NJ: NUTA

Soil Erosion Status of Nepal

Sher Bahadur Gurung
Central Department of Geography, Tribhuvan University
Email: sher.gurung@cdg.tu.edu,np
DOI: 10.3126/nutaj.v8i1-2.44109

Abstract

Soil erosion is one of the problems in Nepal because about 73 percent of the land surface is mountainous and still tectonically active where 60.43 percent people involved in agricultural activities. The paper assesses the soil erosion status based on ecological region and watershed boundary with population density. The ecological region determined based on elevation and the watershed boundary of Nepal was generated using the Advanced Spaceborne Thermal Emission and Reflection Radiometer–ASTER, 30m resolution Digital Elevation Model (DEM) of NASA's Earth Observing System (EOS) on May 14, 2010. The DEM data was processed using remote sensing technique then hydrological analysis conducted using remote sensing and geographic information system to delineate the watershed boundary. The study generates 19 watersheds based on available soil erosion data. The soil erosion rate of ecological zone and watershed are assessed with population data of Nepal from central bureau of statistic, 2011. There is below 50 people per square kilometer watersheds have average soil erosion rate (about 20 t ha^{-1}/y^{-1}) and 100 to 500 people per square kilometer watersheds have high soil erosion rate ranges from 27 to 102 t ha^{-1}/y^{-1}. The main causes of soil erosion of Nepal Himalaya are Himalaya energy and its people activities. These scenarios partial follow the theory of Himalayan degradation. So that there is still environmental degradation is observed and it is needed in detail field based study of Himalaya degradation.

Keywords: GIS, RS, Soil, Soil Erosion, Watershed

Introduction

A soil is a naturally occurring earth body of minerals and organic matter that exists on the earth's surface. It is an essential part of the natural environment which is composed of several physical, chemical, and biological components having a wide range of interactions when it comes to plant growth, with its properties constantly changing as a result of chemical reactions and biophysical processes. In Nepal, Soil types are varied due to many factors, such as geology, physiography, climate, and vegetation types (Gurung, 2020). There has been very little research on soil types and erosion in Nepal (Shah, 1995, Chalise, Kumar & Kristainsen, 2019 and Gurung, 2020).

Soil erosion involves the breakdown, separation, transport, and redistribution of soil particles by powers of water, wind, or gravity (Carson, 1985; USDA, 2006; 2022). Similarly, DesInventar (n.d.),

defined soil erosion as washing away of soil down the outer layer of slope inclines or mass movement due to storm water flow during extraordinary rains or winds and can cause sedimentation in streams/ rivers and areas at the toe of the hill slopes. According to Oldeman (1992), soil erosion take place on globally and under every single climatic condition and is assessed 1094 M/ha universally, though 441 M/ha in Asian mainland, which is 59% of the world. This exploration has led under UNEP's task 'Worldwide Evaluation of Soil Debasement' (GLASOD) by the Global Soil Reference and Data Center (ISRIC). The finding depends on 21 territorial correlator's database. Likewise, FAO (2015) and (2017) had assessed throughout the last ten years, the figures distributed for water disintegration range over a significant degree of ca. 20 Gt/y^{-1} to north of 200 Gt y-1.

Soil erosion is a problem in Nepal. Because more than 73 percent of the land is mountainous (Gurung, 2004) and still tectonically active, and agriculture is the primary source of income for more than 60.43 percent of the population of the country (CBS, 2014). As a result of increased population pressure on agriculture, soil and forest resources have degraded (Chalise, Kumar & Kristainsen 2019). Understanding the spatial behavior of resources and hazards requires mapping soil erosion (Pourghasemi, Kariminejad, and Amiri) (2020). As a result, the current study analyzed soil erosion status based on ecology and watershed using a geographic information system and remote sensing techniques.

Material and Methods

This study is based on previously published documents on ecological and large and small watershed soil erosion condition of Nepal, such as books, reports, and articles, which develop ideas about it. Similarly, the internet provided the majority of the information about Nepal's soil erosion. The ecological region determined based on elevation and the watershed boundary of Nepal was generated using the Advanced Spaceborne Thermal Emission and Reflection Radiometer – ASTER, 30m resolution Digital Elevation Model (DEM) of NASA's Earth Observing System (EOS) on May 14, 2010. The DEM data was processed using remote sensing technique then hydrological analysis conducted using remote sensing and geographic information system to delineate the watershed boundary. The study generates 19 watersheds based on available soil erosion data. The soil erosion rate of watershed is assessed with population data of Nepal from central bureau of statistic, 2011.

Study Area

In terms of geography, Nepal lies within the coordinates 26^{o} 12' to 30^{o} 27' North and 80^{o} 4' to 88^{o} 12' East. It extends from East to West (885 km) on the continent of Asia and north-south width ranges from 145 to 241 km, with an average of 193 km. It's bordered by China to the north and by India to the east, west, and south (buffer state). So that it is a landlocked country surrounded on all sides by land. Its physiography is characterized by the local relief, geological structure, altitude, and geographical distribution. In general, Nepal is divided into Hills and Mountain zones, Tarai and Inner Tarai, occupying roughly 77 and 23 percent of its land respectively (LRMP, 1986). These can be further divided into Tibetan Mountain Ranges, Inner Himalayas, Great Himalayas, Midland Valleys, Mahabhart Lekhs and Chre Ranges. Similarly, Tarai and Inner Tarai regions also can be divided into Inner Terai, Bhabar zone and Main Terai (see Fig. 1a).

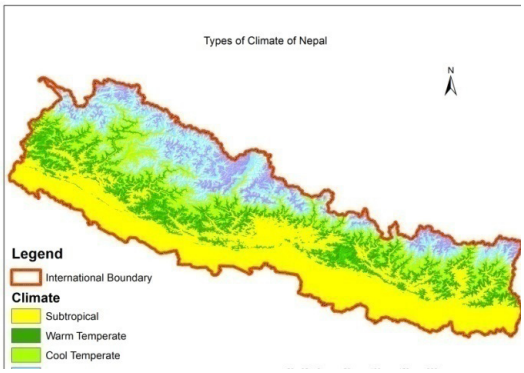


Fig. 1a: Physiographic Region of Nepal

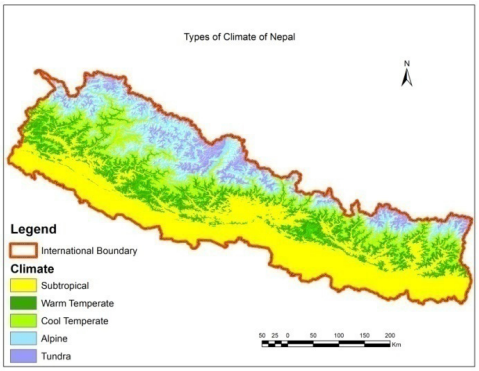


Fig. 1b: Climatic Zone of Nepal

Subtropical, warm temperate, cool temperate, alpine or cold, and tundra or cold desert climates are the most common in Nepal. Up to 1200 meters above sea level, the climate is subtropical. The weather is hot and humid. In this climatic zone, temperatures range from 150°C to 350°C, with rainfall ranging from 1000mm to 2000mm. The warm temperate climate, which can be found between 1200 and 2100 meters above sea level, is a healthy climate. The temperature ranges from 100 to 300 degrees Celsius, with rainfall ranging from 1000 to 2000 millimeters. The cool temperate climate, which ranges in elevation from 2100m to 3300m, is also healthy, but it is a little cooler. The temperature ranges from 50 to 200 degrees Celsius, and rainfall occurs at a height of nearly 1000 meters, with snowfall in the winter (see Fig. 1b).

Results

Soil Erosion

Soil erosion, landslides, and flooding are the most common causes of land degradation in Nepal (Hegen, 1961; Jhonson, Olson and Manandhar, 1982; Carson, 1985; Karan Iijma, 1985; Biot, Blaikie, Jacson, Jones, 1989; ADB, 2015; MOPE, 2015; Chalise, Kumar, and Kristiansen, 2015 and 2019). The main causes of environmental degradation in this region are population growth, deforestation, and rapid development. Joshi, Shrestha, and Joshi (2003) discovered that the ecology was the most important factor in determining the types of land degradation. They discovered that the high Himalayan region experienced rockslides, avalanches, and glacier lake outburst floods above 5000 meters (GLOF). gully erosion, surface erosion (rill and inter rill), and river bank cutting are all examples of mass wasting (slumping, gully, landslide, and rock fall) (table 1).

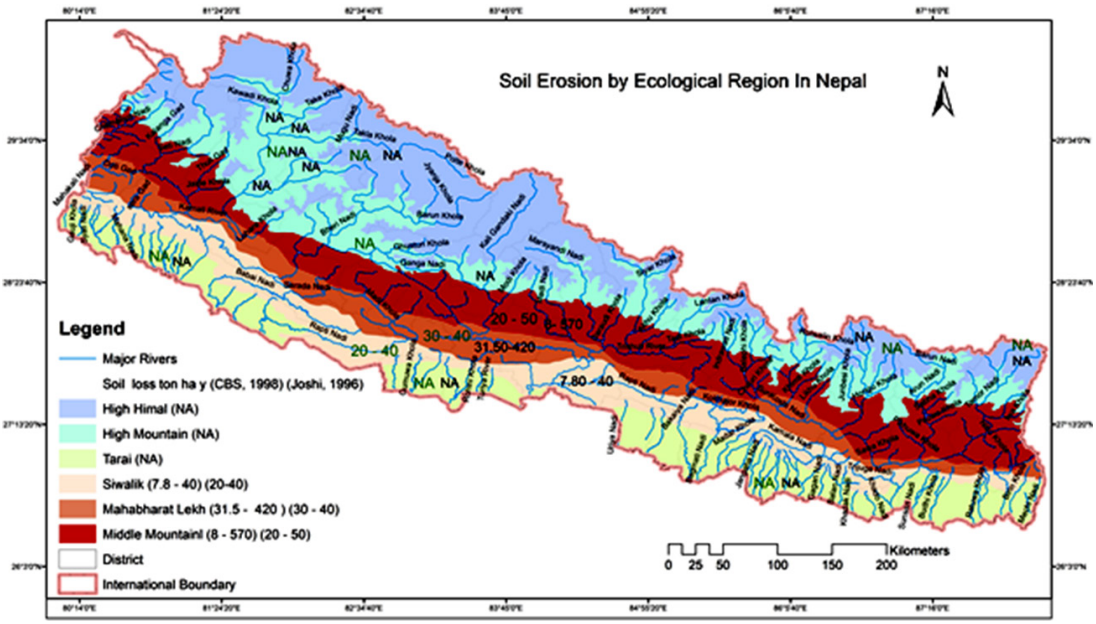
Table 1: Types of Erosion in Nepal

Degradation Type	Affected Area as % of Total Land Area of Nepal	Affected Areas (Million Ha.)
Water erosion	45.4	6.7
Wind erosion	4.0	0.6
Chemical deterioration	1.7	0.3
Physical deterioration	1.3	0.2

Sources: Ministry of Population and Environment, 2016.

Water erosion is the most common form of erosion in Nepal, which is caused by the country's mountainous terrain and monsoon system, which affects 45.4 percent of the country's total area and 6.7 million hectares of land. Similarly, wind erosion, chemical, and physical deterioration have occurred, all of which share 4. 1.7 and 1.3 percent, respectively, and 0.6, 0.3, and 0.2 million hectares of land were severely affected by water erosion, with an erosion rate of 40-200 t ha^{-1}/ y^{-1} and approximate soil loss ranges of 182.38 to 707.91 t ha^{-1}/ y^{-1} of Nepal year-round, with only snowfall and snow storms occurring on rare occasions. This area is also known as the world's third pole.

Figure 2: Soil Erosion by Ecological Region in Nepal



Source: Joshi, 1996 (Joshi, J., Bhattarai, T. N., Sthapit, K. M., and Omura, N., 1998) and Central Bureau of Statistics (A Compendium on Environment Statistics 1998 Nepal)

Soil Erosion by Ecological Region

Nepal's ecological soil erosion was presented by Joshi in 1996. In Shiwalik (Chure) ecologicl region, erosion rate was 20 – 40 ton/ha^{-1}/yr^{-1}, in Mahabharat ecology, erosion rate was 30 – 40 ton/ha-1/yr-1,

and Middle mountain ecology loss was 20 – 50 ton/ha-1/y-1. Similarly, CBS (1998) estimated soil erosion rates for Siwalik (Chure), Mahabharat Lekh, and Middle Mountain at 7.8 to 40, 31.5 to 420, and 8 to 570 ton/ha^{-1}/y^{-1}, respectively. According to CBS (1998), the most soil has been lost from Nepal's Middle Hill (Table 2 and Fig 8).

Table 1: Soil Erosion by Ecological Region

	Erosion Rate (ton/ha^{-1}/y^{-1}	
Ecological Region	Joshi (1996)	CBS (1998)
Siwalik Range (Chure)	20 - 40	7.80 - 40
Mahabharat Lekh	30 - 40	31.50-420
Middle Mountain	20 - 50	8- 570
Table 2: Soil Erosion by Ecological Region		

Source: Joshi, 1996 (Joshi, J., Bhattarai, T. N., Sthapit, K. M., and Omura, N., 1998) and Central Bureau of Statistics (A Compendium on Environment Statistics 1998 Nepal)

Soil Erosion in Large Watershed

WECS (2003) analyzed the soil erosion status of Nepal at the large watershed level based on the work of various authors. As shown in table 3, different authors calculated watershed boundaries in different ways depending on the rate of sediment yield.

Table 3: Large Watersheds Soil Erosion in Nepal

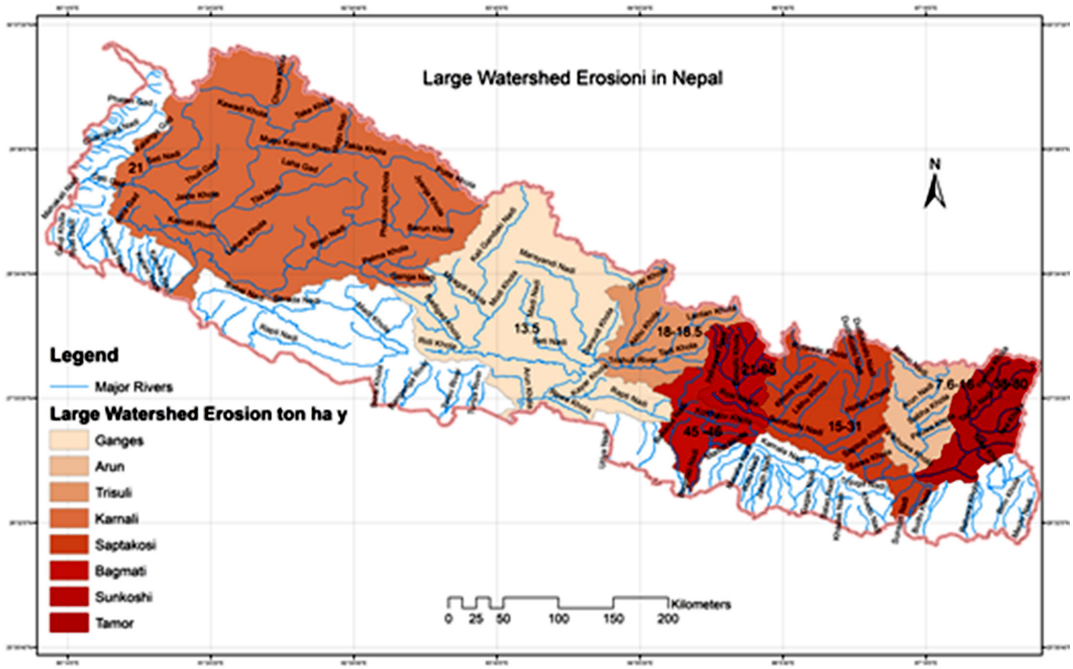
Large Watersheds	Watersheds Area in sqkm	Sediment Transport (ton/ha^{-1}/y^{-1})
Tamor	5770 (1), 5700 (6), 5900 (4), 5770 (5)	38.0 (1), 70.0 (6), 80.0 (4), 38.0 (5)
Sunkoshi	18985 (1), 19000 (3), 19000 (4)	21.0 (1), 65.0 (3), 45.0 (4)
Bagmati	585 (6), 1388 (3)	45.0 (6), 46.0 (3)
Trisuli	4100 (6), 4110 (3)	18.0 (6), 18.5 (3)
Karnali	42890	21.0 (9)
Ganges	1076000?	13.5 (8)
Saptakosi	59280 (1), 62000 (1), 61000 (7), 59280 (5)	15.0 (1), 27.7 (8), 31.0 (7), 15.0 (5)
Arun	34525 (1), 36000 (7), 36533(4), 34525 (5)	7.6 (1), 16.0 (7), (4), 7.6 (5)

Reference : 1,Williams-1977; 2, Sherchan-1991; 3, Schaffner-1987; 4, Upadhaya-et.al. 1991; 5, Ries-1994; 6, Maskey and Joshy- 1991; 7, Karver-1995; 8, Erl – 1988; 9, HPC-1989.

Source : Water and Energy Commission Secretariat/ CIDA.(Himalayan Sediment, Issue and Guidelines, 2003).

The soil erosion rate of Tamor, Sunkoshi, Saptakoshi and Arun are ranges from 38-80, 21-65, 15-31 and 7.6-16 ton/ha^{-1}/y^{-1} respectively. The average erosion rate of Bagmati, Trishuli, Karnali and Ganges are 45.5, 18.25, 21 and 13.5 ton/ha^{-1}/y^{-1} respectively. Saptakosi river system and Bagmati are high sediment yield river of Nepal.

Figure 3: Large Watershed Soil Erosion of Nepal



Source: Water and Energy Commission Secretariat/ CIDA.(Himalayan Sediment, Issue and Guidelines, 2003).

Similarly, Shankar, (1989) had estimated average soil erosion of Surnagad, Karnali, Seti, Saradaa, Babai, west and east Rapti, Kaligandaki, Seti, Trisuli, Narayani, Lothar, Bagmati, Kulekhani, Bagmati, Kamala, Tamur, Saptakosi, and Kankaimai watersheds ranges from only 1.74 to 102.05 t ha^{-1}/y^{-1} with an average of 31 t ha^{-1}/y^{-1} (Chalise and Khanal, 1997).

Soil Erosion in Small Watershed

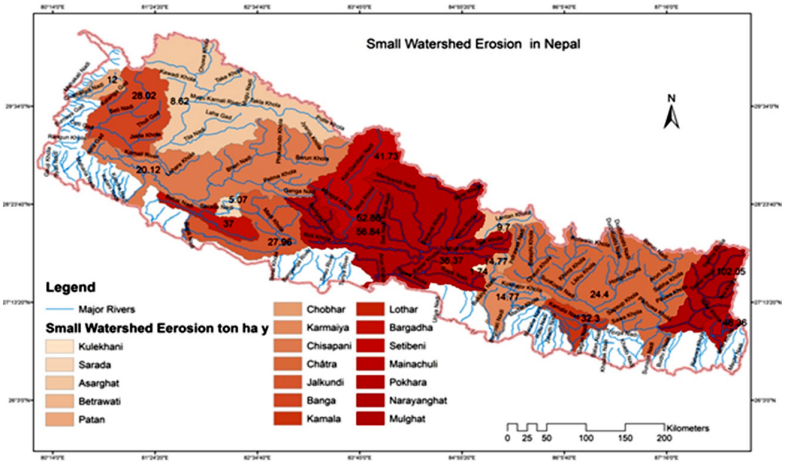
WECS (2003) shows the small watershed or rives soil erosion status of Nepal. The area of water shed is less than or equal to 12500 sqkm and greater than or equal to 8 sqkm. The lowest sediment yield from Surma Khola watershed (2.1 t ha^{-1}/y^{-1}) and the highest sediment transported from Chhukarpo Khola Up stream was 29.8 t ha^{-1}/y^{-1}. There is no differences of sediment yield between small and large watershed (see table 4).

Table 4 Small Watershed Erosion Status of Nepal

Small Watersheds	Watersheds in sqkm	Sediment Transport (t ha^{-1}/y^{-1})
Lahore River	63	6.8 (1)
Bamti Khola	8	13.3 (2)
Chhukarpo Khola (upstream)	23.5	29.8 (2)
Chhukarpo Khola (downstream)	369	3.7 (2)
Surma Khola	570	2.1 (2)
HarpanKhola (Phewa Lake)	12000	8.9 (9)
Kukhuri khola	75	17.0 (11)
Anderi Khola	540	15.0 (11)
Jhikhu	11141	11.0 (11)
Sunsdarizal	1553	12.9 (3)
Godavari	1231	3.3 (3)
Bishnumati	614	10.7 (3)
Mahabharat	19	29.0 (4)
Kulekhani (re-1993)	12500	20.45 (10)
Jhikhu	111.41	22.5 (12)
Yarsha	53.38	26.33 (12)

Reference : 1, Impat-1979; 2, Sherchan-1991; 3, Schaffner-1987; 4, Upadhaya-et.al. 1991; 9, Laban-1978; 10, Mulder- 1978;
11, Carson- 1985. 12, Merz- 2004.
Source : Water and Energy Commission Secretariat/CIDA (Himalayan Sediment, Issue and Guidelines 2003).

Figure 3: Small Watershed Soil Erosion of Nepal



Reference: Shankar, 1989; Source; Chalise and Khanal, 1997

Discussion

Monsoon climatic systems play the vital role to occur water erosion in the Himalya (Pal, 2009). As a Himalayan country, Nepal faces water erosion severely and erosion rate is varying with ecological zone (Biot, Blakie, Jacson and Jones, 1989, Gabet, Burbank, Sitaula, Putkonen and Bookhasen, 2008 and Chalise, Kumar and Kristainsen, 2019). According to the theory of Himalayan degradation (THD), growing population need agriculture land to feed the people so that it lead to deforestation and faced severe soil erosion in the Himalaya (Ives, 1987).

Table 5 shows the soil erosion and population density of river watershed of Nepal. Among the 19 watershed, Kulekhani watershed has the minimum area which is 126 sqkm and the Saptakoshi has maximum area which is 59400 sqkm. The average area of watershed is 10187 sqkm. Similarly minimum number of population live in Lother and Kulekhani watershed which are around 80000 population. The maximum about 4.6 million population live in Narayani watershed. The average population of the watershed is about one million. The soil erosion status of the watersheds are as follow: minimum average soil erosion rate (1.74 t ha^{-1}/y^{-1}) take place in Kulekhani watershed whereas maximum soil erosion (102.05 t ha^{-1}/y^{-1}) take place in Tamor watershed. The average soil erosion rate is 20.25 t ha^{-1}/y^{-1}.

Table 5 Population Density Vs Soil Erosiion

Watershed	**Area sqkm**	**Soil Erosion t ha^{-1}/y^{-1}**	**Population**	**Population Density**
Kulekhani	126	1.74	81547	647
Saradha	816	5.07	280012	343
Karnali (Asarghat)	19260	8.62	578686	30
Trisuli	4640	9.70	93888	20
Surnagad	188	12.00	164682	876
Bagmati (Karmaiya)	2720	14.77	2602558	957
Bagmati (Chobhar)	585	14.77	2375229	4060
Karnali (Chisapani)	42890	20.12	1822432	42
Saptakosi	59400	24.40	2876273	48
West Rapti	5150	27.96	1140348	221
Seti	7460	28.02	845770	113
Kamala	1550	32.30	746090	481
Lothar	169	36.37	81228	481
Babai	3000	37.00	636367	212
Kaligandaki	7130	41.73	477216	67
Kankaimai	1148	48.36	351930	307
Seti	582	52.86	347191	597
Narayani	31100	56.84	4604567	148
Tamur	5640	102.05	662494	117

Source : Water and Energy Commission Secretariat/CIDA (Himalayan Sediment, Issue and Guidelines 2003 and CBS, 2011.

The minimum population density of the watersheds are Trishuli, Karnali, and Saptakoshi which are below 50 people per square kilometer and maximum population density occupy in Bagmati watershed which is 4060 people per square kilometer. The average population density of the watershed is 514 people per square kilometer.

Fig. 4 Population Density and Soil Erosion in Nepal

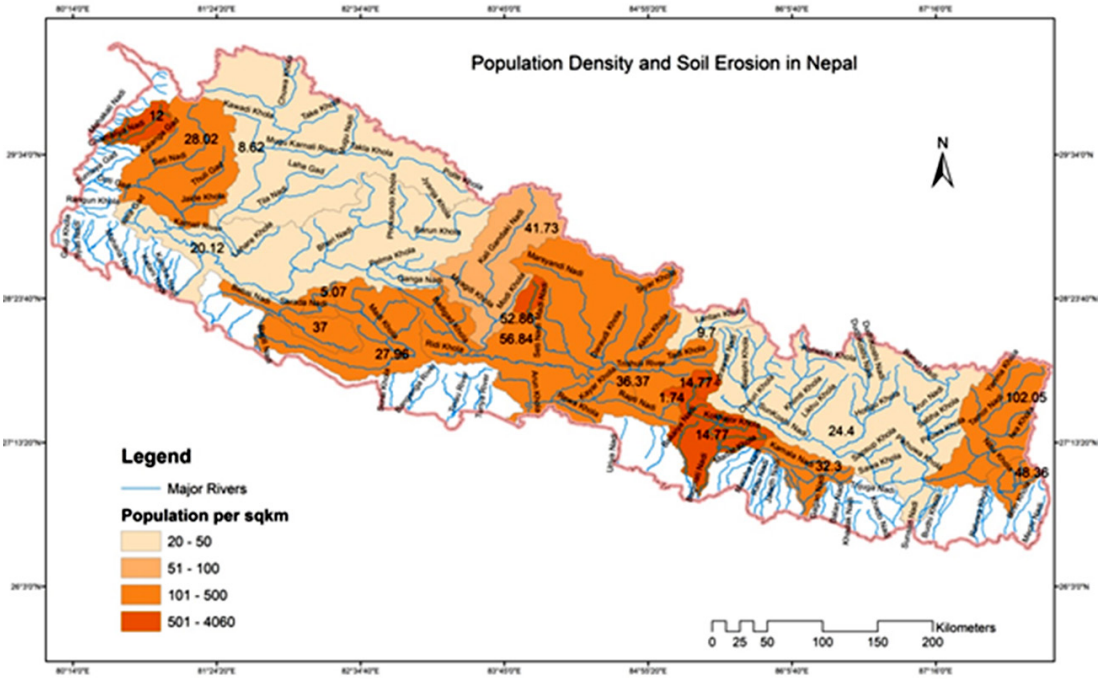


Figure 4 show the population density and soil erosion by watersheds of Nepal. There is below 50 people per square kilometer watersheds have average soil erosion rate (about 20 t ha^{-1}/y^{-1}) and 100 to 500 people per square kilometer watersheds have high soil erosion rate ranges from 27 to 102 t ha^{-1}/y^{-1} . These scenarios partial follow the theory of Himalayan degradation. So that there is still environmental degradation is observed and it is needed in detail study of Himalaya degradation.

Conclusion

Soil is an important natural resource of Nepal Himalaya. The country is facing soil erosion from last century. The water erosion is main soil erosion process of Himalaya and triggered by Monsoon system. It is varying with ecological zone of Nepal Himalaya. The study shows the population pressure on land resources is one of the strongly reason of soil erosion which partially follow the theory of Himalayan degradation. So that there is still environmental degradation is observed and it is needed in detail field based study of Himalaya degradation. The main causes of soil erosion of Nepal Himalaya are Himalaya energy and its people activities.

References

Asian Development Bank, (2015). *Country Environment Notes: Nepal, Country Partnership Strategy: Nepal, 2013–2017*, Asian Development Bank.

Bhandari, G., (2014). A review on soil erosion conservation measure in Nepal. *Peal Journal of Physical and Environmental Science Research,* 2: 41-47.

Biot, Y., Blaikie, P. M., Jacson, C., & Jones, R. P., (1989). *Rethinking Research on Land Degradation in Developing Countries*. WDP Paper No. 289, World Bank, Washington D. C.

Blaikie P. M. Cameron J. & Seddon J. D., (2007) *Nepal in Crisis: Growth and Stagnation at the Periphery*. ADROIT, Delhi, India.

Bjønness, I. M. (1986) Mountain hazard perception and risk-avoiding strategies among the Sherpas of Khumbu Himal, Nepal. International Mountain Society, Særtrykk av: *Mountain research and development*, vol. 6, no 4, 1986 pp 272-292.

Burton, S., Shah, P. B. & Schreier, H. (1989). Soil Degradation from Converting Forest Land into Agriculture in Chitwan District of Nepal. *Mountain research and Development*, Vol. 9, Number 4, Pp. 393 – 404. Downloaded from 202.51.76.211 on Fri, 13 Apr 2018.

Carson, B. (1985). *Erosion and sedimentation processes in the Nepalese Himalaya*, ICIMOD Occasional Pap. no. 1, Kathmandu.

CBS (1998). *A Compendium on Environment Statistics, 1998*. GON., NPC., Central Bureau of Statistics (CBS) Kathmandu Nepal.

CBS, (2014). *Population Monograph of Nepal Volume III: Economic Demography*. GON., NPC., Central Bureau of Statistics (CBS) Kathmandu Nepal.

Chalise, S. R. & Khanal, N. R., (1997). Erosion Processes and their implication in Sustainble Management of Watersheds in Nepal Himalayas. In A. Gustard, S. Blazkova, M. Brilly, S. Demuth, J. Dixon, H. V. Lanen, C. Llast, S. Mkhandi, & E. Servet (Eds.), Proceedings at the Postonjna, Slovenia, Conference: No. 246. FRIEND'97 – Regional Hydrology: Concepts and Models for Sustainable Water Resoure Management (pp 325 – 334). Postojna, Slovenia IAHS Publication. https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers16-04/010026279.pdf

Chalise, D., Kumar, L., Kristainsen, P., (2019). Land Degradation by Soil Erosion in Nepal: A Review. Volume 2, Number 12, *Soil Systems,* Pp 1 – 18.
doi:10.3390/soilsystems3010012.

Cine N. & Mool P. (1981), Landslides in the Kolpa Khola Drainage, Middle Mountains of Nepal Mountain Research and Development 2 (2): 157-173.

Dijkshoorn, J. A., & Huting J. R. M., (2009*). Soil and terrain database for Nepal*. Report 2009/01 (available through: http://www.isric.org), ISRIC – World Soil Information, Wageningen (29 p. with data set)

DesInventar (n.d.). *Definition of Soil Erosion*, Retrieved from https://www.desinventar.net/disasterclassification.html on May 8th 2020.

Department of water Induced Disaster Prevention, (2006).*Collection of Guideline Regarding to the Project Period of DPTC/DMSP, DWIDP*, DWIDP, Kathmandu, Nepal.

FAO. (2017). The future of food and agriculture – Trends and challenges. Rome.

FAO & ITPS. (2015). *Status of the World's Soil Resources (SWSR) – Main Report*. Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy .

Gabet, E. J., Burbank, D. W., Sitaula, B. P.,Putkonen, J., Bookhagen, B., (2008). Modern Erosion Rates in the High Himalayas of Nepal. Issues 267. *Earth and Planetary Science Letters*. Pp 482 – 494. Downloaded from www.elevier.com/locate/EPSL on dec. 2007.

Godard, V., Bourles, D. L., Spinabella, F., Burbank, D. W., Bookhagen, B., Fisher, G. B., Moulin, A., Leanni, L., (2014). Dominance of Tectonics over Climate in Himalayan Denudation. Geology. Volume 42. Number 3. *The Geological Society of America*. Pp 243-246. Downloaded from geology.gsapubs.org on March 4, 2014.

Gurung S. B. (2011). *Slope Stability Analysis of Merin Khola Watershed of Bhimeshwor Municipality, Dolakha District*, CDG, Kathmandu, Nepal.

Gurung, S. B. (2020). Soil Distribution in Nepal. NUTA Journal, 7(1-2), 79–89. https://doi.org/10.3126/nutaj.v7i1-2.39936

Hazarika, M. K., & Honda, K., (2001). Eastimation of Soil Erosion Using Remote Sensing and GIS, Its Valuation and Economic Implication on Agricultural Production. Sttot, D.E., Mohtar, R. H. & Steinhards, G. C., (eds), *Sustaining the Global Farm*. Purde University and USDA-ARS National Soil Erosion Research Laboratory. Pp 1090 – 1093. downloaded from https://www.researchgate.net/publication/228790006 on Dec. 2017

Hegen, T., (1961), *Nepal*, Kummerly and Frey, France.

Impact, P. (1980), *Hydro-metrology for Phewa Watershed: 1979 Data: Project Field Document IWM/PTR/15*, Department of Soil Conservation, Kathmndu Nepal.

International Union of Soil Sciences (IUSS), Food and Agriculture Organization (FAO) and International Atomic Energy Agency (IAEA), *Vienna Soil Declaration*, Internatinal Year of Soils, Veinna, Austria 2015.

Ives, J. (1987). The theory of Himalayan environmental degradation: its validity and application challenged by recent research. *Mountain Research and Devlopment*, 7:189–99

Ives, J. & Messarli, (1989), *The Himalayan Dilemma Reconciling Development and Conservation*, United Nations University, New York.

Joshi, J., Bhattarai, T. N., Sthapit K. M. & Omura H. J. (1998) Soil Erosion and Sediment Disaster in Nepal-A Review, Fac. Agriculture, 42 (3'4),491-502 Kyushu University, Japan.

Karan, P. P., & Iijma. S., (1985). Environmental Stress in Himalaya. Volume 75, Number 1, *American Geological Society* Pp 71 – 92.

Khanal N. R. & Gurung S. B. (2010), *Disasters Induced by Water in the Koshi Basin*, Paper Presented of China International Centre for Integration Mountain Development (CICIMOD) Workshop on Kosi River Basin Project, Emi Mountain, China, August 23-26, 2010.

Lal, R. (2003) Soil erosion and the global carbon budget. *Environment International* 29: 437-450. DOI: 10.1016/S0160-4120(02)00192-7

Land Resource Mapping Project, (1986), *Land System Report: The Soil Landscapes of Nepal*. Kenting Earth Sciences, Kathmandu.

Marasini S. P. (2008), *Disaster Risk Reduction Management in Nepal Country Paper*, July-December, 2008 Asian Disaster Reduction Center, Kobe, Japan.

Ministry of Population and Environment, (2015). *National Action Programme (NAP) on Land Degradation and Desertification, Under the United Nation Conservation to combat Desertification (UNCCD)*. Ministry of Population and Environment - MOPE, Kathmandu, Nepal.

Pal, I. (2009). *Rainfall Trends in India and Their Impact on Soil Erosion and Land Management*. Unpublished PhD Dissertation, St. John's College.

Pradhan B. K., (2007), *Disaster Preparedness for Natural Hazards: Current Status in Nepal*. International Centre for Integration Mountain Development (ICIMOD) Kathmandu, Nepal.

Shah, P. B. (1995). Indigenous agricultural land and soil classifications. Challenges in Mountain Resource Management in Nepal. Processes, *Trends, and Dynamics in Middle Mountain Watershed* . International Centre for Integration Mountain Development, ICIMOD, Kathmandu

Shrestha, D. P., Zink, J. A., & Ranst, E. V., 2004. Modelling Land degradation in the Nepalese Himalaaya. Issues 57, *CATENA*, Pp. 135 – 156 ELSEVIER.

Singh, S. L., Kharel, B. P., Joshi, M. D., & Mathema, P., (2004). *Review and assessment of watershed management strategies and approaches*, Food and Agriculture Organzation (FAO), UN, Rome.

USDA, (2006), *Keys to soil Survey*, Tenth Edition, United States Department of Agriculture, Natural Resources Conservation Service, Washington D.C., USA.

USDA, (2022). *Erosion*. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/landuse/crops/erosion/#:~:text=Soil%20erosion%20involves%20the%20breakdown,water%2C%20wind%2C%20or%20gravity.&text=The%20NRCS%20has%20erosion%20prediction,systems%20to%20address%20soil%20erosion.

Water and Energy Commission Secretariat, (2003), *Himalayan Sediment, Issue and Guidelines*, Ministry of Water and Energy - WECS, Kathmandu Nepal.

Uprety, L. P., 2001. Population Dynamic and Environmental Degradataion in Nepal: An Overview. *Occasional Paper in Socilogy and Anthropology*, Regmi, R. R., Upreti, L. P., & Pokhrel, B., Eds, Vol 7, Central Department of Socialogy and Anthropology (CDSA), TU, Nepal. Pp. 41 – 64.

Zimmerer, K. S., (1993) Soil Erosion and Social (Dis)courses in Cochabamba, Bolivia: Perceiving the Nature of Environmental Degradation, *Economic Geography*, Vol. 69 , Iss. 3, PP 312-327 | Routledge doi: 10.2307/143453, Published online: 09 Jun 2016

https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/landuse/crops/erosion/ Wednesday, 20th December 2017