Supplementary Material

Predicted soil loss and the contribution of soil map units in a tropical protected forest: RUSLE assessment of Ir. H. Djuanda Forest Park, Indonesia

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This Supplementary Material provides the reproducibility details, processing logic, equations, accuracy-assessment table and sensitivity results required to reproduce the analyses described in the manuscript.

S1. Reproducibility metadata

Parameter	Setting
GIS software	ArcMap 10.8.2
CRS	WGS 84 / UTM zone 48S (EPSG:32748)
Processing grid	8.39-m grid; DEMNAS used as snap raster
DEM	DEMNAS, tile 1209-31 (NLP), extended 1 km beyond the park boundary for flow routing
Flow routing	D8; sinks filled before flow direction and flow accumulation
Rainfall	CHIRPS v2.0 daily; 2016–2025; aggregated to monthly totals; spatial mean at 5,000-m nominal scale
Rainfall collection	Google Earth Engine: UCSB-CHG/CHIRPS/DAILY
Soil map	BRMP-SDLP, 1:50,000, Tanah_1209-31
SOC	SoilGrids 2.0 SOC, 0–5 cm, mean prediction; converted according to SoilGrids product metadata
Satellite image	SPOT-6 PMS, 21 July 2022; scene identifier: SPOT6_PMS_202207210244311_ORT
Land-cover classifier	Supervised maximum likelihood; 50 training points per class
Accuracy assessment	10 independent reference points per class, 40 points total; OA, producer's accuracy, user's accuracy and kappa
Baseline concentrated-flow threshold	300 contributing cells = 2.11 ha
Alternative thresholds	75, 150, 2,000 cells; plus unmasked case

S2. Processing environment

Setting	Value
Output coordinate system	WGS_1984_UTM_Zone_48S (EPSG:32748)
Processing extent	Tahura Ir. H. Djuanda boundary with a 1-km buffer (flow routing); park boundary (final products)
Snap raster	DEMNAS mosaic
Cell size	8.3910665 m (cell area 70.41 m²)
Mask	Park boundary; water body (SMU-7) excluded from terrestrial products
Resampling	Nearest neighbour (categorical), bilinear (continuous)

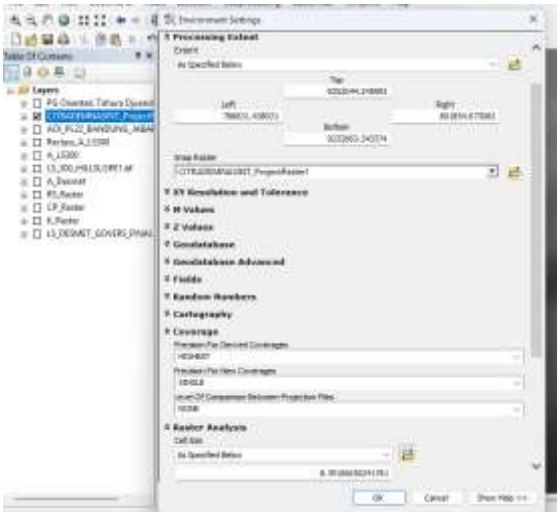


Figure 1. Geoprocessing environment settings applied to all raster operations.

S3. Reproducibility version of the Google Earth Engine workflow

The workflow below exactly matches the stated 2016–2025 monthly CHIRPS aggregation and park spatial mean. The end date is 2026-01-01 because Google Earth Engine filterDate uses an exclusive end date; this includes all 120 months from January 2016 through December 2025.

```
// CHIRPS v2.0 daily rainfall -> monthly totals -> park spatial mean
var roi = /* replace with the archived Tahura boundary geometry */;
var start = ee.Date('2016-01-01');
var end   = ee.Date('2026-01-01');

var chirps = ee.ImageCollection('UCSB-CHG/CHIRPS/DAILY')
  .filterDate(start, end)
  .filterBounds(roi)
  .select('precipitation');

var nMonths = end.difference(start, 'month');
var months = ee.List.sequence(0, nMonths.subtract(1));

var monthly = ee.ImageCollection.fromImages(
  months.map(function(m) {
    var d0 = start.advance(m, 'month');
    var d1 = d0.advance(1, 'month');
    return chirps.filterDate(d0, d1).sum()
      .set('system:time_start', d0.millis())
      .set('year', d0.get('year'))
      .set('month', d0.get('month'));
  })
);

var monthlySeries = monthly.map(function(img) {
```

```
  var meanDict = img.reduceRegion({
    reducer: ee.Reducer.mean(),
    geometry: roi,
    scale: 5000,
    maxPixels: 1e8
  });
  return ee.Feature(null, {
    date: img.date().format('YYYY-MM-dd'),
    year: img.get('year'),
    month: img.get('month'),
    precipitation_mm: meanDict.get('precipitation')
  });
});
```

S3.1 Monthly Precipitation from CHIRPS

No	Year	Month	Rainfall (mm)
1	2016	Jan	91.157
2	2016	Feb	313.309
3	2016	Mar	256.656
4	2016	Apr	305.858
5	2016	May	157.369
6	2016	Jun	397.157
7	2016	Jul	194.735
8	2016	Aug	116.071
9	2016	Sep	97.934
10	2016	Oct	211.968
11	2016	Nov	99.291
12	2016	Dec	258.13
13	2017	Jan	289.813
14	2017	Feb	248.487
15	2017	Mar	415.986
16	2017	Apr	347.828
17	2017	May	795.027
18	2017	Jun	699.868
19	2017	Jul	313.338
20	2017	Aug	204.251
21	2017	Sep	182.18
22	2017	Oct	95.695
23	2017	Nov	213.685
24	2017	Dec	226.938
25	2018	Jan	203.497
26	2018	Feb	255.711
27	2018	Mar	346.842
28	2018	Apr	212.519
29	2018	May	436.258
30	2018	Jun	408.991
31	2018	Jul	135.947
32	2018	Aug	89.38
33	2018	Sep	46.903
34	2018	Oct	33.965

No	Year	Month	Rainfall (mm)
35	2018	Nov	147.584
36	2018	Dec	284.462
37	2019	Jan	429.067
38	2019	Feb	406.564
39	2019	Mar	345.784
40	2019	Apr	347.588
41	2019	May	433.35
42	2019	Jun	241.571
43	2019	Jul	47.419
44	2019	Aug	54.859
45	2019	Sep	24.918
46	2019	Oct	47.884
47	2019	Nov	16.465
48	2019	Dec	99.165
49	2020	Jan	210.675
50	2020	Feb	308.608
51	2020	Mar	407.002
52	2020	Apr	387.139
53	2020	May	410.636
54	2020	Jun	205.429
55	2020	Jul	314.329
56	2020	Aug	75.469
57	2020	Sep	162.837
58	2020	Oct	112.911
59	2020	Nov	171.061
60	2020	Dec	274.073
61	2021	Jan	233.141
62	2021	Feb	296.404
63	2021	Mar	309.424
64	2021	Apr	173.674
65	2021	May	319.614
66	2021	Jun	278.375
67	2021	Jul	341.097
68	2021	Aug	427.26
69	2021	Sep	389.678
70	2021	Oct	85.309
71	2021	Nov	167.289
72	2021	Dec	205.743
73	2022	Jan	183.412
74	2022	Feb	246.812
75	2022	Mar	423.335
76	2022	Apr	237.605
77	2022	May	233.76
78	2022	Jun	456.923
79	2022	Jul	348.598
80	2022	Aug	309.679
81	2022	Sep	245.914
82	2022	Oct	207.766
83	2022	Nov	220.716
84	2022	Dec	214.063
85	2023	Jan	171.795
86	2023	Feb	297.926

No	Year	Month	Rainfall (mm)
87	2023	Mar	215.553
88	2023	Apr	188.789
89	2023	May	186.641
90	2023	Jun	215.341
91	2023	Jul	106.252
92	2023	Aug	64.405
93	2023	Sep	46.019
94	2023	Oct	40.811
95	2023	Nov	37.487
96	2023	Dec	229.697
97	2024	Jan	238.001
98	2024	Feb	258.36
99	2024	Mar	388.73
100	2024	Apr	374.446
101	2024	May	299.054
102	2024	Jun	219.746
103	2024	Jul	208.37
104	2024	Aug	75.406
105	2024	Sep	76.484
106	2024	Oct	106.583
107	2024	Nov	243.324
108	2024	Dec	347.801
109	2025	Jan	253.303
110	2025	Feb	247.776
111	2025	Mar	304.487
112	2025	Apr	443.585
113	2025	May	295.131
114	2025	Jun	441.67
115	2025	Jul	157.476
116	2025	Aug	242.159
117	2025	Sep	98.628
118	2025	Oct	140.719
119	2025	Nov	197.974
120	2025	Dec	274.472

S.3.2 Erosivity Calculation

$MFI = \sum(i = 1\ to\ 12)\ P_i^2 / P$

$R = 17.02\ x\ 10\text{^}[1.5\ log_{10}(MFI) - 0.8188]$

The final row is a summary: the mean R is the arithmetic mean of the ten annual R values. The mean annual precipitation and mean MFI are descriptive summaries and are not inserted into Eq. (3) to obtain the reported baseline R.

Year	P (mm yr−1)	MFI	log10(MFI)	n	10^n	R
2016	2499.635	252.3559	2.4020	2.7842	608.4435	10355.71
2017	4033.096	456.4874	2.6594	3.1703	1480.2778	25194.33
2018	2602.059	292.9915	2.4669	2.8815	761.1714	12955.14
2019	2494.634	342.4158	2.5346	2.9830	961.6804	16367.80
2020	3040.169	300.6787	2.4781	2.8984	791.3233	13468.32
2021	3227.008	302.4790	2.4807	2.9022	798.4412	13589.47
2022	3328.583	303.2064	2.4817	2.9038	801.3230	13638.52
2023	1800.716	197.1278	2.2947	2.6233	420.0701	7149.59
2024	2836.305	281.6773	2.4498	2.8558	717.5097	12212.02
2025	3097.380	298.5451	2.4750	2.8937	782.9155	13325.22

Mean	2,895.959	302.7965	—	—	—	13,825.61

S4. Topographic factor (Desmet–Govers LS)

The DEM mosaic was filled (Fill), and D8 flow direction and flow accumulation were derived before the expressions below were evaluated in the Raster Calculator. They correspond to Eqs. 6–7 of the main text and the McCool et al. (1987) slope factor.

```
slope_rad = "slope_deg" * 0.0174532925
beta      = (Sin("slope_rad") / 0.0896) / (3 * Power(Sin("slope_rad"), 0.8) + 0.56)
m         = "beta" / (1 + "beta")
A_in      = "flowacc" * 70.409997
x         = Con(("flowdir" == 2) | ("flowdir" == 8) | ("flowdir" == 32) | ("flowdir" ==
              128), 1.414213562, 1)
L         = (Power("A_in" + 70.409997, "m" + 1) - Power("A_in", "m" + 1)) /
             (Power(8.3910665, "m" + 2) * Power("x", "m") * Power(22.13, "m"))
S         = Con(Tan("slope_rad") < 0.09, 10.8 * Sin("slope_rad") + 0.03, 16.8 *
             Sin("slope_rad") - 0.5)
LS_DESMET_GOVERS_FINAL = "L_Factor" * "S_Factor"
```



(a) Slope-length factor (L) (b) S factor (c) LS

Figure 2. Raster-calculator expressions for the slope-length factor (L), the slope factor (S) and LS.

The 8.39-m processing grid and the reported contributing-cell areas are used consistently in the reproducibility expressions. The concentrated-flow threshold is applied after LS calculation.

S5. Exclusion of concentrated flow

Scenario	Expression	Reported excluded area
LS_300_HILLSLOPE	SetNull("flowacc" >= 300, "LS_DESMET_GOVERS_FINAL")	baseline; 2.11 ha
LS_75_HILLSLOPE	SetNull("flowacc" >= 75, "LS_DESMET_GOVERS_FINAL")	0.53 ha
LS_150_HILLSLOPE	SetNull("flowacc" >= 150, "LS_DESMET_GOVERS_FINAL")	1.06 ha
LS_2000_HILLSLOPE	SetNull("flowacc" >= 2000, "LS_DESMET_GOVERS_FINAL")	14.08 ha

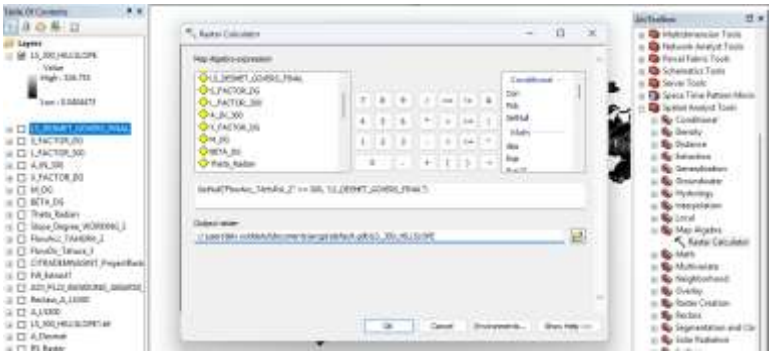


Figure 3. Removal of concentrated-flow cells from the LS raster; the 300-cell threshold defines the baseline and the other thresholds the sensitivity scenarios (Table 11).

S6. Land-cover accuracy assessment

Mapped class	Forest	Shrubland	Built-up	Water	Total	User's accuracy (%)
Forest	10	0	0	0	10	100.0
Shrubland	3	6	1	0	10	60.0
Built-up	1	0	8	1	10	80.0
Water	0	1	0	9	10	90.0
Total	14	7	9	10	40	
Producer's accuracy (%)	71.4	85.7	88.9	90.0		

Overall accuracy = 82.5%; Cohen's kappa = 0.77. The current analysis record does not contain a georeferenced training/reference-point map or a complete description of atmospheric correction and feature selection. These items should not be inferred from the final accuracy statistics; the scene identifier and sampling design reported above are the reproducibility information available in the current record.

S7. Sensitivity analysis

Scenario	Excluded area (ha)	Cells	P50	P90	P95	P99	Mean	SD	Max
Unmasked	—	76,227	19.14	71.47	107.72	600.06	114.00	1,511.86	74,926.10
2,000 cells	14.08	75,215	18.78	67.56	94.96	267.35	32.52	55.38	1,261.90
300 cells (baseline)	2.11	74,344	18.48	64.68	86.84	173.59	28.94	36.13	526.76
150 cells	1.06	73,458	18.17	62.05	81.46	137.56	27.06	29.46	389.82
75 cells	0.53	71,864	17.63	58.46	75.13	110.66	25.16	24.88	220.05

Scenario	Raster-valid area (ha)	Maximum (t ha−1 yr−1)	Upper limit class 1	Class 1 share (%)
Unmasked	505.55	124,166.44	1,460.78	96.99
2,000 cells	498.82	14,435.10	566.08	94.26
300 cells (baseline)	496.64	8,184.15	385.14	93.39
75 cells	479.37	4,862.30	305.09	93.46

S7.1 One-at-a-time proportional factor sensitivity

For R, K, C and P, each factor was perturbed by ±10% while all other factors were held constant. The standardized sensitivity coefficient is $Sx = (\Delta A/A)/(\Delta X/X)$. Because the RUSLE equation is multiplicative, the theoretical response is $Sx = 1.0$ for a uniform factor perturbation.

Factor	Scenario	Multiplier	Maximum A	Change	Sx
R	−10%	0.90×	7,365.74	−10.0%	1.00
R	Baseline	1.00×	8,184.15	0.0%	—
R	+10%	1.10×	9,002.57	+10.0%	1.00
K	−10%	0.90×	7,365.74	−10.0%	1.00
K	Baseline	1.00×	8,184.15	0.0%	—
K	+10%	1.10×	9,002.57	+10.0%	1.00
C	−10%	0.90×	7,365.74	−10.0%	1.00
C	Baseline	1.00×	8,184.15	0.0%	—
C	+10%	1.10×	9,002.57	+10.0%	1.00
P	−10%	0.90×	7,365.74	−10.0%	1.00
P	Baseline	1.00×	8,184.15	0.0%	—
P	+10%	1.10×	9,002.57	+10.0%	1.00

S8. Field evidence for P = 1.0

The P factor was set to 1.0 because field observation and interviews with park managers did not identify visible terraces, contour tillage, strip cropping or runoff barriers in the observed areas. The evidence is qualitative and was not designed as a statistical survey; therefore, P = 1.0 is explicitly treated as a screening assumption rather than an independently validated spatial layer.

Support practice	Observation	Evidence basis	Evidence limitation	Model implication
Terraces	Not observed in observed areas	Field observation + manager interview	Qualitative; no georeferenced inventory	Supports P = 1.0 assumption
Contour tillage	Not observed	Field observation + manager interview	Qualitative	Supports P = 1.0 assumption
Strip cropping	Not observed	Field observation + manager interview	Qualitative	Supports P = 1.0 assumption
Runoff barriers	Not observed	Field observation + manager interview	Qualitative	Supports P = 1.0 assumption

S9. RUSLE raster overlay

```
RKLSCP = "R_SCORE" * "K_SCORE" * "LS_300_HILLSLOPE" * "C_SCORE" * "P_SCORE"
R_SCORE = 13825.61 (uniform)
K_SCORE = SMU-specific values from Table 3
C_SCORE = class values from Table 4
P_SCORE = 1.0
```

Cells with NoData in any factor remain NoData and are excluded from area totals. The RUSLE × SMU intersection is then used for the final area accounting.

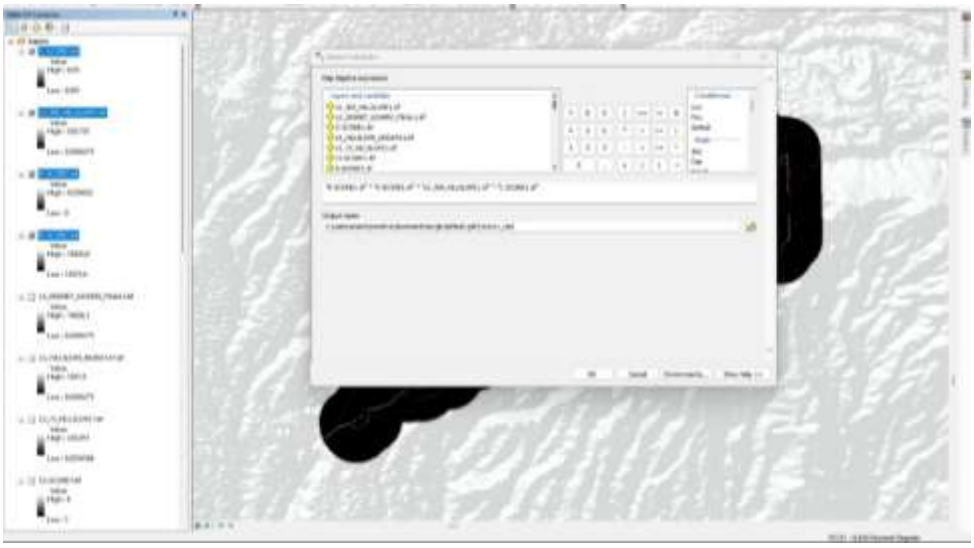


Figure 4. Raster overlay of the RUSLE factors (Eq. 1). Cells with NoData in any factor return NoData and are excluded from all area totals.