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Assessing Soil Erosion Hazards using Land-Use Change and Landslide Frequency Ratio Method: A Case Study of Sabaragamuwa Province, Sri Lanka

Sumudu Senanayake [1], Biswajeet Pradhan [1,2,*], Alfredo Huete [1] and Jane Brennan [1]

[1] The Centre for Advanced Modelling and Geospatial Information Systems (CAMGIS), Faculty of Engineering and IT, University of Technology Sydney, Sydney, 2007 NSW, Australia; sumudu.senanayake@student.uts.edu.au (S.S.); alfredo.huete@uts.edu.au (A.H.); jane.brennan@uts.edu.au (J.B.)

[2] Department of Energy and Mineral Resources Engineering, Sejong University, Choongmu-gwan, 209 Neungdong-ro, Gwangjin-gu, Seoul 05006, Korea

* Correspondence: Biswajeet.Pradhan@uts.edu.au or biswajeet24@gmail.com

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Abstract: This study aims to identify the vulnerable landscape areas using landslide frequency ratio and land-use change associated soil erosion hazard by employing geo-informatics techniques and the revised universal soil loss equation (RUSLE) model. Required datasets were collected from multiple sources, such as multi-temporal Landsat images, soil data, rainfall data, land-use land-cover (LULC) maps, topographic maps, and details of the past landslide incidents. Landsat satellite images from 2000, 2010, and 2019 were used to assess the land-use change. Geospatial input data on rainfall, soil type, terrain characteristics, and land cover were employed for soil erosion hazard classification and mapping. Landscape vulnerability was examined on the basis of land-use change, erosion hazard class, and landslide frequency ratio. Then the erodible hazard areas were identified and prioritized at the scale of river distribution zones. The image analysis of Sabaragamuwa Province in Sri Lanka from 2000 to 2019 indicates a significant increase in cropping areas (17.96%) and urban areas (3.07%), whereas less dense forest and dense forest coverage are significantly reduced (14.18% and 6.46%, respectively). The average annual soil erosion rate increased from 14.56 to 15.53 t/ha/year from year 2000 to 2019. The highest landslide frequency ratios are found in the less dense forest area and cropping area, and were identified as more prone to future landslides. The river distribution zones Athtanagalu Oya (A-2), Kalani River-south (A-3), and Kalani River-north (A-9), were identified as immediate priority areas for soil conservation.

Keywords: soil erosion; land-use change; remote sensing; GIS; RUSLE; Sri Lanka

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The following tables and figures provide the supplementary information pertaining to respective sections of this manuscript. For example **Figure S1.** shows the details of average annual rainfall from 8 rain gauge stations at Sabaragamuwa province of Sri Lanka.

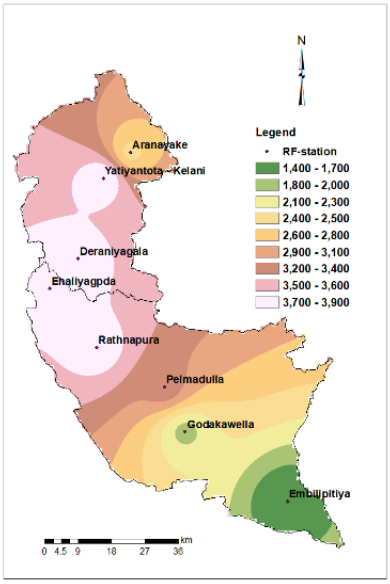

Figure 1. Average annual rainfall at Sabaragamuwa Province of Sri Lanka.

Table 1. The details of average annual rainfall of the area.

	Longitude	Latitude	Period	Annual rainfall (mm)
Aranayake	80.4667	7.18316	1988–2018	2440.0
Deraniyagala	80.3390	6.92312	1988–2018	3749.0
Rathnapura	80.3847	6.70558	1988–2018	3840.0
Pelmadulla	80.5500	6.61000	1988–2018	3260.1
Yatiyantota - Kelani	80.4000	7.12000	1988–2018	3916.9
Ehaliyagpda	80.2700	6.85000	1988–2018	3849.9
Embilipitiya	80.8500	6.33000	1988–2018	1435.2
Godakawella	80.6000	6.50000	1988–2018	1904.0

Table S2. C-factor values and Conservation practices (P-factor) values as per land-cover class and land slope class adapted from Senanayake, Munasinghe & Wickramasinghe (2013); Wijesekera & Samarakoon (2001).

No	Land use type	P Factor Value	C-factor
1	Dense forest	1.0	0.20
2	Low dense forest	0.5	0.45
3	Cropping area	0.35	0.57
4	Paddy	0.5	0.43
5	Urban area	0.8	0.73
6	Streams	0.3	0.50
7	Water bodies	1.0	0.20

Confusion matrix between ground truth data and land-use classes for 2000 and 2010 given in Table S3 and S4.

Table 3. The confusion matrix between ground truths and respective values of Commission, Omission, Producer accuracy and User's accuracy for classified land use classes for 2000.

			Ground Truth Data							
			A	B	C	D	E	F	G	**Total**
Land use dataset	A	Dense forest	23		1		3			27
	B	Water bodies		37						37
	C	Streams			23					23
	D	Cropping area	1		1	47				49
	E	Less dense forest			7		61			68
	F	Urban area						12		12
	G	Paddy	4		4				29	37
		Total	**28**	**37**	**36**	**47**	**64**	**12**	**29**	**267**

	Commission	**Omission**	**Producer accuracy**	**User's accuracy**
Dense forest	27.6	63.8	85.2	82.1
Water bodies	0.0	48.3	100.0	100.0
Streams	0.0	0.0	100.0	63.9
Cropping area	13.0	76.8	95.9	100.0
Less dense forest	28.6	7.3	89.7	95.3
Urban area	0.0	0.0	100.0	100.0
Paddy	68.6	0.0	78.4	100.0

The overall accuracy of image classification is 86.89% and Kappa coefficients is 0.8438.

Table 4. The confusion matrix between ground truths and respective values of Commission, Omission, Producer accuracy and User's accuracy for classified land-use classes for 2010.

			Ground Truth Data							
			A	B	C	D	E	F	G	**Total**
Land use dataset	A	Dense forest	37						1	38
	B	Water bodies		14						14
	C	Streams			21					21
	D	Cropping area				36			1	37
	E	Less dense forest		8			23			31
	F	Urban area						72		72
	G	Paddy							90	90
		Total	**37**	**14**	**21**	**36**	**23**	**72**	**92**	**303**

	Commission	**Omission**	**Producer Accuracy**	**User's Accuracy**
Dense forest	2.63	0.00	97.4	100.0
Water bodies	0.00	57.14	100.0	63.6
Streams	0.00	0.00	100.0	100.0
Cropping area	2.70	0.00	97.3	100.0
Less dense forest	25.81	0.00	74.2	100.0
Urban area	0.00	0.00	100.0	100.0
Paddy	0.00	2.17	100.0	97.8

The overall accuracy of image classification is 96.70% and Kappa coefficients is 0.9150.

Table 5. The major land-use change in each zone.

River basin zone	Dense Forest	Water bodies	Stream	Cropping area	Less dense	Urban area	Paddy	Sign of land-use change
A-1	-144.23	-0.11	2.97	165.79	-103.17	29.41	46.84	Cropping area, Dense forest
A-2	-12.14	-0.01	-0.88	29.66	-23.21	2.55	6.22	Cropping area, Less dense forest
A-3	-67.15	-1.22	-1.13	112.81	-65.10	18.69	12.97	Cropping area, Dense forest
A-4	21.04	-0.59	-22.63	212.38	-181.00	33.55	-10.79	Cropping area, Less dense
A-5	79.96	-0.29	-4.42	-15.31	-39.32	14.17	-32.94	Dense forest, Less dense
A-6	-74.95	2.37	0.06	109.10	-65.63	15.19	11.12	Cropping area, Dense forest
A-7	-20.14	0.14	3.76	20.85	-40.48	13.02	15.86	Less dense forest, Cropping area,
A-8	0.46	0.02	-1.81	63.15	-54.43	4.14	-1.59	Cropping area, Less dense forest
A-9	-101.96	-0.03	-1.02	184.88	-122.93	19.07	27.19	Cropping area, Less dense forest

Reference

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