Terrain Classification for Seismic Acquisition Surveys using Remote Sensing Methods

Geomatics – Remote Sensing

شركة تنمية نفط عمان
Petroleum Development Oman

Context

Background

Objective

Datasets/Processing

RS workflow for terrain classification

Limitations/ challenges

Seismic productivity map

Results

Machine Learning

Lekhwair example

Results

Conclusion

Background

- Understanding surface topography is vital for seismic survey planning
- Surface roughness effects the speed of seismic acquisition
- Seismic acquisition is a costly business utilizing critical labor assets
- Significant amounts of driving and scouting
- Involves high HSE exposure
- Remote areas
- Time inefficient
- Extensive equipment required

Objective

- Use remote sensing technology to improve and automate the terrain classification of seismic surveys in advance of the acquisition

- Capture the following terrain classification types:

  - **Flat:** terrain and undulate gravel plain - accessible to drive with a 4WD vehicle with minimal detours

  - **Rough:** terrain containing broken grounds, scarps, jebels and wadis – drive is restricted with a 4WD vehicle may require detouring

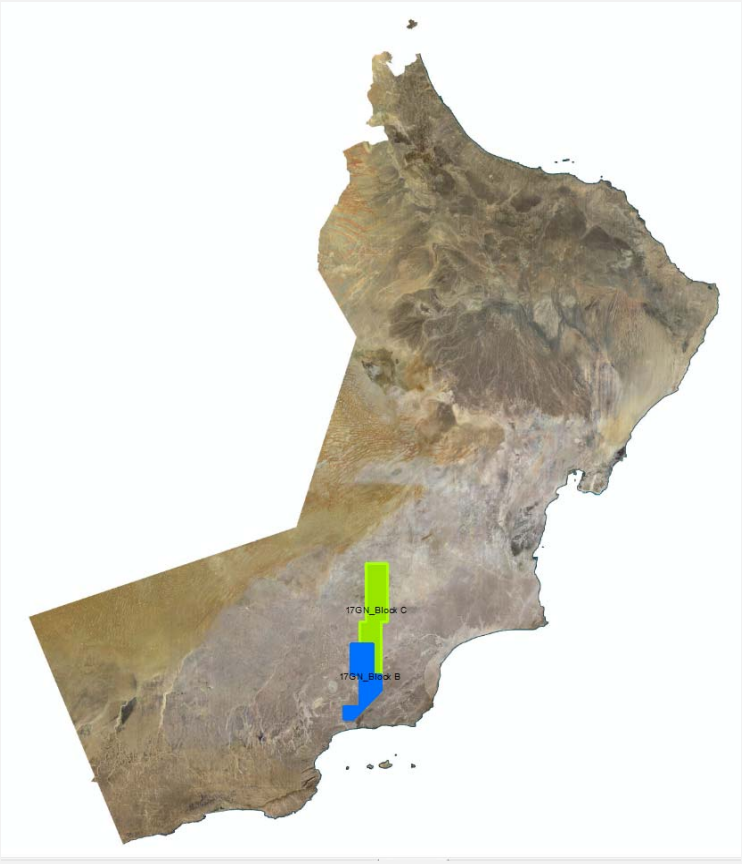
  - **Facilities:** terrain containing frequent occurring surface such as flowlines, wellhead and other oilfield assets and infrastructure – require significant detours

  - **Sand Dunes:** all types of sand dunes considered to be serious impediments

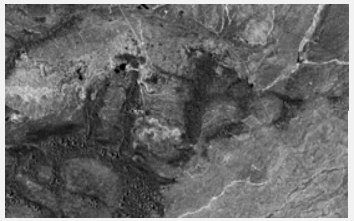
  - **Sabkha:** Salt flat – soft to be graded

Surveyed Area

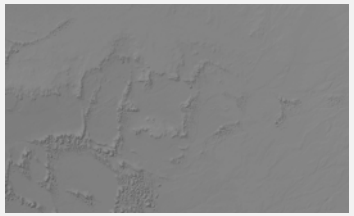
- Nimr B ~ 1997 sqkm
- Nimr C ~ 2687 skqm



Datasets



- Sentinal 1 – Rada imaging (10m) – Polar-orbiting, all weather, day/night radar imaging mission

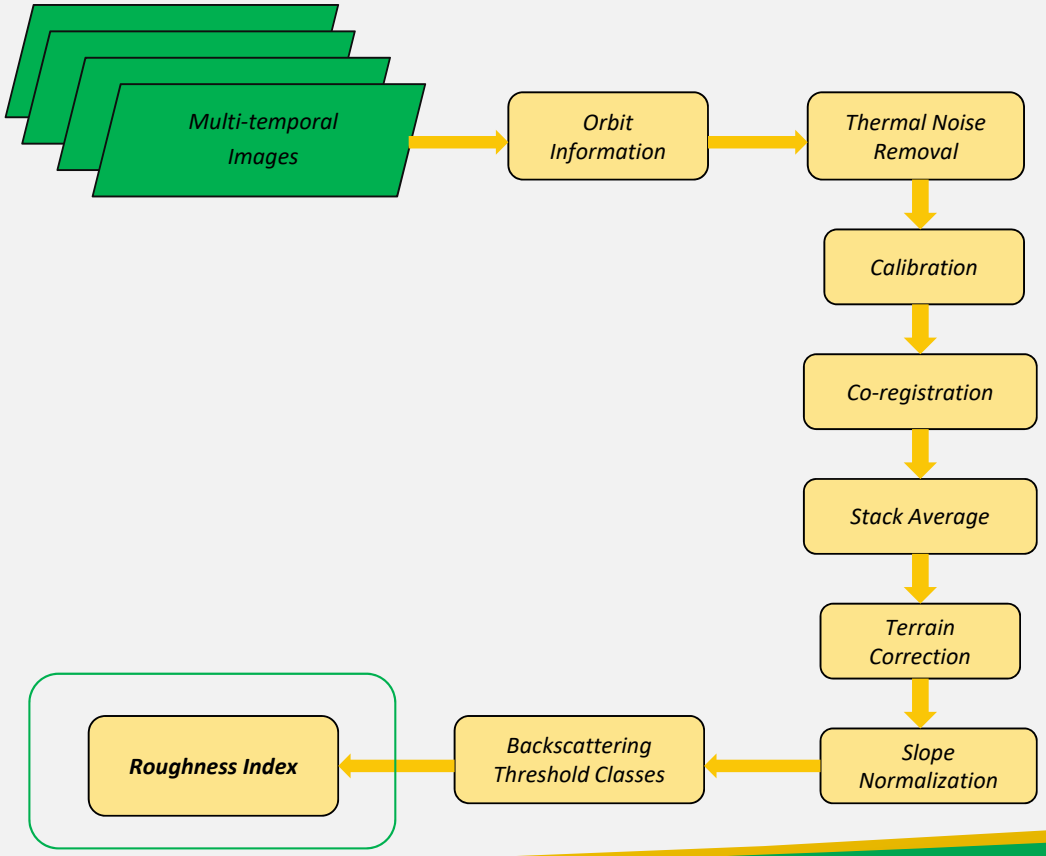


- DSM (2m) – Generated from NSA high resolution aerial imaging

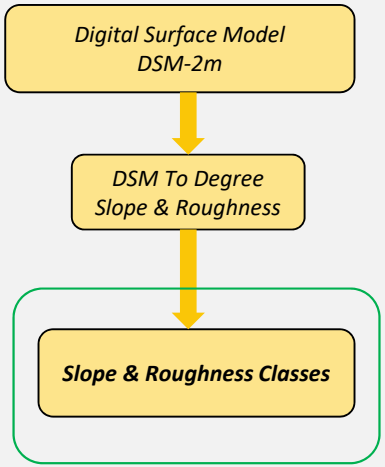
- Aerial Photo (0.5m) – NSA high resolution imaging

Data Pre-Processing

Radar Derived Roughness Index



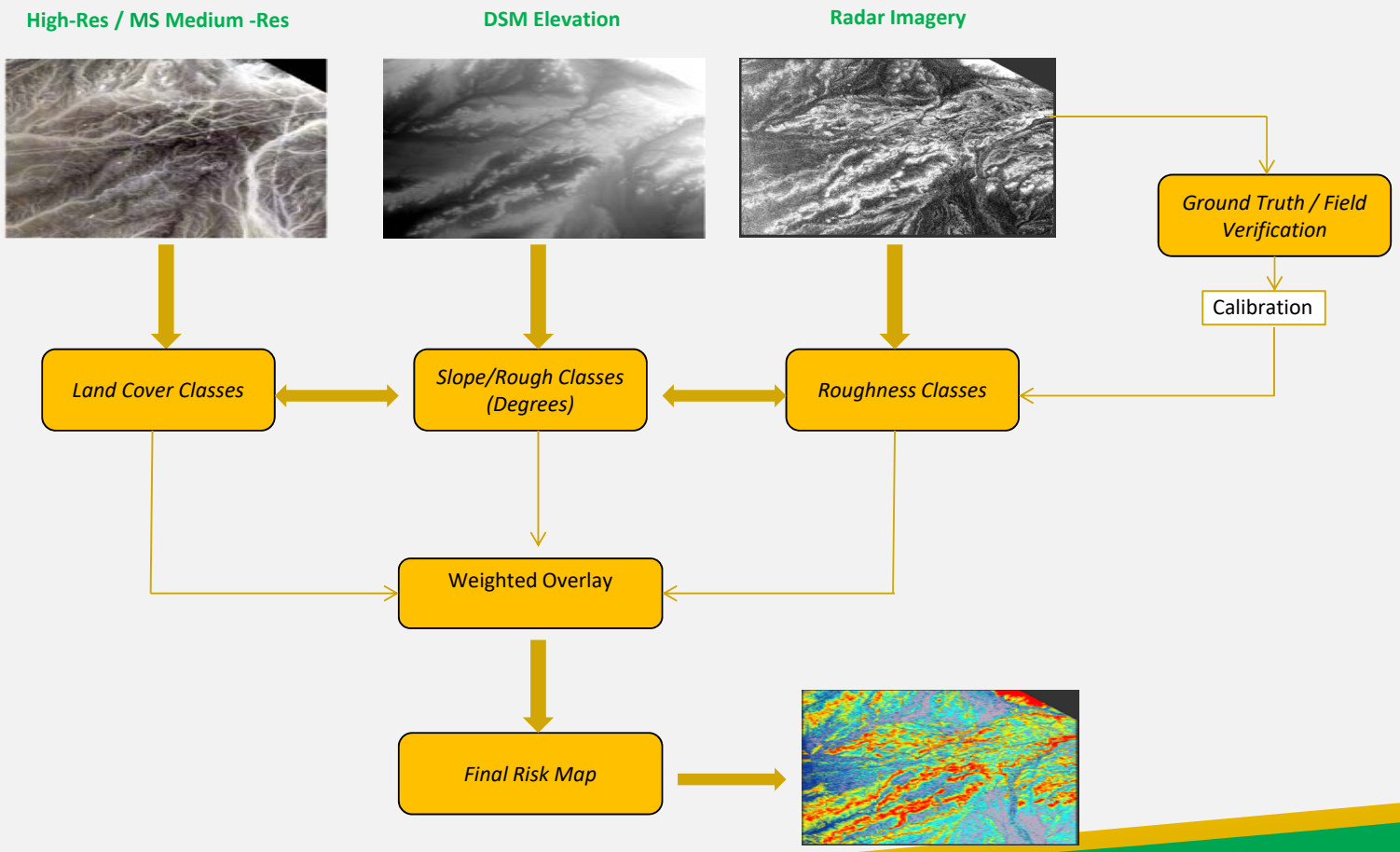
DSM Derived Slope/Roughness



Classification of Optical Images

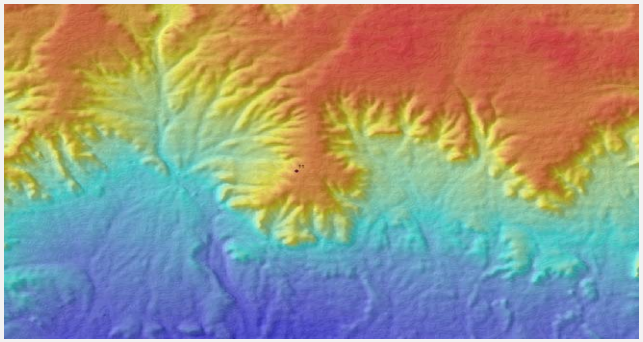
Helped to classify different land cover within AOI

Workflow


High-Res / MS Medium -Res
DSM Elevation
Radar Imagery
Ground Truth / Field Verification
Calibration
Land Cover Classes
Slope/Rough Classes (Degrees)
Roughness Classes
Weighted Overlay
Final Risk Map

Datasets and Processing

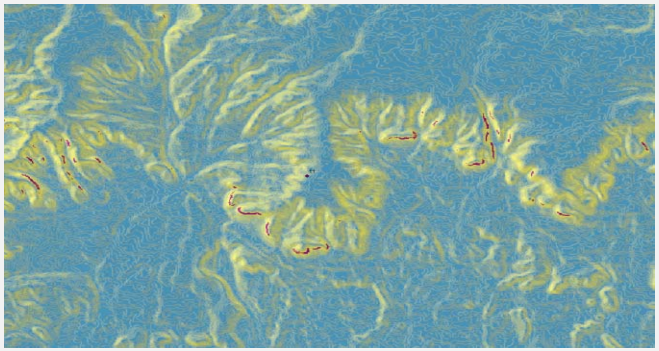
DSM



High :

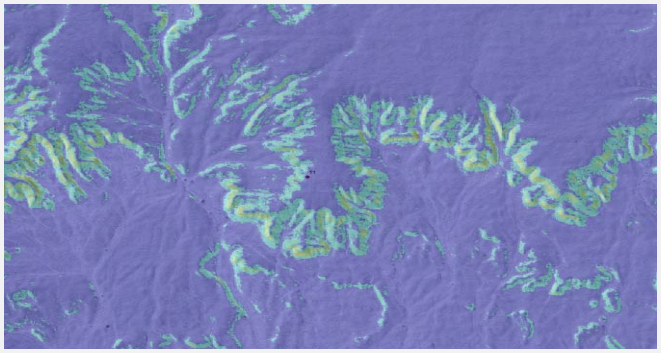
Low :

Slope



0 - 0.641129019
0.641129019 - 1.923387056
1.923387057 - 3.846774112
3.846774113 - 6.731854697
6.731854698 - 11.21975783
11.21975784 - 18.27217703
18.27217704 - 28.53024133
28.53024134 - 45.19959582
45.19959583 - 81.42338538

Roughness

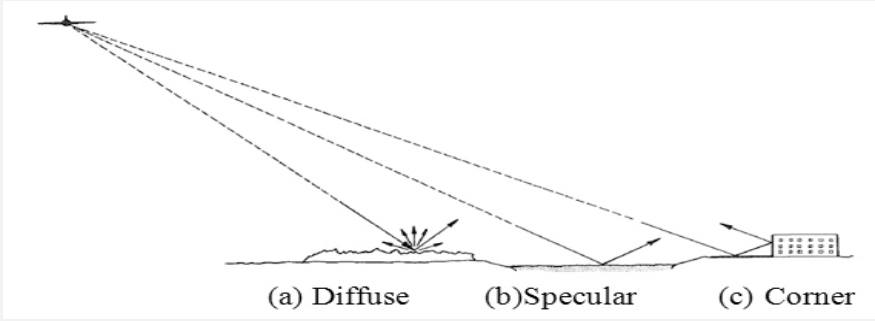


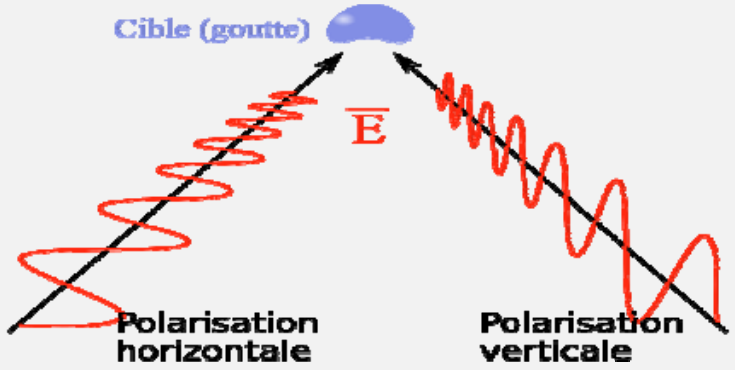
0 - 0.3
0.3 - 0.6
0.6 - 1.60000033
1.600000331 - 5.303704797
5.303704798 - 14.80000305

Slope is the angle of inclination to the horizontal
Roughness is the difference of a central pixel and its surrounding cell

Radar Concept

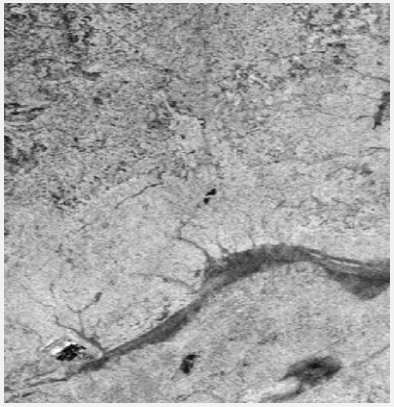
- Rougher surface = higher backscatter (bright pixel)
- Smooth surface = lower backscatter (dark pixel)





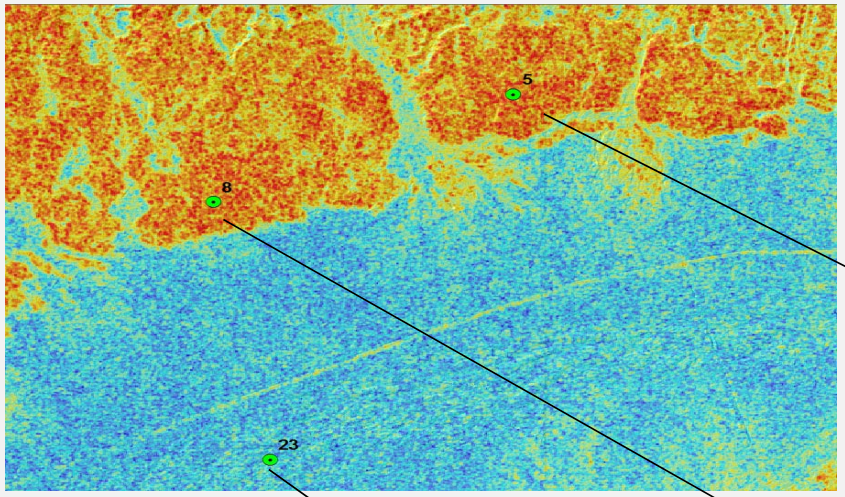
Sentinal 1 VH

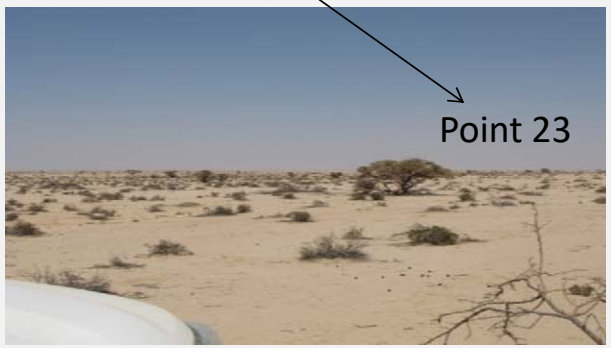
Sentinal 1 VV

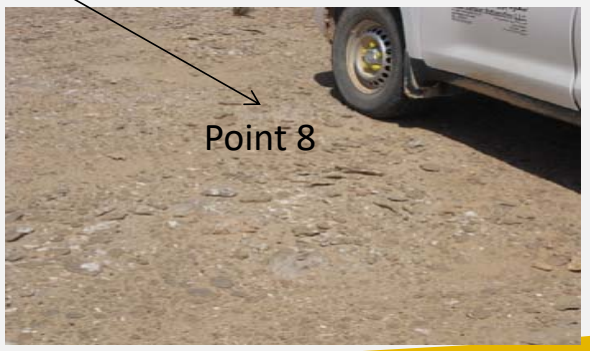


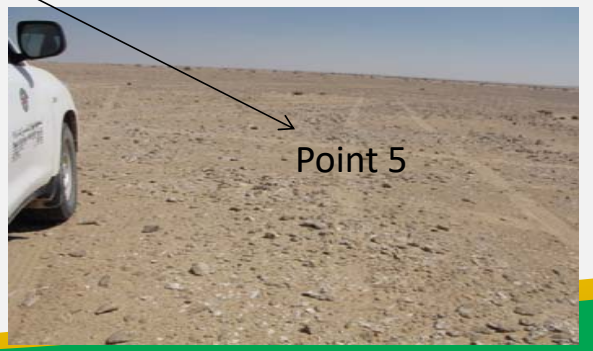
Radar and Ground Truthing

Sentinal 1 VH C band



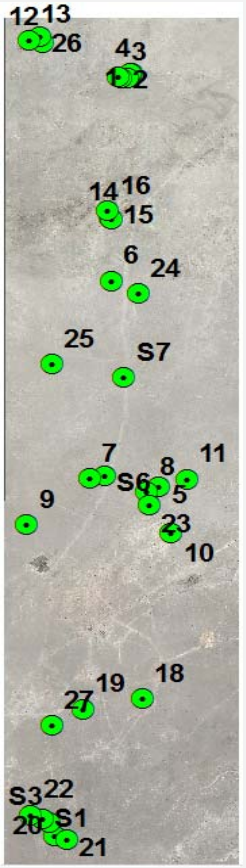






Ground Truthing / Field Verification

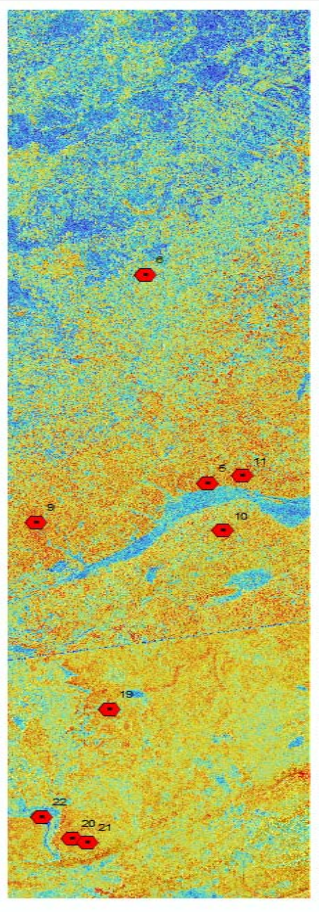
Name	Easting	Northing	Description	CSR Comments	TCF
1	386829	2159820	rough top of a hill/ridge		
2	385012	2158930	low Radar backscatter-flat/smooth?		
3	384591	2159130	High Radar backscatter-rocks?		
4	386661	2159770	flat down the hill/ridge		
5	391722	2079270	High radar backscatter near the wadi	Mostly flat gravel with some undulation and loose/broken rocks on the surface.	
6	383333	2119350	High radar backscatter-flat/gravel?	Flat, featureless gravel.	Flat
7	379464	2080770	High radar backscatter-flat/gravel?	Undulating gravel, bumpy in places.	Flat/borderline Rough
8	389555	2078240	High radar backscatter near the wadi	Flat gravel with a lot of loose/broken rocks on the surface. No elevation change of note with adjacent wadi.	
9	368454	2071840	High radar backscatter-flat/gravel?	Mostly undulating gravel with some rougher/uneven areas.	Flat
10	393883	2070170	High radar backscatter-flat/gravel?	Undulating gravel with some broken up terrain and small/craggy drop-offs. Borderline between categorizing as Flat or Rough.	Flat/Rough
11	396548	2080710	High radar backscatter-rocky hill?	Rocky hill with an undulating, broken up plateau.	Rough
12	371276	2165800	low Radar backscatter-flat		
13	368849	2166290	high radar -mid slop		
14	383203	2131640	high radar-mid slop	Edge of rough plateau, mid slopes.	Rough
15	383250	2131460	high radar - low slop	Rough plateau, low slopes.	Rough
16	382702	2132990	low radar - low slop-flat	Flat, sandy and featureless wadi. NO slope.	Flat
17	386165	2158920	mid radar- low slop- can you drive over it?		
18	388844	2037890	high radar - flat/gravel?	Flat gravel.	Flat
19	378381	2035930	high radar - flat/gravel?	Flat gravel.	Flat
20	373420	2011150	high radar - flat/gravel?	Flat gravel.	Flat
21	375436	2010360	high radar - flat/gravel?	Flat gravel with rocky surface outcrops.	
22	369246	2015290	is this wadi accessible?	Flat sandy/gravel wadi. Wadi is easily accessible; no elevation change of note (<1m) with adjacent undulating gravel plain. Distinctive dark reddish color surface.	Flat
23	389967	2075760	is this wadi accessible?	Wadi is easily accessible; no elevation change with surrounding area. Ground is sandy and soft in places. Surface is rough, bumpy and difficult to drive through with a lot of vegetation.	Rough
24	388057	2116840	is this wadi accessible?	Wadi is easily accessible; no elevation change of note with surrounding area. Soft/sandy ground, bumpy in places with low/medium vegetation.	Rough
25	372907	2103080	is this wadi accessible?	Wadi is easily accessible but there are some rough ridges along the edge of the wadi. Mostly flat sandy/gravel, bumpy in places and with low vegetation.	Flat
26	370691	2167050	med radar- high slope at edge of hill/cliff	Ground is sandy and soft in places. Surface is rough, bumpy and difficult to drive through with a lot of vegetation.	
27	373034	2032640	high radar - low/mid slop	Rough/undulating plateau on top of a small jebel. Confirmed low/mid slopes but photos do not show this clearly.	Rough
CSR Points for Ground Truthing check					
S1	371492	2014592		Rocky, cut-up terrain adjacent to a jebel	Rough
S3	372696	2014088		Gravel plain with exposed rock at surface.	Rough
S6	382346	2081498		Small, rocky wadi with low slopes.	Rough
S7	385846	2100796		Area of extensive earthworks and surface scarring/scrappings.	Rough



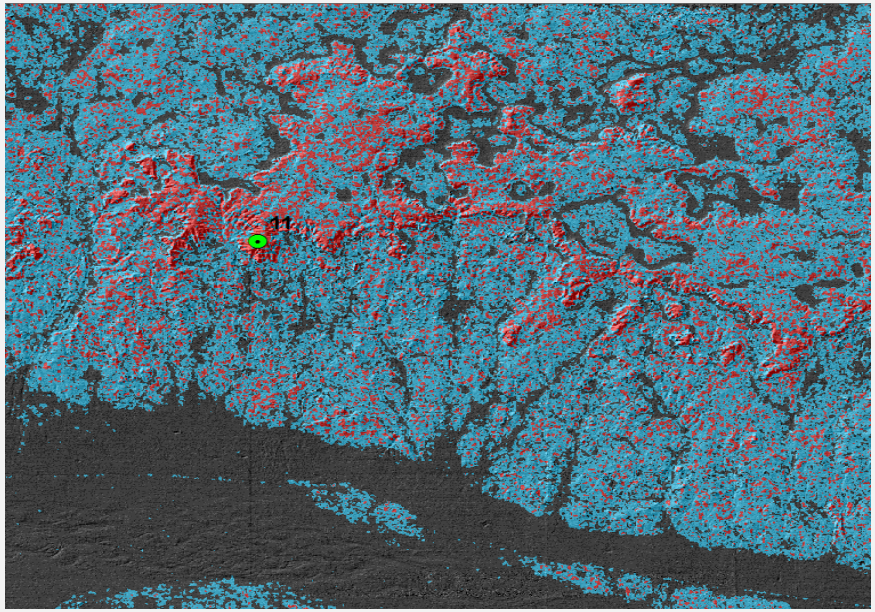
Calibration with Ground Truthing

Attempt to remove gravel backscattering using field data

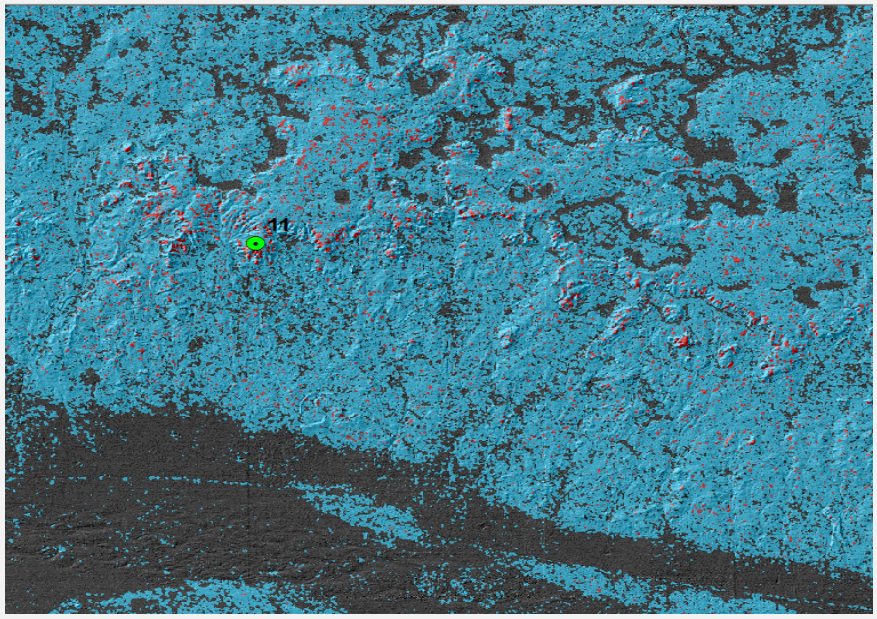
Point number	Sentinal 1 VH (C band, 10m)	Sentinal 1 VV (C band, 10m)
5	-15.23	-11.50
8	-17.20	-7.03
6	-18.87	-12.50
9	-16.20	-10.97
10	-16.79	-10.50
7	-18.11	-10.18
18	-18.53	-10.01
19	-16.33	-11.44
20	-16.76	-10.86
21	-19.50	-11.94
SD	1.35	1.502538962
MIN	-19.50	-12.50
MAX	-15.23	-7.03
MEAN	-17.35	-10.69



Gravel Elimination by backscattering



Sentinal 1 VH

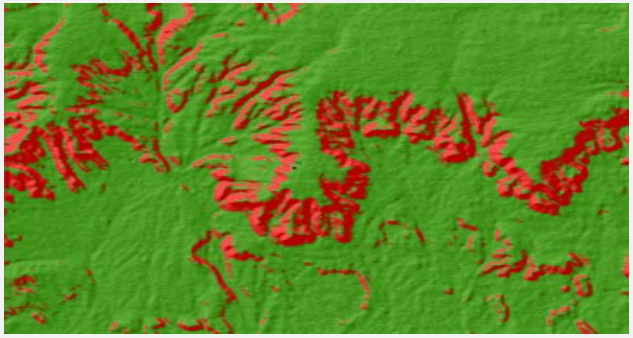


Sentinal 1 VV

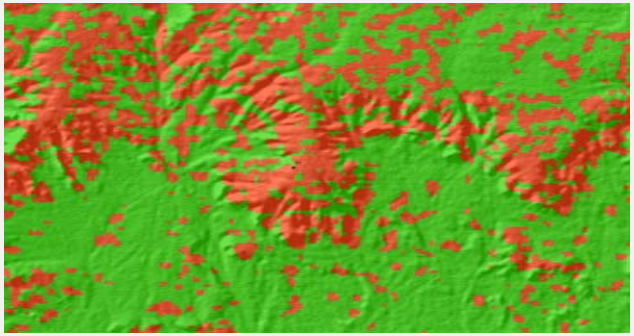
Smooth
Gravel
Rough

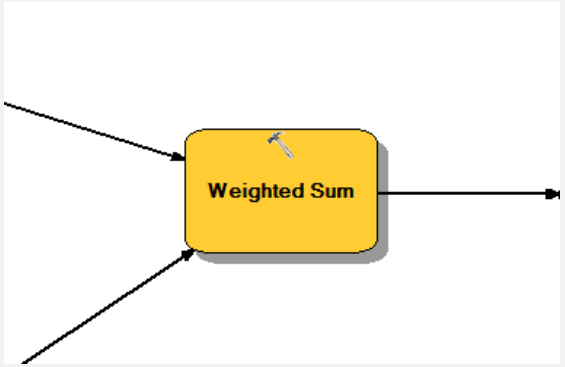
Risk Map Generation

DSM Roughness – 50%

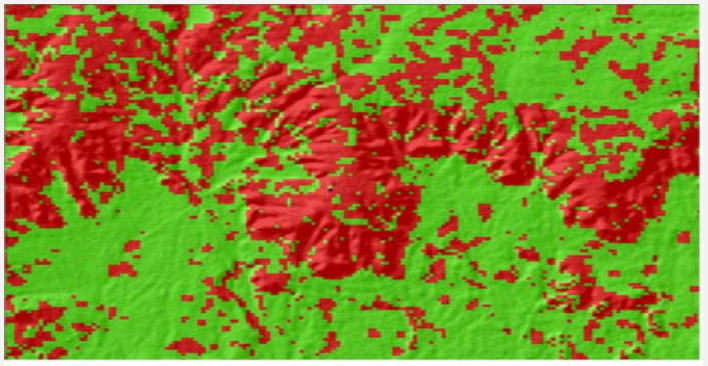


Radar Roughness – 50%





Result

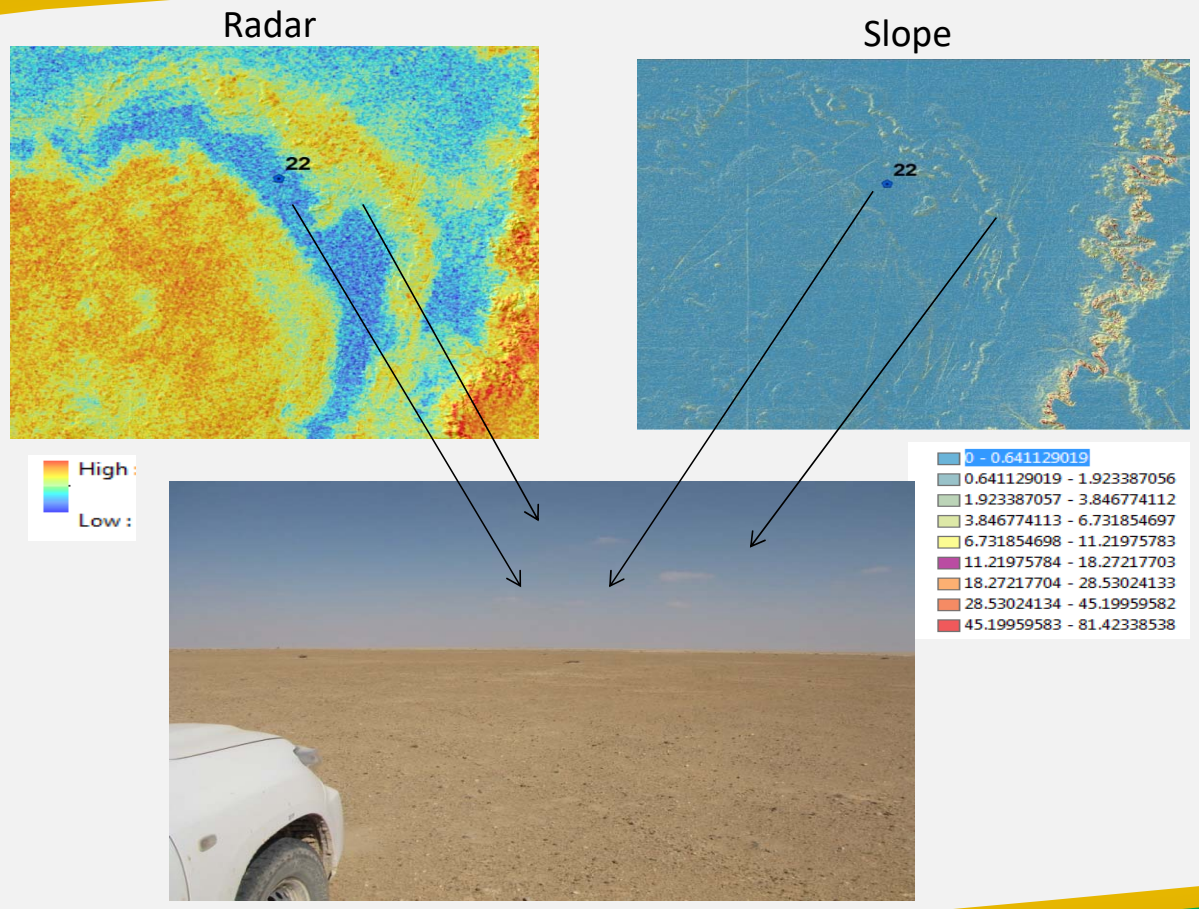


Field Cross-checking & feedback

- Field verification showed very good correlation with RS classification
- RS classification pick up areas of ridges, rough undulations and small hills very well
- Types of rough terrain not picked:
  - Wadis with clumpy vegetation
  - Excavated areas

Limitation / Challenges

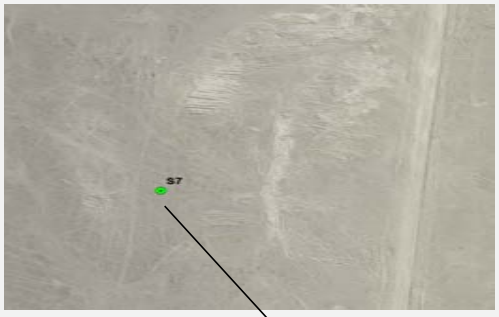
- Mapping vegetation



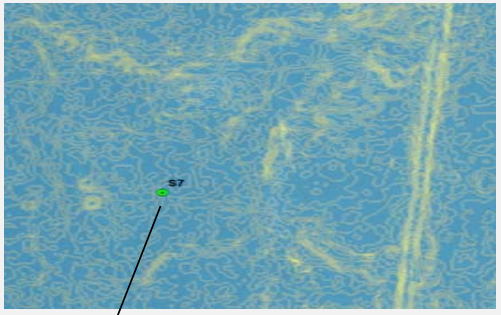
Limitation / Challenges

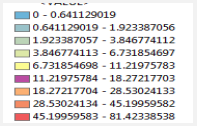
- Mapping earthworks & scrapings

Aerial photo

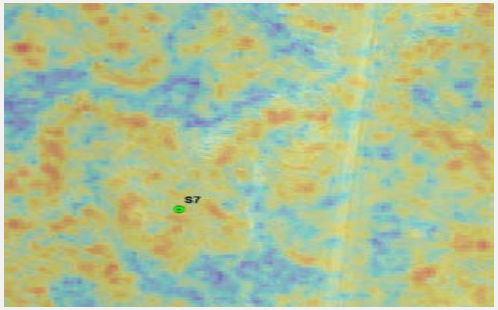


Slope





Radar



Seismic Productivity Forecast Maps

- Use terrain assessment & seismic acquisition production formula
- Create detailed forecast of productivity to assist in project planning and management

CTM= [(3600/(S+M))*22*(N-X)*TCF]*B

Where S=	Sweep length in seconds
Where M=	Move-up time in seconds, as table 1
Where N=	Number of days in the production month
Where X=	Standby time in decimal days
Where B=	Number of vibrators contracted, including any call-off units
Where TCF	Is averaged over the terrain traversed in that production month

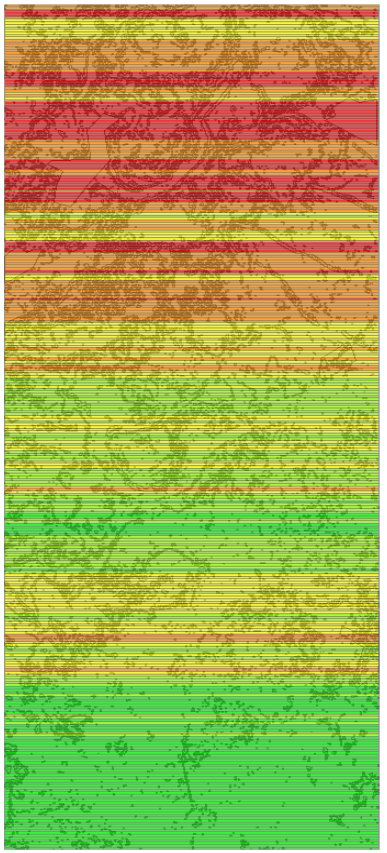
- Accurate production forecast in advance
- Highlight difficult terrain areas to implement mitigation for any reduced productivity that may arise
- Provides input to accurate budget for each project

Productivity Calculation Nimr C

Remote Sensing Terrain Based Seismic Productivity Calculator

Variables can be changed
Calculations DO NOT CHANGE
OUTPUT N Days

Variables						
Variable	Value	Unit	Comments			
S (Sweep Length)	9	Seconds		Project Source Points per Km2		
M (Move up time for Vibrator)	18	seconds		800		
Operation time per day in Hours (constant now)	22	Hours				
B	12	No. Vibrators		Input Area in Each Terrain based on Automated Terrain Classification (Km2)	VPs in each Terrain [Km2 x (VPs/Km2)]	Productivity N (number of days in each area)
TCF (Flat)	0.85	Factor for that area		2578.4	2062704	68.94
TCF (Rough)	0.5	Factor for that area		1293.6	1034872	58.80
TCF (Facilities)	0.55	Factor for that area		266.2	212936	11.00
TCF (Sand Dunes)	0.6	Factor for that area		0.0	0	0.00
TCF (Soft Sabkha)	0.6	Factor for that area		0.0	0	0.00
			Total Project Area (KM2)	4138.1	Total No. Days for a project/Area	138.74



- Flat 62%, rough 32%, facilities 6.4%

Field Cross-checking & feedback

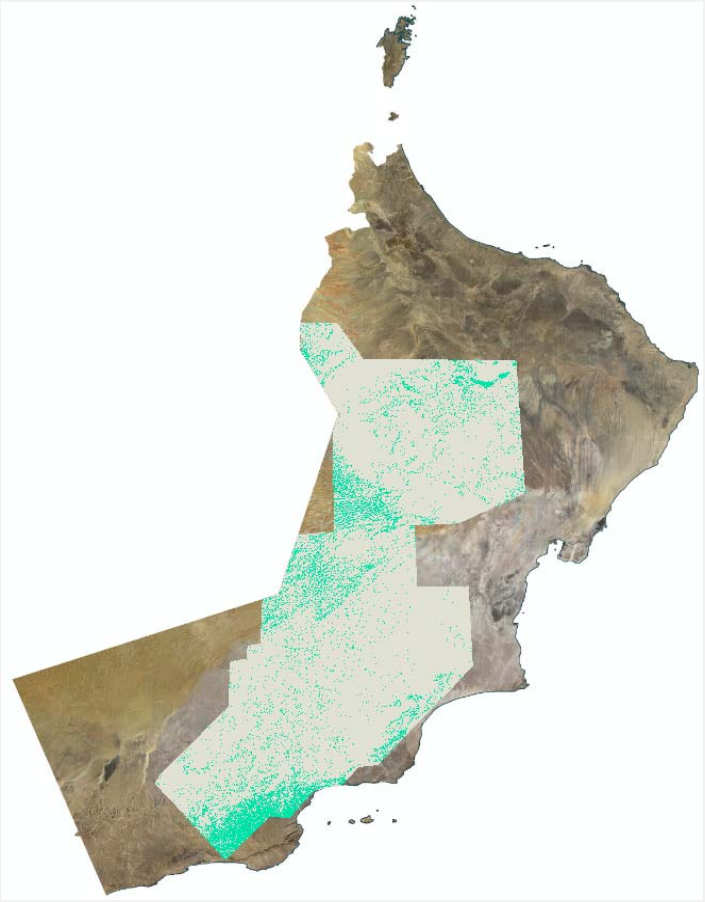
- Field verification showed very good correlation with RS classification
- RS classification pick up areas of ridges, rough undulations and small hills very well
- Types of rough terrain not picked:
  - Wadis with clumpy vegetation
  - Excavated areas

Results

- 83% reduction driven and days spent in the field
- Enhanced HSE planning
- Optimization of resources
- Accurate prediction of deliverables to clients
- Improved budget accuracy and compliance

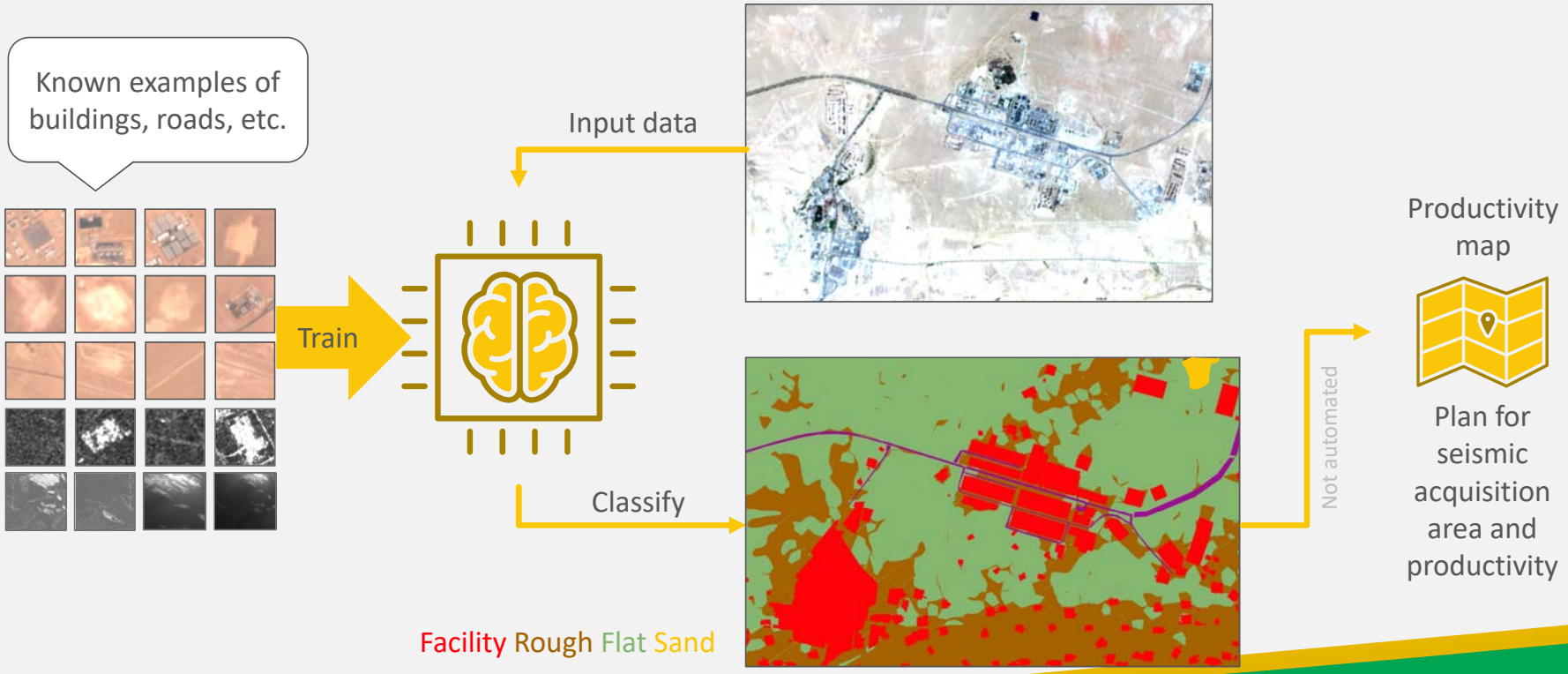
PDO Concession

- Entire block 6

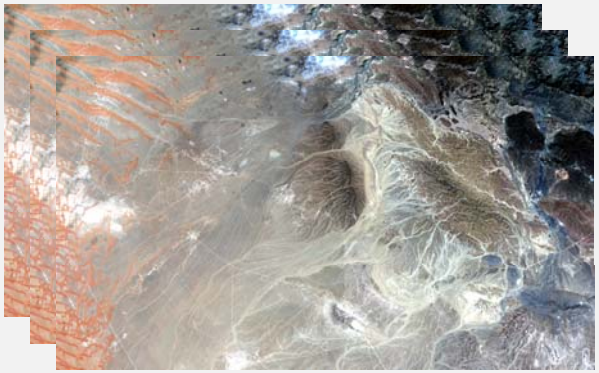


Machine Learning

- Leverage machine learning solution for terrain classification to reduce exploration costs and HSE risk
- Process has potential for optimization

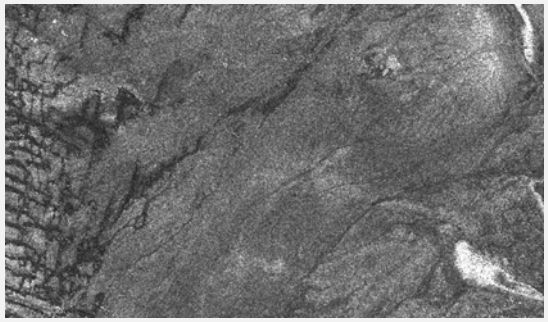


- Multi-spectral satellite imagery, radar imagery and DSM selected as input data sources for the model



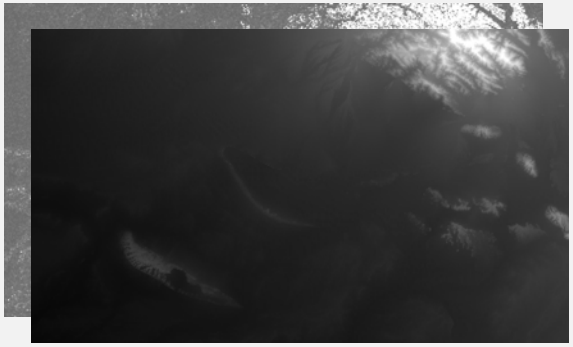
Sentinel-2 optical
- 10m / 20m resolution
- 9 spectral bands

Buildings, roads, sand etc. have different chemical compositions, which reflects across bands



Sentinel-1 SAR
- 10m resolution
- C-band

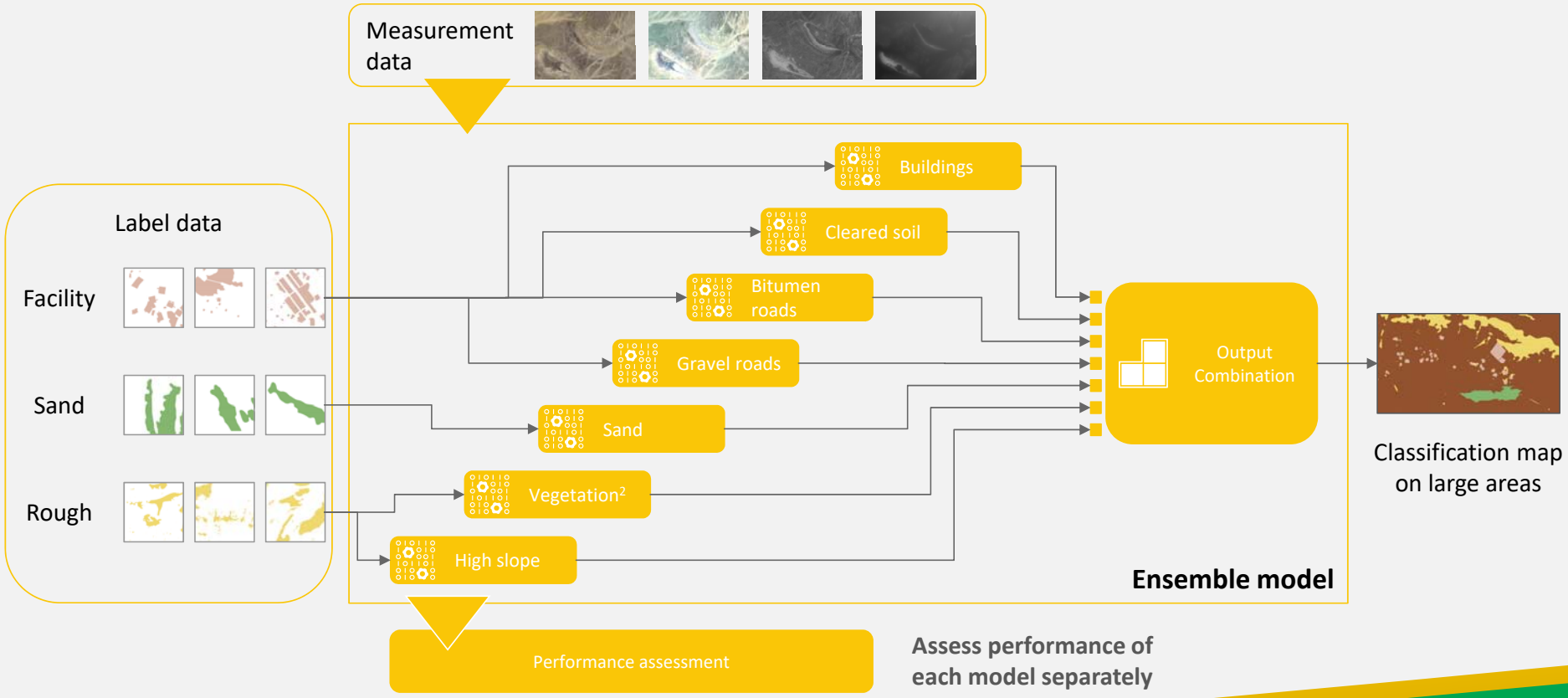
Buildings and other structures standing on the ground produce bright spots on radar imagery



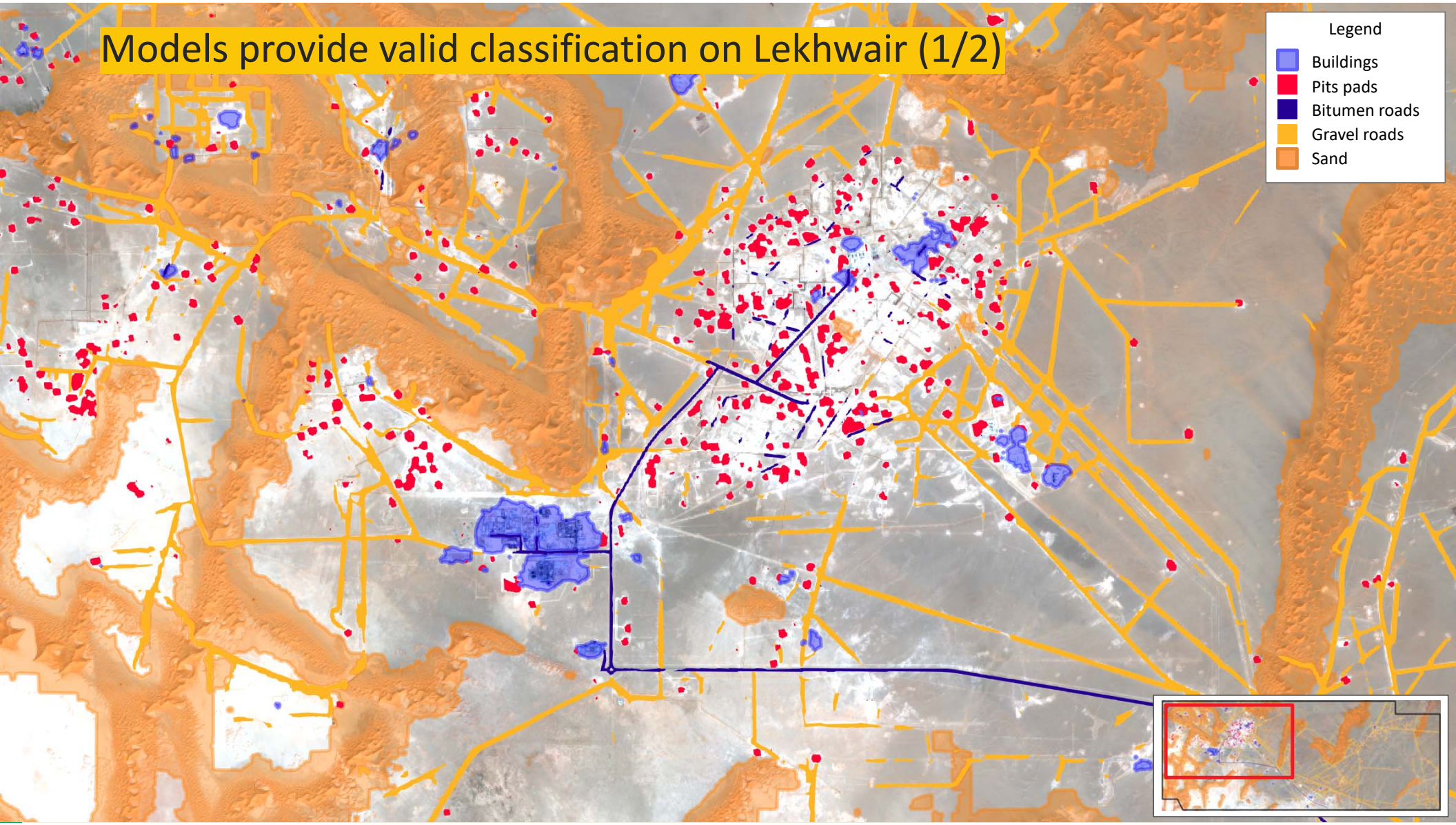
Derived from aerial photography
- 2m resolution
- Elevation and Slope

Elevation and slope are the main contributors to Roughness

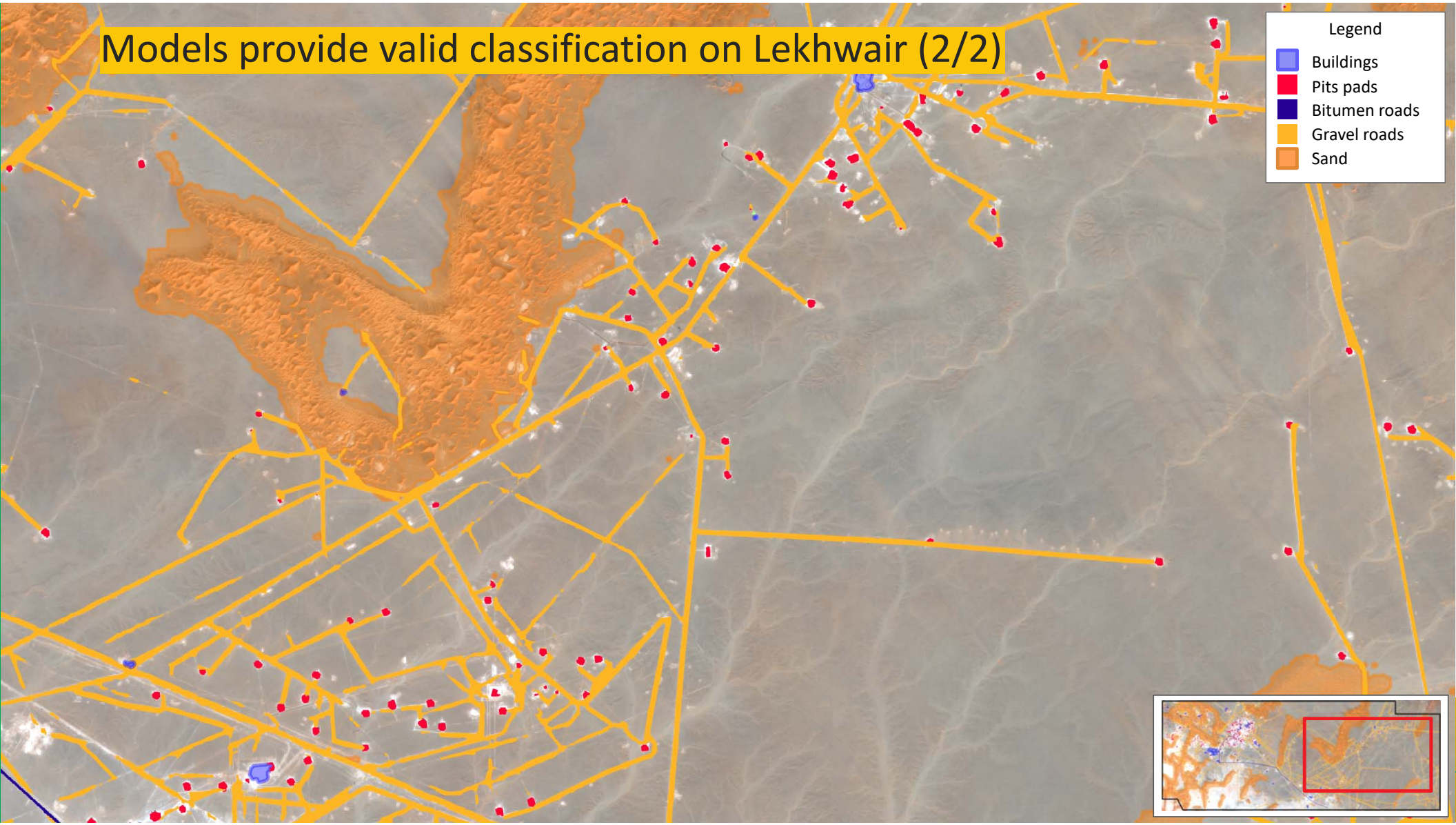
- Ensemble of specialized classifiers is the most common approach to manage the label overlap and improve the overall model performance



Models provide valid classification on Lekhwair (1/2)



Models provide valid classification on Lekhwair (2/2)

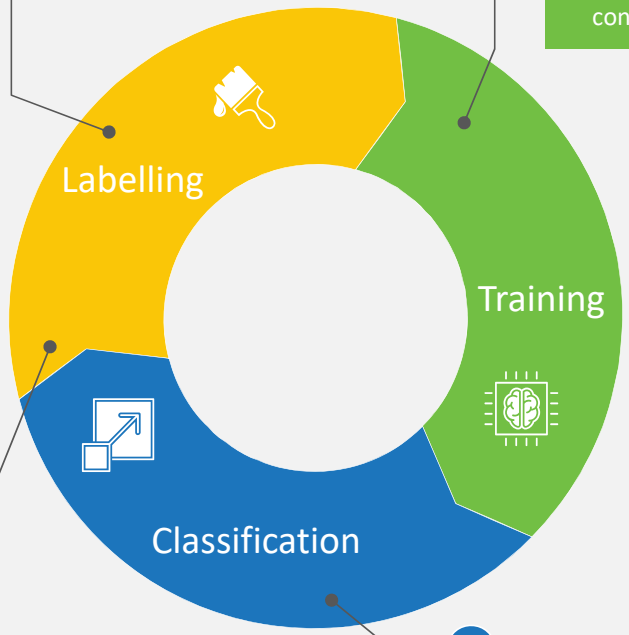


Results

- Item-wise performance assessment reflects better visual assessment; high overall performance with room for improvement for Gravel roads

Label	Visual assessment	Recall / Precision
Bitumen roads	Good	95% / 90%
Sand	Good	95% / 80%
Pits pads (cleared soil)	Good	90% / 88%
Buildings	Good	90% / 62%
Gravel roads	Good	85% / 72%
High slope	Good	N/A (rule-based)

Improvement

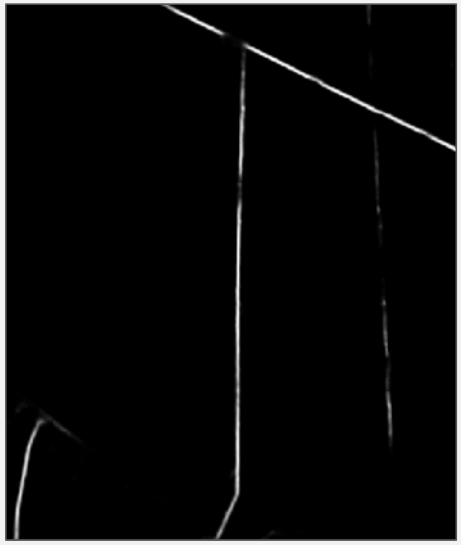


1. Use existing labels
2. (Re-)train on areas with the highest level of confidence in labels
3. Classify areas with low confidence in labels or without labels
4. Improve labels using classification results and include in train area

- Improvement of labels will improve the model performance

Example of gravel road labels improvement using classification results

Gravel road not captured in Test area at first



Classification on Test area

Gravel road labels corrected accordingly

Combining this with item-wise performance, Recall and Precision jumped from 73% / 27% to 85% / 72%

Conclusion

- The approach has been proved successful capturing the desired terrain types
- Improved project planning
- Give accurate production forecast
- Reduced cost
- Reduced time
- Improve HSE exposure

Thank you

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