Establishing a systematic regional scale identification of artificial ground in Catalan territory from geological perspective

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- **Artificial ground** is an area where the pre-existing (natural) land surface or geological succession is modified by anthropogenic processes of material removal or deposition and may include made ground, worked ground, disturbed ground, landscaped ground and infilled ground (British Geological Survey, 2020, https://webapps.bgs.ac.uk/lexicon/).

Made ground
(https://webapps.bgs.ac.uk/lexicon/lexicon.cfm?pub=MGR)

E90-highway embankments raised near Llobregat river.

Worked ground
(https://webapps.bgs.ac.uk/lexicon/lexicon.cfm?pub=WGR)

Aggregate extractive area where the natural surface has been lowered.

Infilled grounds
(https://webapps.bgs.ac.uk/lexicon/lexicon.cfm?pub=WMGR)

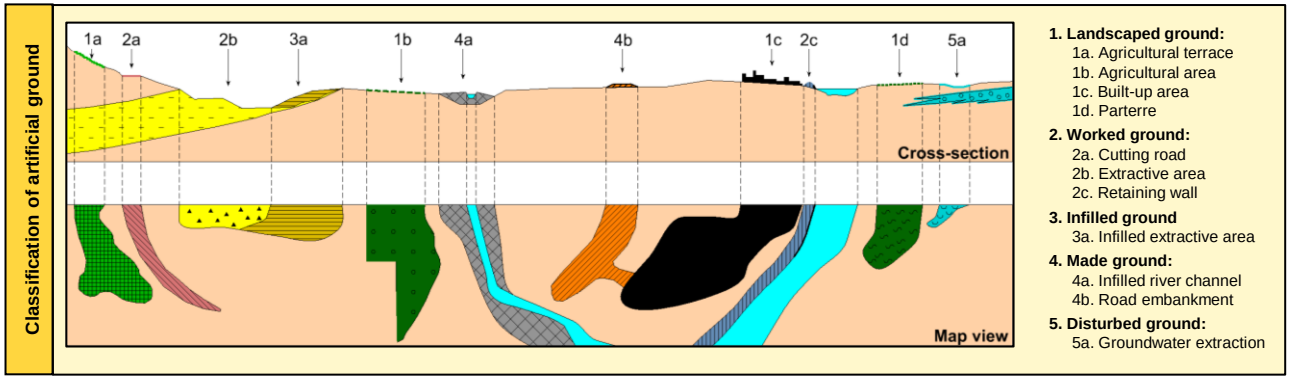
Garraf landfill waste tip, where municipal waste from the Metropolitan Barcelona area was dumped.

Landscaped ground
(https://webapps.bgs.ac.uk/lexicon/lexicon.cfm?pub=LSGR)

Llobregat-delta sector which has been extensively remodelled by logistics and industrial area.

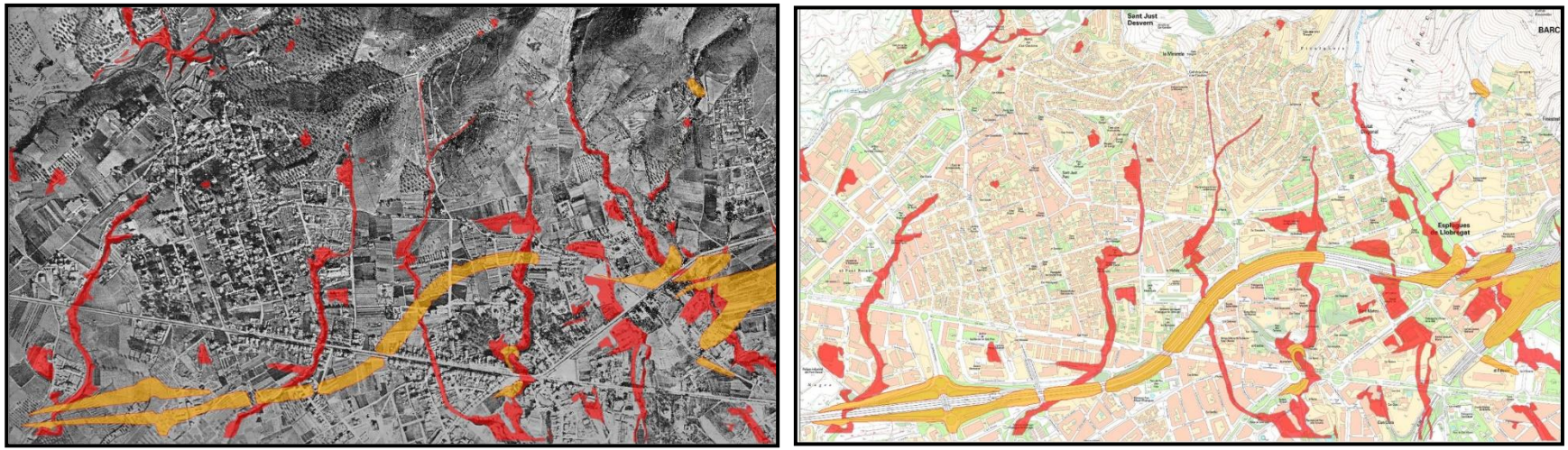
Disturbed ground
(https://webapps.bgs.ac.uk/lexicon/lexicon.cfm?pub=DDGR)

Land collapse in Carmel neighborhood due to the construction of the metro tunnel.



- From a geological perspective, artificial grounds constitute a **volume of material with specific geological features**. Hence, they are a **determining factor** in the field of engineering, geological risk, soil pollution, among other environmental concerns, **especially in urban areas.**

- For instance, the diversion of streams, infilled river channel and road embankments can generate serious repercussions for flood risk management.

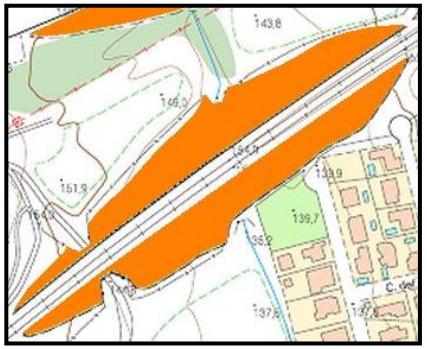


On the left side, the red and orange plots indicate infilled river channels and road embankments respectively on the historical orthophoto of 1945. On the right-hand side, these artificial grounds are indicated on the current 1:5,000 topographic map.

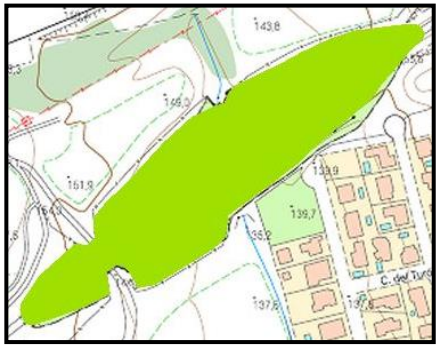
- Therefore, making a catalogue of artificial grounds is essential for the urban management and sustainable development of a territory.

- From geological perspective, despite the effects of artificial grounds, the **systematic characterization of anthropic ground** on a regional scale is **scarcely developed** in some anthropic-information sources in Catalonia such as topographic bases.
- To clarify this issue, as an example, embankments (made grounds) are only identified by embankment slopes in topographic maps. Nonetheless, to geological knowledge, the term of embankments implies slope embankments and roadbed, as both together constitute a certain **volume of material**.

Road embankment
Orthophoto 1:25,000



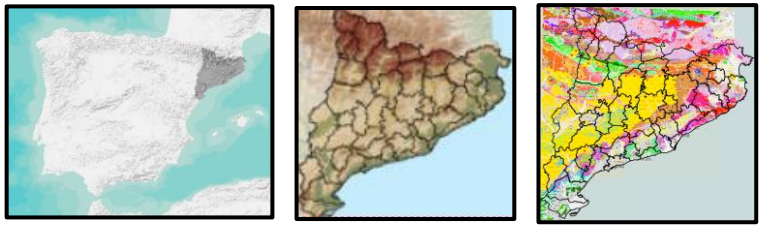
Slope embankment
Topographic base 1:5,000



Road embankment
Geological concept

- Hence, it is necessary to **analyze the data sources** in order to organize, catalogue and revise the information into datasets which can have relevance and application in aspects related to engineering, natural hazards, among other environmental issues.
- So, there is a need for access to practical artificial-ground information. And the Catalan mapping & geological agency (Institut Cartogràfic i Geològic de Catalunya, ICGC) has the function, by law and to the extent possible, to satisfy this need of anthropic information.

- **The Catalan Geological Survey**



Institut Cartogràfic and Geològic de Catalunya **(ICGC)** is the official Catalan mapping & geological agency, belonging to the Catalan Government and aiming to deliver to users valued geographic and geological information and services.

- **Functions of ICGC**

The functions of the ICGC are related to the exercise of skills in geodesy and cartography and the spatial data infrastructure of Catalonia, as well as to promote and carry out actions related to knowledge, prospecting and information on soil and subsoil, in the terms established by Laws 16/2005 and 19/2005. Some of them are:

a) Developing and promoting studies, works and evaluations in the field of geology and related disciplines that contribute to improving the knowledge of the soil and subsoil of Catalonia.

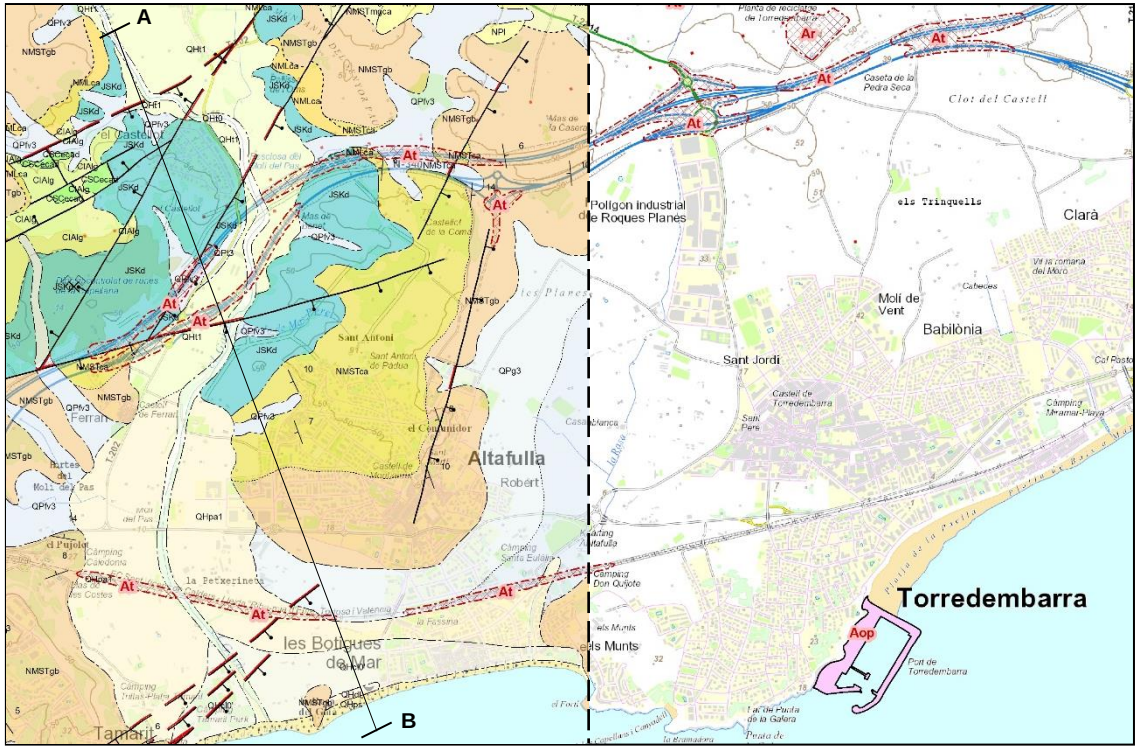
b) Providing the public administrations and the entities and organizations that are attached to the information collected in the databases that are necessary to carry out the works promoting in Catalonia and, in general, to exercise their powers.

c) Elaborating procedures and protocols to be applied in works related to geology and the related disciplines.

For this reason, the ICGC conducts geological studies throughout the territory

- **Regarding the importance of artificial grounds,** one of the lines of ICGC has been the development of the Geological map project of Catalonia at scale 1:25,000 (GT-I). The content is focused on rocks and materials that constitute the subsoil and emerge on the surface ground. Moreover, it incorporates information of artificial ground.

Geological map 1:25,000



Artificial-ground legend

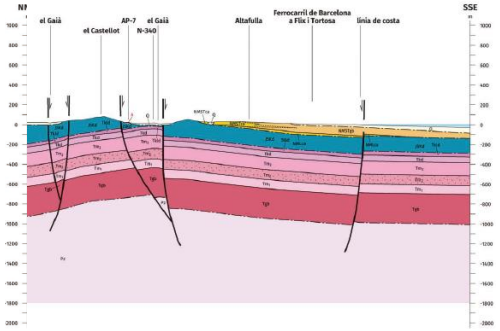
Made ground

At	Road embankment.
Aop	Infrastructure-coast embankment.

Worked ground

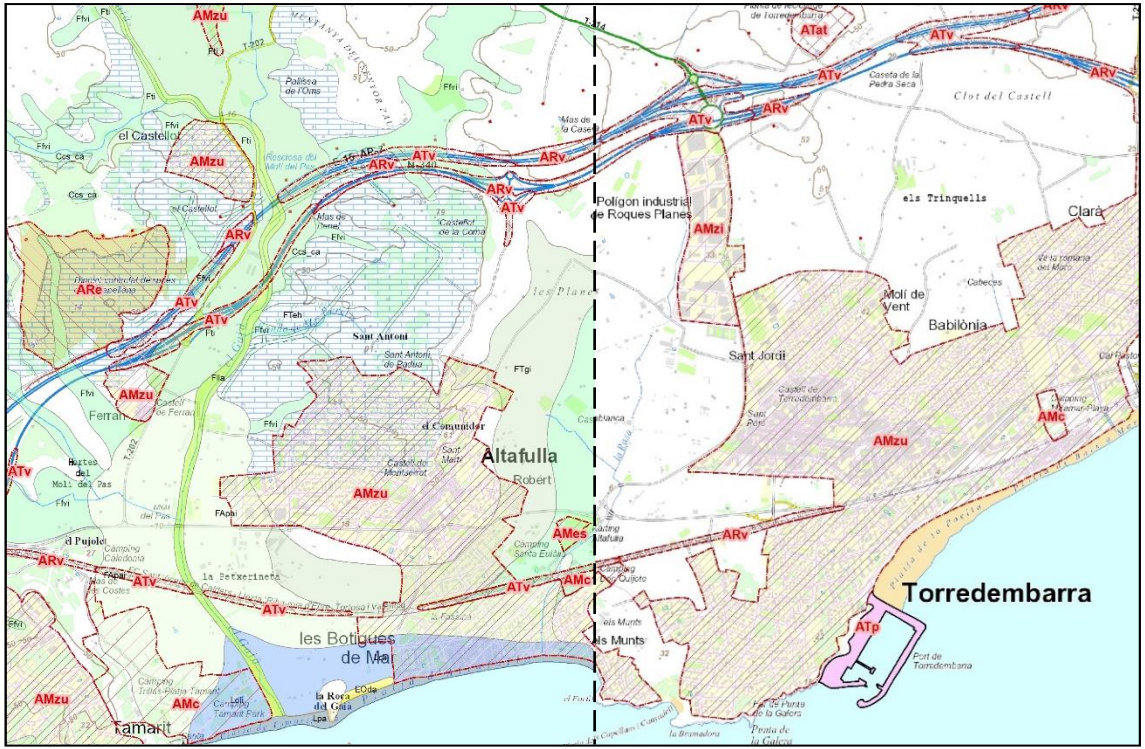
Ar	Cutting road

Cross-section A-B



- **Regarding the importance of artificial grounds,** one of the lines of ICGC has been the development of the Geoanthropic map project of Catalonia at scale 1:25,000 (GT-II), which incorporate information of geological processes and artificial ground.

Geoanthropic map 1:25,000



Artificial-ground legend

Made ground

- ATat — Temporal made ground during a building site.
- ATv — Road embankment.
- ATp — Infrastructure-coast embankment.

Worked ground

- ARv — Cutting road
- ARe — Extractive area

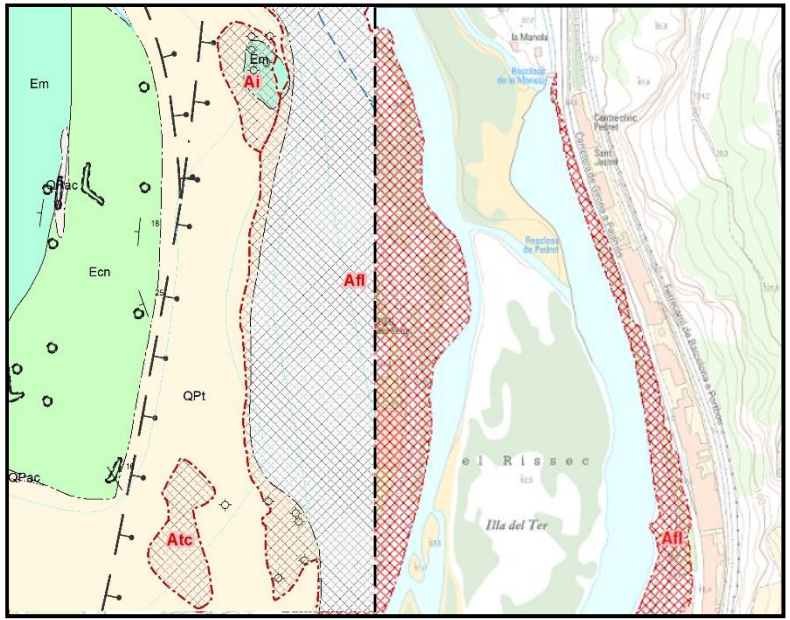
Landscaped ground

- AMzu — Built-up area
- AMzi — Industrial area
- AMc — Camping area
- AMes — Sports activities area

… and so on

- Urban geological map 1:5,000 project (GT-III) also incorporate main artificial-ground information and other relevant material such as ground elevation changes map, borehole's location and anthropic-deposit thickness.

Urban geological maps 1:5,000



Artificial-ground legend

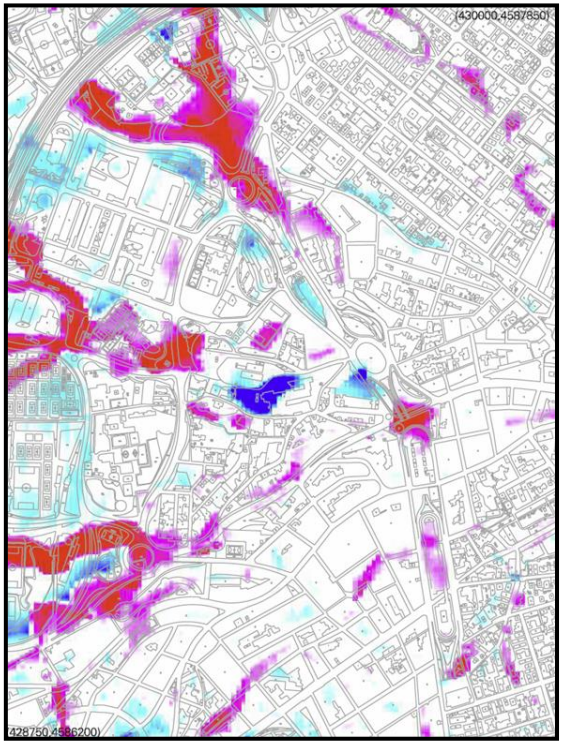
Made ground

Ai — Undifferentiated made ground

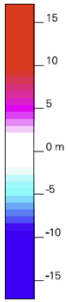
Afl — Main made ground of river sector

Atc — Road embankment

Ground elevation changes map



Legend



Made-ground zones

Worked-ground zones

The ground elevation changes map (on the left) is generated from the difference between Digital Elevation Models (DEM) of different years.

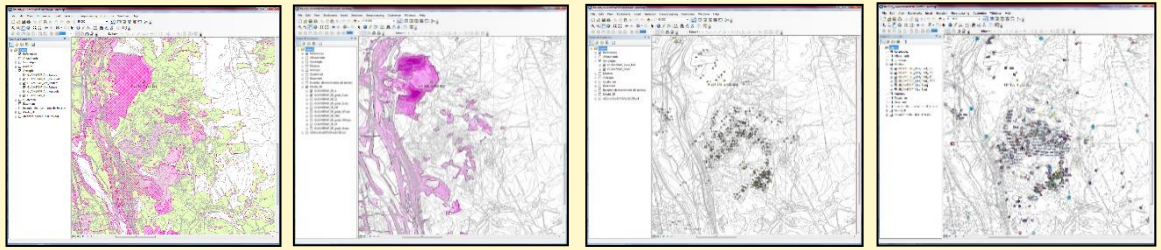
- Recently, in the framework of GT-I, GT-II and GT-III projects, it is proposed to refocus them with the **purpose of providing layers of artificial-ground information** from all over the territory.

Diverse geothematic content integrated into a consistent system

GT-I GT-II GT-III

VS.

System of diverse individual layers of geological information: the case of anthropic issues



Anthropic layer | Thickness of anthropic deposit | Location of boreholes | Samples

… and so on

- This purpose has the following objectives:

  a) Analyzing artificial-ground information in available information sources.

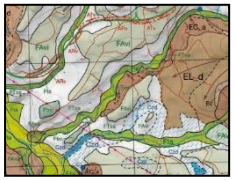
  b) Developing a catalogue of artificial-ground information layers.

  c) Providing several artificial-ground information layers.

  d) Enhancing the value of the geology of artificial grounds.

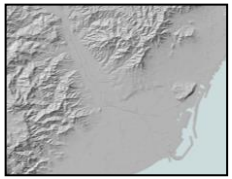
- In this process, an analysis has been carried out to determine which artificial grounds and related information can be obtained for its usefulness in a systematic way in the medium term.

- How can be tackled main artificial grounds based on existing data? **Firstly,** the **available reference information sources** have been **established** from which artificial ground information in Catalonia can be extracted. Basically, these **sources** are:



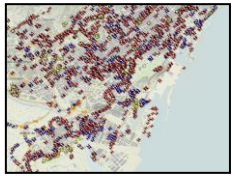
Geothematic maps

Source: ICGC



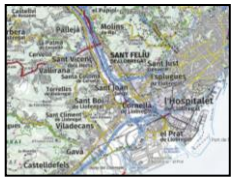
Digital elevation model

Source: ICGC



Geotechnical surveys viewer

Source: Database of boreholes in Catalonia (BDSoC) and geotechnical map of Barcelona

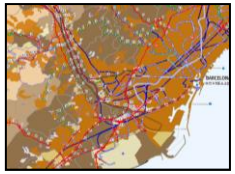


Topographic bases: 1:25,000 and 1:5,000

Source: ICGC

Current Orthophotos

Source: ICGC



Hypermap

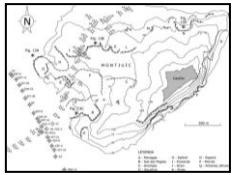
Source: DTS

Land Cover Map

Source: CREAF

Historical orthophotos

Source: ICGC



Historical cartographic documents

Source: ICGC Digital Map Library

- In general, much of the existing information in these sources must be redirected to a geological approach so that it can be used to tackle geotechnics, natural hazards, soil pollution and other environmental concerns. Therefore, from these existing data sources, **what artificial-ground information layers can be provided?**

- Based on the data sources analysis, a series of certain artificial grounds have been evaluated with the aim of capturing them on a systematic identification at regional scale.

Landscaped ground
- Built-up areas
- Agricultural areas
- Sealed ground
- Urban compacity

Made grounds
- Embankments (road, rail)
- Coastal infrastructures (harbour, jetty, breakwater)
- Built-up areas
- Agricultural areas
- Undifferentiated made grounds

Infilled grounds
- Landfills
- Mineral workings
- Undifferentiated infilled grounds

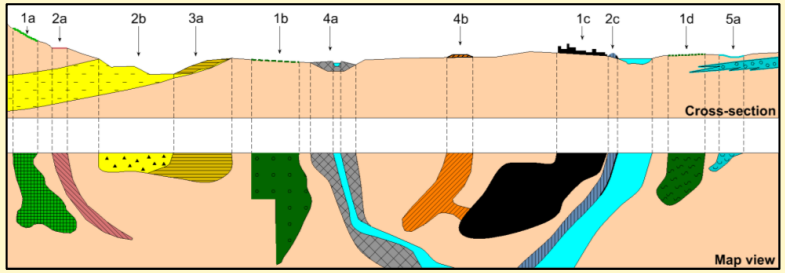
Thickness of artificial grounds
- Anthropic backfill thickness (boreholes)
- Isopach anthropic deposits

Worked grounds
- Cuttings (road, rail)
- Mineral workings
- Undifferentiated worked grounds

Underground infrastructures
- Underground mining area
- Tunnel
- Undifferentiated underground infrastructure

Specific anthropic elements
- Dams
- Locks

Related anthropic elements
- Original drainage network
- Original shoreline
- Marshes and original wetland areas



Classification of artificial ground

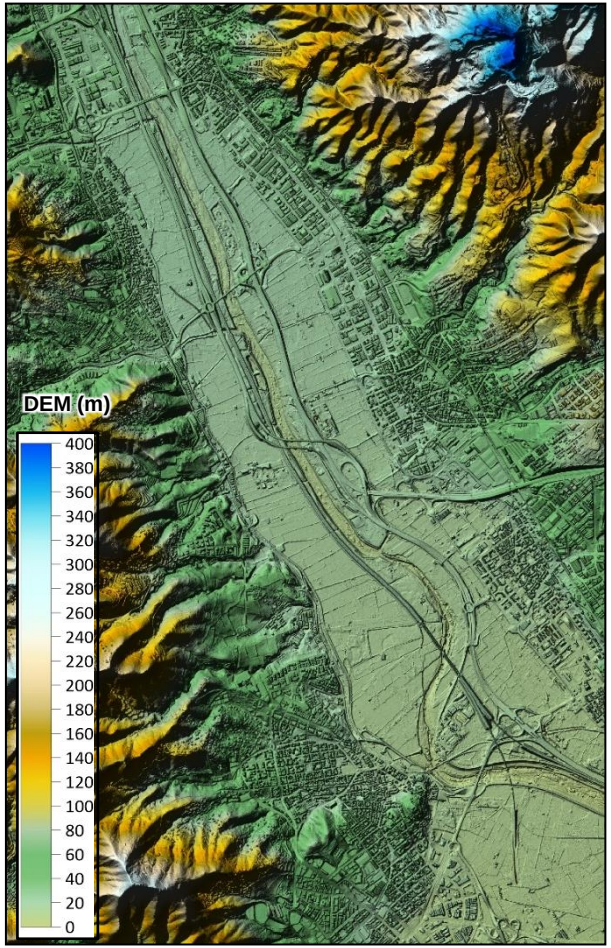
1. Landscaped ground:
1a. Agricultural terrace
1b. Agricultural area
1c. Built-up area
1d. Parterre

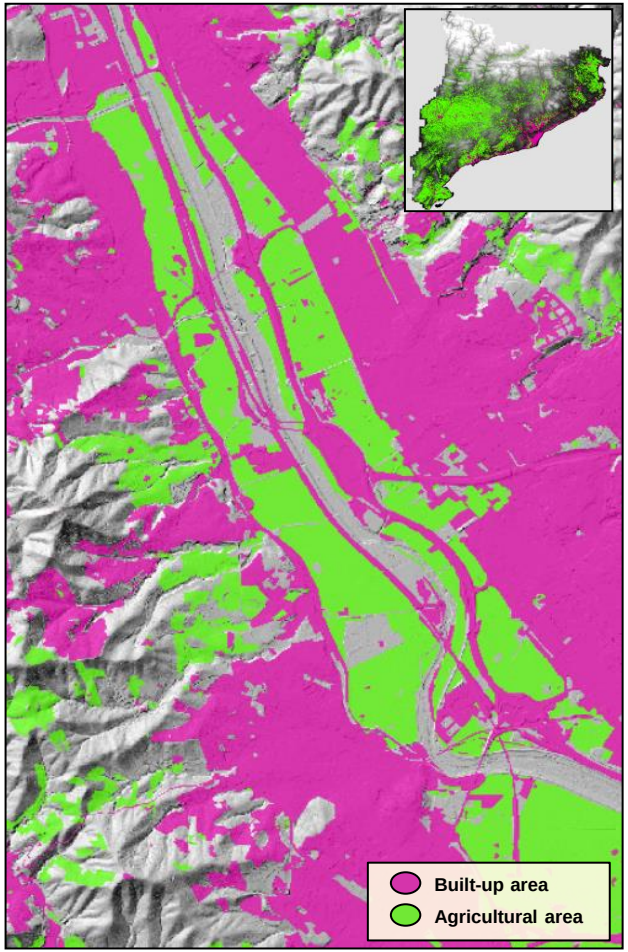
2. Worked ground:
2a. Cutting road
2b. Extractive area
2c. Retaining wall

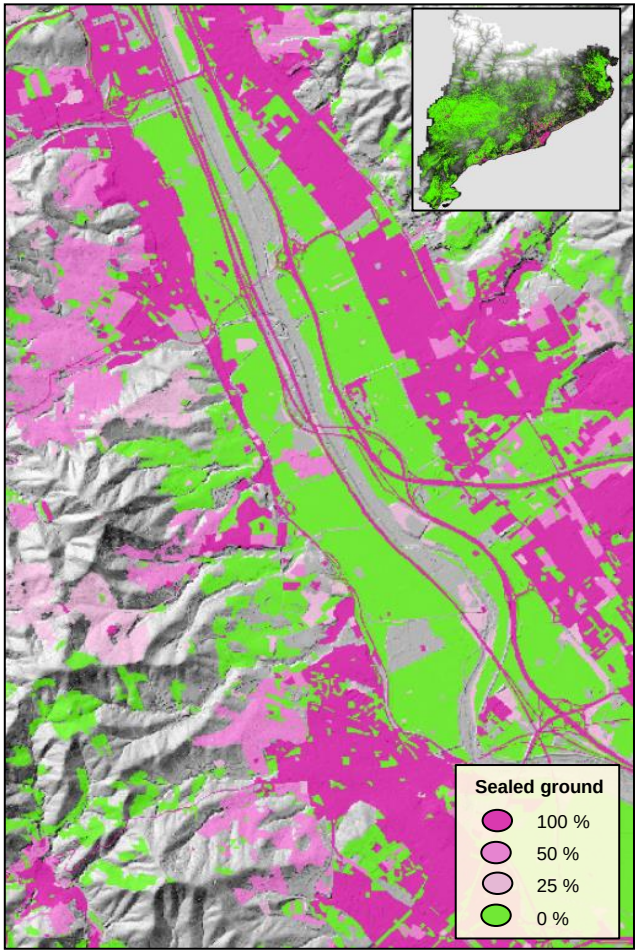
3. Infilled ground
3a. Infilled extractive area

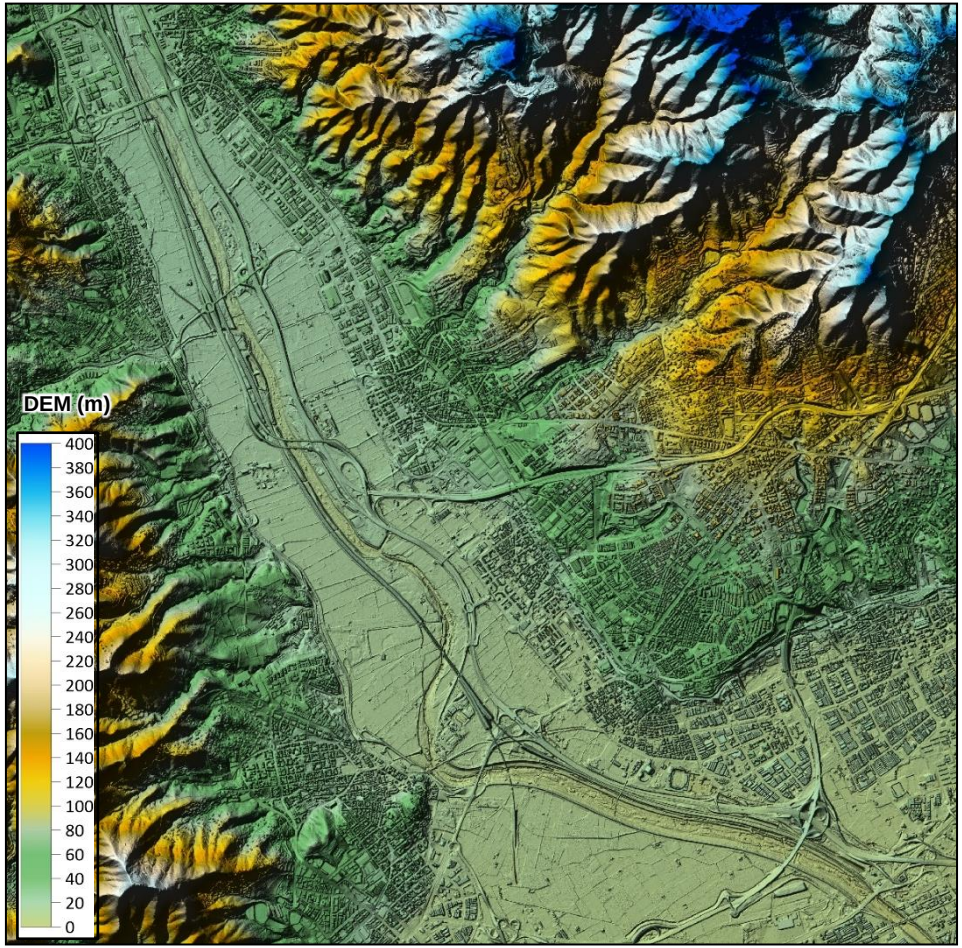
4. Made ground:
4a. Infilled river channel
4b. Road embankment

5. Disturbed ground:
5a. Groundwater extraction


DEM (m)
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0


Built-up area
Agricultural area


Sealed ground
100 %
50 %
25 %
0 %


DEM (m)
400
380
360
340
320
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240
220
200
180
160
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120
100
80
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40
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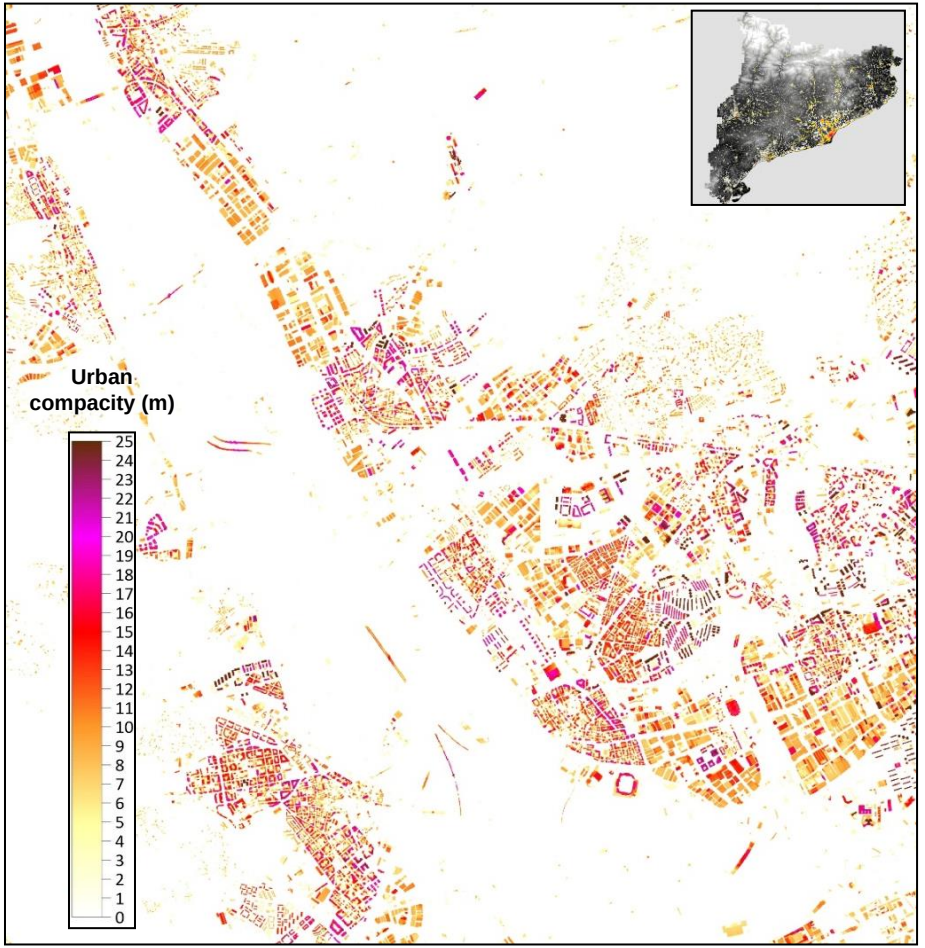
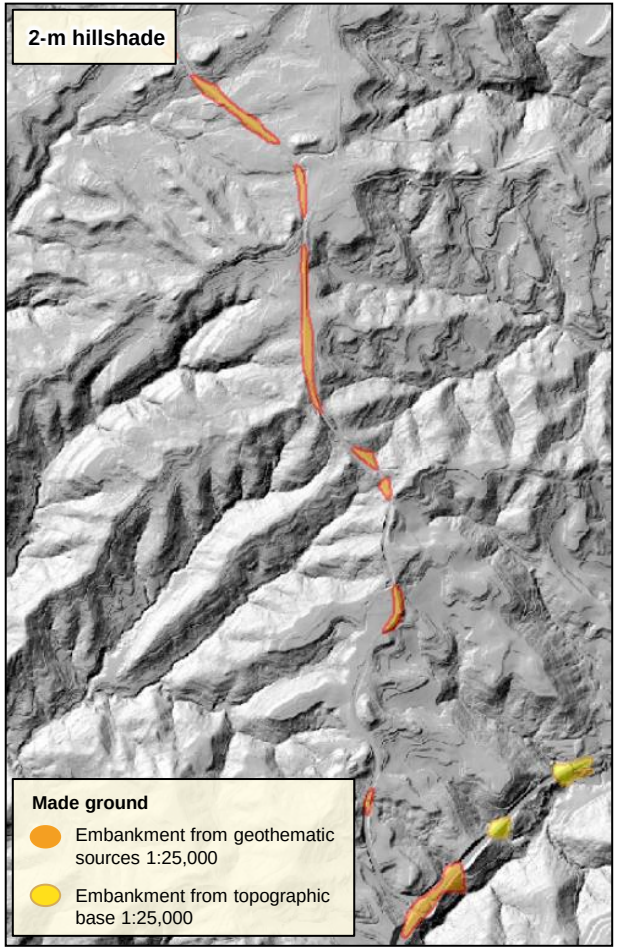
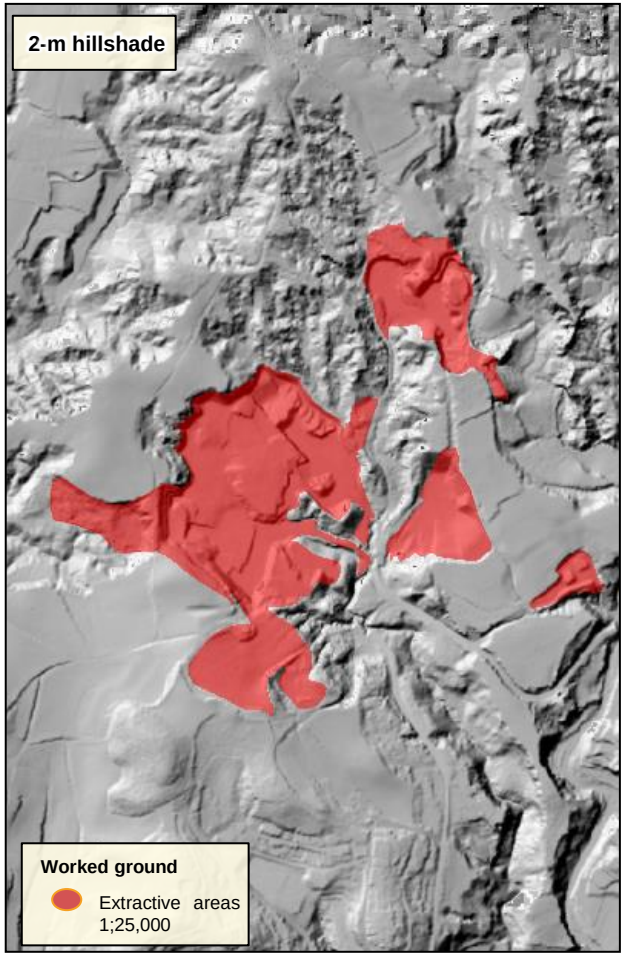
0


Urban compacity (m)
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0

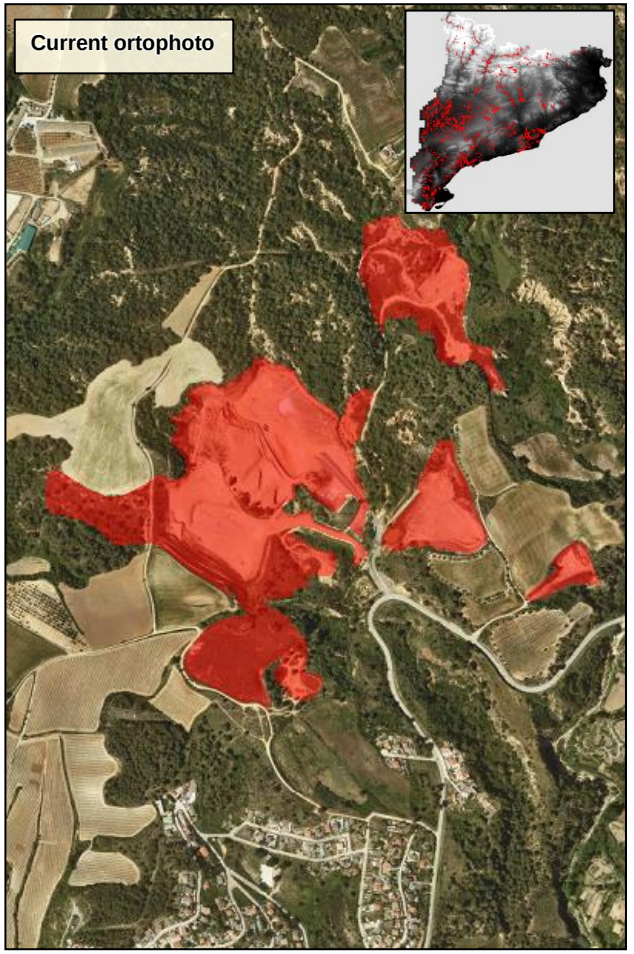

2-m hillshade
Made ground
Embankment from geothematic sources 1:25,000
Embankment from topographic base 1:25,000


Historical ortophoto 1954-55


Current ortophoto


2-m hillshade
Worked ground
Extractive areas 1;25,000


Historical ortophoto 1954-55

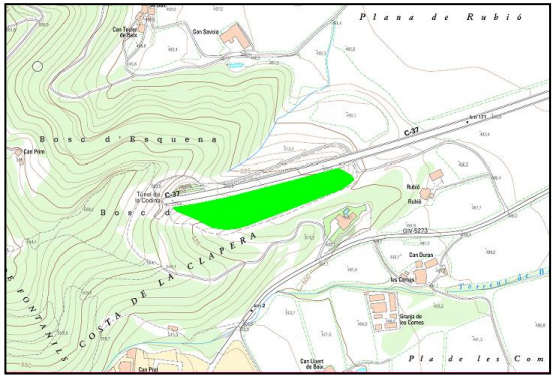

Current ortophoto

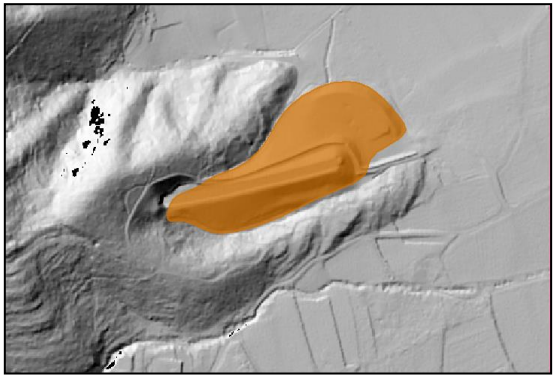
- **The geological aspects of artificial grounds are paramount importance for land management projects. Nevertheless, as a geological concept, the characterization of artificial grounds on a regional scale is scarcely developed in some anthropic-information sources in Catalonia.**

  Anthropic information in data sources is related to relief, hydrography, roads and transport networks, buildings, land cover and so on. But, what about the information related to the effects of anthropization on the territory in information sources?

  From a geological perspective, artificial grounds is a whole set of material which have implications for environmental issues such as urban planning, geological risks management, among other environmental concerns.

  Therefore, making a catalogue of artificial grounds is essential for the urban management and sustainable development of a territory.





Road embankment of the C-37 highway. The load generated by the embankment deposit must be taken into consideration for the stability of the ground.

- **Reference sources contain artificial-ground information galore that needs to be analyzed and reviewed. Moreover, the information may differ depending on the method and the year of capturing the data. Consequently, the capture of artificial grounds may need to be improved.**

Some information sources contain artificial-ground data represented at a representation scale of 1:25.000 or lower. Consequently, the artificial ground has much lower-level detail. For instance, slope embankments in 1:25,000 topographic bases are only captured if their length is greater than 250 meters and their heights greater than 10 meters. Nevertheless, from a geological view, embankments are considered to be relevant from the above 20-meter length and 5-meter height.

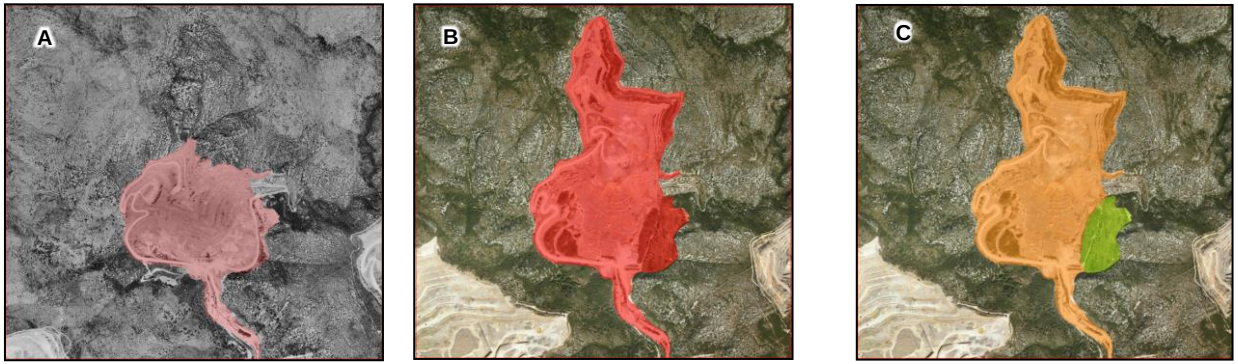
Another factor is the year of data capture. There may be places where the relief has changed due to anthropic activity since the last time data was captured. Extractive areas are an outstanding example. The latest update of this data in the land use map is from 2009, the hypermap from 2014, and the topographic bases from 2019. So, to a certain extent, there could be more worked ground in some sectors until 2020.For this reason, when extracting information from a data source, its limitations need to be taken into account.

The blue outline of the extractive area is from the current 1:5,000 topographic base. This cartographic boundary coincides with the limit of the extractive area in the 2015 orthophoto (A). In the 2016 orthophoto, the extractive area is larger (B). Finally, the red polygon indicates the new outline of the extractive zone. It has been modified concerning the current orthophoto (C).

- **Next step to be taken is to go into more detail with some of the current information layers.**

  In order to clarify this idea, the extractive zones are proposed as an example. Currently, the majority of extractive areas of Catalonia are captured. Then, it would be necessary to integrate the information coming from the geothematic information source, corresponding to the geological map 1:25,000, geoanthropic map 1:25,000 and Urban geological map 1:5,000 projects.

  After that, the next step would be to differentiate worked and infilled grounds of extractive areas, as they have different and relevant implications for territorial management and sustainable development. Worked ground are areas of interest for the subsequent restoration of the extractive area. In the case of infilled grounds, they are areas where material has accumulated during the exploitation of aggregates or resources. These are crucial anthropic deposits to control as they can lead to groundwater and soil pollution. The following figure shows the idea to be carried out.



Red polygon of worked ground of an extractive area in Garraf mountain sector, the outline has been delimited with the 1994 orthophotography (A). Current outline of the extractive area, in which it can be observed that the south-eastern sector has been infilled (B). Worked ground (orange polygon) and infilled ground (green polygon) of the extractive area will be differentiated in near future (C).

Final considerations

- **The artificial-ground information can be classified in different layers depending on the interest of user, administration and institutions.** Considering one of these situations, **the layers should be prioritized regarding the amount of available information, the practical extraction of data and available resources in short or medium term.**

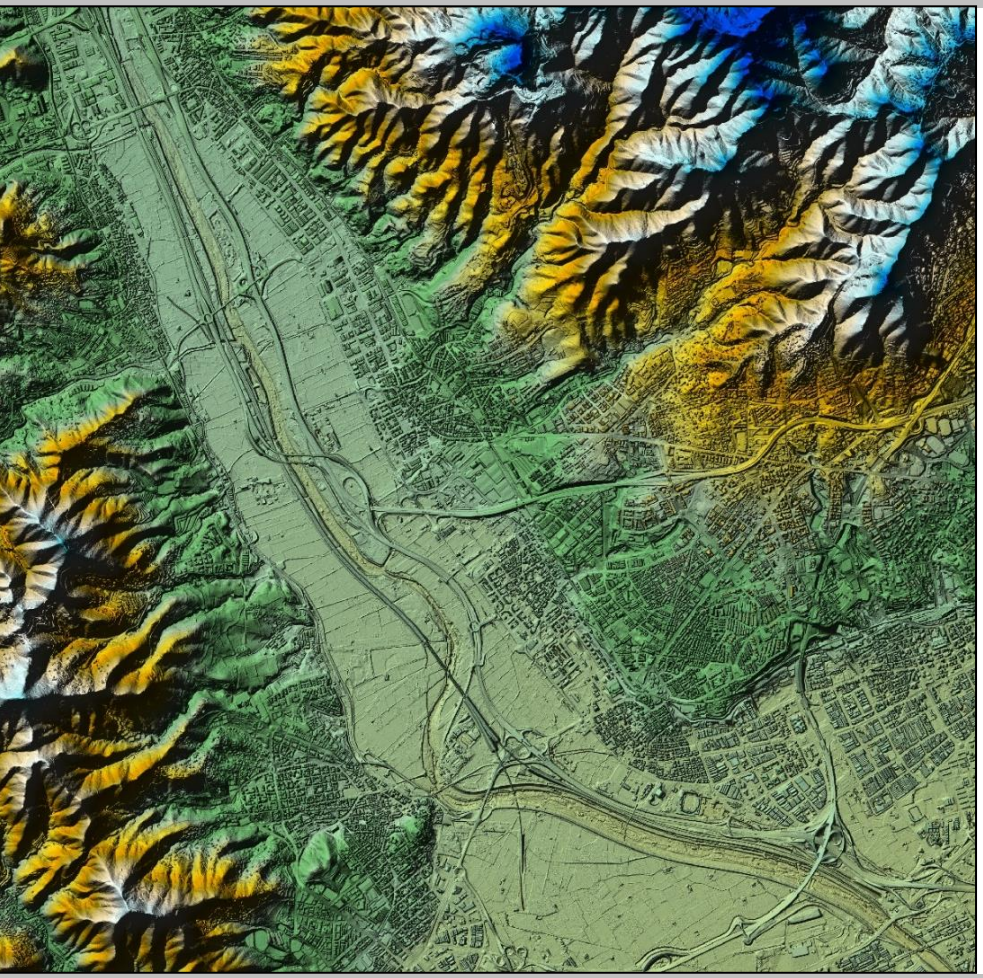
  The cataloguing of artificial ground will depend on the usefulness of each territory. The dataset which can be relevant for territorial management and sustainable development should be prioritized, especially, if there is enough information available in data sources.

  In Catalonia case, it is relevant to have reference layers of urbanized areas, the degree of sealed ground and urban compacity for issues related to environmental issues. As made and worked grounds can have an impact on flood risk or slope instability respectively, road embankments are another usual information which can be provided to this territory.

- **The compilation of data requires establishing a specific work scale and a certain degree of detail. This also depends on whether the layer can be used for specific local studies or regional studies above land management and sustainable development.**

  Even if little information on a particular artificial ground is available, it can be useful to provide their general tendency and distribution in the territory. The information layers will serve as reference information for the development and regeneration and sustainability of urban areas. In any case, its limitations have to be taken into account.

  In addition, it is highly recommended that land-use planning and sustainable development projects conduct their own research to gain a deeper understanding of the characteristics of the terrain in their study area. Therefore, the information layers are only considered to be a tool to complement any study.



Thanks for your interest!

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