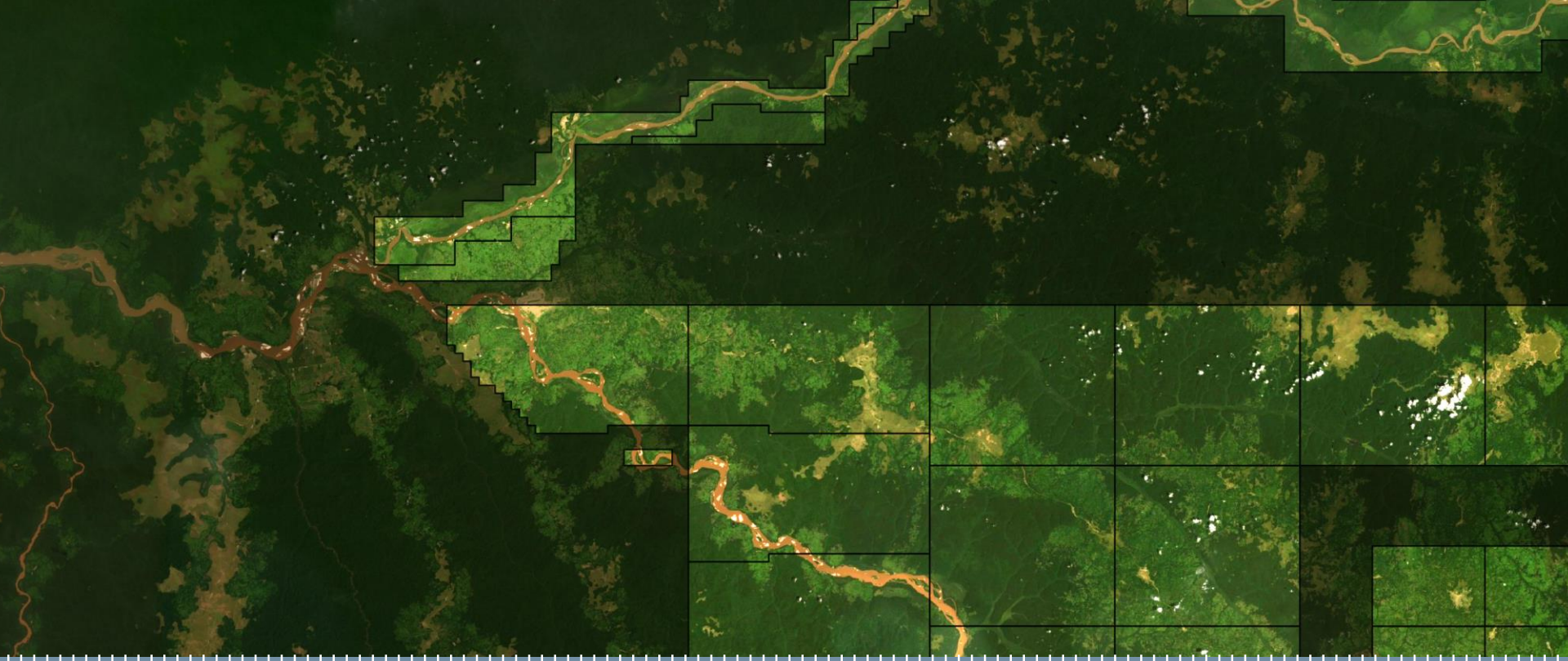

Environmental impacts of diamond mining in the Democratic Republic of Congo

Nikolas Galli, Davide Danilo Chiarelli, Manuel D'Angelo, Maria Cristina Rulli

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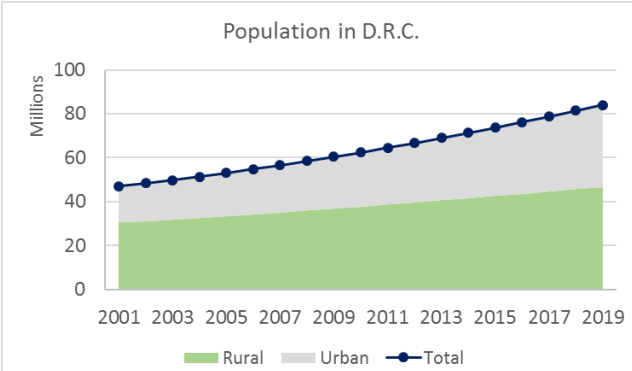
Environmental impacts of diamond mining in the Democratic Republic of Congo

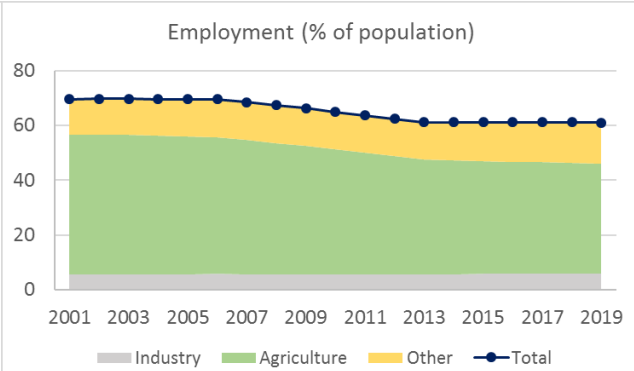
Brief overview of the Democratic Republic of Congo (D.R.C)

Satellite imagery: ESRI (2020)

Environment	
Surface	$2.3 \cdot 10^6$ km^2
Climate classification (Köppen)	Equatorial rainforest Equatorial monsoon Equatorial savannah

Society





Data: World Bank (2020)

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The diamond mining industry in the D.R.C.

Open-pit mining

Main diamond extraction technique throughout the world (Australia, Russia, Canada and southern African countries)

Owners: few major private mining companies manage the whole product chain:

extraction, processing, export, tailings treatment.

Alluvial and small-scale mining (ASM)

Main diamond extraction technique in the D.R.C.

Gems have already left the original rock matrix, usually kimberlite; miners search through sediments.

Owners: two partially state-owned companies and a vast set of cooperatives and self entrepreneurs.

The Congolese Ministry of Mines grants mining permits over areas with ores deposits.

ASM is much more spatially extended than open pit mining and it involves, directly or indirectly, more people and more natural resources.

Left: Alrosa's Udachnaya open pit diamond mine in Yakutia, Russia. (Wikimedia Commons, 2004)
Middle: Artisanal mine in North Kivu Province, eastern D.R.C. (World Rainforest Movement, 2015)
Right: Mining permit areas on the Kasai river near Tshikapa (Ministry of Mines of the D.R.C., ESRI)

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Research questions

- What is the footprint of diamond mining in the D.R.C.?
  - On freshwater
    How much freshwater does the diamond mining industry consume and how relevant is it for the D.R.C.'s water resources?
  - On forests
    How much of the D.R.C.'s deforestation is imputable to diamond mining and how much deforestation does diamond mining require?
  - On soil
    How does the land use change in areas where diamond mining is a primary activity?

  ➢In relation to essential activities that use the same natural resources?
  - Agriculture
    What would be the potential impact of using the resources consumed by diamond mining for agriculture instead?
- What is the impact of diamond mining on society?
  - Working conditions
  - Security/conflicts

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Methods

- Spatial extent: the Democratic Republic of Congo
- Time span: 2001-2018

- Cross-reference of data on mining permits with data on deforestation, land cover, conflicts, and high-resolution hydrological simulations.
- Comparison between the cross-referenced data with analogous national benchmark data to detect differences, individuate prevalences, and evaluate relative impacts.

- Spatial data on mining permits provided by the Ministry of Mines through the globalforestwatch.org platform.
  53% of the permits lacks information on the period of activity → analysis on 2 scenarios:
  - Minimum scenario: only permits complete with opening and closing year considered.
  - Maximum scenario: permits without time information considered as active throughout the whole period.

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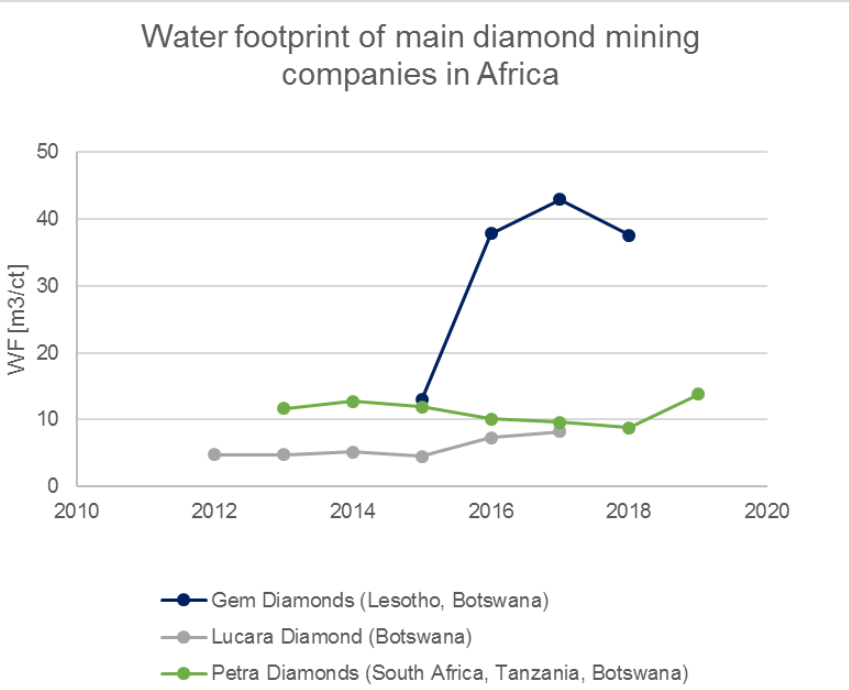
Impact on freshwater resources



Mean	13.9 m^3/ct
S.D.	11.8 m^3/ct

- Data on per-carat water footprint of diamond production are collected from the yearly sustainability reports redacted by the main diamond mining companies working in Africa.
- The reports are available for the period between 2012 and 2019.

- No significant trend over time
  - ➢ No relevant progress in efficiency, although the companies have mid-term sustainability targets.
- High variations depending on the company
  - ➢ Possible differences in the technology used
  - ➢ Possible differences in water footprint computations
- Most variations within the water footprints of the single companies are described in the reports as due to individual occurrences.

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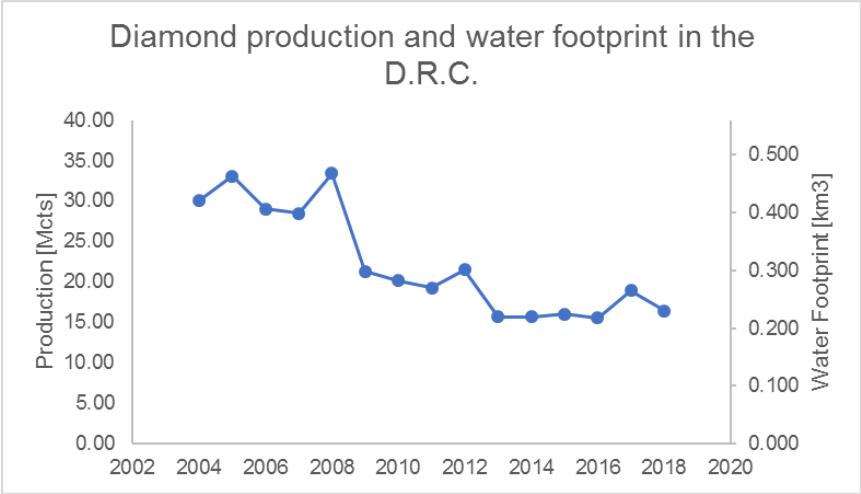

Average over the period	0.311 km^3
Yearly total internal renewable water resources (IRWR)	900 km^3

- Data on the national diamond production provided by the Kimberley Process Certification Scheme (KPCS), established to increase transparency in the diamond sector and to prevent diamond conflicts.
- Data available for the period between 2004 and 2019 (the KPCS was created in 2003).
- Average per-carat water footprint applied to the production data
  - ↳ Estimate of flux of freshwater going into diamond production yearly in D.R.C.
- Comparison with the total internal renewable water resources in D.R.C. (FAO-Aquastat):
  - ➢ High but negligible with respect to 900km^3 (enormous freshwater stock typical for areas with equatorial climates)

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Impact on water for agriculture

Comparison between Water Footprint for diamond industry and agriculture			
Year	Diamond WF (km3)	Green Water (km3)	Blue Water (km3)
2004	0.419	31.237	0.014
2005	0.461	31.705	0.013
2006	0.404	31.747	0.012
2007	0.397	32.380	0.011
2008	0.466	31.532	0.011
2009	0.297	31.309	0.013
2010	0.281	31.079	0.013
2011	0.268	31.341	0.010
2012	0.300	31.211	0.012
2013	0.219	31.259	0.012
2014	0.218	30.900	0.011
2015	0.223	30.887	0.013
2016	0.217	31.001	0.015
2017	0.264	30.797	0.012
2018	0.229	31.365	0.012

- Soil water balance on cultivated areas:
  - Daily
  - 5 arc-minute resolution
  - Crop-specific
  - ➢ Aggregated the results: yearly nation-wide green water and blue water volumes.

$$\frac{\Delta W_{i,j}}{\Delta t} = P_i + BW_{i,j} + k_j ET_{0_i} - D_i$$

Mostly rainfed crops in D.R.C.

Diamond water footprint negligible with respect to green water, but **15 to 35 times higher than blue water**.

Main irrigated crops: rice, sugarcane:
still cost efficient + less «looteable» than diamonds (lower price/weight, more local market).

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Water security in the D.R.C.

Water Stress Index = ratio between water demand and water availability

- Time scale: month
- Time span: 2001-2018
- Resolution: 5 arc-minutes

Domestic water footprint

Industrial water footprint

Agricultural water footprint (blue water)

$$WS_i = \frac{WF_i}{WA_i} = \frac{Dom_i + Ind_i + BW_i}{0.2 \cdot R_i + \langle 0.2 \cdot R_{up(i)} - WF_{up(i)} \rangle}$$

Constant accounting for environmental flows

Runoff in the cell (computed from vertical soil water balance)

Surplus from upstream areas (upstream runoff – upstream withdrawals)

Pointy brackets: argument set to zero if negative

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Water security in the D.R.C.

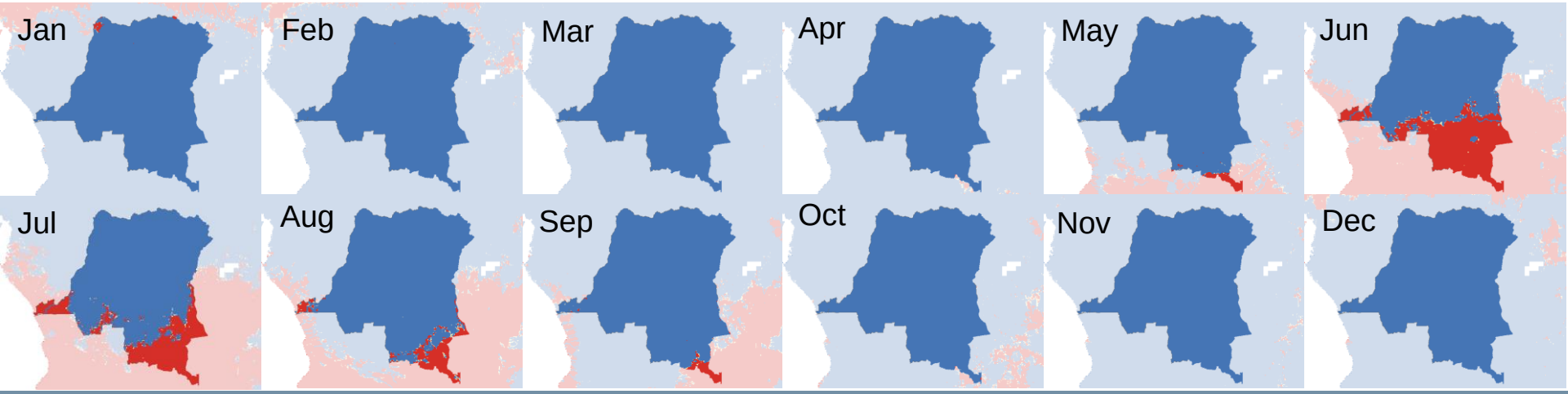
% of population with access to safe drinking-water (Aquastat)			
Years	Total	Rural	Urban
1998-2002	47.9	27.4	84.3
2003-2007	49.7	28.8	83.1
2008-2012	51.4	30.3	81.8
2013-2017	52.4	31.2	81.1

- Maps reported for 2016
  - Values **lower than 1 (blue)** = water available > demand → no water stress
  - Values **greater than 1 (red)** = water available < demand → water stress

\+ No water stress months for most of the country, because of great water availability.

\- Access to safe water extremely difficult, especially in rural areas, where most diamond mines concentrate.

→ **Water scarcity in the D.R.C. is economic** and not physical.



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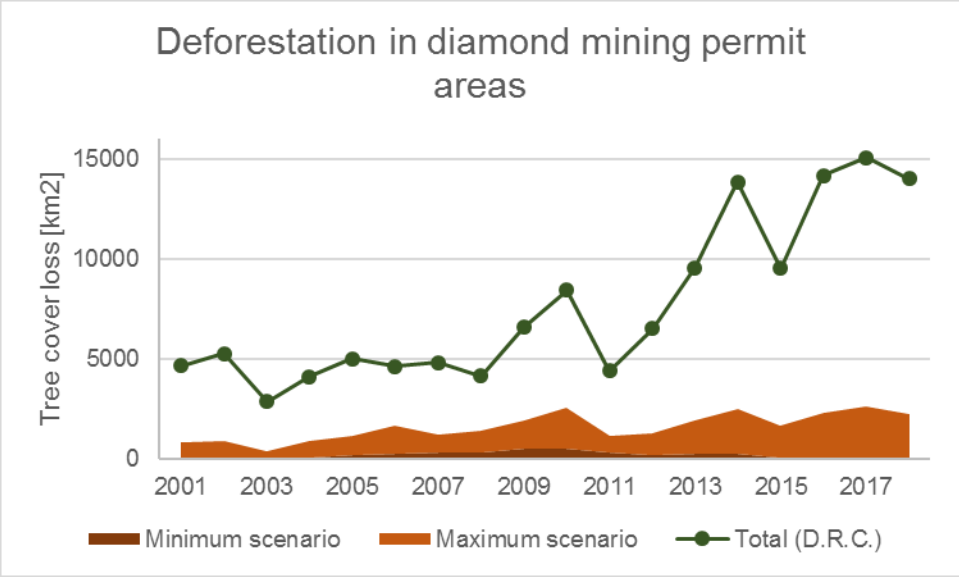
Impact on deforestation



Aggregate results over the 2001-2018 period					
Scenario	Tree cover loss [km2]	Mining area [km2]	Loss in mining areas [km2]	[% total loss]	[% of mining areas]
Minimum	137822	226325	3538	2.57	1.56
Maximum		546083	25324	18.37	4.64

- Data on tree cover loss retrieved from the globalforestwatch.org maps:
  Resolution: 30m
  Period 2001-2018
- Tree cover loss: in the D.R.C. vs in the diamond mining permit areas (minimum and maximum scenario).
  - Graph: time series
  - Table: aggregate values
- No relevant intensity peaks.
- 2.57% to 18.37% of the country's deforestation happens at least close to diamond mines.
  (wide span is due to high share of mining permits with no information about the period of activity)
- Loss in mining areas is less relevant to total mines (1.56~4.64%) than to total loss (2.57~18.37%). This is explained by the enormous extent of the mining permits. In the maximum scenario, almost a quarter of the country is devoted to diamond mining.

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Environmental impacts of diamond mining in the Democratic Republic of Congo

Impact on deforestation

From the graph in the previous slide:

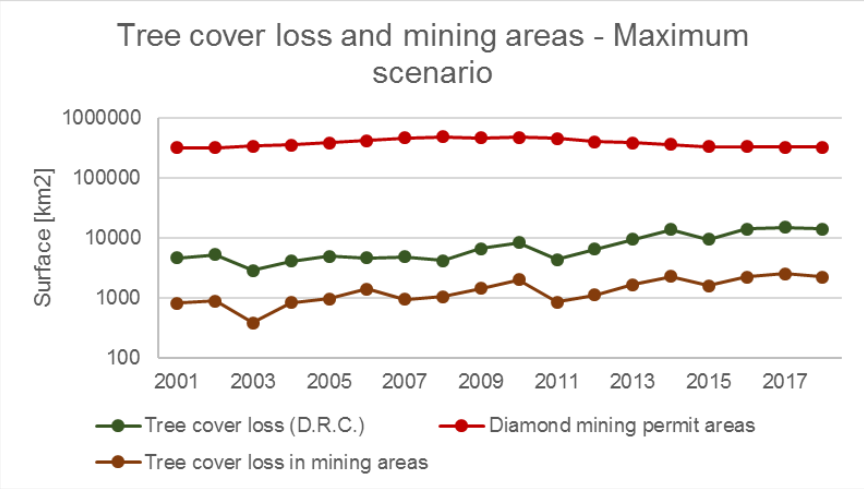
- Evident correlation between total tree cover loss and maximum scenario, what about the minimum?
- Values differing by 1-2 orders of magnitude

→ Compare trends on log scale

- **Maximum scenario:** confirmed correlation to country level tree cover loss
  (very high spatial extent of the mines → significant sample of the national behavior)
- **Minimum scenario:**
  General trend: correlation to the mining areas time series.
  Disturbances: correlation to the country-level deforestation trend.
- Artisanal diamond mining:
  → Deforestation not expected on large scale
  → Fragmentation more predictable

Plausible scenario - intermediate, externally conditioned:

- By mining areas availability
- By the same factors conditioning country-level tree cover loss



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Environmental impacts of diamond mining in the Democratic Republic of Congo

Impact on land use

Class	Land covered [%]		
	D.R.C.	Mining areas	
		Min.	Max.
Cropland, rainfed	3.40	1.86	3.07
Herbaceous cover	3.81	4.49	4.03
Cropland, irrigated or post-flooding	0.30	0.06	0.18
Mosaic cropland (>50%) / natural vegetation	3.03	2.33	3.27
Mosaic natural vegetation (>50%) / cropland	1.09	1.06	1.36
Tree cover, broadleaved, evergreen, closed to open (>15%)	43.54	29.33	39.93
Tree cover, broadleaved, deciduous, closed to open (>15%)	9.62	18.86	11.86
Tree cover, broadleaved, deciduous, closed (>40%)	0.68	1.02	0.55
Tree cover, broadleaved, deciduous, open (15-40%)	18.13	26.13	23.58
Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	2.10	4.69	1.65
Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	0.27	0.20	0.24
Shrubland	1.96	1.38	2.16
Grassland	1.37	0.78	1.19
Sparse vegetation (tree, shrub, herbaceous cover) (<15%)	0.00	0.00	0.00
Tree cover, flooded, fresh or brakish water	6.54	5.01	4.35
Tree cover, flooded, saline water	0.11	0.03	0.04
Shrub or herbaceous cover, flooded	2.10	1.89	2.00
Urban areas	0.07	0.20	0.08
Water bodies	1.84	0.67	0.42

- Data on land cover retrieved from the ESA-CCI maps
  Resolution: 300m
  Time span: 2001-2018
  Overlapped with active mines (minimum and maximum scenario) in each year.
  Table: averages over the period.
- No significant changes between benchmark and mining areas for most land cover classes.
- Main difference in tree cover type: mostly evergreen in the benchmark data and mostly broadleaved in the mining areas: most mining areas located southwards from rainforest region.
- Tree cover in mining areas not dense enough to be classified neither as “closed” nor “closed to open”.

→ **Forest fragmentation rather than deforestation** (coherent with mining extraction technique and tree cover loss data).

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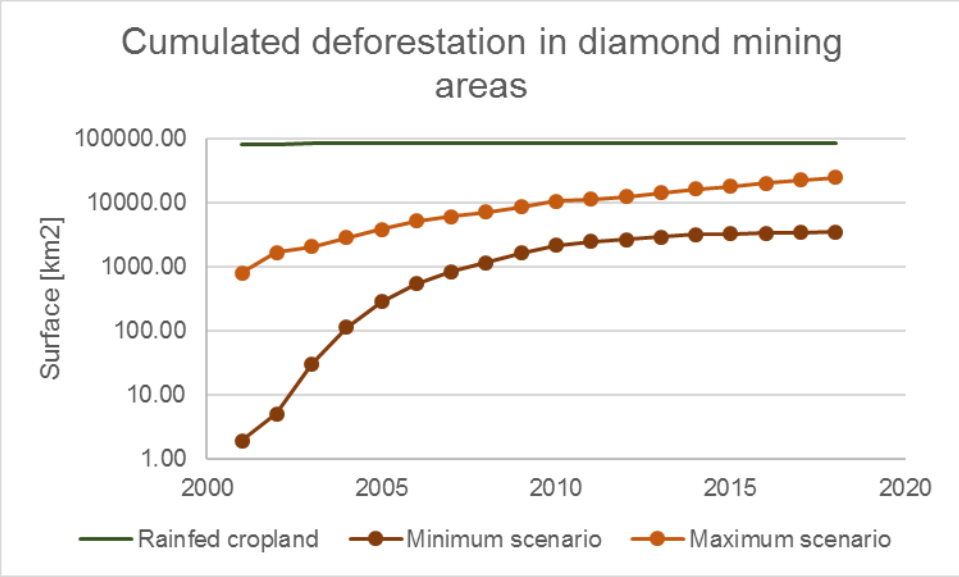
Impact on land use for agriculture



Aggregate results over the 2001-2018 period			
Scenario	Deforestation in mines [km2]	Rainfed cropland [km2]	Potential cropland increase [%]
Minimum	3538.09	86200.23	4.10
Maximum	25323.78		29.38

- Soil footprint of the diamond industries (as tree cover loss in diamond mining permit areas) vs. areas destined to agriculture.
  Graph: cumulated time series.
  Table: aggregate values.
- Value aggregation:
  - Deforestation → sum (new soil consumed every year)
  - Cropland → average (always same soil covered with little yearly obscillations)
- Tree cover loss in mines is low with respect to country-level cropland if taken year by year.
- Alternative use of soil: cumulated loss could increase cropland by 4.10~29.4%

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Environmental impacts of diamond mining in the Democratic Republic of Congo

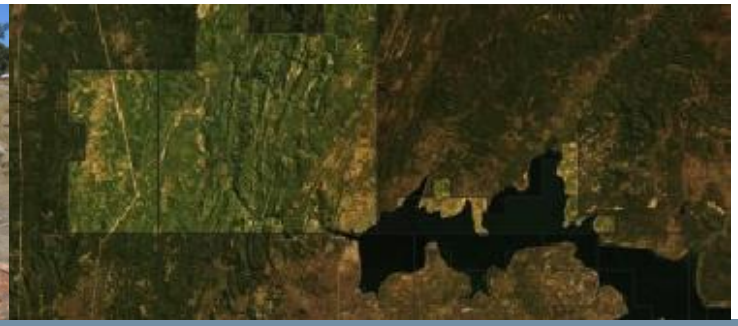
Summarizing the impact of diamond ASM on natural resources

- Water:
  - High water consumption, but not a risk factor for freshwater resources.
  - Economic water scarcity: availability limited by access and infrastructures.
  - Calculated basing on industrial standards. Possible higher values if data on grey water footprint and tailing dams of ASM were available.
- Soil and forests:
  - No significant deforestation on a large scale.
  - High share of the country occupied by mining permits → non negligible portion of tree cover loss associated to diamond mining.
  - Forest fragmentation: ecological consequences can be even worse than those of deforestation.
- Alternative use of resources:

  Conversion to agriculture could significantly improve the country's food security situation.

  D.R.C. diamonds average price: 11$/ct

  Decreasing D.R.C. diamond production. → Crop production: economically safer, lower conflict potential.



Left: Women sorting and separating minerals from the sediment in an artisanal mine at Kansonga (Annie Matundu Mbambi, WILPF, 2016)

Middle: Permit areas including diamond mining (highlighted), amidst mining permit areas for other ores, on the shores of a tailing dam lake near Kolwezi, one of the most important mining centers in the D.R.C. (Ministry of Mines of the D.R.C., ESRI)

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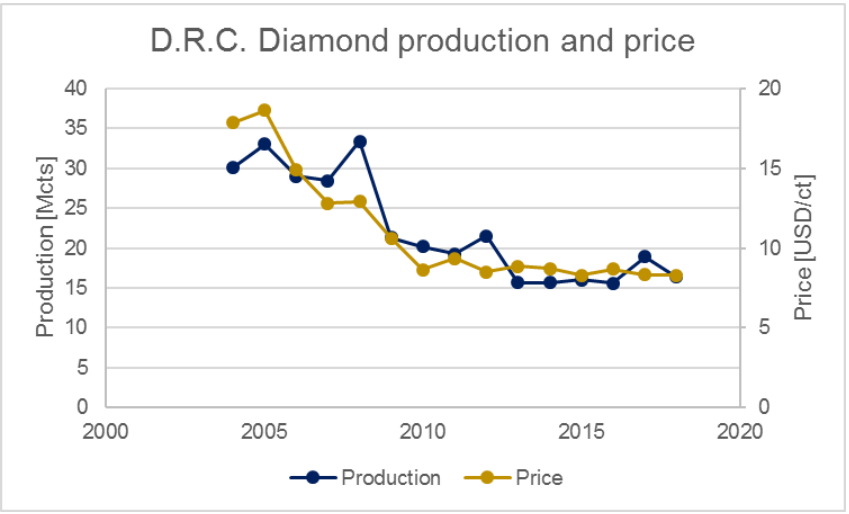
Environmental impacts of diamond mining in the Democratic Republic of Congo

The social and security impact of diamond mining in the D.R.C.



Left: A diamond and gold trading house in Kindu. (Radio Okapi, 2009)

- Data on diamond production and export from the Kimberley Process
- D.R.C. 2018 diamond export world ranking:
  - By carats: 6th
  - By USD: 18th

  → World's cheapest diamonds in 2018
- Production *and* price of Congolese diamonds fallen by half since 2004: decline in demand. Possible reasons:
  - General oversupply crisis in the diamond market, caused by excessive speculative midstream inventories. (James Wilson, *Diamonds suffer from oversupply, price falls in new era*, Financial Times, 03/2016).
  - Ethical implications, coherently with other commodities: international associations discourage their members from importing from the D.R.C. because the revenue finances the conflict (Report by the Tantalum-Niobium International Study Center).

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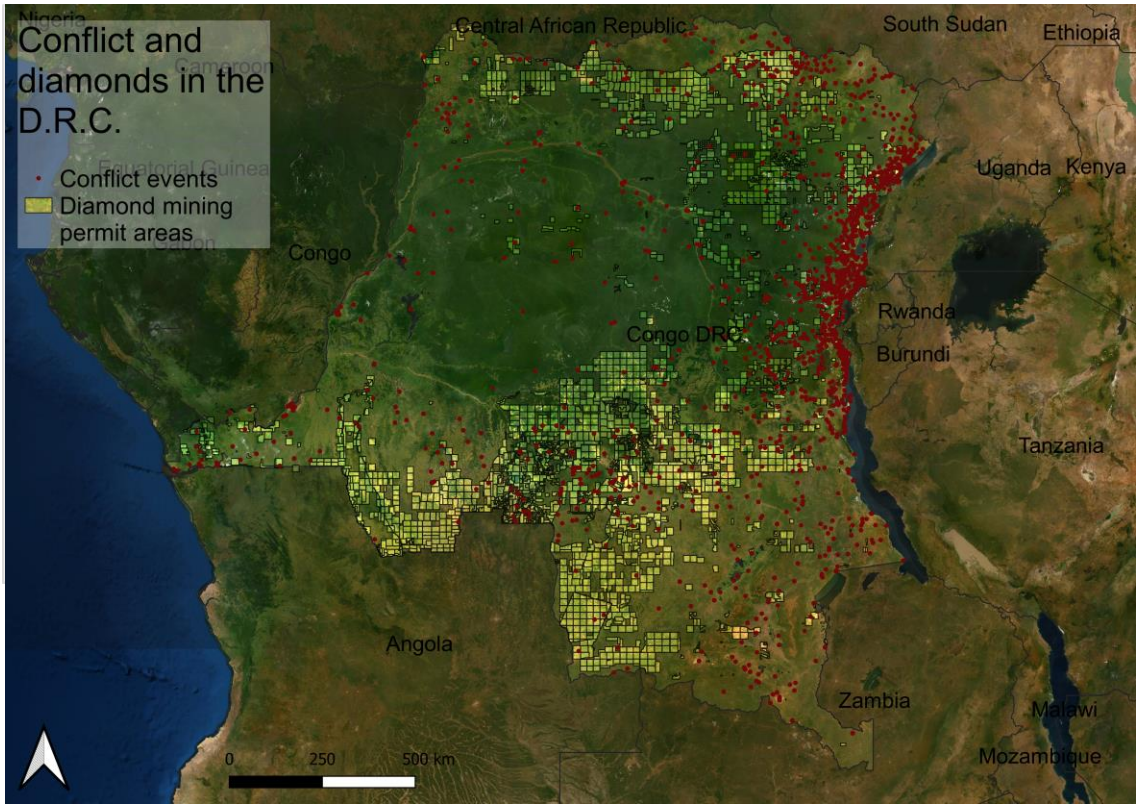
The social and security impact of diamond mining in the D.R.C.



Data on conflicts retrieved from the ACLED database.
Time span: 2001-2018.

Significant cluster in the eastern part of the country, on the border with Uganda, Rwanda and Burundi.
Conflicts in this region often interweave with diamond looting and smuggling.
In 2010:

- 14% to 21% of conflicts happened in diamond mining areas.
- Diamond mining banned in eastern D.R.C.

Between 1998 and 2000:

- Outbreak of Second Congo War
- Uganda and Rwanda declared 6,7 million USD in diamond exports although not having significant diamond production (Samset, 2012).

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Environmental impacts of diamond mining in the Democratic Republic of Congo

The social and security impact of diamond mining in the D.R.C.

- Diamond mining as employment:
  - Fundamentally informal (as 96% of all non-agricultural workers in the country).
  - Unregulated: miners paid by the piece, reported occurrence of child labor.
  - Diamonds often looted, used as a mean of banter, and smuggled across the nation's borders, traded with fake KPCS Certificates.

  (Aryn Baker, *Inside the Democratic Republic of Congo's Diamond Mines*, TIME, 2015; World Bank, 2019; KPCS, 2020)
- Diamond mining permits:
  - Mostly granted to partially state-owned companies
  - Average area: 190km^2, not a punctual granting.

  → Broad legal meaning of mining permits, lack of control over the area.

  → Reported accidents where artisanal miners try and enter company-owned areas.

- Lack of transparency and regulation are also evident in the difficulty in obtaining reliable data on the topic.

Indicator	Survey year	Total D.R.C.	Western Kasai
International Wealth Index [0-100]	2007	20.1	11.1
	2010	16.3	7.28
	2013	20.8	13.3
Underweight children [%]	2007	24.7	32.9
	2010	24.1	34
	2013	23.1	30.3
Men in lower nonfarm jobs [% of employed]	2007	33.7	36.9
	2013	28.2	43.9
Human Development Index [0-1]	2018	0.459	0.427

Left: Children at a diamond mine in Kansonga. (Annie Matundu Mbambi, WILPF, 2016)
Right: Comparison between the values of standard socio-economic development indexes in the D.R.C. and in the Western Kasai province, the center of the Congolese diamond production. (Data retrieved from the World Bank's Globaldatalab.org database)

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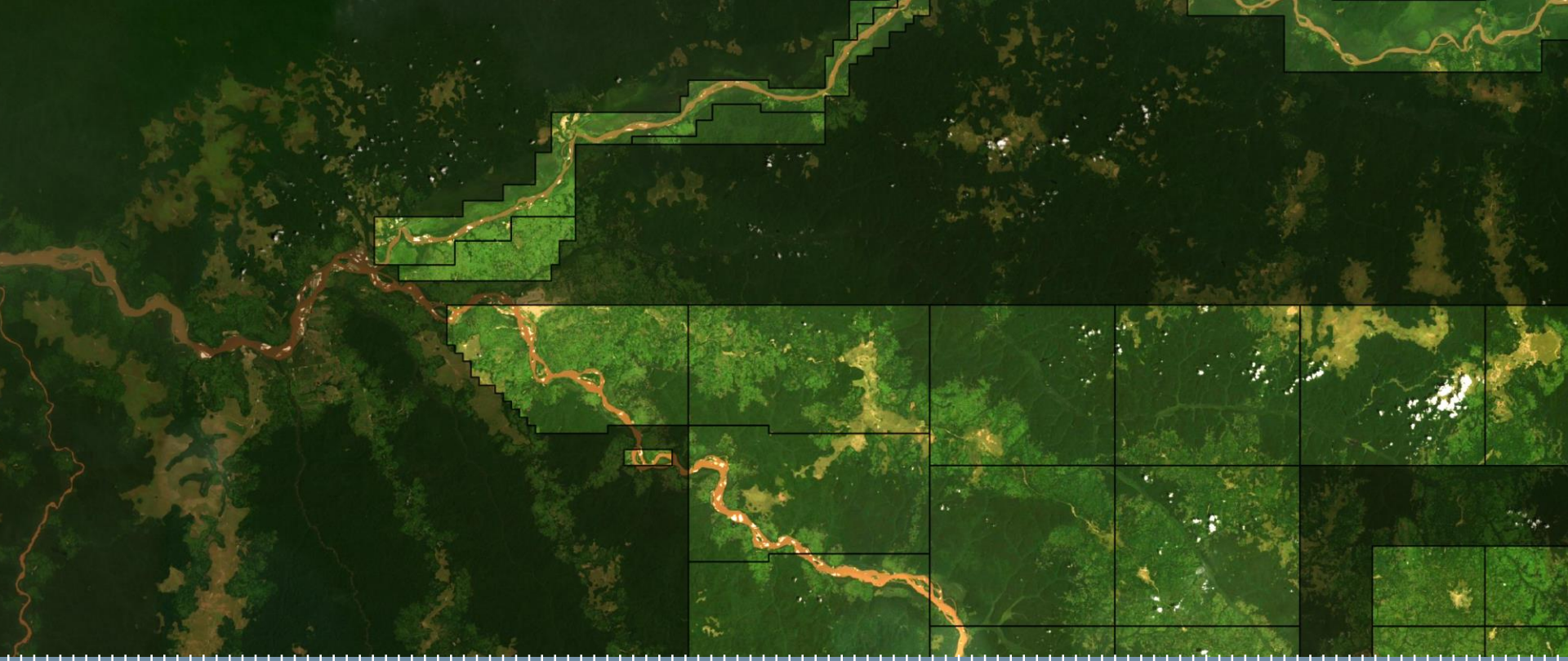

Thank you for reading!

For further comments and questions:
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