ASSESSMENT OF LAND DEGRADATION VULNERABILITY: A CASE STUDY FROM PART OF WESTERN GHATS AND WEST COAST OF INDIA

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CHAPTER 8

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ABSTRACT

A study was conducted in parts of Western Ghats and West Coast of Southern Karnataka to assess the land degradation status and vulnerability covering different physiographic units. Seven soil profiles representing different physiographic divisions *viz*., steep hill ranges, steep low hill ranges, isolated hills and dissected hills and valleys, elongated ridges and foot hill slopes, undulating uplands, lateritic plateau and lateritic mounds, coastal plateau summits, valleys, bars and ridges and beaches and marshes (lower laterite terrace) were identified based on soil morphological, physical and chemical properties. Based on climate, terrain and soil characteristics, the land degradation status and vulnerability was evaluated and categorized into different vulnerability grades *viz.,* very low, low, medium, moderate and high. The status of degradation and vulnerability status assessed in the study area ranged from 0.45 to 0.83. Considering the scale of land degradation, undulating uplands have been placed at high level of land degradation (Molahalli) followed by coastal plateau summits and lower lateritic terrace with moderate land degradation (Murdeswar and Ullal), while steep high hills and low hills and their side slopes showed medium category of land degradation (Sullya and Belthangadi), whereas, elongated ridges and foot hill slopes were recorded as low (Brahmavar) and very low (Kollur), respectively. The simple model used to arrive at the degradation vulnerability can be replicable to hot high rainfall areas of humid tropics.

8.1 INTRODUCTION

Land degradation is one of the most obvious factors influencing the agriculture, peoples economics, health and well being, ecosystem and hence livelihood of world population. The processes of land degradation have posed a worrisome threat to food security and it is linked with population growth and inappropriate land use options (Conacher, 2009) and results frequently from a mismatch between land quality and land use (Beinroth et al., 1994). The millennium ecosystem assessment refers land degradation as the reduction in the capacity of the land to perform ecosystem goods, functions and services that support society and development (Safriel and Adeel, 2005). The causes of land degradation are made up of natural hazards (steep slopes, impermeable soil and high intensities of rainfall), direct causes (unsuitable management practices) and underlying causes (cultivation on slopes by landless poor, non-adoption of conservation practices because of lack of security tenure) (Hegde et al., 2011). The United Nations Convention to Combat Desertification identified land degradation and desertification as one of the most pressing environmental concerns and called for a target of zero net land degradation whereby the rate of deteriorating lands would be counterbalanced by the rate of land improvement (UNCCD, 2002). Assessment of the nature and extent of land degradation using scientifically sound criteria, indicators and techniques will help to plan appropriate reclamation measures (CPC, 2004) and it will also help in determining the possible consequences (Ballayan, 2000). To arrest or prevent land degradation process one should improve the knowledge on causes and consequences of the interest phenomena and identify efficient monitoring tools (Grainger, 2014). In short, one must identify efficient tools for the detection of land degradation vulnerable areas by classifying them in different levels of land degradation vulnerability. At this aim many different methodologies have been used to study land degradation (field measurements, visual interpretation, social enquiries, mathematical models, remote sensing, environmental indicators, etc.), including the use of simple models based on indicators that synthesize information on the state and tendency of complex land degradation status and vulnerability processes (Vito et al., 2013). There are many methods used to assess land degradation *viz.,* expert opinions, land users opinions, field monitoring, observations and measurement, modeling, estimates of productivity changes and remote sensing (Kapalanga, 2008). But often these estimates of its extent and severity are highly unreliable and spurious because its results are not quantitatively replicable due to lack of baseline-measured data (Nicholson et al., 1998). The quoted statistics of 15% of the Earth's surface and 60% of dry lands are degraded (Oldeman, 1994) are acknowledged as qualitative and unsubstantiated data (Thomas and Middleton, 1994). Hence, it is hardly useful for policy making or for scientific investigations to remediate the degraded lands (Glenn et al., 1998). So there is a pressing need for accessible and accurate measurements on the extent of degradation and desertification for policy making, natural resource management and scientific research needs (Veron et al., 2006). The biophysical indicators particularly soil properties have very significant influence on the degradation rate and vulnerability potential (Onwudike, 2015). Land with better organic carbon, total nitrogen, available phosphorus, exchangeable Ca and Mg and base saturation are neither degraded nor vulnerable to degradation and therefore better soil quality indicators, while a land with low exchangeable K is extremely degraded and highly vulnerable to degradation and therefore a poor soil quality indicator (Mensah, 2015). Land with favorable texture, soil pH, exchangeable Na and effective *cation exchange capacity (*CEC) showed moderate rate of degradation and vulnerability and these might be good soil quality indicators (Amara and Momoh, 2014). This will help stakeholders in developing an effective land use plan and plan conservation measures according to the vulnerability class.

8.1.1 ASSESSMENT OF LAND DEGRADATION: GLOBAL PERSPECTIVE

Land degradation is an important global issue for the 21st Century because of its adverse impact on agricultural productivity, the environment, and its effect on food security and the quality of life. Overall at present, a quarter of world population is threatened by the effects of degradation phenomena (Eswaran et al., 2001), which affect nearly 84% of agricultural lands (FAO, 2008a). In that case it is obvious that land degradation is listed among the most important socio-economic, environmental and ecological issues and cultural problems. There are different estimates on the extent and rate of land degradation based on different definitions and methodology hence there is a large variation in the available statistics. It varied from 3.6 billion ha (Dregne and Chou, 1994) to 1.9 billion ha (Oldeman, 1994) (Table 8.1). According to the European Commission, six soil degradation processes (water, wind and tillage erosion, loss of soil organic carbon, compaction, salinization and alkalinization, contamination, and decline in biodiversity) were identified as induced or worsened by bad agricultural practices (Gay et al*.,* 2009). Many methods have been applied to assess degradation in different approaches, which use either qualitative or quantitative measures or both. Global Assessment of Land Degradation (GLASOD) is the only approach that has been applied on a worldwide scale, which is based

TABLE 8.1 Global Estimates of Soil Degradation (Scherr, 1999)

Region	Agricultural land			Permanent pasture			Forests		
	Total	Degraded	Percentage to total	Total	Degraded	Percentage to total	Total	Degraded	Percentage to total
	(million hectares)			(million hectares)			(million hectares)		
Africa	187	121	65	793	243	31	683	130	19
Asia	536	206	38	978	197	20	1273	344	27
South America	142	64	45	478	68	14	896	112	13
Central America	38	28	74	94	10	11	66	25	38
North America	236	63	26	274	29	11	621	4	1
Europe	287	72	25	156	54	35	353	92	26
Oceania	49	8	16	439	4	19	156	12	8
World	1475	562	38	3212	685	21	4048	719	18

on responses to a questionnaire, which was sent to recognized experts in countries around the world (Bridges and Oldeman, 1999). Soil Degradation in South and Southeast Asia (ASSOD) is another approach in which, the degree of soil degradation is expressed by degradation subtypes using qualitative terms such as impact on productivity (Lynden and Oldeman, 1997). Land Degradation Assessment in Dry lands (LADA) considers both biophysical factors and socio-economic driving forces for assessing the land degradation (FAO, 2008b). Pyke et al. (2002) developed a rapid, qualitative method for assessing degradation status of rangelands in the US using 17 indicators to assess 3 ecosystems attributes (soil and site stability, hydrological function, and biotic integrity) for a given location. Eswaran and Reich (1998) attempted to evaluate vulnerability to land degradation and desertification based on coefficient of variability of rainfall, depth of soil, extreme levels of chemical and physical conditions, resilience of soil and using the information incorporated in soil classification term. They found that about 43.3 million km^2 in arid, semi-arid, and sub-humid areas were vulnerable to land degradation and desertification in which 7.8 million km^2 was very highly vulnerable and 7.1, 13.6, 14.6 million km^2 belongs to high, moderate and low vulnerable class, respectively. The FAO and UNEP (1984) proposed a system of criteria for the evaluation of land degradation/desertification status, which contains data on plant cover, water and wind erosion and salinization. Veron et al. (2006) criticized the matrix from several perspectives, particularly the subjective nature of the data.

8.1.2 ASSESSMENT OF LAND DEGRADATION: INDIAN PERSPECTIVE

Land degradation reduces the ability of the land to perform many biophysical and chemical functions (Rashid et al., 2011). In India, initially aerial photographs were used for deriving information on degraded lands (Iyer et al., 1975). Subsequently, the application of remote sensing data gained importance in mapping degraded lands with the launch of ERTS-1/Landsat-1, Landsat-TM, SPOT and IRS Satellites (Dwivedi and Sreenivas, 1998). The estimates of land degradation by different agencies vary widely from about 53.3 m ha to 187.7 m ha, mainly due to different approaches adopted in defining degraded lands and differentiating criteria used (SAARC, 2011). Department of Land Resources (DOLR) in collaboration with Ministry of Rural Development carried out wasteland mapping using remote sensing technique and estimated 53.3 m ha of waste land in 1:1 million scale satellite imagery during 1985. Subsequently an estimate of 63.85 m ha (2000) and 55.27 m ha (2005) of wasteland in the country has been reported based on 1:50000 scale mapping during 2000 and 2005 (Bhattacharyya et al., 2015). According to National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) about 120.72 m ha area is suffering from various kinds of land degradation (ICAR and NAAS, 2010). It includes area affected by water erosion 82.5 m ha, wind erosion 12.4 m ha, salinity/alkalinity 6.7 m ha, soil acidity 17.9 m ha and 1.0 m ha is under other complex problems. This was reported after the realization of the need to harmonize the area statistics on land degradation in the country, the National Academy of Agricultural Sciences (NAAS) took a major initiative to evolve a consensus among concerned organizations*, viz;* NBSS & LUP, Nagpur, Central Soil Water Conservation and Training Institute (CSWCR&TI), Dehradun, Central Arid Zone Research Institute (CAZRI), Jodhpur, Central Soil Salinity Research Institute (CSSRI), Karnal, Forest Survey of India (FSI), Dehradun and National Remote Sensing Agency (NRSA), Hyderabad by adopting a common methodology and procedure for synthesizing the datasets on land degradation. The causes of land degradation include drought, population pressure, failure to implement appropriate technologies, poverty, constraints imposed by recent international trading agreements, and local agricultural and land use policies (Virmani et al*.,* 1994). In Karnataka, 7.7 m ha (40% of TGA) out of the 19.1 m ha of total geographic area, is facing soil degradation problems in which water erosion is the major problem in 5.9 m ha (30.9%) of land area (Shivaprasad et al*.,* 1998). Considerable area has been reported in Southern Karnataka with severely disturbed soil physical qualities by virtue of soil erosion. Rashid et al. (2011) used remote sensing data in conjunction with indicators such as vegetation, slope and land use and land cover for assessing the land degradation status of Kashmir region and found that 13.2% of the area has undergone moderate to high degradation, whereas about 44.1% of the area has undergone slight degradation.

8.2 STUDY AREA

Karnataka has 320 km long, 48–64 km wide coastal land, bordered by the Western Ghats on the east and the Arabian sea on the west. The coastal tract mainly consists of three districts *viz.*, the Uttara Kannada, Udupi and the Dakshina Kannada (Figure 8.1). Seven sites representing major physiographic

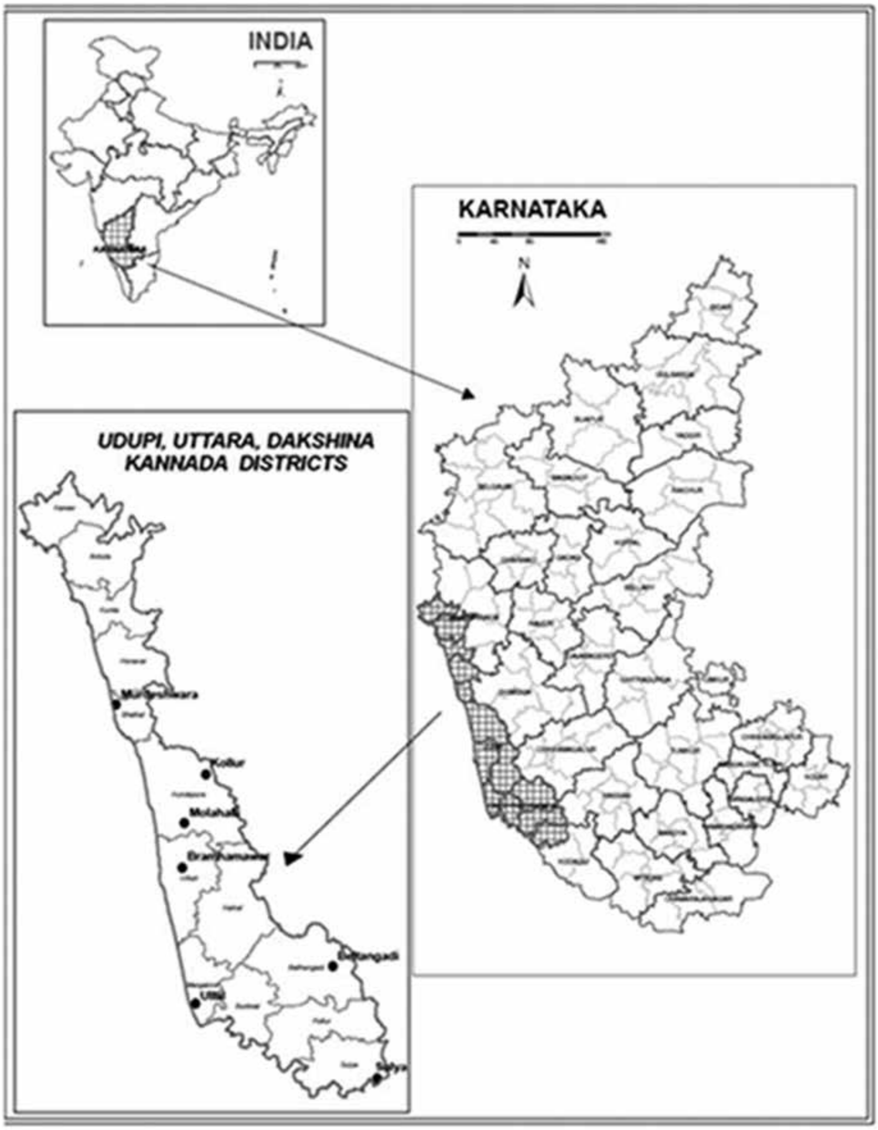

FIGURE 8.1 Location map showing study area and pedons.

units of the coastal tract were selected from these three districts for profile study in *viz.,* Sullya, Beltangadi, Kollur, Molahalli, Brahmavar, Murdeshwar and Ullal. According to delineation of National Agricultural Research Project (NARP) zones in the state, it comes under zone 10 (Coastal zone). The location details are given in Table 8.2. The western coast of Southern Karnataka

TABLE 8.2 Details About the Study Area of West Coast of Southern Karnataka

Pro-file no.	Broad Physiographic unit	Location	District	Latitude & longitude	Land use	Eleva-tion (in m)	Rain-fall (mm)	Soil classification	Erosion	Slope (%)*
1	Steep hill ranges	Sullya (Humid tropics)	Dakshina Kannada	12°31'11.4" N 75°31'0.4" E	Rubber plantation	252	3738	Clayey, kaolinitic, isohyperthermic, Ustic Kandihumults	Severe	5–10
2	Steep low hill ranges, isolated hills and dissected hills and valleys	Beltangadi (Humid tropics)	Dakshina Kannada	13°0'11.1" N 75°26'10.3" E	Rubber plantation	148	4485	Loamy, kaolinitic, isohyperthermic, Ustic Kanhaplohumults	Slight	1–3
3	Elongated ridges and foot hill slopes	Kollur (Humid tropics)	Udupi	13°47'59.1" N 74°53'27.5" E	Rubber plantation	141	3844	Clayey, mixed, iso hyperthermic, Kandic Palehumults	Slight	1–3
4	Undula-ting uplands	Molahalli (hot humid tropics)	Udupi	13°35' 9.4" N 74°48'06.5" E	Forest	25	3844	Laomy, kaolinitic, isohyperthermic, Kanhaplic Haplustults	Moderate	3–5
5	Lateritic plateau and lateritic monds	Brahmavar (Hot humid tropics)	Udupi	13°24'23" N 74°46'04.2" E	Rubber plantation	38	3887	Loamy, kaolinitic, isohyperthermic, Typic Kanhaplustults	slight	3–5

TABLE 8.2 (Continued)

Profile no.	Broad Physiographic unit	Location	District	Latitude & longitude	Land use	Elevation (in m)	Rainfall (mm)	Soil classification	Erosion	Slope (%)*
6	Coastal plateau summits	Murdeshwar (Hot humid tropics)	Uttar Kannada	14° 4'57.3" N 74°30'1.6" E	Cashew plantation	8	3200	Clayey-skeletal, kaolinitic, isohyperthermic, TypicKandiustults	Moderate	3–5
7	Valleys, bars and ridges and beaches and marshes (lower laterite terrace)	Ullal (Hot humid tropics)	Dakshina Kannada	12°51'28.8" N 74°51'47.5" E	Paddy	7	3769	Clayey, kaolinitic, isohyperthermic, TypicKanhaplustults	Slight	3–5

* Slope of specific pedon location.

comes under humid tropical region with mean annual rainfall of 3000–4000 mm. The length of dry season ranged between 4–6 months. Beltangadi and Sullya have experience 4 months of dry period from December to March in a year. Other pedons experience 6 months of dry period from December to May.

The study area is west coast of Southern Karnataka, which covers west facing slopes of Western Ghats including high and low hill ranges, ridges, dissected hills and narrow valleys, isolated hills, flat hill slopes, undulating uplands and lateritic plateaus as well as mounds and coastal landforms. Humid tropical climate with heavy rainfall and high temperature experienced in this region induces intense leaching of bases. Hence, these areas are predominant with deep well drained acidic soils. The major soils of these region are very deep well drained gravelly soils, deep well-drained clayey soils, moderately shallow, well drained, clayey soils and deep imperfectly drained sandy over loamy in valley region with shallow water table. The majority of the west coastal region of Karnataka is under forest plantation followed by agricultural uses. West coast of southern Karnataka is very important and significant agro-climatic zone where number of commercially important crops like rubber, cashew, coconut and paddy.

8.3 MATERIALS AND METHODS

8.3.1 VISUAL INTERPRETATION OF SATELLITE DATA

Proper interpretation of False Color Composite (FCC) imageries based on tonal variation, pattern, texture and spectral reflectance properties of soils, helps in accurate identification of degraded lands. The Survey of India toposheets (48J, 48N, 48O & 48L) of 1:250,000 scales, which cover the west of southern Karnataka, were used to prepare base maps in conjunction with satellite imageries of IRS LISS-III P6 FCC during the year 1986, 1998, 2003, 2011 and Google Earth images wherever necessary. A tracing film was overlaid on the toposheets covering the study area. Boundary of the west coast and important land features like rivers, tanks, roads, etc., were extracted. Thus a map having the above common land features was used as a base map for preparing different thematic maps. Imageries of west coast of southern Karnataka were procured from Karnataka State Remote Sensing Application Centre, Bangalore. The satellite imageries of the study area were visually interpreted in conjunction with respective toposheets, based on tonal variation, texture and pattern. Permanent structures like roads, railway lines, and water bodies were first traced, digitized and super-imposed on the interpreted satellite imageries and different types of soil/land degradation were demarcated on the imageries.

8.3.2 STUDY OF REPRESENTATIVE SOIL PROFILES

The pre-field map showing different land degradation units was overlaid on physiography map and soil map (1:50,000 scale) of Karnataka (Shivaprasad et al., 1998). The major physiographic units and its corresponding soil and its area were demarcated in ArcGIS platform. Each unit with major soil was marked as a pedon in the pre-field map, and seven such representative pedons were identified. In addition sites representing different areas for sampling were chosen on the basis of physiography, geology, vegetation, micro-climate, degree of erosion, away from field boundaries, roads and rivers. A profile of dimension of $1.5 \times 1.5 \times 2$ m^3 was dug. The landform characters such as slope, erosion, drainage, land cover, etc., and morphological properties of the pedons were recorded.

8.3.3 LABORATORY ANALYSIS OF SOIL SAMPLES

The soil parameters *viz.,* pH, EC, organic carbon (OC), soil OC (SOC) stocks, CEC, exchangeable bases, extractable acidity by barium chloride-tri-ethanol amine method and 1 *N* KCl method, effective CEC, available N, P, K, exchangeable Ca and Mg, available S and micronutrients were determined through standard procedures (Jackson et al., 1973). Degradation status map was generated by considering the climatic, soil physical and chemical variables assigning grades for each parameter depending on its impact on making soil degradation in the study area. The parameters considered are total rainfall, deviation from normal spell, thickness of surface horizon, surface texture, BD of surface horizon, OC per cent, etc. To know the status of land degradation, values have been assigned to the related soil parameters. These values of corresponding profiles were divided by the total value of all parameters. In the present study, the total value of all parameters was assigned as 25 (Table 8.3).

TABLE 8.3 Assigning of Ratings/Grades to Soil Parameters for Land Degradation in West Coast of Southern Karnataka

Rainfall (cm)	Dry months	Thickness of surface horizon	Surface texture	B.D. of surface horizon	OC % of surface horizon	SOC (kg m^{-2})	CEC/ clay ratio of control section	B.S./sum of cations ratio of surface horizon	Status of land degradation
3500–4000 = (1)	<5.0 = (1)	>20 = (1)	scl = (1)	<1.2 = (1)	>2.5 = (1)	>12 = (1)	>16 = (1)	>22.5 = (1)	<0.50 = very low
>4000 = (2)	5.0–5.5 = (2)	10–20 = (2)	gscl = (2)	>1.2 = (2)	1.5–2.5 = (2)	9–12 = (2)	12–16 = (2)	15.0–22.5 = (2)	0.50–0.60 = low
<3500 = (2)	5.5–6.0 = (3)	<10 = (3)	gc = (2)		0.75–1.5 = (3)	6–9 = (3)	8–12 = (3)	7.5–15 = (3)	0.60–0.70 = medium
			gsl = (3)		>0.75 = (4)	3–6 = (4)		<7.5 = (4)	0.70–0.80 = moderate
						0–3 = (5)			>0.80 = high

8.4 RESULTS AND DISCUSSION

8.4.1 SOIL PHYSICAL PROPERTIES

8.4.1.1 Soil Depth

Soil depth indicates the depth of the solum occurring above the parent material or hard rock and determines the effective rooting depth of plants and the capacity of the soil to hold water and nutrients. Solum depth reflects the balance between soil formation and soil loss by erosion in any area. Soil depth ranged between 109 to 155 cm or more. Except Molahalli all the pedons recorded a solum depth of more than 150 cm. The lower depth recorded in Molahalli soil profile might be due to washing out the top soil because of lack of proper soil conservation measures. This study area has the slope of 5–10%, which is responsible for formation of very deep soils in the coastal plateau summits and valleys regions. Variation in depth is due to the variation in topography, physiography and slope gradient (Sitanggang et al., 2006). Reduction in depth of solum owing to loss of top soil by sheet erosion, selective removal of finer particles and assorting of coarse grains and gravels on surface gives an indication of the degradation process operating there. This is aggravated by heavy rainfall and high temperature on steep slopes and soil surface devoid of proper vegetation cover. Less thickness of surface horizon is another indication of loss of top soil due to erosion as indicated by the morphological characteristics of soil profiles. Soil of Murdeshwar has maximum depth of 20 cm followed by soil profiles 2 and 6 with 18 cm depth, whereas, other soil profiles are only 10 cm deep.

8.4.1.2 Soil Texture

With regard to land degradation, soil texture of surface horizon was mainly considered, which includes gravelliness and it was influenced by the rainfall in removing the finer particles from the surface horizon, rainwater infiltration and percolation. Soil profile in Brahmavar has the surface texture of clay, Murdeshwar has clay loam surface texture, Kollur and Molahalli have sandy loam texture. Other soil profiles representing Sullya, Beltangadi and Ullal have sandy clay loam surface texture. Total sand percentage is much higher than the silt and comparatively higher than clay fractions in 2, 4, 5 and 7 pedons. The dominance of coarser fractions largely of siliceous nature may be due to granite gneiss parent material (Dutta et al., 2001). Appearance of hard weathered ferruginous schist and hard weathered laterite rock in pedon 3 and 4, respectively in the subsoil horizons might be due to the removal of clay, silt and fine sand particles by sheet erosion, which results in exposing rock fragments and accumulation of heavy soil particles. In the case of gravelliness, the highest gravelliness (31%) among 7 soil profiles was recorded in Molahalli soil profile which was followed by Murdeshwar soil profile (28%). The lowest gravelliness (3%) was recorded in Ullal soil profile with surface texture of clay loam. The removal of finer particles by erosion is responsible for the occurrence of coarse textured soil in the uplands (Dutta et al., 2001).

8.4.1.3 Bulk Density

The bulk density of surface horizon was lower than subsequent lower horizons. The lowest bulk density was observed in Sullya soils (1.08 Mg m^{-3}). The lower bulk density in the surface horizon is due to the high organic carbon content in the surface horizons. Higher surface bulk density was observed in pedons 1 and 4 – Murdeshwar (1.24 Mg m^{-3}) owing to the coarse texture, as a result of washing away of the clay and silt particles from the surface layer leaving well drained dense sand particles and in some cases coupled with low organic carbon (Sitanggang et al., 2006). The bulk density of all pedons has increased with increasing depth owing to dominance of illuviated compacted clay mineral in the lower horizons and low OC as compared to surface layer. In pedons 4 and 6, the bulk density increases with depth. Due to the severity of erosion, most of the soil material was removed leaving only the exposed compact layer below (Bhaskar and Subbaiah, 1995).

8.4.1.4 Soil Drainage and Erosion

Soil drainage is mainly influenced by surface soil texture. If the surface soil texture is heavy, it will permeate the water to penetrate. Soil drainage affects the erosivity. All the pedons are well drained except pedon 7 (Ullal), which is moderately well drained. Severe soil erosion has been observed in Sullya soils due to steep hill ranges (slope 5–10%). In the study area, sheet erosion is the dominant type of erosion because of undulating slope particularly in the granite area, where large quantities of finer silt and clay particles get washed away from the top soil. In the absence of proper soil conservation measures due to continuous loss of fine particles and nutrients, the coarser particles in surface soils may result in unproductive soil over a period of time. In the upland, the sheet erosion is very active and may result in development of coarser textured surface soils (Balak Ram and Chauhan, 1992).

8.4.2 SOIL CHEMICAL PROPERTIES

8.4.2.1 Soil Reaction (pH)

In the study area, the soil reaction in soil profiles is strongly acidic to moderately acidic (Table 8.4). The reason for development of soil acidity might be high rainfall and leaching of bases. Soil acidification and consequent deficiencies of calcium and magnesium along with micronutrients B and Zn is very common in highly leached lateritic soils of coastal districts of Kerala (Kerala State Planning Board, 2013). Soil acidification is also commonly reported in high input plantation crops soils and banana and vegetable growing soils of Kerala in the same study.

8.4.2.2 Soil Organic Carbon

The pedon located at Kollur area registered highest OC content (5.5%), which was followed by the soil profile located at Brahmavar (2.5%). The lowest OC content was recorded at Molahalli (0.66%). Even though the OC varies, all soil profiles surfaces have the OC content at the high status (>0.5%) due to more foliage cover of dense forest in western Ghats, rubber cultivation and deposition of plant litter along with the alluvium (Badrinath et al., 1986).

8.4.2.3 Soil Organic Carbon Stocks

The pedon located at Kollur area registered highest SOC stocks (14.2 kg m^{-2}), which was followed by the soil profile located at Belthangadi (8.56 kg m^{-2}), Ullal (8.14 kg m^{-2}) and Brahmavar (8.01 kg m^{-2}). The lowest SOC stock was recorded at Molahalli (1.71 kg m^{-2}) and Murdeshwar (5.54 kg m^{-2}). The variations in OC stocks in all soil profiles depend on the thickness of horizon with higher OC content at the surface, soil depth, gravelliness and bulk density apart from climate and vegetation. Rajan et al. (2010) termed SOC stocks as the most reliable indicator for monitoring land degradation by soil erosion and sodicity through Principal Component Analysis after soil characterization by field studies in Kolar and Chamarajnagar districts of Karnataka, India.

8.4.2.4 Cation Exchange Capacity

CEC ranged between 8 to 28 cmol (+) kg^{-1}. The highest CEC was recorded in Kollur and Molahalli soil profiles (>16 cmol (+) kg^{-1}) and the lowest was in Murdeshwar and Ullal soil profiles (8–12 cmol (+) kg^{-1}). The CEC /clay ratio of more than 0.25 was observed in surface horizons of pedons 1, 2, 3 and 4 due to high organic carbon content, in subsurface horizon it was less than 0.25 and in rest of the pedons it was less than 0.25 throughout, which might be due to presence of low activity clay 1:1 (Kaolinitic) throughout the solum (Pujari and Moharana, 1993).

8.4.2.5 Base Saturation of Surface Horizon

Base saturation of surface horizon by sum of cations gives a rough indirect indication of the potassium, calcium and magnesium supplying capacity of soil to plant system apart from dominance of sesquioxides over bases. Highest base saturation was noted in Kollur and Brahmavar (23.5–23.9%), followed by Molahalli (20.5%), Sullya, Murdeswar and Ullal (8.6–12.3%) while least was found in Belthangadi (3.8%) owing to very high rainfall and consequent leaching away of bases. Similar observations were recorded in coffee growing areas of per-humid zones of Karnataka in a study conducted by Anil Kumar et al. (2014).

8.5 LAND DEGRADATION AND VULNERABILITY

The undulating upland physiographic unit was found highly vulnerable (0.83) to land degradation due to fragile soils, low fertility and organic carbon status, prolonged dry months and a general low input form of agriculture (Table 8.5; Figure 8.2). The physiographic units *viz*., coastal plateau summits and beaches and marshes were moderately (0.79 and 0.72, respectively)

TABLE 8.4 Horizon Wise Soil Parameters of Different Soil Profiles

Pedons and locations	Horizons	Horizon width (cm)	Vol. % Gravelliness	Texture	pH	OC (%)	CEC/ Clay	CEC [cmol (p+) kg^{-1}]	BS (%)	BD (Mg m^{-3})
Sullya	Ap	0–10	15.9	gscl	5.4	0.94	0.30	18.9	10.4	1.08
	Bt1	10–33	11.9	scl	5.2	1.22	0.20	16.1	10.3	1.04
	Bt2	33–54	7.9	c	5.1	0.59	0.12	12.0	13.0	1.05
	Bt3	54–90	15.9	gc	4.8	0.09	0.10	13.2	9.9	1.14
	Bt4	90–121	23.8	gc	5.2	0.09	0.09	8.5	17.7	1.23
	Bt5	121–150	15.9	gc	5.1	0.09	0.07	10.1	16.5	1.20
Beltangadi	Ap	0–18	27.4	gscl	5.2	2.3	0.37	24.4	3.8	1.22
	AB	18–41	21.4	gsl	5.0	0.9	0.44	15.1	7.3	1.19
	Bt1	41–62	23.0	gsc	5.3	0.46	0.13	12.3	10.6	1.22
	Bt2	62–82	25.4	gsc	5.4	0.13	0.15	9.5	21.4	1.28
	Bt3C	82–119	15.2	gscl	5.4	0.16	0.16	9.8	19.0	1.24
	BC1	119–139	15.1	gcl	5.3	0.16	0.09	6.7	18.2	1.42
	BC2	139–153	13.5	sc	5.4	0.09	0.05	6.5	16.4	1.33
Kollur	Ap	0–10	27.8	gsl	5.3	5.49	0.73	28.2	23.9	1.13
	Bt1	10–27	28.8	gcl	5.5	2.8	0.32	22.5	14.8	1.12
	Bt2	27–53	31.0	gsl	5.3	1.22	0.20	22.1	20.8	1.22
	Bt3	53–88	32.4	gl	5.4	0.99	0.21	14.6	14.7	1.21
	Bt4	88–130	38.6	vgcl	5.6	0.03	0.08	11.4	10.8	1.33
Molahalli	Ap	0–10	31.0	gsl	5.7	0.66	0.27	9.4	20.5	1.21
	Bt1	10–28	32.2	gcl	5.6	0.13	0.09	9.4	20.3	1.21

	Bt2C	28–50	32.6	gsl	5.5	0.13	0.21	8.4	17.5	1.26
	BC1	50–78	34.2	gl	5.7	0.10	0.13	6.0	25.7	1.26
	BC2	78–109	37.0	vgcl	5.5	0.06	0.12	8.5	11.7	1.34
Brahmavar	Ap	0–10	21.4	gc	5.8	2.48	0.20	18.2	23.2	1.17
	BA	10–38	19.5	gcl	5.4	0.46	0.14	13.7	20.0	1.23
	Bt1	38–59	19.1	gc	5.2	0.49	0.08	13.9	4.9	1.22
	Bt2C	59–79	13.9	cl	5.2	0.46	0.14	15.4	9.3	1.19
	BC1	79–113	22.2	gcl	5.3	0.39	0.15	9.7	7.8	1.25
	BC2	113–148	24.2	gcl	5.2	0.13	0.11	13.2	16.9	1.29
Murdeshwar	Ap	0–20	28	gcl	5.7	1.45	0.18	18.0	8.6	1.24
	Bt1	20–47	35	gsc	5.6	0.46	0.10	13.7	12.9	1.23
	Bt2	47–82	60	vgsc	5.5	0.62	0.11	14.0	14.7	1.26
	Bt3	82–112	60	vgc	5.7	0.13	0.12	11.9	22.8	1.28
	Bt4C	112–155	70	egc	5.5	0.06	0.11	12.4	17.8	1.32
Ullal	Ap	0–10	3	scl	5.2	15.9	0.21	22.3	12.3	1.12
	AB	10–20	5	Scl	5.5	11.7	0.17	20.8	13.5	1.52
	Bt1C	20–47	14	c	5.4	3.0	0.12	19.0	14.8	1.32
	Bt2C	47–78	27	gcl	5.4	2.6	0.09	16.9	14.4	1.28
	Bt3C	78–103	14	c	5.4	3.0	0.09	18.2	14.7	1.43
	BC	103–133	15	gcl	5.4	2.4	0.10	19.6	10.5	1.45
	CB	133–151	15	gcl	5.7	2.6	0.14	14.7	15.1	1.42

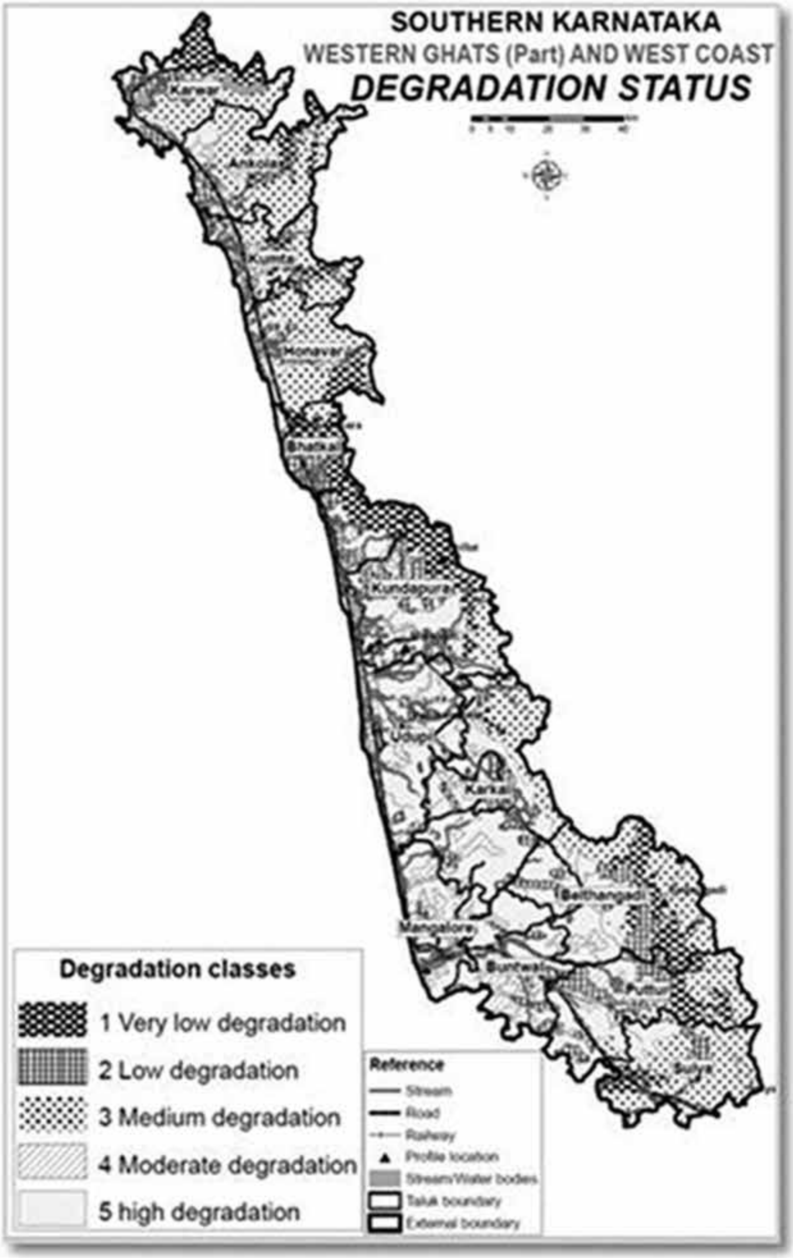

FIGURE 8.2 Land degradation status of parts of Western Ghats and West coast of Karnataka.

TABLE 8.5 Assigned Grades of Soil Parameters for Different Soil Profiles and Land Degradation

Pedon Locations	Latitude & longitude	Rainfall (cm)	Dry months	Surface soils parameters						CEC/clay ratio of control section	Status of land degradation and vulnerability
				Thickness (cm)	Texture	BD (Mg m^{-1})	OC (%)	SOC (kg m^{-2})	BS/ Sum ratio		
Sullya	12°31'11.4" N 75°31' 0.4" E	3738 (1)	4.2(1)	10 (3)	gscl (2)	1.08 (1)	0.94 (3)	6.14 (3)	10.5 (3)	18–12 ((2)	19/29=0.66 (Medium)
Beltangadi	13°0'11.1" N 75°26'10.3" E	4485 (2)	4.5(1)	41 (1)	gscl (2)	1.22 (2)	2.30 (2)	8.56 (3)	3.8 (4)	12–16 (2)	19/29=0.66 (Medium)
Kollur	13°47'59.1" N 74°53'27.5" E	3860(1)	5.4(2)	10 (3)	gscl (2)	1.13 (1)	5.40 (1)	14.20 (1)	23.9 (1)	>16 (1)	13/29=0.45 (Very low)
Molahalli	13°35'9.4" N 74°48'06.5" E	3887 (1)	5.6(3)	10 (3)	gsl (3)	1.24 (2)	0.66 (4)	1.71 (5)	20.5 (2)	>16 (1)	24/29=0.83 (High)
Brahmavar	13°24'23" N 74°46'04.2" E	3887(1)	5.2(2)	10 (3)	gc (2)	1.07 (1)	2.40 (2)	8.01 (3)	23.5 (1)	12–16 (2)	17/29=0.58 (Low)
Murdeshwar	14° 4'57.3" N 74°30'1.6" E	3237(2)	5.2(2)	20 (2)	gscl (2)	1.24 (2)	1.45 (3)	5.54 (4)	8.6 (3)	8–12 (3)	23/29=0.79 (Moderate)
Ullal	12°51'28.8" N 74°51'47.5" E	3769(1)	5.2(2)	10 (3)	scl (1)	1.12 (1)	0.52 (4)	8.14 (3)	12.3 (3)	8–12 (3)	21/29=0.72 (Moderate)

vulnerable to land degradation because of poor organic carbon status and low surface horizon thickness in lower lateritic terrace. The steep hill ranges, dissected hills and valleys were observed to be affected by medium vulnerability (0.66) to land degradation due to poor surface horizon thickness, SOC in the steep hill ranges and low base saturation to total cations ratio of surface horizon in dissected hills and valleys. The lateritic plateau has shown low vulnerability and foot hill slopes were subjected to very low vulnerability towards land degradation because of better soil parameters which reduces land degradation. The land degradation problem is not only a resource research and management issue, but also a human and social issue. The reasons and means to combat the process should be site specific and vary from region to region. A policy which supports mutual goals of optimum soil quality, clean water and sustainable farming should be adopted (Eswaran and Reich, 1998).

8.6 SUGGESTED MANAGEMENT MEASURES

- **Development of Land Resource Information Systems for Land Management**
  A scientific community has to be identified and mobilized to initiate and mount an integrated program for methods, standards, data collection and research networks for assessment and monitoring of soil and land degradation. Based on the information, hot spots can be identified for monitoring the extent of degradation, the factors causing land degradation and its impact assessment.
- **Enhance the Research and Development in Degraded Lands**
  High priorities are to be given to promote public investment in research and development aimed at identifying the root cause of land degradation and developing soil resources conserving, yield enhancing low cost technology for problematic lands.
- **Developing Suitable Land Use Planning and Policies**
  The land use planning has to be developed by considering or identifying the models which incorporate the factors (natural and human induced) that contribute to land degradation.
  Strong land use polices have to be identified, which encourage sustainable land use and management and should arrest the conversion of prime agricultural land into non-agricultural purposes.

- **Encourage Participatory Land Use Planning Involving Local Organization**
  Arrangements have to be made for collaboration between public research institutions, NGOs and local organizations for developing land use plan using locally available inputs and training should be given for effective adaptation of resource conserving and yield enhancing technologies.

8.7 CONCLUSION

Soil degradation status and vulnerability have been assessed by assigning scores to land quality parameters, which favor land degradation. Molahalli soils recorded high and Murdeshwar and Ullal soils showed moderate vulnerability to land degradation. The Kollur soil showed very low vulnerability to land degradation, followed by low vulnerability in Brahmavar, while Sullya and Belthangadi were assigned medium vulnerability. Lands with favorable rainfall, bulk density, base saturation, cation exchange capacity and soil reaction were neither degraded nor vulnerable to degradation in most of the places and while those lands with poor organic carbon status were tagged as highly degraded as in Molahalli sites and highly vulnerable to degradation because of high dry months. The coarse texture and low thickness of the surface horizon showed moderate rate of degradation and vulnerability and these might be good soil quality indicators in the long term if the recommended soil management strategies are adopted. Proper conservation measures like growing cover crops and *in situ* moisture conservation have to be followed. Landform specific soil and water conservation measures need to be followed in the fragile ecosystems like undulating lateritic terrains, involving mechanical measures as well as vegetative barriers.

KEYWORDS

- **Land Degradation Status and Vulnerability**
- **Land Qualities**
- **Land Resources Management**
- **Physiographic Units**

- **Red and Lateritic Soils**
- **Soil Organic Carbon Stocks**
- **Soil Parameters**
- **Southern Karnataka**
- **West Coast**
- **Western Ghats**

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