4 ± 0.71^{bc}	1.49 ± 0.81^{abc}	0.79 ± 0.07^{ab}	4.6 ± 0.39^{c}
Urban land use						
Makuyu Urban	36 ± 4.32^{cd}	5.4 ± 1.0^{bc}	6 ± 0.82^{ab}	1.77 ± 0.16^{abc}	0.8 ± 0.08^{ab}	18.12 ± 4.19^{ab}
Nabongo Urban	21 ± 3.94^{e}	5.2 ± 0.73^{c}	4 ± 1.47^{bc}	1.27 ± 0.21^{bc}	0.79 ± 0.07^{ab}	4.1 ± 0.76^{c}
Coffee factory and Sand Mining						
Coffee Factory	65.5 ± 4.11^{a}	6.8 ± 0.9^{abc}	6 ± 0.71^{ab}	1.81 ± 0.11^{ab}	0.67 ± 0.07^{b}	18.7 ± 4.01^{ab}
Sand Mining	23 ± 2.27^{de}	6.9 ± 0.45^{abc}	3 ± 0.41^{c}	1.23 ± 0.05^{c}	0.76 ± 0.09^{ab}	6.3 ± 1.05^{c}

Macroinvertebrate metrics with different superscripts (a, b, c, d and e) in the same column indicate significant differences (ANOVA at $p \leq 0.05$).

The highest species diversity was recorded at the Kabiriro coffee factory (1.81±0.11) while the lowest was Budadiri sand mining (1.23±0.05) (Table 4, ANOVA at $p \leq 0.05$). Despite the fact that Makuyu planted forest had a significantly different distribution of macroinvertebrate species diversity from Budadiri sand mining, the two sites significantly differed from the rest of the sites (ANOVA at $p \leq 0.05$). The distribution of species evenness was highest at Sipi mixed agriculture with 0.95±0.12 while the lowest was at coffee factor at Kabiriro with 0.67±0.07. Evenness distribution was uniformly distributed throughout the sites apart from Kabiriro coffee factory, Sipi mixed agriculture and Makuyu planted forest. The highest macroinvertebrate relative abundance was recorded at Chebonet natural forest (20.1±2.88) while the least was recorded at Nabongo urban (4.1±0.76).

Influence of landuse on habitat quality in Sironko River catchment area:

The results of influence of land use on habitat quality(physical habitat and physicochemical water quality) are summarized in Table 5.

Table 5: ANOVA results of influence of landuse on habitat Quality in the Sironko River catchment:

	Habitat value from different land uses studied in the River Sironko catchment area.									
Habitat quality parameters	Chebonet natural forest	Sipi natural forest	Sipi mixed agriculture	Kabiriro coffee factory	Makuyu urban	Makuyu planted forest	Budadiri sand mining	Nabongo banana plantation	Nabongo urban	Muyembe sugarcane plantation
SIC(%)	12 ± 2.16^{abcd}	13 ± 1.22^{abcd}	8 ± 0.82^{d}	9 ± 0.82^{cd}	18 ± 2.48^{a}	18 ± 2.48^{a}	15 ± 1.08^{abc}	15.5 ± 1.44^{ab}	10 ± 0.1^{bcd}	11 ± 0.1^{bcd}
Vg(%)	12 ± 0.82^{a}	10 ± 1.22^{ab}	11 ± 0.1^{a}	11.5 ± 0.87^{a}	3 ± 0.1^{d}	4 ± 0.10^{cd}	3.25 ± 0.63^{d}	6 ± 0.1^{bcd}	3 ± 0.1^{d}	8 ± 0.1^{abc}
OH(%)	10 ± 0.82^{cd}	12.75 ± 0.63^{bcd}	12 ± 0.1^{bcd}	9 ± 0.71^{d}	14 ± 0.1^{abc}	16 ± 0.41^{ab}	18 ± 0.1^{a}	16 ± 0.41^{ab}	12 ± 0.41^{bcd}	9 ± 0.1^{d}
SC(%)	31±1.4	29 ± 0.1^{ab}	26±1.47	27±2.16	22 ± 0.1^{cd}	27 ± 1.41^{ab}	27 ± 0.1^{a}	25±2.	21±0.	27±1.78

	1[a]		[bc]	[ab]			[b]	04[bcd]	71[d]	[ab]
IHAS(%)	65±0.82[a]	65±0.82[a]	57±0.1[bc]	57±0.41[bc]	57±1.78[bc]	65±0.82[a]	63±0.08[ab]	62±0.1[abc]	46±0.82[d]	54.75±1.03[c]
Narrative	Good	Good	Fair	Fair	Fair	Good	Fair	Fair	Poor	Fair
Ec(µS/cm)	67.08±4.39[de]	71.92±12.19[de]	41.5±4.52[e]	188±6.49[bc]	162.5±11.98[bc]	133.25±6.29[cd]	121.75±10.54[cde]	222.75±16.46[ab]	294.25±49.95[a]	174.55±10.97[bc]
TDS(ppm)	38±4.83[cde]	24.62±2.91[de]	20.27±1.16[e]	89.8±3.75[ab]	84.5±4.41[abc]	73.25±6.41[bcd]	124.5±13.98[a]	123±8.04[a]	77.55±28.01[abc]	69.53±11.61[bcd]
pH	7.47±0.23[bc]	10.37±1.13[a]	8.27±0.15[ab]	6.01±1.23[c]	8.62±0.91[ab]	6.88±0.46[bc]	8.2±0.24[b]	7.75±0.22[bc]	7.66±0.26[bc]	6.98±0.08[bc]
D.O(ppm)	11.06±1.33[b]	9.83±1.12[b]	10.95±0.31[b]	9.82±0.33[b]	8.7±0.41[b]	14.56±1.77[a]	8.6±0.72[b]	8.64±0.26[b]	8.7±0.49[b]	8.28±0.50[b]
Transp (cm)	25.75±4.21[bc]	42.42±4.06[b]	63.75±4.19[a]	32.75±1.71[bc]	38.6±8.19[bc]	42±1.68[b]	30.5±2.22[bc]	21.25±1.38[c]	20.57±0.90[c]	34.5±2.4[bc]
Temp(^{0}C)	17.5±0.89[de]	17.68±0.27[de]	16.05±0.87[e]	21.55±0.24[bc]	21.5±0.3[bc]	19.4±0.83[cd]	21.05±0.50[bc]	22.3±1.21[ab]	24.45±0.81[a]	21.65±0.71a[bc]
Disch(m^3/s)	4.5±0.39[abc]	2.1±0.27[cde]	4.9±0.57[ab]	0.2±0.07[e]	5.28±0.77[a]	1.7±0.07[de]	1.6±0.12[de]	0.3±0.11[de]	1±0.09[de]	2.7±0.25[bcd]

Notes: Different land use types with different letters (a, b, c, d and e) in the same row indicate significant differences at 5% level.

Table 5 show that forested sites had the same value of habitat quality with total IHAS of 65±0.82% and classified as good habitatin the river Sironko catchment. Similarly, Sipi mixed agriculture, coffee factory and Makuyu urban had similar habitat quality with a total IHAS ranging from 57±0.1 to 57±1.78%. Nabongo Urban had poor habitat quality. It is the only one that had a poor habitat quality in the catchment area with a total IHAS of 46±0.82%. The distribution of IHAS totals in forest sites was similar (at $p>0.05$) but this significantly differed from the rest of the sites (at $p<0.05$).

Generally, thestream condition in the catchment ranged between 21±0.71 – 31±1.41%. Of all the land uses, the natural forest at Chebonet site had the best stream condition of 31±1.41%, followed by Makuyu planted forest with 27±1.41% which had similar score as Kabiriro coffee factory and sugarcane plantation. The highest in stone current habitat was found at Makuyu urban and Makuyu planted forest with 18±2.48% while the least was recorded at Sipi mixed agriculture with 8±0.82%. The stream condition at Sipi natural forest differed significantly from the rest of the sites at $p<0.05$

The highest vegetation habitat was provided by Chebonet natural forest (12±0.82%) and the lowest was at Makuyu urban (3±0.1%, Table5). The distribution of vegetation was similar at sites of Chebonet natural forest, mixed agriculture and coffee factory (at $p>0.05$) but these significantly differed from the rest of the sites at $p<0.05$. Budadiri sand mining had the best stream habitat of 18±0.1% while the least stream conditionwas recorded at Muyembe sugarcane (9±0.1%). The habitat quality generally ranged from good to fair and poor. Out of the ten stations sampled, three had good habitat all with total IHAS of 65%, fair ones ranged between57%-63% total IHAS, while only one had a poor habitat with total IHAS of 46%.

The highest conductivity was recorded at Kabiriro coffee factory (188±6.49 µS/cm) while the least was 41.5±4.52 (µS/cm) at Sipi mixed agriculture. The distribution of conductivity was similar at forest sites (at $p>0.05$) but differed significantly from the rest of the sites (at $p<0.05$). TDS was highest at Budadiri sand mining site with124.5±13.98ppm but lowest at Sipi mixed agriculture with 20.27±1.16ppm. One way ANOVA distribution indicated that the distribution of TDS was similar between urban sites at $p<0.05$ but significantly differed from the rest of the sites at $p<0.05$.The lowest pH was recorded at Kabiriro coffee factory (6.01±1.23) but highest at Sipi natural forest with 10.37±1.13. pH at banana plantation site, sugarcane plantation site and Nabongo urban were similar at $p>0.05$ but significantly differed from the rest of the sites at $p<0.05$. The highest Dissolved oxygen was recorded at Makuyu planted forest with 14.56±1.77ppm but least at Budadiri sand mining with 8.6±0.72ppm. The dissolved oxygen at the planted forest site differed from the rest of the sites at $p<0.05$. The clearest water was associated with mixed agriculture at 63.75±4.19cm where pasture dominated the site as compared to crop farms, while water was most turbid at a site in the Nabongo urban center with only 20.57±0.90cm. Water temperature was coolest in the Sipi mixed agriculture with about 16.05±0.87^{0}C but became warmer at Nabongo urban with 24.45±0.81^{0}C. The distribution of water transparency and temperature was similar at sites of sand mining, coffee factory, makuyu urban centre and the sugarcane plantation at $p>0.05$ but these differed significantly from the rest of the sites at $p<0.05$. The highest volume of water (discharge) was recorded at Makuyu urban with 5.28±0.77m^3/s while low water volume was recorded at Kabiriro stream with 0.2±0.07 m^3/s.

Relationship between,macroinvertebrate assemblage metrics and habitat quality in the River Sironko catchment area:
Results of the Pearson's correlation (r) between habitat quality parameters are shown in Table 6.

Table6: Pearson's correlation coefficients(r) between macroinvertebrate metrics, habitat quality parameters

Macroinvertebrate metrics	**Habitat parameters in the river Sironko catchment area**											
	Stones in current	Vegetation	Other habitat	Stream condition	IHAS totals	Conductivity	TDS	PH	D.o	Transparency	Temperature	Discharge
SASS	-0.18	0.77	-0.34	0.59	0.46	-0.49	-0.42	-0.02	0.01	0.14	-0.47	0.05
	0.268	**0.000****	**0.035***	**0.000****	**0.003****	**0.001****	**0.007****	**0.919**	**0.513**	**0.389**	**0.002****	**0.740**
ASPT	0.03	0.41	0.14	0.77	0.60	-0.53	-0.32	0.18	-0.12	0.01	-0.35	-0.17
	0.866	**0.009****	**0.376**	**0.000****	**0.000****	**0.000****	**0.043***	**0.274**	**0.471**	**0.935**	**0.025***	**0.291**
RICHNESS	0.11	0.14	0.06	0.22	0.33	-0.08	-0.32	-0.12	-0.12	0.18	-0.06	-0.04
	0.486	**0.376**	**0.741**	**0.166**	**0.037***	**0.608**	**0.049***	**0.446**	**0.487**	**0.257**	**0.721**	**0.785**
DIVERSITY	0.19	0.15	0.04	0.25	0.29	-0.23	-0.07	0.01	-0.12	0.03	-0.10	-0.08
	0.246	**0.351**	**0.796**	**0.125**	**0.06**	**0.155**	**0.658**	**0.964**	**0.474**	**0.875**	**0.524**	**0.629**
EVENNESS	0.12	-0.02	0.26	0.26	0.13	-0.25	-0.26	0.010	-0.11	0.23	-0.12	0.01
	0.471	**0.899**	**0.09**	**0.09**	**0.425**	**0.199**	**0.100**	**0.539**	**0.523**	**0.145**	**0.451**	**0.945**
RELATIVE ABUNDANCE	0.13	0.39	-0.15	0.27	0.30	-0.13	-0.04	-0.06	-0.15	-0.24	-0.06	0.05
	0.418	**0.013***	**0.344**	**0.09**	**0.061**	**0.442**	**0.825**	**0.709**	**0.380**	**0.131**	**0.729**	**0.756**

Notes: Bolded are P-values, Unbolded are coefficients, Bolded with * is significant relationship at 5% level, while Bolded with is significant relationship at 1% level.**

There was a highly significant positive correlation between SASS scores and riparian vegetation (r = 0.77, p≤0.01), stream condition (r=0.59, p≤0.01) and IHAS totals(r=0.46, p≤0.01). This indicates that an improvement in vegetation, stream condition and IHAS totals increased the SASS scores. However, there was a high significant but negative correlation the between SASS scores and stream conductivity(r= -0.49, p≤0.01) and temperature (r= -0.47, p≤0.01). Other habitats had a significant negative correlation with the SASS scores (r = -0.34, p≤0.05, Table 6). SASS was negatively affected by temperature, TDS, conductivity and other habitat which implies that an increase in these habitat parameters lead to a decrease in the SASS score. On the other hand, riparian vegetation, stream condition and IHAS totals had a positive significant effect on the SASS scores, meaning that an increase in these habitat parameters caused a significant increase in the SASS. Similarly, results in Table 6 show that there was a highly significant positive correlation between ASPT and vegetation (r = 0.41, p≤0.01), stream condition (r=0.77, p≤0.01) and IHAS totals (r=0.60,) and a strong negative correlation with conductivity (r = -0.53, p≤0.01). ASPT had a weak negative correlation with total dissolved solids and temperature. Macroinvertebrate taxa richness had a weak positive correlation IHAS and a weak negative correlation with total dissolved solids. The relative abundance of macroinvetebrate had a weak positive correlation only with the vegetation.

IV. DISCUSSION

Influence of land use on macroinvertebrate assemblage.

Unlike Kobingi*et al.,* (2009) who found Hemiptera and Dipteradominating land uses in his study, this study revealed the most dominant orders in all land uses as Ephemeroptera and Odonata represented by the 5 families (16.7%) each while the smallest one was Gastropoda, Lepidoptera and Plecoptera each represented by 1 family hence 3.3% of the total community. The most dominant family was Hydropsychidae with 28.2%. This difference could be as a result of differences in the intensity, arrangement and altitudinal location of the land uses considered in this study.

The natural forest had the highest number of individuals of about 1230, dominated by sensitive taxa with over 55% of the total population in this landuse. This is probably because of the limited disturbance by human activities where the forest is reserved as a national park hence low temperature, high D.O and most importantly, it was in a higher altitude area. This finding is not peculiar to the Sironko catchment area, a similar study by Kasangaki*et al*., (2008) illustrated that sensitive families of EPT dominated forested area of Bwindi impenetrable National Park.Mixed agriculture immediately after natural forest of River Sipi was associated with reduction in the number of taxa and individuals. Tolerant taxa increased but moderately sensitive taxa dominated the landuse followed by tolerant and not sensitive as was in the natural forest. This is because limno-chemical water quality changed due to the influence of animal watering, runoff from arable gardens draining into the river. This is in agreement with Kasangaki*et al.,* (2008)and Turyahabwe, et al., (2023) who both indicated that tolerant families of diptera and Hemiptera dominated agriculturally impacted sites, while Kobing*et al*.,(2009) indicated that grazing and direct watering of animals affected water quality and macroinvertebrate assemblage.The ecosystem health of the Kabiriro stream was natural at the start of the coffee factory but changed to poor downstream of the factory. In general, the coffee factory activity was associated with majority of macroinvertebrate taxa of 76% being tolerant and only 8% sensitive. This is because the effluent from the factory caused a reduction in the pH, increase turbidity to make the habitat so polluted that sensitive taxa could not survive. This condition however, provides a feeding ground for the tolerant taxa which confirms Kobing*et al's*., (2009) assertion that organic wastes from riparian zones acted as food for tolerant groups like chironomidae.Despite the fact that it is located in the lower part of the mountain, banana plantation was associated with a natural ecosystem health. This was due to the good mulching that increased filtration of water draining into the river, coupled with limited pollution and runoff thereby improving ecosystem health of the river. This is in agreement with Van Butsel*et al.,* (2017) who stated that agriculture did not impair macroinvertebrates seriously apart from a few locations.

The ecosystem health of Muyembe sugarcane plantation improved progressively from the start and by the middle of the landuse, the ecosystem had turned to natural from poor.This was attributed to a number of factors such as, filtering capacity of sugarcane leaves which acted as riparian and in-stream vegetation just like papyrus, limited runoff due to dense cover and more still the relief and velocity of the river were low in this wide channel.While assessing the current overall health status of River orange in Namibia, Munyika et al., (2014), observed that sub catchments that were dominated by agriculture were associated with an increased number of pollution tolerant taxa of macroinvertebrate along the river. This condition was found in the mixed agriculture where despite the location of the site being in pristine regions of the river, Chironomidae dominated the land use. This was due to the cow dung that was found on banks of the river as well as the deposited waste material from the adjacent crop gardens.

Influence of land use on habitat quality:

Urban centres of Makuyu and Nabongo were dominated by tolerant taxa due to the constant dumping of domestic waste in the water that does not only clog the macroinvertebrate habitats such as interstitial spaces but also affects the water quality habitat which stresses and kills or leads to migration of sensitive taxa. This confirms what Chutter*et al.,* (1998) indicated by stating that apart from Physico-chemical water quality, habitat quality is the next best factor that influences macroinvertebrate distribution. In this study, the IHAS score (habitat quality) at Nabongo urban was poor (46%), which could not favor a natural ecosystem health.The middle of the sand mining was associated with drastic reduction in the number of individual organisms and the habitat quality had dropped. This was attributed to constant bank and bed dredging thereby denying taxa the habitat which made them migrate to the downstream of the mining point. A similar scenario had been found by Van Butsel*et al.,* (2017) in river Mpanga, in western Uganda.

The coffee factory at Kabirirocaused a high degradation of macroinvertebrate habitat as majority of the taxa were tolerant. This is because the habitat was so degraded that only tolerant taxa could survive. This finding rhymes well with Kobingi's (2009) finding that indicated that industrial waste discharges in the Kisian and Kisati catchments did not only have chemical but also physical disturbance on the macroinvertebrate habitat health which led to migration and mortality of sensitive taxa while favoring tolerant taxa.According to Mbaka (2010), use of riparian areas for human activities has been reported to be detrimental on stream channels through sedimentation and on canopy cover reduction thereby increasing sun's insolation that increases the water temperature making the habitat unfavorable for some macroinvertebrate species sensitive to sedimentation and warm temperature. This found that urban areas of Nabongo and Muyembehad detrimental effects on macroinvertebrate habitat characterized by higher temperature, lower D.O, higher EC and higher TDS than neighboring land uses in the same catchment area.

Relationship between habitat and macroinvertebrate assemblage in River Sironko catchment.

Forested areas both natural and planted were associated with the highest IHAS totals of 65% as a result of limited human interruption and the riversthus have pristine conditions. That is why this IHAS quality rhymed with High SASS and ASPT with higher sensitive taxa.M'Erimba*et al*., (2014) stated that sensitive taxa were sensitive to habitat quality, where EPT were found in areas with high Qualitative Habitat Assessment (QHA) scores of 82.5% while the tolerant ones were associated with 59.7%.Planted forest at Makuyu improved the ecosystem health. It was associated with a higher number of sensitive taxa (43%). This is attributed to increased D.O, reduced temperature and pH. It was also associated with filtration by stones in current that had been deposited in channel of the river amidst no further pollution. In this study,the low IHAS of 46% at the Nabongo urban centre corresponded with low SASS and ASPT which was expected because poor habitat discourages diverse assemblages of macroinvertebrates. The habitat qualities of plantation farms of banana and of sugarcane were all fair yet both of them had similar SASS and ASPT class of Natural ecosystem health conditions. This is because of their ability to filter water draining through them to the river allowing little or no erosion, thereby keeping low turbidity, higher D.O, and low pH.

Forested areas were found to be associated with high D.O, low temperatures and high macroinvertebrate habitat availability. This is because of limited human influence hence limited erosion. The many woody debris that fall in the river do not only work as food for macroinvertebrates but also habitats for EPT sensitive species as was the case with both planted and natural forested areas. This agrees with what Kasangaki et al.,(2008) found in the Bwindi impenetrable National Park streams and what Van Butsel et al ., (2017) found in the Mpanga river running through Kibale National Park which are both natural tropical forest reserves in Uganda.

V. CONCLUSIONS

This study found that there was apositive relationship between landuse,macroinvertebrate assemblage and habitat quality where SASS,ASPT corresponded with IHAS total i.e., the higher the IHAS the higher the SASS and the higher the ASPT in a given landuse stream. Forested areas were dominated by sensitive taxa hence having natural ecosystem health while urban centres were more stressed and dominated by tolerant taxa indicating poor ecosystem health. Planting forests along river banks improves ecosystem health as it improves physical habitat quality, limno-chemical quality, reduces runoff by stabilizing banks. Sand mining needs to be regulated and kept on a small scale to avoid mass loss of ecosystem health.

Acknowledgements:

We are grateful to the biology department of Busitema University for the laboratory space, equipment and expertise you gave us in macroinvertebrate sampling and analysis during the study that made it a successful one.

REFERENCES

[1]. BagalwaMudherwaNsomboAnd Mujugu Eliezer Kateyo(2014), Assessment Of Physico- Chemical Parameters In Relation With Fish Ecology In IshashaRiver And L. Edward, Albertine Rift Valley, East Africa. International Journal Of Current Microbiology And Applied Sciences.

[2]. Bagalwa, M., Yalire, M., Balole, E., And Karume, K. (2014). A Preliminary Assessment OfPhysico-Chemical And Bacteriological Characteristics Of Lake Edward And Major Tributaries Rivers, Democratic Republic Of Congo. Scholars Academic Journal Of Biosciences (SAJB), 2(3): 236-245

[3]. Chikodzi D, Mabhegedhe, M. And Tunha T (2017), Biomonitoring Of MuchekeAnd ShagasheRivers In Masvingo, Zimbabwe Using Macroinvertebrates As Indicators Of Water Quality. Journal OfGeoscience And Environmental Protection.

[4]. Chutter F.M (1998), Research On TheRapid Biological AssessmentOf Water Quality Impacts In Streams And AndRivers. WRC Report No. 422/1/98, Water Research Commission, Pretoria.

[5]. Dickens CWS And Graham PM (2002), The South African Scoring System (SASS) Version 5 Rapid Bioassessment Method For Rivers. African Journal Of Aquatic Science

[6]. Karr, JR (1999). Defining And Measuring River Health. Freshwat. Biol.41:221-234.

[7]. Kasangaki.A, Chapman L J, Balirwa J. (2008), Land Use And The Ecology Of Benthic Macro-Invertebrate Assemblages Of High-Altitude Rain Forest Streams In Uganda. Fresh Water Biology.

[8]. Kobingi, Nyakeya, Raburu, Philip Okoth, Masese, Frank OnderiAnd Gichuki, John (2009), Assessment Of Pollution Impacts On The Ecological Integrity Of The KisianAnd KisatRivers In Lake Victoria Drainage, Basin Kenya. Journal OfEnvironmental Science And Technology.

[9]. M'Erimba C.M, Mathooko J.M., Karanja H.T And Mbaka J.G (2014), Monitoring Water And Habitat Quality In Six Rivers Draining The Mount Kenya And AberdareCatchments Using Macroinvertebrates And Qualitative Habitat Scoring. Egerton Journal Of Science And Technology.

[10]. Mcmillan P.H. (1998) .An Integrated Habitat Assessment System (IHAS Version 2), For The Rapid Biological Assessment Of Rivers And Streams. CSIR Research Report No. ENV-P-I 98132, WaterResources Management Programme, Council ForScientific And Industrial Research, Pretoria, 44pp.

[11]. Plumptre, A.J., Behangana, M., Davenport, T., Kahindo, C., Kityo, R., Ndomba, E., Nkuutu, D., Owiunji, I. Ssegawa, P., Eilu, G E., (2003). The Biodiversity Of The Albertine Rift. Albertine Rift Technical Reports No. 3, Wildlife Conservation Society, 2003. ISSN: 1543-4109

[12]. MbalassaMulongaibalu, Jean Jacques MashingamoBagalwaMuderwaNsomboAnd Mujugu Eliezer Kateyo(2014), Assessment Of Physico-Chemical Parameters In Relation With Fish Ecology In IshashaRiver And L. Edward, Albertine Rift Valley, East Africa. International Journal Of Current Microbiology And Applied Sciences.

[13]. NEMA. (2004). The State Of Environment Report For Uganda, NEMA Kampala, Uganda

[14]. RaburuPhilip.Okoth, J.B OkeyoAnd Frank OnderiMasese (2009), MacroinvertebrateBased Index Of Biotic Integrity (M-IBI) For Monitoring The NyandoRiver, L. Victoria Basin,Kenya. Scientic Research AndEssay.

[15]. Rossouw, J.N. (2004). Water Quality In The Ecological Reserve For River Ecosystems. Proc. WaterInstitute OfSouthern Africa (WISA) Biennial Conference, 2-6 May 2004, Cape Town, South Africa.

[16]. Turyahabwe, R; Turyabanawe, G. L; Andama, E; Othieno, T; Wamono, E. (2023). Spatio-Temporal Variations in Water Quality and Fish Assemblages in Odoponyi Seasonal Stream as a response to disturbance from Selected Agricultural Landscapes in Tororo, Uganda. J. Appl. Sci. Environ. Manage. 27 (9) 1881-1888

[17]. Turyahabwe. R, Mulabbi. A, Asaba.JAndOlowo. M (2021), Ecological Responses OfMacroinvertebrates To An In-Stream Ecosystem Restoration Technique In A Tropical Stream In Eastern Uganda. East African Journal OfEnvironment And Natural Resources Https//Doi.Org/10.37284/2707-4242.