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A regional scale approach to assess non-residential buildings, transportation and croplands exposure in Central Asia

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Abstract

The Central Asia region encompasses a wide variety of climatic areas and geological settings. It is therefore prone to multiple hazards which can affect different parts of the region, including transboundary areas. Floods and landslides are increasing in number and intensity due to climate change, while earthquakes are a well-known threat for the region. Knowing the location, type and characteristics of exposed assets is paramount in order to develop disaster risk reduction strategies. Floods, landslides and earthquakes can affect a wide range of exposed assets in the region, but past research efforts were mostly focused on residential buildings. Here, we develop the first regionally-consistent exposure database for selected asset types (namely, non-residential buildings, transportation and croplands) in Central Asia. We assembled the available global and regional datasets together with country-based information provided by local authorities and research groups, including reconstruction costs. The exposure database presented here supports further analysis to integrate data from national and sub-national projects and support regional-scale disaster risk reduction strategies.

Short summary

Central Asia is prone to multiple hazards such as floods, landslides and earthquakes, which can affect a wide range of assets at risk. We develop the first regionally-consistent database of assets at risk for non-residential buildings, transportation and croplands in Central Asia. The database combines global and regional data sources and country-based information and supports the development of regional-scale disaster risk reduction strategies for the Central Asia region.

1. Introduction

The Central Asia region encompasses a wide variety of climatic areas and geological settings. It is therefore prone to multiple hazards which can affect different parts of the region, including transboundary areas (e.g. the Ferghana Valley, where many residential and agricultural activities are located). In particular, floods are increasingly frequent and, in the past, their impacts were often exacerbated by the difficulties related to trans-boundary cooperation, for example in water management (UNECE 2017). Central Asia is also prone to earthquakes as demonstrated by several regional-scale studies carried out in the last decades (Ulomov et al., 1999; Bindi et al., 2012; Ullah et al., 2015). Landslides, together with earthquakes and floods, are very frequent in Central Asia and, in the past, were often triggered by natural events such as earthquakes, floods, rainfall and snowmelt (Saponaro et al., 2014; Strom and Abdrakhmatov, 2017). The type and spatial

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distribution of floods and landslides is also expected to vary due to climate change, which is strongly affecting the region. Another emerging hazard in Central Asia is drought (Zhang et al., 2019) which might affect the region by disrupting productive activities and exacerbating water management conflicts.

Natural hazards such as the ones mentioned here can affect a wide range of exposed assets in the region. Past projects in the region were mostly focused on the assessment of exposure for selected assets such as residential buildings (Pittore et al., 2020). However, other exposed assets are also relevant and contribute to the overall disaster risk. In particular, non-residential buildings comprise workplaces (e.g. industrial sites, commercial buildings), services (e.g. public offices, schools) and other facilities that are extremely relevant in case of emergencies (e.g. hospitals). Non-residential buildings can suffer physical consequences (e.g. buildings structural damage) which can cause harm and casualties. Also, they can suffer indirect damages, such as the production disruption due to power blackouts and its related financial consequences. Non-residential buildings also play an important role in the generation of cascading impacts which should be taken into account in disaster risk reduction strategies (e.g. soil/water/air contamination due to consequences of hazardous phenomena, Krausmann and Cruz, 2021). For these reasons, they should not be overlooked when performing a comprehensive damage/risk assessment for the Central Asia region. The transportation system is also a relevant exposed asset as it enables both the people movement and the transportation of goods across the Central Asia region. Its disruption can strongly affect both emergency management (e.g. disrupting search and rescue activities) and socio-economic sector (disrupting people and freights transportation with consequences on internal commerce and import/export). For this reason, an exposure layer at regional scale should be assembled in order to support risk management plan and manage financial impact of disasters on transportation. Finally, agricultural activities are very relevant for the economy of most Central Asian countries. In particular, the primary sector (agriculture, forestry and fishing) accounts for the 26 and 24% of Uzbekistan and Tajikistan GDP, respectively (World Bank 2 , 2020). The share of national GDP in Kyrgyz Republic and Turkmenistan is 14 and 11%, while the lowest value is associated with Kazakhstan (5%). Cotton and cereals (in particular, wheat) are the dominating cropping system in all Central Asia countries (Kienzler et al., 2012). Cotton and wheat, in particular, account for a fraction of cropland area that varies between 30% in Turkmenistan) and 80% in Kyrgyz Republic (FAO, 2019). Croplands are extremely relevant for the Central Asia economies as they guarantee both food security and economic development. However, they are threatened by a number of hazardous phenomena, including floods and drought, often exacerbated by climate change and water management issues (Punkari et al., 2014; Li, 2020). Knowing the spatial distribution of main croplands and their average yield and production can support the development of risk reduction strategies.

Exposure assessment is the process of collecting information on the type, characteristics and spatial distribution of assets potentially damageable by natural or man-made hazards. Exposure layers are therefore paramount for Disaster Risk Reduction (DRR) as they allow developing strategies to cope with disasters. However, despite their importance, regional-scale exposure datasets are not currently available in Central Asia for the three aforementioned exposed asset types (non-residential buildings, transportation and croplands). However, without clear and reliable exposure layers it is impossible to estimate expected damages on exposed assets, and subsequently develop risk management plans. An effort is therefore required in order to assemble national and regional-scale exposure layers and integrate the available data sources and knowledge. Exposure-related information is in fact currently inhomogeneous and scattered across different sources including global databases (e.g. openstreetmap) and national-scale aggregated statistics (e.g. national census). In this study, we assembled the first regionally consistent exposure database that comprises multiple assets, including non-residential buildings of different types (e.g. residential, commercial, industrial), transportation and croplands.

2. Data collection

The available information on non-residential buildings, transportation system and croplands was collected across the 5 Central Asia countries. The data collection phase was carried out in collaboration with representatives of each country. Data

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were collected at two different spatial scales, global/regional and national/sub-national, and comprised both official sources and personal communications.

Category	**Type**	**Global / Regional Data**	**National Or Sub-National Data**				
			Kazakhstan	**Kyrgyzstan**	**Tajikistan**	**Turkmenistan**	**Uzbekistan**
Non residential buildings	Industrial	OpenStreetMap (https://www.openstreetmap.org) Global mines dataset (https://pubs.usgs.gov/of/2010/1255/, Baker et al., 2010) SERA exposure dataset (https://gitlab.seismo.ethz.ch/efehr/esrm20_exposure, Crowley et al., 2020)	Total employed force and percentage employed in industrial sector (https://data.worldbank.org/indicator/SL.TLF.TOTL.IN and https://data.worldbank.org/indicator/SL.IND.EMPL.ZS, from World bank data portal)				
	Commercial	Eurostat employment data (https://ec.europa.eu/eurostat/databrowser/view/LFSQ_EISN2__custom_1304651/default/table?lang=en, last accessed 2022) Eurocommerce employment data (2017) SERA exposure dataset (https://gitlab.seismo.ethz.ch/efehr/esrm20_exposure, Crowley et al., 2020)	Percentage employed force in industrial sector https://data.worldbank.org/indicator/SL.SRV.EMPL.ZS, from World Bank data portal)				
	Education	Schools number and location (https://projectconnect.unicef.org/map/countries)	Total number of schools in each Oblast (Bureau of National Statistics of the Republic of Kazakhstan, 2018); Schools location shapefile	School location shapefile; UNICEF school database; Number of schools in each Oblast; School material statistics	Number of schools in each city; Schools location shapefile (https://geonode.wfp.org)	Total number of schools in each Oblast	Total number of schools in each Oblast
	Healthcare	Healthcare facilities database (https://www.healthsites.io/)	Total number of hospitals in each Oblast (Bureau of National Statistics of the Republic of Kazakhstan, 2018)	Number of hospitals in each city; hospitals Location (http://geonode.mes.kg/)	Number of hospitals in each city	Total number of hospitals in each Oblast	otal number of hospitals in each Oblast
Agriculture	Crops	Global crop dominance ma (https://catalog.data.gov/dataset/global-food-security-support-analysis-data-gfsad-crop-dominance-2010-global-1-km-v001, Teluguntla et al., 2015); Global land cover fraction (https://lcviewer.vito.be/download)	Wheat, cotton and total cereals area, yield production for each Oblast (Bureau of National Statistics of the Republic of Kazakhstan, data for 2020)	Wheat, cotton and total cereals area, yield and production for each Oblast	Agricultural area for each crop type in each district.	Cotton and total cereals area and production for each Oblast	Wheat, cotton and total cereals area. Yield and production for each Oblast
Transports	Roads, railways and bridges	Openstreetmap database (https://www.openstreetmap.org); Global Roads Inventory Project - GRIP (https://www.globio.info/download-grip-dataset, Meijer et al., 2018)	Description of the transportation network and main highways/railways	Road maps collected from Caiag geonode (https://geonode.caiag.kg/); Bridges characteristics (World Bank project P149630, Measuring eismic Risk in Kyrgyz Republic')	n.a.	Maps and description of road and railway network	Map of main railroads, total length of railroads per type, railway classified by age of construction

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Table 1: Exposure data collected at regional scale and for each country for the considered exposed assets (non residential buildings, agriculture and transports). Data are collected from global/regional databases, national official sources (e.g. governmental agencies) or were provided directly by local partners and contributors.

3. Methodology

The general method adopted to assemble regional-scale exposure databases relies on two main procedures:

- Spatial disaggregation. Exposure information is often available in an aggregated form (e.g. total value over a region). In such cases, a common method is spatially to distribute the total value using proxies such as population or land use maps. This operation is called spatial disaggregation and is usually performed using Geographical Information Systems (GIS) or spatial analysis libraries (e.g. Gdal, https://gdal.org/).
- Definition of typologies for exposed assets. Exposure assessment requires the definition of asset typologies based on their characteristics (e.g. buildings are classified by material, age, etc.). However, this information might not be available for some exposed assets. In this case, broad typologies can be defined based on information available for parts of the study area and/or for countries outside the study region with similar characteristics. Typologies were then described using the GED4ALL taxonomy (Silva et al., 2018), specifically developed for multi-hazard and risk assessment purposes.

Following these two principles, we combined the information collected for each exposed asset type (Table 1) to develop exposure layers for non-residential buildings, transportation and croplands. A strong harmonization effort was performed in order to combine all collected exposure data and support regionally consistent risk assessment activities.

3.1 Non-residential buildings

Exposure layers were developed separately for each non-residential asset types considered (schools, healthcare facilities, commercial and industrial) based on the data collected in Table 1. For non-residential buildings, few exposure layers were available and there was scarce information on buildings typologies. The definition of typologies was therefore aimed at identifying the main characteristics of non-residential buildings based on two main assumptions:

- The main building typologies in Central Asia defined in the EMCA project (Wieland et al., 2015; Pittore et al., 2020) are considered valid for non-residential buildings. Note that these typologies were also adopted for the development of the residential exposure layer (Scaini et al., this volume).
- In absence of specific country-based information, we used data sources from post-soviet countries, assumed to be similar in terms of past socio-economic context and technical background with regards to construction methods. In particular, data from the SERA non-residential buildings' exposure layers (Crowley et al., 2020) for the available post-soviet countries (Estonia, Latvia, Lithuania, Moldova) were used, while for the others (Belarus, Ukraine and Russia) data were not available.

Specific methods adopted for each non-residential asset type are described in the following subsections.

3.1.1 Schools

School typologies were extracted from a previous UNICEF project in Kyrgyz Republic collected the main exposure characteristics for 1260 schools constituted by 8380 building units surveyed separately. Statistics were performed on the UNICEF layer assuming that each building block is a separate school sample. According to the dataset, all surveyed schools are constituted by load-bearing masonry or precast concrete (80 and 20%, respectively), and the vast majority is found in rural areas (88%). This is similar to the overall distribution of residential buildings in Kyrgyz Republic, which, according to Pittore et al. (2020), has more than 90% of load-bearing masonry buildings. We assumed that, in absence of specific data for

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schools in other countries, all Central Asia schools have the same characteristics surveyed in Kyrgyz Republic. Construction material was therefore defined as a weighted combination of most common school materials in Kyrgyz Republic. Two school typologies were defined (rural and urban) and associated with the most frequent age, area and occupancy value obtained from the UNICEF database for Kyrgyz Republic:

- Urban schools: material: weighted combination of the most common school typologies in Kyrgyz Republic (59% EMCA1, 10% EMCA3, 31% EMCA4); year of construction: 1960-1990; area: 500-1000 m² (average: 750 m²); occupancy: 300 students; taxonomy: UNK + YBET:1960,1990

- Rural schools: material: weighted sum of the most common school typologies in Kyrgyz Republic (56% EMCA1, 22% EMCA3 and 22% EMCA4); year of construction: 1960-1990; area: 50-500 m² (average: 275 m²); occupancy: 50-200 students (125); taxonomy: UNK + YBET:1960,1990

School structural costs were provided by local partners in each country. The value of 550 USD/m² was adopted in agreement with most data provided, but high discrepancies were found between the cost in Turkmenistan and Kazakhstan (who provided the highest values, ranging between 2000 and 4500 USD/m²) and Kyrgyz Republic (the lowest, 470 USD/m²).
Digital maps of schools were available for Kyrgyz Republic, Kazakhstan and Tajikistan (Table 1). Each point in the spatial dataset was associated with urban or rural school typologies. Urban schools were identified by intersecting them with the urban polygons available from the GRUMP dataset (CIESIN, 2021), while all other schools were considered rural. The location of schools in Uzbekistan and Turkmenistan was not available, but local partners provided the total number of schools in each Oblast, which were distributed in the GRUMP urban areas (CIESIN, 2021): rural schools were associated with polygons with an area smaller than 20 km².

3.1.2 Healthcare facilities

The location of healthcare facilities by type (clinics, hospitals, polyclinic, dentists, doctors, laboratories and pharmacies), last updated in 2019, is available from the Healthsites database (Weiss et al., 2020). No information was available on the main characteristics (age, material, floor area) of hospitals in Central Asia. Based on the SERA project (Crowley et al., 2020), which provides non-residential buildings exposure data for European countries, we extracted the characteristics of hospitals in post-soviet countries for which the information is available (Estonia, Latvia, Lithuania and Moldova). The average hospital area is 10,000 m² which was assumed valid for all hospitals of Central Asia. Similarly, for clinics, the average area from the SERA dataset of post-soviet countries was of 1,000 m². As for the material, we assume that the majority of hospitals are reinforced concrete buildings which correspond to the EMCA2 or EMCA3 typologies of the residential buildings classification introduced by Pittore et al., (2020) and refined by Scaini et al., (this volume).
Clinics and other healthcare businesses (dentists, doctors, pharmacies) were assumed to have a material similar to the residential buildings in each country. Their typology was defined as the weighted combination of the residential building typologies in each country, based on their fraction, discarding those whose presence is lower than 5%. Other healthcare facilities (dentists, doctors and pharmacies) were assumed to have the same building typologies and reconstruction costs of retail commercial buildings. Their area was estimated as the weighted sum of the areas of the most common residential building typologies in each country. In particular, the floor area was considered for single-family building typologies, while the dwelling area was used for multi-family building typologies, following the same approach used for medium-to-small retail buildings.
Hospital structural reconstruction costs was estimated based on the country-based costs (USD/m2) provided by local partners in each country: an average value of 1.500 USD/m2 was assumed. The replacement cost of hospitals content is assumed to be 150% of the hospitals structural costs following the approach of Hazus (FEMA, 2021). The other healthcare facilities

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(clinics, dentists, doctors and pharmacies) construction and content costs were assumed to be equal to the construction and content cost of the commercial retail building typologies most common in each country.

3.1.3 Commercial buildings

Commercial and services buildings, named here as 'commercial', are broadly distinguished into two categories:

- Wholesale and services. Given the lack of specific data for commercial buildings in Central Asia, we assumed that wholesale and services industrial buildings in Central Asia are similar to the post-soviet ones in European countries, obtained from the SERA database (Crowley et al., 2020). A single wholesale and services building typology was defined as the combination of the most common EMCA typologies in the post-soviet countries (namely, EMCA1, EMCA2 and EMCA5 which represent the 26, 37 and 36% of commercial building stock). The average area and occupancy are calculated as the weighed combination of the area and occupancy of the typologies present in the SERA commercial buildings dataset. The so-defined wholesale and services building typology has an average area of 476 m² and the occupancy is 243 people. This is consistent with existing statistics which estimate that wholesale employees are between 10 and 249 employees, but large wholesale firms can employ up to 700 people (OXIRM, 2014).
- Retail buildings, which are assumed to be distributed along residential areas and to have characteristics similar to residential buildings. A single commercial retail typology was defined, in each country, as the combination of the most common residential building typologies in the national building stock. The most common residential building typologies are EMCA1 (masonry) and EMCA4 (adobe) for Kyrgyz Republic, Tajikistan and Turkmenistan with the additional presence of EMCA5 (wood) and EMCA6 (steel) for Kazakhstan. These typologies are low-to-mid rise and encompass a wide range of construction decades, from the '30s until today. Typologies which account for less than 5% of the residential buildings were discarded. The average retail buildings area was estimated as the weighted combination of storey/dwelling area for each building typology. In particular, the floor area was considered for single-family building typologies, while the dwelling area was used for multi-family building typologies. As for the occupancy, in Europe the large majority of retail businesses are micro-businesses employing fewer than 10 people (but there are large retail companies that employ few thousand people, OXIRM, 2014). In this work, we assumed that retail companies accommodate on average 5 people, and we did not account for large retail companies. Structural cost for retail building typologies was computed as the average of structural costs of each EMCA typology weighted by their relative presence in each country obtained from the residential exposure layer developed in Scaini et al., (this volume). The content cost is assumed to be equal to the structural cost following the HAZUS inventory technical manual (2021).

Given that no prior information was available on the number of commercial buildings in Central Asia, their number was estimated based on labor market data based on the following indicators:

• Total number of employees in the commercial sector, derived as a percentage of the total labor force for each country (Table 1).

• Total employees in wholesale and retail sector calculated as a percentage over the total employees in the commercial sector activities. To this purpose, values for Europe were used (Eurostat, last accessed 2022).

• Number of retail employees, calculated as a fraction of the total employees in the Total employees in the wholesale and retail sector. According to Eurocommerce (2017), the fraction of employees in the retail sector in 2015 in Europe was 72%, while in post-soviet countries that belong to the EU union (Estonia, Latvia, Lithuania) was 75% (Eurocommerce, 2017). The remaining fraction is associated with wholesale and services.

• Average occupancy of wholesale and services buildings, obtained from the SERA dataset for post-soviet countries. For retail buildings the occupancy was inferred from the European statistics (Eurocommerce, 2017).

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The number of commercial buildings was finally estimated by dividing the total employees in the two categories (services wholesale and retail) by the average occupancy of each category.

Wholesale and services and retail buildings were spatially distributed in urbanized areas extracted from the GRUMP dataset (CIESIN, 2021). In absence of additional information on their spatial distribution, they were disaggregated based on population density, so that a higher fraction of buildings was distributed on highly-populated areas. This approach is similar to the one adopted in the SERA project (Crowley et al., 2020). Commercial areas identified in OSM were also inspected but their coverage was deemed insufficient, so the OSM polygons were not used to locate commercial buildings.

3.1.4 Industrial buildings

No prior information was available on the number of industrial buildings in Central Asia (Table 1). The number of industrial buildings was then estimated by dividing the employed force by the average buildings' occupancy. The total employed force and the percentage employed in the industrial sector of each country was obtained from the World Bank data portal (Table 1). In absence of country-based or regional-based information, the average occupancy in industrial buildings was inferred from the SERA non-residential buildings' exposure layers (Crowley et al., 2020) for Post-soviet EU countries.

Industrial buildings can belong to more than one EMCA typology. According to the SERA dataset (Crowley et al., 2020), industrial buildings in post-soviet countries are constituted by 31% of load-bearing masonry (EMCA1), 25% reinforced concrete (EMCA2) and 33% steel (EMCA6). Other typologies are present in lower fraction (less than 10%). In absence of specific information, one broad typology was defined as a combination of the three EMCA typologies. Characteristics such as the average area and the structural cost were computed as the average value of the EMCA typologies weighted by their relative fraction in the building stock. An average area of 2013 m² and an occupancy of 35 was obtained. The structural cost for industrial buildings was computed as the weighted average of the costs retrieved for each considered EMCA typology (see Scaini et al,. This volume). As for the content, its value is estimated as 150% of the construction cost, following the HAZUS inventory technical manual (2021).

The location of industrial buildings was associated with industrial areas extracted from the OSM database. Areas devoted to mining and other primary sector activities, available from the global mines dataset (Baker, 2010), were removed from the industrial areas. In order to account for the industrial built-up area only, we assumed that half of the industrial area is accommodating buildings. The estimated number of buildings in each country was distributed on the industrial areas identified by OSM, in a number proportional to the polygons' area. The distribution was made so that there is at least one industrial building for each industrial area.

3.2 Transportation assets

For each country, roads and railways were extracted from OSM which was found more reliable for the identification of the primary road network with respect to the GRIP database (Global Roads Inventory Project - GRIP, Meijer et al., 2018). Total length of transportation networks (roads and railway) obtained from OSM was compared with data available at national scale for Uzbekistan and Turkmenistan, showing some discrepancies. However, the spatial location of main transportation lines was also compared with non-digital maps of railway lines provided by local partners (e.g., for Turkmenistan) showing an overall good agreement. Roads and railways were then extracted from OSM and classified based on the GED4ALL taxonomy (Silva et al., 2018) which is in its turn based on the OSM classification. Roads were classified into 4 classes: motorway and trunk, primary, secondary and tertiary. Railways were distinguished between high speed and conventional. Roads classified as 'residential', 'service' and 'unclassified' as well as railways tagged as 'subway', 'tram' and 'unknown' were not included in the analysis.

Bridges were extracted from the OSM layer and additional ones were identified by intersecting the primary road layer with other potential obstacle (rivers, motorways and trunks, primary and secondary roads and railways). The bridge typologies were defined based on the data provided by past projects in the region (e.g., 'Measuring Seismic Risk in Kyrgyz Republic', implemented by the World Bank) and those provided by one of the Uzbekistan local partners (TSTU), which has a deep expertise in the construction of railways and bridges in the region. Since GED4ALL does not provide a taxonomy for bridges but uses OSM taxonomy for roads, we classified bridges based on a custom taxonomy. Two types of bridges were identified:

• Road bridges: In Uzbekistan, 86% of bridges were constructed between 1960 and 1990. Information on bridge material is not available from local partners, but the project 'Measuring Seismic Risk in Kyrgyz Republic' (World Bank project P149630) identified 1500 bridges in Kyrgyz Republic, most of them made of reinforced concrete and steel. We therefore assume that most road bridges (>80%) are constructed between 1960 and 1990 in reinforced concrete or steel.

• Railway bridges are mostly made of reinforced concrete (95% of the total) and they are multi-span; the average length of span ranges between 12 and 24 m but most bridges are less than 25m long. We assume that these characteristics are common to all railway bridges in Central Asia.

As for costs, no prior official information on transportation assets' reconstruction costs was available. We defined the costs based on country-based information provided by local partners. Given the variability of costs collected, also due to the different soil and construction conditions, we provide both ranges and average values (Table 3 in the results section).

3.3 Croplands

The cotton area and yield in each Central Asia country and each sub-national administrative unit (Oblast) was provided by local partners. Such values were used as a starting point for the definition of the exposure layers. The spatial distribution of different croplands was inferred in two steps:

- First, the areas where cotton and wheat are cultivated were inferred from the global crop dominance dataset (Teluguntla et al,. 2015), available at 1-Km resolution. Cotton is associated with class 3 ("Irrigated Mixed Crops"), together with wheat, rice and orchards. Wheat is also found in other classes (1,2,4,5,7), while class 8 was not considered since the wheat fractions is considered negligible with respect to the other crop dominance classes.
- Second, the land cover cropland fraction (Table 1), which has higher resolution (100m), allows discarding cells with low fraction of cropland coverage.

Having identified the areas where cotton and wheat crops are present, the country-based information obtained for each country and Oblast was distributed spatially. The total cultivated area of cotton and wheat in each Oblast was disaggregated in each 100-m cells, proportionally to the cropland fraction. The taxonomy for croplands corresponds to the one proposed by GED4ALL taxonomy (Silva et al., 2018). In order to assess the expected exposed value, country-based values of yield and price were used (Table 4 in the results section). Based on the collected information on production and cost, we calculated the exposed value of cotton and wheat croplands in each 100-m cell and the total values per Oblast and country.

4. Results

4.1 Non residential buildings

Results of the exposure assessment provide the total number of buildings and exposed value for each country and for the considered non-residential building types (Table 2).

Table 2. Number of healthcare (hospitals and clinics), schools, commercial and industrial buildings and their corresponding total reconstruction cost in each Central Asia country and for the entire region (in million USD).

	Non residential building types				Total reconstruction costs (million USD)			
Country	**Hospitals and clinics**	**Schools**	**Commercial**	**Industrial**	**Hospitals and clinics**	**Schools**	**Commercial**	**Industrial**
Kazakhstan	768	7462	848015	65838	2045	2103	137700	39760

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Kyrgyz Republic	316	1260	207866	21793	823	355	15000	11845
Tajikistan	180	858	138868	13309	503	242	9400	7502
Uzbekistan	804	10287	1105651	118704	2274	2900	204100	64517
Turkmenistan	176	1868	139425	33727	268	527	8100	12220
Central Asia	2244	21735	2439825	253371	5913	6127	368900	135844

Higher total non-residential buildings reconstruction costs and are found in Kazakhstan and Uzbekistan. The larger reconstruction costs are associated with commercial buildings, followed by industrial buildings. Both are present in larger number with respect to healthcare and school facilities, but have a lower reconstruction cost per building unit. On average, non-residential buildings account for the 40% of total buildings reconstruction costs estimated in Central Asia, with larger values (up to 50%) in Turkmenistan and values lower than 30% in Tajikistan.
Non-residential building assets were collected in a geospatial database. Figure 1 shows the distribution of education and healthcare facilities in Central Asia. Similar maps can be produced based on the geospatial database developed for other non-residential building types considered during the project.

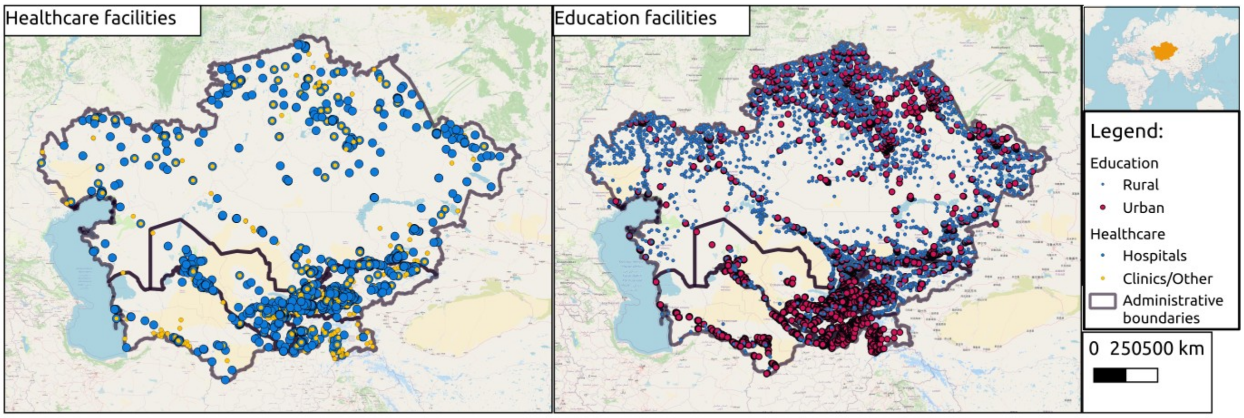

Figure 1. Map of healthcare facilities in Central Asia classified into hospitals and clinics and other facilities (left). Map of education facilities classified into rural and urban (right). Map data from OpenStreetMap available from https://www.openstreetmap.org (© Openstreetmap contributors, 2023, distributed under the Open Data Commons Open Database License – OdbL v1.0).

4.2 Transportation

Results of the analysis is a geospatial database of the main transportation assets (roads, railways and bridges) in central Asia and the estimation of the associated reconstruction costs. Figure 2 shows the map of transportation assets in Central Asia. Table 3 provides the total length of each type of roads in each country of Central Asia and for the entire region, together with the total estimated reconstruction costs. Average unit costs for each road type are also provided in the table. The larger reconstruction costs are associated with Kazakhstan, followed by Uzbekistan, and are mostly associated with motorways and highways which have the larger unit cost and a wide coverage in the two aforementioned countries, in particular in Kazakhstan (Fig. 2 and Table 3).

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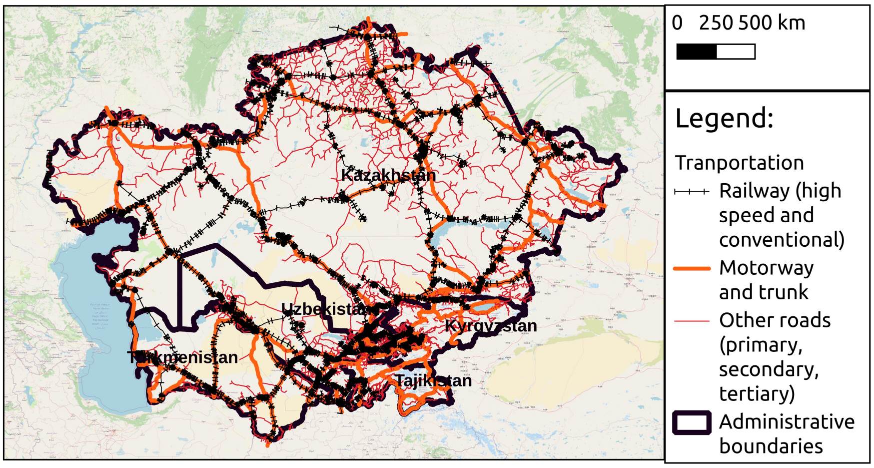

Figure 2: Map of the road and railway network in Central Asia included in the exposure database, classified into different types (motorway, trunk, primary, secondary and tertiary). Map data from OpenStreetMap available from https://www.openstreetmap.org (© Openstreetmap contributors, 2023, distributed under the Open Data Commons Open Database License – OdbL v1.0).

Table 3: Total length of road network types and total reconstruction costs estimated for each Central Asia country and for the entire region. Average unit costs for each road type are also provided (third row).

	Road network				**Total reconstruction cost (Billion USD)**		
Country	**km motorway, highway, trunk**	**km 1ary**	**km 2ary**	**km 3ary**	**Cost motorway, highway, trunk**	**Cost 1ary**	**Cost (all road types)**
Average unit cost (USD/km)	2000	850	500	240			
Kazakhstan	17,430	8,506	19,845	46,414	34.9	7.2	63.2
Kyrgyz Republic	2,787	1,996	1,878	6,578	5.6	1.7	9.8
Tajikistan	2,645	1,014	2,856	5,539	5.3	0.9	8.9
Uzbekistan	6,297	4,414	6,539	16,743	12.6	3.8	23.6
Turkmenistan	6,402	1,240	1,862	7,762	12.8	1.1	16.7
Central Asia	35,561	17,170	32,980	83,036	71.2	14.7	122.2

4.3 Croplands

Figure 3 shows the exposure maps produced at regional scale for cotton and wheat croplands at 100-m resolution. Table 4 provides the total wheat and cotton production in each Central Asia Country and Oblast, together with country-based average yield and price. Largest productions of cotton are found in Uzbekistan and Turkmenistan. The greatest production of wheat is found in Kazakhstan, followed by Uzbekistan.

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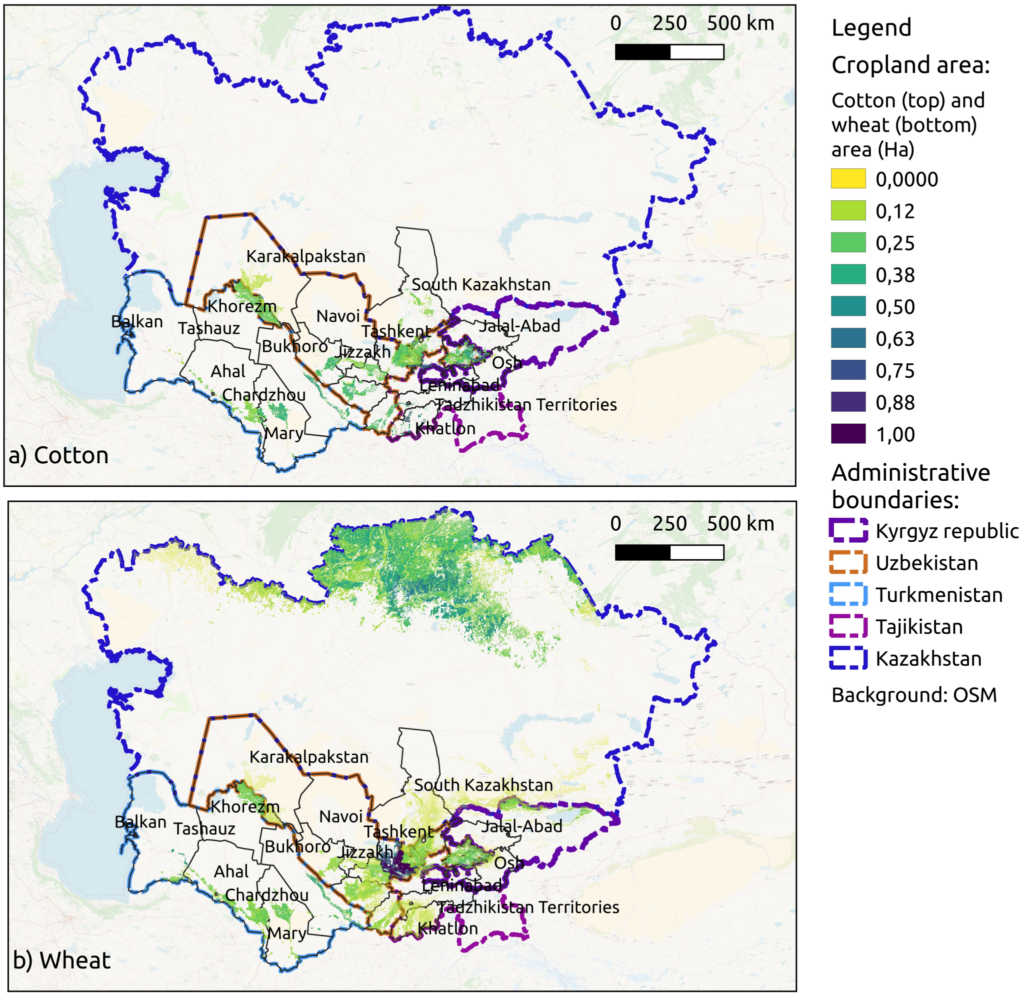

Figure 3. Exposure maps produced for wheat (top) and cotton (bottom) croplands at 100m resolution. Map data from OpenStreetMap available from https://www.openstreetmap.org (© Openstreetmap contributors, 2023, distributed under the Open Data Commons Open Database License – OdbL v1.0).

Table 4: Total value of cotton and wheat production in each Country and for the entire Central Asia region. Average price and yield are also provided for each country.

Country	Cotton					Wheat				
	Area (KHa)	**Production(Thousand T)**	**Average price (USD/T)**	**Average Yield(Tons/Ha)**	**Total exposed value (Million USD)**	**Area (KHa)**	**Production(Thousand T)**	**Average price (USD/T)**	**Average Yield(Tons/Ha)**	**Total exposed value (Million USD)**
Kazakhstan	126	328	304	2.6	99	12142	13874	91	1.4	1166
Kyrgyz Republic	25	73	600	3.3	48	253	629	150	2.4	98

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Tajikistan	146	272	421	0.7	43	234	1416	141	5.9	204
Uzbekistan	855	3094	300	3	757	2240	7453	93	6.2	1098
Turkmenistan	467	1841	482	2	449	802	1843	229	2.3	422
Central Asia	1619	5608	421.4	2.32	1396	15671	25215	141	3.6	2988

5. Discussion

The work presented here develops the first regional-scale exposure layers for selected exposed assets (namely, non residential building, transportation and croplands). The work is based on several assumptions which are required in order to assemble the first regional-scale layers of their kind. For non-residential buildings, in particular, we assumed that the socio-economic data (e.g. percentage of employees in different sectors) in Europe or post-soviet countries applies to Central Asia as well. However, the relative importance of retail and wholesale varies across EU Member States and might vary as well across Central Asia. Hence, further analysis might be required in the future in order to achieve a higher accuracy. Also, we defined broad typologies that comprise multiple building types (e.g. EMCA typologies). These typologies can be associated with multiple vulnerability or fragility curves, combined under general assumptions. For example, retail commercial buildings were assumed to be similar to residential buildings, hence they were defined based on each country's residential building stock. However, this can only support simplified damage/risk assessment that should be calibrated and validated carefully based on past events, when possible, and more specific information on the performance of building typologies considered.

In order to develop the exposure layers, an effort was needed to collect the available information, which is often dishomogeneous and scattered across sources. A common critical point is the lack of geospatial data for some assets (e.g. croplands, non residential buildings) for which country-based data are often provided in tabular form. Also, while some non-residential buildings have been mapped by global projects (e.g. schools), information on commercial and industrial buildings is scarce, and does only support a simplified spatial distribution based on proxies (e.g. population or land-use). Finally, the time coverage of the data is dishomogeneous and often incomplete: further efforts should be done in order to update the database in the future.

The suggested usage of layers depends on the type, coverage and quality of data used as input. In particular, road and railways database was developed based on OSM, which is considered a reliable source both in terms of location and classification of assets, and is consistent with the available country-based data. Similarly, the croplands dataset is developed based on recognized products which undergo specific validation processes and national-scale official data (e.g. wheat/cotton production for each oblast). Both datasets are therefore considered reliable for regional-scale damage and risk assessment purposes. With respect to schools and hospitals, despite the presence of geospatial databases for some countries which include the location and type of assets (e.g. healthsites), information on their characteristics is scarce and does not support a highly-reliable exposure assessment. For this reason, they are considered of medium reliability. Finally, exposure layers for commercial and industrial buildings are developed based on strong assumptions both on the type and distribution of assets, and data integration is required in order to validate the layer. For the time being, their use is suggested as a starting point for further exposure development efforts rather than proper damage/risk assessment. Similarly, the dataset of bridges extracted from OSM and identified based on spatial analysis is likely to be incomplete and should not be used to perform a specific risk assessment, but can act as a starting point for the collection of additional information based on complementary surveys and analysis of remote sensing images.

Future work might be required in order to resolve these critical aspects using country-based specific information. In particular, a strong effort should be devoted to validating the dataset based on additional data, which might be available to local public and private stakeholders. This is particularly valid in areas with low data coverage and/or undergoing land use changes. The layers provided here are nonetheless a first step towards Disaster Risk Reduction (DRR) in the region, and allow the first-level assessment of expected damages and risks in the region. However, the selection of assets at stake is not limited to the ones considered here, and others might be potentially relevant (e.g. energy production sites and infrastructure). Future work in this direction might include the estimation of expected risk in the region for one or multiple hazardous phenomena and accounting for potential cascading effects (e.g. flood and drought impacts on croplands and food industry disruption).

6. Conclusions

This work describes the methodology employed to develop regional-scale exposure layers for four non-residential buildings classes (healthcare, educational, commercial and industrial), transportation and croplands in Central Asia. We assembled the available global and regional datasets together with country-based information provided by local authorities and research groups. Results are geospatial layers containing the exposed assets classified into broad typologies and associated with reconstruction costs. Total reconstruction costs were also estimated at regional scale, showing that the contribution if non-residential buildings, croplands and transportation is not negligible for disaster risk reduction purposes. The exposure database provided here supports further analysis to integrate data from national and sub-national projects within the layer, enrich the risk-related knowledge in the region and support regional-scale disaster risk reduction strategies.

Data Availability

The data used to develop the input layer are available at the links provided in Table 1. In particular, the road and railway network was extracted from Openstreetmap database (https://www.openstreetmap.org) and from the Global Roads Inventory Project - GRIP (https://www.globio.info/download-grip-dataset) and, for Kyrgyz Republic, from https://geonode.caiag.kg/. The global mines dataset is available at: https://pubs.usgs.gov/of/2010/1255/. Employee statistics were retrieved from the World Bank data portal (https://data.worldbank.org/i) and the Eurostat database (https://ec.europa.eu/eurostat/databrowser) (see Table 1 for details). Healthcare facilities dataset can be downloaded from the Healthsites website (https://www.healthsites.io/), while national data for Kyrgyz Republic can be retrieved at http://geonode.mes.kg/. The global school dataset was retrieved from the Unicef website (https://projectconnect.unicef.org/map/countries), while national maps are available for Tajikistan ((https://geonode.wfp.org)). Global crop dominance layers can be retrieved at the following link: https://catalog.data.gov/dataset/global-food-security-support-analysis-data-gfsad-crop-dominance-2010-global-1-km-v001, while global land cover fraction was downloaded from https://lcviewer.vito.be/download. National statistics for educational and healthcare facilities, croplands and transportation were provided by local partners for the purpose of the SFRARR project, but are not publicly available. The spatial layers of exposure for non residential buildings, transportation and croplands developed in this work will be made available at the World Bank data portal (https://datacatalog.worldbank.org) together with the technical reports developed during the SFRARR project. Data are associated with metadata following the Ged4ALL system (http://riskdatalibrary.org/resources).

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Authors contributions

CS, AT, EF developed the exposure assessment methodology, and CS and AT carried out the analyses. All co-authors contributed to the data collection and to the discussion of results. CS prepared the manuscript with contributions from all co-authors.

Competing interests

The authors declare that they have no conflict of interest.

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