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Amphibian diversity in relation to environmental change in Harenna Forest, Bale Mountains National Park, Ethiopia: A Remote sensing and GIS Approach

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ABSTRACT

Amphibian diversity and abundance in relation to environmental change in Harenna Forest, BMNP was assessed using GIS and Remote sensing. Sampling of amphibian communities was conducted during July-August 2008 and February 2009; which includes wet and dry seasons in the area. Data on diversity, evenness and dominance was analyzed; seven endemic amphibian species belonging to one order, 5 families and 5 genera were recorded. The current results were compared with the past investigation of amphibians in the Harenna Forest. The results showed a decrease in abundance and diversity of amphibians over the past decades. GIS and Remote sensing methods using satellite images of the Harenna Forest were used to quantitatively analyze land use/land cover changes from 1973 to 2000. The results showed a significant reduction in the forest cover and wetlands followed by the establishment of new land use types, such as agricultural land and settlement in 2000.

INTRODUCTION

The Bale Mountains are a center of endemism, and are the most important area for a number of threatened Ethiopian endemics. (Yalden 1983; Asefa , 2011; Yalden and Largen 1992; Largen and Spawls, 2011; Shimelis, 2011; Birdlife International 2005; Birdlife International 2006; Williams *et al*. 2004).

The most known factors threatening biodiversity appear to be contributing to worldwide amphibian population declines. Habitat destruction is the most important factor leading to amphibian population declines. Clearing of forests is among the main causes of decline of such ecosystems.

Modern technology such as Remote Sensing and Geographic Information System (GIS) added more success in biodiversity conservation and of mapping and interpretation techniques.

Such approaches are used for providing detailed data on land use even in remote areas; their types, conditions, spatial distribution and their as temporal changes. These data in integration with available other data sources have been used to investigate such environmental changes. Mendis & Vadigamnawa (1996).

This study was aimed to obtain a base line data, on the current occurrence, diversity, abundance, and distribution of the amphibians in the Harenna Forest of the BMNP in relation to the state of the environment over 30 years.

METHODS

The study area

The present study was performed in The Harenna Forest which is found in a highland natural forest region of the Bale Mountains, in the Oromia Region of southeastern Ethiopia (Figure 1). It covers almost half of the Bale Mountain National Park in area, at the southern park boundary and is a magnificent example of moist tropical forest. It extends over a wide range of altitude, from 1,500 to 3,500 m. (Hillman, 1986).

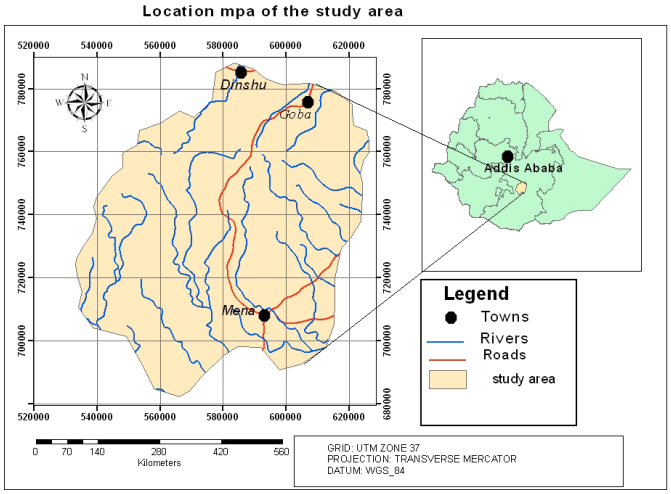

Fig. 1: A map of the study area

Amphibians survey:

The inventory techniques included**,** Systematic searching of amphibians in the randomly selected 20 x 20 m plots, Random search around the plots**,** Visual encounter surveys (VES) and Acoustic Encounter surveys (AES), checking through vegetation, searching under stones, logs, rocks, and other potential hiding places such as moss on trees and on the ground and along streams, swamps, rivers, ponds and marshy areas. A fixed amount of time/per person was spent every day at sampling site.

When amphibians are found, the GPS coordinates of the spot are recorded. Habitat data, time and weather were recorded, where possible photographed, Then the voucher specimens identified at least to the genus level tentatively, color notes taken, labels attached to specimens, anesthetized in MS222, preserved in 10% formalin and finally transferred to 70% ethanol. Preserved specimens were placed in Addis Ababa University for the identification using Largen's Key for amphibians, and compared with reference materials from A.A.U Museum and literature.

Shannon Wiener index was used to compute the diversity of the amphibians.

Remote Sensing and GIS Techniques

Land-use/land-cover changes during the period 1973 -2000 was performed by using Satellite Imageries of the years in MSS of 1973, ETM+ of 2000. The row images of the selected years were introduced to ERDAS 9.1 Software to classify the land use/land - land cover through the maximum likelihood classification algorithm. The accuracy of classified data of the year of ETM + was assessed. Using the indices of the overall accuracy and Kappa statistics. Thus, the statistics of the land-use/land cover was organized by the Microsoft excel and presented in the form of table.

RESULTS

The sampling of amphibians was conducted during two seasons of the year; wet season (July- August/2008), and dry season (February/2009).

During the study periods 7 amphibian species belonging to order Anura, 5 families, and 5 genera, were recorded in the Harenna Forest, in which all of them are endemic. Four species (*Altiphrynoides malcolmi, Balebreviceps hillmani, Ericabatrachus baleensis and* Altiphrynoides osgoodi) have only been found in the Bale mountains so far.

The classification list of the amphibian species, encountered with their altitudinal range is given in Table 1.

Table 1: Taxonomy of the amphibians encountered in the present study * Species recorded only in the study area

Family	Genus	Species	Altitudinal range (m)
Arthroleptidae	*Leptopelis*	*Leptopelis gramineus* (Boulenger 1898)	2361 - 3266
		Leptopelis ragazzii (Boulenger 1896)	2360 -2829
Bufonidae	*Altiphrynoides*	*Altiphrynoides malcolmi* (Grandison 1978)*	3149 - 3225
		Altiphrynoides osgoodi (Loveridge, 1932)*	3147 - 3165
Brevicipitidae	*Balebreviceps*	*Balebreviceps hillmani* Largen & Drews 1987*	2827 - 3339
Ptychadenidae	*Ptychadena*	*Ptychadena neumanni* (*Ahl 1924*)	2361 - 2936
Pyxicephalidae	*Ericabatrachus*	*Ericabatrachus baleensis* Largen 1991*	3149

Systematic list of species encountered during the present study:
Family; Arthroleptidae
Genus; Leptopelis
Leptopelis gramineus (Boulenger, 1898)

Plate 1: *Leptopelis gramineus*

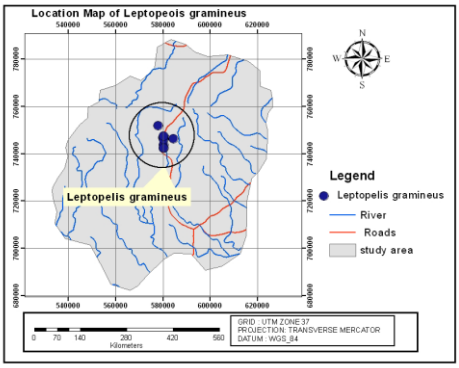

Fig. 2: Distribution map of *Leptopelis gramineus*

Occurrence in the study area: In the present study *Leptopelis gramineus* (Fig. 2-plate1) was encountered at altitudinal range of 2361- 3266 m a.s.l at different sites in Rira and Galema mainly in swamps located close to streams.

***Leptopelis ragazzi* (Boulenger, 1896)**

Occurrence in the study area: In the present study *Leptopelis ragazzi* was encountered at an altitudinal range of 2360 -3163 m a.s.l. in a swamp around a small village named Rira and along the sides of Shawe stream, inside a forest called Katcha (Fig. 3 – plate 2).

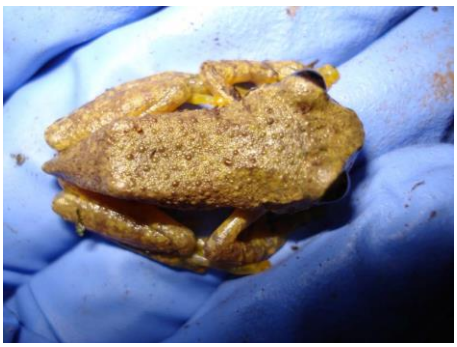

Plate 2: *Leptopelis ragazzi*

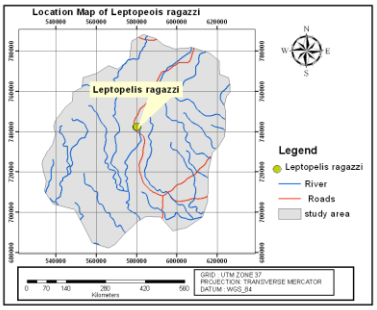

Fig. 3: Distribution map of *Leptopelis ragazzi*

Family; Bufonidae

Genus; *Altiphrynoides*

Altiphrynoides malcolmi (Grandison 1978)

Occurrence in the study area: In the current survey *Altiphrynoides malcolmi* was encountered at altitudes between 3149 - 3225 at different localities, namely, Tulla Negesso (highly disturbed forest area) and Fute, an area with low disturbance, hiding under rocks and in some circumstances, under fallen logs (Figure4- plate3).

Plate 3: *Altiphrynoides malcolmi*

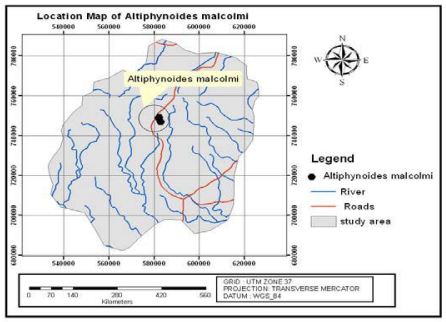

Fig. 4: Distribution map of *Altiphrynoides malcolmi*

Altiphrynoides osgoodi (Loveridge, 1932)

Occurrence in the study area: In the current study, Altiphrynoides osgoodi has been encountered under fallen logs, at altitudes of 3147 – 3163 m at a locality called Fute within the study area (plate4).

Plate 4: *Altiphrynoides osgoodi*

Family; Brevicipitidae
Genus; *Balebreviceps*
Balebreviceps hillmani Largen & Drewes, 1989

Occurrence in the study area: In the present study this species was encountered at altitudes between 2827-3339 m, at different localities namely, Rira, Fute and Galema under fallen logs (Fig. 5- plate5).

Plate 5: Balebreviceps hillmani

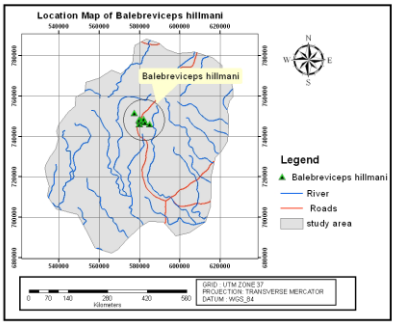

Fig. 5: Distribution map of *B. hillmani*

Family; Ptychadenidae
Genus; *Ptychadena*
Ptychadena neumanni (Ahl, 1924).

Plate 6: *Ptychadena neumanni*.

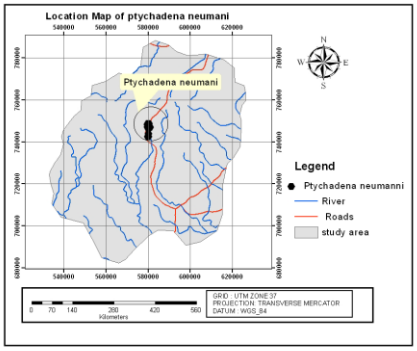

Fig. 6: Distribution map of *Ptychadena neumanni*.

Occurrence in the study area: *Ptychadena neumanni* was found between 2361-2908m a.s.l. at different localities namely, Rira and Katcha, in swamps located close to streams (Fig. 6- Plate 6).

Family; Pyxicephalidae
Genus; *Erichabatrachus*
***Erichabatrachus baleensis* Largen,1991**

Occurrence in the study area: In the present investigation, *Erichabatrachus baleensis* was found at an altitude of 3149 m at a local place called Fute (plate7).

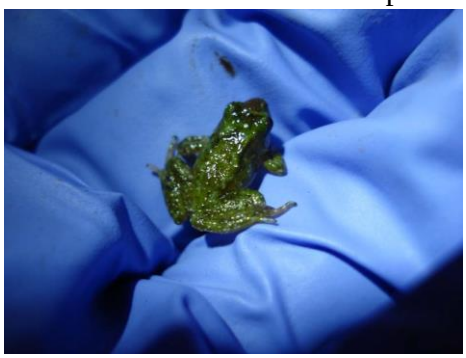

Plate 7: *Erichabatrachus baleensis*

Conservation status

Three species are classified by IUCN as Critically Endangered *Altiphrynoides osgoodi* (Loveridge, 1932)**,** *Balebreviceps hillmani* Largen & Drews 1987 and *Ericabatrachus baleensis* Largen 1991); one species as Endangered, *Altiphrynoides malcolmi* (Grandison 1978); one species as Vulnearable, *Leptopelis ragazzii* (Boulenger 1896) and two species as Least concern, *Leptopelis gramineus* (Boulenger 1898) and *Ptychadena neumanni* (*Ahl 1924*). Five of the seveven recorded species not listed in CITES, but two species, *Altiphrynoides malcolmi* (Grandison 1978) and *Altiphrynoides osgoodi* (Loveridge, 1932), are listed in CITES appendex 1.

The results of the amphibian survey show that the number of amphibians collected during the dry season is greater than that of the wet season. The variation

observed in the number of amphibians could be due to habitat preferences. As it can be seen from figure 6, most of the frogs *(Leptopelis* and *Ptychadena*) were observed in swamps and streams located around Rira. While the forest species *Altiphrynoides malcolmi*, *Balebreviceps hillmanni* and *Altiphrynoides osgoodi* were found hiding themselves under logs and under rocks in moist places inside the Ericaceous Forest.

It was very hard to find amphibians in the upper parts of the forest , in this study perhaps due to amphibian decline in the area , except very few specimens of *Altiphrynoides malcolmi*, *Balebreviceps hillmanni* (gower et al., 2013). *Altiphrynoides osgoodi*. Amphibian numbers appeared to have declined rapidly in comparison with the survey made in 1986 (Harenna Forest expedition).

The more common species are most likely expected to undergo direct development (i.e. without an aquatic tadpole stage) and may, therefore, be less dependent on "pristine" water flows. It is interesting to note that some eggs were collected under moss on trees and under fallen logs near adult *Altiphrynoides malcolmi* specimens, during the wet and dry season surveys.

The comparison of the surveys conducted in 1986 and this one revealed that, there were more amphibian species in the past. For example, *Afrixalus enseticola*, and *Paracassuna kounhiensis* were not collected in the current study.

The number of *Altiphrynides malcolmi* has decreased by 50% when we consider the time taken and the effort done to search those species.

In addition, *Ericabatrachus baleensis* was found on or near the grassy banks of small fast-flowing streams, in Erica arborea woodland at 3200 m (Largen, 2001).

In the current study only one specimen of this species was found close to a stream around a place called Fute. This species was not recorded from the type locality. The location appears to have changed substantially in recent years.

Therefore, the difference might be due to habitat loss. This fact can be supported by the results of remote sensing, which showed that about 37% of the wet lands that existed in 1973 were converted to other land use systems such as grasslands and settlements in 2000. The decline in the forest cover is indicated by the results of the remote sensing i.e. the change from 369237 ha in 1973 to 272780.5 ha in 2000 which shows 26% reduction in the forest cover within 27 years time. Thus habitat destruction is the best explanation for the decrease in the number of forest species in Harenna. However further research on this question will be required.

While in the case of *Leptopelis* and *Ptychadena* species, their distribution is found restricted to wet areas i.e. along the sides of streams and within swamps mainly at two sites of the forest, Rira and Katcha. These two genera seem to be rare on other sites of the Harenna forest and are at the risk of population declines when one considers the disturbance of the habitat in Rira, the statistical results showing a measure of DI and the results of remote sensing indicate a significant decline in the coverage of wet lands.

Comparisons of the results of the current study with the past

The most recent and successful expedition of amphibians is the 1986 Harenna Forest expedition, conduced for 3 weeks, by EWCO. During this expedition, amphibian specimens were collected along the road to Mena. It was then that *Altiphrynoides malcolmi* was first recorded south of the Sanetti plateau. The Bale endemics, *Ballebreviceps hillmani* and *Ericabatrachus baleensis* were described from the specimens collected in August 1986 (Largen, 2001).

A comparison between the number and kind of species collected during 1986 expedition and the current study is given in Table 7.

Table 7: Results of amphibian survey from 1986 Harenna Forest expedition and present study (July- August 2008 and February 2009)
Source 1986 survey: (Largen, 2001).

Species	**1986 survey**			2008– 2009 Survey		
	No of individuals	**No of Days**	**Personnel**	**No of individuals**	**No of Days**	**Personnel**
Afrixalus enseticola	**5**	**8**	**1**	**0**	**23**	**3**
Altiphrynoides malcolmi	**18**	**“**	**“**	**9**	**“**	**“**
Altiphrynoides osgoodi	15	**“**	**“**	4	**“**	**“**
Balebreviceps hillmani	**15**	**“**	**“**	**14**	**“**	**“**
Ericabatrachus baleensis	**23**	**“**	**“**	**1**	**“**	**“**
Leptopelis gramineus	3	**“**	**“**	51	**“**	**“**
Leptopelis ragazzi	20	**“**	**“**	29	**“**	**“**
Paracassina kounhiensis	8	**“**	**“**	0	**“**	**“**
Ptychadena erlangeri	5	**“**	**“**	0	**“**	**“**
Ptychadena neumanni	**21**	**“**	**“**	51	**“**	**“**
Total	**133**			**159**		

The results show greater diversity and evenness during the Harenna Forest expedition in less time (effort) compared with the present study (Table 8).

Table 8: Comparisons of diversity indices for the species of amphibians encountered during current study (2008-2009) and the Harenna Forest expedition (1986).

Indices	**2008- 2009**	**1986**
No of species	**7**	**10**
Total number of Individuals/day/person	**159/23/3=2.3**	**133/8/1=16.6**
Dominance	0.75	0.12155
Shannon - weaver’s (H)	1.541	2.144
Evenness	0.792	0.931

The total of each land use cover types are tabulated and the trends are examined between the years. Table 9 lists the change statistics from 1973 to 2000. Due to data limitations only the 1973 and 2000 data of satellite images are used to interpret the

change in land cover type of the study area. Values in the tables were sorted by area and listed in descending order.

Forest, grass land, bush land, and wet lands are the major land covers and the changes in their proportions represent the most significant changes. Agricultural expansion is the most important change.

The accuracy of the classified data of the year 2000 found to be 95% of the overall accuracy and the Kappa statistics 0.86. In the year 1973, grassland, forest covers, wet lands and bare land were the major land-use/land-cover classes. In 1973, the scene was predominated by the natural covers made-up of forest cover, wetland and grass land that accounted for 82.30% of the land-cover (Table 9; Fig. 9). In most of the study areas lands of the central parts of the study area, forest covers were composed of 55.7 % of the land-use/ land-cover matrix. On the other hand, the crop cover class comprised the cover about 14.25 % of the land in 2000. In relation to this, built-up land covered with the extent of 2134.99 ha (0.32 %), and forest cover declined to 272,780.5 ha with (14.55 %) net reduction from the year 1973. Thus, this was a heavy decline with the extent of wet land and forest covers with the corresponding increase human-made alteration of changed land-use/land-cover patterns. The grassland increased with an extent of 1,7991.8 ha **(** 2.71%) in the year 1973 – 2000).

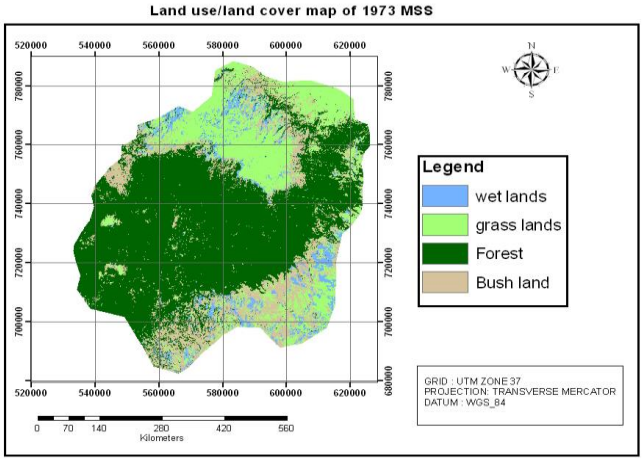

Fig. 9: Land use /land cover map of 1973

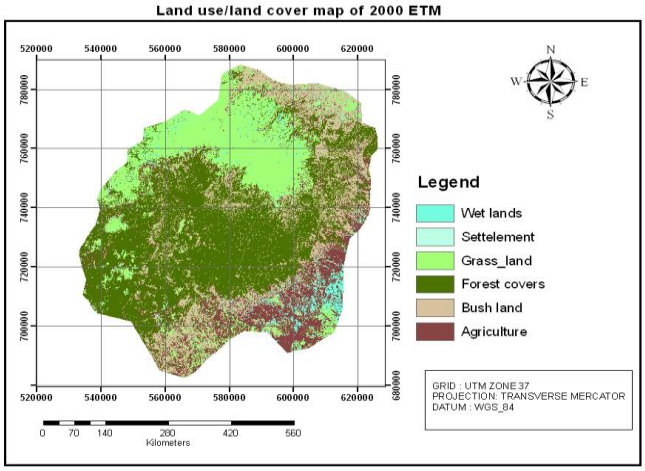

Fig. 10: Land use /land cover map of 2000.

Table 9: Land cover changes of the Harenna forest from 1973 to 2000.

Land cover	1973		2000		Change	
	Area ha	%	Area ha	%	Area ha	%
Forest	369,237	55.7	272,780.5	41.15	-96456.5	**- 14.55**
Grassland	139,895.4	21.1	157,887.2	23.81	+1,7991.8	**+2.71**
Bushland	117,039.7	17.7	114,463.8	17.26	-2,575.9	**-0.39**
Wetlands	36,677.88	5.5	23,221.9	3.50	-13,455.98	**-2.0**
Agriculture	-	-	94,497	14.25	+ 94,497	+ 14.25
Settlement	-	-	2,134.99	0.32	+2,134.99	+ 0.32
Total	662850		662850.4			

DISCUSSION

The changes in land use/ land cover is an indicator of the status of ecosystem including biodiversity (Wallelign 2007).

From 1973 to 2000, forest land, Wetlands and Bush land have decreased, while grasslands have increased. The reason for this increase is due to burning of the forest, by the local people for cattle grazing and other purposes.

On the other hand new land uses, which didn't exist in 1973, (agriculture and settlements) have been established inside the forest from 1973 to 2000. Farmland and urban settlement expansion were found to be major drivers of land use/ land cover change (Gibbs et al., 2010; Nune et al., 2016 & 2019) .

In addition, (Schwaller 2009), noted that the main forest losses are visible in the south eastern part of Harenna Forest below 2000 m in a mid – altitudinal range of 2000 – 2500 m a.s.l. and in the ericaceous forest zone near to two settlements, Rira and Gora. For the area below 2000 m a. s. l. a large number of presumably deforested patches were already present in 1973, shortly after the establishment of BMNP.

The forest in the surroundings of Rira has decreased, especially marked by being more fragmented and separated from the lower forested area. Whereas in 1973 a near- continuous forest was present, the upper part of the forest is nowadays only connected in the south- west to the rest of Harenna forest.

CONCLUSIONS

- 7 amphibian species belonging to order Anura, 5 families, and 5 genera, were recorded in the Harenna Forest, in which all of them are endemic.
- Four species (*Altiphrynoides malcolmi, Balebreviceps hillmani, Ericabatrachus baleensis and Altiphrynoides osgoodi* have only been found in the Bale mountains so far.
- Non forest species such as *Leptopelis* and *Ptychadena* were found in rather large numbers in many non-forested and highly disturbed swampy areas and along streams in both wet and dry season sampling periods.
- Significant decline in the species diversity and abundance of amphibians is observed, since the time of the past surveys in the area i.e. the 1986 Harenna Forest expedition.
- Three species are classified by IUCN as Critically Endangered; one species as Endangered, *Altiphrynoides malcolmi* (Grandison 1978); one species as Vulnearable, and two species as Least concern, Five of the seven recorded species not listed in CITES, but two species, are listed in CITES appendex 1.

- Remote sensing revealed that, the Harenna Forest show significant change in land use/ land cover for the past 30 years. Forest land decreased by 14.55% from 1973 to 2000, while wet lands decreased by 2.0% i.e. from 36,677.8 hectares in 1973 to 23,221.9 hectares in 2000. On the other hand agricultural fields and settlements increased by 14.25% and 0.32% respectively. Thus the conversion of forest cover and wetlands of the Harenna, into new types of land uses such as agricultural crop production and settlements resulted in the destruction of habitats which in turn resulted in the decline of amphibian numbers.
- The hypothesis which states there has been change in land use/land cover in Harenna, from 1973 to 2000 is accepted.

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