Landuse and Landcover Change Detection between 1985- 2005 in Parts of Highland of Eastern Ethiopia using Remote Sensing and GIS Techniques

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Abstract
An attempt has been taken to access the pattern and driving forces of landuse and landcover changes in the area between Harer and Dire Dawa, Eastern Ethiopia highland. At this end, Landsat satellite images of 1985 and 2003 were used to produce ten classes of land use using Geographical Information System (GIS) with field verification. The unsupervised and supervised classification was done in ERDAS, V.8.6 with accuracy assessment of 88% and landuse maps of the area were prepared in ArcGIS software. The results show many changes among the landuses and landcovers in the year between 1985 and 2003. The highest change is observed in grasslands which is decreased by 42.4% (716.7 ha).The highest rate of changes are seen in temporal cropland which is -393.4 ha in every year and bare land which is 171.6 ha/year. Beside grasslands, shrubs and temporal cropland are also decreased in size by 20.7% and 25.4% respectively in 2003, when compared with 1985. Conversely, perennial cropland, marshy area, residents and wood lands increased by 26.6%, 705.9%, 109.7% and 7.3% respectively, in the last 20 years. These land area / covers increased mainly at the expense of grass lands and shrubs. All the landuse/landcover changes are mainly due to their conversion to agriculture lands. Population growth, topography of the area, unwise use of land and other socio-economic activities are major driving forces for the observed changes. Hence different landuse practices, environmental rehabilitation programs and family planning education are some of the appropriate interventions.

1. Introduction

Landuse and Landcover change is taken as a serious problem in changing the environment, which in turn, could lead to global climatic change (Dale, 1997, Imbrnaon, 1999, Li, 1996 and Meyer and Turner, 1991). This change could be the result of intricate interactions of socio economic and biophysical situation like economic, technological advancement, demography, scenic and etc (Reid et al., 2000). Landuse and Landcover are dynamic in nature. However, various processes influence the speed of the change, the distribution and the type of landcover and landuse. Increasing number of population in an area is one of the factors that rapidly change both the distribution and type of landuse and landcover (Solomon, 1994). As discussed above, there are a few studies that are conducted on landuse and landcover change in different parts of the country. For instance, Solomon (1994) reported cover changes of land in Metu area, south western Ethiopia. Similarly, Giest (2002) and few others have reported a significant study of landuse landcover changes in north highlands of Ethiopia. Lakew et al., (2000) stated that during 1958 and 1986, in Kalu district, southern Wollo, in the north eastern part of the country, shrub land and grazing land expanded at the expense of forest land. Furthermore (Woldeamelake, 2002) has reported the expansion of cultivated land and grazing land at the expense of forest land in the period since 1850 in Chomoga watershed, Blue Nile Basin. However, most of the studies on landuse/landcover change detection have been concentrated in Northern Highland of Ethiopia, and relatively less attention is paid in eastern highlands of Ethiopia. Therefore this study mainly aims to integrate GIS and remote sensing to detect landuse and landcover change, and it's driving forces and consequences in terms of land degradation, in the area between Harer and Dire Dawa, Eastern Ethiopia highland. An attempt has also been made to analyze the overall impact of the change against the local agricultural productivity. Thus, this study attempts to contribute empirical analyses of the pattern, rate of change, quantity and to map of these changes by using GIS and remote sensing techniques, and there by analyzing the impact of the change on the land, agriculture and livestock and to forward suggestion for sustainable use in the future.

2. Study Area

The study area is located in the Eastern highlands of Ethiopia, which is administratively situated in Eastern Harerghe Zone, Oromia Regional National state. It is situated at $9^0 23'$– $9^0 26'$North latitude and $41^0 59'$ – $42^0 02'$East longitude (Figure 1). The study area mainly concern Alemaya Woreda and part of it's surrounding, which lies in the towns between Harerghe and Dire Dawa. The main road that joins Addis Ababa to Harer passes through the area, so it can be accessed easily from the main road sides. The Harerghe highlands lying in the eastern part of the country are generally known for their rugged topography, mountainous landscapes which govern the variations in regional geomorphology, soil tops sequences, ecological zones, quantity and quality of plant and animal life (Tamire, 1981). About 71% of Alemaya area is characterized by undulating and rolling topography. The hilly and steep land in the east and northeast of the area covers only 8%. The remaining part is a flat land in the middle and close to the Alemaya Lake. The altitude of the area ranges between 1980 and 2343 M.A.S.L. It is characterized by undulating relief and rolling topography.

3. Methodology

3.1 Image Interpretation and Image Classification System

In this study, interpretation and classification was carried out in such a way that first false color composite (741 RGB) and unsupervised classification of Landsat ETM + of 2003 had been prepared and taken to the field, then in the field it was cross checked using Garmin GPS. Using ENVI software, 32 points (GCPS) were selected from each classified groups to be checked in the field. Later some more points were added in the field which was important for feature identification of the image. So, based on the ground checked points supervised classification is done in the image. For the year 2003, false color composite was prepared using the order of 7,4,1 band sequence and for the year 1985, true color composite also done using the band sequence of 3,2,1. Then different enhancements were made to increase the visual interpretation of the image. The false color composite and unsupervised classifications were done using ENVI software where as supervised classification was done in ERDAS with accuracy assessment of 88% and land use maps of the area was prepared in Arc view. At last, the supervised classified images were exported to Arc view GIS for manual digitization on screen in to different landuse /landcover classes.

4. Lansuse/landcover Pattern Change and Detection (1985-2003)

4.1 Description of Landuse /Landcover Categories in the Study Area

Perennial crop lands: It is Agricultural land which used primarily for production of chat crop which is known by its scientific name as "Catha edulis". It also includes land that is used for coffee and grain. Also Landused for the production of tree crops, and other agricultural activities is included in this category. They are found almost green in all seasons of the year so that they are easily identifiable in the image from the temporal crops, which are not available in all seasons

Temporal crop land: It is another Agriculture land mainly consisted with seasonal crops. This subcategory includes land used for the cultivation of food crops like sorghum and maize. These crops do not found all the year unlike the perennial crop so that are mostly harvested at November and December that is why also they are called seasonal or temporal crops. They are found covering large part of the study area. Unless careful field observation is done they might confuse with bare land since have similar spectral response in some parts especially in the image which is taken in the winter season.

Bare Lands: This category includes non-forested, non-vegetated, and non-agricultural land that has less than 50 percent herbaceous cover. Lands which were formerly agricultural but now due to erosion and over use became worthless are also classified under this category. This types of lands are widely found in the southern part of the area .To some extent barelands are also found in the former lake area, especially in Adele lake area i.e. when the lake completely dry up part of the lake area will become a kind of bareland. In the image they are easily identified because due to their high reflectance value they appear whiter than the surround features.

Plantation: Plantations are lands that are covered by man made forests/trees of eucalypts and conifers species, which are about 3 meter or more in height .Otherwise there is no natural forest in the study area. This category includes managed areas of tree growth such as eucalyptus and conifers tree farms that meet the basic criteria for forest areas. The conifers do not seasonally lose their leaves.

Residential: Residential land uses range from high density, represented by the multiple-unit structures of urban cores, to low density, where houses are on lots of coverage and which could be identifiable from image, at the periphery of urban expansion. Linear residential developments along transportation routes extending outward from urban areas are included. Areas of sparse residential land use surrounded by other uses (e.g., Agricultural) are not included in this subcategory

Grasslands: This category includes areas dominated by native or introduced grasses and forbs, including grass like plants such as sedges and rushes, and small flowering and non-flowering plants occurring on upland and lowland areas. To be placed in this subcategory, the area should have roughly a 50-50 mix of plant cover versus bare land. This subcategory includes agricultural pasture land.

Shrub land: This category includes land predominantly covered by communities of grasses, grass like plants, including medium flowering and non-flowering plants, and mixtures of them includes unmanaged land as well as significant managed areas of herbaceous cover such as pasture.

Woodlands: Woodlands are dominated by low woody plants generally below 3 meters in height. Included are areas of immature trees that may be in transition to forest. They are also mainly from eucalyptus and conifers species. More over this wood lands are not natural rather human made vegetations like plantation.

Marshy area: It is obvious that most marsh areas are resulted from the drying of water body. They also resulted from temporal logging of water, especially in rainy season, so that land will remain as marsh area. Hence, areas which are like wet land and a mixture of grass and water are classified under this category. Large part of this kind of land is delineated from the lake areas.

Water Bodies: This category includes all areas of surface water with no, or minimal, emergent vegetation. All lakes, ponds, rivers, and streams, that cover an area large enough to be delineated as area features, are included in this category.

5. Change Detection for the Period 1985-2003

5.1Landuse/ Landcover of the Area in 1985

In 1985(Figure 2), majority of the land was occupied by temporal crop (maize and sorghum) which is 51.6%, bare land 22.8%, perennial crops (mainly chat) 17.2% and water body covers 1.3%. (Table 2). The smaller landcovers were residents and marsh areas which covers 33.4 ha and 279.7 ha, respectively.

5.2 Landuse/ Landcover of the Area in 2003

In 2003(Figure 3), land was still mainly caught by temporal cropland which is 41.12% of the total. The other landuses covers, barelands 26.72%, perennial crops (chat) 21.50%, and marsh 3.32%, and wood land 2.36%. The smaller landuses were covered by grass which is 1.43%, residents 1.05, and water which is the smallest 0.54 % (Table 1.)

6. Landuse/ Landcover change Analyses for the Period 1985-2003

It is true that variety of changes in landuse and landcover especially in agriculture (temporal and perennial crops), water body, grassland and bareland are seen in the area within the period between 1985-2003. Hence the overall change is analyzed here under (Table 3). The detail about the changes in landuse and landcover and the causes that result the changes are explained well in discussion part.

Table 1: Land use /land cover class for the year 2003

Land use /cover	Area (ha)	Area (%)
Grass	973.1	1.43
Bare land	18,119.2	26.72
Marsh	2,254.3	3.32
Perennial crop	14,579.7	21.50
Plantation	933.4	1.38
Residents	701.7	1.04
Shrub	391.2	0.58
Water	362.6	0.54
Wood land	1,604.1	2.36
Temporal crops	27,881.2	41.12
Total	**67,750.1**	**100%**

Table 2: Land use/ land cover class for the year 1985

Land use /cover	Area in ha.	Area in %
Grass	1689.8	2.49
Bare land	15,029.8	22.18
Marsh	279.7	0.41
Perennial crop	11,528.9	17.41
Plantation	1,054.5	1.56
Residents	334.6	0.49
Shrub	493.3	0.73
Water	886.7	1.30
Wood land	1496	2.21
Temporal crops	34,962.8	51.60
Total	**67,756.1**	**100%**

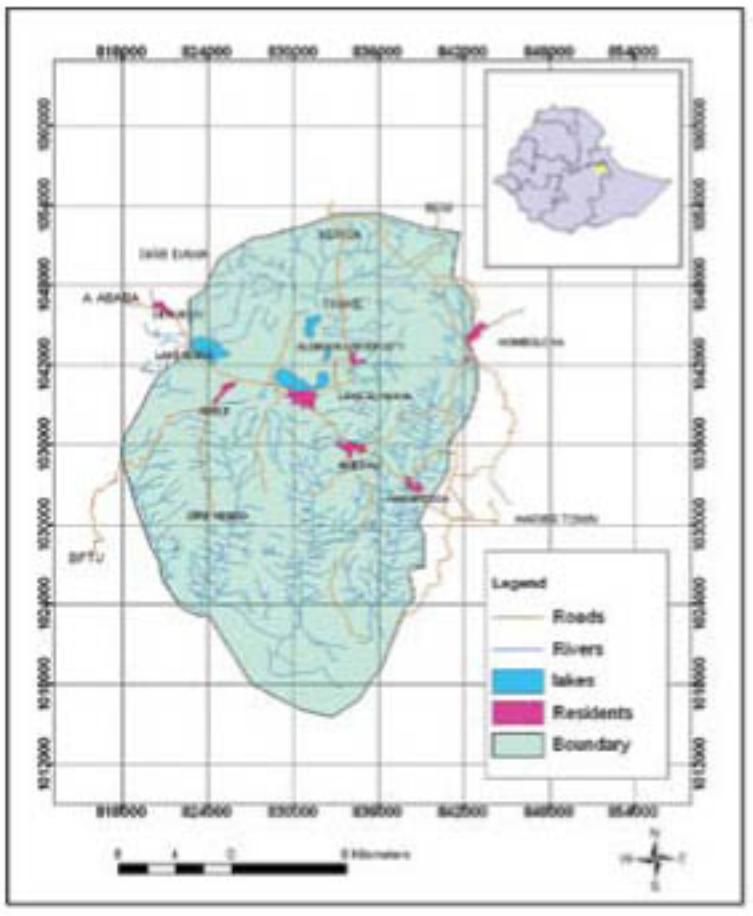

Figure 1: Location map of the study area

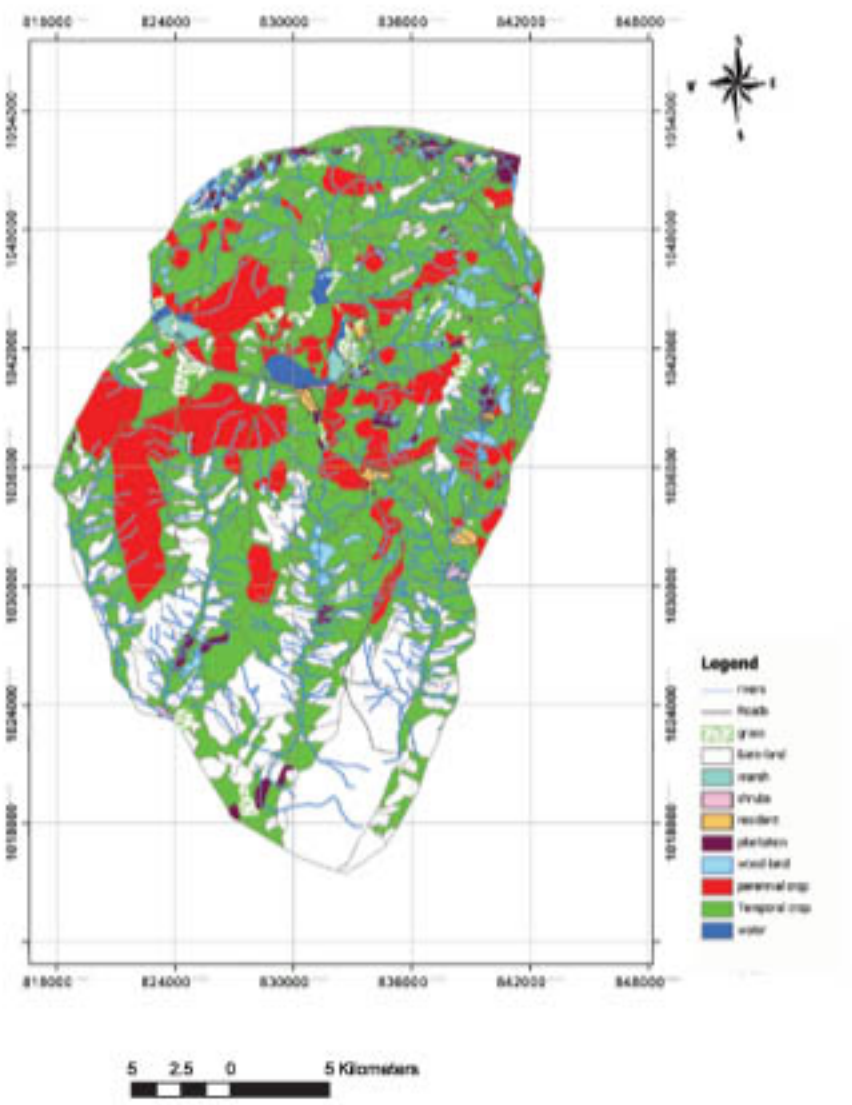

Figure 2: Landuse/ Landcover map of 1985

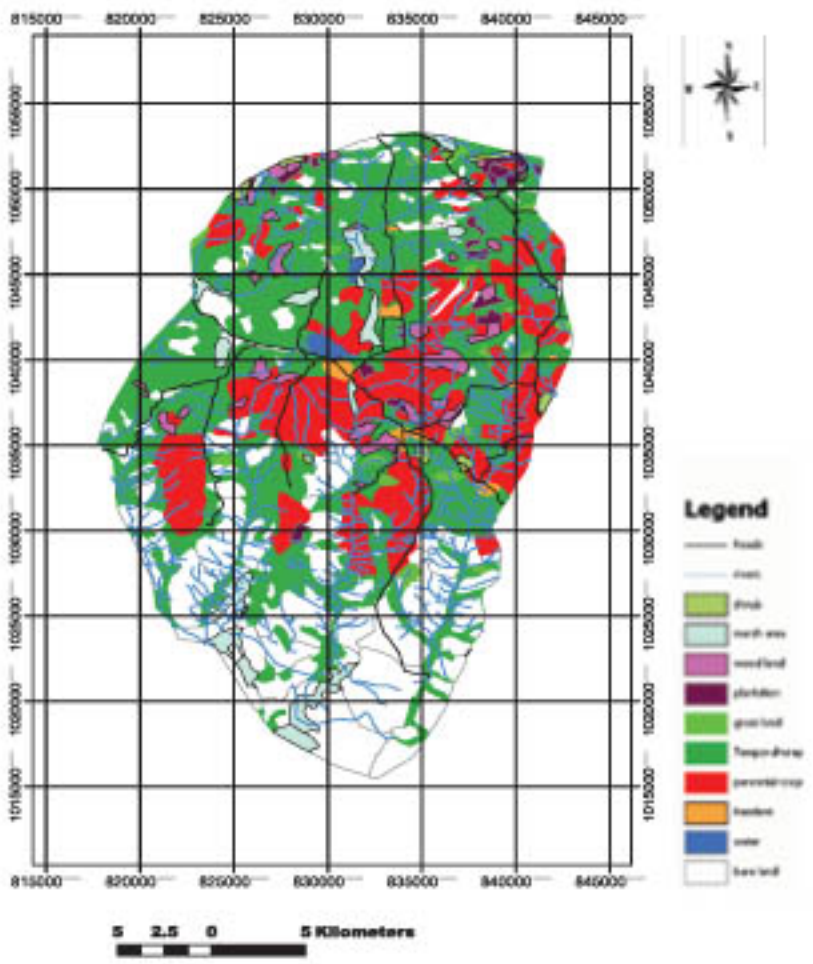

Figure 3: Landuse/ Landcover Map of 2003

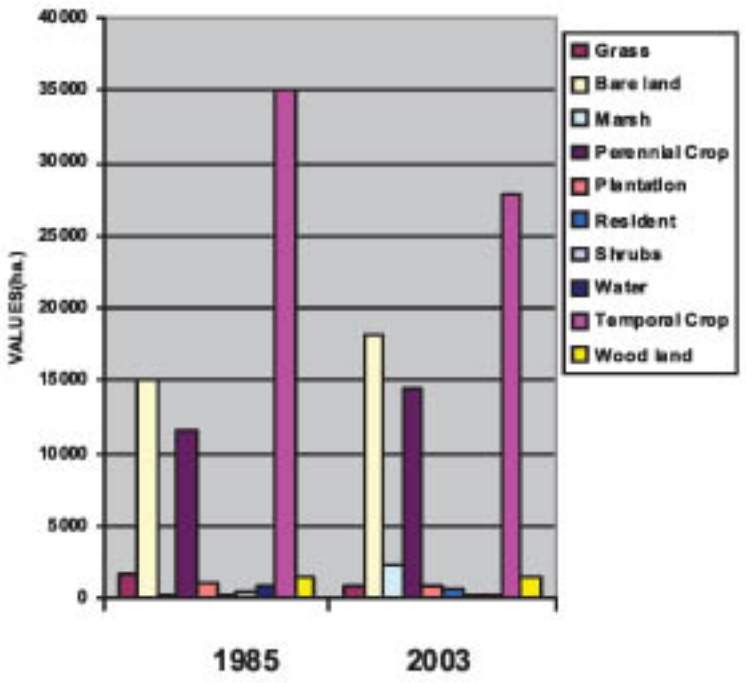

Figure 4: Landuse/Landcover diagram of 1985 and 2003

Table 3: Landuse /Land cover class and change in the period (1985-2003)

Class	Year		Changes	
	1985 (ha)	2003 (ha)	Change (ha)	Change (%)
Grass	1689.8ha	973.1ha	-716.7	-42.41%
Bare land	15,029.8	18,119.2	3089.4	20.56
Marsh	279.7	2,254.3	1974.6	705.97
Perennial crop	11,528.9	14,579.7	3050.8	26.47
Plantation	1,054.5	933.4	-121.1	-11.48
Residents	334.6	701.7	367.1	109.71
Shrub	493.5	391.2	-102.3	-20.73
Water	886.7	362.6	-524.1	-59.11
Wood land	1496	1,604.1	108.1	7.23
Temporal crops	34,962.8	27,881.2	-7081.6	-25

Rate of land use land cover changes

The rate of land use/ land cover change for each class was calculated as follow:

Rate of change (ha/year) = (A-B)/C

Where, A= recent land use / cover area in ha, B= Previous area of land use /cover in ha, C= interval between A and B in years.

The result of the change rate is summarized in a table below (Table 4.)

Table 4: Landuse/Land cover class change rate (1985-2003)

Class	Year (ha)		Rate of change (ha/year)
	1985 (ha)	2003 (ha)	
Grass land	1689.8	973.1	-39.82
Bare land	15029.8	18,119.2	171.63
Marsh	279.7	2,254.3	109.7
Perennial	11528.9	14,579.7	169.49
Plantation	1054.5	933.4	-6.73
Residents	334.6	701.7	20.39
Shrubs	493.5	391.2	-5.68
Water	886.7	362.6	-29.12
Wood lands	1496	1,604.4	6.01
Temporal crops	34,962.8	27,881.2	-393.42

7. Discussion

In this study different software were used to identify, classify and digitize landuse and landcover classes and different results were obtained. Both supervised and unsupervised classifications were attempted and supervised classification was preferred because it gave a better result while the unsupervised classification generalized some landuses on others. So that since the supervised classification matched with each land classes, digitization also done based on it (Figure 2 and 3). In both images (1985 and 2003) ten landuse classes were identified but most of the landuse either increased or decreased in size at different change rate in 2003, as compared to 1985(Figure 4). Marshy area increased from 279.7ha to 2,254.3 ha with change rate of 109.7ha /year. The cause is obvious that when the water body dries, at 1st stage they become marshy area. Bare lands also increased from 15,029.8 ha to 18,119.2 ha with change rate of 171.63 ha/year mainly at the expense of temporal cropland, grasslands and shrubs and to some extent water bodies. This is the most dynamic landcover type which is extending itself every year and major problem in the area. Perennial crop in their turn increased from 11,528.9 ha to 14,579 ha it is because of more lands from shrubs and grass as well as from temporal croplands were converted to perennial cropland, mainly to cultivate chat. Woodlands are the other classes that showed some increment in 2003. This is mainly due to different initiatives of environmental rehabilitation programs and soil conservation in some selected places. These initiatives and woodland expansion were largely done and being held by Alemaya University and Harer Brewery factory (Table 2). Grass lands and shrubs, since already converted to Agricultural lands

and partly to bare land they decreased from 1689.8 ha to 973.1 ha and from 493.5 ha to 391.2 ha respectively. Temporal crop lands also decreased from 34, 62.8 ha in 1985 to 27,881.2 ha in 2003. This cause is due to conversion to bare land and perennial crop land. This kind of landuse changes are observed in many places in the study area.

8. Conclusions

In this study landuse and landcover changes are assessed by integrating GIS and remote sensing techniques. In the study area, the largest landuse and landcover is occupied by temporal crops (maize and sorghum), which covers 51.6% of entire area in 1985 and 41.2% in 2003. It's conversion to bare land and to some extent to perennial crop land are main factors for its decline in 2003. Next to temporal crop land, bare land and perennial crop land possesses larger landuses each of which contain 26.7% and 21.5% of entire study area respectively. Even though many changes are observed among the landuses and landcovers in the year between 1985 and 2003, the highest change is observed in grass lands which is decreased by 42.4%.The highest rate of changes are seen in temporal cropland which is -393.4 ha in every year and bare land which is 171.6 ha/year. Beside grassland, shrubs and temporal crops are also decreased in size by 20.7%, 25.4% and 59.1% respectively in 2003, when compared with 1985. Conversely, perennial cropland, marshy area, residents and wood lands increased by 26.6%, 20.6%, 705.9%, 109.7% and 7.3% respectively, in the last 20 years. These land area / covers increased mainly at the expense of grass lands and shrubs. Due to population growth the area of residents which means urban settlements is increased from 334.6 ha to 701.7 ha.

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