

# Evaluation of Land Use Types and Physical Soil and Water Conservation Structures in Wyebela Watershed, Northwest Ethiopia

Simeneh Demissie Walie<sup>1</sup>, Getachew Fisseha<sup>2</sup>

Department of Soil resources and watershed management, Gambella University, Ethiopia

Department of Natural Resource Management, Bahir Dar University, Ethiopia

<sup>1</sup>simeneh2003@gmail.com; <sup>2</sup>fissiha.getachew@yahoo.com

Received: 28 October 2015. Revised: 31 December 2015. Accepted: 20 January 2016

**Abstract-**The present study was carried out in the Wyebela watershed Goncha Siso Enesie Woreda, Northwestern Ethiopia. Similar to the other highland areas in the country, the Wyebela watershed is characterized by severe soil erosion and acute water scarcity problems. Hence, the objective of the current investigation was to evaluate different land use types, and physical soil and water conservation (SWC) practices in Wyebela Watershed, Northwest Ethiopia. To check whether the current land use types match with treatment-oriented capability classification (TOCC), a transect walk was conducted and measurements were taken during a field survey. Fitness ratings of recommended versus existing physical SWC structures were given based on a TOCC scheme. Data were analyzed using descriptive statistics and correlation. From results of the TOCC scheme, it can be seen that current land use practices match with recommended land use types at 83.33% on average. However, with regard to rating fitness of existing SWC practices, only 36.8% match the recommended SWC measures.

**Keywords-** Land Use Types; TOCC; SWC; Wyebela Watershed

## I. INTRODUCTION

Land degradation is one of the major challenges in agricultural production in many parts of the world, especially in developing nations like Ethiopia (Dagnaw B., 2007; Fikru A., 2009). It typically occurs because of land management or human development practices that are not sustainable over a long period of time (Fitsum H. *et al.*, 1999). De Vries *et al.* (2008) state that a 13% yield loss is a result of severe degradation on 40% of agricultural land, and moderate degradation on a further 9% of agricultural land is equivalent to a decline in water use efficiency of at least 13 percent. The severity of soil degradation in the Ethiopian highlands is a result of past and present agricultural activities, mountainous and hilly topography, torrential rainfall, low degree of vegetative cover and unsustainable land resource management (Hurni, 1988; Awulachew S., 2010).

The problem of soil degradation in Ethiopia is a well-established fact. The causes and consequences have been substantiated in different regions in the country (Hurni, 1988; Nyssen *et al.*, 2008). The average annual rate of soil loss in the country is estimated to be 12 tons/hectare/year, and it can be even higher (300 tons/hectare/year) on steep slopes and in places where the vegetation cover is low (Abera B., 2003).

In the recent past, the ill effects of land use on the environment and the environmental sustainability of agricultural production systems have become issues of concern, especially because inappropriate land use leads to inefficient utilization of natural resources, destruction of the land resource, poverty and other social problems (Ruiee *et al.*, 2004). To stop, prevent and reverse further land degradation, sustainable land management (SLM) is crucial to minimizing land degradation, rehabilitating degraded areas and ensuring the optimal use of land resources for the benefit of present and future generations (FAO, 2008).

In the Wyebela watershed rapid population growth had forced farming families to expand their fields to forest and grazing areas. As a result, large areas, which were once under forest cover, have been exposed to heavy soil erosion and serious threats to sustainable agriculture and human health. Water is essential for human life. However, this precious resource is depleted though time as a result of inefficient use of natural resources in the watershed. To overcome these problems, a huge amount of physical SWC structures have been implemented each year. However, there is a problem of ensuring sustainability. The watershed community is motivated by subsidies from NGOs to implement improved SWC measures. The research gaps were not well studied before to recommend the correct land use types and SWC measures in the study areas. Therefore, the objective of this paper is to evaluate current land use types against TOCC in the study area.

## II. MATERIALS AND METHODS

### A. Description of the study area

This study was carried out at the Wyebela watershed, Chemo Kebele, Goncha Siso Enesie Woreda, in the highlands of the Amhara Region, Ethiopia. The Wyebela watershed is located at 351 km North West of the capital Addis Ababa (WAO, 2009; Zemene W., 2010).

According to the simplified traditional agro-climatic classification system, which considers only altitude, the study watershed lies within the dega (temperate) zone. The altitude range of the study watershed is from 2631-2792 masl. Agriculture is the main source of income in the area, where the farming system is characterized by small-scale production of mixed crops and livestock. Crop and livestock production dominate the farmer economy. The major crops grown are cereals teff (*Eragrostis tef*), wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), pulses beans (*Vicia faba*), and field peas (*Pisum sativum*). The typical livestock herd (flock) is composed of cattle, sheep, and donkeys, as well as chickens and bee colonies (WAO, 2012). Tree growing niches include degraded areas, gullies, farmlands and homesteads. The rarely distributed natural trees that grow on different niches of the watershed consist of *Acacia abyssinica*, *Juniperus abyssinica*, *Rhamnus prinoides*, and *Croton macrostachys*. The dominant exotic tree species in the watershed are *Eucalyptus globules*, *Acacia saligna*, *Acacia decurrens*, and *Sesbania sesban*. The benefits from trees are wood for fuel, construction, farm improvements, animal fodder, profit from selling, and environmental protection (WAO, 2012).

Land capability classification for the purpose of SWC is a basic tool for field work to understand the capability of the land in terms of sustained production of major types of land uses, i.e., crop production, grazing, homestead and forest. The majority of land resource in the study area is allocated for cultivation purpose (490.40ha).

The Wyebela watershed is characterized by different landforms that range from flat or undulating plains and rolling land to steep mountains. This topography terminology is adopted from the slope capability classification by (Awoke C., 2002). Topography influences the type and intensity of physical SWC measures to be used. The degradation severity also varies as one move from flat to steep areas.

### B. Data Collection

To check whether the current land use practices match with TOCC classification, a transect walk was conducted by dividing the watershed into three parts across the slope of the watershed. In each part of the watershed, there is relative homogeneity of soil depth, land use and SWC measures. Along the transect line, sample plots with dimensions of 50m\*50m at every 200 m distance were taken. The transect lines were established on three categories of the watershed as the top, middle and bottom of the watershed at the middle of each category. At each category, the sample plot, percentage slope, and soil depth were measured. At each measuring site, the current land use types and the kind of SWC practices were also recorded.

To compare whether the current land use practices match with the recommended land use types, the treatment oriented (TO) scheme of classification was used. The values of slope percentage, soil depth, and land use types were checked against the modified TO capability classification scheme for use in the Northern Ethiopian highlands (Belay T., 2003). Types of SWC practice(s) were evaluated against recommended treatments capability units of the TO classification scheme.

### C. Data Analysis

Depending on the type of information collected from the field, different data analysis methods were applied. Data collected was organized, analyzed and summarized with Microsoft Excel using descriptive statistical analysis methods such as percentage, mean, frequency and correlation.

## III. RESULTS AND DISCUSSION

### *Evaluation of Current Land Uses against Treatment Oriented Capability Classification*

Land capability classification serves as a guide to assess suitability of the land for different land use types. In the Wyebela watershed, though the majority of land is being used as per its capabilities, land capability classification in this area helps to provide warning signal (precautionary) measures to sustain existing land use. The Treatment - Oriented capability (TOC) classification scheme showed that current land use matches with recommended land use with 80%, 100% and 70% on the upper, middle and bottom of the watershed, respectively, and 83.33% on average (Tables 1, 2 & 3). The result obtained in the middle part of the watershed is in line with a study done by Asnake M., (2006). In his study, the existing land use matched completely with the recommended one because of the lower slope (less than 17%) and deep soil (deeper than 34cm). The result obtained in the bottom parts of the watershed is similar to a study done by Belyneh A., (2005). It should be noted that in the Wyebela watershed, the current land use shows similar results because the slope was not steep (less than 15%) and the soil was also not shallow (deeper than 30 cm) except for one plot in the upper catchment (Figs. 1 & 2). The greater problem comes with regard to the type of SWC measures that are recommended in those land use types. With regard to land treatment, 36.80% of the existing SWC practices fit with the recommended ones on average (Tables 1, 2 & 3). Though the result obtained shows better matches than the result obtained by Belyneh A. (2005), which is only 15% of the required SWC structures, meaning that it is below satisfactory. The greatest mismatches were obtained on the upper watershed part, where only 31.67% of the existing SWC practices fit with the recommended ones while relatively better results were obtained from the middle parts of the watershed (44.44%) (Table 2 & Fig. 3). This percentage is still less than required. Getachew F. *et al.*, (2012) discovered that although it is recognized that SWC practices can substantially contribute to reversing soil degradation, the performances of past and ongoing SWC programs in Ethiopia have, in most cases, been disappointing.

The blanket approach of technology prescription without considering the socioeconomic context of the farmers always brings failure in adoption of technology (Azene B., 1997; Woldeamlak B., 2005; Mitiku H. *et al.*, 2006; cited in Getachew F. *et al.*, 2012). Therefore, it can easily be concluded that the current land degradation process will continue as long as the current trends do not change. Land once there was under forest cover turned to free grazing and this is the main cause to gully erosion development in the study area.

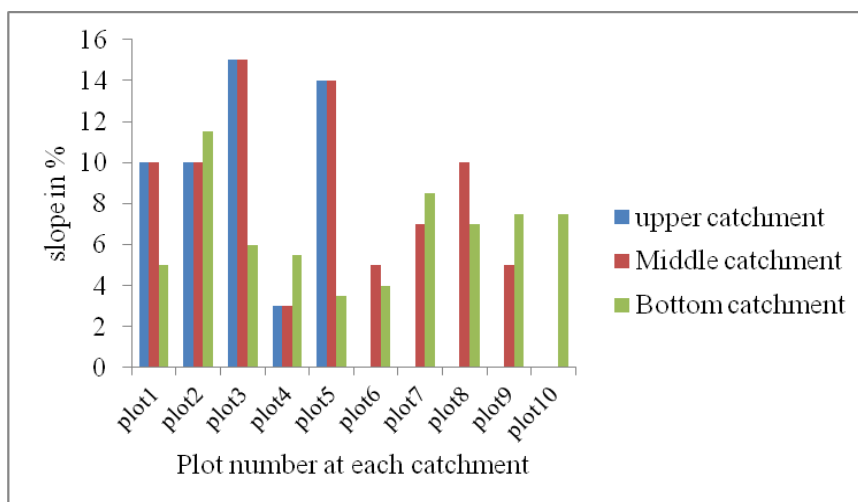


Fig.1 Average slope percentage at the three parts of catchment

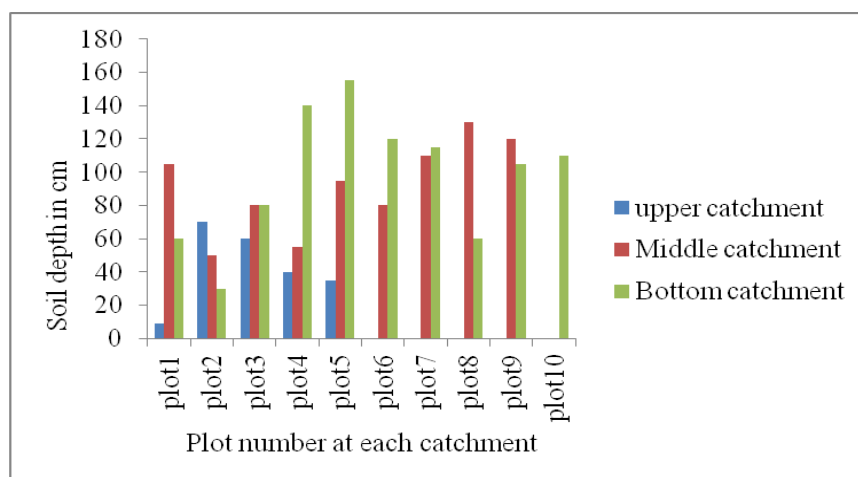


Fig. 2 Soil depth at three transect line plot sites

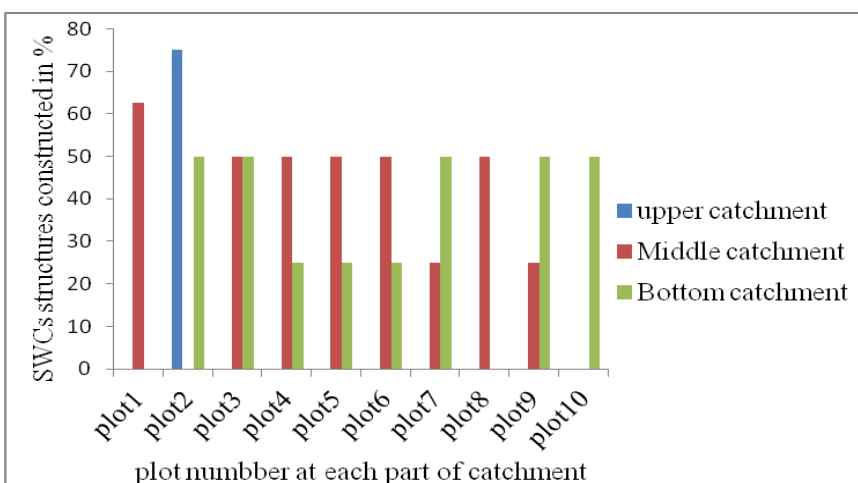


Fig. 3 Percentage of SWCs structures constructed in each plot

TABLE 1 ANALYSIS SHEET FOR EVALUATION OF CURRENT LAND USES AGAINST TOC CAPABILITY CLASSIFICATION SCHEME UPPER WATERSHED

| Plot no. | Soil depth (cm) | Slope (%) | Recommended |   | Current (existing) |   | RVsE LU type | Rating fitness of RVsE SWC (%) |
|----------|-----------------|-----------|-------------|---|--------------------|---|--------------|--------------------------------|
|          |                 |           | LU type     | Soil conservation practices   | LU type            | SWC practices   |              |                                |
| 1        | 9               | 10        | P           | Use for improved or managed pasture, rotational grazing, zero grazing                   | P                  | Trench, Micro basin, Plantation, Area closure                     | Match        | 33.33                          |
| 2        | 70              | 10        | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C                  | Contour cultivation, terraces are strengthen by vegetations       | Match        | 50                             |
| 3        | 60              | 15        | C2          | Bench terracing, terracing  | F                  | Micro basin, pond not functional know, micro basins (vegetations) | Not match    | 0                              |
| 4        | 40              | 3         | C1          | Contour cultivation , strip cropping, vegetative and rock barriers, broadbased terraces | C                  | Contour cultivation   | Match        | 25                             |
| 5        | 35              | 14        | C2          | Bench terracing, Terracing  | C                  | Terraces are strengthen by vegetations, contour cultivation       | Match        | 50                             |
| Average  | 42.8            | 10.4      |             |   |                    |   | 80% match    | 31.67%                         |

\*\* C = Cultivation, Pasture and, F = Forests

\*\* LU = land use, RVsE = recommended versus existing, RVsELU = recommended versus existing land use

NB: All the terraces on the table (existing column) are not broad-based terraces

TABLE 2 ANALYSIS SHEET FOR EVALUATION OF CURRENT LAND USES AGAINST TOC CAPABILITY CLASSIFICATION SCHEME MIDDLE WATERSHED

| Plot no. | Soil depth (cm) | Slope (%) | Recommended |   | Current (existing) |   | RVsELU type | Rating fitness of RVsE SWC (%) |
|----------|-----------------|-----------|-------------|---|--------------------|---|-------------|--------------------------------|
|          |                 |           | LU          | Soil conservation practices   | Land Use           | Soil conservation Practices   |             |                                |
| 1        | 105             | 4.5       | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C                  | Damaged Soil bund, strengthen by vegetations, no water way, contour cultivation   | Match       | 50                             |
| 2        | 50              | 12        | C2          | Bench terracing, Terracing  | C                  | Waterway stone paved, terraces are strengthen by vegetations, contour cultivation | Match       | 50                             |
| 3        | 80              | 12.5      | C2          | Bench terracing, Terracing  | C                  | Terraces, contour cultivation   | Match       | 50                             |
| 4        | 55              | 13.2      | C2          | Bench terracing, Terracing  | C                  | Waterway stone paved, terraces strengthen by vegetations, contour cultivation     | Match       | 50                             |
| 5        | 95              | 5.7       | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C                  | Terraces strengthen by vegetations, contour cultivation, waterway (poor)          | Match       | 50                             |
| 6        | 80              | 5         | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C                  | Soil bund strengthen by vegetations, contour cultivation                          | Match       | 50                             |
| 7        | 110             | 7         | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C                  | Terraces, contour cultivation   | Match       | 25                             |

|         |       |     |    |   |   |   |            |        |
|---------|-------|-----|----|---|---|---|------------|--------|
| 8       | 130   | 10  | C1 | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C | Terraces are strengthen by vegetations, contour cultivation | Match      | 50     |
| 9       | 120   | 5   | C1 | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C | Contour cultivation   | Match      | 25     |
| Average | 91.66 | 8.4 |    |   |   |   | 100% match | 44.44% |

\*\* C = Cultivation, P = Pasture and, F = Forests

\*\* LU = land use, RVsE = recommended versus existing, RVsELU = recommended versus existing land use

NB: All the terraces on the table (existing column) are not broad-based terraces

TABLE 3 ANALYSIS SHEET FOR EVALUATION OF CURRENT LAND USES AGAINST TOC CAPABILITY CLASSIFICATION SCHEME BOTTOM WATERSHED

| Plot no. | Soil depth (cm) | Slope (%) | Recommended |   | Current (existing) |  | RVsELU type | Rating fitness of RVsE SWC (%) |
|----------|-----------------|-----------|-------------|---|--------------------|--|-------------|--------------------------------|
|          |                 |           | Land Use    | Soil conservation practices   | Land Use           | Soil conservation Practices  |             |                                |
| 1        | 160             | 5         | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | P                  | No soil conservation structures, free grazing                        | Not match   | 0                              |
| 2        | 30              | 11.5      | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | F                  | Terraces are strengthen by vegetations, contour cultivation          | Not match   | 50                             |
| 3        | 80              | 6         | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C                  | Terraces are strengthen by vegetations, contour cultivation          | Match       | 50                             |
| 4        | 140             | 5.5       | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C                  | Contour cultivation  | Match       | 25                             |
| 5        | 155             | 3.5       | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C                  | Terraces, contour cultivation, waterway (stone faced)                | Match       | 25                             |
| 6        | 120             | 4         | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C                  | Terraces, contour cultivation  | Match       | 25                             |
| 7        | 115             | 8.5       | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C                  | Terraces are strengthen by vegetations, contour cultivation          | Match       | 50                             |
| 8        | 60              | 7         | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | P                  | No soil conservation structures, Free grazing                        | Not match   | 0                              |
| 9        | 105             | 7.5       | C1          | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C                  | Terraces are strengthen by vegetation, Contour cultivation, waterway | Match       | 50                             |

|         |       |     |    |   |   |  |           |        |
|---------|-------|-----|----|---|---|--|-----------|--------|
| 10      | 110   | 9.5 | C1 | Contour cultivation, strip cropping, vegetative and rock barriers, broad-based terraces | C | Terraces are strengthen by vegetation, contour cultivation, waterway | Match     | 50     |
| Average | 107.5 | 6.6 |    |   |   |  | 70% match | 34.09% |

\*\* C = Cultivation, P = Pasture and, F = Forests

\*\* LU = land use, RVsE = recommended versus existing, RVsELU = recommended versus existing land use

NB: All the terraces on the table (existing column) are not broad-based terrace

Although the average soil depth of the area was as deep as 88 cm, but there were farm plots in which soil depth was as low as 10 cm (Fig. 2). However, the TOC classification scheme prohibits tillage of land with a soil depth less than 20 cm. In such farm fields, the soil depth cannot accommodate local plowing activity. This shallow depth of soil, accompanied by poor water infiltration capacity, has aggravated the rate of erosion. In the Wyebla watershed, plots that have less than 20 cm soil depth were kept under area closures and used for plantation purposes by constructing water harvesting structures (Fig. 4).



Fig. 4 Degraded area under area closure

Soil depth and slope percentage at each plot showed significant variability. The variability of soil depth was generally higher than slope percentage variability. This variability has implications for the necessity of planning SWC activities for each plot. It was also possible to see the correlation between these two parameters. They had a negative relationship ( $r = -0.558^{**}$ ). This means that the soil depth decreases with an increase in the slope percentage. However, the relationship was significant both at 0.01 and 0.05 levels. The reason for the negative relationship was that higher slope areas were plowed without proper SWC practices, which resulted in higher erosion and reduced soil depth.

#### IV. CONCLUSIONS

Along the transect line, the existing land use type and the recommended one showed a good correlation. Even so, the research findings showed that the current land use types deviated from the recommended land use types. This result is obtained as a result of low slope range and percentage in the area. As compared to the recommended SWC measures the fitness of existing SWC measures is low (below half). The problem is more serious on land use types other than cultivated land. From the three parts of watershed, relatively better results were obtained on the middle parts of the watershed on arable land use types. In general, even the constructed structures were not managed properly. This implies that the treatments that could shield the area from deterioration are missing.

#### ACKNOWLEDGEMENT

The authors would like to thank Mertule Mariam ATVET College, which provided materials mainly for field work, and natural resource management department staff teachers who supported the authors for the success of their work. Thanks area also extended to the Goncha Siso Enesie Woreda Office of Agricultural Natural Resource Development and Conservation experts and Chemo kebele agricultural development agents for offering basic data of the study area and data gathering, respectively.

#### REFERENCES

- [1] B. Abera, "Factor influencing the adoption of soil conservation practices in North West Ethiopia," discussion papers, No. 32, Institute of Rural Development University of Goettingen, Germany, pp 1-78, 2003.
- [2] M. Asnake, "The role of land-use on impacts of drought in Shebel Berenta Wereda, Amhara National Regional State, Ethiopia: a case

- study in Kutkwat Sekela catchment,” M.Sc thesis, Addis Ababa University, Ethiopia, 2006.
- [3] C. Awoke, “Vetiver in rehabilitation of the degraded ZegZeg watershed in Ethiopia,” Project Report, Coffee and Tea Authority, Addis Ababa, Ethiopia, p. 31. 2002.
  - [4] S. Awulachew, “Improved water and land management in the Ethiopian highlands and its impact on downstream stakeholders dependent on the Blue Nile,” CPWF Project Number 19, CGIAR Challenge Program on Water and Food Project Report series, *Cgiar Challenge Program on Water & Food*, pp. 1-125, 2010.
  - [5] B. Azene, “A participatory agro-forestry approach for soil and water conservation in Ethiopia,” Tropical resource management papers, No.17, Wageningen Agricultural University, the Netherlands, *Tesemma*, p. 229, 1997.
  - [6] T. Belay, “Combining land capability evaluation, geographic information systems and indigenous technologies for soil conservation in Northern Ethiopia,” *Eastern Africa Social Science Research Review*, vol. 19(2), pp. 23-53, 2003.
  - [7] A. Belayneh, “Land degradation assessment and evaluation of current land uses and soil conservation structures at upper Chena catchment, South Gondar, Ethiopia,” M.Sc thesis, Addis Ababa University, Ethiopia, p. 71, 2005.
  - [8] B. Dagnew, “Assessment of cause and extent of land degradation Hashenge catchment Southern Tigray,” M.Sc thesis, Addis Ababa University, Ethiopia, p. 65, 2007.
  - [9] F. De Vries, H. Acquay, D. Molden, S. Scherr, C. Valentin and O. Cofie, “Learning from bright spots to enhance food security and to combat degradation of water and land resources,” *Conserving land, protecting water*, CABI, pp. 1-19, 2008.
  - [10] FAO (Food and Agriculture Organization of the United Nations), Feeding the World Sustainable Management of natural resources fact sheets. Rome, May, 2008.
  - [11] A. Fikru, “Assessment of adoption behavior of soil and water conservation practices in the Koga watershed, highlands of Ethiopia,” M.Sc thesis, Cornell University, United State, p. 62, 2009.
  - [12] H. Fitsum, P. John and G. Nega, “Land Degradation in the highlands of Tigray and Strategies for Sustainable Land Management,” Addis Abeba, Ethiopia, 1999.
  - [13] F. Getachew, G. Heluf, K. Kibebew, B. Bobe, and Y. Birru, “Participatory development of soil conservation measures at the Debre-Mewi Watershed in the upper catchment of the Blue Nile Basin, Northwest Ethiopia,” *J. Bio. & Env. Sci.*, vol. 1(6), pp. 199-213, 2012.
  - [14] H. Hurni, “Degradation and conservation of the resources in the Ethiopian highlands,” *Mountain Research and Development*, vol. 8, pp. 123-130, 1988.
  - [15] H. Mitiku, K. Herweg and B. Stillhardt, “Sustainable land management – A new approach to soil and water conservation in Ethiopia,” Mekelle, Ethiopia, p. 269, 2006.
  - [16] J. Nyssen, J. Poesen, J. Oeyerson, M. Haile and J. Deckers, “Dynamics of soil erosion rates and controlling factors in the Northern Ethiopian highlands-towards a sediment budget,” *Earth Surface Processes and Landforms*, vol. 33, pp. 695-711, 2008.
  - [17] R. Ruiee, N. Werahai and S. Aree, “Land evaluation for an agriculture land reform area using GIS, Ministry of Agriculture and Cooperatives,” Bangkok, Thailand, 2004.
  - [18] B. Woldeamlak, “Land degradation and adoption of conservation technologies in the Digil watershed Northwestern Highlands of Ethiopia,” *Trop. Res. Manag.*, p. 50, 2005.
  - [19] WAO (Woreda Agricultural Office), ANRS East Gojjam Administration Zone Goncha Siso Enesie Woreda finance and economic development office 2009 beget year statistical bulletin.
  - [20] WAO (Woreda Agricultural Office), Kebele integrated watershed management plan document, 2012.
  - [21] W. Zemene, “Investigating chicken production system consumption pattern and egg quality parameter Goncha Siso Enesie District of Amhara Region,” M.Sc thesis, Hawassa University, Ethiopia, p. 100, 2010.