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IMPACTS OF LAND DEGRADATION ON DENDI CRATER LAKE, DENDI DISTRICT, OROMIA STATE, ETHIOPIA

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Abstract: Land degradation mainly in the form of soil erosion and nutrient depletion reduces the productivity of land and poses serious threat on water quality, soil characteristics and potential biodiversity thereby affecting the livelihood status of households. The present study was designed with objectives of examining the causes and impacts of land degradation and its implications on the water and soil characteristics of Dendi Crater Lake. The methods employed for the data collection of this study include structured questionnaire survey, key informant interview, focus group discussion, direct field observation and laboratory analysis of selected water and soil parameters. Dendi Sulu and Dendi Mumicha, the two wards very close to the
Dendi Lake were selected for the current study. Among the 70 interviewed sample household heads of the two purposively selected wards, 91.43% respondents could distinguish impacts of land degradation on their own plots of lands that has got a direct effect on their crop production, soil quality as well as the water quality of Lake. 77.1%, 10 %, 8.6 %, and 4.3 % of the respondents believed respectively that soil erosion, soil nutrient depletion, change in soil structure and chemical contamination were the main causes for land degradation in the locality. The study found that the fish resource potential of the lake during the study period was not promising due to some social taboos existing in the locality, as well as lack of proper scientific knowledge about the fish varieties fit for the Crater Lake circumstances. Three representative sites were selected for the water and soil sample collection. The study showed a direct relation with the land degradation in the locality as well as the soil and water quality parameters of the lake. Unsustainable agricultural practices as well as other anthropogenic activities in the shores of the lake cause severe erosion and leaching problem to the lake. This is revealed by the hardness (59.92 mg/L of $CaCO_3$) and total dissolved solids (93.26 mg/L) of the water, as well as the accumulation of phosphorus (269.94 mg/Kg) and total nitrogen content (0.543%) of the soil in the lake. The study strongly proposes a sustainable land management practice for the area along with proper awareness among the local community about the use of sustainable agricultural practices as well as demerits of land degradation so as to save the lake from further damages.

Key words: Dendi Sulu, Dendi Mumicha, Land degradation, Water, Soil

INTRODUCTION

Land degradation is augmenting worldwide and this is attributed to natural processes and also due to intense agriculture activity. The intensity of land degradation depends largely on the terrain nature and the type of soil. Soil erosion has been occurring frequently in highlands where the land profile is steep. Floods as a consequence of torrential rains are responsible for gully formations on high lands which further lead to soil erosion. In Ethiopia, it is frequent and the high lands form about 43% of the land mass in Ethiopia. Mismanagement of arable areas by farmers and grazing areas by livestock owners is one of the major causes of land degradation (FAO, 1995). Among land use practices, agriculture and forestry are important, as they support the well being of human being, where soil is an important component. Land use practices have been affecting the aquatic ecosystems to a considerable extent causing water and soil quality deterioration and loss of aquatic biodiversity as aquatic systems are the sink of all leached out material from the land. Ethiopia, a country with undulating topography is blessed with huge inland water resources, and these water bodies receive huge quantities of eroded soils with high quantities of agrochemicals. The areas adjacent to Dendi Crater Lake is occupied by large number of human population and their main activity is agriculture and livestock rearing in the pasture lands and also investments on hotel and tourism is flourishing in the area.

MATERIALS AND METHODS

Description of the area: The Dendi district is located in West Shewa Administrative Zone, 77 km West of Addis Ababa along Nekemete high way. It is 35 km far from Zonal capital of Ambo town to East direction. The district is bounded by Jeldu and Ilfata districts in the north, Ejere district in the East, Ilu district in the South east, Dawo and Waliso districts in the South, Ambo district in the West. The capital town of the district is Ginchi. It is located between the coordinates of 8°50'44"N latitude and 38°00'33"E longitude. Dendi Lake is located in Dendi district, 29 km away from Ginchi in South direction with an area of 820 hectares (West Shoa Finance and Economic Development office report, 2012). Figure 1 shows the location map of Dendi Crater lake area and the view of Dendi lake environments.

Questionnaire survey: Dendi Suluu and Dendi Mumicha are the two wards (Kebeles) bordering the Dendi Lake was selected purposively for the study. Structured questionnaires, detailed interview and focal group discussions were used to collect primary data for identifying the land use practices of the study area. Samples from each sample wards were selected based on probability proportional to size sampling technique (Kotari, 2006)(Table 1).

Water and soil analysis: In order to identify the impacts of land degradation on the Dendi lake water and soil characteristics, three sites were identified for water and soil sample collection

Fig. 1. Location map of Dendi Crater Lake (Source: West Shoa Finance and Economic Development office report, 2012)

Table 1. Number of Interviewee, Discussions and Respondents of households and sample size

Name of Kebeles	Total Number of House Holds	Number of Respondents	Members of Focus Group Discussions	Number of Key informant Interviewee
Dendi Suluu	530	30	10	5
Dendi Mumicha	670	40	10	5
Total	**1200**	**70**	**20**	**10**

based on the site characteristics. First site was the main input point for the lake (MI site), which carries the water, soil and related components from the surroundings to the main body of the Dendi lake. The second site was 500 meters left to the main input site (LMI), land degradation in the form of soil erosion and agriculture practices, land inclination and high siltation flow and excess algal growth in the water were very prominent near to this study site. The third site was also 500 meters right to the main input site (RMI). Land degradation in the form of soil erosion, agriculture practices, irrigation and algal growth were very prominent of this study site also. Triplicates of representative samples of water and soil were collected from each sampling sites in between 8.30-10.30 in morning hours of three consecutive months during December 2012-February 2013. Selected soil and water quality parameters were analyzed using standard methods following standards procedures (APHA, 1998) at the laboratory of Ambo University.

Data Analysis: Descriptive statistics was applied for the qualitative data generated through the study. For quantitative data analysis, statistical tools such as mean and standard deviation were used. The data was presented in the form of charts and tables.

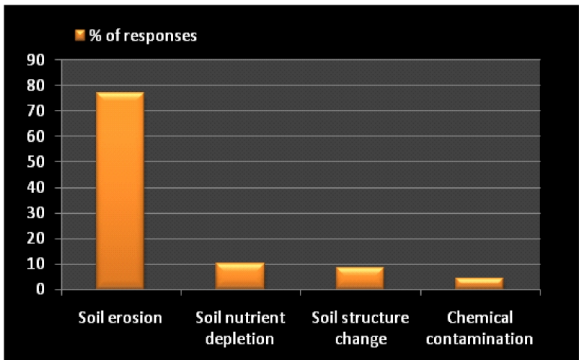
RESULTS AND DISCUSSION

Educational status of the respondents: Education is a very important determining factor in land degradation. An educated farmer is able to use modern agricultural technologies, perform improved farming activities based on cropping calendar, and manage resources properly. All this factors boosts production, which improves availability and accessibility of enough food for their families by preventing their lands from degradation (Fekadu, 2010). The current study revealed that, literacy level or education level of house hold is important variable that affects participation in land management. Educated respondents were easily adopting newer technologies and opportunities than non educated respondents. The study revealed that 15.7% of the respondents got secondary education, 72.9% could read and write and 11.4% were illiterate. Table 2 shows the educational Status of the respondents.

Table 2. Educational Status of the respondents

Educational Level of the respondents	No. of Household heads	Percentage
Illiterate	8	11.4
Primary School	51	72.9
Secondary School	11	15.7
Total	**70**	**100**

Land use patterns of the respondents: The population pressure which is growing at a very rapid rate annually has been clearing forest and vegetation, and expansion of cultivation area and rearing of high cattle population affect natural resources to satisfy their basic requirement as specified by Brook Lemma, (2004). The respondents were asked about their idea about the causes/forms of land degradation and resource depletion. 77.1 % respondents recognized that various forms of land degradation occur due to soil erosion, 10% agreed with soil nutrient depletion, 8.6% agreed the soil structure change and 4.3% approved chemical contamination as forms of land degradation.



Fig, 2. Main forms of land degradation in the locality as per respondents

Among the 70 sampled household heads, 91.43 % respondents agreed that the land degradation on their plot directly affect the productivity of their land. 8.57 % commented that rather than the production loss for them, it has an impact on the Dendi Lake water quality and soil characteristics. The researcher observed that the said plots were very close to the Dendi Lake. Ploughing of steep slopes, overgrazing, over cultivation, deforestation,

weak conservation practices and population pressure as well as excessive rain fall were the prime causes for land degradation in the locality identified by this study.

All respondents of this study (100%) agreed that Dendi Lake size and depth was decreasing from time to time due to land degradation and related siltation problems. Many plant species were occupying the banks of the lake and it has been progressing towards the water column of the lake. Formation of open gullies and widening of the already formed gullies are serious problems which also contributed to the input of soil to the lake. Plates 1 show the various faces of land degradation in the study site.

Farming systems of the study area: Mixed farming system (crop production and rearing of animals) was practiced in Dendi Sulu and Dendi Mummicha kebeles of Dendi district. Crop production takes the major share. Livestock as part of mixed farming system was paramount significant to a household economy. Livestock plays an important role in the farming system of the area. Cattle, sheep and goat, equine and chicken were kept by farmers for income source, draft power and food (milk, meat, egg). Farmers commonly rear oxen, cows, bulls, heifer, calves, donkey, horse, sheep, goats and chicken. Farmers also practice bee keeping as an alternative income source. Agriculture is highly dependent on rainfall only 20 % of the interviewed households use irrigation practices for crop production. Land is the main natural resource on which the livelihood of farmers directly depends. From the total area of lands of interviewed household heads, 74.3 % was

Table 3. Cropping system and irrigation trends of sample households in the study site

Households Practice	No. of Household heads	Percentage
Intercropping use	7	10
Non use of Intercropping	63	90
Total	**70**	**100**
Irrigation use	14	20
Non use of Irrigation	56	80
Use of Water harvest technology	-	-
Total	**70**	**100**

Gulley mouth in the study

Eroded banks and herds of cattle

Lush growth of vegetation towards the lake

Agricultural practices on the banks of the lake

Plates 1. Different phases of land degradation near to the Lake Dendi

used for crop production, 20 % for grazing purpose as well as only 5.7 % left as fallow. From two sample kebeles only one kebele has access to small scale irrigation scheme. A water-harvesting strategy has been implemented by the government through its extension package; however, farmers at the study area did not adopt the practice as expected (Afework, 2008). In the study area no one of the sample respondent household heads have practiced water harvesting technologies to irrigate their farms throughout long dry season of the year and for future of their livelihood. Table 3 shows the cropping systems and irrigation trends of the study area.

Institutional factors: Institutional support like extension services, timely input supply, and availabilities of agricultural technologies, irrigation scheme, and other rural infrastructure development is the central part to development. The survey result indicated that from the total sample household heads about 95.71 percent of households were users of farm inputs like chemical fertilizer, improved seed and herbicides. Inappropriate use of agrochemicals could have an impact on the quality status of the water and soil of Dendi Lake and thus on the biodiversity also.

Extension service is provided by extension workers and to some extent by non-governmental organizations. Two to three development agents were assigned at each kebele to give frequent and continuous technical support and advice. 36 household heads (51.4%) respondents agreed that they were getting chance to interact with the authorized extension agents once in a week. But due to unavailability of infrastructure and housing facilities, all development agents do not reside in their assigned kebeles. This keeps the local people away from seeking expert opinion on time for agro-practices. Almost all sample households of the survey had responded that development agents have been assigned, but most of them complained that they did not get sufficient agricultural extension services on time. Some old farmers are very confident in their practical knowledge and skills. They are reluctant to hear the expert opinion from young officers or reluctant to adapt new technologies. The questionnaire survey and group discussions show that the lack of awareness as well as reluctance of some farmers to seek expert opinion lead the farmers to use non recommended lands like steep slopes, extreme shore of the lake, for agricultural purposes. These practices have very serious adverse impacts on the lake and its biodiversity. Practicing the agricultural activities in the extreme shore of the lake was common in the locality. This leads to bank erosion, collapse of shore land and serious agrochemical pollution as well as water and soil pollution in general to the lake environment.

Fish Status of the Lake: The respondents of the focal groups were asked about the availability and fish resource potential of Dendi Lake. All the respondents agreed that there was no availability of fish from the lake for many years. The respondents confirmed that two decades back the Agriculture Bureau tried to enhance the fish resource potential of the lake, but due to lack of proper knowledge about the fish varieties suitable for the conditions of the lake, and lack of proper follow up due to decentralization process at that time, the programme failed miserably. Presently the local people are not using the lake for getting fish for their diet. Some social believes existing in the locality also prevented the locals from using lake for fishing purpose. EFASA, (2012) reported that in Ethiopia water resources have been developed minor extent even though they have been using for various purposes. The potential of aquatic bodies in Ethiopia for fish production has to be taken into account for the poverty alleviation of the country. According to Leta (2012), the Dendi Crater Lake is relatively deep, clear and less productive and the low temperature especially in the rainy season affects the plankton production. The prevalence of low temperature (<15^{o}C) in the post rainy period also indicates that the productivity of the Lake is influenced by low temperature since the lake is situated 3,260 m.a.s.l.

Analysis of Selected Water quality parameters:

Temperature: Fig 3 shows the temperature of the water samples collected during the study period. The temperature values of Dendi water during the study period ranges between 16^{o}C to 18^{o}C. The highest temperature value was

recorded in the month of February in the right station. The cumulative mean values do not show significant difference between the three stations.

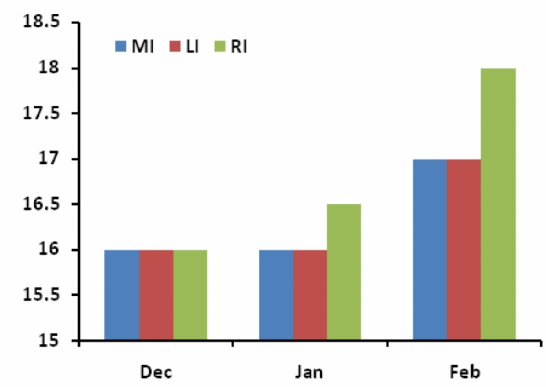


Fig. 3. The temperature (°C) of the water samples during the study period

pH: The cumulative mean of P^H values of Dendi lake water samples during the study period do not show a significant spatial difference and the values are within the permissible limit of Ethiopian drinking water standards also. USEPA (1991) reported that the pH outside the range of 6.5-8 reduces the biodiversity in lakes because it stresses the physical system of most organisms and can reduce reproduction. Table 4 shows the results of selected water quality parameters of Dendi Crater Lake.

Conductivity: The recorded conductivity value was lowest in the month of February with the right side station (118 µS/cm ± 4) and the highest conductivity value was also recorded in the same station in the month of January (179 µS/cm±2). The conductivity indicates the presence of ions in the water. The electrical conductivity of water is directly related to the concentration of dissolved solids in the water.

Turbidity: Turbidity is a gauge of water clarity. The material suspended in water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes and other substances. The turbidity value of the right side station was highest in the month of February (78 ± 3). This is associated with the cultivation of crops with irrigation and cattle watering in the nearby areas of the station as well as using the site for washing and bathing by the local people. Higher turbidity increases water temperatures because suspended particles absorb more heat. The study results also confirmed this. In February month the same station recorded the highest temperature of the whole study period (18°C). This could be because of the presence of suspended particles in the station.

Table 4. Results of water sample analysis (Mean ± SD) n=3

			Parameters					
Sample	**month**	**Sample station**	**pH**	**Conductivity (µS/cm)**	**Turbidity (cm)**	**Dissolved Oxygen (mg/L)**	**Total Dissolved Solids (mg/L)**	**Total Hardness (mg/L)**
1st	01/12/2012	MI	6.9 ± 0.2	171 ± 2	43.5 ± 0.5	7.13 ± 0.73	98 ± 1	62 ± 2
		LI	7.7 ± 0.9	175 ± 6	43.33 ± 2.7	11.4 ± 0.4	97.67 ± 1.53	64 ± 2
		RI	6.9 ± 0.3	173 ± 4	48.5 ± 2.5	8.93 ± 0.7	100 ± 1.73	58.67 ± 1.15
2nd	01/01/2013	MI	8.0 ± 0.1	149 ± 9	51.5 ± 3.5	8.07 ± 1.7	93 ± 1	61.33 ± 1.15
		LI	7.9 ± 0.2	171 ± 15	65 ± 2	6.2 ± 1.78	91.67 ± 1.15	56.67 ± 3.06
		RI	7.9 ± 0.1	179 ± 2	59 ± 5	9.53 ± 0.31	100 ± 1	58.67 ± 8.08
3rd	01/02/2013	MI	8.0 ± 0.2	136 ± 2.65	47.2 ± 2.2	13 ± 1.31	85 ± 1	59.33 ± 1.15
		LI	6.9 ± 0.1	131 ± 2	67 ± 7	6.33 ± 1.63	86 ± 1.73	60.67 ± 1.15
		RI	7.5 ± 0.2	118 ± 4	78 ± 3	11.73 ± 1.61	87.67 ± 1.53	58 ± 3.46

Dissolved Oxygen: The concentration of oxygen in fresh water has inference for the survival and allocation of organisms, and its deficiency can result in the loss of aquatic flora and fauna. More over there is a negative correlation between temperature and dissolved oxygen. The standard dissolved oxygen level in fresh water ecosystems are between 8 and 10 mg/L (APHA, 1998). The current study shows a dissolved oxygen level of 6.2 to 13 mg/L, *i.e.* within the permissible limit of drinking water standards. The lowest dissolved oxygen level was recorded in the main station (6.2 ±1.78) during the month of January. This may be due to irrigation activities and human and cattle interference that cause the higher temperature during the dry month. Studies show that the dissolved oxygen concentration of Lake Dendi was lower when compared to Lake Babogaya and Hora-Arsedi and this lower dissolved oxygen of Lake Dendi may be due the lower biomass of phytoplanktons (Leta, 2012; Tadesse, 2007; Abebaw, 2006).

Total Dissolved Solids: Total dissolved solids obtained as the difference between total solids and total suspended solids. Total dissolved solids are a measure of the total amount of all the materials natural and anthropogenic, organic and inorganic that is dissolved in water. The study reveals the highest total dissolved solid value in Right to the main input station at the month of January (100 ± 1 mg/L). During the dry period especially in the month of January, people use this site more for irrigation, domestic water for cattle drinking purpose. People were using this place more for washing and bathing purpose especially in the month of the study period because all other small water bodies nearby were dry during that time. The study results agreed with the results stated in Afework (2008). The cattle population in the locality also higher compared to other months. This may lead to the leaching of organic as well as inorganic substances to the sampling sites.

Total Hardness: The current study shows the hardness range of 56.67-64 mg/L. Hardness is caused by multivalent metallic cations and with certain anions present in the water. The principal hardness-causing cations are the divalent calcium, magnesium, strontium, ferrous iron and manganese ions. During the survey and focal group discussions, the respondents complained about the hardness of the Dendi lake water. The local people were using more soap and detergent during the dry months for washing clothes. The hardness value is highest in the left station (64 ± 2 mg/L). This may be because of the leaching of agrochemicals and soil rich with nutrients to that site and other anthropogenic activities in the locality. Near to left side station, the cattle grazing and cattle watering also very common.

Table 5. Results of soil quality parameters (Mean ± SD), n=3

Sample month	Station	Parameters						
		pH	Cond. (µS/cm)	Temp. (°C)	OC (%)	OM (%)	TP (mg/kg)	TN (%)
28/02/2013 15/01/2013 25/12/2012	MI	5.347 ±0.025	83.8 ± 0.02	26.1 ± 0.1	4.582 ±0.099	7.899 ± 0.171	81.167 ± 14.01	0.373 ± 0.0763
	LI	5.547 ±0.045	124.93 ± 0.451	25.07± 0.025	9.649 ± 0.155	16.634 ± 0.267	279.99 ± 123.31	0.4306 ± 0.037
	RI	5.43 ±0.025	98.1 ± 0.046	25.43 ± 0.351	8.693 ± 0.452	14.987 ± 0.779	354.64 ± 23.943	0.3690 ± 0.016
	MI	5.237 ± 0.025	70.73 ± 1.42	24.9 ± 0.2	3.0 ± 0.212	5.907 ± 0.371	72.881 ± 20.593	0.3530 ± 0.022
	LI	5.353 ± 0.025	121.5 ± 0.92	24.9 ± 0.2	6.753 ± 1.469	11.642 ± 2.532	405.59 ± 33.195	0.5972 ± 0.083
	RI	5.287 ± 0.015	148.97 ± 0.95	25.0 ± 0.025	8.273 ± 0.183	14.263 ± 0.316	352.03 ± 24.721	0.4368 ± 0.066
	MI	5.0 ± 0.05	42.2 ± 0.0	27.7 ± 0.2	4.0 ± 0.044	6.266 ± 0.076	141.0 ± 25.350	0.4069 ± 0.037
	LI	5.42 ± 0.0361	164.83 ± 0.764	26.9 ± 0.1	5.845 ± 0.618	10.076 ± 1.865	366.90 ± 17.483	0.3444 ± 0.031
	RI	5.58 ± 0.02	47.4 ± 0.04	25.6 ± 0.1	7.436 ± 0.561	12.820 ± 0.967	366.22 ± 7.715	0.3374 ± 0.026

Cond-Conductivity, Temp-Temperature, OC-Organic carbon, OM- Organic matter, TP-Total phosphorous, TN-Total Nitrogen

Soil Sample analysis: Soil samples were extracted from the Lake shore by using standard Augar soil sampler device followed by air drying and analysis of selected soil parameters by following the standard methodologies. The pH value of the soil, conductivity, organic carbon, organic matter and total phosphorus as well as total nitrogen were done in chemistry laboratory of Ambo University. Table 5 shows the Mean ± SD values of the analysis results during the study period from the three selected sites.

Soil pH: The pH value of the soil is in the acidic range (5.0 to 5.58). There is a significant difference between stations considering the pH value.

Soil conductivity: The main Input point shows the lowest conductivity value compared to the other two stations. The highest conductivity value was recorded in the left to the main Input point. Near to this station, the anthropogenic activities were significantly high and washing clothes with some synthetic and locally available detergents were common. This could be the added reason which enhances the ions of the soil and thus the conductivity.

Soil Temperature: The soil temperature of the three stations does not show significant differences. The range is between 25.42°C to 26.23°C that relatively similar to room temperature.

Soil Organic Carbon: The soil organic carbon content is highest in the left station (9.649 ± 0.155 %) compared to other two stations. This has a relation with the regular irrigation agricultural activity on this site compared to the other two sites. The main input station shows the lowest soil organic carbon (3.88%). This may be due to the regular inflow of water towards the lake through this site from the nearby areas, thus the sedimentation and the soil organic carbon content in the particular locality is comparatively less.

Organic matter: The highest organic Matter recorded in the month of December with the left station (16.634 ± 0.267 %). This is associated with the higher rainfall compared to other two months and thus higher leaching and inflow to the lake in this month. Agriculture activities near the banks as well as human interventions in the left station were more compared to other two sites. This is contributing to the higher organic matter value in this site.

Total phosphorus: Increasing concentration of phosphorus and nitrogen compounds in fresh water leads to eutrophication and associated effects. The highest value obtained in the month of January with left to the main input station (405.59 ± 33.195 mg/kg). These points to the unsustainable agrochemical practices existing to the sites. January is the month of harvest season for wheat and Barley in the locality. Just before that the farmers were using many agrochemicals could contribute to the said results. Leaching of soil to the water bodies rich with phosphorus is another contributing factor for the issue. Tamiru *et al.* (2005) reported the severity of phosphate contamination in Addis Ababa Rivers in relation with the land use practices and human interferences in the banks of the rivers.

Total Nitrogen: Akan *et al*. (2010) reported that the over concentration of nitrates in water and soil of fresh water bodies can cause eutrophication problem to the water body as such and the consumption of that water for drinking can create methamoglobinemia in human beings.

The total nitrogen content indicates the accumulation of nitrogen fertilizers in the study site. Left site shows the higher percentage of total Nitrogen compared to the other two sites (0.5972 ± 0.0827%). This has a direct relation with the unsustainable agricultural activities in the area and other anthropogenic activities such as washing clothes and bathing by using chemical detergents or soaps. Agricultural activities in the extreme shores of Dendi Lake point to the chances of eutrophication due to nitrogen fertilizers. The researcher observed overgrowth of algal species near to the study sites also points to the stated result.

CONCLUSIONS

The study focused on the insight of local people about land degradation at the selected two Kebeles of Dendi Lake area and the impacts of land degradation on the components of the Lake

ecosystem. The study revealed that the soil erosion, nutrient depletion and soil structure change were the major forms of land degradation in the locality. Unsustainable agricultural practices on the slopes and banks of the Lake also create severe disturbance to the Lake environment. Lack of knowledge among locals about the sustainable agricultural practices and negative impacts of land degradation on the Lake Ecosystem system also connected to the severity of the problem in the area. The fish potential of the Lake was not at all utilized because of some existing social taboos in the area as well as lack of scientific studies on the appropriate fish varieties for the special circumstances of the Crater Lake. The analysis of selected water and soil parameters showed a significant influence of land degradation on the Lake environment. Soil analysis and water analysis shows potential results of the existing conditions of the Lake surroundings. Even though most of the selected water quality parameters were within the stipulated limits of the drinking water quality standards, there was an increasing trend of land degradation and associated problems in the surroundings of the Lake. The study proposes the need for a sustainable land management in the locality to save the Lake from further damage.

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