INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 9, No. 6, p. 1-12, 2016
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

The effects of land use and land cover change on freshwater snail distribution in Katana region, Democratic Republic of Congo

M. Bagalwa*[1,2], N. Zirirane[2], C. Batumike[1], B. Baluku[1], M. Majaliwa[2,3], N. Mushagalusa[2], K. Karume[2,4]

[1]*Department of Biology, Centre de Recherche en Science Naturelles de Lwiro, Bukavu, D. R. Congo*

[2]*Faculté des Sciences Agronomiques et Environnement, Université Evangélique en Afrique, Bukavu, D.R. Congo*

[3]*College of Agricultural and Environmental Sciences, Makerere University, Uganda*

[4]*Department of Geochemistry, Observatoire Volcanologique de Goma, D.R. Congo*

Article published on December 30, 2016

Key words: Land use and land cover change, Freshwater snail, Katana region, Congo

Abstract

Land use and land cover change is a factor that significantly affects the loss of biodiversity and distribution of species. Remote sensing through satellite imagery and land use and land cover classifications systems can identify certain locations where freshwater snails have colonized in ecosystems that have changed over time. The objective of this study is to investigate the influence of land use and land cover change on freshwater snail distribution and diversity in Katana region, Democratic Republic of Congo. Land sat images of 1987, 2001 and 2010 (30 m spatial resolution) were used to determine the magnitude and trends of land use and land cover changes in the region. Samplings of individual snails were identified at genus and species levels through the use of the extensive malacological literature. The continuous environmental variables considered in the correlation analyses were land use and land cover classes, different years, species richness, and snail distribution. The results obtained in this study shown clearly that land use and land cover changes affect the distribution of snails in the Katana region. The changes observed in land use and land cover are altering the distribution of snail in the region. There is an increase in taxa richness during different years in the micro-catchment. There is a positive correlation between snail richness and built-up area class and a negative correlation between snail richness and forest, wetland. This study shows a wide distribution of snails in the region shifting at high altitude.

***Corresponding Author:** M. Bagalwa ✉ mashibagalwa@yahoo.fr

Introduction

Land use and land cover change contributes significantly to earth–atmosphere interactions and biodiversity loss and distribution. It is a major factor in sustainable development and an indicator of human responses to global change (Meyer and Turner, 1994; Lambin *et al.*, 2001). Studies of freshwater snails are designed at one of three discrete spatial scales: (1) comparisons among bodies of water (e.g., multiple stream, wetland or lake comparisons); (2) comparisons within a body of water but between habitat types, and (3) land use and land cover change. One of the goals of freshwater ecology study is to understand how communities of freshwater species are structured in space and time and to determine how environmental factors affect their distribution (Chlyeh *et al.*, 2006; Herringshaw *et al.*, 2011; Camara *et al.*, 2012). The majority of the research conducted on this topic reveals that critical aspects of the physical environment include disturbance, water velocity, substrate particle and land use and land cover (Delucchi, 1988; Minshall, 1984; Camara *et al.*, 2012). Other studies have found that food abundance, predation and competitive interactions may also be important at this scale (McAuliffe, 1984; Lodge *et al.*, 1987). At the microhabitat scale (within habitat types and bodies), biotic factors such as food availability and predation have been found to be primarily influential in determining the abundance of snail organisms (Peckarsky and Dodson 1980; Hildrew and Townsend, 1982).

To indentify location in the watershed were change have occur over time and where freshwater snails have colonized, techniques of remote sensing using satellite imagery and the land use and land cover classification can provide useful data. Land use and land cover changes seem to be a common physical factor that impacts freshwater snail distribution and diversity (Salanki *et al.*, 2003; Camara *et al.*, 2012). These effects result largely from patterns of human land use and subsequent effects on aquatic ecosystems (Allan, 2004; Pyron *et al.,* 2006). Although land use patterns are unlikely to change in the near future, identification and awareness of existing fauna can provide a baseline for further monitoring and conservation.

A number of studies have shown marked changes in chemical water quality associated with land use and land cover change (Hoare and Rowe, 1992). Recent comparisons of the physicochemical habitat and invertebrate biota amongst streams showed progressive modification from conditions under native forest, to exotic forest, scrubland, and pasture (Harding and Winterbourn, 1995). The structure of the invertebrate communities changed along this "ecological gradient". Land use and land cover change and transformations in the way land is managed are key drivers of changes in biodiversity in the area. In the past decade, a number of factors have contributed to transformation of Lake Kivu catchment, particularly Katana micro-catchment. These factors include political instability, refugee migration and civil war, large-scale land clearance to satisfy energy demand, construction and timber harvesting from neighboring countries as well as from within the DRC (Majaliwa *et al.*, 2010). Water resources in the region are at risk because of a combination of agricultural, urban, and other human impacts. Over the years, the impact of various factors on snails distribution has been investigated (Bagalwa and Baluku, 1997). However, the role of human environmental disturbance on snail diversity patterns has only been done superficially in the region (Baluku, 1987). But given the proceeding degradation of these freshwater ecosystems in developing countries, particularly in tropical Africa, it is hypothesized that human influences impact snail diversity patterns. Comprehensive investigation of the role of anthropogenic factors on snails' diversity patterns could probably contribute to a better understanding and management of problems associated with potential diseases as well as snail conservation. The present study seeks to investigate the influence of land use and land cover change on freshwater snail distribution and diversity in Katana region of the DRC.

Materials and methods

Study area

The study area is constituted by two micro-catchments of tributaries in the western region of Lake Kivu: the river Lwiro and river Cirhayobowa (Fig. 1).

The micro-catchment is dominated by steep (<3%) hilly topography underlain by sedimentary sandstones and siltstones soils which are predominately volcanic where volcanic ash deposits are easily eroded. Its geology is dominated by Precambrian metamorphosed sediments (metamorphic rocks) and Proterozoic platform sediments (Cahen and Lepresonne, 1967).

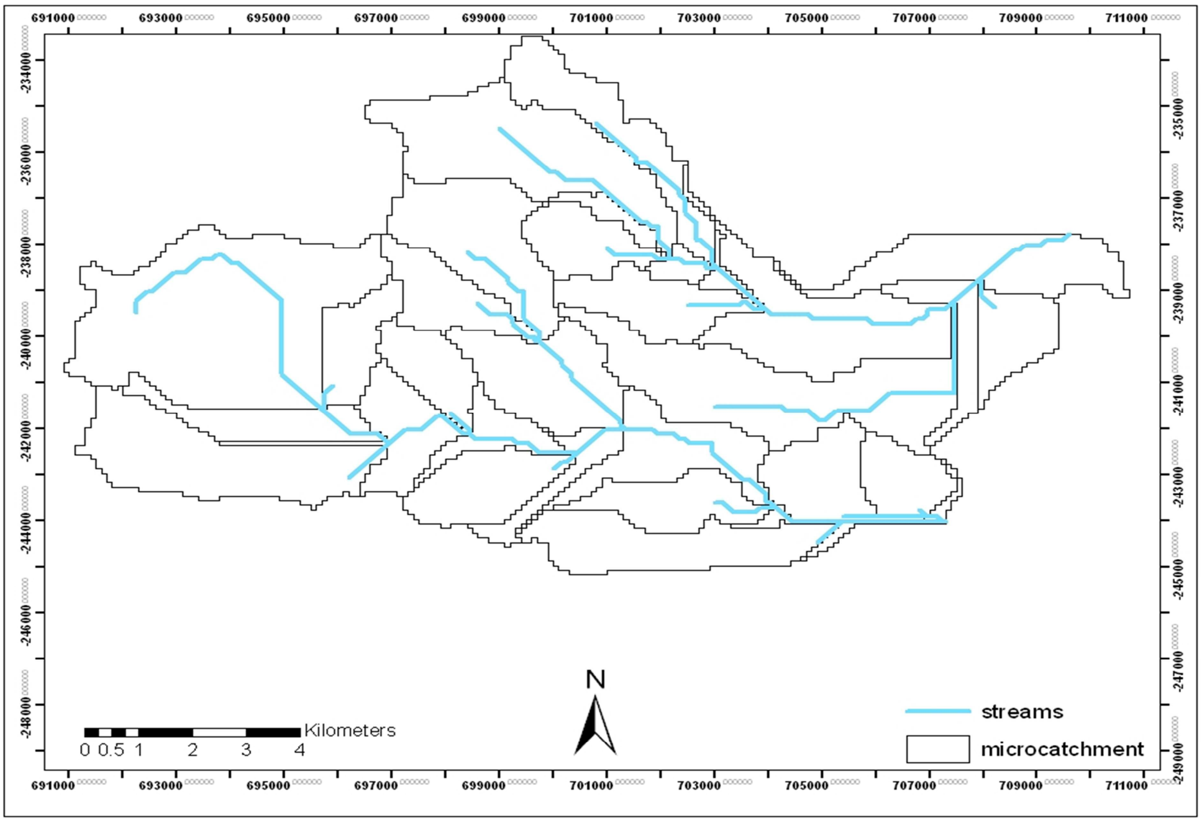

Fig. 1. Map of the micro-catchment of Katana region, Democratic Republic of Congo.

The climate is tropical with bimodal rainfall distribution. The dry season spans from June to August and the rainy season from September to May. Annual rainfall is about 1500 mm (Bagalwa, 2006; Bagalwa *et al.*, 2013a). About 70% of the land is used for agriculture and 10% for irrigated sugar cane field located in the swamp area (Bagalwa *et al.*, 2013b). Vegetation is dominated by cultivated savanna which replaced the original forest of *Albizia grandibracteata* (Bagalwa et Baluku, 1997). Most of the Lwiro river micro-catchment area is characterized by cropland with scarce woodlands and forested highlands. The main croplands consist of maize, beans, cassava, and potato. Besides the cultivated lands, the main land cover types are grasslands, marshland, and forest with patches of shrubs, eucalyptus woods, and trees.

Demographic pressure (more than 350 habitats per square kilometer) threatens the natural environment because of the growing logging and cultivation activities (UICN, 1990; Bagalwa *et al.*, 2013c).

The region experienced fluxes of refugees resulting from the Rwandan civil war in 1994 and the Congolese civil war in 1996–2010 (Karume, 2010; Barhimanya *et al.*, 2014; Bagalwa *et al.*, 2014).

Dynamic of land use and land cover in the Katana micro-catchment

The study utilized ortho-rectified and cloud free land sat TM/ETM images (1987, 2001 and 2010) of 30 x 30 m spatial resolution obtained from the Google Earth Image domain to determine the magnitude and trends of land use and land cover changes.

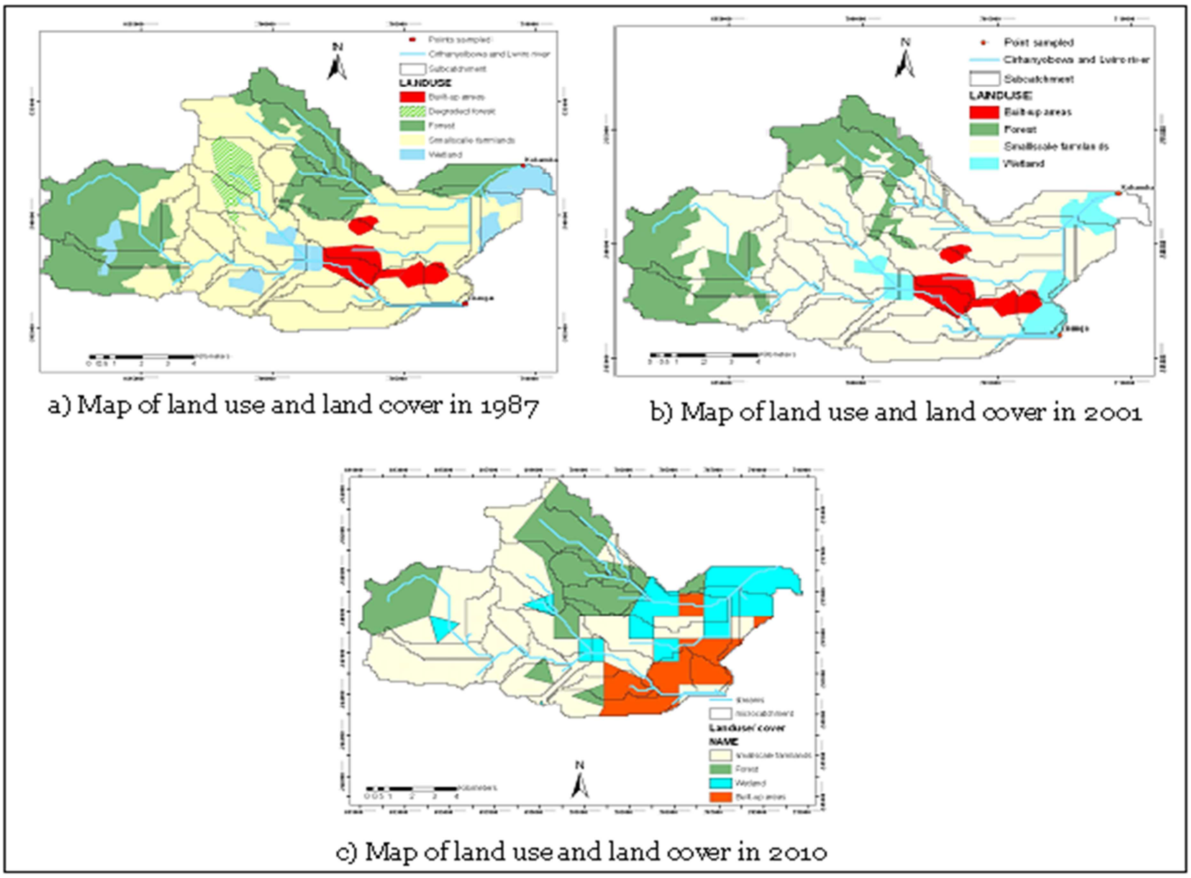

Fig. 2. Land use and land cover in Katana watershed for years 1987, 2001 and 2010.

All the images chosen were limited to dry season months to minimize seasonal effects (Maingi and Marsh, 2001; Basnet and Vodacek, 2012). The year 1987 shows the state of ecological system at the time of instability in the region as previously described. The year 2001 is chosen as an intermediate point to distinguish the immediate effects of refugees and their movements in the region and the year 2010 coincides to the end of civil war in the Lwiro micro-catchment.

The ortho-rectified satellite images were subjected to unsupervised classification procedures using ILWIS 3.3 software. The unsupervised classification was used because of more information present in unsupervised compared to supervised classification (Jensen, 1986).

A four-class land use and land cover classification scheme was adopted: (1) forest, (2) agriculture, (3) built-up land and (4) wetland. The time series regressions were used to determine the trend of all the land use and land cover types.

The change rates of single land use and land cover type were determined according to Peng *et al.,* (2008) procedures.

Sampling and identification of species

A sampling of individual snails was identified at their genus and species level by using the extensive malacological literature (Brown, 1994). Snail richness corresponding to the number of taxa (genera or species) was collected in each sampled ecosystem. Thirty four sampling sites distributed in different ecosystems (forest 3, wetland 14, agricultural 10 and built-up area 7) were investigated monthly for this study during all the three periods (1987, 2001 and 2010) without to be change.

Data analyses

The continuous environmental variables considered in the correlation analyses were land use and land cover classes, different years, species richness, and snail distribution.

Correlations among percentage of land use and land cover classes for different years and percentage of species richness were tested using the Pearson's correlation coefficient.

Variation of percentage of snail richness between four land use and land cover classes was analyzed using ANOVA one way with Past 1 software.

Results

Dynamic of Land use and land cover change in Katana watershed

The change of land use and land cover in the Katana watershed during the years 1987, 2000, and 2010 is present in fig. 2. The results of land use and land cover classification of the study area over the study period revealed four categories (Forest, agriculture, wetland and built-up area).

The most dominant land use/land cover trend in 1987 was light agriculture which covered 6405.37 hectares (51.32 %) while forest covered 4458.81hectares (35.72%), wetland 1036.6 hectares (8.31 %) and built-up area 580.21 hectares (4.65 %) (Table 1).

Table 1. Land use and land cover dynamics in the watershed of Katana during the period of 1987, 2001, 2010.

Land use and land cover classes	Year 1987 (hectare)	Year 2001 (hectare)	Year 2010 (hectare)
Forest	4458.81 (35.72 %)	3028.15 (24.26 %)	3234.68 (25.92 %)
Agriculture	6405.37 (51.32 %)	8046.82 (64.47 %)	6688.79 (53.59 %)
Wetland	1036.6 (8.31 %)	760.81 (6.1 %)	760.81 (6.10 %)
Built-up area	580.21 (4.65 %)	645.21 (5. 17 %)	1796.71 (14.40 %)
Total	12480.99 (100 %)	12480.99 (100 %)	12480.99 (100 %)

In 1987 the trend further revealed that built-up area constituted the least land use and land cover. According to Table 1 in 2001, the dominant land use and land cover remained agriculture with 8046.82 hectares (64.47 %), followed by forest 3028.15 hectares (24.26 %), wetland with 760.81 hectares (6.1 %) and built-up area 645.21 hectares (5.17 %).

Table 2. Number of snails collected during sample years (1987, 2001, and 2010) in different ecosystems in Katana micro-catchment.

Snail Taxa	1987	2001	2010
Biomphalaria pfeifferi	399	515	1132
Biomphalaria smithi	0	0	603
Bulinus forkalii	12	0	0
Bulinus globosus	12	6	0
Bulinus truncatus	0	13	24
Ceratophallus natalensis	0	0	6
Ferrissia burnipi	0	17	33
Gabiella humerosa	2	5	0
Lentorbis junodi	4	0	3
Lymnae collumela	0	3	11
Lymnae natalensis	4640	2212	13334
Melanoides tuberculata	4	3	6
Physa acuta	0	0	1708
Pila ovata	0	1956	12790
Pisidium casernatum	124	12	46
Potadoma freethi	0	5	126
Potadoma ignobilis	826	1961	2001
Segmentorbis kempi	0	17	0
Tomchia hendrickxi	5	4	15
Tomchia kivuensis	756	571	1017
Tomchia ventricosa	0	0	3
Total	6784	7300	32858
Percentage (%)	14.45	15.55	70.00
Specific richness	11 (52.38 %)	15 (71.42 %)	17 (80.95 %)

For the year 2010, the trend remains the same with agriculture with 6688.79 hectares (53.59 %), followed by forest 3234.68 hectares (25.92 %), built-up area 1796.71 hectares (14.40 %) and wetland with 760.81 hectares (6.10 %).

Dynamic of land use and land cover change in the Katana watershed varied during the years 1987 and 2010 (Fig. 3). The fig. 3 indicates that forest and wetland have decrease respectively about 11.5 % (1430.66 hectares) and 2.2 % (275.79 hectares) between 1987 and 2001; agriculture increased about 12.3 % (1540.79 hectares) and built-up area remained unchanged. However, between 2001 and 2010, agriculture decreased about 15.6 % (1921.26 hectares) alongside an expansion of forest by 1.7 % (206.53 hectares), wetland growth of 5.4 % (659.46 hectares) and built-up area increase of 9.9 % (1216.5 hectares).

Table 3. Number of snail taxa and land use and land cover classes.

Snail Taxa	Forest	Built-up area	Agriculture	Wetland
Biomphalaria pfeifferi	0	1022	601	423
Biomphalaria smithi	0	0	0	603
Gabiella humerosa	0	0	0	7
Segmentorbis kempi	0	0	17	0
Ceratophallus natalensis	0	0	0	6
Lentorbis junodi	0	2	5	0
Lymnae collumela	0	0	10	4
Lymnae natalensis	98	11702	4441	3945
Ferrissia burnipi	0	15	35	0
Bulinus globosus	0	18	0	0
Bulinus truncatus	0	0	0	37
Bulinus forkalii	0	12	0	0
Physa acuta	102	485	466	655
Potadoma ignobilis	80	3009	1247	452
Potadoma freethi	0	18	113	0
Tomchia kivuensis	0	1180	711	433
Tomchia hendrickxi	0	0	15	9
Tomchia ventricosa	0	0	3	0
Melanoides tuberculata	0	0	0	13
Pila ovata	101	11010	3635	0
Pisidium casernatum	6	48	79	49
Specific richness	5	12	14	13

Number of the snail collected in Katana micro-catchment

The number of snails collected from different aquatic ecosystems of Katana during the years 1987, 2001, and 2010 is present in the table 2. The number of snails recorded during the years 1987, 2001, and 2010 varied in the Katana region. In 1987, 11 snail species were recorded in the thirty five sampling sites distributed in diverse ecosystems in the region. This number increased in 2001 (15 species) and in 2010 (17 species). With each sampling year, new species were recorded in the region such as *Physa acuta*, *Tomchia ventricosa* and *Ceratophallus natalensis*. The number of snails collected in the different land use and land cover classes are present in the table 3. The high specific richness was recorded in the agriculture area (14 species) while the lowest specific richness at the forest area. Some species are specific to the wetland area such as *Biomphalaria smithi, Gabiella humerosa, Ceratophallus natalensis, Bulinus truncatus and Melanoides tuberculata. Other species, such as Segmentorbis kempi* and *Tomchia ventricosa*, were found to be exclusively present in the agriculture class.

Table 4. Number of snail collected during different years (1987, 2001 and 2010) and land use and land cover classes.

		Number of Snail/year		
	Number of sampling site	1987	2001	2010
Forest	3	97	123	167
Wetland	14	1876	1935	2845
Agriculture	10	3641	2736	5001
Built-up area	7	7842	10425	10254

The percentage of snails collected in various land use and land cover classes during different years in the sampling period are presented in the fig. 4. This figure shows that the agriculture class has a high percentage of snails collected during the different years. The percentage of snails increased in built-up area class during 2010, the last year of sampling. This can be observed in the table 4 which present the number of snail collected during the different years and different land use and land cover classes. Person's r correlation between snail richness and different land use and land cover classes is presented in table 5. Snail specific richness has a negatively significant correlation with forest and wetland area (r = -0.91 and -0.94 respectively) and positive correlation with built-up area (r = 0.78) but weak positive correlation with agriculture (r = 0.34).

Table 5. Person's r correlation between specific richness of snail, land use and land cover classes and years (1987, 2001 and 2010).

	Snail richness	Forest	Built-up area	Agriculture	Wetland
Snail richness	0				
Forest	-0.91	0			
Built-up area	0.78	-0.47	0		
Agriculture	0.34	-0.69	-0.30	0	
Wetland	-0.94	0.99	-0.54	-0.63	0

The forest class has a weak negative correlation (r = -0.47) and negative correlation (r = -0.69) with built-up area and agriculture classes, respectively. However, the forest class has a strong positive correlation with wetland (r = 0.99). Built-up area has a weak correlation with agriculture (r = 0.30) and a negative correlation with wetland (r = -0.54) whereas the agriculture class is negatively correlated with wetland (r = -0.63).

Discussion

The results obtained in this study show that land use and land cover changes affect the distribution of snails in the Katana region, Democratic Republic of Congo. Environmental condition is one of the main predictors of the distribution of snails (Scholte *et al.*, 2012).

The increase forest recorded in 2010 was due to the movement of the population to others sites living vegetation growing at these places. Furthermore, tree plantation installed where forest was cut during the period of an influx of refugees in the region contributes to changes in the environmental condition of the forest area. As for the agriculture class, there was a recorded increase of snail populations between 1987 and 2001, however, this decreased between 2001 and 2010. This decline in snail population was compensated by built-up area which showed a shift to 10 % of the surface. The construction was observed near Lake Kivu where the insecurity is reduced. The area occupied by the wetland reduced also between 1987 and 2001 but it remains the same between 2001 and 2010.

Similar results were observed in other parts of the South Kivu region where political instability occured (Bagalwa, 2012; Azanga, 2013). The changes observed in land use and land cover are affecting the distribution of snails in the region. There is an increase of taxa richness during the years sampled in the micro-catchment. Previous studies made in 1957 and 2005 in the Banco river basin failed to report the presence of freshwater snails in this river (Binder, 1957; Bony *et al*., 2008); but in 2008, *Physa marmorata* was sampled in the tributary of the Banco River at sampling sites characterized by low canopy cover. Species that can utilize a larger range of habitat types have been able to cover different land use and land cover classes as also observed by Pfenninger (2004).

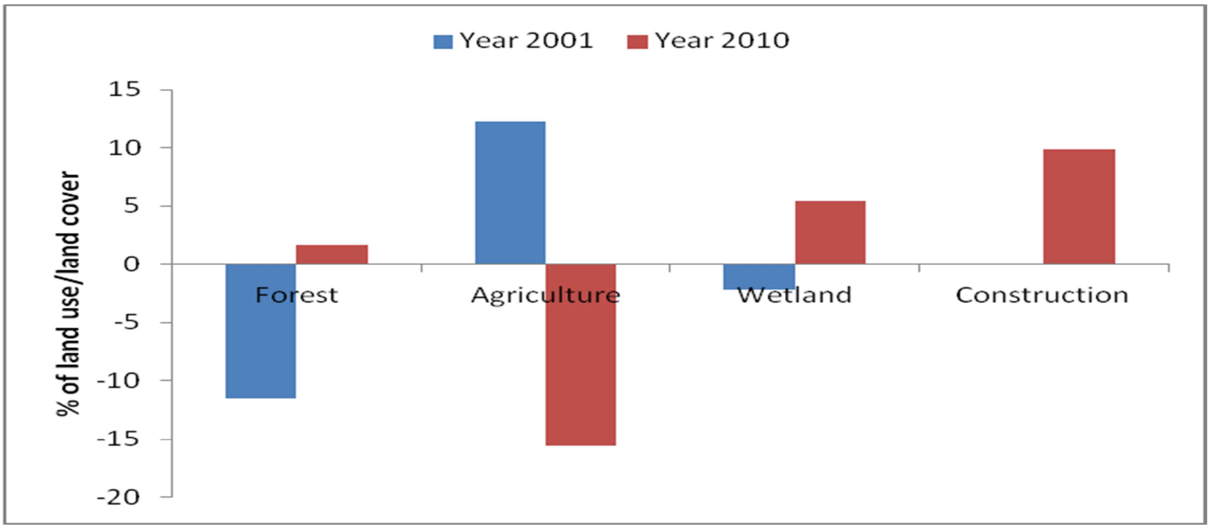

Fig. 3. Dynamic of land use and land cover (%) in the Katana watershed during the years (1987 - 2001 and 2001- 2010).

This should be true in particular for passively dispersed organisms since the chance of reaching a suitable habitat is increased according to habitat specialists. Therefore, *Biomphalaria pfeifferi* that occur in various types of habitat and/or whose preferred habitat types cover a larger area should have larger ranges.

It is evident that the number of sites with snails and the number of snail in general in the Katana region has increased every year from 1987 to 2010 caused by the changes in land use and land cover activities. Changes in land use and land cover within the Katana region were correlated with site distribution of snails for the period 1987–2010. Both agriculture and urban development increased significantly during this time and were strongly correlated with the number of sites populated by snails. A strong relationship between land cover and invertebrate variables at both local and sub-basin measurement scales in the Iowa watershed, USA has previously been observed (Herringshaw *et al*., 2011).

This suggests that increasing water temperatures and clearance of vegetation have enabled the snails to spread more easily.

This created additional habitat for the freshwater snail that is known to inhabit irrigation ditches that run adjacent to agricultural fields. Deforestation attempts to make room for agriculture may be helping drive the trend of snail distribution throughout the late 1987s and early 2010s.

Future research efforts to address land use and land cover change impacts on snail distribution should incorporate higher resolution satellite data.

The data used in the current study was 30 m x 30 m. Higher resolution imagery will not only help to validate classification results but will enable researchers to classify smaller land cover objects such as irrigation ditch canals which may only be a few meters wide.

Future efforts should also consider drug treatment to avoid potential confounding and making inaccurate conclusions regarding the land use and snail distribution correlation results.

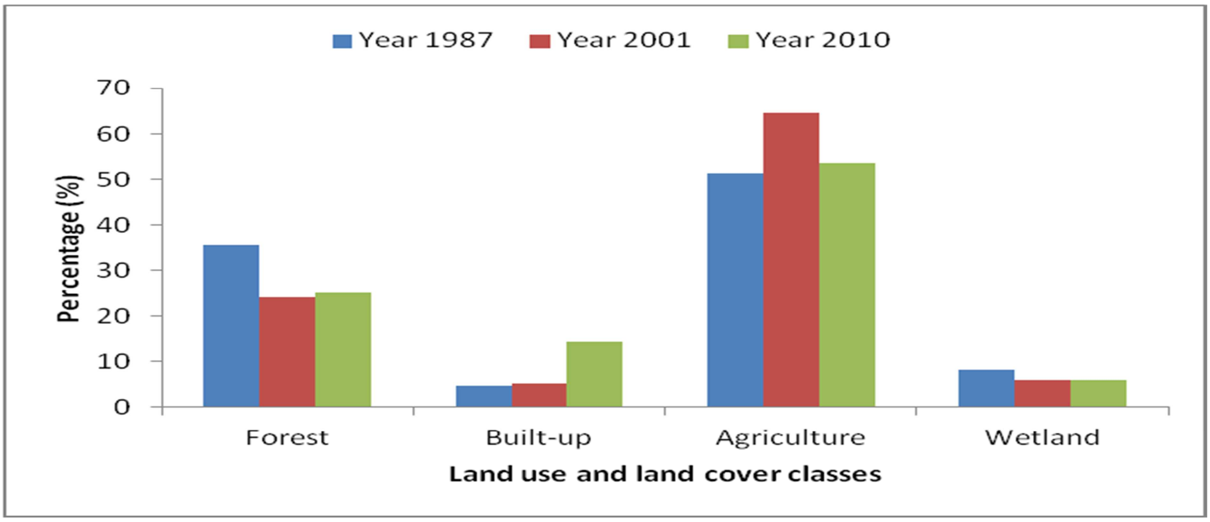

Fig. 4. Percentage of snails collected in different land use and land cover classes during the different sampling years.

Conclusion

This study showed a wide distribution of snails in the region shifting at high altitude. It has helped to identify the relationship between reduced vegetation cover and urbanization on snail distribution. The data recorded has facilitated a greater understanding how anthropogenically related land use and land cover changes can potentially influence snail distribution.

Acknowledgement

The authors thank the Centre de Recherche en Sciences Naturelles of Lwiro for giving us the opportunity to conduct this research and especially the personnel of the Laboratory of Malacology for technical assistance. We also thank Dolnald M. Waller and Emily Davies for the valuable comments on this manuscript.

References

Allan JD. 2004. Landscapes and river scapes: The infuence of land use on stream ecosystems. Annual Review of Ecology and Evolution Systems **35,** 257-284.

Azanga E. 2013. Sediment and Nutrient hot spot Areas Dynamics in selected micro-catchments of the lake Tanganyika Basin in Democratic Republic of Congo (Published Master's thesis), Makerere University, 75 p.

Bagalwa M, Baluku B. 1997. Distribution des mollusques hôtes intermédiaires des schistosomoses humains à Katana, Sud - Kivu, Est du Zaïre. Médecine Tropicale **57,** 369-372.

Bagalwa M, Karume K, Bayongwa C, Ndahama N, Ndegeyi K. 2013b. Land-use effects on Cirhanyobowa river water quality in D.R. Congo. Greener Journal of Environment Management and Public Safety **3**, 1, 21-30.

Bagalwa M, Karume K, Mushagalusa NG, Ndegeyi K, Birali M, Zirirane N, Masheka Z, Bayongwa C. 2013a. Risques potentiels des déchets domestiques sur la santé des populations en milieu rural: Cas d'Irhambi Katana (Sud-Kivu, République Démocratique du Congo)», VertigO - la revue électronique en sciences de l'environnement [En ligne] **13,** 2, 12.

Bagalwa M, Majaliwa JGM, Mushagalusa N, Karume K. 2013c. Estimation of transported pollutant load from small urban Kahuwa river micro-catchment in Lake Kivu. Democratic Republic of Congo. Journal of Environment Science and Engineering B **2,** 460–472.

Bagalwa M, Majaliwa JGM, Mushagalusa N, Karume K. 2014. Dynamics of land use and land cover in Kahuwa river micro-catchment in response to urbanization from 1986 to 2010. Greener Journal of Geology and Earth Sciences **2,** 1, 1- 8.

Bagalwa M. 2012. Estimation of pollution loading into Lake Kivu. Case of Kahuwa micro-catchment in Democratic republic of Congo. Maters thesis, UEA, Democratic Republic of Congo, 97p.

Bagalwa M. 2006. The impact of land use on water quality of the river Lwiro, Democratic Republic of Congo, Central Africa. African Journal of Aquatic Science **31,** 1, 137-143.

Barhimanya RJ, Wafula M, Mburunge M, Bagalwa M, Nyaweza M, Bisimwa C, Ngotuly M, Zihindula R. 2014. Impact des guerres a répétition sur l'environnement dans le groupement de Bugorhe de 1996-2009. Cahiers du CERUKI, 212–222.

Basnet B, Vodacek A. 2012. Multi-temporal landsat imagery analysis to study the dynamics of land cover lake Kivu region. 1st EARSeL Workshop on Temporal Analysis of Satellite Images, Mykonos, Greece, 23rd – 25th, 1-9.

Binder E. 1957**.** Mollusques aquatiques de Côte d'Ivoire. I-Gastéropodes. Bullettin. IFAN, série A, **19**, 1, 97-125.

Bony YK, Koussi NC, Diomande D, Gourene G, Verdoit Jarraya M, Pointier P. 2008. Ecological conditions for spread of the invasive snail Physa marmorata (Pulmonata: Physidae) in the Ivory Coast. African Zoology **43,** 1, 53 – 60.

Brown D. 1994. Fresh snails of Africa and their medical importance. Revised 2nd Edition. Taylor and Francis, London, 608 p.

Cahen L, Lepresonne J. 1967. The Precambrian of the Congo, Rwanda and Burundi. In: Rankama K (Ed) The Precambrian. Interscience Publishers, New York, 143-290.

Camara IA, Bony YK, Diomandé D, Edia OE, Konan FK, Kouassi CN, Gourène G, Pointie JP. 2012. Freshwater snail distribution related to environmental factors in Banco National Park, an urban reserve in the Ivory Coast (West Africa). African Zoology **47**, 1, 160–168.

Chlyeh G, Dodet M, Delay B, Khallaayoune K, Jarne P. 2006. Spatio-temporal distribution of freshwater snail species in relation to migration and environmental factors in an irrigated area from Morocco. Hydrobiologia **553,** 129–142.

Delucchi CM. 1988. Comparison of community structure among streams with different temporal flow regimes. Canadian Journal of Zoologie **66,** 579-586.

Harding JS, Winterbourn MJ. 1995. Effects of contrasing land use on physic-chemical conditions and benthic assemblages of streams in a Canterbury (South Island, New Zealand) river system. New-Zealand Journal of Marine and Freshwater Research **29**, 479 – 492.

Herringshaw CJ, Stewart TW, Thompson JR, Anderson PF. 2011. Land Use, Stream Habitat and Benthic Invertebrate Assemblages in a Highly Altered Iowa Watershed. The American Midland Naturalist **165(2),** 274-293..

Hildrew AG, Townsend CR. 1982. Predators and prey in a patchy environment: A freshwater study. Journal of Animal Ecology **51**, 797-816.

Hoare RA, Rowe LK. 1992. Water quality in NZ. Pp. 207-228 *in:* Waters of New Zealand, Mosley, M. P. *Ed.* Wellington, New Zealand Hydrological Society.

Jensen JR. 1986. Introductory Digital Image Processing: A remote sensing perspective. Prentice Hall, Upper Saddle river, NJ, USA.

Karume K. 2010. Overview of energy sector, South-Kivu province: A shame. Les Editions du CERUKI, 65p.

Lambin EF, Turner II BL, Geist HJ, Agbola SB, Angelsen A, Bruce JW, Coomes OT, Dirzo R, Fischer G, Folke C, George PS, Homewood K, Imbernon J, Leemans R, Li X, Moran EF, Mortimore M, Ramakrishnan PS, Richards JF, Skånes, H, Steffen W, Stone GD, Svedin U, Veldkamp A, Vogel C, Xu J. 2001. The causes of land-use and land-cover change: Moving beyond myths. Global Environmental Change **11,** 261–269.

Lodge DM, Brown KM, Klosiewski SP, Stein RA, Covich AP, Leathers BK; Bronmark C. 1987. Distribution of freshwater snails: Spatial scale and the relative importance of physicochemical and biotic factors. American Malacology Bulletin **5,** 73-84.

Maingi JK, Marsh SE. 2001. Assessment of environmental impacts of river basin development on the riverine forests of eastern Kenya using multi-temporal satellite data. International Journal of Remote Sensing **22,** 14, 2701-2729.

Majaliwa JG, Twongyirwe R, Nyenje R, Oluka M, Ongom B, Sirike J, Mfitumukiza D, Azanga E, Natumanya R, Mwerera R, Barasa B. 2010. The Effect of land cover change on soil properties around Kibale National Park in South Western Uganda. Applied and Environmental Soil Science **10,** 1-7.

Mc Auliffe JR. 1984. Competition for space, disturbance, and the structure of a benthic stream community. Ecology **65**, 894-908.

Meyer WB, Turner BL. 1994. Changes in land use and land cover: A global perspective. University Press, Cambridge.

Minshall GW. 1984. Aquatic insect-substratum relation- ships. In: Resh, V. H. and Rosenberg, D. M. (Eds), The ecology of aquatic insects. Praeger, New York, 358-400 p.

Peckarsky BL, Dodson. 1980. Influence of detritus upon colonizations of stream invertebrates. Canadian Journal of Fish and Aquatic Sciences **37,** 957-963.

Peng J, Wu J, Yin H, Li Z, Chang Q, Mu T. 2008. Rural land use change during 1986-2002 in Lijiang, China based in Remote Sensing and GIS data. Sensors **8,** 8201-8223.

Pfenninger M. 2004. Comparative analysis of range sizes in *Helicidae s.l.* (Pulmonata, Gastropoda). Evolutionary Ecology Research **6,** 1–18.

Pyron M, Lauer TE, Gammon JR. 2006. Stability of the Wabash River fish assemblages from 1974 to 1998. Freshwater Biology **51,** 1789-1797.

Salanki J, Farkas A, Kamardina T, Rozsa KS. 2003. Molluscs in biological monitoring of water quality. Toxicology Letters, **140-141,** 403-410.

Scholte RCG, Calvalho OS, Malane JB, Utzinger J, Vounatsou P. 2012. Spatial distribution of *Biomphalaria* spp., The intermediate host snails of *Schistosoma mansoni*, in Brazil. Geospatial Health **6**, 3, S95-S101.

UICN. 1990. La conservation des écosystèmes forestiers d' Afrique Centrale. London.

ISSN 2220-6663 (Print)
ISSN 2222-3045 (Online)

JBES

INNSPUB

Journal of Biodiversity and Environmental Sciences

Volume 9, Number 6, December 2016

INNSPUB
International Network For Natural Sciences
Website: www.innspub.net