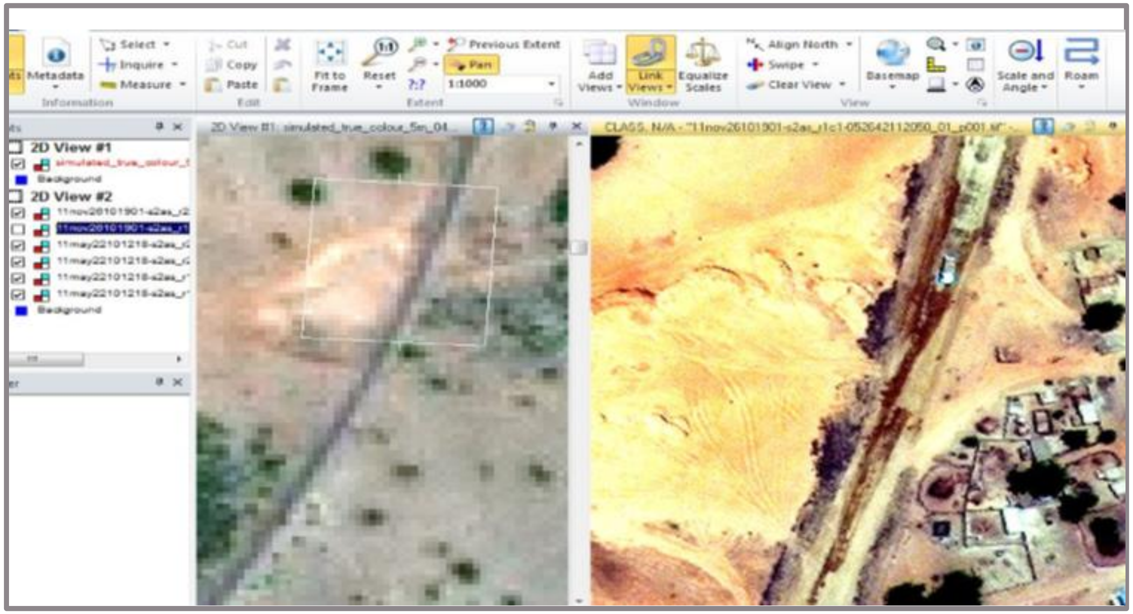


Satellite imagery and road condition

Robin Workman, TRL

Specialised Technical Session on Sustainable Transport

25 November 2019, Vic Falls, Zimbabwe

What is the Problem?

- Limited data available on rural road networks
- Lack of resources to update and extend this information
- Terrain and conflict make areas inaccessible to traditional surveys
- Lack of information makes planning and prioritisation of maintenance difficult
- Leads to restricted access and ultimately affects poverty

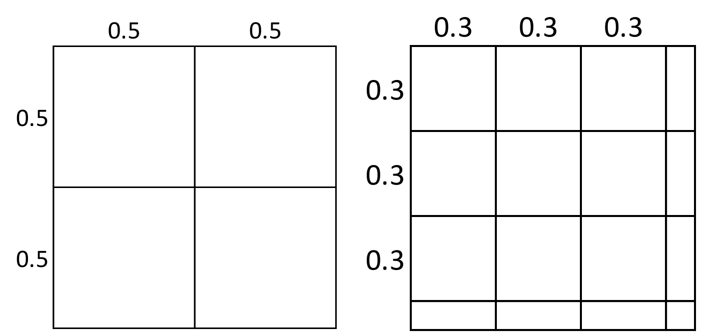
How can satellites and remote sensing help with asset management?

- Rapid assessment over large areas
- Logistically easier
- Provides a permanent record of the network
- Imagery can be used for other applications
- Safer, avoids the need to visit areas in conflict

Background

- Satellite Applications Catapult project in Nigeria (with Airbus)
- Follow-up with ReCAP in 5 countries in Africa (with Airbus)
- **Manual assessment** of road condition using 0.35 m to 0.5 m resolution imagery
- Outputs on ReCAP website
- TRL further research

Pixels for 1.0 m^2

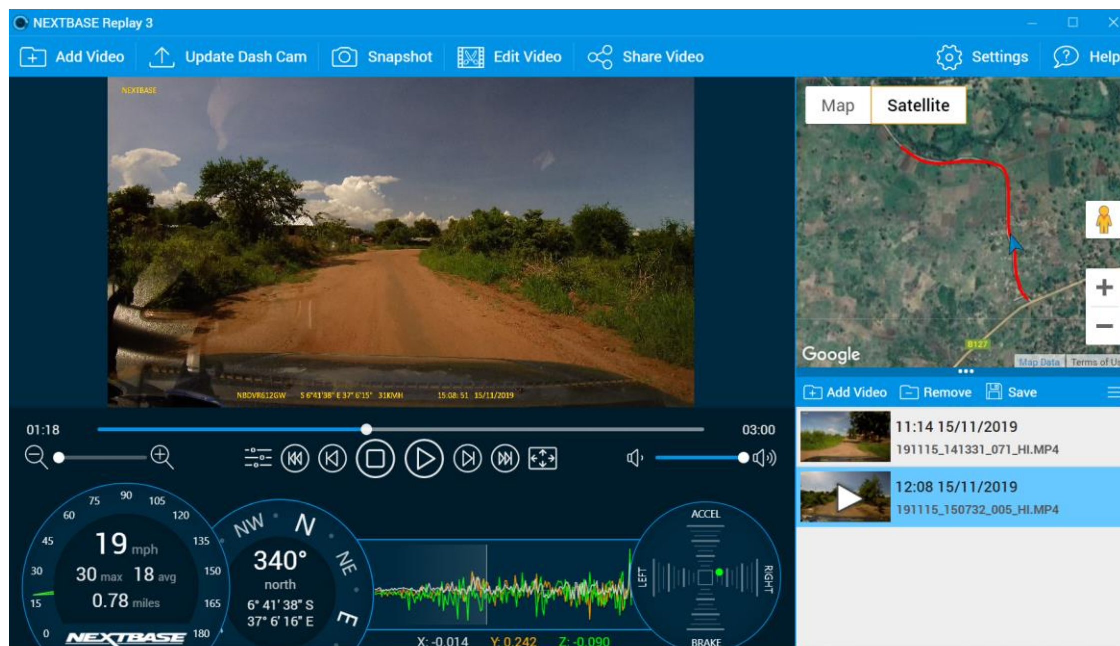


Methodology for road condition monitoring by satellite imagery

- Establish network / centrelines
- Carry out Ground Truthing to establish country specific conditions
- Develop a calibration guide
- Imagery Acquisition
- Train in software and image interpretation
- Assess Satellite imagery for road condition

Ground Truthing

- Establish typical conditions for road types in a country:
  - Visual assessment
  - Speed assessment
  - Roughness



Assessment of Condition

- Identify features that indicate long-term change in condition:
  - Change in width of the road
  - Straightness and integrity of road edges
  - Surface texture/shading/hue
  - Surface colour
  - Shadow
  - Patterns in surface, wheel tracking if visible

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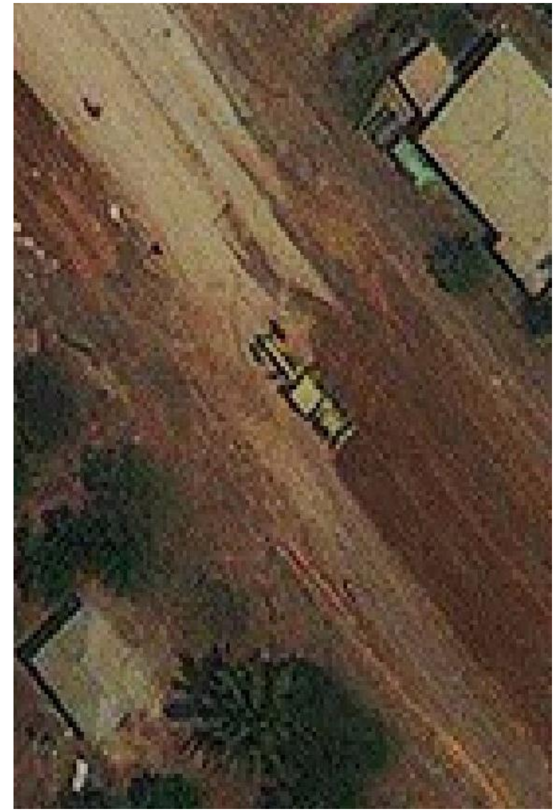
Good Condition
(smooth texture, consistent width)

Fair Condition
(uneven texture, slight variation in width)

Poor Condition
(high variation in texture, broken edges and variable width)



Under Rehabilitation
(machinery and different materials visible)

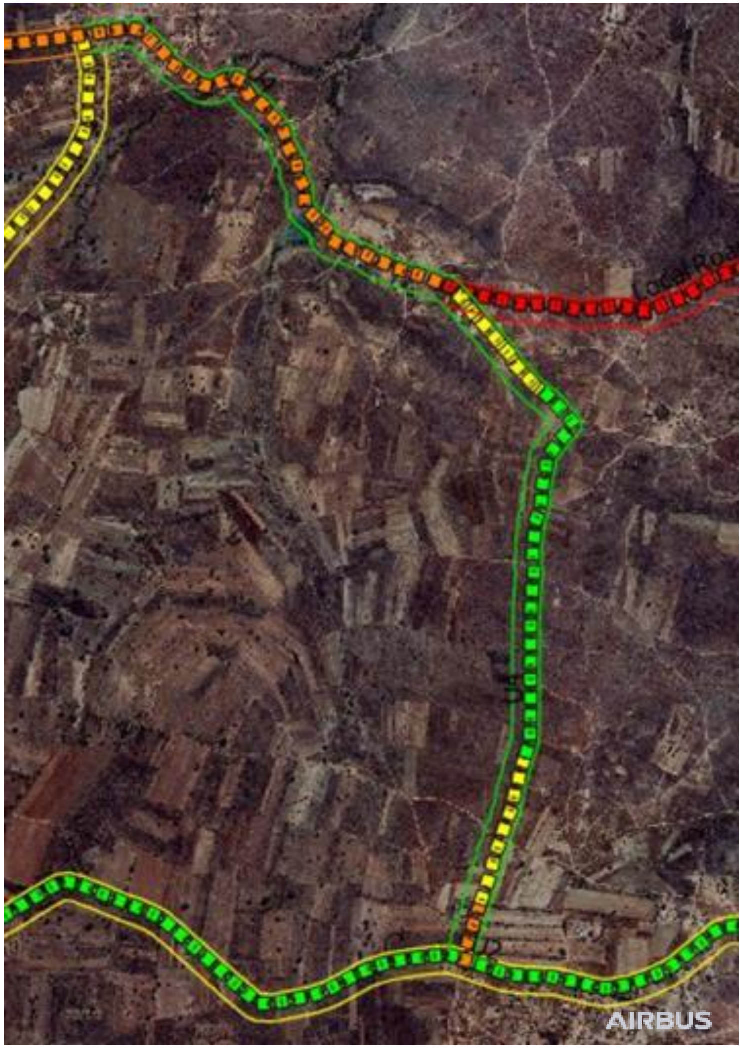
Assessment of Condition

- Three to five level assessment

Very Good	Good	Fair	Poor	Very Poor	Unknown
Dark Green	Light Green	Yellow	Amber	Red	Blue

Good	Fair	Poor	Unknown
Light Green	Yellow	Red	Blue

- Compare the ground truthing to the condition assessment results



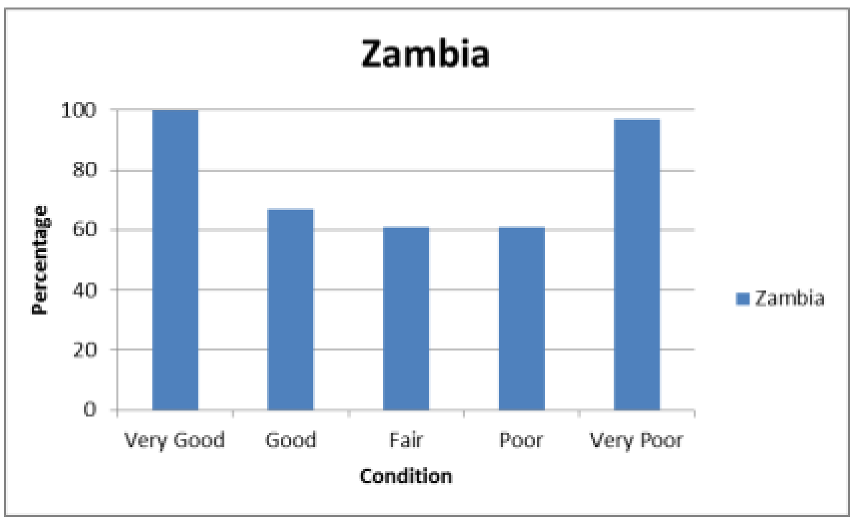
Zambia: Unpaved

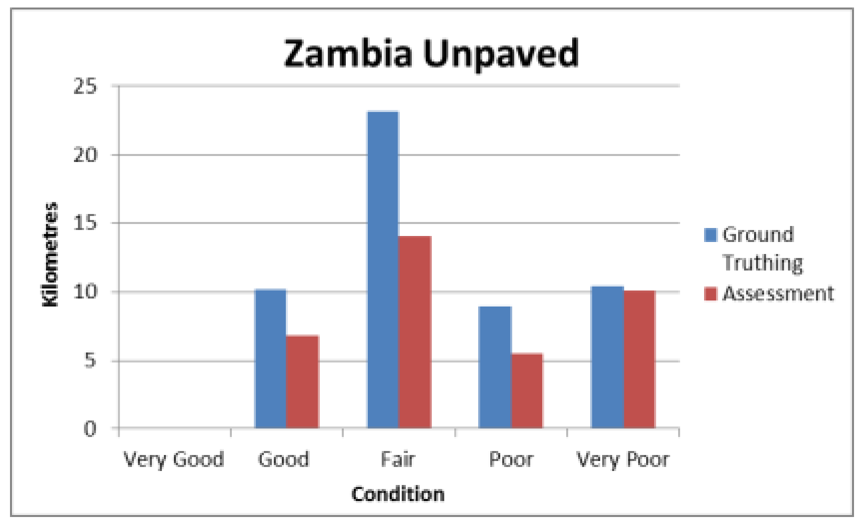
Assessment			Misclassified as;					
	Ground truthing (km)	Corresponding Satellite assessment (km)	V.Good	Good	Fair	Poor	V.Poor	Unknown
V Good	0	**0**						
Good	10.191	**6.829**			1.139	2.223		
Fair	23.153	**14.087**		6.835		2.231		
Poor	8.973	**5.514**			3.459			
V Poor	10.402	**10.129**				0.273		
	52.719	**36.559**						

Correlation			Percentage of correctness
V Good	0.00	0.00	100%
Good	10.191	6.829	67%
Fair	23.153	14.087	61%
Poor	8.973	5.514	61%
V Poor	10.402	10.129	97%
	52.72	**36.56**	**69%**

Misclassified as more than one level out:

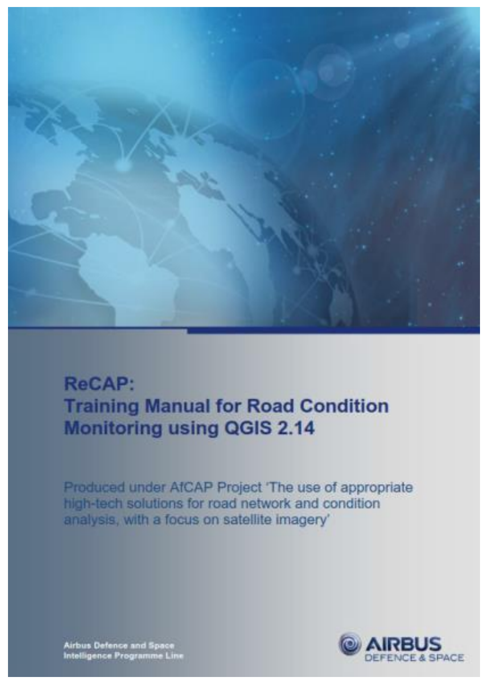
2.223 4.22% > 1 level out





Outputs

- Guideline on the use of high tech solutions for network and condition assessment
- Training materials



Status

- Can provide a rapid assessment of large areas, but will need support or partnership with remote sensing organisations
- Flexible enough to fit with existing condition assessment systems, can be calibrated to local conditions
- Would benefit from embedment in a RAMS
- Most beneficial (at present) for countries that have limited knowledge of their networks via accessibility, conflict etc.
- Application depends on the needs of the asset owner, the level of information provided and cost (VHR imagery)

Way Forwards

- Further research by TRL with satellites and machine learning
- Use of remote sensing technologies for RAI measurement?
- Other remote sensing technologies that can add to knowledge of African road networks?

TRL reinvestment project

Machine Learning to assess road condition on unpaved roads from geospatial imagery

- Literature Review, imagery identification (Tanzania)
- Approach, labelling, understand imagery quality, test
- Traditional algorithms for road edges and width variation
- Explore issues, occlusion, pixel variation
- Develop methodology, identify software/toolkits, challenges
- Trial ML on imagery in Tanzania, classify condition, assess performance
- Trials report, paper, demo pack, video, etc.

PhD:Understanding unpaved road condition for asset management by Earth Observation in LICs

Question: How can road condition assessed from optical satellite imagery contribute to the asset management of unpaved roads in low income countries in a cost effective and sustainable way?

- What level of unpaved road condition can be measured using optical satellite imagery?
- How useful would unpaved road condition from optical satellite imagery be for asset management and road maintenance prioritisation?
- How practical would this technology be for asset management of unpaved roads?

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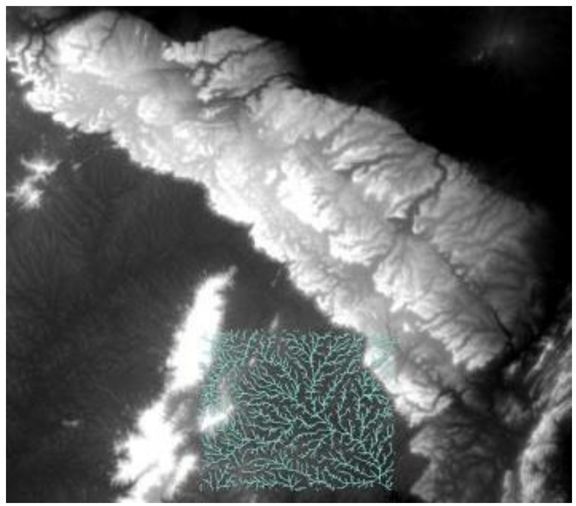
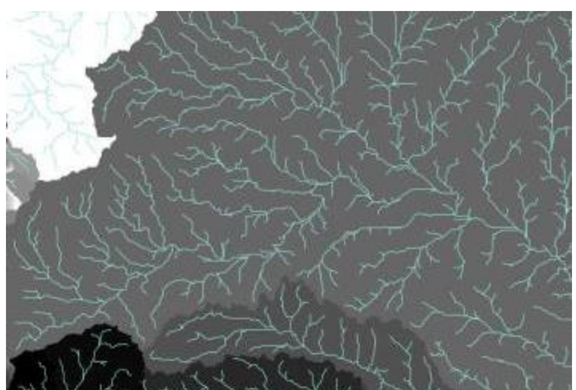
Other Remote Sensing Technologies

Digital Elevation Models (DEMs)

Free imagery can be processed to show drainage basins & channels.





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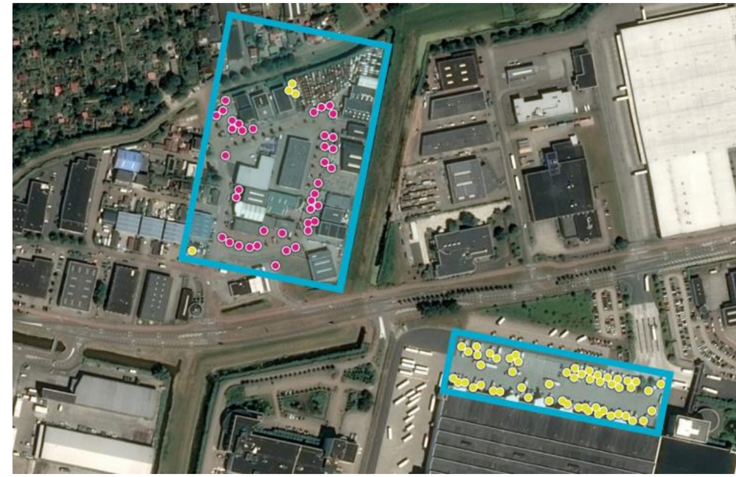
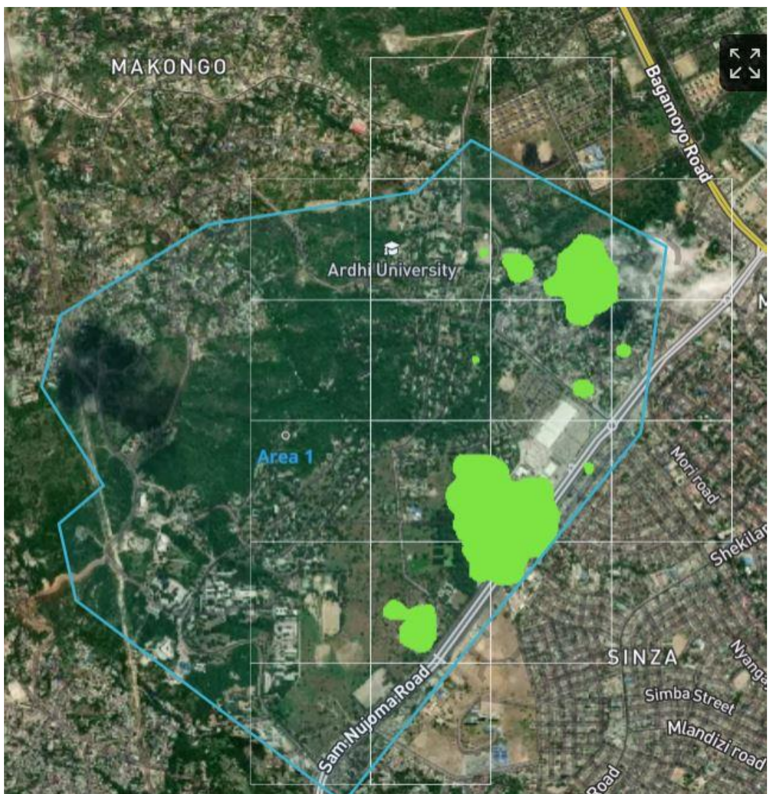
Change Detection

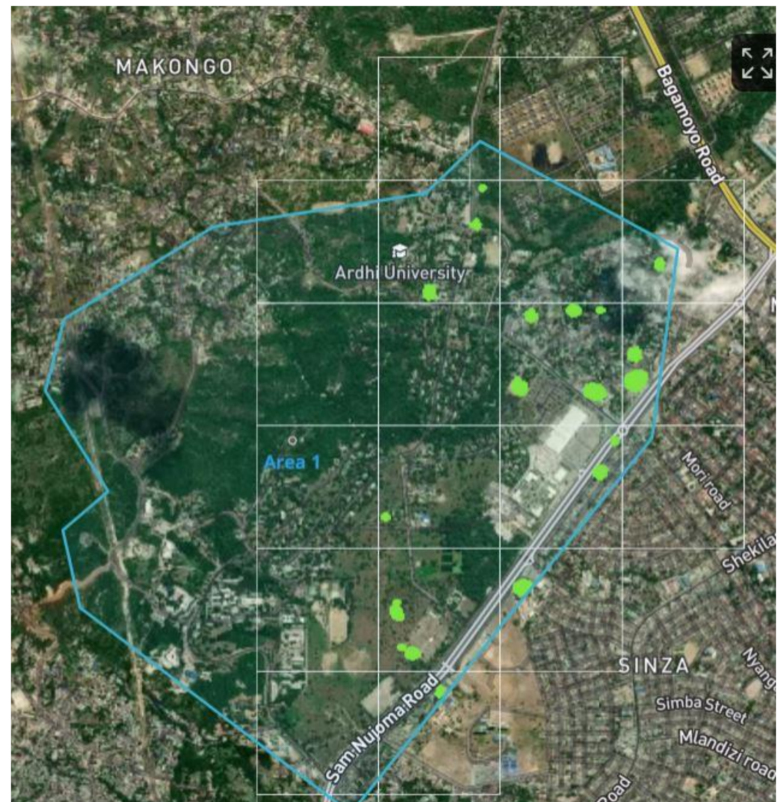
One Atlas and Earth Monitor



Date Feb 18 2018

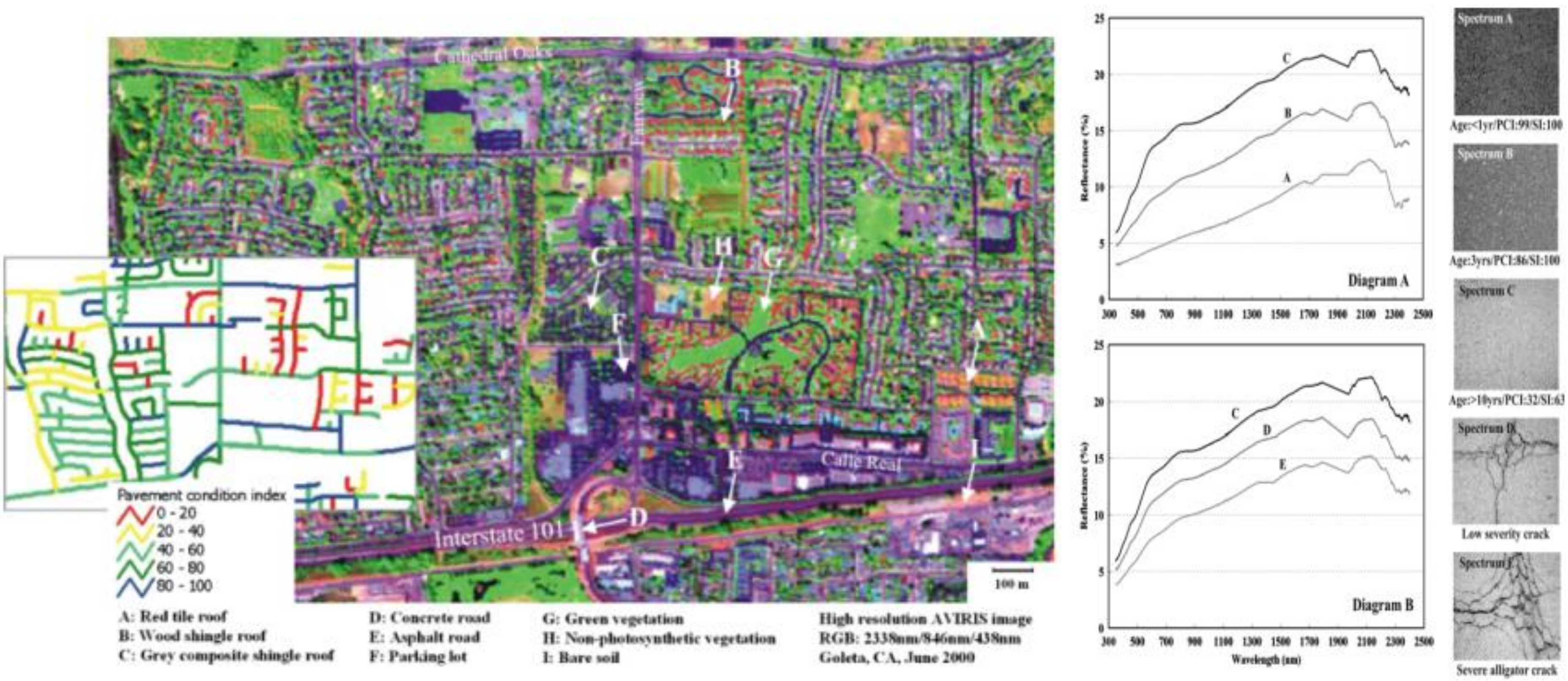


Date Apr 1 2019



Spectral reflectance for paved roads

Uses brightness of visual images, used for material identification (TRL projects in Mozambique, Ethiopia)



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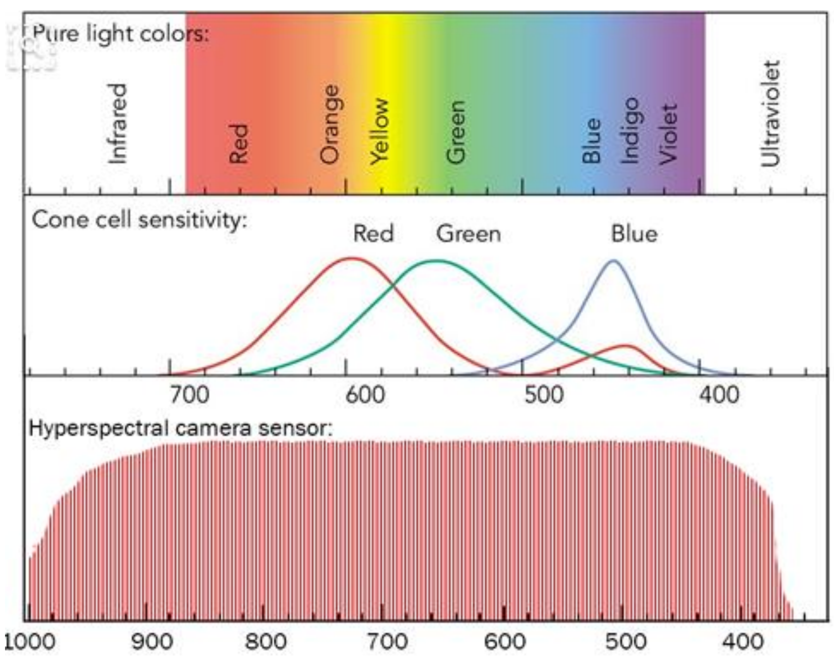
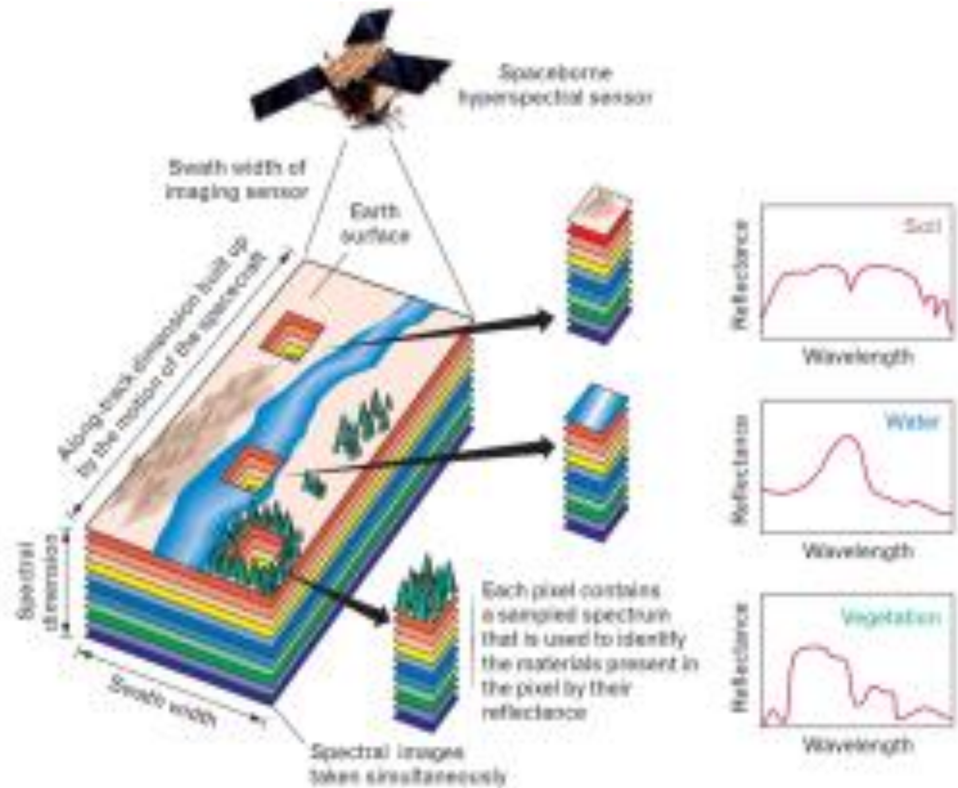
Hyperspectral Imaging

Several pictures at different wavelengths (200 bands), detect minerals, monitor development and health of crops, track pollution, detect new oil and gas reserves, water content….etc.





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UAVs (with LIDAR or cameras)

Mapping, road condition through photos or LiDAR, high cost, limitations on use, USA research, Tanzania research

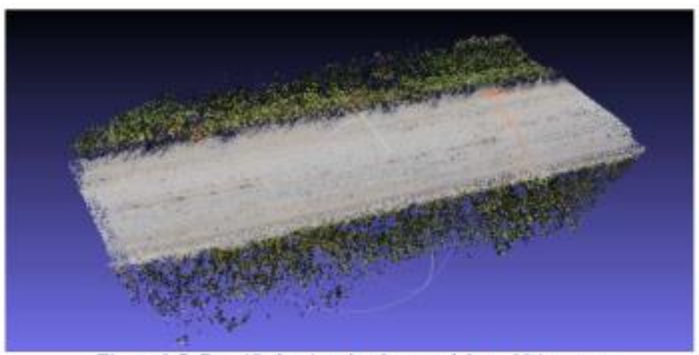

Figure 3-7: Densified point cloud created from 28 images.

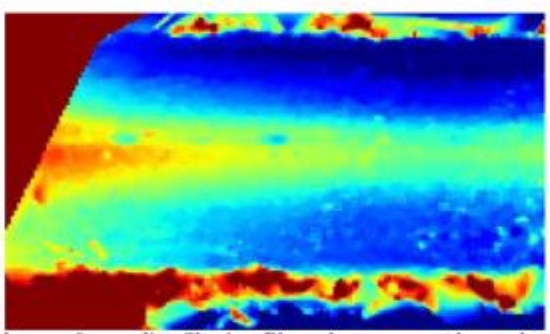

Figure 3-8: Depth map after median filtering. Blue colors represent lower elevations, red colors represent higher elevations.

Figure 3-11: A 3-D point cloud generated through the project's structure-from-motion based remote sensing processing system software using overlapping UAV-collected imagery of Welch Road.

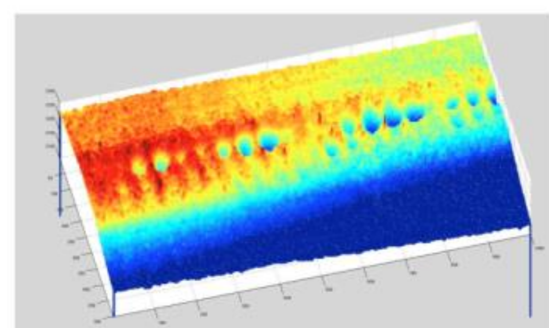

Figure 3-12: Part of the Welch Road segment displaying a height map where potholes and their depths can be seen.

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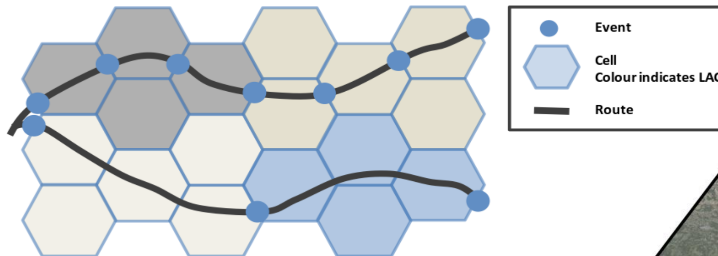
Z-Roads

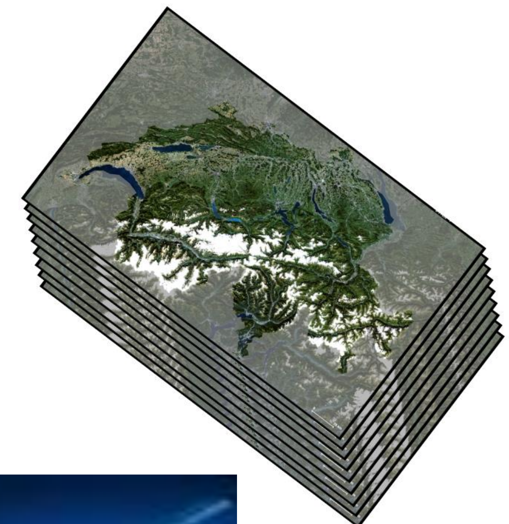
Z ROADS
AI MAPPING OF ZANZIBAR UNPAVED ROAD CONDITIONS

- Drone imagery and Machine Learning
- Mainly paved roads (although unpaved road study)
- Problems with image processing (5,000 out of 70,000 tiles useable)
- Good, Poor or ‘Review’, 73% accuracy

Other.....

- Mobile Phone data
- Crowdsourcing
- Africa Data Cube
- Data scraping
- Pseudo satellites
- Etc.





Discussion;

- Is current data collection appropriate for **unpaved** roads? i.e. frequency, volume, type, quality, etc.
- Would satellite condition data be sufficient to plan and prioritise maintenance for **unpaved** roads?
- Would the satellite imagery be useful for any other **rural road** uses?

Questions:

- How many levels of condition are **necessary** for assessing **unpaved** (earth and gravel) roads? i.e.
  - **3** - Good/Fair/Poor
  - **4** - Good/Fair/Poor/Bad
  - **5** – Very Good/Good/Fair/Poor/Very Poor
- Considering the resources available for rural roads, how frequently should **unpaved** road condition data be collected?
  - **6 monthly**
  - **Annually**
  - **Every 2 years**
  - **Less frequently**

Questions:

- Is **all** of the data you collect on unpaved roads now, actually used for maintenance planning? **Yes / No / Unsure**
- Would a Good / Fair / Poor type assessment of road condition by remote sensing (drone, satellite) be sufficient for **unpaved** rural roads? **Yes / No / Unsure**
- Would recent very high resolution **satellite imagery** of roads (as shown previously) be useful for any other road related purpose? **Yes / No / Unsure**
- If **Yes**, please state potential use/s:
  - **?**
  - **?**

Thank you for your attention

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25 November 2019, Vic Falls, Zimbabwe