

Article

Evaluation of Environmental and Economic Benefits of Land Reclamation in the Indonesian Coal Mining Industry

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Supplementary Material

Table S1. General heavy equipment for land preparation task.

Type of Heavy Equipment	Unit Series or Type	Specifications	Unit
Hydraulic Excavator	PC-200 or similar	Horsepower (gross)	147 HP/ 2000 rpm
		Horsepower (net)	138 HP/ 2000 rpm
		Operating weight	19800–20500 kg
		Bucket capacity	0.5–1.2 m ³
		Tank capacity (Full)	400 Liters
		Bucket capacity Fuel	0.8 m ³ Diesel machine
Bulldozer (Dozer)	D 65P LGP or D 6 R LGP	Engine power	121 kW
		Operating weight	15440 kg
		Tank capacity (Full)	320 Liters
		Width of blade	3.99 meter
		Height of blade	1.05 meter
		Fuel	Diesel machine
Dump Truck	Class capacity 20 ton	Power	260 PS/ 2500 rpm
		GVWR	26000 kg
		Load capacity	m ³
		Tank capacity	200 Liters
		Fuel	Diesel machine

Note: effectivity rate of all equipment on 70-85%

Table S2. Properties of each revegetation technique (mining company, personal communication, 2018).

Properties	Conventional Technique	Mechanical Technique
Water usage (Liter/ ha)	2, 500–4,000	20,000
Fuel usage (diesel, Liter/ ha)	50–60	130
Organic material used	Less	High rate
Chemical material used	Less (if necessary)	Less (if necessary)
Target area	Flat, slope max. 30%	Flat to the steep slope (30-60%), well-access
Growth successful rate	Trees: moderate-high Land cover crop: low to moderate	Trees: low to moderate Land cover crop: moderate-high
Speed of coverage area by ground-cover crop (min. 80%)	Over six months on average	3-5 months on average
Trees germination and growth	Three months in the nursery	3-6 months in the area
Production rate (on average)	15-25 ha/ month	20-26 ha/ month
Final result	Trees: homogenous growth, line up in a row, plantation forest-like model	Trees: scattered, irregular growth, natural forest-like model

Table S3. Primary resource and materials used in revegetation task (mining company, personal communication, 2018).

Resources	Unit	Conventional		Mechanical	
		Planting	Maintenance Allocation	Planting (Spraying)	Maintenance Allocation
Water	Liters/ha	2500–4000		20,000	
Diesel Fuel	Liters/ha	50–60		130	
Electricity	kWh/ha	0		18.15–23.6	
Materials:					
(a.) Adhesive/ bonding agent	Kg/ha	0	0	15–20	1.5–2
(b.) Organic fertilizer	Kg/ha	3,300	0	145–175	15–17.5
(c.) Chicken manure or compost	Kg/ha	0	0	3500–5000	350–500
(d.) Organic material for mulch	Kg/ha	0	0	1500–2500	150–250
(e.) Chemical*	Kg/ha	0	5	300	300
Seeds of land cover crop and trees	Kg/ha	25–40	0	100	100
Seedlings	Trees/ha	1,111	111	0	0

Table S4. Fuel consumption of heavy equipment for reclamation work.

Activities	Heavy Equipment	Fuel Consumption (Liter/ ha)
Topsoil management	Excavator PC 200	920
	Dump truck capacity 20 ton	2760
Surface re-grading	Bulldozer D65P LGP or similar	1380–1610
Topsoil spreading	Excavator PC 200	920
	Dump truck capacity 20 ton	2760
	Bulldozer D65P LGP or similar	990–1155

Table S5. Sensitivity analysis on an annual increasing rate of 10% for 20 years.

		Average Total Benefit (USD/ha)																				
Average Total Cost (USD/ha)	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
		18,774	27,803	30,583	33,642	37,006	40,706	44,777	49,255	54,180	59,598	65,558	72,114	79,325	87,258	95,983	105,582	116,140	127,754	140,529	154,582	170,041
	1	9,029	18,774	21,554	24,612	27,977	31,677	35,748	40,225	45,151	50,569	56,529	63,085	70,296	78,228	86,954	96,553	107,111	118,725	131,500	145,553	161,011
	2	9,932	17,871	20,651	23,709	27,074	30,774	34,845	39,323	44,248	49,666	55,626	62,182	69,393	77,326	86,051	95,650	106,208	117,822	130,597	144,650	160,108
	3	10,925	16,878	19,658	22,716	26,080	29,781	33,852	38,329	43,255	48,673	54,633	61,188	68,400	76,332	85,058	94,656	105,215	116,829	129,604	143,657	159,115
	4	12,018	15,785	18,565	21,624	24,988	28,688	32,759	37,237	42,162	47,580	53,540	60,096	67,307	75,240	83,966	93,564	104,122	115,736	128,512	142,564	158,023
	5	13,220	14,583	17,364	20,422	23,786	27,487	31,557	36,035	40,960	46,378	52,338	58,894	66,105	74,038	82,764	92,362	102,920	114,534	127,310	141,363	156,821
	6	14,542	13,261	16,042	19,100	22,464	26,165	30,235	34,713	39,638	45,057	51,016	57,572	64,784	72,716	81,442	91,040	101,598	113,212	125,988	140,041	155,499
	7	15,996	11,807	14,587	17,646	21,010	24,711	28,781	33,259	38,184	43,602	49,562	56,118	63,329	71,262	79,988	89,586	100,144	111,758	124,534	138,587	154,045
	8	17,595	10,208	12,988	16,046	19,410	23,111	27,182	31,659	36,585	42,003	47,963	54,518	61,730	69,662	78,388	87,986	98,545	110,159	122,934	136,987	152,445
	9	19,355	8,448	11,228	14,287	17,651	21,351	25,422	29,900	34,825	40,243	46,203	52,759	59,970	67,903	76,628	86,227	96,785	108,399	121,174	135,227	150,686
	10	21,290	6,513	9,293	12,351	15,715	19,416	23,487	27,964	32,890	38,308	44,268	50,823	58,035	65,967	74,693	84,291	94,850	106,464	119,239	133,292	148,750

11	23,420	4,383	7,164	10,222	13,586	17,287	21,357	25,835	30,761	36,179	42,138	48,694	55,906	63,838	72,564	82,162	92,720	104,334	117,110	131,163	146,621
12	25,762	2,041	4,822	7,880	11,244	14,945	19,016	23,493	28,419	33,837	39,797	46,352	53,564	61,496	70,222	79,820	90,379	101,993	114,768	128,821	144,279
13	28,338	(535)	2,246	5,304	8,668	12,369	16,439	20,917	25,843	31,261	37,220	43,776	50,988	58,920	67,646	77,244	87,802	99,416	112,192	126,245	141,703
14	31,171	(3,368)	(588)	2,470	5,834	9,535	13,606	18,083	23,009	28,427	34,387	40,942	48,154	56,086	64,812	74,410	84,969	96,583	109,358	123,411	138,869
15	34,289	(6,486)	(3,705)	(647)	2,717	6,418	10,488	14,966	19,892	25,310	31,269	37,825	45,037	52,969	61,695	71,293	81,851	93,465	106,241	120,294	135,752
16	37,717	(9,914)	(7,134)	(4,076)	(712)	2,989	7,060	11,537	16,463	21,881	27,841	34,396	41,608	49,540	58,266	67,864	78,423	90,037	102,812	116,865	132,323
17	41,489	(13,686)	(10,906)	(7,848)	(4,483)	(783)	3,288	7,766	12,691	18,109	24,069	30,625	37,836	45,769	54,494	64,093	74,651	86,265	99,040	113,093	128,551
18	45,638	(17,835)	(15,055)	(11,996)	(8,632)	(4,932)	(861)	3,617	8,542	13,960	19,920	26,476	33,687	41,620	50,345	59,944	70,502	82,116	94,891	108,944	124,403
19	50,202	(22,399)	(19,619)	(16,560)	(13,196)	(9,496)	(5,425)	(947)	3,978	9,396	15,356	21,912	29,123	37,056	45,782	55,380	65,938	77,552	90,328	104,380	119,839
20	55,222	(27,419)	(24,639)	(21,580)	(18,216)	(14,516)	(10,445)	(5,967)	(1,042)	4,376	10,336	16,892	24,103	32,036	40,761	50,360	60,918	72,532	85,307	99,360	114,819

Table S6. Sensitivity analysis on an annual increasing rate of 20% for 20 years.

		Average Total Benefit (USD/ha)																				
Average Total Cost (USD/ha)	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
		18,774	27,803	33,364	40,036	48,044	57,652	69,183	83,019	99,623	119,548	143,457	172,149	206,579	247,894	297,473	356,968	428,361	514,034	616,840	740,209	888,250
	1	9,029	18,774	24,334	31,007	39,014	48,623	60,154	73,990	90,594	110,519	134,428	163,120	197,549	238,865	288,444	347,939	419,332	505,004	607,811	731,179	879,221
	2	10,835	16,968	22,529	29,201	37,208	46,817	58,348	72,184	88,788	108,713	132,622	161,314	195,744	237,059	286,638	346,133	417,526	503,199	606,005	729,373	877,415
	3	13,002	14,801	20,361	27,034	35,041	44,650	56,181	70,017	86,621	106,546	130,455	159,147	193,576	234,892	284,471	343,966	415,359	501,032	603,838	727,206	875,248
	4	15,603	12,200	17,761	24,434	32,441	42,050	53,580	67,417	84,021	103,945	127,855	156,546	190,976	232,292	281,871	341,365	412,759	498,431	601,238	724,606	872,648
	5	18,723	9,080	14,641	21,313	29,321	38,929	50,460	64,296	80,900	100,825	124,734	153,426	187,856	229,171	278,750	338,245	409,638	495,311	598,117	721,485	869,527
	6	22,468	5,335	10,896	17,569	25,576	35,185	46,715	60,552	77,156	97,080	120,990	149,681	184,111	225,427	275,006	334,500	405,894	491,566	594,373	717,741	865,783
	7	26,961	842	6,402	13,075	21,082	30,691	42,222	56,058	72,662	92,587	116,496	145,188	179,617	220,933	270,512	330,007	401,400	487,073	589,879	713,247	861,289
	8	32,353	(4,550)	1,010	7,683	15,690	25,299	36,829	50,666	67,270	87,194	111,104	139,795	174,225	215,541	265,120	324,614	396,008	481,680	584,487	707,855	855,897
	9	38,824	(11,021)	(5,461)	1,212	9,219	18,828	30,359	44,195	60,799	80,724	104,633	133,325	167,754	209,070	258,649	318,144	389,537	475,210	578,016	701,384	849,426
	10	46,589	(18,786)	(13,225)	(6,553)	1,455	11,063	22,594	36,430	53,034	72,959	96,868	125,560	159,990	201,305	250,884	310,379	381,772	467,445	570,251	693,620	841,661
	11	55,907	(28,104)	(22,543)	(15,870)	(7,863)	1,746	13,276	27,113	43,716	63,641	87,551	116,242	150,672	191,988	241,566	301,061	372,455	458,127	560,934	684,302	832,344
	12	67,088	(39,285)	(33,724)	(27,052)	(19,044)	(9,436)	2,095	15,931	32,535	52,460	76,369	105,061	139,491	180,806	230,385	289,880	361,273	446,946	549,752	673,120	821,162
	13	80,506	(52,703)	(47,142)	(40,469)	(32,462)	(22,853)	(11,323)	2,514	19,117	39,042	62,952	91,643	126,073	167,389	216,968	276,462	347,856	433,528	536,335	659,703	807,745
	14	96,607	(68,804)	(63,243)	(56,571)	(48,563)	(38,955)	(27,424)	(13,588)	3,016	22,941	46,851	75,542	109,972	151,288	200,866	260,361	331,755	417,427	520,234	643,602	791,643
	15	115,928	(88,125)	(82,565)	(75,892)	(67,885)	(58,276)	(46,745)	(32,909)	(16,305)	3,620	27,529	56,221	90,650	131,966	181,545	241,040	312,433	398,105	500,912	624,280	772,322
	16	139,114	(111,311)	(105,750)	(99,078)	(91,070)	(81,462)	(69,931)	(56,095)	(39,491)	(19,566)	4,344	33,035	67,465	108,780	158,359	217,854	289,248	374,920	477,727	601,095	749,136
	17	166,937	(139,134)	(133,573)	(126,900)	(118,893)	(109,284)	(97,754)	(83,917)	(67,313)	(47,389)	(23,479)	5,212	39,642	80,958	130,537	190,031	261,425	347,097	449,904	573,272	721,314
	18	200,324	(172,521)	(166,960)	(160,288)	(152,280)	(142,672)	(131,141)	(117,305)	(100,701)	(80,776)	(56,867)	(28,175)	6,255	47,570	97,149	156,644	228,037	313,710	416,517	539,885	687,926
	19	240,389	(212,586)	(207,025)	(200,352)	(192,345)	(182,736)	(171,206)	(157,369)	(140,766)	(120,841)	(96,931)	(68,240)	(33,810)	7,506	57,084	116,579	187,973	273,645	376,452	499,820	647,862
	20	288,466	(260,663)	(255,103)	(248,430)	(240,423)	(230,814)	(219,284)	(205,447)	(188,843)	(168,919)	(145,009)	(116,318)	(81,888)	(40,572)	9,007	68,501	139,895	225,567	328,374	451,742	599,784

Table S7. Sensitivity analysis on an annual decreasing rate of 10% for 20 years.

	Year	Average Total Benefit (USD/ha)																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Average Total Cost (USD/ha)		18,774	27,803	25,023	22,520	20,268	18,242	16,417	14,776	13,298	11,968	10,771	9,694	8,725	7,852	7,067	6,360	5,724	5,152	4,637	4,173	3,756
	1	9,029	18,774	15,993	13,491	11,239	9,212	7,388	5,746	4,269	2,939	1,742	665	(304)	(1,177)	(1,962)	(2,669)	(3,305)	(3,877)	(4,392)	(4,856)	(5,273)
	2	8,126	19,677	16,896	14,394	12,142	10,115	8,291	6,649	5,172	3,842	2,645	1,568	599	(274)	(1,059)	(1,766)	(2,402)	(2,974)	(3,490)	(3,953)	(4,371)
	3	7,314	20,489	17,709	15,207	12,955	10,928	9,104	7,462	5,984	4,655	3,458	2,381	1,411	539	(247)	(953)	(1,589)	(2,162)	(2,677)	(3,141)	(3,558)
	4	6,582	21,221	18,440	15,938	13,686	11,659	9,835	8,193	6,716	5,386	4,189	3,112	2,143	1,270	485	(222)	(858)	(1,430)	(1,946)	(2,409)	(2,827)
	5	5,924	21,879	19,099	16,596	14,344	12,317	10,493	8,852	7,374	6,044	4,847	3,770	2,801	1,928	1,143	436	(200)	(772)	(1,287)	(1,751)	(2,168)
	6	5,332	22,471	19,691	17,189	14,937	12,910	11,086	9,444	7,966	6,637	5,440	4,363	3,393	2,521	1,735	1,029	393	(180)	(695)	(1,159)	(1,576)
	7	4,799	23,004	20,224	17,722	15,470	13,443	11,619	9,977	8,500	7,170	5,973	4,896	3,926	3,054	2,269	1,562	926	353	(162)	(625)	(1,043)
	8	4,319	23,484	20,704	18,202	15,950	13,923	12,099	10,457	8,979	7,650	6,453	5,376	4,406	3,534	2,748	2,042	1,406	833	318	(146)	(563)
	9	3,887	23,916	21,136	18,634	16,382	14,355	12,531	10,889	9,411	8,081	6,885	5,808	4,838	3,966	3,180	2,474	1,838	1,265	750	286	(131)
	10	3,498	24,305	21,525	19,022	16,770	14,743	12,919	11,278	9,800	8,470	7,273	6,196	5,227	4,354	3,569	2,862	2,226	1,654	1,139	675	258
	11	3,148	24,655	21,874	19,372	17,120	15,093	13,269	11,627	10,150	8,820	7,623	6,546	5,577	4,704	3,919	3,212	2,576	2,004	1,488	1,025	607
	12	2,833	24,970	22,189	19,687	17,435	15,408	13,584	11,942	10,465	9,135	7,938	6,861	5,891	5,019	4,234	3,527	2,891	2,318	1,803	1,340	922
	13	2,550	25,253	22,473	19,970	17,718	15,691	13,867	12,226	10,748	9,418	8,221	7,144	6,175	5,302	4,517	3,810	3,174	2,602	2,087	1,623	1,206
	14	2,295	25,508	22,728	20,225	17,973	15,946	14,122	12,481	11,003	9,673	8,476	7,399	6,430	5,557	4,772	4,065	3,429	2,857	2,342	1,878	1,461
	15	2,066	25,737	22,957	20,455	18,203	16,176	14,352	12,710	11,232	9,903	8,706	7,629	6,659	5,787	5,002	4,295	3,659	3,086	2,571	2,107	1,690
	16	1,859	25,944	23,164	20,661	18,409	16,383	14,558	12,917	11,439	10,109	8,912	7,835	6,866	5,993	5,208	4,501	3,865	3,293	2,778	2,314	1,897
	17	1,673	26,130	23,350	20,847	18,595	16,568	14,744	13,103	11,625	10,295	9,098	8,021	7,052	6,179	5,394	4,687	4,051	3,479	2,964	2,500	2,083
	18	1,506	26,297	23,517	21,015	18,763	16,736	14,912	13,270	11,792	10,462	9,266	8,188	7,219	6,347	5,561	4,855	4,219	3,646	3,131	2,667	2,250
	19	1,355	26,448	23,667	21,165	18,913	16,886	15,062	13,420	11,943	10,613	9,416	8,339	7,370	6,497	5,712	5,005	4,369	3,797	3,282	2,818	2,401
	20	1,220	26,583	23,803	21,301	19,049	17,022	15,198	13,556	12,078	10,749	9,552	8,475	7,505	6,633	5,847	5,141	4,505	3,932	3,417	2,953	2,536

Table S8. Sensitivity analysis on an annual decreasing rate of 20% for 20 years.

	Year	Average Total Benefit (USD/ha)																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Average Total Cost (USD/ha)		18,774	27,803	22,242	17,794	14,235	11,388	9,110	7,288	5,831	4,665	3,732	2,985	2,388	1,911	1,528	1,223	978	783	626	501	401
	1	9,029	18,774	13,213	8,765	5,206	2,359	81	(1,741)	(3,199)	(4,365)	(5,298)	(6,044)	(6,641)	(7,119)	(7,501)	(7,806)	(8,051)	(8,247)	(8,403)	(8,528)	(8,629)
	2	7,223	20,580	15,019	10,571	7,012	4,165	1,887	65	(1,393)	(2,559)	(3,492)	(4,238)	(4,835)	(5,313)	(5,695)	(6,001)	(6,245)	(6,441)	(6,597)	(6,723)	(6,823)
	3	5,779	22,024	16,464	12,015	8,456	5,609	3,332	1,510	52	(1,114)	(2,047)	(2,793)	(3,390)	(3,868)	(4,250)	(4,556)	(4,800)	(4,996)	(5,153)	(5,278)	(5,378)
	4	4,623	23,180	17,619	13,171	9,612	6,765	4,488	2,665	1,208	42	(891)	(1,638)	(2,235)	(2,712)	(3,094)	(3,400)	(3,645)	(3,840)	(3,997)	(4,122)	(4,222)
	5	3,698	24,105	18,544	14,096	10,537	7,690	5,412	3,590	2,132	966	33	(713)	(1,310)	(1,788)	(2,170)	(2,476)	(2,720)	(2,916)	(3,072)	(3,198)	(3,298)
	6	2,959	24,844	19,284	14,835	11,276	8,429	6,152	4,330	2,872	1,706	773	27	(570)	(1,048)	(1,430)	(1,736)	(1,980)	(2,176)	(2,333)	(2,458)	(2,558)
	7	2,367	25,436	19,875	15,427	11,868	9,021	6,744	4,921	3,464	2,298	1,365	618	21	(456)	(838)	(1,144)	(1,389)	(1,584)	(1,741)	(1,866)	(1,966)
	8	1,894	25,909	20,349	15,900	12,342	9,495	7,217	5,395	3,937	2,771	1,838	1,092	495	17	(365)	(671)	(915)	(1,111)	(1,268)	(1,393)	(1,493)
	9	1,515	26,288	20,728	16,279	12,720	9,873	7,596	5,774	4,316	3,150	2,217	1,470	873	396	14	(292)	(537)	(732)	(889)	(1,014)	(1,114)
	10	1,212	26,591	21,031	16,582	13,023	10,176	7,899	6,077	4,619	3,453	2,520	1,773	1,176	699	317	11	(234)	(429)	(586)	(711)	(811)
	11	970	26,833	21,273	16,824	13,266	10,419	8,141	6,319	4,861	3,695	2,762	2,016	1,419	941	559	253	9	(187)	(343)	(469)	(569)
	12	776	27,027	21,467	17,018	13,460	10,613	8,335	6,513	5,055	3,889	2,956	2,210	1,613	1,135	753	447	203	7	(150)	(275)	(375)
	13	620	27,183	21,622	17,173	13,615	10,768	8,490	6,668	5,210	4,044	3,111	2,365	1,768	1,290	908	602	358	162	6	(120)	(220)
	14	496	27,307	21,746	17,298	13,739	10,892	8,614	6,792	5,334	4,168	3,235	2,489	1,892	1,414	1,032	726	482	286	130	4	(96)
	15	397	27,406	21,845	17,397	13,838	10,991	8,713	6,891	5,434	4,267	3,335	2,588	1,991	1,513	1,131	826	581	385	229	104	4
	16	318	27,485	21,925	17,476	13,917	11,070	8,793	6,971	5,513	4,347	3,414	2,668	2,071	1,593	1,211	905	661	465	308	183	83
	17	254	27,549	21,988	17,540	13,981	11,134	8,856	7,034	5,577	4,410	3,478	2,731	2,134	1,656	1,274	969	724	528	372	247	147
	18	203	27,600	22,039	17,591	14,032	11,185	8,907	7,085	5,627	4,461	3,528	2,782	2,185	1,707	1,325	1,019	775	579	423	298	197
	19	163	27,640	22,080	17,631	14,072	11,225	8,948	7,126	5,668	4,502	3,569	2,823	2,226	1,748	1,366	1,060	816	620	463	338	238
	20	130	27,673	22,112	17,664	14,105	11,258	8,980	7,158	5,701	4,534	3,602	2,855	2,258	1,780	1,398	1,093	848	652	496	371	271

