ARPAT
Agenzia regionale per la protezione ambientale della Toscana
INSIEME PER UN FUTURO SOSTENIBILE

Sistema Nazionale per la Protezione dell'Ambiente

REGIONE TOSCANA

2D/3D soil consumption tracking in a marble quarry district

Ing. Cinzia Licciardello

Agenda

- Carrara marble district - history
- Land Cover changes (2D monitoring)
- Volume changes (3D monitoring)
- Changes representations with FOSS solutions:
  - Data Processing
  - Viewer

Marble extraction history in Apuan Alps

Iron Age

Roman Age

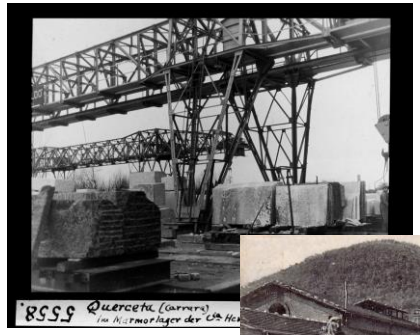
Renaissance

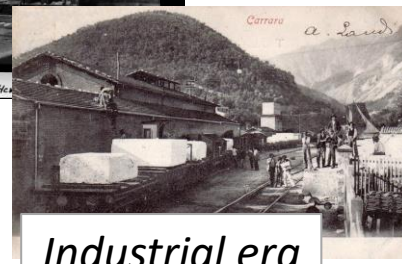
XVI Century

Hand-made

Industrial Revolution (1830-1850)

1839-1848: +50%
1849-1858: +500%





Industrial era

Motors and electification (1900-1914)

Export: 300.000 T/y
65% raw blocks / 35% slabs and masterpieces

Post-WWII

460.000 T/y (30% exported)

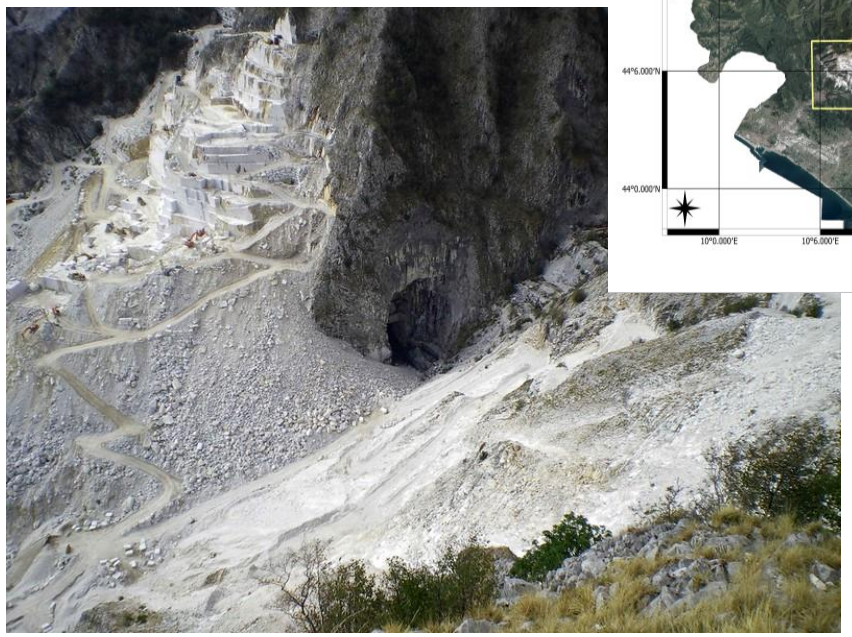
1977-1983

1977: 650.000 T/y
1983: 900.000 T/y

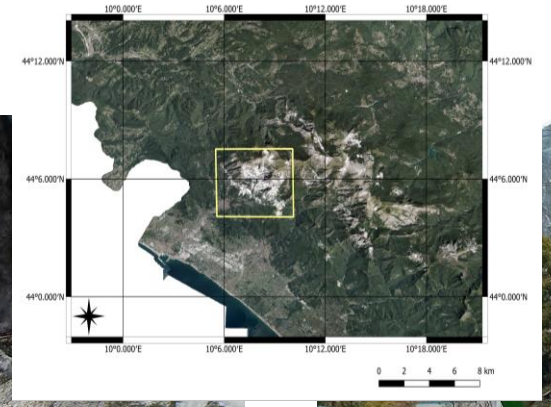
Massive cuts

Livorno-Massa Carrara Industrial Association ('Confindustria') – Marble Sector's Sustainability Report (2° Edition)

Environmental Challenges



Onsite dumps
(ongoing/past activities)



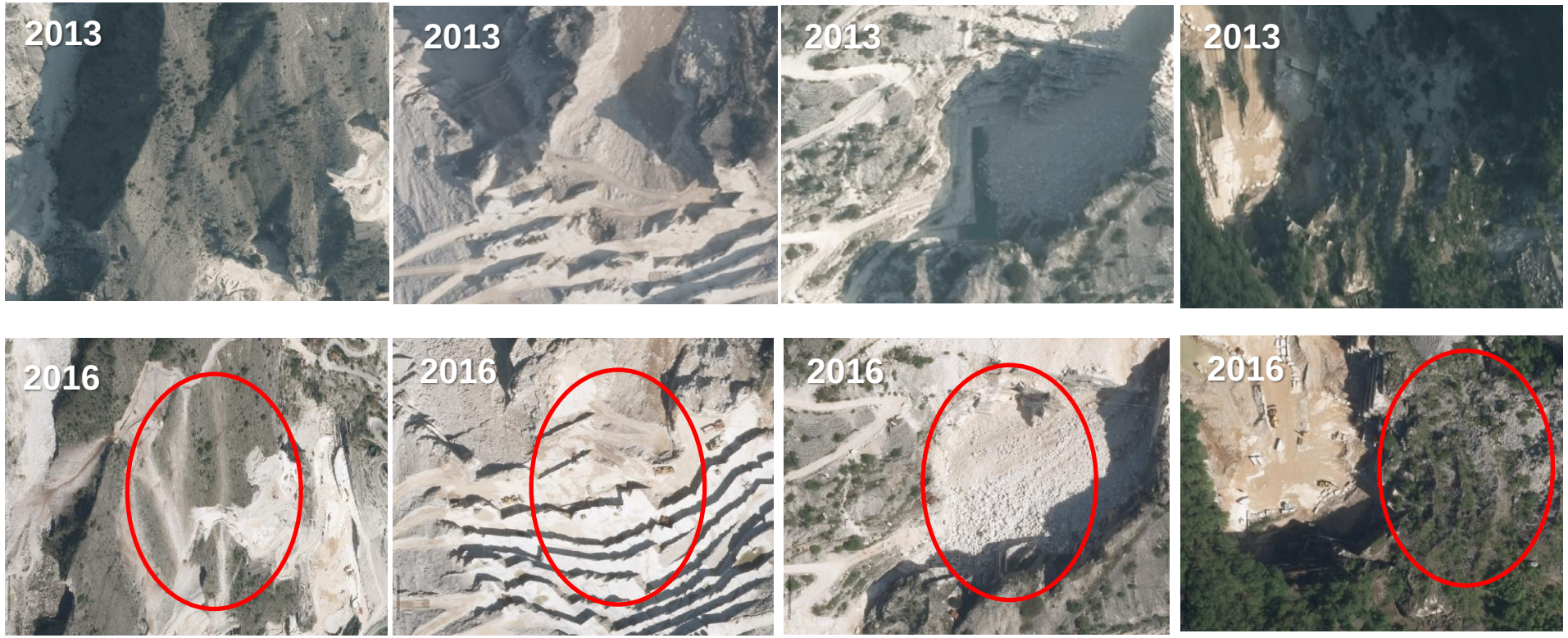
Marble powder ('marmettola')
in surface water

Onsite marble rocks/fine-grained debris are a major factor of surface water pollution ($CaCo_3$ diluition by rainfall) with oil leakage from cutting processes.

The Regional Special Monitoring Project

- Tuscany Regional Government has issued fo 2016-2020 a Special Monitoring Project involving many regional directorates and the Regional Environmental Agency (ARPAT)
- Project goals:
  - Enforcing in-situ environmental controls about:
    - Rainfall & waste management
    - Marble powder collection & management
  - **Evaluation of the potential of Remote Sensing Techniques in environmental controls' prioritization:**
    - **Land cover changes**
    - **Extracted/in-situ disposed volumes' changes (earth & rocks)**

Land cover changes



Natural soil loss

Onsite dumps removal

Exhausted quarries refilling

Vegetation growth over old dumps

Land cover changes can occour either from (a) anthropic (marble extraction, exhausted quarries' filling) or (b) natural processes (vegetation growth)

Land cover changes and sustainability goals

- **Protected areas preservation**
  > *(2D) borders monitoring*
- **Natural loss reduction**
  > *(2D) natural surface changes monitoring*
- **Exhausted quarries restoration** (whenever possible)
  > *(2D/3D) debris refilling*
- **Extraction dumps onsite reduction**
  > *(2D/3D) debris extraction for industrial reuse*
- **Sustainable quantities extraction** (production vs. damaged materials)
  > *(2D/3D) extracted/onsite volume balance*
- **Circular economy** (reuse of extracted materials)
  > *(2D/3D) extracted/onsite volume balance*

2D monitoring and sustainability (2009-2019)

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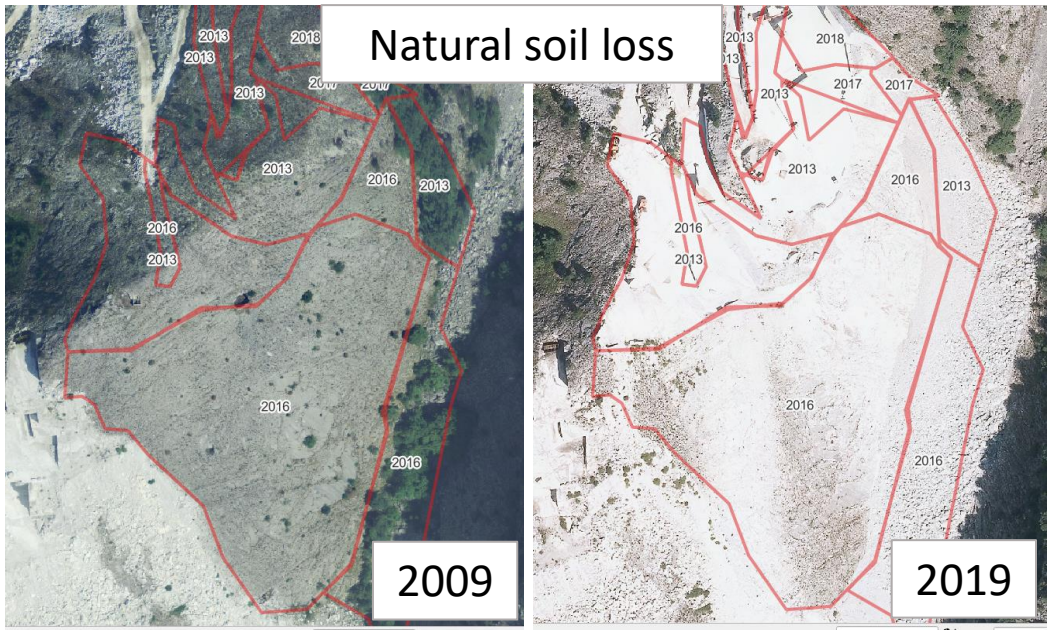
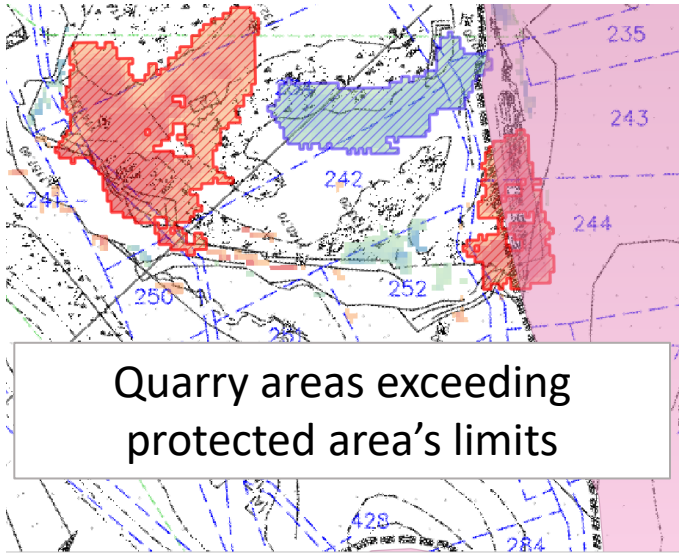
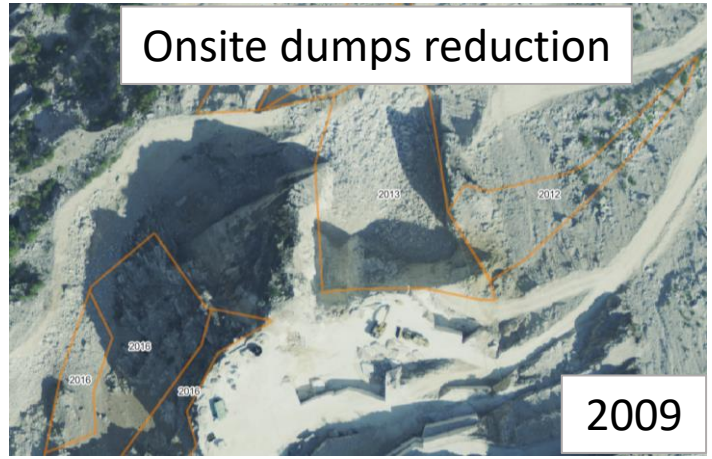
Natural soil loss

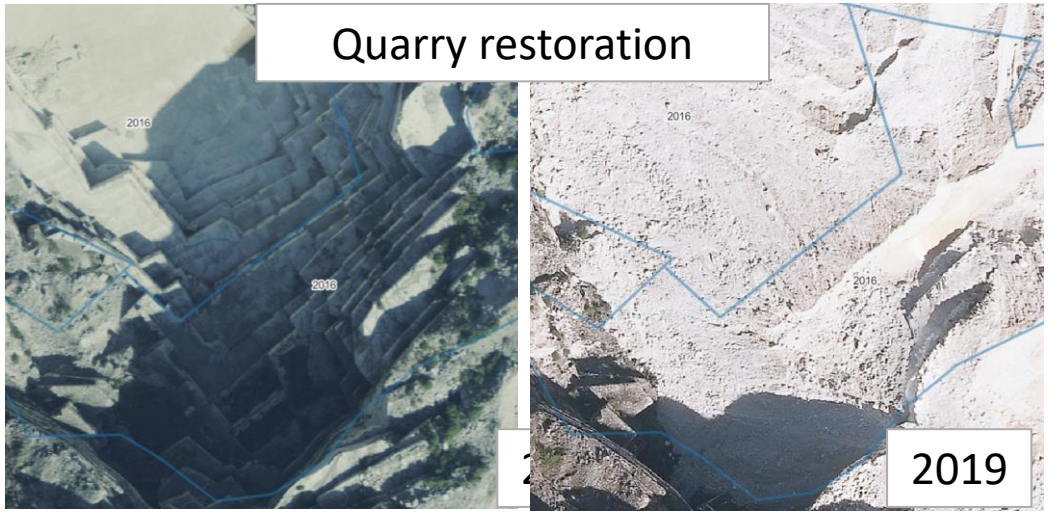




Onsite dumps reduction



Quarry restoration



3D monitoring and sustainability (2009-2019)

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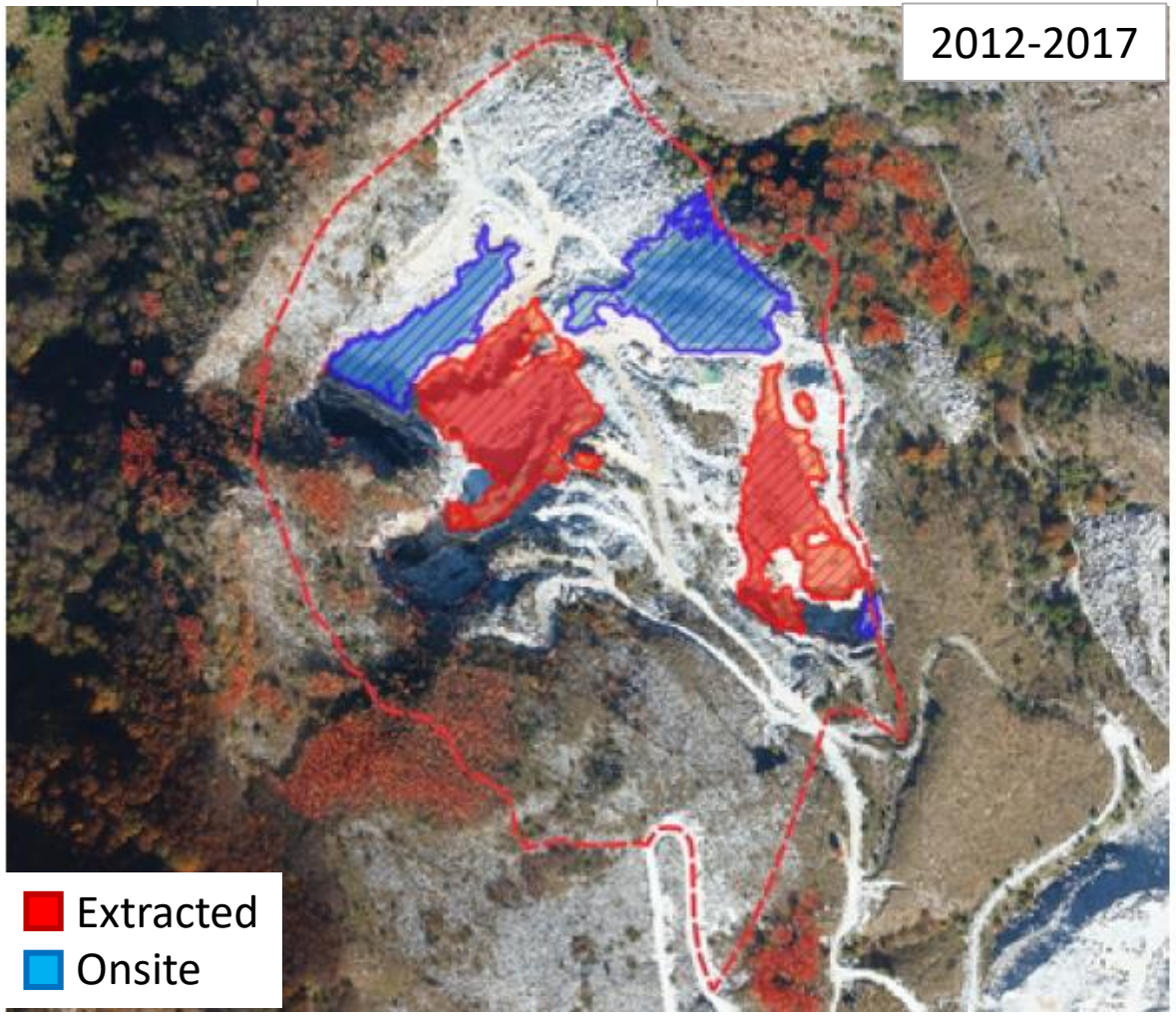

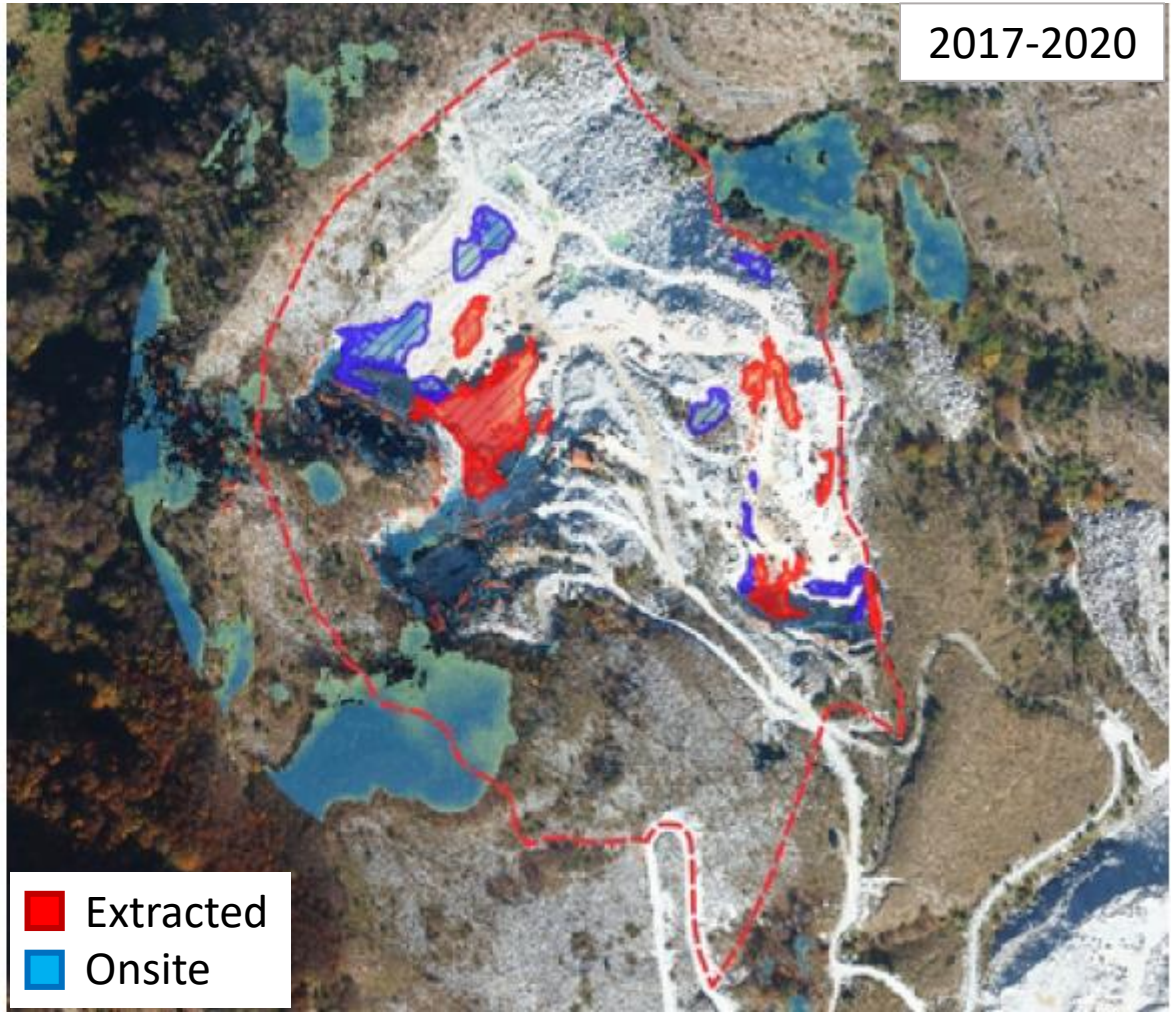

$$V_{extracted} = V_{removed} + V_{onsite}$$

2D Data Sources (Open Data) imagery & FOSS processing

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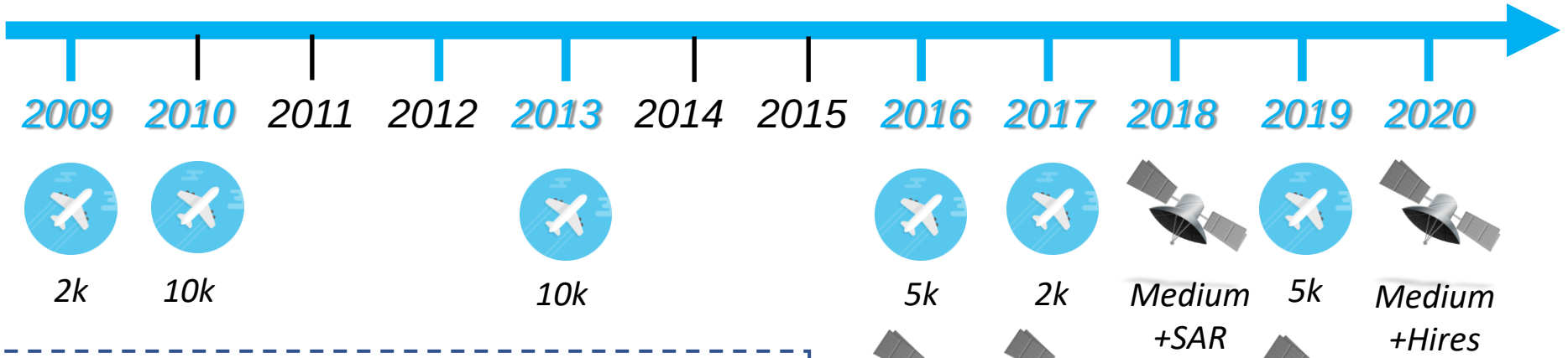
Aerial Imagery

1:10.000 (PAC 3-yearly monitoring up to 2013)
1:5.000 (PAC 3-yearly monitoring from 2016)
1:2.000 (specific monitoring: ~ 10-yearly)

Satellite Imagery

10m (Sentinel-2) – for verification purposes over high time intervals
3m (Cosmo Skymed SAR) – for inter-annual verification purposes
50cm (Pléiades) - limited quota on ESA Project Proposal submission



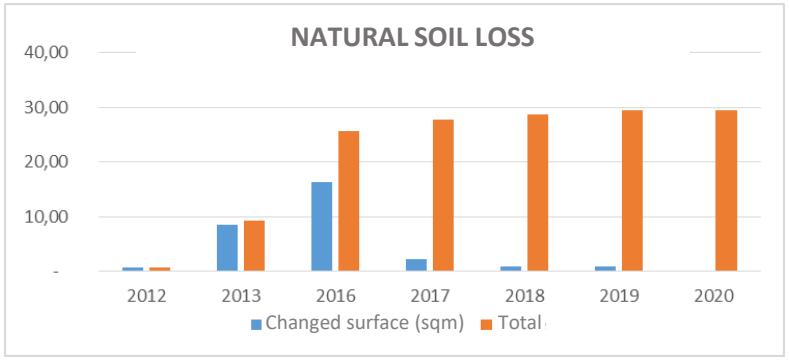
QGIS *2D digitizing*

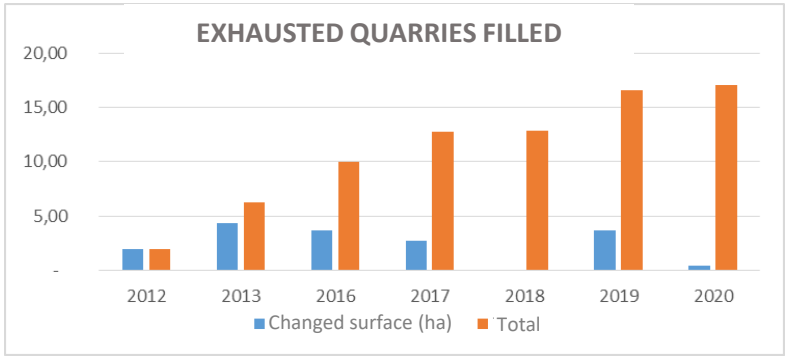
GDAL *Orthoimagery (RPC)*

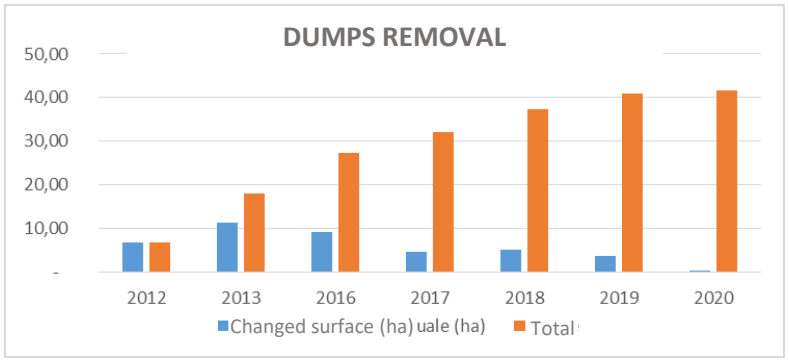
Texture Analysis

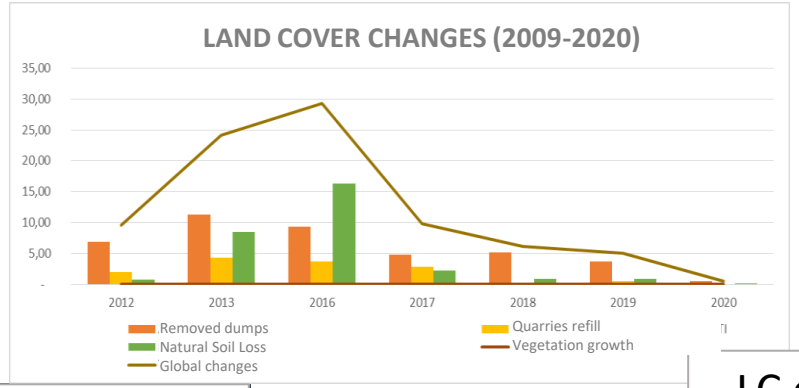
SNAP *SAR processing*

2D monitoring - Results

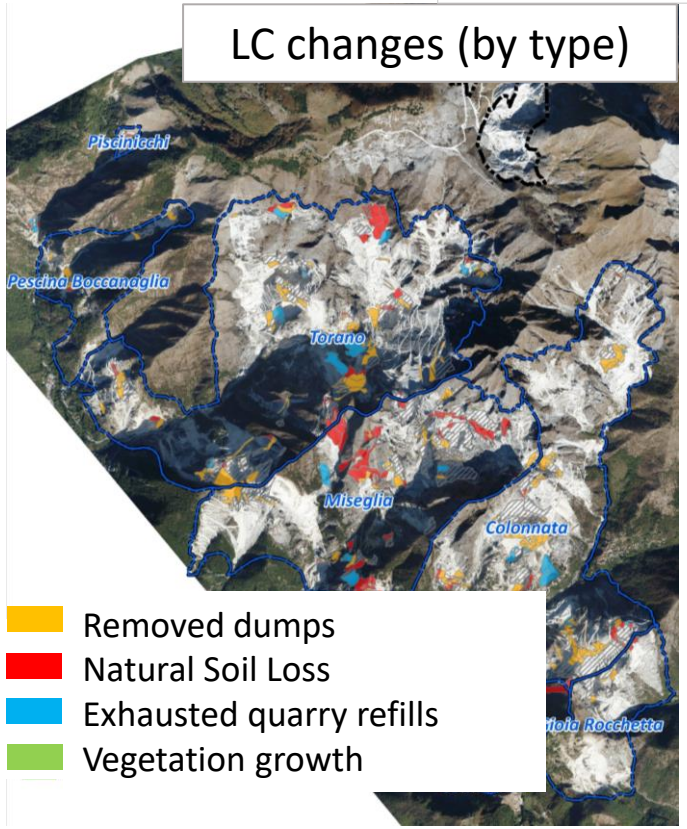






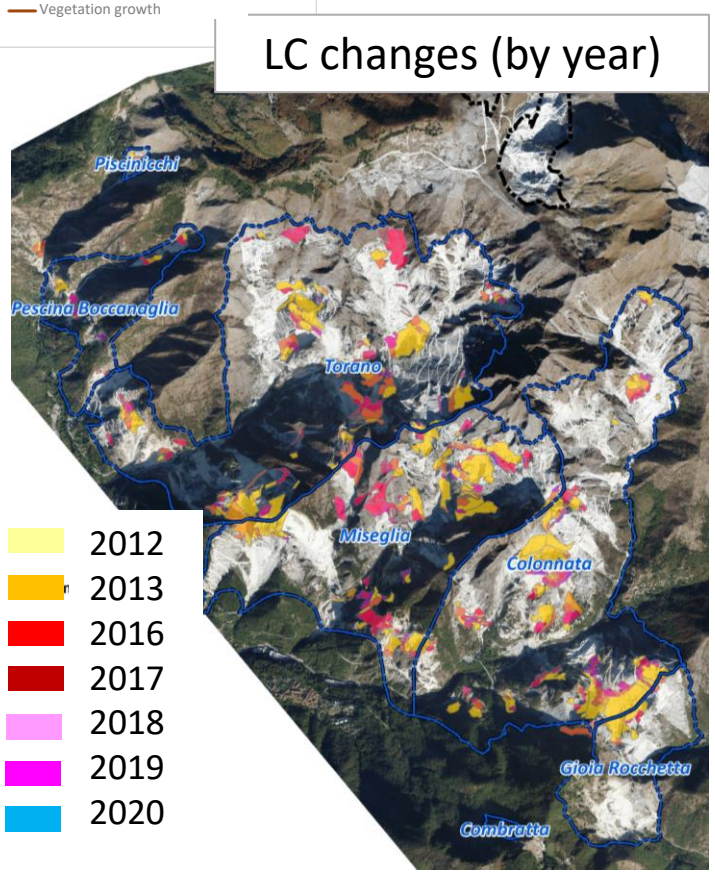


LC changes (by type)



- Removed dumps
- Natural Soil Loss
- Exhausted quarry refills
- Vegetation growth

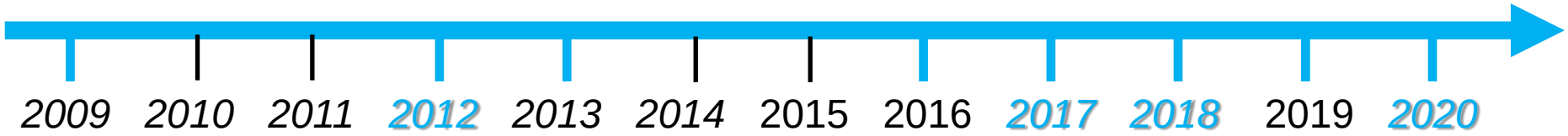
LC changes (by year)



3D Data Sources (Open Data) – LiDAR/stereo imagery & FOSS processing

Aerial Imagery
1:2.000 LiDAR surveys
(specific monitoring: ~ 10-yearly)

Satellite Imagery
50cm (Pléiades) stereo imagery
limited quota by ESA Project Proposal submission



LiDAR

LiDAR

Hires

SAR
+Hires

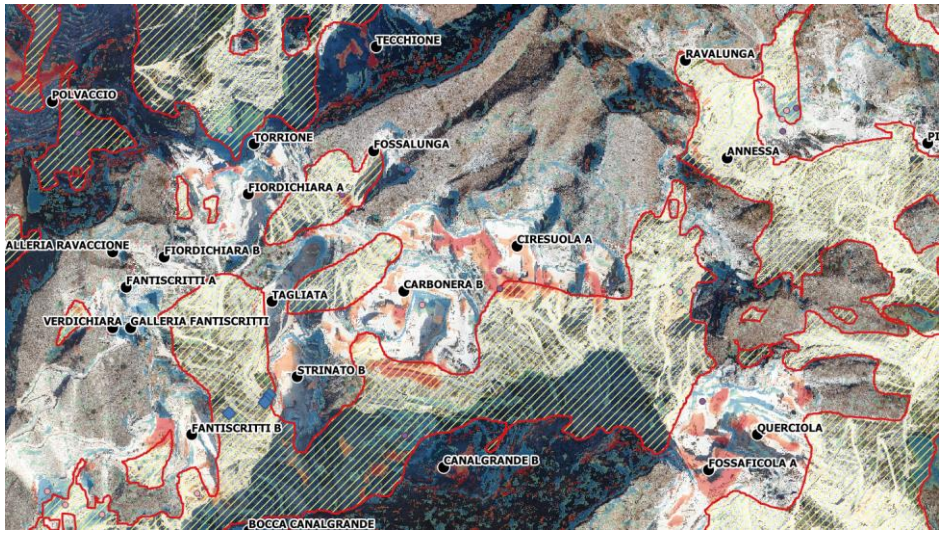
SAR
+Hires

3D differencing

Stereo processing
(ASP/s2p)

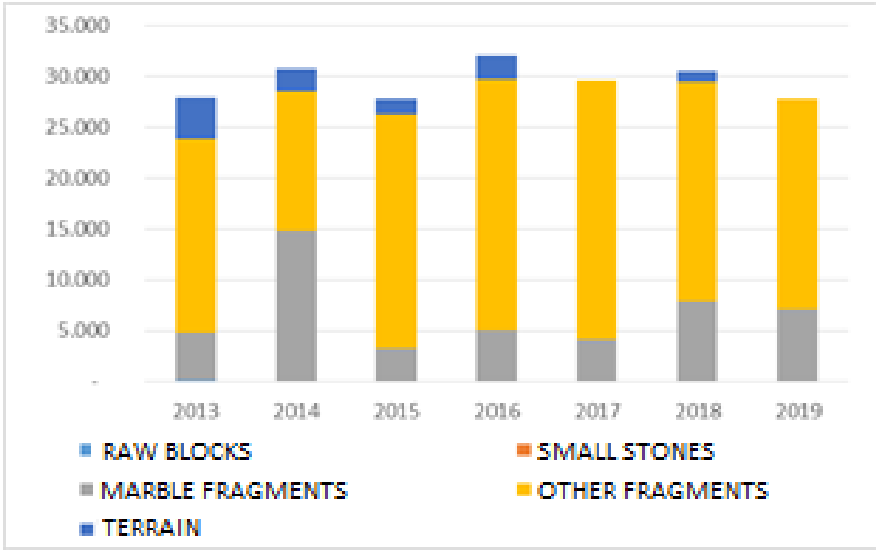
SAR processing

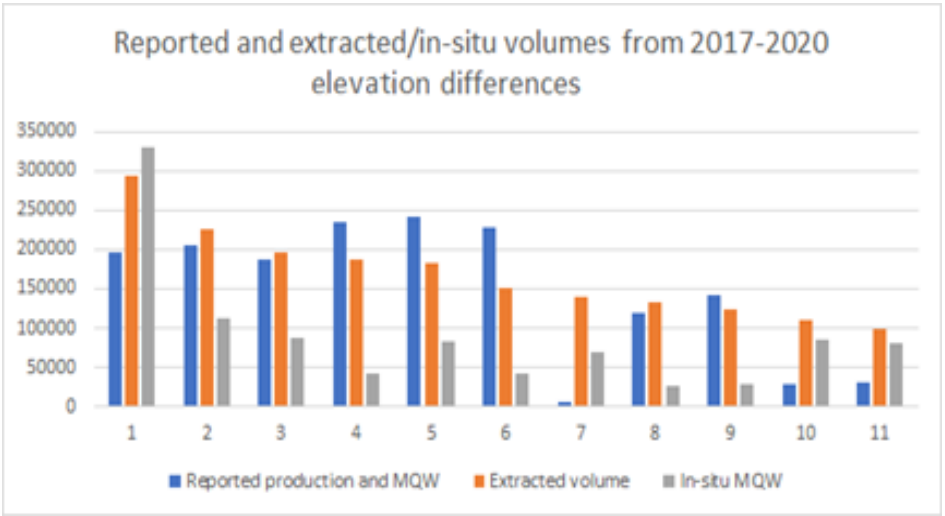
3D monitoring - Results



- Extracted volumes
- In-situ added volumes
- Earth/Rocks dumps

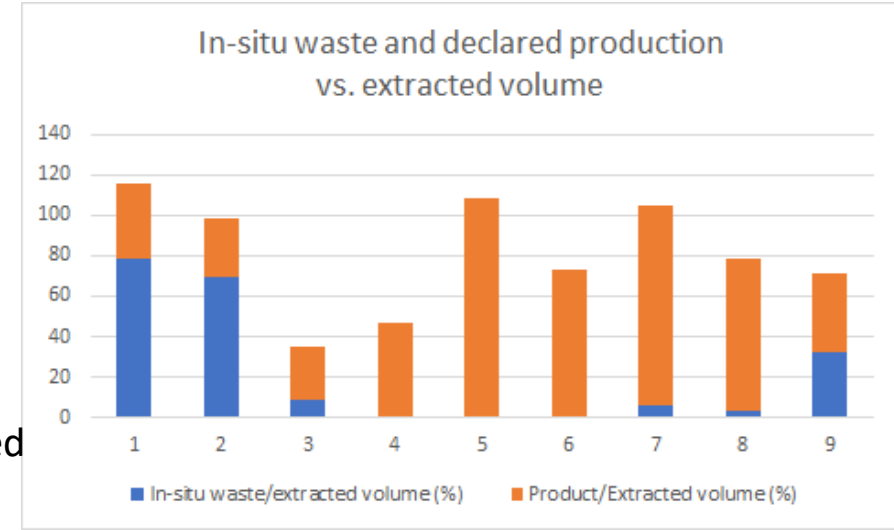
Reported production (quarry owners)





(a) Extracted/In Situ volumes vs. whole reported production *(sample sites)*

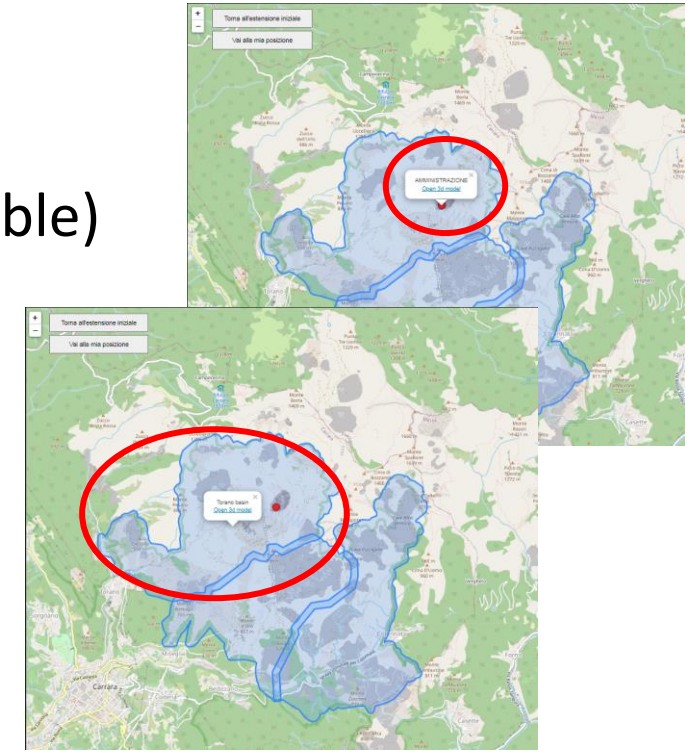
(b) In situ/reported volumes vs. extracted *(sample sites)*



3D Publishing - Requirements

Geographic viewes

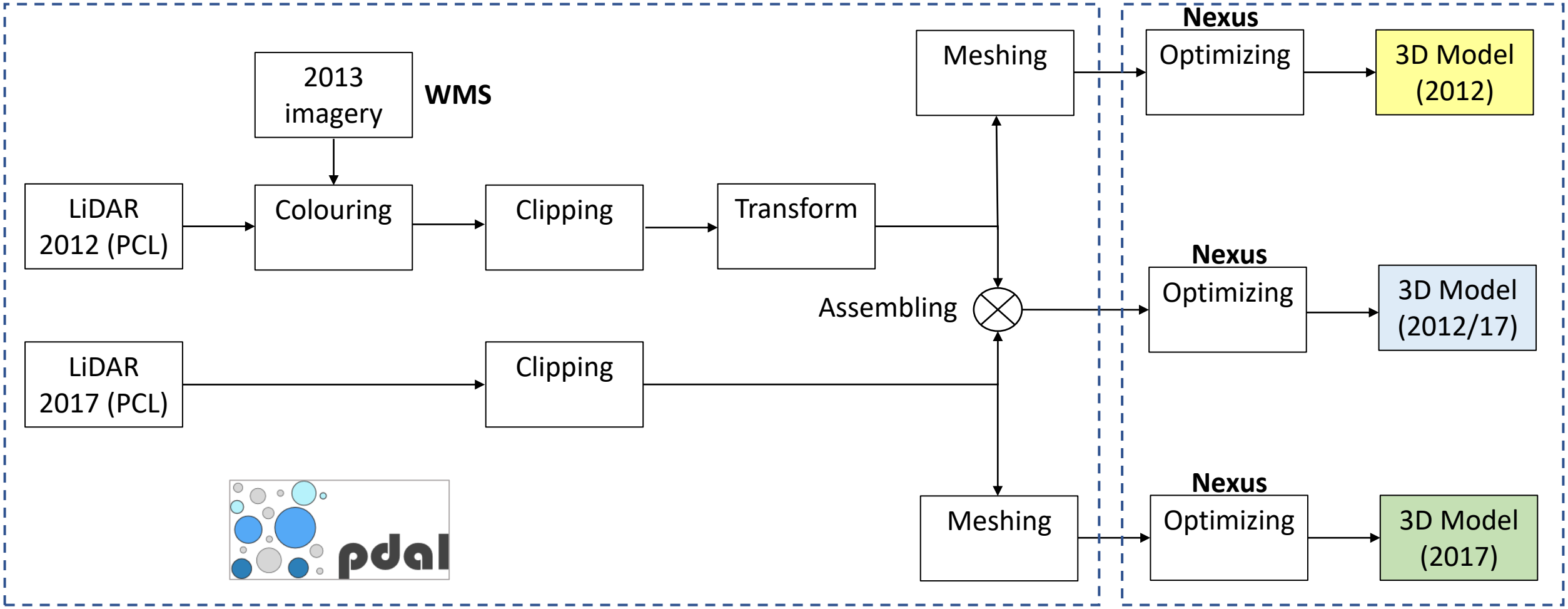
1. Per-basin (panoramic)
2. Per-quarry (TLS/APS single surveys – when available)



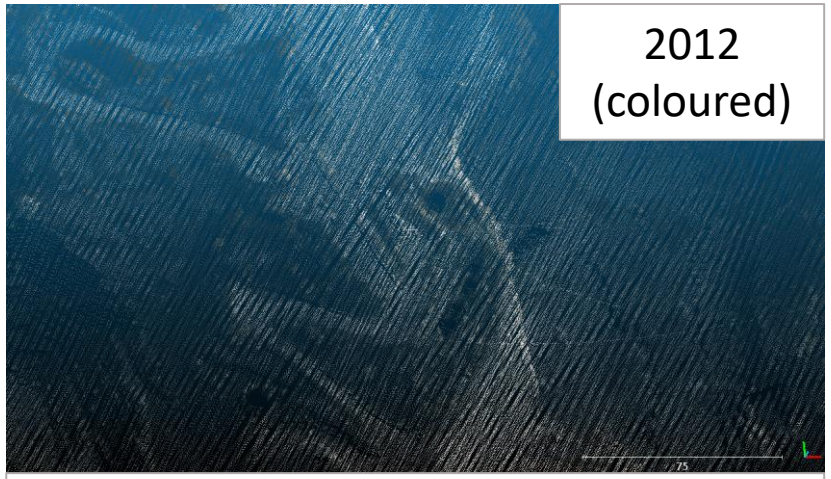
Representations

1. RGB (natural colors)
2. Surface changes
3. Volume changes

3D Publishing - Processing

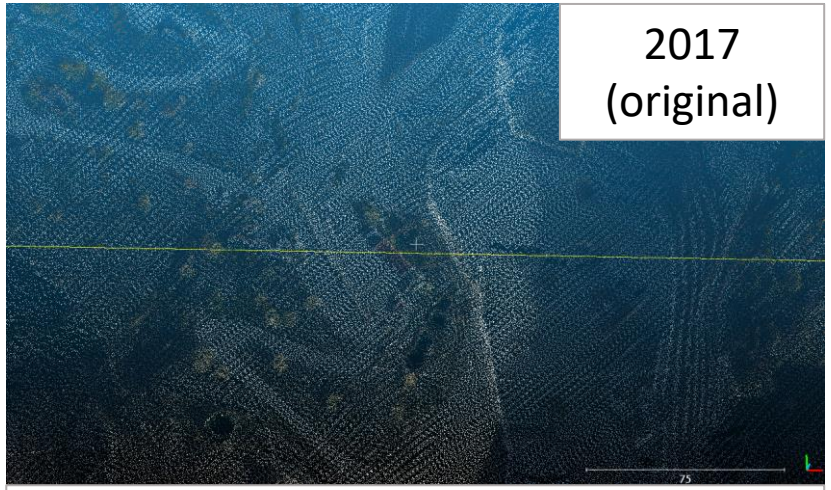


3D Publishing - Models



2012 (coloured)

32MB – filtered: ~ 12MB (.laz)



2017 (original)

42MB – filtered: ~ 16MB (.laz)

5 quadrants per basin ~ 60MB

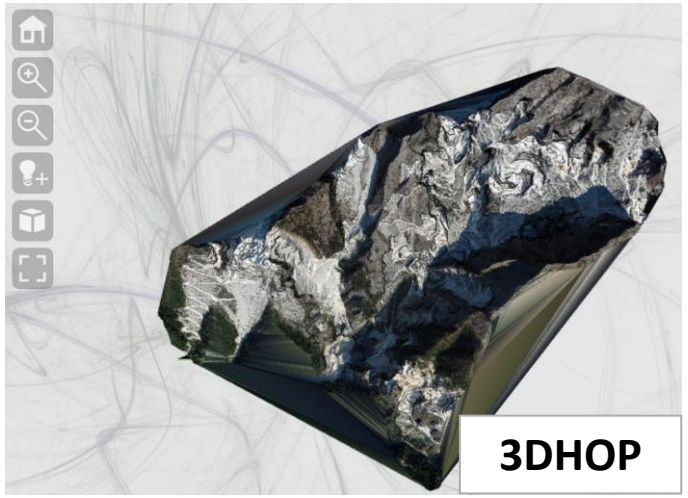
Istituto di Scienza e Tecnologie dell'Informazione "A. Faedo" Consiglio Nazionale delle Ricerche

rem mesh building
nxsbuild basin.ply

rem mesh simplifying
nxsedit basin.nxs -l –o simplified_basin.nxs

rem mesh compressing
nxcompress simplified_basin.nxs

Nexus



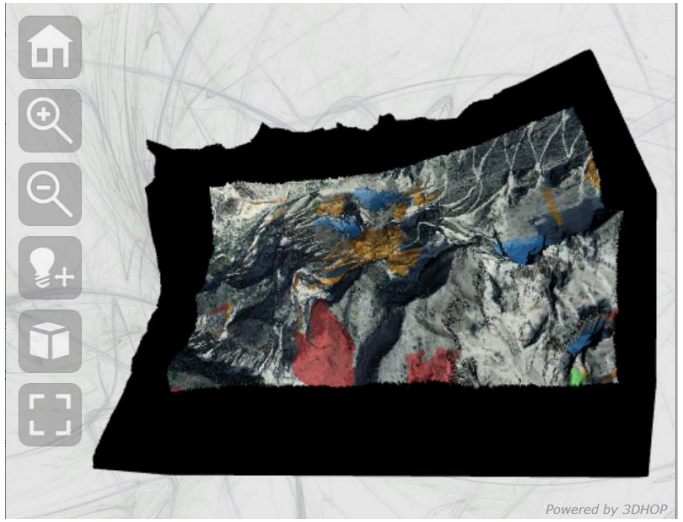
3DHOP

simplified_basin.nxz

Whole basin ~ 25MB (.nxz)

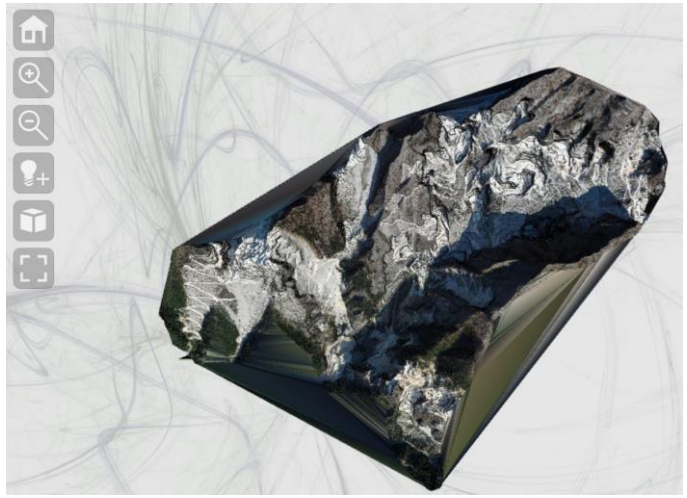
3D Publishing - Representations

Land Cover Change

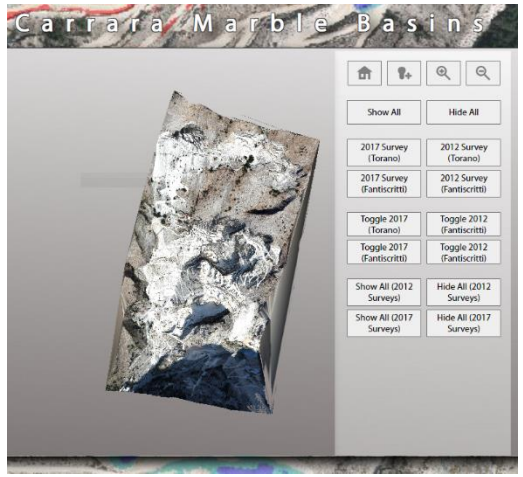


- Natural Soil Loss
- Dump removal
- Quarry refilling

Natural Color



- Extracted volumes
- New dumps



Multiple models

Conclusions

- 2D/3D aerial and satellite high resolution Open Data allow environmental monitoring of complex extractive basins to track sustainability goals stages

- 3D representation of large amount of data can be challenging, but Open Source tools for 3D data management/processing have a fairly good maturity level to enable complex representations

- Combined 2D/3D representation is a ‘must-have’ to grant access to both basin-scale and quarry-scale environmental indicators

Thank for your attention

ARPAT – SIRA working group

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