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LAND-USE/LAND-COVER DYNAMICS IN *NONNO* DISTRICT, CENTRAL ETHIOPIA

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ABSTRACT

Ethiopia is a country characterized by swift environmental conversions and modifications attributed to various adverse human actions, like expansion of farm plots at the expense of vegetated lands, massive fuelwood and charcoal production, overgrazing and encroachment of farmsteads into vegetated lands. Hence, a systematic analysis of land-use/land-cover (LU/LC) change is so crucial to exactly comprehend the extent of the change and take necessary measures to scale down the rate of changes and protect the land cover resources sustainably. This LU/LC study has made use of sequential satellite images (1984, 2002, and 2007) and GIS technologies in combination with ground verification. The study detected both types of changes (conversion and modification) and six major land use types in the district of *Nonno*. Woodland and farmland are found to be the two most shrinking and expanding land use types in the district, respectively. The woodland, which accounted for 26 % of the district in 1984, reduced to only 5.5% in 2007. It shrunk at the rate of 3.5 and 8.8 percent per year from 1984 to 2002 and from 2002 to 2007, respectively. This change involved a gradual thinning of the woody plants and its modification to grasslands. A significant conversion from natural vegetation cover to cropland was observed between 2002 and 2007, where the cultivated land expanded by 26.5 percent. Another major land use type, resettlement site, appeared only in the satellite image of 2007. This is attributed to the 2003/04 intra-regional 'voluntary' resettlement programs through which the government relocated about 1,800 farm households in *Nonno*. The change from the vegetated land to the urban area over years was found to be insignificant. The area occupied by the two small towns (Silk-Amba and Dire-Gudo) accounted only for less than 0.4 percent of the total area of the district in 2007.

Keywords: Land; Land Cover; Land Use; Nonno; Oromiya

BACKGROUND ISSUES

Ethiopia, situated in the *Horn* of Africa at 2^0 54'N-15^0 18'N latitude and 32^0 42'E-48^0 18'E longitude, has the total area of over 1.12 million km^2, which is 432,424 $mile^2$ (MoME, 2003). It is a country where about 80 million people, containing 50.46 percent male (CSA, 2010), is grappling with all sorts of natural and manmade problems, like famine; environmental degradation; erratic rainfalls; prevalence of malaria and HIV/AIDS; poor but improving, governance; and widespread poverty. About 84 percent of the people live in the rural areas (CSA, 2008) driving their livelihoods from subsistence agriculture, which is a sector suffering from lack of essential inputs and erratic rainfall. Poverty is rife in Ethiopia, though slightly declining over time. MoFED (2008) indicates that over 38.7 percent of the population is found below the poverty

line. The problem of poverty is highly pronounced in rural areas, more than it does in towns or cities with the coverage of 39.3 and 35.1 percent of the respective population.

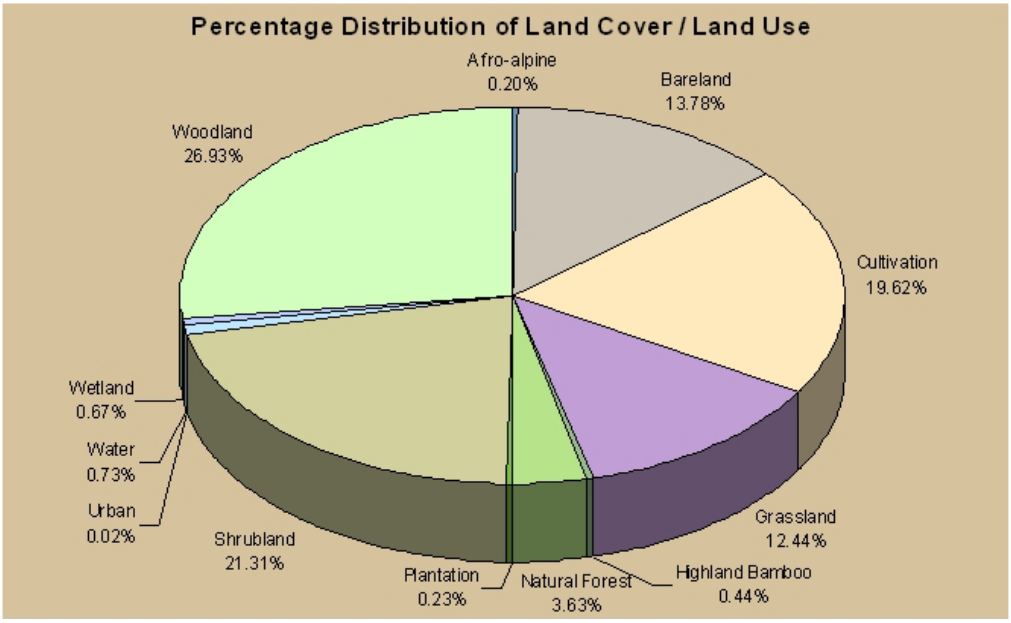
Ecologically, Ethiopia is characterized by abundant, but shrinking, diversity in biological resources: forest, woody, and grassy lands, shrubs, and varied wildlife. It is also renowned for its massive mountain ranges, high flat plateaus, deep gorges, river valleys, lowland plains, extensive wetlands, and deserts. As indicated by Aklilu (2006), about 45 percent of the country is highland, with an altitude of greater than 1500m, in which about 88% of the country's population is located. The geographical setting of the country is generally distinguished by the highlands in the central part, circumscribed by the flat lowlands. Overpopulation, extensive croplands, and frequent incision by ravines and gullies characterize the highlands. The Great East African Rift System bisects the central highlands into the northwestern and southeastern sections. The altitude of the country ranges from the highest peak of 4620 m above the mean sea level (amsl) at *Ras Dashen* down to about 120m below mean seas level (bmsl) at Danakil/Afar Depression (EMA, 1988; OPEDB, 2000).

On the basis of altitude and its influence on temperature and rainfall, Ethiopia is traditionally classified into four broad agro-climatic zones. These are termed as: *wurch* (cold-moist); *dega* (cool-humid); *woinadega* (semi-humid); and *qolla* (arid and semi-arid). *Wurch* encompasses all areas 3200m above the mean sea level, with an average annual rainfall of over 22 meters. The *dega* zone consists of areas with altitudes ranging from 2400 to 3200 m and an average annual rainfall of 1200 to 2200 mm. *Woinadega* zone accommodates areas within the altitudinal range of 1500 to 2400 m and an average annual rainfall of 800 to 1200 mm. Finally q*olla* zone refers to areas lying below 1500 m with the average annual rainfall of 800 mm (Negash, 1987).

The abovementioned traditional broad groupings of the Ethiopian physical environment can further be classified into 11 more detailed ones. These are (1) *bereha (*meaning desert); (2) dry-*qolla*; (3) moist-*qolla*; (4) wet-*qolla*; (5) moist-*woinadega*; (6) wet-*woinadega*; (7) moist-*dega;* (8) wet-*dega*; (9) moist-*wurch*; (10) wet-*wurch;* and (11) high-*wurch* (Negash, 1987). More, recently, the Ethiopian Ministry of Agriculture and Rural Development (MoARD) produced the most detailed agro-ecological classification of the country by taking into consideration moisture regimes, in addition to altitude and temperature. Accordingly, the country has 18 major and 49 sub agro-ecological zones, each with its own agricultural and biological potentials.

Large parts of the cultivated areas in the country are found in the *dega* and *woinadega* agro-climatic zones, while *qolla* areas are dominated by subsistence pastoral and agro-pastoral systems. Altogether, over 66 percent of the total area of the country is reported to be suitable for agricultural production (Abera, 2010) and about 20 percent is covered yearly by crops, of which the vast majority (75%) is temporary crops. Other major land-use types of the country are indicated in the diagram, below.

Figure 1: Percentage Distribution of LU/LC: Ethiopia



Source: Produced based on the raw data obtained from Ministry of Agriculture

Ethiopia is also noted by severe environmental degradation of which the most notable ones are soil erosion, water depletion (such as the disappearance of *Haramaya* Lake, near the town of Harar), and shrinking vegetated lands. Historical documents show that forest and woodlands once covered over 40 percent of the total area of the country (Badege, 2005). Presently this figure is estimated at less than 3 percent. As Woldeamlak (2009) cited FAO (1986, 1999), the country's annual deforestation rate is estimated to be about 62,000 hectares, attributed primarily to the increased demand for farmland, fuelwood, and settlement sites. This has resulted in severe soil degradation (about 2 billion tons per year), alteration of hydrologic regimes, disturbance of local and/or regional climates, loss of biodiversity, and expansion of desert ecological conditions.

Recurrent droughts and erratic rainfall are also common in East Africa, in general, and Ethiopia, in particular. This area has a prolonged and frequent history of drought conditions and drought-related, distressing famines. Surprisingly, as noted by Dercon (1999), quoted by Woldeamlak (2009) "one every three or four years is a drought year" in Ethiopia.

The aforementioned appalling environmental and climatic conditions in Ethiopia, in conjunction with the consequential failure in agricultural productivity, have been afflicting Ethiopians over years. The crop failure and the resultant humanitarian crises of 1958, 1973, 1984-86, and 2002 (Degefa, 2006), for instance, are the most distressful cases in point although Ethiopia has a long history of famine, beginning from 240BC (Dessalegn, 2005). The drought-induced famines of 1973/74 and 1984/85 are among the worst in Africa's history, both in intensity and spatial coverage (Woldeamlak, 2009, White, 2005; von Braun & Olofinbiyi, 2007). An estimated 250,000 people had died in the 1973/1974 drought alone while more than 1 million people died in the 1984/1985 drought (Fransen and Kushminder, 2009; Mberu, 2006). The drought of 2002 distressed 13 to 15 million Ethiopians, although no significant number of deaths was reported. Similarly, the shortage of rainfall was reported, in 2009, in the lowland areas, as affecting over 6,200,000 inhabitants, according to MoARD Disaster Management

and Food Security Sector of Ethiopia. Even recently, despite the government's earnest effort to develop the Ethiopian agriculture, the problems of food insecurity, hunger, famine, and malnutrition still remain the greatest threat to the people.

The entire above-mentioned environmental, climatic, and socio-economic problems call for an accurate investigation in the status, causes, processes, and rate of LU/LC changes in the country. Such inquiries enable researchers, policy/strategy formulators, and aid providers to have accurate data related to the subject and proceed accordingly. In fact, some studies (Negash, 1987; Belay, 2002; Bezuayehu, 2002; Woldeamlak, 2002; Olson, Misana, Campbell, Mbonile, and Mugisha, 2004; Badege, 2005) have shown that the LU/LC has been rapidly changing in Ethiopia, owing to the population pressure, resettlement programs, climate change, and other human- and nature-induced driving forces. Particularly, anthropogenic activities are the single most significant factors adversely altering the natural status of the Ethiopian landscape. This resulted in impressive changes in the land-use/land-cover patterns of the country over time. Hence, as precisely noted in Belay (2002) and Mausel, Brondizio and Moran (2003), well-timed and accurate change detection of the natural resources (such as vegetation cover, water, and soil) provides a foundation to clearly comprehend the prevailing interactions between people and the environment. This, in turn, enables the people to manage and use the resources sustainably.

As indicated in Belay (2002), LU/LC change analysis is one of the most precise techniques to understand how land was used in the past, what types of changes are to be expected in the future, as well as the forces and processes behind the changes. It also yields valuable information for the analysis of the environmental impacts of population pressure, agriculture, urban expansion, resettlement program, climate change, and others. Such analysis is of great use to natural resources managers, development agents, fund providers, socio-economic development planners, public administrators, and environmentalists because it provides accurate information related to LU/LC changes.

Nevertheless, there is no such critically investigated LU/LC change studies carried out in and around the district of *Nonno* so far. The district adequately represents the central Ethiopian low-lying plateau, where crop cultivation and human inhabitation has taken place since time immemorial. It is characterized by distinct dry and wet seasonal climatic conditions, expanding farming activities, and ever-increasing population settlements, making this study realistic.

THE STUDY AREA

Location and brief biophysical profile

The district of *Nonno* is found in the West *Shewa* Administrative Zone of Oromiya National Regional State, Central Ethiopia. The surface area of *Nonno* district is about 693.7 km^2, of which the rural area accounts for 99.07 percent. Topographically, *Nonno* is found within the central Ethiopian tableland, commonly known as Shewan Plateau in the upper catchment of the *Gibe* River. *Nonno* is a flat terrain milieu with an altitude ranging from about 1126 meters above sea level (in *Gibe* Valley) to about 2,192 m amsl. The area is comprised of small mountains (hills), known as *Qondala* (1646m), *Tullu Setana* (1640m), and *Silk-Amba* (1820m). It is drained by numerous perennial and seasonal rivers, locally known as Ghibe, *Ejersa Guda, Warabessa, Nonno, Wenni,* and *Silmi*.

Climatically, most parts of the district of *Nonno* belong to *woinadega (*90.83 percent) and *qolla* (9.16) agroclimatic zones. Table 1 presents a brief description of the sub-agroecological zones and the dominant crops in the district.

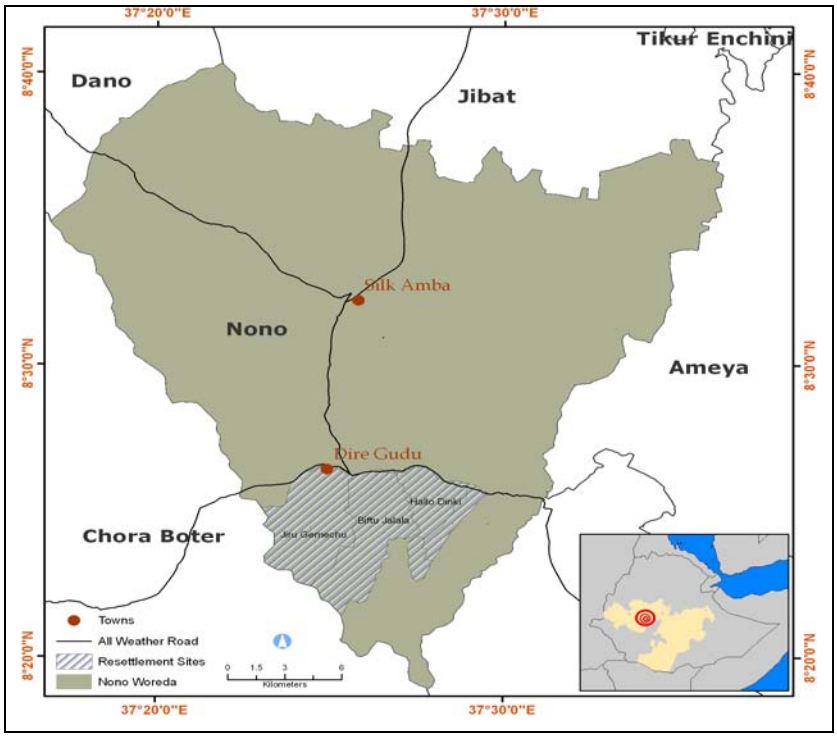
Table 1: Agro-climatic zones of *Nonno*

Characteristics	**Agro-climatic zones**			
	Moist *qolla* (Warm semi-arid)	Wet *qolla* (Semi-arid)	Moist *woinadega* (Semi-humid)	Wet *woinadega* (Humid)
Altitude (m amsl)	500-1500	500-1500	1500-2400	1500-2400
Rainfall (mm)	800-1400	>1400	900-1400	>1400
Dominant crops	Sorghum, maize, sesame	Sorghum, maize, teff, Chili pepper	Teff, barley, maize, sorghum, wheat, nigger seed, finger millet,	Teff, barley, maize, sorghum, wheat, beans, chickpeas

Source: Limited fieldworks based on Negash (1987)

Note: amsl stands for 'above mean sea level'

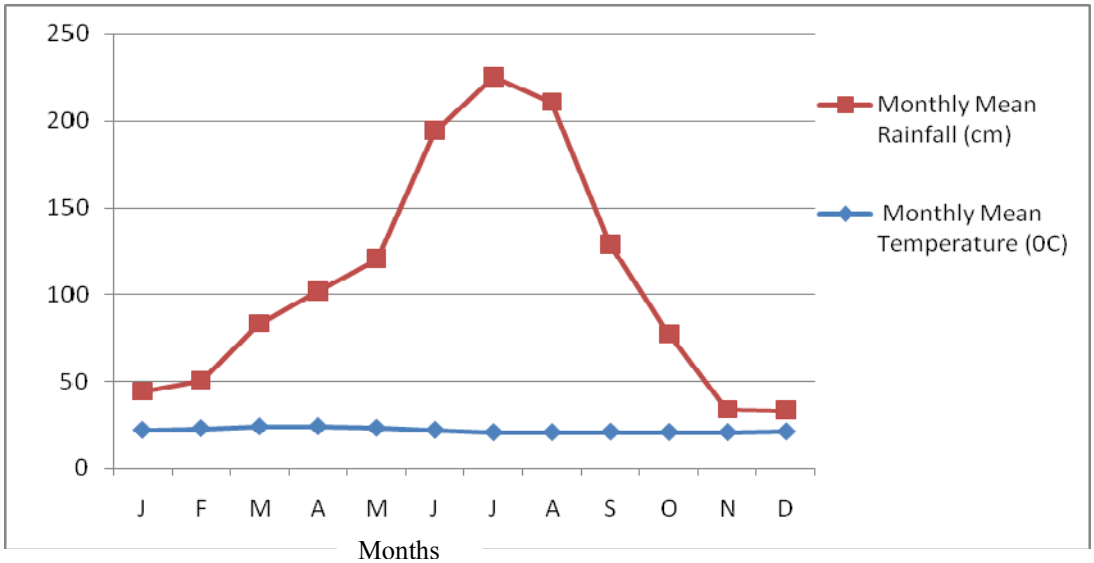
Figure 2: *Nonno* district in its regional and national settings



Source: Produced based on unprocessed satellite images obtained from Ethiopian Mapping Agency

The long-term mean monthly temperature (T^0) and total annual rainfall for *Yaya Otona* (1,550 m amsl), the only meteorological station at closest vicinity, are 21.94^{0}C and 1039.8 mm, respectively. The rainiest and planting months in the area are June, July, and August.

Figure 3: Long-Term Mean Monthly Temperature (T^0) and rainfall for *Yaya* (1,200 m amsl) meteorological station



Source: Computed based on the raw data obtained from National Meteorological Agency of Ethiopia

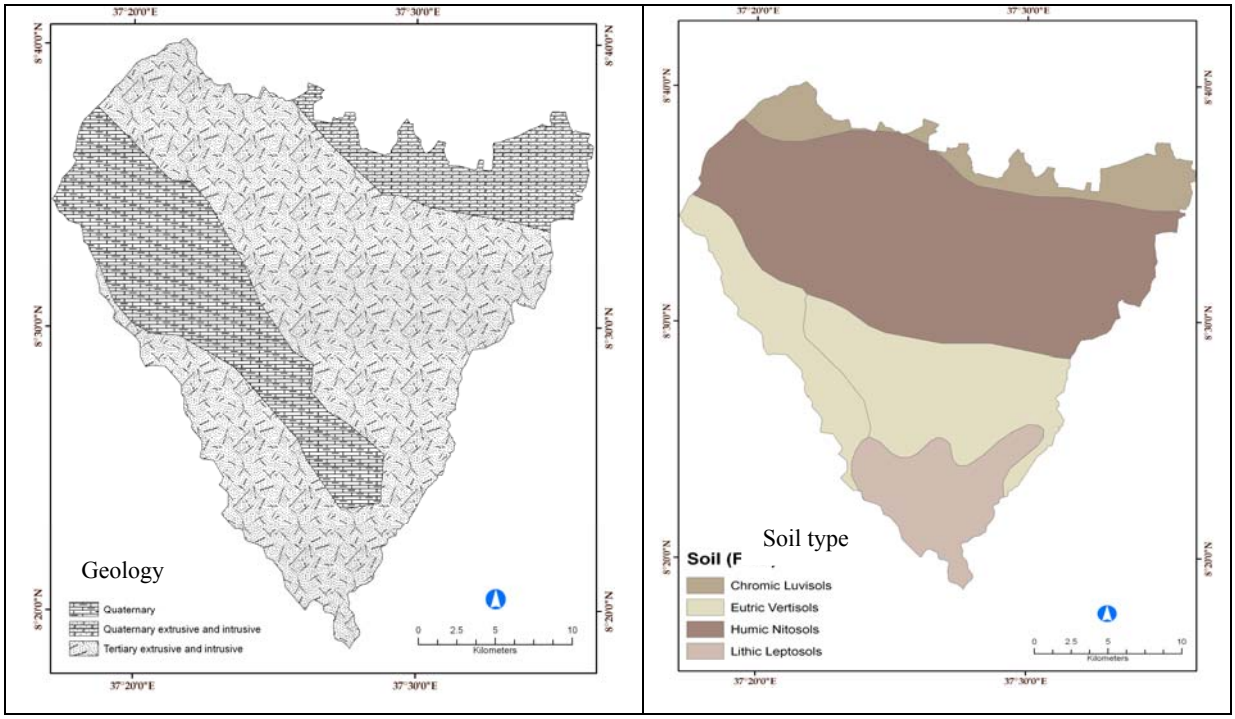
As of July 2010, the district's total population was about 92,188, of which 52 percent was male and 95.78 percent lived in the rural areas. The crude population density of the district was 135persons/km^2. This figure is slightly lower than the population density of the highland parts (≥ 1500m) of Ethiopia (about 142 persons/ km^2) and far greater than that of the population density of the whole country (about 73 persons/ km^2).

Geology and soil

The geological structure of the Ethiopian highlands, in general, and *Nonno* and its environs, in particular, is characterized by extreme folded and foliated basement Precambrian rocks which are found overlain by Mesozoic marine strata and Cenozoic basement traps. This series was uplifted in the Upper Eocene as part of the Arabo-Ethiopian swell, resulting in the present day Ethiopian highlands (MoME, 1996; MoME, 2003). Specifically, the major geological formations of the district of *Nonno* are primarily intrusive and extrusive, quaternary and tertiary traps.

As it is the case in other parts of the earth, the geological formations of the district resulted in the existing various soil types, which can broadly be classified into Chromic Luvisols, Eutric Vertisols, Humic Nitosols, and Lithic Leptosols. Humic Nitosols and Eutric Vertisols cover the largest proportion of the district: 52.19 and 28.08 percent, respectively. According to FAO (2006), vertisols are churning, heavy clay soils which develop mostly in areas with an alteration of distinct wet and dry seasons, like central Ethiopia where the district of *Nonno* is located. Such soils are common in grass-covered and/or woodland areas, like most parts of *Nonno*. Vertisols, on the other hand, have substantial agricultural potential if appropriately managed for sustainable agricultural production. It is good for the production of crops, like sorghum, cotton, chickpeas, wheat, barley, and flax, as it can be evidenced by the current actual practices in *Nonno*. Amazingly, all three resettlement sites (*Biftu Jalala, Hallo Dinki,* and *Jiru Gamachu*) are located in the areas of vertisols in the district.

Figure 4: Geology and Soil Maps of the District of *Nonno*



Source: Analyzed based on unprocessed satelite images obtained from Ethiopian Mapping Authority

Nitosols, the other abundant soil types in the district, are fairly textured, well-drained, and easily workable. Such soils are resistant to erosion and belong in the most productive soil groups in the humid tropics (FAO, 2006).

The two minor soil types in spatial coverage in the district are Lithic Leptosols and Chromic Luvisols; covering about 10.66 and 9.08 percent, respectively. According to FAO (2006), Leptosols are very shallow, gravelly, and stony soils that are particularly good for wet-season grazing and forestland. Luvisols, on the other hand, are soils that are well known for their higher clay content in the subsoil, than in the top soil, owing to the permeation of the particles. Such soils are suitable for a wide range of agricultural activities.

LIVELIHOOD STRATEGIES IN *NONNO*

Subsistence rain-fed crop cultivation, supplemented with traditional livestock production, constitutes the basis of the economy of the people of the *Nonno* District and the environs. The farmers produce predominantly maize (*Zea mays*), sorghum (*Sorghum bicolor)* (in *qolla* agro-climatic zones), teff (*Eragrostis tef*), wheat (*Tiriticum* vulgare), and barley (*Hordeum vulgare*) (in *woinadega* parts). Sesame (*Sesamum indicum*), nigger seed *(Guizotia abyssinica),* chick pea (*Cicer arietinum*), and lentil (*Lens culinaris*) are other significant crops in *Nonno*. Crops, such as onion (*Allium cepa*), garlic (*Allium sativum*), potato (*Solanum tuberosum*), cabbage (*Brassica oleracea*), pepper (*Capsicum spp*.) and various types of spices are also cultivated as cash crops, but these are usually planted on a very small portion of the arable land, particularly on the basis of traditional small-scale irrigation schemes. Rivers, streams, and ponds are used as sources of water for irrigation.

Animal rearing is also practiced, mixed with crop cultivation in *Nonno*. Domestic animals, such as cattle, goat, sheep, donkey, chicken, and bees, are kept on a traditional basis. This subsector provides the community with milk, butter, hides and skins, honey, and traction and transportation powers. It also serves as a means of security against crop failure.

Figure 5: Traditional Farming Practices as Major Livelihood Strategy

Traditional farmland preparation

Livestock rearing

Rainwater harvesting pond

Another notably important, but 'illegal' and environmentally devastative, source of livelihood in the area is the production and sale of charcoal and firewood. Some households produce charcoal/firewood and sell it at the nearest towns for their daily cash requirements. Similarly, some others make and sell dung-cakes for survival. The business of dung-cake making is usually the work of women and children. As noted by Aklilu (2006), such practices are said to be 'selling the future to survive' as they are practiced at the expense of environmental protection and soil fertilization.

Moreover, several resettler households in the district had partly lived on Productive Safety Net Program (PSNP). This program is one of the giant government programs to deliver social transfers to the poor farming households through public environmental protection works or as a direct support for households that are labor-constrained. As noted in Devereux and Guenther (2007), PSNP in Ethiopia, in general, and in *Nonno,* in particular, are aimed at smoothening food consumption, protecting household property, and building community assets.

Figure 6: Petty Trades as Livelihood Strategies: *Dire Gudo* Town

Roadside fast food trade

Cloth making and sale

Chat trade

Professional employment, retail, and petty trades are also important economic activities in the district's urban areas, *Silk-Amba and Dire-Gudo*.

RESEARCH METHODS AND PROCEDURES

The main data input for the research is the remotely sensed satellite images of varied resolutions obtained from Ethiopian Mapping Agency (EMA). The three such images used for this study are the Landsat Thematic Mapper of 1984 with 30 meters resolution, Landsat Enhanced Thematic Mapper Plus (ETM+) Image of 2002 with 30 meters resolution, and SPOT Image of 2007 with 5 meters resolution. Pre-processing activities were carried out in order to enhance the quality of the image and readability of the features. The Landsat satellite images of 1984 and 2002 were geometrically corrected and the projection was set to Local Projection Systems. Radiometric correction of dark subtraction (haze reduction) was carried out to enhance readability of the features on the image. Dark subtraction activities were performed as part of the image pre-processing.

The land cover classes of woodland, shrub-grassland, grassland, resettlement sites, and urban centers were identified and the layers were recreated, accordingly. For analyzing the changes in LU/LC condition, the total area for each land cover classes for all the three years were calculated and the results were compared against each other.

First and foremost, the unsupervised classification was made to group the land cover classes depending on their reflectance properties. This was followed by field verification and, accordingly, accuracy assessments were made for all the three images. In due course, the overall accuracy level of the Landsat TM (1984), Landsat ETM+ (2002), and SPOT (2007) was found to be 82.23, 86.12, and 94.33 percent, respectively.

After obtaining the ground verified polygons, the supervised classification was done by incorporating the field data. The final output of LU/LC map was prepared for the three different years (1984, 2002, and 2007). The final LU/LC classes were classified and mapped. ENVI 4.3 and ArcGIS 9.3 softwares were used to process both the pre-and post image processing and quantification works.

Few well-informed and experienced respondents were purposively selected from the community to acquire supplementary data related to the prevailing LU/LC changes in the district. The respondents put in invaluable information to the matter through interviews and discussions. Moreover, secondary (un/published) data were obtained from the offices of Agricultural and Rural Development, Land and Environmental Protection, National Meteorological Agency (NMA), Ministry of Mines and Energy (MoME,) and Central Statistical Authority (CSA) of Ethiopia.

RESULTS AND DISCUSSIONS

Characteristics of the land-cover units

Table 2: Brief Description of Land-Cover Types Identified in Nonno District

Land-cover types	Brief description
Woodland 	Areas covered with sparse woody plants mixed with shrubs, bushes, and grasses. It is a low-density forest forming vegetation. Woodland is the most important source of firewood, charcoal, and woods for construction and traditional farm equipment making in *Nonno* and the environs.
Shrub-grassland 	Area with a plant community, characterized by a mixture of shrubs, grasses and herbs. Here, grasses and shrubs are the most dominant vegetation type. The community uses this land-cover type mostly for grazing and browsing. It is also the source of firewood and thatch.
Grassland 	Grasslands are non-woody areas where the vegetation is dominated by grasses and herbs with nil or little proportion of shrubs. Coarse grasses are used as roofing on thatched houses, while grasses are used for grazing in *Nonno.*
Cultivated land 	This category encompasses areas allotted for crops production (both annual/seasonal and perennial), dispersed rural settlements, and homesteads. Most cultivated lands are meant for seasonal subsistence rain-fed crops. Cultivated land LU/LC includes the existing few areas used for traditional irrigation schemes.
Resettlement site 	Permanent residential areas of varied patterns and scale occupied by backyards, compounds, and individual huts. The separation of individual settlements from the surrounding farm plots was not possible in this study.
Town 	Urban areas (*Silk-Amba* and *Dire-Gudo*)

Five major land-cover types were identified on the 1984 and 2002 satellite images of the district of *Nonno*. These were shrub-grassland, woodland, grassland, cultivated land, and a town. Although an all-weather road cuts the district north-south, it is found to be negligible in the spatial coverage in this analysis. Another major land-cover, resettlement site, was identified only in the image of 2007. This inspired the researcher to carryout fieldworks to recognize how the settlements emerged and become the main land-cover type, within such a short period of time (2002-2007). Hence, firsthand and secondary data were collected and analyzed to come up with appropriate findings. Accordingly, the settlement was found to be the result of the government's resettlement (land access) program, which was part of the National Food Security Strategy. The land access program was launched as one of the most viable options to alleviate food insecurity in Ethiopia. It targeted to relocate about 440,000 land-poor/landless rural households (2.2 million people), of which about 1,800 households were resettled in the district of *Nonno* in 2003 and 2004 (FDRE, 2004).

Types and trends of LU/LC changes in Nonno District

Grassland is the predominant type of LU/LC (land-use/land-cover) in 1984 and 2002 in the *Nonno* District (Table 3). It covered an enormous part of the district in its central, southern, southeastern, and southwestern segments (See Figures 8). Grassland is alarmingly reduced to 34.7% of the spatial coverage of the district in 2007. Amazingly, cultivated land constituted only 2% and 3% in 1984 and 2002, respectively. This makes the *Nonno* area different from the other highland parts of the country where cultivated land has been dominating for over a long period of time, as noted in Belay (2002) and Solomon (2005), among others.

The proportion of the cultivated land rose amazingly to 30.5% of the *woreda's* spatial coverage in 2007. These, along with the other firsthand data from the elderly community, confirmed the fact that the area has been densely vegetated and sparsely populated until recently. The vast area of the northern, northwestern, and northeastern part of the woreda was covered by woodland LU/LC types in 1984.

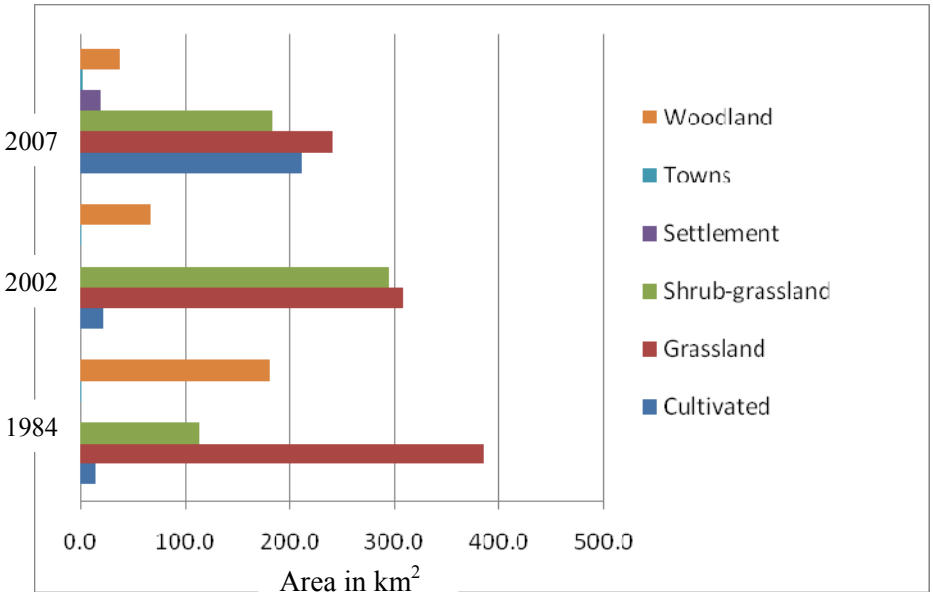
Table 3: Area of LU/LC Units at Different Periods in the District of *Nonno*

LU/LC category	1984		2002		2007	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Woodland	180.63	26.0	67.64	9.7	38.00	5.5
Shrub-grassland	112.84	16.3	295.16	42.5	182.30	26.3
Grassland	385.54	55.6	308.06	44.4	240.50	34.7
Cultivated land	14.10	2.0	21.15	3.0	211.60	30.5
Town	0.65	0.1	1.76	0.3	2.60	0.4
Settlement	0.0	0.0	0.0	0.0	18.70	2.7

However, in 2002 and 2007, the woodland diminished alarmingly and restricted to river valleys and streamsides (Figures 8 (2002) and 8 (2007)). The diminishing of woodland coverage is ascribed to the removal of plants for farmland preparation,

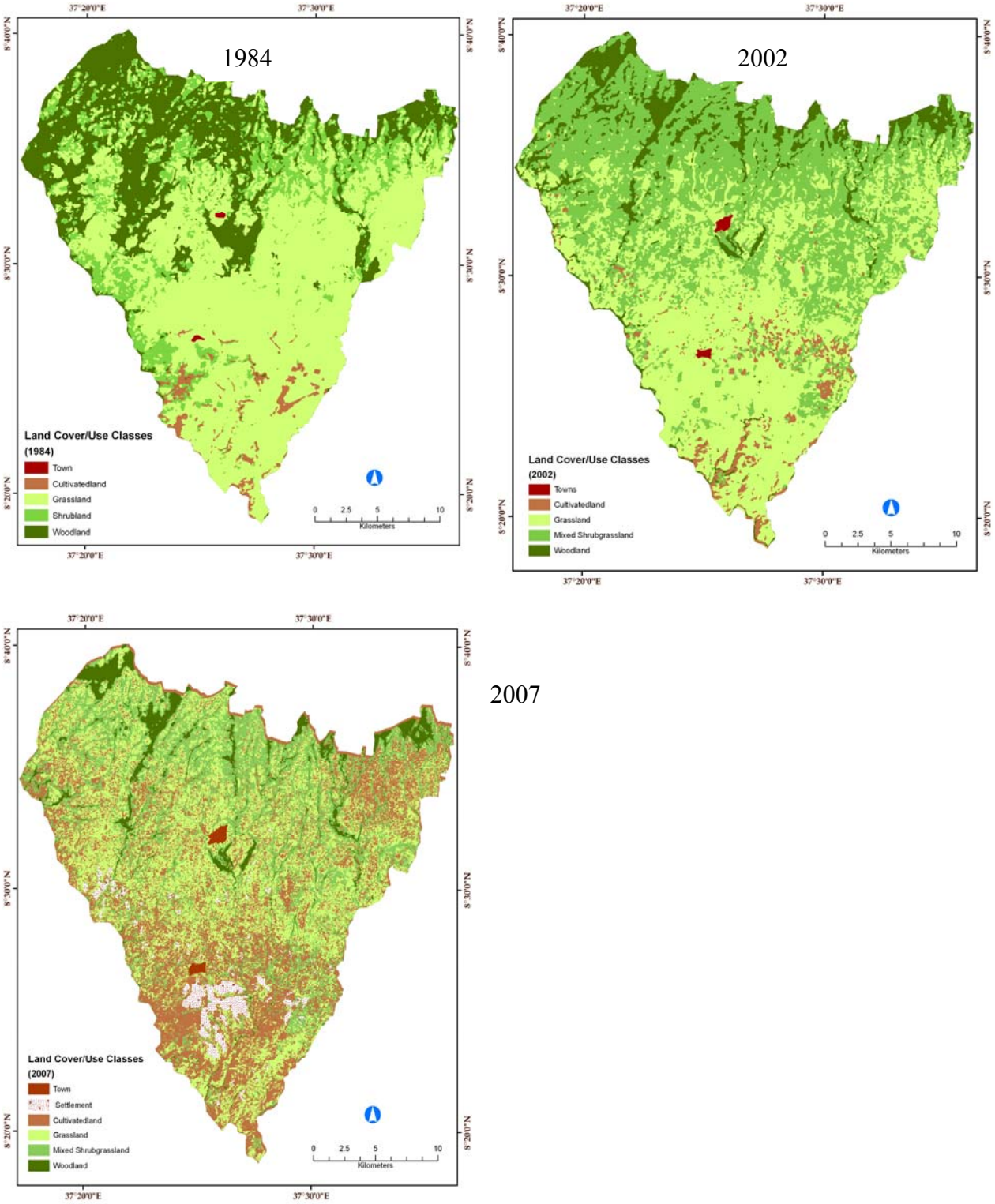
fuel wood, construction, charcoal preparation, and traditional farm equipment making. Most vegetated LU/LC types in 1984 and 2002 were alarmingly changed to cultivated land in 2007 (Figure 8(2007)). This finding sharply contrasts with that of Belay (2002) which reported an insignificant increase of cultivated land for South Wello Zone (North Central Ethiopia) for the period of over 43 years. Woldeamlak (2002) also reported a shrinking of farmland by only 2 percent between 1982 and 1998 in *Chemoga* Watershed, Ethiopia. This may be attributed to both spontaneous and planned/sponsored ecological-induced internal population displacements (in migration), coupled with the existing natural population increase within the district, over the last few decades, which resulted in intensive population pressure in the district of *Nonno* very recently, unlike the case of other highland areas in the country.

Figure 7: Area of LU/LC units at different periods in the district of Nonno



The analysis of LU/LC changes for the district of *Nonno* evidenced both modification and conversion types of changes. Woodland and grassland diminished by 62.6 and 20.1 percent (with the average diminishing rate of 3.48 and 1.11 percent per year), in that order, within 18 years (1984 to 2002). Contrarily, shrub-grassland stretched extensively by 161.6 percent (with the annual average expansion rate of 8.98 percent) over the same period. Amazingly, all three vegetated LU/LC types (grassland, shrub-grassland and woodland) diminished between 2002 and 2007, which resulted in a merely 5.5 percent spatial coverage of woodland in 2007 (Table 3, Table 4, and Fig 8).

Figure 8: LU/LC types of the district of *Nonno* in1984, 2002 and 2007



Source: Produced based on unprocessed satellite images obtained from Ethiopian Mapping Agency

Table 4: Trends of LU/LC changes in the district of *Nonno*

LU/LC category	1984-2002			2002-2007		
	Change in km^2	% change	Average annual rate of change (% per year)	Change in km^2	% change	Average annual rate of change (% per year)
Woodland	-112.99	- 62.6	-3.48	-29.64	-43.8	-8.76
Shrub-grassland	+182.32	+ 161.6	+8.98	-112.86	-38.2	-7.65
Grassland	-77.48	- 20.1	-1.11	-67.56	-21.9	-4.39
Cultivated land	+7.05	+ 50.0	+2.78	+190.45	+900.5	+180.09
Town	+1.11	+ 170.8	+9.49	+0.84	+47.7	+9.55
Settlement	0.00	0.00	0.00	+18.7	----	----

It is very shocking to see the rapid conversion of the vegetated land (about 900 percent) into cultivated land within 5 years period (2002 to 2007). The average annual conversion rate of was over 180 percent. Uniquely, those areas contiguous to the resettlement sites, in the south central part of the district are intensively converted to farmlands (Figure 8 (2007)). This is a dreadful and devastative episode that may result in irreversible environmental degradation and humanitarian disaster, unless appropriate actions are designed and implemented soon.

CAUSES OF LU/LC CHANGES IN *NONNO* DISTRICT

The discussions earlier in this document indicate that the district of *Nonno* is experiencing fast LU/LC changes especially in this decade. Enormous extent of vegetated land uses (woodland, shrub-grassland, and grassland) were converted to farmland. Significant successive modifications amongst the vegetated land uses were also evidenced. Moreover, the encroachment and establishment of settlement sites in vegetated areas is found to be another major LU/LC change in the district.

A case in point is what an 83 years elderly key informant said:

> "…I was born and grownup here. The whole area of this district was covered by dense forests and coarse grasses during my childhood. Giant trees and woody plants were plentiful in the area. I am a living witness for the fact that the forest coverage and wild animal flocks have been diminishing gradually all over my age. Woodlands are severely deforested and converted into grazing and cultivated lands. Most vegetation areas are plummeted into almost bare land these days. Particularly, the current arrival of the resettlers [in 2003 & 2004] severely exerted a heavy pressure on the environment…"

At this juncture, one may raise a question regarding the causes of LU/LC changes in *Nonno*. As indicated in Belay (2002), LU/LC changes are the result of a number of interacting variables and processes. Correspondingly, the series of interviews and discussions conducted with the community indicate that four interlinked major socio-economic and environmental

driving forces appear to explain a large part of LU/LC changes in the district of *Nonno*. Amidst other causes, (1) land tenure arrangements, (2) livelihood strategies, (3) population growth owing to natural increase, in-migration and resettlement, and (4) access to market appear to play a major role. Forest-fire (that occurred in *Mettu Silmi Kebele* in 2008, for a case in point) and overgrazing also take part in changing the LU/LC of the district.

The discussants for this study corroborated the fact that the first of these interacting LU/LC changing variables in the district of *Nonno* is the preceding land tenures. As noted in Olson, Misana, Campbell, Mbonile and Mugisha, (2004), land tenure is one of the most significant driving forces of LU/LC changes in East Africa. Tenure security provides the right incentives to invest or make improvements in land and natural resources. A land tenure system that ensures the holders a more secure landownership position usually results in better environmental conservation practices which, in turn, minimizes the rate of LU/LC changes.

The three most notable land tenure systems in Ethiopia are that of the *Imperial* Government (1930-1975), the *Derg* regime (1975-1993), and the Federal Democratic Republic of Ethiopia (FDRE) (1993-recent). The land policy of the *Imperial* government, though varied spatially, was favoring individual landlords to amass and possess the land indefinitely. This might have encouraged the landowners to take care their land and the resources on it which, in turn, might have resulted in relatively stable LU/LC changes for over a long period of time.

Contrarily, the Military Government (*Derg)* nationalized the land and the natural resources on it under the umbrella of the renowned motto, "*Land to the Tiller*". Consequently, land and the resources were divided into pieces among peasants or smallholding farmers, which resulted in massive deforestation of vegetated lands meant for various purposes. This, in turn, might have resulted in dramatic LU/LC changes throughout the country, in general, and the *Nonno* area, in particular. The local informants confirmed that the enormous size of land had been converted and modified during the *Derg* regime in *Nonno,* owing to this change in land tenure arrangements.

Land remained a public property and was administered by the government since the 1975 radical land reform. In fact, the land use policy of the FDRE has offered the rural community the right to use land indefinitely. Particularly, Oromiya National Regional State, where *Nonno* is located, in its Proclamation Number 130/2007 (the proclamation to amend the previous Oromiya rural land use administration) assures the rural people the right to use, lease/rent, and transfer the land and the natural resources that it encompasses. It also authorizes sale of perennial crops on the land for restricted periods. However, selling land or getting collateral arrangements against a loan is strictly forbidden by this law (ONRS, 2007). Although this FDRE's land tenure arrangement appears to be better compared to the previous regimes, the respondent farmers are still lacking confidence to rehabilitate their land resources in fear of the possible confiscation. They feel as if they have no right over their land. Moreover, since the landholding per household is very small, the farmers are forced to encroach into vegetated lands for cropping, grazing, and settlement.

The major livelihood strategy-induced driving forces towards the existing rapid LU/LC changes in *Nonno* are the expansion of agricultural land, charcoal production, and firewood collection. The farmers are currently converting the land into plots of farmlands in order to increase their crop output and cope with the problems of food shortfalls. Meanwhile, some rural households are increasingly engaged in charcoal preparation and firewood extraction as lucrative livelihood strategies. Particularly, those economically unfortunate households are highly dependent on charcoal and firewood sale to fulfill the livelihood requirements of their family. The combined effects of these factors certainly result in rapid conversion and/or modification of the district's LU/LC.

The existing high rate of population growth, because of the high natural increase and in-migration/resettlement, also exerts immense pressure on land resources in *Nonno*. Agrarian population in Ethiopia, in general, and *Nonno,* in particular, is experiencing high annual growth rate, exceeding 2.6 percent (CSA, 2008). According to the respondents for this study, people from different overpopulated and drought-stricken areas of the country have been spontaneously coming to *Nonno* over the past few decades. The government also resettled about 1,800 'voluntary' resettler households (about 9,000 people) from different overpopulated rural areas of Oromiya Region in 2003 and 2004 (Messay, 2009). This, undoubtedly, intensifies the conversion and/or modification processes of the district's land use types. Available satellite images and the host community evidenced the fact that the current resettlement sites (namely *Biftu Jalala, Hallo Dinki,* and *Jiru Gamachu*) were covered by dense woody plants and coarse-grasses a decade earlier than today. However, the plants were massively bulldozed to prepare farm plots and to construct hundreds of thatched houses for the incomers.

The district's spatial access to numerous surrounding urban centers (markets) seem an important driving force to the current rapid LU/LC changes in the district of *Nonno*. The alarmingly thinning woodland provides the surrounding towns (over 20,000 urbanites) (CSA, 2008) with charcoal and firewood. This undoubtedly results in extensive destruction of woody vegetation in the area. Similar to the other urban centers of Ethiopia, the population of these major towns, which constitute the major charcoal and firewood consumers, is rapidly growing, thereby exerting severe pressure on the woody lands in *Nonno*.

CONCLUDING REMARKS

Sequential satellite images and GIS technologies, in combination with field observations, have been used to investigate the LU/LC changes in the district of *Nonno*. The study revealed both LU/LC conversion and modification processes. The woodlands, which accounted for 26 percent of the LU/LC in 1984, shrank down to 9.7 percent in 2002, and further plummeted to 5.5 percent in 2007. These figures suggest that the woodland was disappearing at the rate of 1.1 and 4.39 percent per year between1984-2002 and 2002-2007, respectively. Similarly, another vegetated land use type, grassland, dropped from 55.6 percent in 1984 to 34.7 in 2007. Contrary to the other two vegetated land use types, the shrub-grassland broadened from 16.3 percent in 1984 to 26.3 percent in 2007, indicating the modification of an enormous size of woodland to the shrub-grassland.

The expansion of farming is a primary force of vegetation clearing, environmental degradation, and LU/LC changes in the district. Of the total area of the district, the cropland accounted for 2.0, 3.0, and 30.5 percent in 1984, 2002, and 2007, respectively. These figures are excellent evidences for an alarming conversion of naturally vegetated land use types to cropland, chiefly between 2002 and 2007. Conversions of shrub-grassland and grassland have contributed significantly to the expansion of the cropland. It was primarily the shrub-grassland that has expanded at the expense of the woodland.

The towns (*Silk-Amba and Dire-Gudo*) and the resettlement sites accounted for only 3.1 percent of the district. The resettlement sites have appeared on the landscape as new land-cover types, only in the satellite image of 2007. These cover types have very little direct influence on the state and change of LU/LC in *Nonno.*

The overall consequence of these conversion and modification processes of the LU/LC is the severe degradation of the natural environment in the area. Vegetated land-cover types in *Nonno* may entirely disappear within the coming 10 to 20 years if the situation continues unabated. Most parts of the area may be entirely deforested and converted to plots of farmlands within the indicated period of time. This, coupled with the current frightening problems related to global warming, certainly leads to severe soil loss and deterioration of its nutrients, micro-climatic change, destruction of wildlife resources, and the suffering of the human population in the area. Hence, it is imperative to take all the necessary measures by the local government offices and other concerned bodies to impede the existing extensive destruction of the vegetated lands due to increased demands for farmland, charcoal, firewood, and settlement areas in the district.

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