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Soil Erosion and Sedimentation Rate in the Blue Nile River Basin of Ethiopia

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Abstract: Substantial runoff is a feature of the Ethiopian Nile River Basin because its soils are erodible and poorly organized, resulting in high soil loss and sedimentation rates. The rate of soil erosion and sedimentation in the basin was reported to be quite variable, which could be owing to the methodology utilized and data quality used. By reviewing recent studies, this review primarily aimed to give information on the range of soil erosion and sedimentation rates. Recent studies at small watersheds and basin levels were reviewed. Soil loss and sedimentation rates in Ethiopia's Blue Nile River Basin ranged from 16 to 67.37ton ha^{-1} year^{-1} and 4.2 to 18ton ha^{-1} year^{-1}, respectively. Similarly, at watersheds level soil loss and sedimentation rates were reported to range from 8.25 to 100ton ha^{-1} year^{-1} and 1.1 to 43.34ton ha^{-1} year^{-1} respectively. Hence it is concluded that high soil erosion and sedimentation rates are serious problems in the basin. So, appropriate soil and water conservation measures are recommended throughout the basin to reduce both on-site and off-site effects of soil erosion. It is also highly advised to utilize uniform techniques and a common data source for soil erosion and sedimentation rates estimation at different levels.

Keywords: Blue Nile River Basin, Erosion Rate, Sedimentation Rate

1. Introduction

In the Blue Nile River Basin system, the Ethiopian Plateau is the primary supplier of sediment [1]. Land degradation caused by erosion is the most common problem in Ethiopia's highlands, where a large amount of fertile soil is lost each year [2-4]. The Blue Nile Basin has higher runoff than the White Nile through the catchment area [5], and its soils are erodible and poorly structured [6], which could lead to increased soil erosion and sedimentation in the river basin. In the upper Blue Nile Basin, poor land-use practices and a lack of soil conservation methods are important contributors to downstream reservoir sedimentation [7].

In Ethiopia, average annual soil loss has been recorded as 42ton ha^{-1} year^{-1} for many decades, and it has recently been reported as 12ton ha^{-1} year^{-1}, with estimates ranging from 300ton ha^{-1} year^{-1} in very exposed locations to 100ton ha^{-1} year^{-1} in Ethiopia's highlands. The estimated sediment delivery ratio (SDR) at the basin level reveals that about 55% of sediment remains in the landscape and does not enter the stream system [8].

There are various research papers on soil loss and sedimentation rates in Ethiopia's Blue Nile Basin at the basin, sub-basin, catchment, and watershed levels. Though the risk of soil erosion and sediment yields varies by location, some environmental (e.g., landforms; soil characteristics; rainfall amount, intensity, and distribution; vegetation type and cover; lithology) and socio-economic factors, such as the implementation of anti-erosive land use and management practices, generally control the course of action [9, 10].

Different watersheds in the basin have reported significant soil loss rates that are beyond the acceptable level, and the outcome varies from place to place due to various variables. Also, different reports from the same location exist, which could be related to data quality or methodology used. Only a handful of the various research on soil erosion/sediment load in the Blue Nile Basin questioned the methodology employed to estimate the amount and/or rate of soil loss and sediment. The major goal of this review is to determine the rate of soil loss and sedimentation in Ethiopia's Blue Nile basin by evaluating recent research findings at the basin, sub-basin, catchment, and watershed levels.

2. Description of the Study Area

The Blue Nile River (known as the Abay River in Ethiopia) rises in the Ethiopian highlands in the region of West Gojam and flows northward into Lake Tana. It leaves the south-eastern corner of the lake, flowing first south-east before looping back on itself, flowing west and then turning north-west close to the border with Sudan. In the highlands, the basin is composed mainly of volcanic and Precambrian basement rocks with small areas of sedimentary rocks [11].

The catchment is cut by deep ravines in which the major tributaries flow. The valley of the Blue Nile River itself is 1300 m deep in places. The primary tributaries in Ethiopia are the Bosheilo, Welaka, Jemma, Muger, Guder, Finchaa, Anger, Didessa and Dabus on the left bank and the North Gojam, South Gojam, Wombera and Beles on the right bank [11].

3. Soil Loss Rate in Blue Nile River Basin

The average annual soil loss in Ethiopia is 12tons ha^{-1} per year [12], but it can be as high as 300tons ha^{-1} year^{-1} in very exposed locations with steep slopes and no vegetation cover [13]. Soil erosion rates in Ethiopian Highlands range from 0.4 to 88tons per ha per year, with an average of 12tons ha^{-1} year^{-1}; the main hotspot locations for soil erosion are steep slopes, gullies, community grazing, and cultivated lands [14]. In contrast, the Ethiopian Highlands Reclamation Study (EHRS) of 1984, on the other hand, concluded that 100ton ha^{-1} year^{-1} soil is eroded and lost from the highlands, resulting in an annual soil loss of 8mm depth [5]. The most severe erosion (50-100tons ha^{-1} year^{-1}) is found mostly south of the Abay, and includes the top and middle steep and cultivated slopes of the Middle Abay Gorge Sub-basin in East Wellega, as well as two subsidiary sections of the Upper Didessa Valley with high erosion danger [11].

Estimation of potential soil loss for conservation planning in Ethiopia's upper Blue Nile Basin was reported as 28.68 [15]. Amdihun A. *et al.* [16] used an empirical model to calculate a soil loss rate of 67.37tons ha^{-1} year^{-1} in Ethiopia's Blue Nile basin, resulting in a total soil loss of 1.3 billion tons per year. According to Alamirew T. [17], the average soil erosion rate in the Blue Nile river basin was predicted at 30.5ton ha^{-1} year^{-1} based on small watersheds, but this number is too high for a basin the size of Abbay (Blue Nile), and 7 to 10ton ha^{-1} year^{-1} is a reasonable estimate. According to Mengistu D. *et al.* [18], the Blue Nile Basin's antecedent mean annual soil loss was 16ton ha^{-1} year^{-1} and when compared to the findings of Amdihun A. *et al.* [16], this result is more than 70% lower.

The upper Blue Nile River Basin topsoil loss rate was reported to be 27.5ton ha^{-1} year^{-1}, with gully erosion accounting for 10% of the total, and roughly 39% of the river basin area suffering from severe to very severe (>30ton ha^{-1} year^{-1}) soil erosion [19]; and at Agew Mariam watershed it was reported 25ton ha^{-1} year^{-1} and more than of the 33% of the watershed encounters over tolerable soil loss rate [20].

In the Andessa watershed, soil loss was estimated at 55 tons per hectare per year, with an increasing trend since 1985 [21]. Similarly, the Gilgel Abbay watershed saw a 32.8 ton ha^{-1} year^{-1} soil loss rate [22]. On non-treated, previously treated, and recently constructed soil bund treated sites in the Gumara watershed Upper Blue Nile Basin, respectively, 58.1, 45.64, and 23.5ton ha^{-1} year^{-1} soil loss was found [23]. The upper Beles watershed had a 13.2ton ha^{-1} year^{-1} soil erosion rate, according to Kebede Y. S. *et al.* [24].

In North-Western Ethiopia, Olika G. and Iticha B. [25] reported a 33.7ton ha^{-1} year^{-1} topsoil loss rate, and about 45.3 percent of the North Gojjam sub-basin of the upper Blue Nile river basin was reported to be at high to very high soil loss risk, with an average soil loss of 46ton ha^{-1} year^{-1} [26].

The mean annual soil loss in the North Showa of the Ajema watershed is 8.25ton ha^{-1} year^{-1} [27]; contrarily, the mean annual soil loss in the Chereti watershed, North Eastern Ethiopia, is 38.7ton ha^{-1} year^{-1} [28]. Similarly, more than 75% of the Koga watershed is prone to soil erosion or is in an erosion hotspot [29]. According to Gashaw T. *et al.* [30], the Gelleda watershed's mean soil loss was estimated to be 23.7ton ha^{-1} year^{-1}, with estimates ranging from nil to 237ton ha^{-1} year^{-1}. Soil erosion in the Chomega watershed is projected to be greater than 125tons ha^{-1} year^{-1}, with more than 58 percent of the region experiencing severe or very severe erosion of more than 80 tons per hectare per year [31].

Soil erosion rates in the semi-arid highlands of Northern Ethiopia's Agula watershed were decreased by 64 percent, from 28 to 10tons ha^{-1} year^{-1}, due to watershed management methods implemented in the area [32]. More than 13.4% and 27.93% of the Rib watershed in the Lake Tana sub-basin, and in the northwestern section of Ethiopia's highlands, are at risk of soil erosion, respectively [33].

In the Hanger river watershed of North West Ethiopia, mean soil erosion potential was assessed at 55.5tons ha^{-1} year^{-1} in 2005 and 70.5tons ha^{-1} year^{-1} in 2017, with an upward trend [34]. Soil erosion rates in the Guder watershed in Central Ethiopia ranged from 25 to 30tons ha^{-1} yr^{-1} [35]. According to this, the estimated annual mean soil loss rate of the Blue Nile basin's Beshilo catchment was determined to be 37ton ha^{-1} year^{-1}, which is more than two times higher than the maximum tolerated soil loss value (16tonha^{-1} year^{-1}) [36]. In the Anjeb watershed in North Western Ethiopia, annual soil loss was estimated to be 17.3tonha^{-1} year^{-1} [37].

4. Sedimentation Rate in Blue Nile River Basin

The Nile tributaries that originate on the Ethiopian plateau transport significant amounts of sediment, estimated to be between 160 and 180 million tons per year. Due to sedimentation, dam reservoirs built on these tributaries are losing capacity at an alarming rate, with the Great Ethiopian Renaissance Dam (GERD) reservoir estimated to have an annual sediment load of 245 million tons [38]. The Ethiopian Highlands are a major source of sediment in the Nile [39];

and Ethiopia's Blue Nile Basin is a major source of sediment load (122 million tons year^{-1}) in the reservoir of Rosaries Dam on the Ethio-Sudan border [5].

The Blue Nile river basin's 17 year simulation resulted in an annual average suspended sediment yield of 4,842,000 tons year^{-1}, or 7.5tons ha^{-1} year^{-1} [40]. According to Fetene F. *et al.* [41], the average annual sediment yield of the Blue Nile river basin was 4.26ton ha^{-1} year^{-1}, with a total of 91.3M tonnes year^{-1} from the entire Blue Nile river basin of Ethiopia; and according to Betrie G. *et al*. [42], it is 6.34ton ha^{-1} year^{-1}, with the result reduced by 44 percent, 41 percent. Easton Z. *et al*. [43] showed that the sediment export rate in the Blue Nile river basin ranged from 0 to 12ton ha^{-1} year^{-1}. The mean silt deposition rate in the Blue Nile basin reservoir is estimated to be between 13 and 20 million m^3 per year [44], which is equivalent to 1800ton km^{-2} year^{-1} or 18ton ha^{-1} year^{-1}. The projected mean annual sedimentation rate in the Angereb reservoir was reported as 1200ton km^{-2}year^{-1}, or 12ton ha^{-1} year^{-1}.

The mean sediment yield in the Guder watershed in Ethiopia's Central Highlands was 6.79, 8.65, and 9.44 tons ha^{-1} year^{-1} in 1973, 1995, and 2015, respectively, indicating an upward trend [35]. These results reveal that the rate of sedimentation in the watershed is increasing. Similarly, in 2015, the Andessa watershed of the upper Blue Nile Basin silt yielded 22.1ton ha^{-1} year^{-1} an increase from 1985 [21]. The Nashe catchment had a high sediment yield of 25-27tons ha^{-1} year^{-1}, which covered about 60% of the catchment area [45]; while the Gumera watershed's average annual sediment yield is reported to be 11 to 12-tons ha^{-1} year^{-1} [46].

The sediment yield in Shina and Selamko reservoirs in the Tana Sub-basin of Lake Tana was found to be more than the global average at 24.99 ton ha^{-1} year^{-1} and 43.34 ton ha^{-1} year^{-1}, respectively [47]. More than 18.4 percent of the Lake Tana sub-basin has considerable erosion potential, with sediment yields exceeding 30 tons ha^{-1} year^{-1} [48]. With an annual average of 31.02M suspended load and bed load, the rate of sedimentation in Lake Tana was observed to be 9.8 kg m^{-2} year^{-1}, which is equivalent to 9.8ton ha^{-1} year^{-1} [49].
Hurni H. [50] observed a sediment export rate of 1.1ton ha^{-1} year^{-1} in vegetation-rich catchments in South-Western Ethiopia. Similarly, the average annual sediment yield in the Anjeb watershed in north-western Ethiopia was calculated to be 2.11tons ha^{-1} year^{-1} [37]. Contrarily, the average sediment yield for 11 reservoirs in the Ethiopian Blue Nile basin was determined to be 9.89ton ha^{-1} year^{-1} [51]. Also, in the May Zegzeg catchment, Northern Ethiopian highlands, Jan Nyssen [52] reported a 5.6ton ha^{-1} year^{-1} mean sediment yield, and Asfaw A. T. [7] reported 13.6ton ha^{-1} year^{-1} sedimentation for Megech Dam in the area.

5. Conclusion

Soil erosion from Ethiopia's highlands is a constant threat to Ethiopians living in the Blue Nile river basin's biophysical environment as well as their socioeconomic well-being. The Blue Nile river basin in Ethiopia transports a lot of sediment, which puts dams, reservoirs, and irrigation infrastructure in Ethiopia and downstream countries at risk. Many studies show that both soil erosion and sedimentation rates are higher than national records, which are also higher than the allowed limit. Mean soil loss rates at small watersheds and basin levels reported to be 8.25 to 100ton ha^{-1} year^{-1} and 16 to 67.37ton ha^{-1} year^{-1}, respectively; whereas sedimentation rates were reported to be 1.1 to 43.34ton ha^{-1} year^{-1} and 4.2 to 18ton ha^{-1} year^{-1} at small watersheds and basin level, respectively.

To reach such results, researchers frequently used GIS-based USLE, RUSLE, MUSLE, SWAT, SDR, and field measurement. These studies differ, which could be due to the method used and the quality of the data collected, as well as other aspects including location, climate, soil, and human-environmental interaction. By using standardized methodology and validated data as an input, soil erosion and sedimentation rate report variance based on methodologies and data quality must be avoided as much as possible in the basin.

References

[1] Hydrosult, Tecsult, DHV, Nile Consult, Comatex Nilotica and T & A Consulting, 2006. Cooperative regional Assessment (CRA) for Watershed Management. Transboundary Analysis Abay-Blue Nile Sub-Basin. *Report to Eastern Nile Technical Regional Office, Nile Basin Initiative.*

[2] Betrie GD, Mohamed YA, Van Griensven A, Srinivasan R. 2011. Sediment management modelling in the Blue Nile Basin using SWAT model. *Hydrol Earth Syst Sci 15 (3): 807–818* 1824105ja.

[3] Mekonnen M, Keesstra SD, Baartman JE, Ritsema CJ, Melesse AM (2015). Evaluating sediment storage dams: structural of-site sediment trapping measures in northwest Ethiopia. *Cuadernos de Investigación Geográfca 41: 16. https://doi.org/10.18172/cig.2643*144912op.

[4] Gessesse B, Bewket W, Bräuning A (2016). Determinants of farmers' tree planting investment decisions as a degraded landscape management strategy in the central highlands of Ethiopia. *Solid Earth 7: 639–650. https://doi. org/10.5194/se-7-639-2016*22251606ja.

[5] Ahimed A. A. and H. A. E. Ismail. 2008. Sediment in the Nile river Basin system. *International Hydrological Programme. International Sediment Initiatives. Khartoum, Sudan.*

[6] Zaitchik, B. F., Simane, B., Habib, S., Anderson, M. C., Ozdogan, M., & Foltz, J. D. (2012). Building climate resilience in the blue nile/abay highlands: A role for earth system sciences. *International journal of environmental research and public health, 9 (2), 435-461.*2251615ja.

[7] Abebe Tarko Assfaw, 2020. Modeling Impact of Land Use Dynamics on Hydrology and Sedimentation of Megech Dam Watershed, Ethiopia. *Hindawi the Scientific World Journal https://doi.org/10.1155/2020/6530278*144900op.

[8] Awulachew S. B.; McCartney, M.; Steenhuis, T. S; Ahmed, A. A. 2008. A review of hydrology, sediment, and water resource use in the Blue Nile Basin. *Colombo, Sri Lanka: International Water Management Institute. 87p. (IWMI Working Paper 131)* 47504an.

[9] Amare B (2007). Landscape transformation and opportunities for sustainable land management along the eastern escarpment of Wollo (EEW), Ethiopia. *PhD dissertation. University of Bern, Bern.*

[10] Bewket W. 2007. Soil and water conservation intervention with conventional technologies in northwestern highlands of Ethiopia: acceptance and adoption by farmers. *Land Use Policy 24: 404–416*671525ja.

[11] Matthew P. McCartney & Michael Menker Girma (2012): Evaluating the downstream implications of planned water resource development in the Ethiopian portion of the Blue Nile River, Water International, 37: 4, 362-379: http://dx.doi.org/10.1080/02508060.2012.706384.

[12] Tsegaye B. 2009. Effect of Land Use and Land Cover Changes on Soil Erosion in Ethiopia. *Int J Agric Sc Food Technol 5 (1): 026-034. DIO: 10.17352/2455-815X.000038*2251613ja.

[13] Demeke, A. B. 2003. Factors influencing the adoption of soil conservation practices in North-western Ethiopia. *Discussion Papers (Germany).*

[14] Tamene, L., Adimassu, Z., Ellison, J., Yaekob, T., Woldearegay, K., Mekonnen, K., Thorne, P. and Quang Bao Le. 2017. Mapping soil erosion hotspots and assessing the potential impacts of land management practices in the highlands of Ethiopia. *Geomorphology 292 (1): 153–163.*2251611ja.

[15] Nega T. Endalamaw, Mamaru A. Moges, Yadeta S. Kebede, Bekalu M. Alehegn, Berhanu G. Sinshaw, 2021. Potential soil loss estimation for conservation planning, upper Blue Nile Basin, Ethiopia. *Environmental Challenges, Volume 5, 2021, 100224, ISSN 2667-0100; https://doi.org/10.1016/j.envc.2021.100224.*144914op.

[16] Amdihun A., Gebremariam E., Rebelo L. and Zeleke G. 2014. Modeling soil erosion dynamics in the Blue Nile (Abbay) basin: A landscape approach. *Research Journal of Environmental science 8 (5): 243-258, 2014; ISSN 1819-3412/DOI. 10.3923/rjes.2014. 243.258*2191861ja.

[17] Tena Alamirew 2020. Hydro-Sedimentation burden shift in the Blue Nile (Abbay) Basin; *International conference on Nile and GERD: Presentation 3.*

[18] Mengistu D., Bewket W., Lal R. (2015) soil erosion hazard under the current and potential climate change induced loss of soil organic matter in the upper blue nile (Abay) River Basin, Ethiopia. In: Lal R., Singh B., Mwaseba D., Kraybill D., Hansen D., Eik L. (eds) Sustainable Intensification to Advance Food Security and Enhance Climate Resilience in Africa. *Springer, Cham. https://doi.org/10.1007/978-3-319-09360-4_7.*76850bc.

[19] Haregeweyn, N.; Tsunekawa, A.; Poesen, J.; Tsubo, M.; Meshesha, D. T.; Fenta, A. A.; Nyssen, J.; Adgo, E. 2017. Comprehensive assessment of soil erosion risk for better land use planning in river basins: *Case study of the Upper Blue Nile River. Sci. Total Environ., 574, 95–108.*144906op.

[20] Gebrehana Girmay, Awdenegest Moges and Alemayehu Muluneh. 2020. Estimation of soil loss rate using the USLE model for Agewmariayam Watershed, northern Ethiopia. *Agric & Food Secur (2020) 9: 9 https://doi.org/10.1186/s40066-020-00262-w*144905op.

[21] Temesgen Gashaw, Tafa Tulu, Mekuria Argaw, and Abeyou W. Worqlul. 2019. Modeling the impacts of land use–land cover changes on soil erosion and sediment yield in the Andassa watershed, upper Blue Nile basin, Ethiopia. *Environmental Earth Sciences (2019) 78: 679; https://doi.org/10.1007/s12665-019-8726-x*144916op.

[22] Gashaw T, Worqlul AW, Dile YT, Addisu S, Bantider A, Zeleke G (2020) Evaluating potential impacts of land management practices on soil erosion in the Gilgel Abay watershed, upper Blue Nile basin. *Heliyon 6 (8): e04777*144904op.

[23] Belayneh, M., Yirgu, T. & Tsegaye, D. 2020. Runoff and soil loss responses of cultivated land managed with graded soil bunds of different ages in the Upper Blue Nile basin, Ethiopia. *Ecol Process 9, 66 (2020). https://doi.org/10.1186/s13717-020-00270-5*144901op.

[24] Kebede Y. S., N. T. Endalamawa, B. G. Sinshawb, H. B. Atinkut. 2021. Modeling soil erosion using RUSLE and GIS at watershed level in the upper beles, Ethiopia. *Environmental Challenge 2 (2021): 100009; https://doi.org/10.1016/j.envc.2020.100009* 144907op.

[25] Olika, G.; Iticha, B. 2019. Assessment of Soil Erosion Using RUSLE and GIS Techniques: A Case of Fincha'a Watershed, Western Ethiopia. *Am.-Euras. J. Agric. Environ. Sci., 19, 31–36.*2251610ja.

[26] Ewunetu, A.; Simane, B.; Teferi, E.; Zaitchik, B. F. 2021. Mapping and Quantifying Comprehensive Land Degradation Status Using Spatial Multicriteria Evaluation Technique in the Headwaters Area of Upper Blue Nile River. *Sustainability, 13, 2244. https://doi.org/10.3390/ su13042244*144902op.

[27] Tilahun H, Taddesse G, Melese A, Mebrate T. 2018. Assessment of spatial soil erosion hazard in Ajema Watershed, North Shewa Zone, Ethiopia. *Adv Plants Agric Res. 2018; 8 (6): 552-558. DOI: 10.15406/apar.2018.08.00384*2094682ja.

[28] Negese A., Fekadu E. and Getnet H., 2021. Potential Soil Loss Estimation and Erosion-Prone Area Prioritization Using RUSLE, GIS, and Remote Sensing in Chereti Watershed, Northeastern Ethiopia. *Air, Soil and Water Research Volume 14: 1–17 Air, Soil and Water Research; Volume 14: 1–17: DIO: 10.1177/1178622120985814*144915op.

[29] Assefa, T. T., Jha, M. K., Tilahun, S. A., Yetbarek, E., Adem, A. A. & Wale, A. 2015. Identification of Erosion Hotspot Area using GIS and MCE Technique for Koga Watershed in the Upper Blue Nile Basin, Ethiopia. *American Journal of Environmental Sciences, 11 (4), 245-255. https://doi.org/10.3844/ajessp.2015.245.255*2251601ja.

[30] Gashaw T, Tulu T, Argaw M. 2017. Erosion risk assessment for prioritization of conservation measures in Geleda watershed, Blue Nile basin, Ethiopia. *Environ Syst Res 6: 1*144903op.

[31] Bewket, W., Teferi, E., 2009. Assessment of soil erosion hazard and prioritization for treatment at the watershed level: case study in the Chemoga Watershed, Blue Nile Basin, Ethiopia. *Land Degrad. Dev. 20, 609–622.* 1273689ja.

[32] Fenta, A. A., Yasuda, H., Shimizu, K. *et al.* Dynamics of Soil Erosion as Influenced by Watershed Management Practices: A Case Study of the Agula Watershed in the Semi-Arid Highlands of Northern Ethiopia. 2016. *Environmental Management 58, 889–905 (2016). https://doi.org/10.1007/s00267-016-0757-4*2251605ja.

[33] Berhanu G. Sinshaw, Abreham M. Belete, Agumase K. Tefera, Abebe Birara Dessie, Belay B. Bizuneh, Habtamu T. Alem, Simir B. Atanaw, Daniel G. Eshete, Tsegaye G. Wubetu, Haimanot B. Atinkut, Mamaru A. Moges. 2021. Prioritization of potential soil erosion susceptibility region Using Fuzzy Logic and Analytical Hierarchy process, Upper Blue Nile Basin, Ethiopia. *Water-energy Nexus, Volume 4; Pages 10-24, ISSN 2588-9125, https://doi.org/10.1016/j.wen.2021.01.001;(https://www.sciencedirect.com/science/article/pii/S2588912521000011)*2251602ja.

[34] Tukura, N. G., Akalu, M. M., 2019. Soil erosion risk assessment due to land use/land cover changes (LULC) in Hangar River watershed, Northwest Ethiopia. Journal of Sedimentary Environments, 4 (4): 379- 3862251614ja.

[35] Kidane M., Bezie A., Kesete N., Tolessa T. 2019. The impact of land use and land cover (LULC) dynamics on soil erosion and sediment yield in Ethiopia. *Heliyon 5 (2019) e02981; https://doi.org/10.1016/j.heliyon.2019.e02981.*144908op.

[36] Yesuph, A. Y., and Dagnew, A. B. 2019. Soil erosion mapping and severity analysis based on RUSLE model and local perception in the Beshillo Catchment of the Blue Nile Basin, Ethiopia. *Environ Syst Res 8, 17; https://doi.org/10.1186/s40068-019-0145-1*144917op.

[37] Lewoye Tsegaye and Rishikesh Bharti 2021. Soil erosion and sediment yield assessment using RUSLE and GIS-based approach in Anjeb watershed, Northwest Ethiopia.*SN Applied Sciences, 3: 582; https://doi.org/10.1007/s42452-021-04564-x*144910op.

[38] Tadesse Tufa Borji, 2013. Sedimentation and sustainability of hydropower reservoirs: Case of GERD on the Blue Nile River in Ethiopia. *A MSc. Thesis submitted to Norwegian University of Science and Technology.*

[39] Ndorimana, L., Saad, S. A., Eldaw, A. K., Naggar, O. M., Nindamutsa, A., Chane, B., Fadul, H. (2005). "Watershed Erosion and Sediment Transport". *Group III, Nile Basin Capacity Building Network for River Engineering (NBCBN-RE), River Morphology, Research Cluster, Sudan.*

[40] Nadew B, Chaniyalew E, Tsegaye T (2018) Runoff Sediment Yield Modeling and Development of Management Intervention Scenarios, Case Study of Guder Watershed, Blue Nile Basin, Ethiopia. *Hydrol Current Res 9: 306. doi: 10.4172/2157-7587.1000306*144913op.

[41] Fetene, F., Awulachew Seleshi Bekele andTeklie, N., 2009. Development of rainfall-runoff-sediment discharge relationship in the Blue Nile Basin. *Conference Papers h042512, International Water Management Institute.*

[42] BetrieG. D., MohamedY. A., A. van Griensven, R. Srinivasan, and A. Mynett. 2010. Sediment management modelling in Blue Nile Basin using SWAT model. *Hydrol. Earth Syst. Sci. Discuss., 7, 5497–5524, 2010 www.hydrol-earth-syst-sci-discuss.net/7/5497/2010/ doi: 10.5194/hessd-7-5497-2010*2251603ja.

[43] Easton Z. M., Fuka D. r., White E. D., Collicks A. S., Ashagre B. B, 2010. A multi basin SWAT Model analysis of runoff and sedimentation in the Blue Nile, Ethiopia. *Hydrol. Earth Syst. Sci., 14: 1827.1841*1277046ja.

[44] MoWR, 1998. Abay river basin master plan, Phase 2 data collection sites investigation survey and analysis. *Volume XXI part 7. MoWR (Ministry of Water Resources), Addis Ababa, Ethiopia.*

[45] Dereje Gizaw Namomsa, Tamene Adugna, Swat Based Soil Erosion Modeling of Nashe, Blue Nile Basin, Ethiopia. 2019. *Journal of Civil, Construction and Environmental Engineering. Vol. 4, No. 1, 2019, pp. 35-41. doi: 10.11648/j.jccee.20190401.14*2251604ja.

[46] Tenaw M, Awulachew BS (2009) Soil and Water Assessment Tool (SWAT) Based runoff and Sediment Yield Modeling: A Case of the Gumera Watershed in Lake Tana Sub basin. *Intermediate Results Dissemination Workshop on "Improved Water and Land Management in the Ethiopian Highlands: Its Impact on Downstream Stakeholders Dependent on the Blue Nile" IWMI Sub regional office for East Africa and Nile Basin, Ethiopia.*

[47] Moges, M. M., Abay, D., & Engidayehu, H. (2018). Investigating reservoir sedimentation and its implications to watershed sediment yield: The case of two small dams in data-scarce upper Blue Nile Basin, Ethiopia. *Lakes and Reservoirs: Research and Management, 23 (3), 217–229. https://doi.org/10.1111/lre. 12234.*2251609ja.

[48] Shimelis G. Setegn, Ragahavan Srinivasan, Bijan Dargahi1 and Assefa M. Melesse, 2009. Spatial delineation of soil erosion vulnerability in the Lake Tana Basin, Ethiopia. Hydrol. *Process. Published online in Wiley Inter Science (www.interscience.wiley.com) DOI: 10.1002/hyp.7476*2013277ja.

[49] Lemma H., Frankl A., Dessie M., Poesen J., Adgo E., Nyssen J. 2020. Consolidated sediment budget of Lake Tana, Ethiopia (2012–2016). *Geomorphology, Volume 371, ISSN 0169-555X, https://doi.org/10.1016/j.geomorph.2020.107434.*144909op.

[50] Hurni H. 1985. Erosion–productivity–conservation systems in Ethiopia. *Proceedings 4th International Conference on Soil Conservation, Maracay, Venezuela; 654–674.*

[51] Haregeweyn N, Poesen J, Deckers J, et al. (2008) Sediment-bound nutrient export and associated costs from micro-dam catchments of Northern Ethiopia. *Land Degradation and Development 19: 136–152.*2251607ja.

[52] Jan Nyssen, Jean Poesen, Jan Moeyersons, Mitiku Haile and Jozef Deckers, 2007. Dynamics of soil erosion rates and controlling factors in the Northern Ethiopian Highlands – towards a sediment budget. *Earth Surf. Process. Landforms (2007); (www.interscience.wiley.com) DOI: 10.1002/esp.1569*2251608ja.