SATELLITE IMAGERY FOR ESTABLISHING INVENTORY AND CONDITION OF UNSURFACED ROADS

Robin Workman
Contents

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• Ground Truthing
• Mapping
• Condition Assessment
• Incorporation into iRoads
• Conclusions
• Way Forward
Introduction

• Satellite industry booming, potential for roads
• Transport Infrastructure Monitoring Project
  - Aim
  To promote satellite data for the monitoring and assessment of a road network
  - Focus
  To assess satellite applications in countries with remote regions or security issues
Partners

Transport Research Laboratory:
(with NIAF II, funded by DFID)

Airbus Defence and Space:
(formerly Astrium)

Satellite Applications Catapult:
Transport Infrastructure Monitoring Project

Phase 1 - Feasibility study

• Identify and assess potential applications
• Interaction with potential stakeholders in Nigeria
• Planning of the second phase
• Producing a road map for the way forwards
Why Nigeria?

- Limited established information on the road network
- Accessibility, security and flooding issues are present
• TRL have an established presence in country, NIAF II

NIAF II Labour-based training pilot roads

• Have support from the Nigerian government
Nigerian Road Network:

• Federal – Paved, 34,000km
• State – Mainly paved, 30,000km
• LGA – Mainly earth or gravel, ‘unknown’ km

No established inventory of LGA road network
Little maintenance carried out on LGA road network
Ownership/responsibility often unclear between State, LGA and Municipalities
Phase One - Summary

Potential applications identified:
- Engineering
- Hazard management
- Transport Project Monitoring
- Network Characterisation
- Network Management

Following discussions with stakeholders:
- Mapping location and condition of the road network
- Identify wet season ‘wash-outs’ and damage
- Monitor condition of steep winding roads in highland areas
Phase 2 - Objectives

1. Can Nigeria use available SPOT data to improve their knowledge of their road network, or is higher resolution data required?

2. Can satellite very high resolution optical imagery help in determining road condition?

3. Can incorporation of road network and road condition be demonstrated using RAMS?
Ground Truthing
Using an Image Collector
Forward facing images
## Condition Assessment system

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Present state of road</th>
<th>Capital work required to drainage</th>
<th>Capital work required to surface condition</th>
<th>Present condition</th>
<th>~ IRI</th>
<th>Category</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paved</td>
<td>Not relevant for this project</td>
<td>None</td>
<td>None</td>
<td>N/A</td>
<td>N/A</td>
<td>0P</td>
<td>Not used in this study</td>
</tr>
<tr>
<td>Earth</td>
<td>Fully Maintainable</td>
<td>Drainage present or not required</td>
<td>None</td>
<td>Good to Fair</td>
<td>&lt;10</td>
<td>0E</td>
<td>Routine maintenance can be applied immediately</td>
</tr>
<tr>
<td>Gravel</td>
<td>Fully Maintainable</td>
<td>Drainage present or not required</td>
<td>None</td>
<td>Good to Fair</td>
<td>&lt;8</td>
<td>0G</td>
<td>Routine maintenance can be applied immediately</td>
</tr>
<tr>
<td>Earth</td>
<td>Maintainable with minor work</td>
<td>Drainage present but some silting or slight damage</td>
<td>Surface in fair condition, some loss of shape or minor potholes</td>
<td>Fair</td>
<td>10-15</td>
<td>1E</td>
<td>Minor drainage works, minor surface repairs, retain as earthen surface. Apply heavy maintenance for 6 months to bring to maintainable condition.</td>
</tr>
<tr>
<td>Earth</td>
<td>Non-maintainable</td>
<td>Drainage present but some rehab. necessary</td>
<td>Surface in fair to poor condition, camber needs restoring, surface damage</td>
<td>Fair to Poor</td>
<td>15-30</td>
<td>2E</td>
<td>Rehabilitate surface to maintainable standard, rehabilitate drainage, assume no new culverts necessary</td>
</tr>
<tr>
<td>Earth</td>
<td>Non-maintainable</td>
<td>Drainage in poor condition, needs rehab, replace, new</td>
<td>Surface in poor condition, no camber and large damaged areas</td>
<td>Poor</td>
<td>15-30</td>
<td>3E</td>
<td>Rehabilitate surface to maintainable standard, install or upgrade basic drainage, assume 1 culvert per km</td>
</tr>
<tr>
<td>Earth</td>
<td>Non-maintainable or non-motorable</td>
<td>Drainage not functioning or no drainage present</td>
<td>Surface very poor, erosion, soft spots and impassable in places</td>
<td>Very Poor</td>
<td>&gt;30</td>
<td>4E</td>
<td>Reconstruct road including installing all necessary drainage such as side drains, turnouts and 2 culverts per km</td>
</tr>
<tr>
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<td>Maintainable with minor work</td>
<td>Drainage present but some silting or slight damage</td>
<td>Surface in fair condition, some loss of shape or minor potholes</td>
<td>Fair</td>
<td>8-12</td>
<td>1G</td>
<td>Minor drainage works, minor surface repairs, retain as earthen surface. Apply heavy maintenance for 6 months to bring to maintainable condition.</td>
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<td>&gt;25</td>
<td>4G</td>
<td>Reconstruct road including installing all necessary drainage such as side drains, turnouts and 2 culverts per km</td>
</tr>
</tbody>
</table>
Condition assessment from the images
## Summary of costs

<table>
<thead>
<tr>
<th>General Section Rating</th>
<th>Total Length (km)</th>
<th>Total Cost (N)</th>
<th>Approximate labour days</th>
</tr>
</thead>
<tbody>
<tr>
<td>0E</td>
<td>19.966</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>0G</td>
<td>0.905</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>1E</td>
<td>167.348</td>
<td>65900094.57</td>
<td>11,681</td>
</tr>
<tr>
<td>1G</td>
<td>14.555</td>
<td>7595188.77</td>
<td>972</td>
</tr>
<tr>
<td>2E</td>
<td>396.982</td>
<td>453565524.20</td>
<td>267,844</td>
</tr>
<tr>
<td>2G</td>
<td>0.310</td>
<td>657324.90</td>
<td>265</td>
</tr>
<tr>
<td>3E</td>
<td>115.076</td>
<td>175706562.74</td>
<td>77,642</td>
</tr>
<tr>
<td>3G</td>
<td>8.040</td>
<td>23993536.36</td>
<td>6,872</td>
</tr>
<tr>
<td>4E</td>
<td>23.033</td>
<td>58039550.63</td>
<td>36,346</td>
</tr>
<tr>
<td>4G</td>
<td>0.000</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>0P</td>
<td>194,378</td>
<td>0.00</td>
<td>401,622 TOTAL</td>
</tr>
<tr>
<td>1P</td>
<td>5.731</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

| Totals                 | 947.348          | 785,457,782    |                         |
Satellite Images for Mapping and Condition Assessment
Pilot area: Kano State
Available Sources of Satellite Data

• NigeriaSat-2 – Optical at 2.5m resolution. Suitable for Mapping

• SpotMaps derived from Spot 5 at 2.5m resolution covering most of the country. Suitable for Mapping.

• Pleiades 0.5m resolution covering urban areas.

• Large amount of archive 1 metre optical imagery covering the North of the country. Originally collected to support a polio vaccination program.

• Spot 6 / 7 available at 1.5m resolution.

• In the cloudy south Radar imagery has been collected for the Federal Government at both 3m resolution and 1m (urban areas).
Data actually used in Project

- **SPOT6** satellite image 1.5m resolution for road mapping
- **Pleiades** satellite image 0.5m resolution for road condition
Kano State
Selected ‘square’, 11.5km x 8.5km area in Kano
Mapping methodology

Roads classified by width
- <3m – not to be mapped as likely to be a track, not a road.
- 4-6m – Minor Road
- 7-9m – Standard Road
- >10m – Trunk Road

Road network split at junctions
## Condition Assessment by Satellite

Condition Assessment system

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0P</td>
<td>Paved, good to fair condition</td>
</tr>
<tr>
<td>0E</td>
<td>Earth, good to fair condition</td>
</tr>
<tr>
<td>1E</td>
<td>Earth, fair condition</td>
</tr>
<tr>
<td>2E</td>
<td>Earth, fair to poor condition</td>
</tr>
<tr>
<td>3E</td>
<td>Earth, poor condition</td>
</tr>
<tr>
<td>4E</td>
<td>Earth, very poor condition</td>
</tr>
</tbody>
</table>
Condition assessment rules determined from Pleiades satellite & Image collector
Condition assessment by satellite image

- Road condition assessment based on rules
- 50cm resolution Pleiades satellite imagery
Condition assessment by satellite image
Comparing satellite and ground conditions
Drainage identification

- Bridge > 3m
- Culvert < 3m with wing/head walls
- Possible Culvert - no wing walls
- Ford - no obvious structure
Bridge identification
Bridge identification
Culvert identification
Culvert identification
Condition assessment by satellite:
- Edges of road: clear, broken, faint
- Width of road: varied or uniform
- Surface: uniform, shading or colours
- Wheel tracks: visible, straight or winding

Limits:
- Auditing: by IC images when available
- Automation of process limited
- Vegetation cover: OK in northern Nigeria....
- Differences between wet and dry seasons
## Condition assessment accuracy

<table>
<thead>
<tr>
<th>Condition</th>
<th>Length (km)</th>
<th>Positive Correlation with Image Collector</th>
<th>Negative Correlation with Image Collector</th>
<th>% Correlation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0P</td>
<td>1.9</td>
<td>1.9</td>
<td>0</td>
<td>100</td>
<td>Excellent correlation</td>
</tr>
<tr>
<td>0E</td>
<td>1.7</td>
<td>0.2</td>
<td>1.5</td>
<td>12</td>
<td>Condition for only one road - 0E looks like 0P on imagery</td>
</tr>
<tr>
<td>1E</td>
<td>8.5</td>
<td>6.7</td>
<td>1.8</td>
<td>79</td>
<td>Very good correlation</td>
</tr>
<tr>
<td>2E</td>
<td>19.4</td>
<td>11.5</td>
<td>7.9</td>
<td>59</td>
<td>Good correlation - tendency to condition as 3E</td>
</tr>
<tr>
<td>All</td>
<td>31.5</td>
<td>20.3</td>
<td>11.2</td>
<td>64</td>
<td>Good correlation for all scenarios</td>
</tr>
</tbody>
</table>
Incorporation into iRoads

Shape files
Incorporation into iRoads

Satellite condition assessment

Ground condition assessment
Incorporation into iRoads – road widths
Summary of Data:

Satellite
- 180km of road assessed by Airbus
- Approx. 4 days to assess 180km, about 50km a day

Ground Truthing
- 35km of ground condition data supplied by TRL
- Approx. 2 days to collect 35km, about 17km a day
- Approx. 1 day to assess 35km, about 35km a day

iRoads
- Images incorporated into iRoads in less than ½ day
- Will take longer to enter full data, i.e. junctions, features, links, etc.
Conclusions

• Satellite Imagery used to cost effectively map the road network and assess road condition

• Some parameters cannot be assessed directly by satellite, such as road camber and small defects

• A good level of correlation can be achieved between satellite imagery and ground truthing

• High potential for savings in time and cost by using satellite imagery

• There is also potential for satellite imagery to enhance the management of road networks

• Can provide employment to local engineers and satellite experts
Way Forward:

• Great potential for fragile and conflict affected states, as well as inaccessible areas
• Replicable in other countries
• Appropriate to partner with African Governments and local organisations
• Future technological developments of satellites will further enable mapping and condition assessment
Do You Have Any Questions?