SYMIN

SYstem for Monitoring Law Enforcement of INformal Mining

User Dossier
And
Technical Specification Sheet

Kabul and Logar Valley, Afghanistan

Quarrying and Brick Production Activities

08.01.13

Prepared by

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Abbreviations

Term	Description, Explanation
AOI	Area of Interest
EO	Earth Observation
GIS	Geographic Information System
GPS	Global Positioning System
VHR	Very High Spatial Resolution

1 Introduction

Purpose

This user dossier intends to assist potential users as cadastre or inspectorate officers of the Ministry of Mines in getting a better understanding on:

1. What can be recognized on the optical satellite imagery – in general and specifically concerning mining activities,
2. How possible ground activities may be detected on radar images,
3. How features might be evaluated and compared with cadastral and other information.

This dossier covers two examples. Firstly it deals about open quarries for gravel, construction material and chromite production around Kabul and secondly about clay pits and associated kilns for brick production in the same area. Figure 1 below gives an overview of the area of interest (AOI) and the acquired satellite image footprints and map sheets.

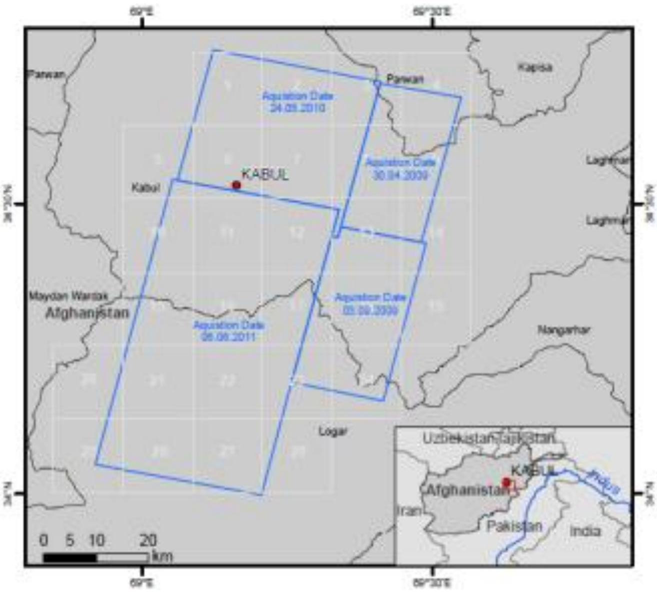


Figure 1: Area of Interest (AOI), including satellite image footprints and map sheet index for detail maps.

Suitability for business processes

The products and services described below are major work contributions to the typical business process activities of

1. Mining inventory,
2. Mine verification,
3. Title / Application Availability, and
4. Compliance monitoring works

as specified in the service trial specification document D3, 1.1, of July 2012.

Results of Demonstration service

The present service shows principally three major results:

1. The satellite image maps - described in more detail below,
2. The Geographic Information System (GIS) compatible interpretation layer - described in more detail below
3. And the documentation at hand (User Dossier and Technical Specification Sheet).

The maps produced (see annex 2) show quarrying, clay pit and brick production activities in the greater Kabul area and the Logar Valley. The EO data used to produce these maps are very high spatial resolution (VHR) optical data (Cartosat, see annex 1, technical specification sheet). The optical VHR data are the base for the overview and detail maps. Besides the optical imagery two COSMO-Skymed images were acquired (04./20.06.2012, annex 1) in order to perform coherence calculations to demonstrate the possible application of these for monitoring of mining, and transportation activities. However, only samples were used and no full detail maps were produced from this dataset, because some of the radar data show miscalculation of coherence due to the strong relief of the AOI. The conclusions of chapter 5 mainly cover aspects of the satellite imagery and to a lesser extent additional data (see below).

Further evaluation possibilities of imagery

In addition to the image map description in chapter 3, chapter 4 describes the interpretation layer, possible measures to enhance the value of this layer and possible further interpretations that result from the combination of the imagery with other GIS compatible data sets (e.g. ground truth data, cadastral information, infrastructure, topography or geology).

2 Contents of the image maps

All maps are in geographic projection, i.e. maps units are degrees, minutes and seconds and the rectangular x, y axes are defined by longitude and latitude. This projection was selected as it equals the one used in the cadastre. However, this projection is not suitable for direct – on the map – distance, area and angular measurements. More technical details about the datasets and maps are given in annex 1 and 2.
The content of the image maps shows in general 4 layers:

1. Optical satellite image data as background
2. Coordinates of known quarries around Kabul were provided by the Ministry of Mines, Afghanistan in February 2012 in order to i) verify the interpretation of the imagery and ii) determine between known and new quarries.
3. Additionally the team received vector data on clay pits and kilns mapped on EO-data vintage 2003/04 (R. Grayson, pers. comm.). These datasets were used to show the development of brick production activities in the area.
4. GIS-compatible Interpretation layer of the image map and its comparison with the other data above. The layer attributes “new”, “extant”, and “gone” respectively “Quarry”, “Machinery” etc. below are value-addings to the image interpretation (see chapter 4).
    a. Quarry: new, extant
    b. Machinery: new, extant
    c. Clay Pits: new, extant, gone
    d. Bull’s Trench Kiln: new extant, gone
    e. Fixed Chimney Kiln: new, extant, gone
    f. Movable Chimney Kiln: new, extant, gone
    g. Movable Chimney Kiln changed into Fixed Chimney Kiln, extant
    h. Traditional Kilns: new, extant, gone

3 Image Analysis Guide

Image analyses were performed on a visual basis by means of a stereo station which allows 3D analysis. This method enhances the retrieval of information from the imagery. The results of the interpretation have not been verified in the field. Photographs taken during field visits were used to facilitate the interpretation.

In addition the consultant refers to literature that describes various studies concerning the EO image analysis for mining activities. A summary of typical mining activity indicators is given by the website EO-Miners - Preliminary results - Indicators - Application of EO techniques.

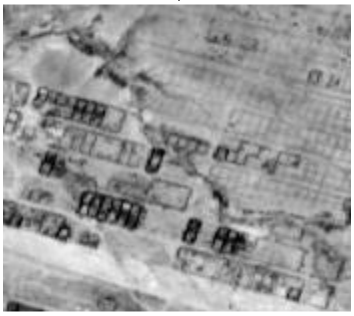
3.1 General features

The images below depict general features visible on the satellite imagery in order to facilitate the understanding of the imagery used as backdrop on the maps.

The recognition of specific objects generally is not a direct question of size, but of size in its environment context. As example, even a single car (2 pixels) might be recognized in this resolution if it appears as bright dots on a road. However it will probably not be recognized as a single object that is off-road.

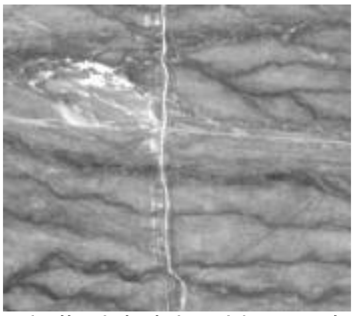
Built up area

Industrial area

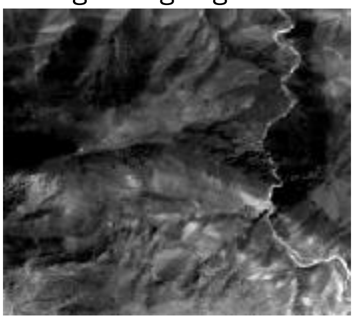


Housing construction site

Tar road running left of water course meandering through agricultural areas



Incised alluvial plain with gravel road crossroads



Mountainous terrain with river valley

Figure 2: General features seen on the satellite imagery. Scale 1:10 000

The following chapter shows some results of the interpretation and gives a comparison of features relevant to mining activities detected on the satellite imagery with the photographs.

3.2 Quarry activities and features

Similarly to general features, mining activities are also best recognized if they appear in an appropriate context. The right picture below shows dirt tracks mounting a hill and obviously ending at areas of bare soil and serve as transport chain to multiple areas of bare soil. It is the overall context that leads to the interpretation of several quarries that are aligned along this track.

Figure 3: Aerial view of quarries east of Kabul…

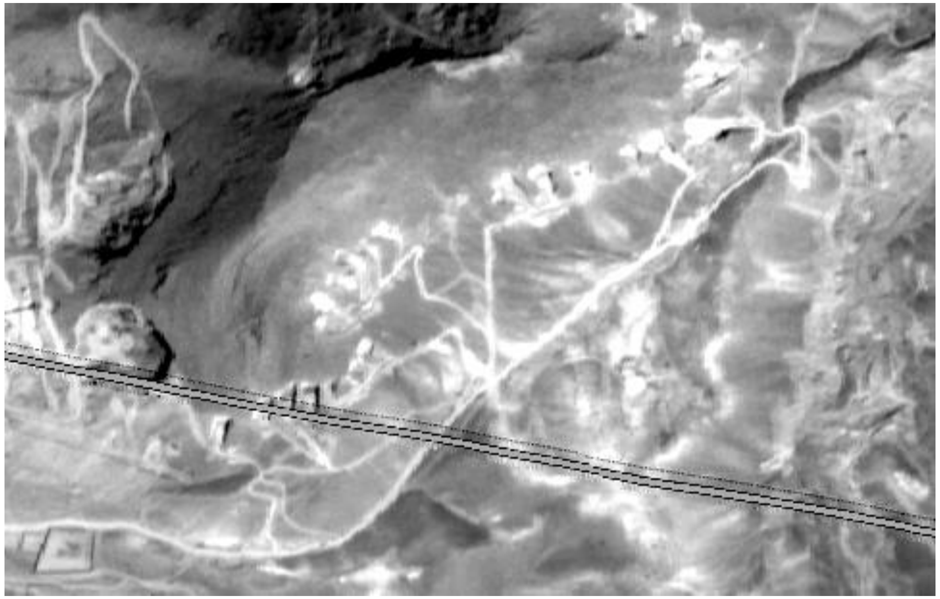


Figure 4:…and satellite view of the area. The line crossing the image relates to a sensor error during acquisition. Scale 1:10 000

Figure 6: Photograph of one of the crushing and sorting plants shown on the satellite image on the right.

Figure 7: Photograph of the quarries shown on the right part of the satellite image on the right.

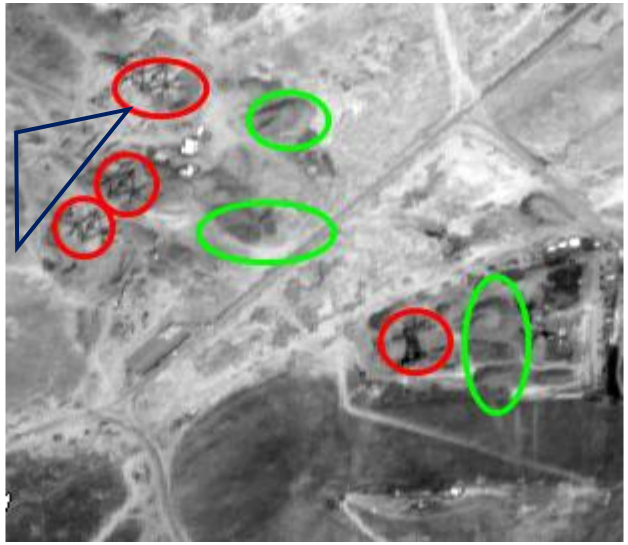


Figure 5: Satellite image of crushing and sorting plants (red) and related stockpiles (green). The blue triangle indicates angle of view of the photograph on the left. Scale 1:10 000

Figure 8: Photograph of three quarrying sites

Figure 9: Satellite imagery of the scene on the photograph above. Red triangle indicates angle of view. Scale 1:10 000. A Qanat/Kariz water management system (light blue) can be seen running from the top right corner to bottom middle.

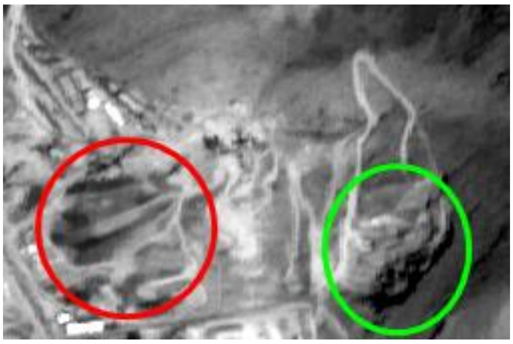


Figure 10: Stock piles (red) and associated quarry (green). Scale 1:10 000

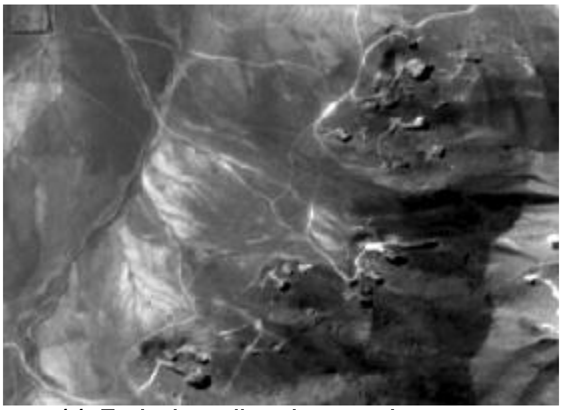


Figure 11: Typical small scale quarrying. Scale 1:10 000

The left image above is also a good example how image features may be interpreted only due to their context with other features that obviously relate to each other.

The image below shows an example of the limits of interpretation. In this case two very small chromite quarries were identified by a ground survey[1] but in the imagery, due to the small spatial footprint and due to the lack of any context features, the activities may not be clearly interpreted as mining activity but solely as some open, bare soil or rock at the hill sides.

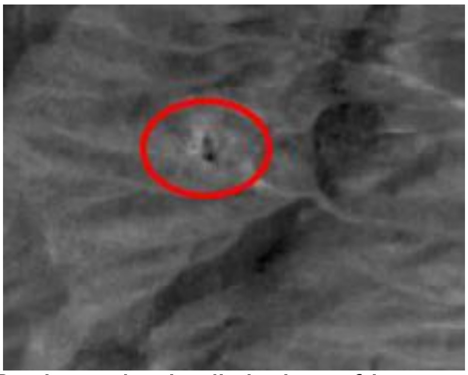


Figure 12: Satellite imagery of chromite quarries in Logar Province showing limitations of interpretation. Scale 1:10 000

[1] A. J. Benham, P. Kovác, M. G. Petterson, I. Rojkovic, M. T. Styles, A. G. Gunn, J. A. McKervey and A. Wasy: Chromite and PGE in the Logar Ophiolite Complex, Afghanistan, 2009

3.3 Clay pit and kiln activities and features

Figure 13: Typical river mining structures. The Bull's Trench kilns - marked in red - indicate that mining is for clay. Scale 1:10 000. Again two features are recognized by their context. The recognition of the river itself would not lead to the conclusion that clay pits exist, but the recognition of kilns at the shore of the river indicate the presence of clay pit activities.

Figure 14: Photograph of river mining for clay.

Figure 15: Clay pits and kilns located in agricultural area. The trail of smoke - marked in red - central on the kiln indicates a fixed chimney kiln. Scale 1:10 000

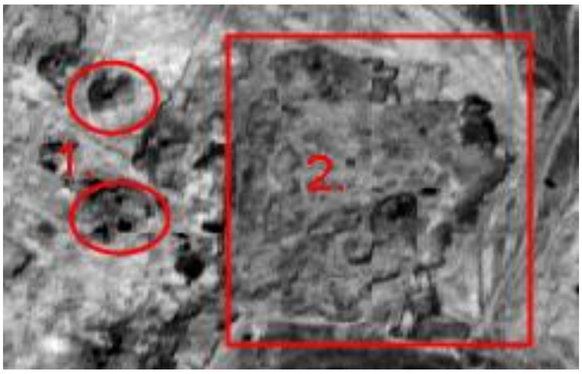


Figure 16: Conical structures (1) indicating traditional kilns. (2) Associated clay pit. Scale 1:10 000

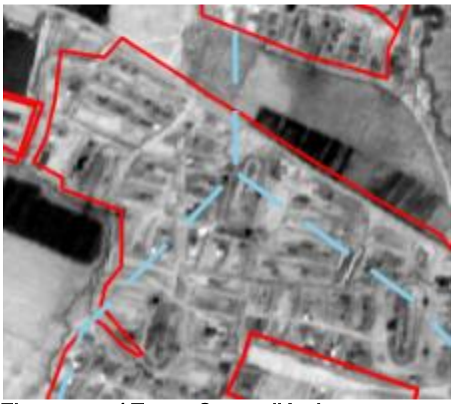
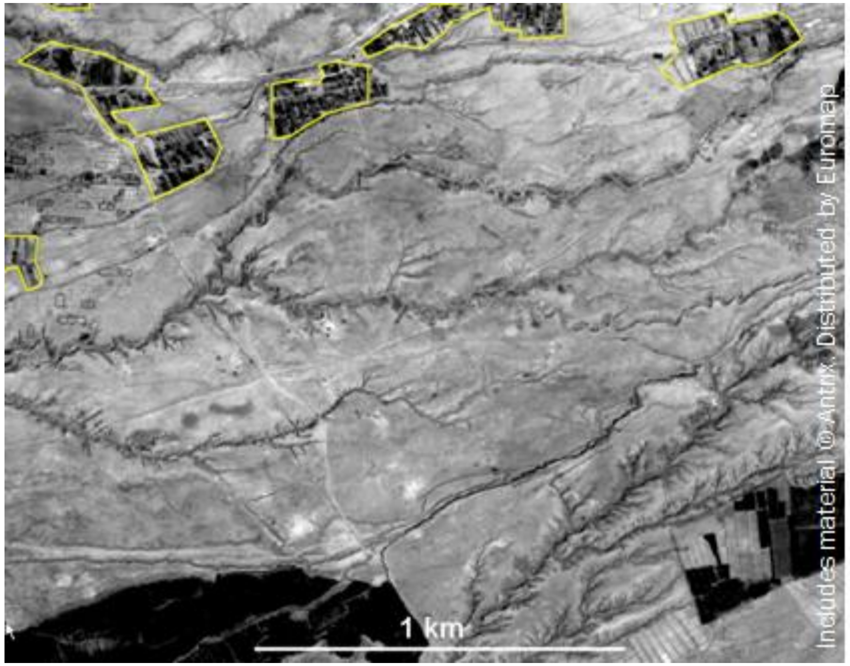


Figure 17: Qanat/Kariz water management system (light blue) mapped on topographic maps, destroyed by clay mining (red). Scale 1:10 000

3.4 Mine activity mapping by coherence imagery of radar data



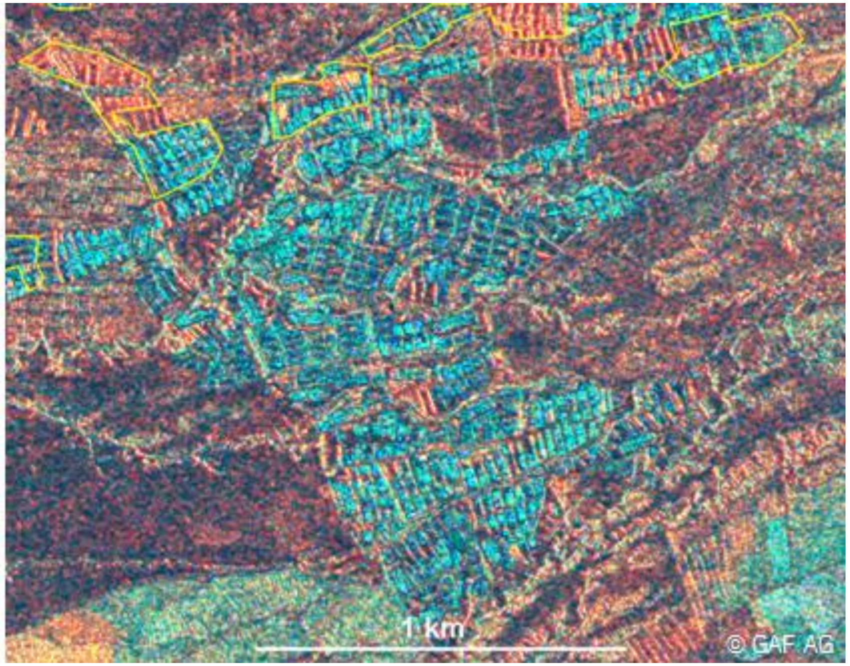


Figure 18: Left: Cartosat-1 IRS-P5 ortho-image (acquisition date: 24.05.10) shows areas of clay brick production in northern Kabul. The yellow outlines delineate areas with clay pits and kilns.
Figure 19: Right: Composite coherence image of the same scene with the same yellow outlines. Blue areas within the outlines show activity within the acquisition interval (04. and 20.06.212). Areas of low to absent activity are shown in red colours). Moreover, between 2010 and 2012 the central area in this scene was made ready for newer clay pits and kilns, being a highly active area in the right image.

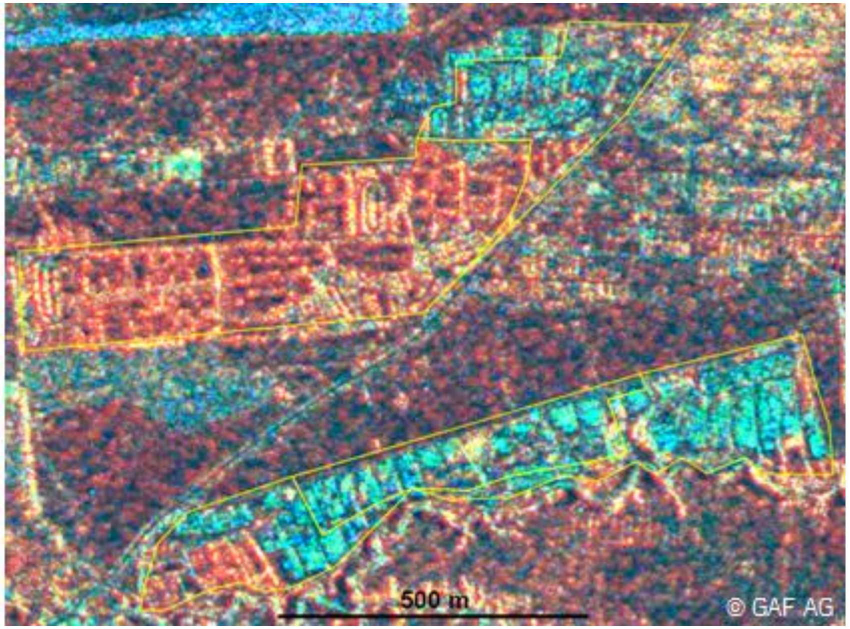
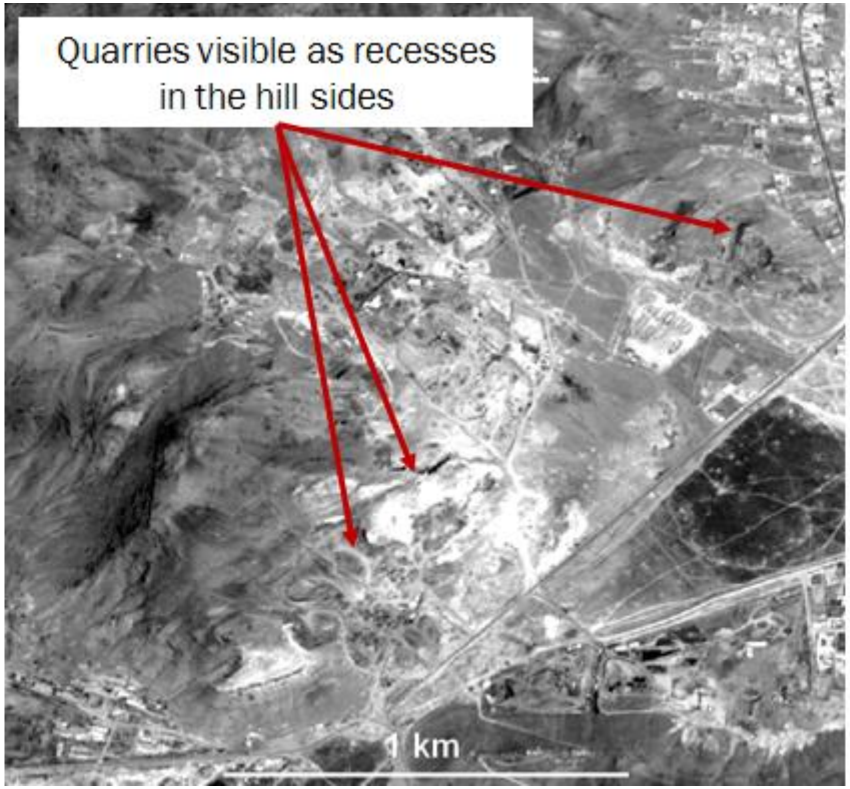
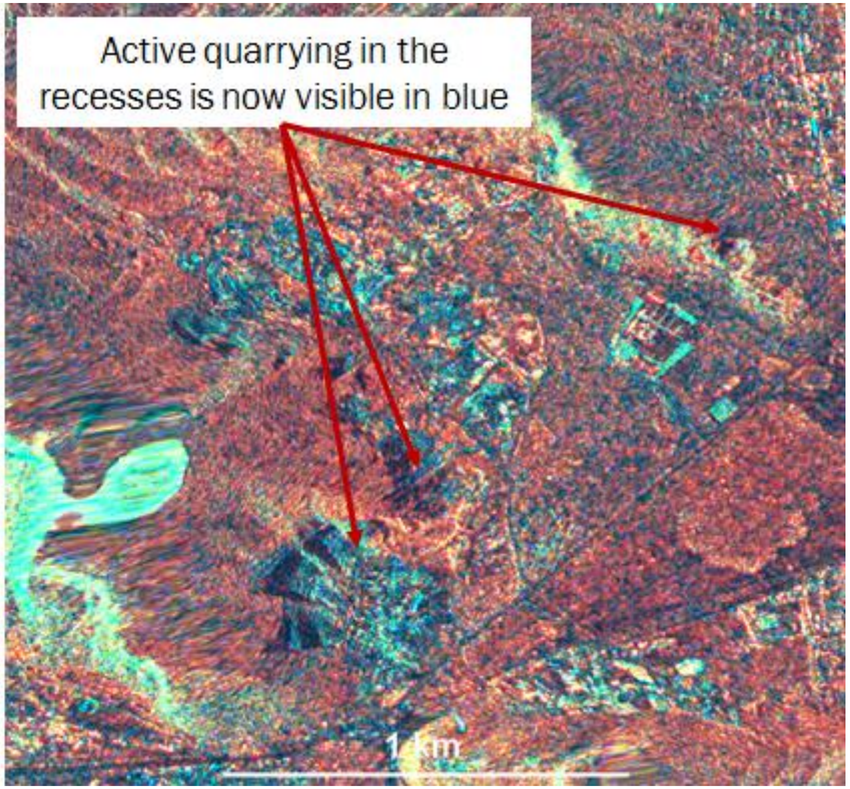


Figure 20: Left: Cartosat-1 IRS-P5 ortho-image (acquisition date: 24.05.2010) shows areas of clay brick production in northern Kabul. The yellow outlines delineate areas with clay pits and kilns.

Figure 21: Right: Composite coherence image of the same scene with the same yellow outlines. Blue areas within the outlines show activity within the acquisition interval (04. and 20.06.2012). Areas of high activity can be distinguished from areas of low to absent activity (red colours).





Left: Cartosat-1 IRS-P5 ortho-image (acquisition date: 24.05.2010) shows recesses at the hill side

Figure 22: Right: For better visualization generated colour composite of a coherence image (acquisition dates: 04. and 20.06.2012) of a quarrying area in Kabul. In the output RGB image the blue areas are decorrelated (which means that there are significant changes in ground structure) while the red and green colour range represents areas of high correlation (no significant changes). This scene shows areas of strong decorrelation (blue).
Figure 23: Left: Satellite imagery of the same area.

4 GIS interpretation layer

The analyses of the satellite images resulted in the generation of GIS compatible vector layers (in this quarry and clay pit example: points and polygons) that provide additional information and several advantages to the image maps:

1. Attribute information (see next chapter) was added and evaluated statistically (see chapter 4.3)

2. It might be compared and value-added with ground truth, cadastral or any other spatial layers in a GIS (chapter 4.2) for inspectors and cadastre officers of the Ministry of Mines.

3. The final interpretation layer is GIS compatible making it suitable
    a. for mobile, i.e. Global Positioning System (GPS) supported GIS solutions, e.g. GeoRover® software
    b. for adaptable layouts as selective attribute displays, transparency etc.
    c. for multi-spatial layer analyses and intersection methods used in standard GIS

Below the consultant explains the possible design and possible evaluation methods of this interpretation layer.

4.1 Interpretation layer attributes

This vector interpretation layer is not only the spatial expression of the imagery interpretation and analysis as given in the produced image maps, but contains some ordinal and numerical attribute information that might be essential for the mine verification and monitoring activities. To realize these activities the data have to be handled in a GIS.

Typical attributes of the interpretation layer, respectively each spatial unit in this layer, should be defined – and thus might be attributed accordingly:

1. Interpretation date

2. Satellite image acquisition date used

3. The mine feature identified in the image (e.g. in this dossier: clay pit, kiln, quarry)

4. Possible status or activity of this mine feature (e.g. below: gone, new ,extant)

5. Its area (in case of polygon) or length (in case of line features). These geometric attributes may be generated semi-automatically in modern GIS systems.

6. Its relation to the cadastre layer (e.g.: “within license/application area”, “intersects license/application area” or “outside license/application area”)

7. Conclusions drawn from comparison with other geo-information layers (e.g. comparison with geological map/mineral occurrences: “possibly chromite quarry”)

8. Compliance status according interpretation and satellite image acquisition date and relation to cadastral or inspectorate information (e.g.: “compliant”, “non-compliant” or “un-defined”)

9. Possible monitoring activities of the cadastre/inspectorate identified (e.g. “check extent”, “check activity”, etc.)

Points 1-9 may be used for quantitative, semi-quantitative and multi temporal statistical analyses and points 6-9 have specific significance for compliance studies, i.e. the business process mentioned above.

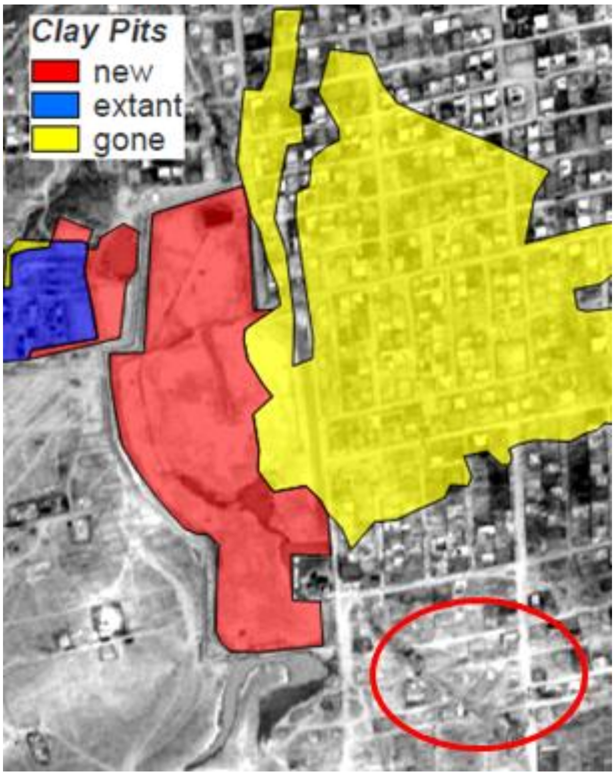


Figure 24: Typical clay pit development. New clay pits are established near construction sites (red circle) and exhausted clay pits are used as building sites as in general the subsoil is now more suitable for building. Scale 1:10 000

4.2 Comparison with independent information

The interpretation may be further compared with all kind of independent information, e.g. infrastructure, geology or hydrographic information, if the data are available.

Below we describe possible conclusions that can be drawn from intersection of the interpretation layer with spatial layers of the cadastre or other geo-information.

Principally five situations are recognized concerning the cadastral compliance:

1. Interpretation of image map and other information complies with the status of the cadastre and inspectorate. No action required.

2. The image map hints to a mine activity or feature but no corresponding entry in the cadastre or inspectorate exists. This hint should initiate a ground check for mine verification and/or mine inventory purposes.

3. The cadastre/inspectorate entries/layers indicate a license/application, but nothing is visible in the satellite image map. This is the contrary case as above but should result in the same action, if the application or title is older than the satellite image.

4. A geometric offset exists between the cadastre/inspectorate entries and the image map feature. If an artefact (calculation/projection/classification error) may be excluded, this should also trigger a ground check for mine verification or compliance monitoring purposes[2].

5. Activities interpreted from the image map do not correspond to title rights. E.g.:
   - 5.1. A single quarry license area obviously includes several quarries [2],
   - 5.2. A quarry license shows shaft towers, i.e. underground activity,
   - 5.3. An exploration license shows large dump sites ,
   - 5.4. River waters needed for irrigation are obviously affected by dump site of adjacent mine,
   - 5.5. A marble quarry – acc. License documents – lies within chromite field (as seen on a geologic map) and might indicate additional chromite production

These examples demonstrate the power of the monitoring possibilities if careful image analysis and comparison with other data is applied in a GIS environment to give full information potential to the interpretation layer.

[2] This conclusion would not be valid in the present case where the regulatory framework for quarry mining allows multiple quarries in one grid cell

These five principal situations are highlighted as schematic diagram in the table below. The scale of the sample images is 1:10 000.

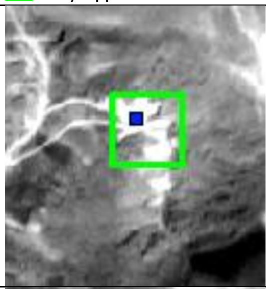
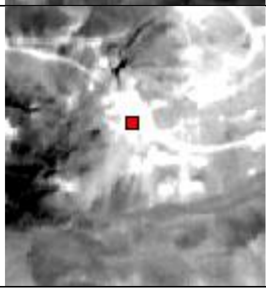
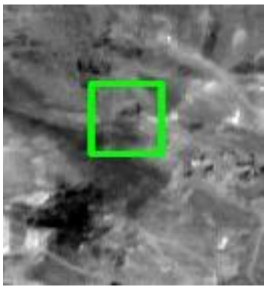
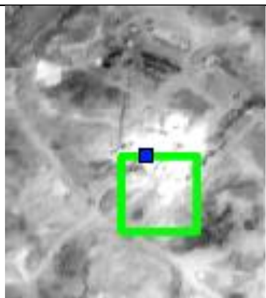
No.	Observation	Schematic representation: ■/■ mine feature / activity □ title / application	Conclusion	Possible reactions
1	EO derived Mine activity and feature correspond with cadastre/inspectorate layer / information		EO-data are compliant with title/ application information	If no other (non-EO) information available, no action needed
2	EO-derived Mine feature / activity but no associated title / application area in the cadastre layer		Independent on relative age of the EO data to the cadastre layer there is a hint for ancient or new mining	1. Check geometry (projection) 2. Ground check
3	Cadastre layer indicates mine feature / activity but the EO-data show no indication for mining		The EO-data probably are older than the cadastre	1. Compare EO data acquisition date with cadastre initial date 2. Check geometry (projection) 3. Ground check
4	Geometric offset and/or overlap between the cadastre layer and the EO-derived mine feature / activity		Geometric projection wrong (of EO or cadastre data) Misunderstanding during title / application process between mine and Ministry	Careful check of coordinate and projection parameters Ground check and communication with mine
5	Obvious misfit between EO-derived mine activities and title / application constraints (e.g. here single quarry against multiple quarries)		EO data point to illegal or informal mine activity	Verify legal status of cadastre layer Ground check and communication with mine

Table 1: Schematic overview of the five principal situations concerning cadastral compliance

4.3 Selected quantitative and multi-temporal analysis

The geometric, date and status attributes mentioned in chapter 4.1 (1-5) may be used to generate – at least in cases where the information is completely available - quantitative and multi-temporal analyses of provinces, commodities or time periods. The example below gives an example how the data about clay pits extracted from the imagery is used to show the development of the areas used for brick production.

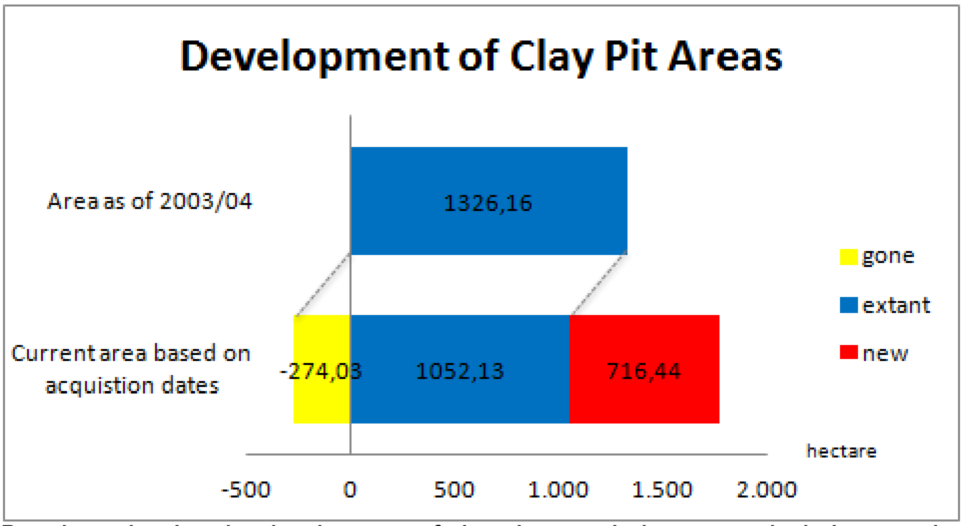


Figure 25: Bar chart showing the development of clay pit areas in hectare; calculations are based on the areas mapped as seen at the time of acquistion of the optical EO-data sets. It shows clearly that allthough some clay pits have ceased to exist, clay mining/brick production is a still increasing activity with regards to area consumption.

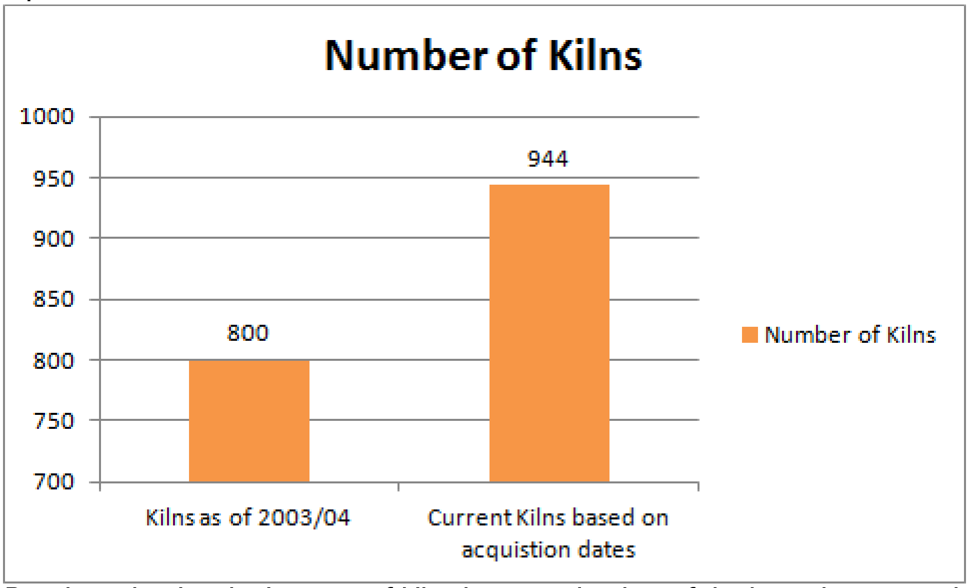


Figure 26: Bar chart showing the increase of kilns between the date of the base data set and the optical EO-data. This underlines that clay mining/brick production is a still increasing activity within the AOI.

5 Conclusions

1. The optical image maps show that quarries, pits, and construction works associated with these mines are recognized. In the above example the typical minimum size to recognize quarries or clay pits is around 5x5 pixels (ca.150 sqm) if they appear in typical environment context.

2. Similarly specific mine and ground activities may be identified in the optical or in the radar imagery if the time window of the image acquisition is suitable for the relevant purpose. Thus a clear awareness of the significance of the acquisition dates of the satellite images is important – in particular for radar data but for the optical imagery too. Anyway, the radar data (coherence imagery) should be read carefully to avoid misinterpretations due to steep relief (shadows) and or very unstable soils (dune sands, e.g.).

3. If ground truth data are available – even if they are historically – they should be used to verify, check consistency, and to add and correct valuable information in the interpretation layer.

4. If recent imagery data are available for reasonable prices they should also be acquired to get the possibility to monitor changes in the mine features detected in older imagery.

5. The attributes of the interpretation layer should be standardized as far as possible – to facilitate database querying and thus enhance use and usefulness of following GIS and database works and thus the verification and compliance monitor purposes.

6. Any other geo-information layer is useful to enhance the value of the image maps in a GIS environment: This concerns in particular any kind of ground truth and cadastral data, but also any other data that may give information about legal (administrative boundaries, toponyms), infrastructural (traffic lines, power facilities), environmental (land use and management), or geologic issues.

6 Annex 1: Technical Specification Sheet

PARAMETER	SPECIFICATIONS
Data sets	*Raster and vector data*
Satellite sensor	Optical: Cartosat-1 IRS-P5
	SAR: Cosmo-SkyMed Stripmap Himage (amplitude) and derived coherence images
Image quality	Cloud and haze free <10%
Image acquisition date	Optical: 30.04.09; 03.09.09; 24.05.10; 06.06.11
	SAR: 04.and 20.06.12
Spatial resolution	Optical: 2,5 m
	SAR: 3 m
Spectral range	Optical: PAN
	SAR: X-Band
Image analysis	Visual Interpretation on Stereo Station
Geo-location Accuracy (CE90)	Optical: < 10 m
	SAR: <3,5 m
Geographic coverage	Optical: ~3055 km² - N-Lat: E-Long: 34.764488930 69.122698330 34.710011050 69.411380200 34.683026680 69.549866040 34.432021100 69.489787630 34.160140820 69.415962460 34.191707440 69.257620200 33.997725450 69.205688010 34.050166770 68.919042690 34.541995150 69.052437140 34.764488930 69.122698330
	SAR: ~1600 km² NW Lat: 34,75944706 NW Long: 69,08812386 SE Lat: 34,26801672 SE Long: 69,63477699

Table 2: Technical specification of satellite data used

7 Annex 2: List of map products and geo-information layers

All images and layers are produced or re-projected in geographic coordinates with datum WGS 84, angular unit degree and prime meridian Greenwich.

Type	Title	Scale, Size or Accuracy	Format
Overview Map	Quarrying and Brick Production Activities	1:160 000, ISO A1,	pdf
Detail Map – Sheet No. 1-28	Quarrying and Brick Production Activities Sheet No. 1-28	1:27 500, ISO A1	pdf
Sample images Included in report	Coherence, 04.and 20.06.12	<3,5 m	tif
GIS layer Included in Overview Maps	Interpretation layer with 9 + 3 attributes: quarry, machinery, clay pit, bull kiln, chimney kiln, movable chimney kiln, movable chimney kiln fixed, traditional kiln and new, extant, gone	< 10m	ESRI shapefile
GIS layer Included in Detail Maps	Interpretation layer with 9 + 3 attributes: quarry, machinery, clay pit, bull kiln, chimney kiln, movable chimney kiln, movable chimney kiln fixed, traditional kiln and new, extant, gone	< 10m	ESRI shapefile

Table 3: Overview of map products and geo-information layers