



**AfCAP**  
Africa Community Access Partnership



## The use of appropriate high-tech solutions for road network and condition analysis, with a focus on satellite imagery

DRAFT Interim Trials Report



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## **Acronyms, Units and Currencies**

|         |   |
|---------|---|
| AfCAP   | African Community Access Partnership                          |
| AfDB    | African Development Bank                                      |
| AoI     | Area of Interest  |
| CERSGIS | Centre for Remote Sensing and Geographic Information Services |
| DEM     | Digital Elevation Model                                       |
| DFID    | Department for International Development                      |
| ESA     | European Space Agency   |
| GIS     | Geographical Information System                               |
| GPS     | Global Positioning Satellite                                  |
| HIC     | High Income Country   |
| IoT     | Internet of Things  |
| IQL     | Information Quality Level                                     |
| IRI     | International Roughness Index                                 |
| LIC     | Low Income Country  |
| LIDAR   | Light Detection and Ranging                                   |
| LVR     | Low Volume Road   |
| MTRD    | Materials Testing and Research Division                       |
| NRSC    | National Remote Sensing Centre                                |
| OSM     | Open Street Map   |
| PMU     | Programme Management Unit                                     |
| RAI     | Rural Accessibility Index                                     |
| RAMS    | Road Asset Management System                                  |
| RCMRD   | Regional Centre for Mapping of Resources for Development      |
| RDU     | Research and Development Unit                                 |
| ReCAP   | Research for Community Access Programme                       |
| SAR     | Synthetic Aperture Radar                                      |
| UAV     | Unmanned Aerial Vehicle                                       |
| UK      | United Kingdom  |
| UNRA    | Ugandan National Roads Authority                              |
| VHR     | Very High Resolution  |

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## 1. Executive Summary

This interim trials report is almost two months later than planned, due to delays in the implementation of the trials. The majority of the trials have been focused on the satellite condition assessment using satellite imagery, which is being implemented in all four countries, Ghana, Kenya, Uganda and Zambia. Other high-tech solutions have been investigated but no trials have yet been completed.

Training has been completed in two countries, and three have finished the ground truthing. Zambia has completed an initial assessment by satellite and has analysed the results, but there is not yet enough analysed data to make any overall conclusions. It is hoped that all countries will complete their training and analysis within the next month, and some conclusions and recommendations can be made in the final trials report, due at the end of March 2017.

## 2. Introduction

This project is designed to look to the future for road management in Africa and explore different and innovative solutions to well established problems. It is a regional project that started on 25<sup>th</sup> April 2016 and is due to complete in May 2017. There are two main aspects to the project, the high-tech solutions to increase knowledge of rural road networks, and the assessment of road condition using satellite imagery. There was a provisional sum of £20,000 allocated for the provision of satellite imagery towards the second aspect of the project, but there were no capital funds allocated to the high-tech solutions aspect, which was to be funded by the countries themselves, or other partners.

The project is now well into the trials period. A comprehensive introduction and background can be seen in previous reports, but this report covers the implementation of trials in the four countries; Ghana, Kenya, Uganda and Zambia. This report was originally intended to be a full Trials Report, but due to delays in some of the countries the report has been divided into an Interim Trials Report (this report) and a Final Trials Report, to be submitted at the end of March 2017.

So far there have been no research trials into the high-tech solutions, but all four countries have participated in the satellite condition assessments. As well as researching the technical aspects of high-tech solutions, the project is considering the sustainability of the system and how it can be designed to be easily used and replicated by local institutions.

This interim report covers the period up to the end of February 2017.

## 3. Appropriate high-tech solutions

A number of alternative high-tech solutions were identified in the desk study report. All have the potential to enhance knowledge of rural road networks in some way, but it was not possible to explore all of them within the resources of the project. Therefore a number were prioritised and investigated further, with a view to making recommendations for future research.

### 3.1 Prioritised technologies

The following technologies were investigated:

- **Social media/Facebook app.** All countries were interested in developing an app that could be used on a social media platform to allow people to report aspects of road condition or safety. Ghana has started to develop this as an app for Facebook. It has been noted the

roughness app RoadLab has the capacity to take photos, geo-reference them and send them to a specific site. This is essentially what the Facebook app would do, except that there is much more accessibility and the options for crowdsourcing are wider because so many people use Facebook. For an example if a dangerous defect was identified through the app, it could be shared with others and there could be a limit set whereby if enough likes are identified in the same area it could be passed on to the local roads authority as a potential hazard. An example of the draft app interface can be seen in Annex 1.

- **Back analysis.** Some countries expressed interest in using archive satellite imagery to analyse road networks and road condition in past years. There are many potential uses for this, such as identifying the spread of urban areas, or to determine the necessary frequency of condition assessments on rural roads. At present most countries try to assess their roads on an annual basis, but if it could be proved that they only need to carry out this assessment every 2, or 3, or even 4 years, it would save a lot of resources. It was not possible to trial this solution as there were no funds available for satellite imagery and the budgeting time was too short to apply for funds in the next financial year. Additionally, this would be better implemented after the methodology for the satellites project has been completed, as it would essentially rely on this make the assessments.
- **Unmanned Aerial Vehicles (UAVs).** There has been a lot of research in the USA into how UAVs can be used to increase the knowledge of unpaved roads. Most notably the research project by Michigan Tech Uni (<http://integratedglobaldimensions.com/unpaved/>) which took 3 years and \$2.5M to investigate various remote sensing systems to assess unpaved road condition. There are also companies in Africa who are promoting bridge inspections by UAV, and the World Bank has carried out a comprehensive UAV survey of Dar es Salaam, with exciting results. An extract from the report can be seen in Annex 2.

UNRA in Uganda is in the process of procuring a UAV, which they intend to use for alignment surveys and other road-related surveys. Some countries were interested to trial this technology, but the capital costs of procuring a UAV were prohibitive and there are very few places in Africa where they can be hired. The World Bank does have two fixed wing UAVs, which could have the potential for a future joint project. Otherwise it has proved too expensive to carry out trials within the current project, but some uses have been identified:

- Alignment surveys, to assess inaccessible areas for new road alignments
  - Surveys of structure that are hard to get to, such as underneath large bridges or inside large culverts
  - To survey landslides and other roadside faults
  - To check the condition of roads
- **Spectral reflectance.** We are hoping to be able to carry out a small trial in Ghana, if the imagery is sufficiently clear. However, there are insufficient funds to carry out a separate trial.

### **3.1 Existing technology utilised:**

- **DashCams:** These Dashboard Cameras (DashCams) are High Definition (HD) video/still cameras that fix inside the windscreen of a vehicle. They are primarily designed to record accidents and illegal activity within the area of the vehicle, but the project has identified an innovative way to use them for condition surveys. The cameras actually capture GPS data for

the route as it is being driven, as well as speed, orientation and an approximate X, Y, Z movement of the vehicle as it travels, which potentially provides an approximation of roughness that could possibly be linked to IRI. These cameras were utilised during ground truthing, so that a permanent record of the roads and their condition can be saved. This allows audits of the ground truthing to be carried out. An example of the DashCam software can be seen in Annex 3.

- **Mobile phone apps:** There are many mobile phone apps that measure roughness of the road, using the accelerometer within the smartphone. The first developed was Roadroid, but many others have now been developed, including RoadLab which is a World Bank product. RoadLab is free at source and easily downloadable; it is available for use on Android devices from 4.4 upwards and also works on Apple devices, so most staff in road agencies will already have the hardware necessary to run the application. Some of the alternative apps are free initially but ultimately have costs associated if the user wants to use the full variety of tools and applications of the software. The project decided to use this to supplement the ground truthing visual surveys to provide an approximation of roughness, which is discussed further later in this report. An example of the RoadLab interface can be seen in Annex 4.
- **Climate Change:** In terms of climate change and road network assessment, satellite imagery does have some potential uses. It can possibly be used to identify areas vulnerable to flooding, using Digital Elevation Models (DEMs). Additionally, SAR imagery can identify changes between two images very clearly by recognising changes at pixel level, as shown in Annex 5.

### **3.2 Other ideas not taken up:**

As mentioned above, it was not possible to trial all of the potential technologies. The desk study for this project shows how the technologies were prioritised, and the following were not selected for further research, although they all have promise in the roads sector.

- **Big Data.** There is certainly potential for using Big Data in the future. However, trials were not possible as part of this research as we did not have feedback from the partner countries as to what type of big data that would be useful for their operations. However, some recommendations will be made on potential uses in the final report.
- **Mobile phones.** The potential for mobile phones was explored with the use of the roughness apps. Apart from RoadLab, the partner countries did not take this any further for other applications. A wider application of mobile phone information would have required permissions from the mobile phone companies to use their data. This possibility was not fully explored, but would most likely have involved onerous and possibly legal procedures to obtain. It was decided that a comprehensive plan for use of the data would be necessary before applying for permission to use the data.
- **Mini satellites:** The main applications that were identified for mini satellites at the present time were mapping and humanitarian emergencies. With the provision of VHR imagery in the Aols the mapping option was not deemed necessary. The main use of these satellites is seen as being most effective when their capacity increases to provide higher resolution imagery, perhaps in the medium term. It is expected that mini satellites will develop sufficiently in the future to be able to assist with road condition assessment, but at present the resolution is too low. UNRA in Uganda has been in touch with Planet Labs, who provide mini-satellite imagery, but have so far been unable to actually acquire the imagery they need.

### 3.3 Other potential links:

There are also existing projects that are using high-tech solutions to solve problems in the rural roads sector.

#### **Rural Access Index (RAI):**

The RAI is a transport headline indicator designed to focus on the critical role of access and mobility in poverty reduction. It was first established in 2006 and is now in the process of being updated.

This World Bank initiative is designed to determine the percentage of rural populations that live more than 2 km from an all-weather road. This is an important global indicator and is based on household surveys. They are now considering a second phase to the RAI and are considering using more high-tech options for gathering the information. This could include satellites, UAVs and other technologies.

A similar application was developed in Nepal that determined accessibility in terms of walking time, rather than distance. This was more appropriate for communities living in mountainous, high altitude areas as the distance from the nearest road could vary greatly and would not necessarily represent accessibility.

Comments on the synergies between this project and the RAI will be covered in the final report.

#### **Open Street Map (OSM):**

This initiative is designed to use crowdsourcing to provide detailed information on roads across the world. The public can sign up as a contributor to the system and upload information on roads to the main map. This works in much the same way as Wikipedia, the online encyclopaedia, and has been made possible by greater accessibility to freeware and increased bandwidth in many areas of the world. This has transformed how maps are being produced, mapping used to be confined to highly qualified and equipped surveyors or cartographers, but with the increase in high-tech equipment and accessibility to GPS satellites, anyone can produce maps with limited experience or prior knowledge. OSM is essentially producing a bottom-up map made by local people.

OpenStreetMap aims to use mainly local knowledge. Contributors can use any appropriate means at their disposal to provide information, such as aerial imagery, GPS devices, or low-tech data collected in traditional ways. The people who contribute to OSM are diverse, including GIS professionals, engineers, mapping enthusiasts, humanitarian workers mapping disaster-affected areas and others, but all have a common interest in producing an up to date map for their region.

OSM is open data, so it is free to be used for any purpose, so long as OSM and the contributors are credited. There are copyright protections and licences may be needed for certain uses.

OSM uses four main sources of data to produce its maps; Nodes, Ways, Relations and Tags.

- Nodes are points on the ground that have a geographic position. They are represented as longitude and latitude. They are used to represent map features with a single point.
- Ways are ordered lists of nodes, representing a shape if they form a closed loop. They are used to represent linear features such as streets and rivers, or areas such as forests, lakes, etc.
- Relations are lists of nodes and /or ways in order. Each member can optionally have a "role" (a string); relations are used for representing the relationship of existing nodes and ways.

Relations are used to represent things like turning restrictions on roads, routes that span several existing ways or areas with holes.

- Tags are key-value pairs, both of which are arbitrary strings. They are used to store metadata on the map objects, such as type, name and physical properties. Tags are always attached to an object, for example to a node, a way or a relation.

The coverage of OSM for the areas of interest covered under the satellite condition surveys was checked and found to be quite sparse. Other mapping resources such as Google Maps had more comprehensive coverage. The accuracy of Google maps was also checked within the Aols and some minor errors were found.

It is recognised that OSM is a work in progress and is likely to receive more data for urban areas, before rural areas are completed. Projects such as this would be able to provide accurate and comprehensive mapping information to OSM that would enhance their existing dataset. Very High resolution satellite imagery can produce highly accurate mapping through digitisation. As mentioned in the desk study it may be possible to provide some semi-automated mapping tracks produced from this imagery, but this project is still relying on manual assessments.

A full assessment of the potential linkages between OSM and this project will be commented on in the final report.

## **4. Condition assessment by Satellite Imagery**

### **4.1 Imagery:**

The imagery was procured as close to the time of the ground truthing as possible, in order to rule out any discrepancies due to changes in road condition that may have happened as a result of traffic, environment or indeed maintenance. Generally the imagery was tasked with criteria of < 10% cloud cover and < 12° angle of incidence.

A range of different suppliers were checked, in line with comments from the peer review, but ultimately imagery from DigitalGlobe and Pleiades were acquired, as well as some SPOT imagery and SAR. Others were available, but these were the most cost effective.

It was planned to acquire the imagery during the dry seasons in each country, in order to maximise the chances of getting cloud-free images. This was largely achieved, although due to delays in implementation some issues with cloud cover were experienced.

Comments on the comparative quality of the imagery are included later in the report.

### **4.2 Overall Progress:**

This section summarises the overall progress of the partner countries towards the ultimate goal of completing the condition assessment of a network of rural roads using satellite imagery.

#### **4.2.1 Uganda:**

- Imagery was obtained in good time, within two weeks of the date of ground truthing. Pleiades VHR imagery was tasked and procured.
- Ground truthing was collected in September 2016, by a team from the UNRA planning department. It was analysed according to planning department guidelines during the visit of

the Team Leader to Uganda in February 2017, but to date it has not yet been digitised in QGIS. This is in process and will be completed within March 2017.

- The satellite assessment was completed and digitised following the Airbus training in November 2016. A small amount of the imagery was subject to cloud cover, so the digitisation team are in the process of completing the mapping network, using the GPS tracks obtained during ground truthing to complete sections of road obscured by cloud.
- Drainage has been identified and digitised. This still needs to be checked against the DashCam videos to gauge how accurate it is.
- Comparisons of the Satellite assessment against the ground truthing will take place when the digitisation has been completed. It is hoped that this will be completed within March 2017.
- Airbus produced two downsampled images of the AoI in order to test the viability of using lower resolution imagery for road condition assessment. The image was downsampled to approximately 1.0m and 1.5m. This will be assessed by the team during March 2017 and reported in the final trials report.

**Main issues:**

Some issues were encountered with the existing mapping of the area, which was found to be out of date in some places. The UNRA roads were accurate, but some of the minor roads were not represented accurately. The ground truthing location information was sketchy on some forms. The descriptions of start and end points, and geographical locationing was not always sufficient to accurately locate the road on the map. In general the roads that UNRA is responsible for are either paved or gravel, they do not generally have earth roads. In terms of condition assessment and maintenance there is a difference between the two, but the condition assessment forms do not make that distinction. An example of the forms and analysis can be seen in Annex 6.

There were also some issues with the collection of roughness and video information. Some IRI measurements taken using RoadLab were found to be missing when they were downloaded from the mobile phones. This was most likely an error on saving the information, other users have encountered similar issues. Also, some of the videos from the DashCams were missing. It transpires that the files were not downloaded at the end of each day, as instructed. This results in the videos being overwritten and the RoadLab data for some roads was subsequently lost. Team Leader and Mr. Rubarenzya were able to make a site visit to compensate for some of the lost data, and although the condition may have changed slightly, the GPS tracks were useful in locating the roads accurately.

Approximately 150km of road was completed during the ground truthing and all of this has been assessed using the satellite imagery. A summary of the roads covered can be seen in Annex 7.

**4.2.2 Zambia:**

- Imagery was obtained in good time, within two weeks of the date of ground truthing. DigitalGlobe VHR imagery was tasked and procured.
- Ground truthing was collected in September using the GEM project system of condition assessment. RDU received training and supervision in the collection process. The data was collected on hard copy forms; videos and RoadLab assessments were also collected. To date the data has not been analysed and is not due to be analysed until April 2017, using TMH22. RDU will need training in how to analyse this data. As the satellites project has a deadline to produce a trials report by the end of March 2017, an ad-hoc system was devised by the

Team Leader and the RDU staff to analyse the data, in order to progress the project and digitise the ground truthing. When checked against the videos and the World Bank scale of assessing condition from speed, the analysis proved to be broadly accurate.

- Drainage has not yet been identified and digitised. This is expected to be available for the final Trials Report.
- When the ground truthing was audited, there were a few small errors in the colour allocation of some sections. This was corrected quickly.
- The satellite condition was assessed and digitised from the DigitalGlobe VHR imagery. This was carried out by a different team to the ground truthing in order to ensure impartiality.
- An audit was also conducted on the satellite assessment. This was found to be broadly accurate within the parameters of the guideline that was produced. Two roads were found to have areas that could have been misinterpreted, so the team will look at these again, however the initial results will be used for the correlation exercise.
- Comparison of the ground truthing and satellite assessment is under way. The two digitised tracks can be seen in Annex 8.

***Main issues:***

The main issue so far has been the lack of analysis of the condition surveys. Although an analysis has been done, it is not in line with TMH 22 and may not be appropriate to the way the data was collected. The Team Leader has forwarded the locally devised analysis to the GEM project expert for assessment. The full analysis is expected in April 2017, so the roads can be re-assessed at that time using the TMH 22 analysis.

The mapping for this area of Chongwe was poor, it was produced on an excel spreadsheet and is not GIS enabled. NRSC did an exercise to digitise the area, identifying roads, tracks, footpaths etc. and produced a geo-referenced map in GIS. When checked against the DigitalGlobe imagery this mapping was found to be offset to the real network. Although the same projection was used, this does appear to be an issue with projection, which will be investigated further. It is recommended that RDU and NRSC work together to use this resource to produce a comprehensive map of the area, which should be relatively easy to do now that the surveys have taken place and there are GPS tracks available for all of the roads from both the DashCam and the RoadLab surveys.

There was also an issue with the road condition data collection. Some of the forms were poorly detailed in terms of road descriptions, and some roads were incorrectly labelled. For example, some had no information for start and end points, which made it hard to locate roads accurately. An example can be seen in Annex 9. Following a revision exercise with the condition assessment team the roads within the satellite AoI have now been resolved, as four had been incorrectly labelled.

Similarly to Uganda, earth and gravel roads are not distinguished in analysis of condition for ground truthing according to the prevailing TMH 22. In this instance the weighting used was changed for earth roads, so that factors such as gravel loss and corrugations were not used as they are not relevant for earth road condition. This can be seen in Annex 10.

Videos and RoadLab IRI were taken for all roads and the data is available. RDU staff are at present busy with the T2 conference organisation, but were able to find time to carry out the assessments.

In comparison to the Uganda imagery, the quality of imagery for Zambia appeared to have less detail and clarity. The images were from different sources, but it is not clear whether the difference is due to atmospheric conditions, image processing or other factors. This will be investigated further as the quality of the image could have an impact on the overall outcome of the project.

Approximately 50km of road was assessed. It was hoped that about 150km could have been captured, but the surveys were limited by the resources of RDU to undertake surveys for the GEM project.

#### *4.2.3 Ghana:*

- To date the visual imagery has been partially procured for the AoI in Ghana, due to cloud cover issues. This was expected as this area of Ghana is tropical, despite it being the dry season. The Pleiades HVR imagery has been procured for almost half of the AoI, approximately one month following the ground truthing, as shown in Annex 11. This is within the acceptable timing as it is the dry season so weather will not have changed the road condition, and no maintenance has been carried out in the intervening month.
- SAR imagery was procured almost immediately after the ground truthing, as it is not dependent on having no cloud cover. In order to provide a comparison for the SAR area, some archive Pleiades imagery has been procured which is approximately one year old. Although not ideal, this is acceptable, as very little maintenance has been carried out on those particular roads and the visual imagery is being used as a comparison, not as the primary assessment. A screenshot of the SAR imagery can be seen in Annex 12.
- SPOT 6 imagery has also been procured for the whole of the AoI. This has a resolution of approximately 1.5m and will be assessed in order to test the feasibility of using lower resolution (and therefore cheaper) imagery to assess road condition.
- The ground truthing has been completed and analysed. The Team Leader is visiting Ghana in the first week of March 2017 to carry out training, so the information will be checked then and the results will be made available for the final trials report.
- There is now enough imagery to initiate training. The date for training has been set for the 8<sup>th</sup> to 10<sup>th</sup> March 2017.
- Assessment of the satellite imagery and digitisation can only happen after the training, so it is expected to take place within March 2017.

#### **Main Issues:**

Existing mapping is quite good, but needs updating. The original maps were produced by a DFID project in 2008, but updating has not happened since.

The satellite imagery tasking is taking a long time, due to cloud over. The selected provider is Pleiades imagery. The dry season in Ghana is from December to March, with the best months for image capture being January and February. The image acquisition request has been active since early January 2017, but the team is still hopeful that the full area can be acquired before the wet season sets in again. The training can be carried out with the imagery that is available, then the assessment team can wait until the full area has been acquired to carry out assessment on the entire AoI.

The total length of roads will be determined during the training visit, but it is likely to be in the region of 150km.

#### *4.2.4 Kenya:*

- The imagery has been procured for the training area at Kajiado, south of Nairobi, as shown in Annex 13. A separate training area of 100km<sup>2</sup> was chosen because the main AoI is about 1

day's drive to the north of Nairobi and therefore would be impractical for a site visit. It also approximates the main area as it is quite arid with little vegetation.

- For the main Aol, two parts of the Aol have been procured, using Pleiades imagery. Other imagery was considered such as DEIMOS, but because Airbus is not an approved supplier for DEIMOS the Pleiades imagery proved to be more cost effective. The two parts acquired, as shown in Annex 14 are the areas with most roads and have roads with a good variety of condition. It was hoped that the imagery could be procured during the main dry season, but due to delays in ground truthing surveys this was not possible. As Kenya is coming into the winter dry season and the Aol is essentially a desert, it is hoped that full procurement will take place very soon.
- The ground truthing process is being undertaken by MTRD. The training area has been assessed and videos and IRI have been taken, as can be seen in Annex 15. The data needs to be analysed by MTRD so that each road section can be allocated a condition, as per the prevailing system in Kenya. MTRD staff are waiting on funding and allowances for the ground truthing survey of the main Aol. Until this is complete, the training cannot be arranged.
- During the last visit of the Team Leader the training was tentatively planned for the week commencing 6<sup>th</sup> March 2017, but was dependent on the ground truthing being completed by then. This date is now unlikely and the training will have to be scheduled for later in March.
- Assessment and digitisation of the satellite imagery and ground truthing can only happen after the training has been completed. The training will be undertaken by RCMRD, as the regional experts on remote sensing in East and Southern Africa. RCMRD experts attended the Uganda training, in order to be able to develop and run the course for MTRD in Nairobi.

#### **Main Issues:**

The imagery procurement for the main Aol was delayed due to delays to the ground truthing. As the image acquisition was only started in January, it has taken longer than expected due to cloud cover, especially taking into account that the Aol is in a desert area. Some imagery has been acquired, but the remaining imagery is expected to be procured very soon.

MTRD has had problems in securing funding for training, initial scoping visits and the ground truthing. ReCAP has agreed to fund the training for the provisional sums budget, and TRL paid for MTRD staff accommodation and allowances to carry out a scoping visit to the main Aol. Despite applying for the funding for the ground truthing survey in October 2016, allocation of the funds through the government system has been held up and to date funds are still not available. This has caused delays to the overall programme.

### **4.3 Mapping**

The status of existing mapping in the partner countries varied greatly. For example, in Ghana and Uganda the roads agencies had access to well established GIS maps. In both cases there was some updating necessary, but the core network was accurate. When the project started to look at the rural and less accessible roads it became clear that updating was necessary, but overall the maps would be sufficiently accurate for the task in hand if they were updated.

In Kenya there were some basic GIS maps available, but the MTRD had limited access to them and did not hold a master copy at their own offices. Many of the smaller rural roads were not shown and the ownership/responsibility for some of the roads that were included in the project was unclear. In this case the GPS information collected during the ground truthing exercise was used to create more accurate maps.

In Zambia there were no GIS maps available that showed the rural road network. The RDA have a map produced in excel, but it was only representative and did not show the true alignment of the roads. Given this situation the NRSC were able to produce a GIS map of the project area using archive satellite imagery and freely available resources such as Google earth. When the NRSC digitised map was shown in QGIS over the satellite image, there was found to be an offset from the road shown on the image. The offset was consistent, so it was thought that the projection used was different. However, when checked this proved not to be the case, so NRSC are investigating the cause of the offset further.

#### **Issues:**

A number of issues were encountered with the existing mapping, and the production of maps as part of the project. They are summarised below:

- Presence of maps: Some countries had out of date or incomplete maps.
- Accuracy of maps: Some maps were not geo-referenced and some were inaccurate.
- Date of maps: No maps were current, some had not been updated for six or seven years.
- Extent of maps: Some maps only showed the main network accurately, and had sparse coverage of the local network.
- Labelling of maps: Most maps had insufficient labelling to accurately locate the start and end points of roads.
- Inclusion of all roads on maps: On most maps there were roads missing, mainly due to additional construction since the map was produced, or due to a lack of knowledge of the network itself.

As part of the project the digitisation process on the VHR imagery will produce mapping that should be very accurate. If any future automation of the process is researched, this level of accuracy will be required.

## **4.4 Ground Truthing Data**

In line with the principles of this research, it was decided that each country would carry out ground truthing in line with the existing system that is used to collect condition information in that country. This would test the methodology in the real conditions in which it would have to operate, and would allow the results to be put in context, especially in terms of condition surveys in previous years. The exception to this was Zambia, which is involved in the ReCAP GEM project and is introducing a new condition assessment regime.

### **4.4.1 Visual Surveys:**

Each country has a different system, which is explained below:

- **Ghana:** In Ghana there is a simple 3-level system, Good – Fair – Poor, as shown in Annex 16. This is assessed primarily on the speed that a vehicle can drive, along with other factors such as camber, drainage and traffic. Ghana recently retrained all of their road condition

assessors, as condition surveys had not been carried out for 3 to 4 years, due to lack of resources. This was completed just before the ground truthing was carried out, so the condition survey was completed by newly trained staff.

- **Kenya:** In Kenya a five level system is used, Very Good – Good – Fair – Poor – Very Poor. This is assessed using visual surveys and standard forms. This is sometimes supplemented by roughness measurements, but mainly on the strategic network. Kenya have been using the Roughometer, a Japanese roughness measurement device and previously a bump integrator, to measure roughness, but this is not normally practised on unpaved roads. MTRD is also in the process of carrying out some research into the relative accuracy of a number of roughness measuring devices, including mobile phone apps.
- **Uganda:** In Uganda they use a standard form for visual condition assessments, as can be seen in Annex 17. This form takes into account a wide range of factors that influence condition, such as potholes, gravel thickness, corrugations, erosion and drainage. There are also detailed guidelines on how to use the forms and assess each particular condition. For the condition analysis they have attached weighting factors to these results, which put more weight on gravel thickness and roughness than other factors. This will be commented on in more detail later. The ground truthing has been summarised, as can be seen in Table 1.

**Table 1**

| Condition | GT condition km | Satellite km |
|-----------|-----------------|--------------|
| V.Good    | 0.0             |              |
| Good      | 19.0            |              |
| Fair      | 27.3            |              |
| Poor      | 84.4            |              |
| V.Poor    | 17.5            |              |
|           | <b>148.2</b>    |              |

- **Zambia:** As mentioned above, Zambia is using the GEM project condition assessment system, as shown in Annex 18. This system is based on the TMH22 document from South Africa and uses an involved system to record defects and translate them into a condition for each section of road. The system assigns a condition to every 5km of road, which is quite a coarse assessment compared to the systems employed in the other countries. The satellite assessment methodology allows for changes in condition as and when the visible condition changes, which could result in sections as short as a few hundred metres. Clearly this would pick up short sections of different condition, whereas any short areas of different condition are likely to be lost in the overall assessment of condition for sections of 5km. If time permits we will also assess the satellite images on a 5km basis so that the accuracy can be compared fairly.

#### 4.4.2 Roughness:

As mentioned above, all countries used a mobile phone app to record IRI measurements. There are several apps on the market now that measure roughness, but it was decided to use the World Bank RoadLab app, as this is free at source and is also being used by the GEM project. This makes it more sustainable and allows results to be compared between projects.

The app requires that the mobile phone is held steady within the vehicle using some sort of mounting device. In many cases it was noticed that the partners did not have an appropriate holder

for the phone, which caused warnings that the roughness collected may not be accurate. This can affect the overall accuracy of the data collected.

During the surveys the accuracy of the app itself was also called into question. The app only shows one range of conditions linked to IRI, which it is assumed is for paved roads. There does not seem to be an alternative for unpaved roads. Previous work done by the World Bank has clearly defined different IRI values for paved and unpaved roads (<http://siteresources.worldbank.org/INTRURALM/Resources/514903-1159879214291/td-rt2.pdf>).

The range given by RoadLab is:

- Excellent IRI <2
- Good IRI 2 – 4
- Fair IRI 4 – 6
- Poor IRI >6

This is not an appropriate range of IRI values for an unpaved road. It can be seen from Table 1 below that the IRI ranges for unpaved roads are much higher. The RoadLab range actually compares most closely to that used by HDM4 for paved roads.

In addition RoadLab only has four levels of condition: Excellent – Good – Fair – Poor. Most countries use either three levels or five levels, as shown in Table 2. Previous World Bank studies have also used five levels for visual assessment of roughness.

**Table 2**

| Condition description | World Bank visual IRI for unpaved roads | World Bank visual IRI for paved roads | HDM4 IRI for paved roads | RoadLab IRI |
|-----------------------|---|---------------------------------------|--------------------------|-------------|
| Very Good/Excellent   | <5.0                                    | < 3.0                                 | < 2.5                    | <2.0        |
| Good                  | 6.0 – 11.0                              | 4.0 – 6.0                             | 2.5 – 3.5                | 2.0 – 4.0   |
| Fair                  | 11.0 – 15.0                             | 7.0 – 8.0                             | 3.5 – 6.0                | 4.0 – 6.0   |
| Poor                  | 15.0 – 19.0                             | 9.0 – 10.0                            | 6.0 – 10.0               | > 6.0       |
| Very Poor             | 19.0 – 24.0                             | >11.0                                 | > 10.0                   | N/A         |

From Table 2 above it can be seen that the RoadLab IRI does not agree with any of the established IRI scales, although it is closest to that from HDM4. It clearly approximates to paved roads, and it can be seen that the scale for unpaved roads is very different. The results obtained from RoadLab surveys on roads in the four countries only returned a maximum IRI value of 11.6, for a section in very poor condition according to the ground truthing. On the World Bank visual scale this would only have shown a condition of 'Fair', despite the road surface having very deep and extensive potholes and the vehicle only being able to travel at about 10 kph. Many IRI measurements require a minimum speed to be maintained (approximately 20 kph) before they can be effective.

From this evidence it can be concluded that the RoadLab app is not appropriate for unpaved roads that are in fair, poor or very poor condition. For Good and Excellent condition roads it provides an approximation, but should not be relied upon as an absolute measurement of roughness.

#### 4.4.3 Cameras:

For all surveys, Dashboard cameras were used. The model used was the Nextbase 402G, with GPS. These cameras are designed for use as security cameras in vehicles, but have been found to be very appropriate to record the visual condition of the road. They are Full HD to 1080P, have 140° wide angle lenses and internal GPS devices that can record the location and track of the camera as the vehicle moves along. The GPS is accurate to between 3 and 10m, which is good enough to locate the road but not accurate enough to determine the centre-line for mapping purposes.

The camera is mounted inside the vehicle, using a suction cup on the windscreen. This protects it from the elements and makes it easy to operate from inside the vehicle. The driver must be reminded to keep the windscreen clean during surveys, otherwise the quality of the video can be compromised. When the videos from the camera are played on the provided software, they display the speed of the vehicle, the GPS location, a Google earth map where the location is shown and animated as it moves along the road, as well as the X,Y,Z movement of the GPS, which could potentially be used as an approximation for roughness.

With a 32GB SD card the camera can record up to 4 hours of HD video, after which the camera starts to overwrite the initial data on a loop. The data can be protected, but essentially the assessor must download the data every four hours so as not to lose any of the data already collected. Two SD cards were provided with each camera, which is ample storage for a full day of surveys. Guidelines were produced for use of the cameras as condition assessment tools, which stressed that data must be downloaded at the end of each day and the SD cards wiped clean. It also recommended formatting the cards every few days in order to ensure reliable data collection. A guideline for use of the DashCams has been written by the Team Leader and can be seen in Annex 19.

The videos from these cameras are of sufficient quality to be able to make an approximate visual assessment of road condition. With the wide angle lens they are also able to capture side drains, some details of culverts and headwalls, structures and other road furniture. The speed shown on the videos is also very useful to help determine road condition, using the World Bank guidelines as mentioned in the Desk Study report, as duplicated in Table 3 below. This scale is relatively accurate when compared to the condition assessment systems already used for the ground truthing.

**Table 3**

| Condition rating (WB rating) | Typical Speeds achieved in km/h on an unpaved road |
|------------------------------|--|
| Very Good (Excellent)        | 80-100   |
| Good (Good)                  | 70-80  |
| Fair (Fair)                  | 40-70  |
| Poor (Poor)                  | 30-40  |
| Very Poor (None)             | <30  |

Figure 1 below shows a screen shot of the DashCam recorder software, which clearly shows the video of the road and associated information, such as speed, location, orientation and the map. It can be seen from the speed and the X/Y/Z movements at the bottom of the screen that the vehicle is currently in an area that is in reasonable condition, as the speed is 53kph and the blue 'Z' line from the GPS is fairly flat. However, the 'Z' line can be seen to increase to the right of the present position (shown by the white vertical line), indicating that the road will deteriorate in the near future.

Figure 1



#### 4.5 Condition assessment

The project has so far been able to carry out condition assessments in two partner countries. Although the trials are not all complete, there have been some encouraging results. So far three countries have completed the ground truthing aspects of the project and two have been trained in satellite interpretation and road condition assessment. It is hoped that the remaining training and assessments can take place during March 2017.

Zambia has carried out its satellite assessment and compared it to the ground truthing. The overall assessment, assuming that the ground truthing is the baseline, showed that 59% of the satellite assessment correlated with the ground truthing. However, as discussed later the ground truthing was carried out on the basis of one condition for each 5km section of road, whereas the satellite assessment changed whenever a change in the surface condition was visible. More analysis needs to be done to check where the differences were and to what extent the results could be improved by using a similar system for ground truthing and satellite assessment.

The remaining results will be collected and analysed in the final trials report.

#### 4.6 Methodology

The methodology followed was to carry out manual assessments of the road condition in all four countries. This is a similar methodology to that used in the Nigeria research, but with some important differences:

- In Nigeria the rules and criteria for the research were developed by the NIAF project and were set to satisfy project objectives. All of the ground truthing and satellite assessment was carried out under project conditions using project staff, so the potential issues and barriers to implementing the system sustainably and integrating it with the existing condition assessment system in a country were not encountered.
- In Nigeria the ground truthing was carried out using an Image Collector, which was at the time being used by the NIAF project. The image collector had been tasked with collecting road conditions in three States with the objective to identify the backlog of rural road rehabilitation for Nigeria, so the condition parameters and assessment methodology were

somewhat skewed to provide information that would assist in determining rehabilitation needs, rather than pure road condition.

- The data from the image collector was used to determine condition for the ground truthing. The videos that were taken were viewed by local engineers in the NIAF offices to create a record of road conditions. Each image collector had a team, including an engineer and usually a local technician who was able to direct the vehicle to the correct roads. The video interpretation was carried out by a different engineer who had no prior knowledge of the roads.
- The satellite image interpretation for the Nigeria project was carried out by Airbus engineers in their office at Leicester in UK. There was no contact with the engineers who did the ground truthing in Nigeria. The current project has also maintained this gap between the staff who carried out ground truthing and staff who interpret the satellite imagery. It is important that the assessments are independent so that no prejudice is present in determining the condition by satellite.

#### *4.6.1 Local partnerships*

As this project essentially involves two different sectors, those of roads and remote sensing, the local road organisations were partnered with an appropriate local remote sensing organisation. These organisations were identified in the country selection report and are essentially a local remote sensing organisation, usually part of government, who can assist the road department with the remote sensing and GIS aspects of the project. This also makes it more sustainable into the future, as GIS expertise is often limited in roads departments.

The local remote sensing organisation also provided supplementary training where necessary, in advance of the formal project training. This was to ensure that everyone was of a similar level of GIS knowledge, which meant that the formal training could be more efficiently delivered.

#### *4.6.2 Training*

Training was an essential part of the project. So far the training has been completed in Zambia and Uganda and was carried out by Ned Chisholm of Airbus and Robin Workman of TRL. Photographs from the trainings in Uganda and Zambia can be seen in Annex 20. Training manuals and powerpoint presentations have been produced and handed over to the countries for future use. Each training course lasted for 3 days, including a half-day field trip.

RCMRD attended the Uganda training, in order to prepare for the Kenya training, which they will be conducting. They were engaged as a local supplier to test if the training could be carried out sustainably from a supplier within the region.

Training assessment questionnaires were completed by all of the participants and a training assessment report will be attached to the final trials report.

#### *4.6.3 Alternative research options:*

The following technologies are being tested as part of the trials and will form part of the final methodology if found to be feasible for road condition assessment.

##### ***Downsampling:***

One of the objectives of using VHR satellite imagery was to see if it is possible to use lower resolution imagery, which would be cheaper to procure and would also be more readily available as archive imagery, which is even cheaper again. In Uganda a trial is planned to use 1.0m and 1.5m imagery of the same area to test what accuracy it is possible to get when using lower resolution

imagery. In order to do this Airbus has downsampled the 0.5m resolution Pleiades imagery to approximately 1.0m and 1.5m resolution. It is important to use the same imagery as the condition will be the same, the only difference will be the clarity of the image. This downsampled imagery will be used to assess condition against the ground truthing.

***Spectral reflectance:***

This is the process of using the brightness of the visual image to identify different materials on the ground. It has been used in the past to identify road construction materials, as well as other uses. The aim of using this process in this project was to see if the age and possibly the condition of a road could be identified using spectral reflectance. This is only applicable to paved roads, as they have a standardised surface where the materials can be reasonably identified or assumed from the imagery. There is also more accurate information available for paved roads than for unpaved roads, so the baseline is more easily established, even if it is a proxy baseline. It is planned to trial this technology in Ghana as the Aol contains a high proportion of paved roads.

***SAR imagery:***

In Ghana a scene of SAR imagery was procured in order to test the feasibility of using this type of imagery for road condition assessment. The SAR imagery is only panchromatic and tends to be very grainy, so it does not readily represent a visual image of the earth. The consequence of this is that roads are not immediately obvious, as they would be on a visual image. It takes some skill and practice to be able to interpret a SAR image. This technology will be trialled when the Ghana training takes place.

***4.6.4 Issues with satellite condition assessment methodology:***

This section primarily looks at the potential issues and barriers to replicating this system sustainably using local resources that have been identified so far. The final report will make recommendations as to how these can be overcome, avoided or managed in the final methodology.

The issues encountered so far are:

- Imagery procurement has varied between countries. The imagery was planned to be tasked as close to the date of the ground truthing as possible, in order to represent the true condition on the ground. The imagery for Uganda and Zambia was tasked very quickly and was within one or two weeks of the ground truthing exercise. The Kenya imagery has taken some time to task, although the ground truthing has been seriously delayed as well. At the present time the training area in Kenya has been procured, as well as two sections of the main area near Marsabit. The ground truthing is expected to complete imminently, so the dates of both will actually be quite close, within a month. Procurement of the imagery for Ghana has been more challenging, as was expected because Ghana is a tropical country with high rainfall for much of the year. The imagery for the SAR area was procured within one week, as this does not rely on cloud cover. The tasking order for the visual imagery was confirmed in early January, but to date no procurement has been made due to unfavourable weather conditions. Although it is the dry season in Ghana and January/February are the best months to procure satellite imagery, the satellite has not been able to find a clear window in which to take the image.
- Forgetting to download the DashCam data every day. As a consequence much of the survey data was overwritten and essentially lost. Despite the written guideline and verbal reminders from the staff at head office, the data was not downloaded on a daily basis.

- Accuracy of the RoadLab app for road roughness measurement. It was found that RoadLab is not very appropriate for measuring the roughness of unpaved roads. The IRI scales that are quoted do not match the industry established scales, the four-level condition criteria do not easily translate to the more often used three or five level criteria and the general accuracy did not seem to match the visual assessments, especially for fair, poor and very poor roads.
- Some partners struggled to find funding to carry out the ground truthing. They did not have enough time to include the project in their annual plans, so it had been difficult to transfer funding from other projects to this one.
- The subjectivity of the assessments was initially highlighted as a potential issue. This is true with any condition assessment process that relies on human intervention to assess the road condition. In many visual surveys there have been attempts to reduce the subjectivity of the assessments by breaking the assessment down into constituent parts and creating forms that require information to be entered for each category of condition, i.e. potholes, gravel loss, corrugations, etc. In a similar way the satellite assessment system relies on the guideline produced during the ground truthing to guide the user in which condition to select for each section of road. It is recognised that a system that relies on subjective assessment is not perfect, but if the guideline is followed carefully it can give good results. It is important that the system is consistent and can be audited.
- The size of the assessed sections in some of the existing condition assessment systems was quite long, for example in Zambia the condition was assessed on the basis of every 5km of road. This means that for example if half of that section is Poor and half is Good, the average would be a Fair section, whereas none of the road was actually in Fair condition. This is also true to some extent with 1km sections, but is less likely to produce larger distortions.
- Accuracy of the satellite assessments has been a slight issue. From the audits carried out it was noticed that some roads were assessed as just one condition, when the condition actually varied along the road. Assessors did not change the condition for very short sections (less than 100m), but did sometimes ignore changes of less than 1km. In the overall assessment this is likely to make little difference, but the audit process is important to check that larger discrepancies do not occur. There are two factors that could have caused this:
  - The assessors tended not to zoom in and out very much, so when scrolling along a road they only had one aspect view. Regular zooming in and out would have given them a better overall perspective on the road condition as some aspects are clearer when zoomed in (surface irregularities) and some when zoomed out (width and consistencies of the road edge)
  - The assessors tended to speed up their assessment towards the end of the assessment, and the latter roads were less accurate than the first. This could be due to overconfidence, time pressure of work, or just being keen to finish, but it is important that the assessors maintain their concentration until the end. This suggests that supervision will be necessary, and perhaps some sort of time targets. Auditing is again needed.
  - The current methodology was therefore designed to test the feasibility and cost effectiveness of the system in a real environment where the resources and skills of the local staff were used with minimal support from the consultant. These issues will be taken into account when revising the methodology, in order to make it more sustainable and consistent for every situation.

The current methodology was therefore designed to test the feasibility and cost effectiveness of the system in a real environment where the resources and skills of the local staff were used with minimal support from the consultant. These issues will be taken into account when revising the methodology, in order to make it more sustainable and consistent for every situation.

## **5 Programme**

The programme has been revised, mainly due to delays in implementation of the satellite trials. Various issues have been encountered, as explained in more details previously in this report, but they can be summarised as:

- Some delays with availability of local staff to carry out the trials. In some countries the trials period coincided with busy times of the year, training courses or other local commitments.
- Delays for local partners to secure resources to provide the necessary counterpart inputs to the project, including funding, transport, allowances, training, etc.
- Delays in acquiring the VHR imagery for Kenya and Ghana. This was due to weather issues, with unexpected persistent cloud cover.
- There was a delay in arranging the contract for the peer review, due to differences between standard contracts. There was also a slight delay in carrying out the review when the contracts had been signed.
- Minor delays in signing licence agreements for the satellite imagery, the licences are unfamiliar and local government legal departments had to check them before they could be committed to.

This has resulted in the project being approximately two months behind schedule. In addition the project has been requested to visit Tanzania to present the project and scope the possibility of involving Tanzania in a potential second phase, maybe as a roll-out country. This will also have an impact on the overall progress of the project as this input will be approximately 3 weeks.


If the remaining training and assessment goes ahead within March as planned, it should be possible to make up some of this time, but it is expected that the project will complete approximately two and a half months late. This is shown in the revised programme in Annex 21, with the revised milestones and expected submission dates highlighted.

## **7. Conclusions and Recommendations**

This is an interim trials report, and although we have some data from the partner countries, it is not possible to make overall conclusions until the full data set has been collected and analysed. Therefore, the conclusions and recommendations will be made in the final trials report, when all of the data has been collected and analysed.


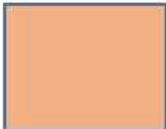


## Annex 1

### Facebook app.

Select Road Defect 

- Pot Hole
- Depressions
- Rutting
- Cracks
- etc

Take/Upload Photos



Add Notes

GPS Coordinates picked if phone is used

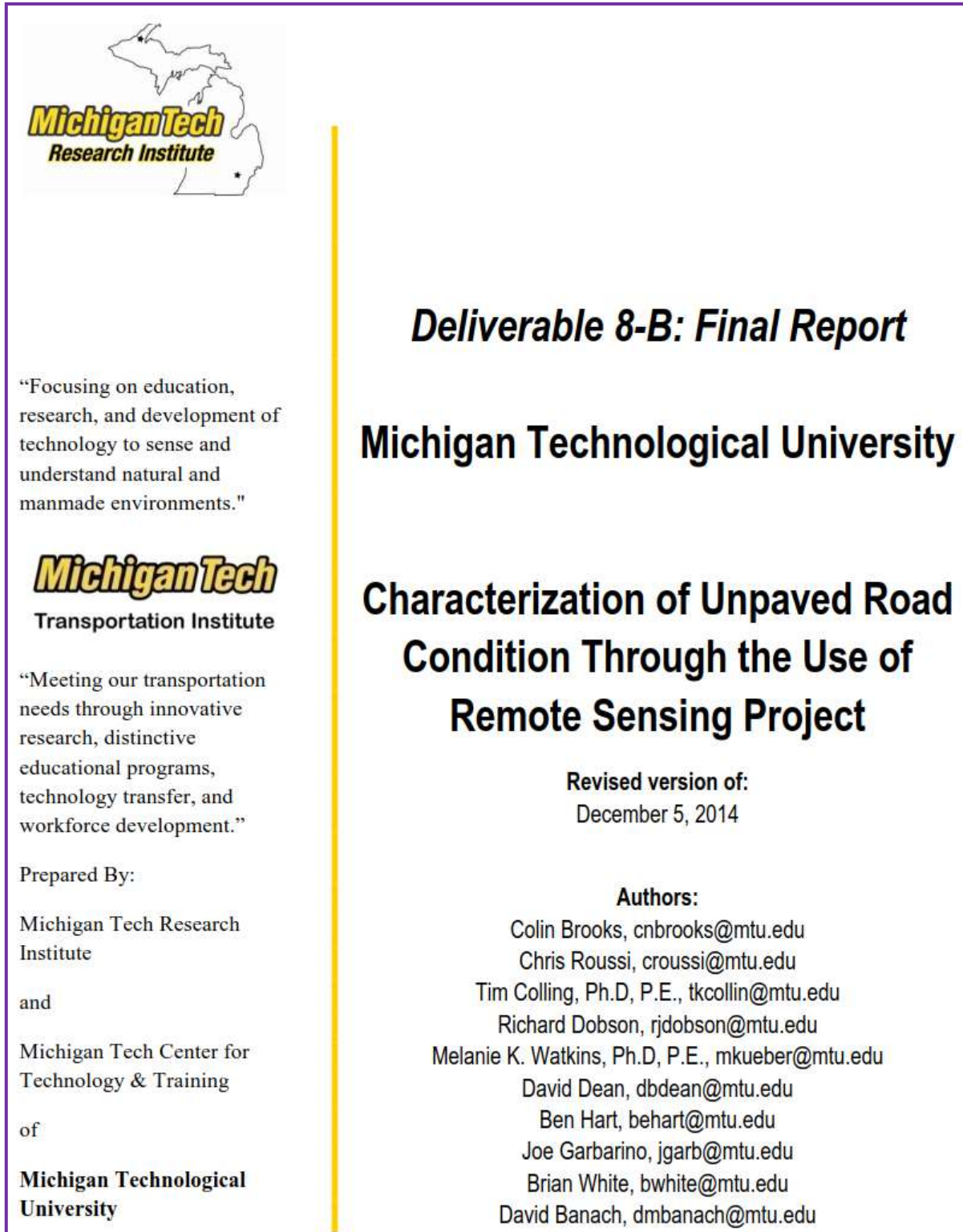
**Submit**

## Annex 2

### UAV Michigan Tech. Report

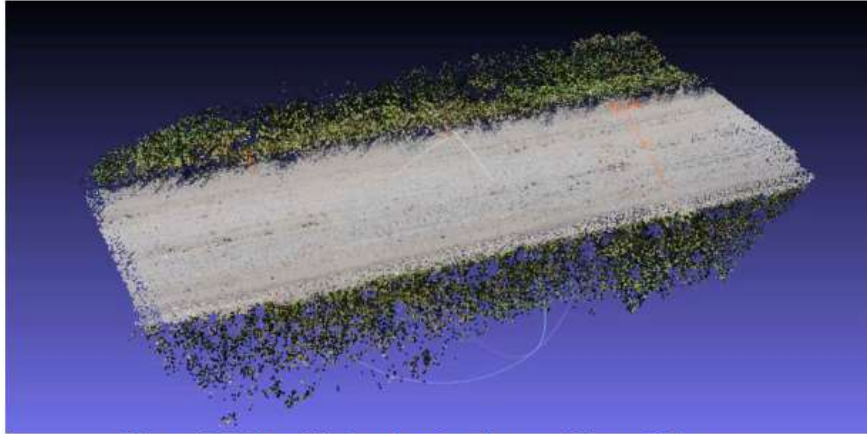
Front cover of the research carried out by Michigan Tech research institute into the characterisation of unpaved road condition using remote sensing, in this case UAVs.

Figure A2.1

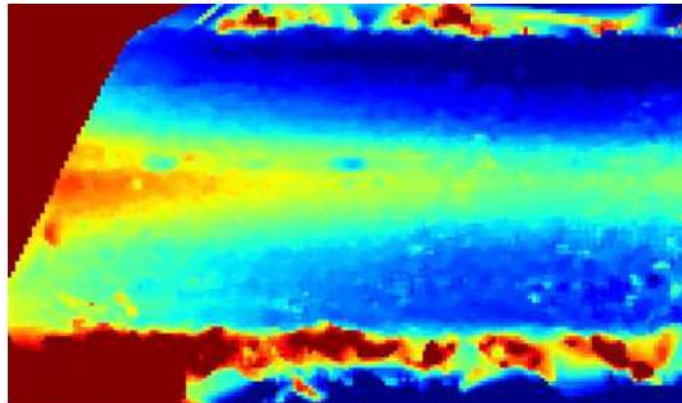


Extracts from the above report, showing the point cloud image created from the drone photographs, and a depth map of the surface using colours to show the elevations.

**Figure A2.2**



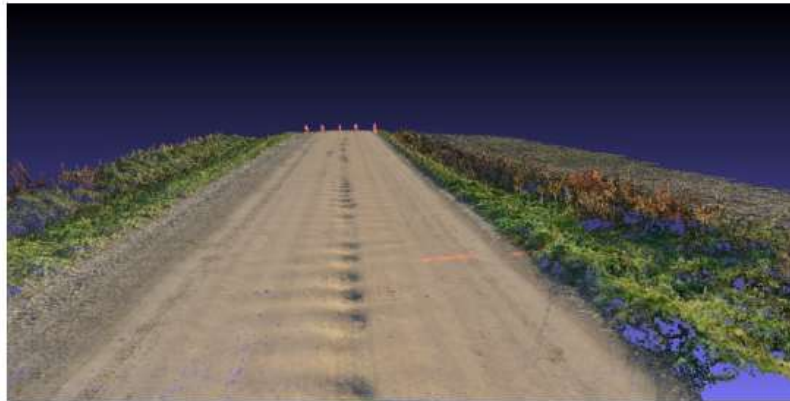
**Figure 3-7: Densified point cloud created from 28 images.**



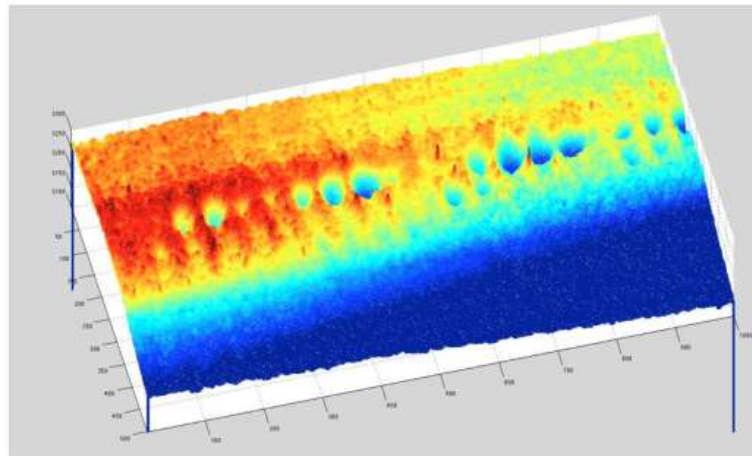
**Figure 3-8: Depth map after median filtering. Blue colors represent lower elevations, red colors represent higher elevations.**

Extracts from the report showing a 3D image of the road created from a point cloud, generated by overlapping visual images from the UAV platform, with a height map of the same area showing potholes and their depths.

**Figure A2.3**



**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.**

### Annex 3

#### DashCams

Figure A3.1 shows the DashCam located in the vehicle, attached to the windscreen with a sucker cup.

Figure A3.1



Figure A3.2 shows the video images as presented in the DashCam software.

Figure A3.2

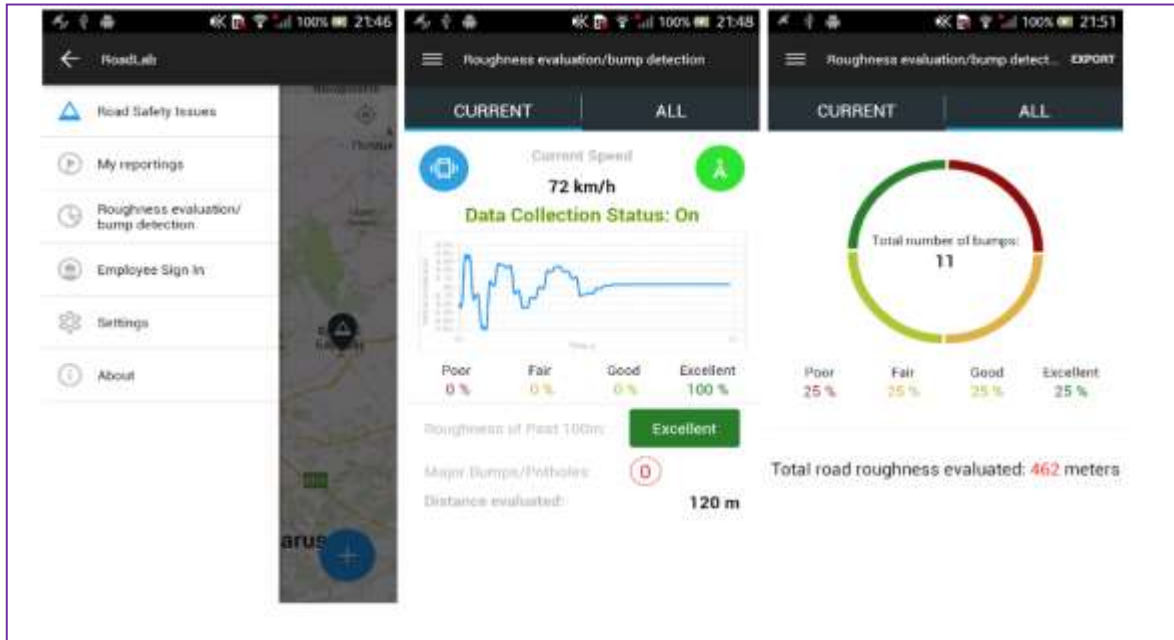


## Annex 4

### RoadLab

Figure A4.1 shows the interface of the RoadLab app.

Figure A4.1

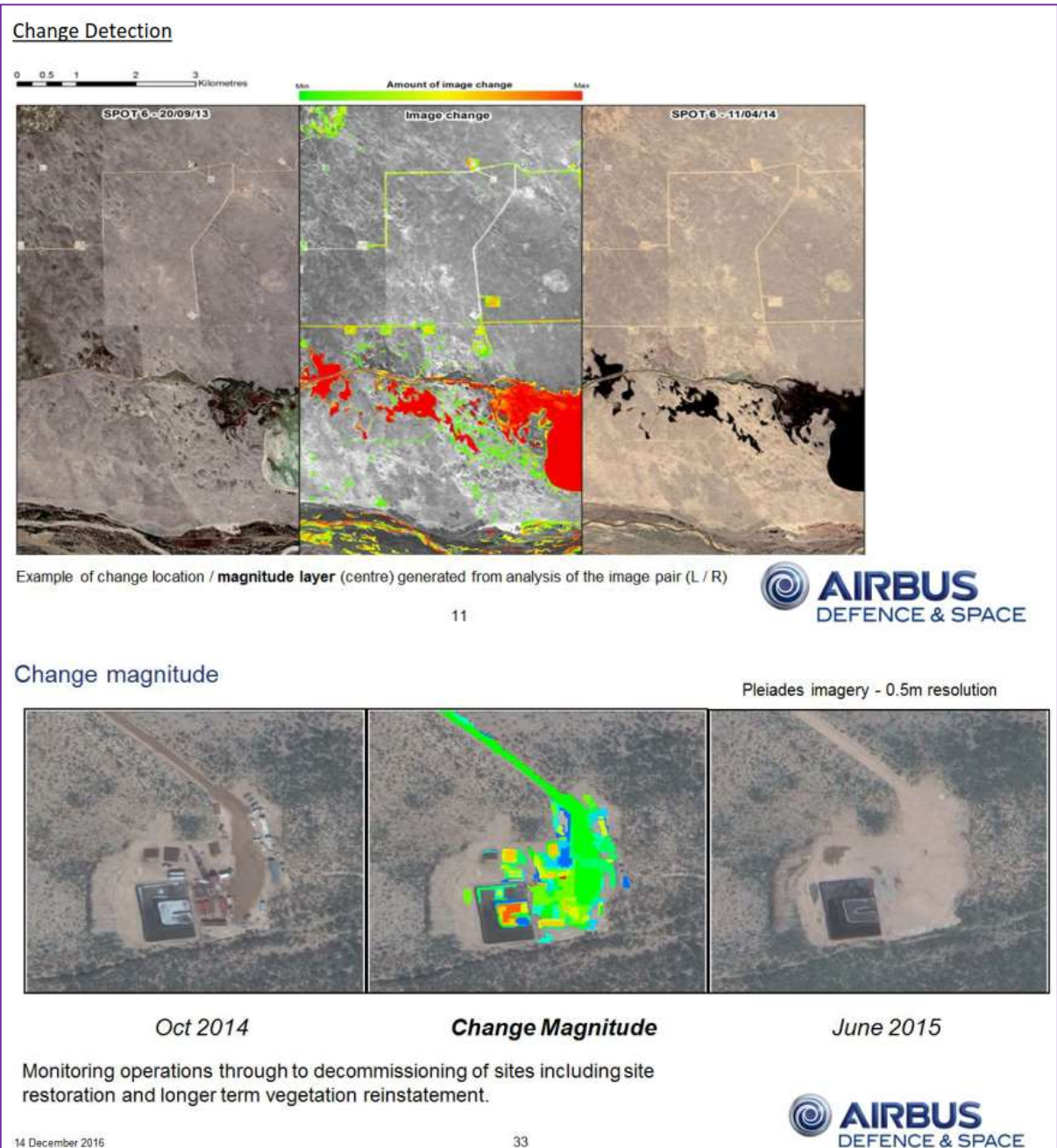


## Annex 5

### SAR comparisons

The images below in Figure A5.1 show the possibility for showing changes between images of different dates, which could be useful for climate change resilience.

Figure A5.1



## Annex 6

### UNRA ground truthing forms/analysis

The form in Figure A6.1 shows the excel forms that were used to capture the condition data and analyse it. The weighting factors shown in blue at the bottom of the sheet were used to apply to the condition scoring and produce an overall condition rating, shown in red. It is assumed that this is a gravel road, as the factors for gravel thickness and corrugations have been applied.

Figure A6.1

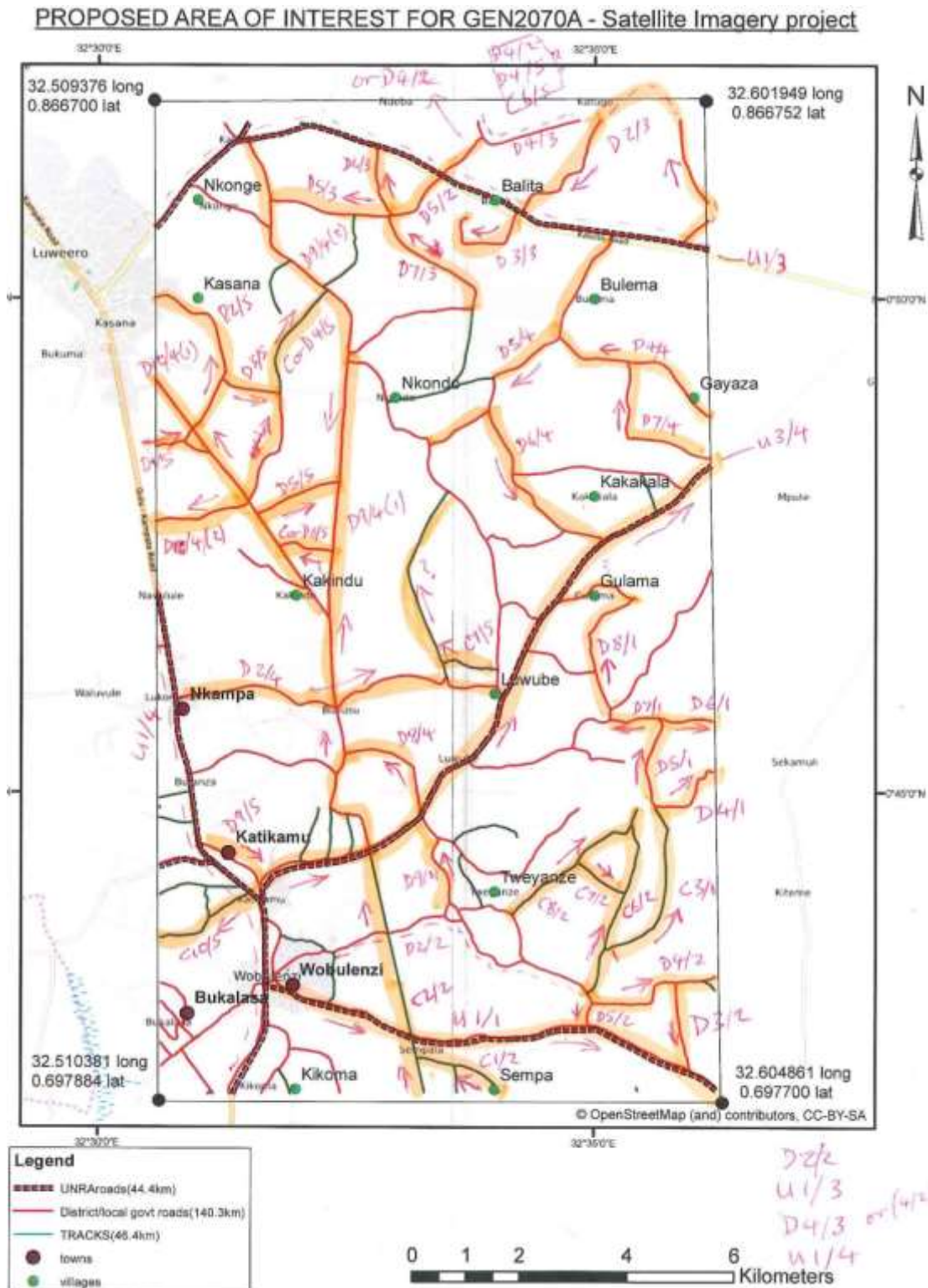
| Uganda National Roads Authority<br>UnPaved Roads Condition Survey data entry Form |            |                 |                |                    |                        |                              |                                |                          |                        |   |                |               |                    |                         |                          |                                |                         |                       |                               |              |   |  |
|---|------------|-----------------|----------------|--------------------|------------------------|------------------------------|--------------------------------|--------------------------|------------------------|---|----------------|---------------|--------------------|-------------------------|--------------------------|--------------------------------|-------------------------|-----------------------|-------------------------------|--------------|---|--|
| Road No U11   |            |                 |                |                    | Wobulenzi -Bamunanika  |                              |                                |                          |                        | Link No: 3                                  |                |               |                    |                         | Date:13-10-2016          |                                |                         |                       |                               |              |   |  |
| Chainage From:0000  |            |                 |                |                    | Chainage To: 8000      |                              |                                |                          |                        | Sheet No:1                                  |                |               |                    |                         |                          |                                |                         |                       |                               |              |   |  |
| Survey Starting Point: 0  |            |                 |                |                    | Survey End Point: 8000 |                              |                                |                          |                        | Inspector: Asaba Francis and Doreen Wafuja. |                |               |                    |                         |                          |                                |                         |                       |                               |              |   |  |
| Chainage  |            | Carriage Way    |                |                    |                        |                              |                                |                          |                        |   |                |               |                    |                         |                          |                                |                         |                       |                               |              |   |  |
| Ch_From (km)  | Ch_To (km) | Road Type (G/E) | Road Width (m) | Shoulder Width (m) | Left Side              |                              |                                |                          | Overall                |   |                |               |                    |                         | Right lane               |                                |                         |                       | UNRA Formula for gravel roads | UNRA rounded | Comments                                      |  |
|   |            |                 |                |                    | CL_Rd Friction [1/3/5] | CL_Friction type [RA/NMT/MT] | Drainage Formation Level [1-5] | Drainage Condition [1-5] | Gravel Thickness [1-5] | Roughness [1-5]                             | Potholes [1-5] | Rutting [1-5] | Corrugations [1-5] | Erosion Gullies [1/3/5] | Drainage Condition [1-5] | Drainage Formation Level [1-5] | CR_Friction [RA/NMT/MT] | CR_RdFriction [1/3/5] |                               |              |   |  |
| 0+000   | 1+000      | G               | 7.500          | 1.000              | 3                      | All                          | 3                              | 3                        | 3                      | 3   | 3              | 4             | 2                  | 3                       | 3                        | 3                              | All                     | 3                     | 3.0                           | 3            | Start at Wobulenzi Town Junction to Buwanika. |  |
| 1+000   | 2+000      | G               | 7.500          | 1.000              | 3                      | NMT                          | 3                              | 3                        | 3                      | 3   | 3              | 4             | 3                  | 3                       | 3                        | 3                              | NMT                     | 3                     | 3.1                           | 3            |   |  |
| 2+000   | 3+000      | G               | 7.500          | 1.000              | 3                      | NMT                          | 3                              | 3                        | 3                      | 3   | 3              | 4             | 3                  | 3                       | 3                        | 3                              | NMT                     | 3                     | 3.1                           | 3            |   |  |
| 3+000   | 4+000      | G               | 7.500          | 1.000              | 3                      | NMT                          | 3                              | 3                        | 3                      | 3   | 3              | 4             | 3                  | 3                       | 3                        | 3                              | NMT                     | 3                     | 3.1                           | 3            |   |  |
| 4+000   | 5+000      | G               | 7.500          | 1.000              | 3                      | NMT                          | 4                              | 4                        | 4                      | 3   | 3              | 4             | 3                  | 3                       | 4                        | 4                              | NMT                     | 3                     | 3.6                           | 4            |   |  |
| 5+000   | 6+000      | G               | 7.500          | 1.000              | 3                      | NMT                          | 4                              | 4                        | 4                      | 3   | 3              | 4             | 3                  | 3                       | 4                        | 4                              | NMT                     | 3                     | 3.6                           | 4            |   |  |
| 6+000   | 7+000      | G               | 7.500          | 1.000              | 3                      | NMT                          | 3                              | 3                        | 3                      | 3   | 2              | 4             | 3                  | 3                       | 2                        | 2                              | NMT                     | 3                     | 2.8                           | 3            |   |  |
| 7+000   | 8+000      | G               | 7.500          | 1.000              | 3                      | NMT                          | 3                              | 3                        | 3                      | 3   | 2              | 4             | 2                  | 3                       | 2                        | 2                              | NMT                     | 3                     | 2.7                           | 3            |   |  |
| UNRA Weighting Factors  |            |                 |                |                    |                        |                              | 0.08                           | 0.07                     | 0.2                    | 0.15  | 0.1            | 0.05          | 0.1                | 0.1                     | 0.07                     | 0.08                           |                         |                       |                               |              |   |  |

### Annex 7

#### UNRA maps

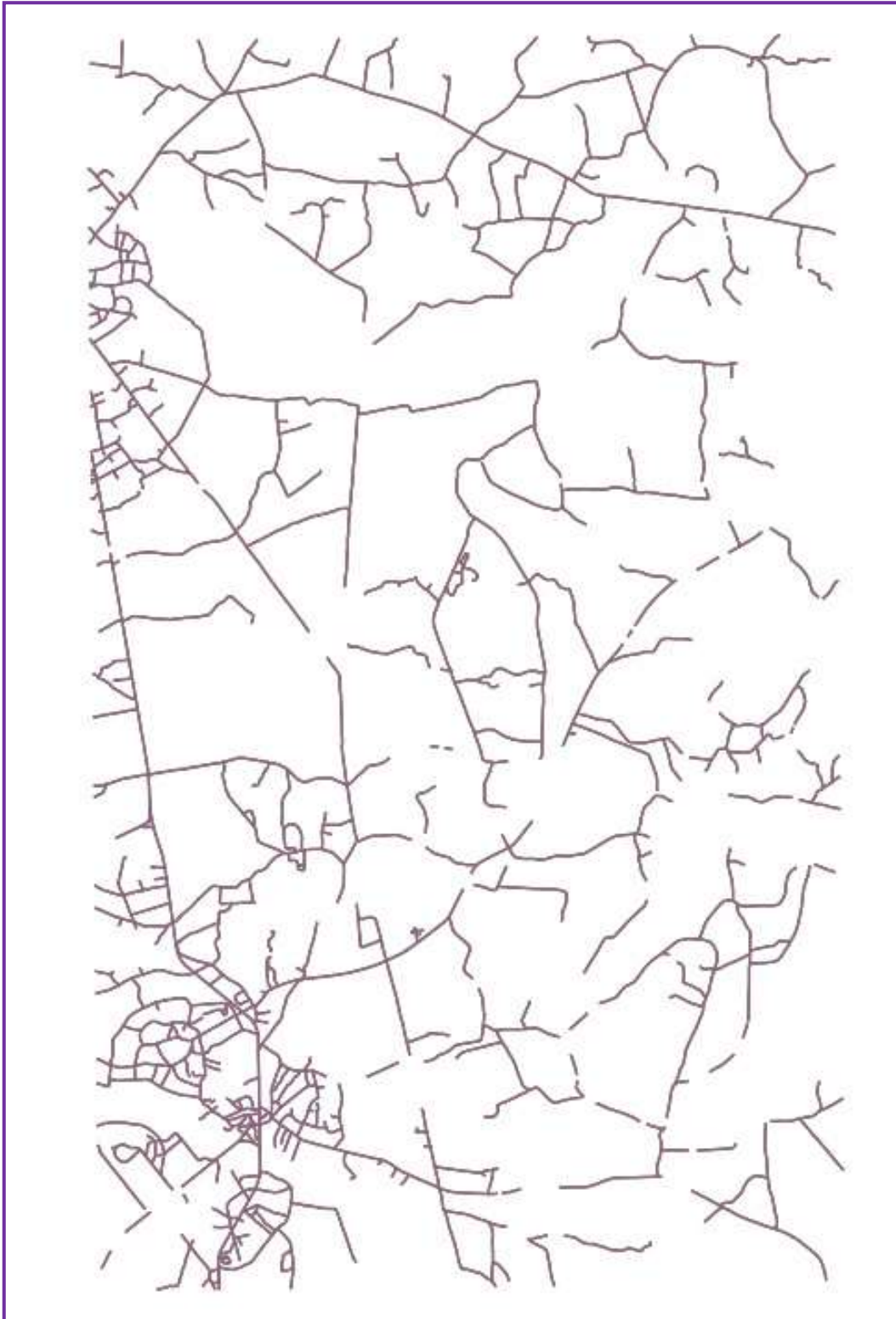
The map in Figure A7.1 shows the rural network in Luweero, using available maps. Note that district/local roads are not well defined. The Highlighted roads are those that were assessed.

Figure A7.1



A7.2 shows the digitised roads in Luweero, digitised from the Pleiades imagery. Note that there are some disconnections where cloud cover obscured some of the roads, but the assessment team are in the process of completing this map using the GPS tracks from the DashCam and the RoadLab data.

**Figure A7.2**



## Annex 8

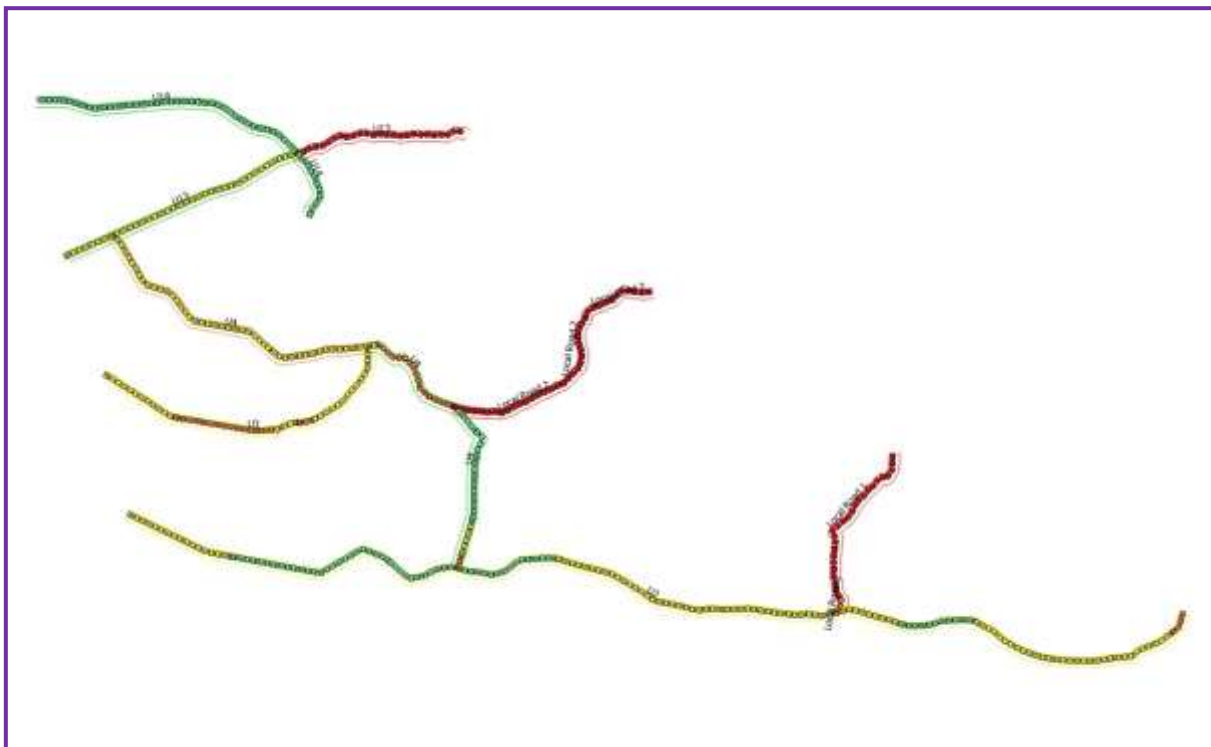
### Zambia RDU digitised tracks

Figure A8.1 shows the basic map of the surveyed roads in Chongwe, Figure A8.2 shows the digitised map with ground truthing and satellite assessment both shown.

Figure A8.1



Figure A8.2



## Annex 9

### Condition assessment forms Zambia

Figures A9.1 and A9.2 show the field forms for road condition assessment in Chongwe, Zambia.

Figure A9.1

**Unpaved Road Condition Survey Form**

Road Agency Name: \_\_\_\_\_ Province: USAKA District: CHONGWE Reported By: \_\_\_\_\_ Date: 29 April 2016

Road No: 44 Road Name: \_\_\_\_\_ Section Name: \_\_\_\_\_ Start Km: 0+000 End Km: 5+500

| Change (Km)<br>From to | DEFECT EXTENT/OCCURRENCE/QUANTITY                        |   |   |   |              |   |   |   |                 |   |   |   |                       |   |   |   |              |   |   |   |          |   |   |   |         |   |   |   |               |   |   |   |   |   |   |  |  |  |  |  |
|------------------------|--|---|---|---|--------------|---|---|---|-----------------|---|---|---|-----------------------|---|---|---|--------------|---|---|---|----------|---|---|---|---------|---|---|---|---------------|---|---|---|---|---|---|--|--|--|--|--|
|                        | % of length: 1. <5% 2. 5-10% 3. 10-25% 4. 25-50% 5. >50% |   |   |   |              |   |   |   |                 |   |   |   |                       |   |   |   |              |   |   |   |          |   |   |   |         |   |   |   |               |   |   |   |   |   |   |  |  |  |  |  |
|                        | Gravel Loss  |   |   |   | Usable Width |   |   |   | Erosion - C/Way |   |   |   | Erosion - Side Drains |   |   |   | Corrugations |   |   |   | Potholes |   |   |   | Rutting |   |   |   | Impassability |   |   |   |   |   |   |  |  |  |  |  |
|                        | 1  | 2 | 3 | 4 | 5            | 1 | 2 | 3 | 4               | 5 | 1 | 2 | 3                     | 4 | 5 | 1 | 2            | 3 | 4 | 5 | 1        | 2 | 3 | 4 | 5       | 1 | 2 | 3 | 4             | 5 | 1 | 2 | 3 | 4 | 5 |  |  |  |  |  |
| <u>0+000 - 1+500</u>   |  |   |   |   |              |   |   |   |                 |   |   |   |                       |   |   |   |              |   |   |   |          |   |   |   |         |   |   |   |               |   |   |   |   |   |   |  |  |  |  |  |

Insert DEFECT DEGREE/SEVERITY:

1. Slight 2. Slight to Warning 3. Warning 4. Warning to Severe 5. Severe




Figure A9.2

**Unpaved Road Condition Survey Form**


Road Agency Name: \_\_\_\_\_ Province: \_\_\_\_\_ District: \_\_\_\_\_ Reported By: \_\_\_\_\_ Date: 29 April 2016

Road No: 45 Road Name: \_\_\_\_\_ Section Name: \_\_\_\_\_ Start Km: 0+000 End Km: 4+133

| Change (Km)<br>From to | DEFECT EXTENT/OCCURRENCE/QUANTITY                        |   |   |   |              |   |   |   |                 |   |   |   |                       |   |   |   |              |   |   |   |          |   |   |   |         |   |   |   |               |   |   |   |   |   |   |  |  |  |  |  |
|------------------------|--|---|---|---|--------------|---|---|---|-----------------|---|---|---|-----------------------|---|---|---|--------------|---|---|---|----------|---|---|---|---------|---|---|---|---------------|---|---|---|---|---|---|--|--|--|--|--|
|                        | % of length: 1. <5% 2. 5-10% 3. 10-25% 4. 25-50% 5. >50% |   |   |   |              |   |   |   |                 |   |   |   |                       |   |   |   |              |   |   |   |          |   |   |   |         |   |   |   |               |   |   |   |   |   |   |  |  |  |  |  |
|                        | Gravel Loss  |   |   |   | Usable Width |   |   |   | Erosion - C/Way |   |   |   | Erosion - Side Drains |   |   |   | Corrugations |   |   |   | Potholes |   |   |   | Rutting |   |   |   | Impassability |   |   |   |   |   |   |  |  |  |  |  |
|                        | 1  | 2 | 3 | 4 | 5            | 1 | 2 | 3 | 4               | 5 | 1 | 2 | 3                     | 4 | 5 | 1 | 2            | 3 | 4 | 5 | 1        | 2 | 3 | 4 | 5       | 1 | 2 | 3 | 4             | 5 | 1 | 2 | 3 | 4 | 5 |  |  |  |  |  |
| <u>0+000 - 4+133</u>   |  |   |   |   |              |   |   |   |                 |   |   |   |                       |   |   |   |              |   |   |   |          |   |   |   |         |   |   |   |               |   |   |   |   |   |   |  |  |  |  |  |

Insert DEFECT DEGREE/SEVERITY:

1. Slight 2. Slight to Warning 3. Warning 4. Warning to Severe 5. Severe





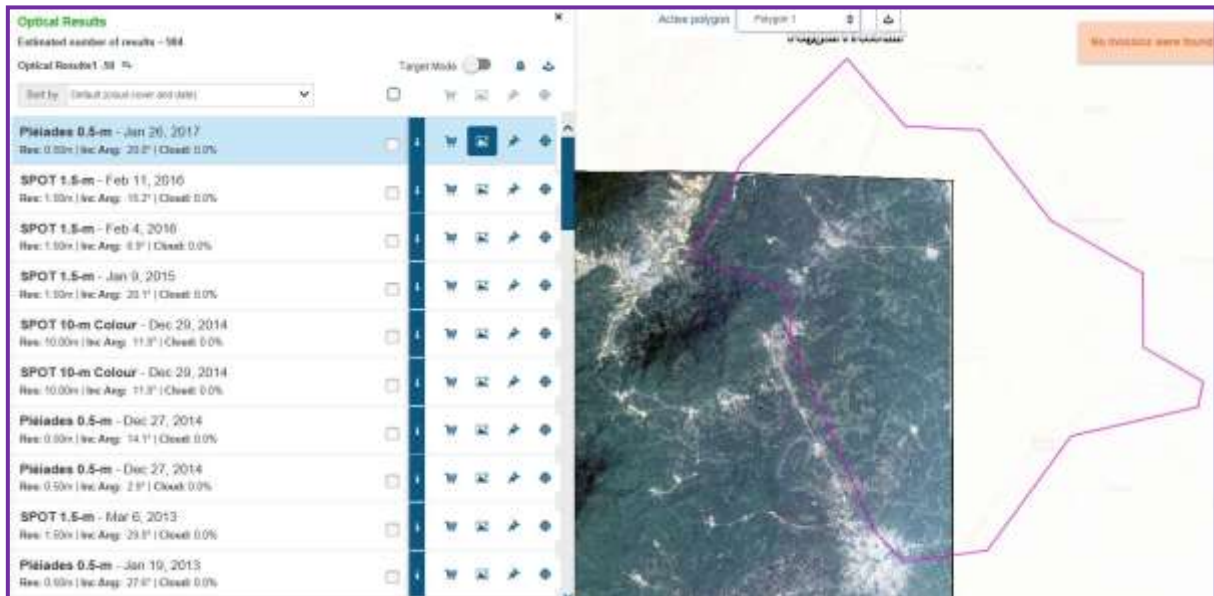


## Annex 11

### Pleiades imagery in Ghana

Figure A11.1 shows the Pleiades acquisition for Ghana, with the AoI shown as a purple line.

Figure A11.1



## Annex 12

### SAR imagery for Ghana

Figure A12.1 shows the proposed Area of Interest for SAR imagery in Ghana, which is inside the main Aol.

Figure A12.1

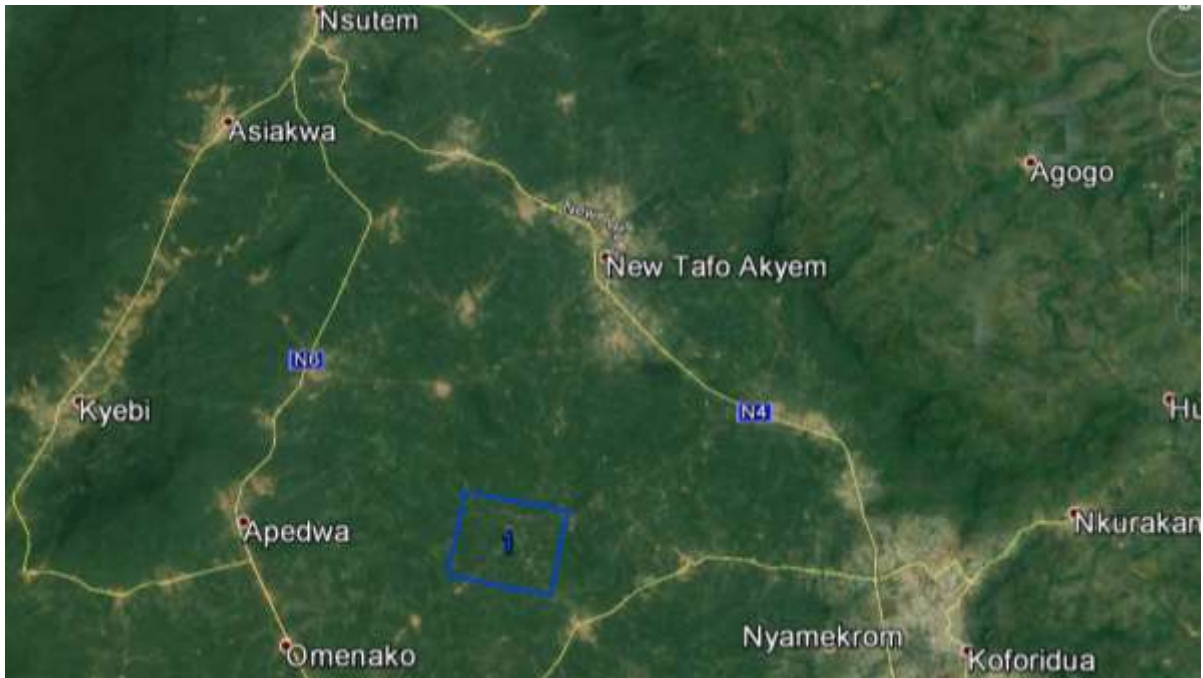
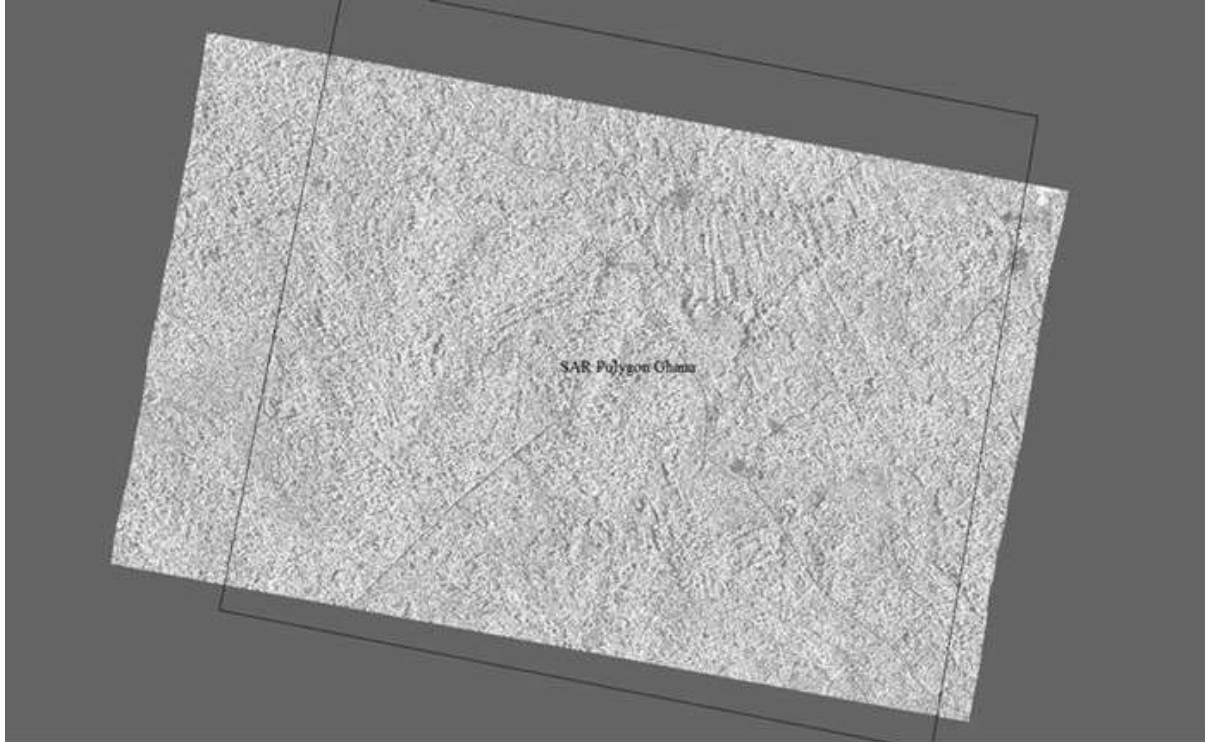


Figure A12.2 shows the acquired SAR imagery for Ghana, with the proposed AoI outlined in black. It was not possible to acquire the exact area as SAR imagery is sold in 'scenes' and is dependent on the location and orientation of the satellite when it passes the area.

**Figure A12.2**



## **Annex 13**

### **Kenya training Aoi**

Figure A13.1 shows the training Aoi in Kenya, outlined in blue, situated south of Nairobi.

**Figure A13.1**



## Annex 14

### Pleiaides imagery for northern Kenya

Figure A14.1 shows the planned Aoi for northern Kenya, shown outlined in blue.

Figure A14.1



Figure A14.2 shows the two areas of the northern Kenya Aoi where imagery has been acquired, outlined in green.

Figure A14.2



## Annex 15

### Kenya Dash cams and RoadLab

Figure A15.1 shows the tracks for the roads surveyed using the RoadLab mobile app. with the condition colour coding shown for sections of approximately 100m.

Figure A15.1



Figure A15.2 shows the GPS tracks from the DashCam.

Figure A15.2



## Annex 16

### Ghana condition assessment system

The following is the current condition assessment system employed in Ghana.

#### ROAD CONDITION SURVEY AND TRAFFIC COUNT

The table below shall be used to determine the condition of the road and its appurtenances

| Summary for unpaved roads    |              |  |   |   |  |         |  |
|------------------------------|--------------|--|---|---|--|---------|--|
| Roughness<br>(average speed) |              | Camber<br>(is surface drainage effective?) |   | Drainage<br>(are side drains and culverts effective?) |  | Traffic |  |
| Good                         | > 60 km/h    | Good                                       | > 5% camber                                     | Good  | Drains clear                               | Low     | >10 veh/day<br>(grass between wheel paths)     |
| Fair                         | 40 – 60 km/h | Fair                                       | Slight camber/ some surface irregularities      | Fair  | Some evidence of ponding or standing water | Medium  | 10 – 50 veh/day<br>(some grass on carriageway) |
| Poor                         | < 40 km/h    | Poor                                       | No camber and/or serious surface irregularities | Poor  | Most water cannot drain from sides of road | High    | >50 veh/day<br>(no vegetation on carriageway)  |

#### Traffic Count

Undertake a 2 day, 12-hour, traffic tally count on the market day and a non-market day using the methodology in the handbook to estimate the Average Daily Traffic Summary (p.5 of handbook).

#### Roughness

Roughness is the irregularity of the road surface. This is sometimes identified as “riding comfort” and is a measure of the longitudinal evenness of the road. Roughness is normally measured in units on the international roughness index (IRI)

Definitions of three roughness levels are suggested, and it is possible to correlate each level to an IRI value, or the comfortable travel speed of a vehicle, although the latter requires careful calibration. Below is the relationship between IRI and speed.

| Description | IRI | Speed (kph) |
|-------------|-----|-------------|
| G – Good    | 6   | > 60        |
| F – Fair    | 9   | 40 – 60     |
| P – Poor    | 12  | < 40        |



Below are the guidelines for visual condition rating in Uganda.

**VISUAL CONDITION RATING GUIDELINES**

**PAVED ROADS**

All Cracking:

| Grade | Description  |
|-------|--|
| 1     | No cracking  |
| 2     | Isolated or continuous all cracking; Area of all cracking < 5% of surface area.                |
| 3     | Isolated or continuous all cracking; Area of all cracking between 5% and 15% of surface area.  |
| 4     | Isolated or continuous all cracking; Area of all cracking between 15% and 30% of surface area. |
| 5     | Isolated or continuous all cracking; Area of all cracking > 30% of surface area.               |

Wide Cracking:

| Grade | Description   |
|-------|---|
| 1     | No wide cracking  |
| 2     | Isolated or continuous wide cracking; Area of wide cracking < 10% of all cracking area.               |
| 3     | Isolated or continuous wide cracking; Area of wide cracking between 10 and 25% of all cracking area.  |
| 4     | Isolated or continuous wide cracking; Area of wide cracking between 25% and 50% of all cracking area. |
| 5     | Isolated or continuous wide cracking; Area of wide cracking > 50% of all cracking area.               |

Potholes:

No./km, where area of one pothole is 1m<sup>2</sup>.

Width Loss

| Grade | Description  |
|-------|--|
| 1     | No edge break.   |
| 2     | Isolated edge break on one side or both sides; Average width of edge break < 50mm of section length. |
| 3     | Edge break on one or both sides; Average width of edge break > 50mm and <=150mm.                     |
| 4     | Edge break on one or both sides; Average width of edge break > 150mm and <=250mm.                    |
| 5     | Severe edge break on one or both sides; Width of average edge break > 250mm.                         |

Edge Drop

| Grade | Description   |
|-------|---|
| 1     | Shoulder level with road surface.   |
| 2     | Average height of edge drop $\leq$ 50mm of section length.                |
| 3     | Average height of edge drop $>$ 50mm and $\leq$ 100mm of section length.  |
| 4     | Average height of edge drop $>$ 100mm and $\leq$ 150mm of section length. |
| 5     | Average height of edge drop $>$ 150mm of section length.                  |

Ravelling

| Grade | Description   |
|-------|---|
| 1     | No aggregate loss   |
| 2     | Little loss of aggregates Disintegration area $<$ 5% of surface area.   |
| 3     | Distinct loss of aggregate or disintegration of asphalt layer in small areas; Disintegration area $>$ 5% and $\leq$ 15% of surface area.    |
| 4     | Distinct loss of aggregate or disintegration of asphalt layer in greater areas; Disintegration area $>$ 15% and $\leq$ 30% of surface area. |
| 5     | General disintegration of asphalt layer or loss of slurry in large patches; Disintegration area $>$ 30% of surface area.                    |

Rutting

| Grade | Description   |
|-------|---|
| 1     | No rutting  |
| 2     | No visual rutting ( $\leq$ 5mm).  |
| 3     | Rutting discernible (visible); Rut depth between $>$ 5mm and $\leq$ 10mm.     |
| 4     | Obvious rutting; Rut depth between $>$ 10mm and $\leq$ 20mm.                  |
| 5     | Severe rutting, dangerous, affects directional stability; Rut depth $>$ 20mm. |

Roadside Friction

| Grade | Description   |
|-------|---|
| 1     | No roadside friction  |
| 2     | NOT USED  |
| 3     | Roadside Friction discernible (visible), speed reduction necessary.     |
| 4     | NOT USED  |
| 5     | Significant roadside friction, dangerous, severely affects road safety. |

**VISUAL CONDITION RATING GUIDELINES**

**UNPAVED ROADS**

Gravel Thickness

| Grade | Description  |
|-------|--|
| 1     | Plenty of gravel; Good shape and no stones protrusion; Gravel thickness $\geq 150\text{mm}$ .  |
| 2     | Gravel loss can be seen but still good shape and only a few stones protrusion; Gravel thickness $> 100\text{mm}$ and $\leq 150\text{mm}$ .                   |
| 3     | Medium gravel loss can be seen but no exposure of the sub-grade; Sub-grade exposed in local areas Gravel thickness $> 50\text{mm}$ and $\leq 100\text{mm}$ . |
| 4     | Severe exposure of sub-grade; Engineered cross section on road non existing on part of the road; Gravel thickness $\leq 50\text{mm}$ .                       |
| 5     | No gravel found on the section 100 percent of sub-grade exposed: Engineered cross section on road non existing   |

Potholes

| Grade | Description  |
|-------|--|
| 1     | No potholes.   |
| 2     | Area of potholes $\leq 1\%$ of the observed area. (equal to potholes of a total area of $1\text{m}^2$ for every $100\text{m}^2$ area of the road).                             |
| 3     | Area of potholes $> 1\%$ and $\leq 3\%$ of the observed area. (equal to potholes of a total area of $1\text{m}^2 - 3\text{m}^2$ for every $100\text{m}^2$ area of the road).   |
| 4     | Area of potholes $> 3\%$ and $\leq 10\%$ of the observed area. (equal to potholes of a total area of $3\text{m}^2 - 10\text{m}^2$ for every $100\text{m}^2$ area of the road). |
| 5     | Area of potholes $> 10\%$ of the observed area. (equal to potholes of a total area of $10\text{m}^2$ for every $100\text{m}^2$ area of the road).                              |

Rutting

| Grade | Description   |
|-------|---|
| 1     | No Rutting  |
| 2     | Limited Rutting ( $< 10\text{mm}$ ).  |
| 3     | Rutting discernible (visible); Rut depth $> 10\text{mm}$ and $\leq 30\text{mm}$ .     |
| 4     | Obvious rutting; Rut depth $> 30\text{mm}$ and $\leq 60\text{mm}$ .                   |
| 5     | Severe rutting, dangerous, affects directional stability; Rut depth $> 60\text{mm}$ . |

Corrugations

| <b>Grade</b> | <b>Description</b>   |
|--------------|--|
| 1            | No corrugations.   |
| 2            | Can be felt and heard; No speed reduction necessary.                       |
| 3            | Can be felt and heard; Speed reduction necessary.                          |
| 4            | Significant speed reduction necessary.                                     |
| 5            | Drivers select a different path and drive very slowly; Safety is affected. |

Formation Level

| <b>Grade</b> | <b>Description</b>  |
|--------------|---|
| 1            | Well above ground level;<br>Edges of road are at least 600 mm above bottom of ditch   |
| 2            | Slightly above ground level;<br>Road is between 300 and 600 mm above bottom of ditch;   |
| 3            | Drainage is level with road surface;<br>Road is generally at ground level with ineffective side drains;<br>Stormwater could cross in most places. |
| 4            | Isolated areas of the road are below natural ground level;<br>No side drains are present and localised ponding of water will occur.               |
| 5            | Road is the lowest point and serves as drain for the entire area.   |

Drainage Condition

| <b>Grade</b> | <b>Description</b>  |
|--------------|---|
| 1            | Clear no visible obstacles  |
| 2            | Generally clear with a few obstacles                                |
| 3            | Slightly overgrown with some obstacles                              |
| 4            | Partly blocked, depth of drainage less than designed due to siltage |
| 5            | Blocked, eroded and not functioning as drainage                     |

## Annex 18

### Zambia condition assessment system

Figure A18.1 shows the main assessment spreadsheet to be used for condition analysis in Zambia.

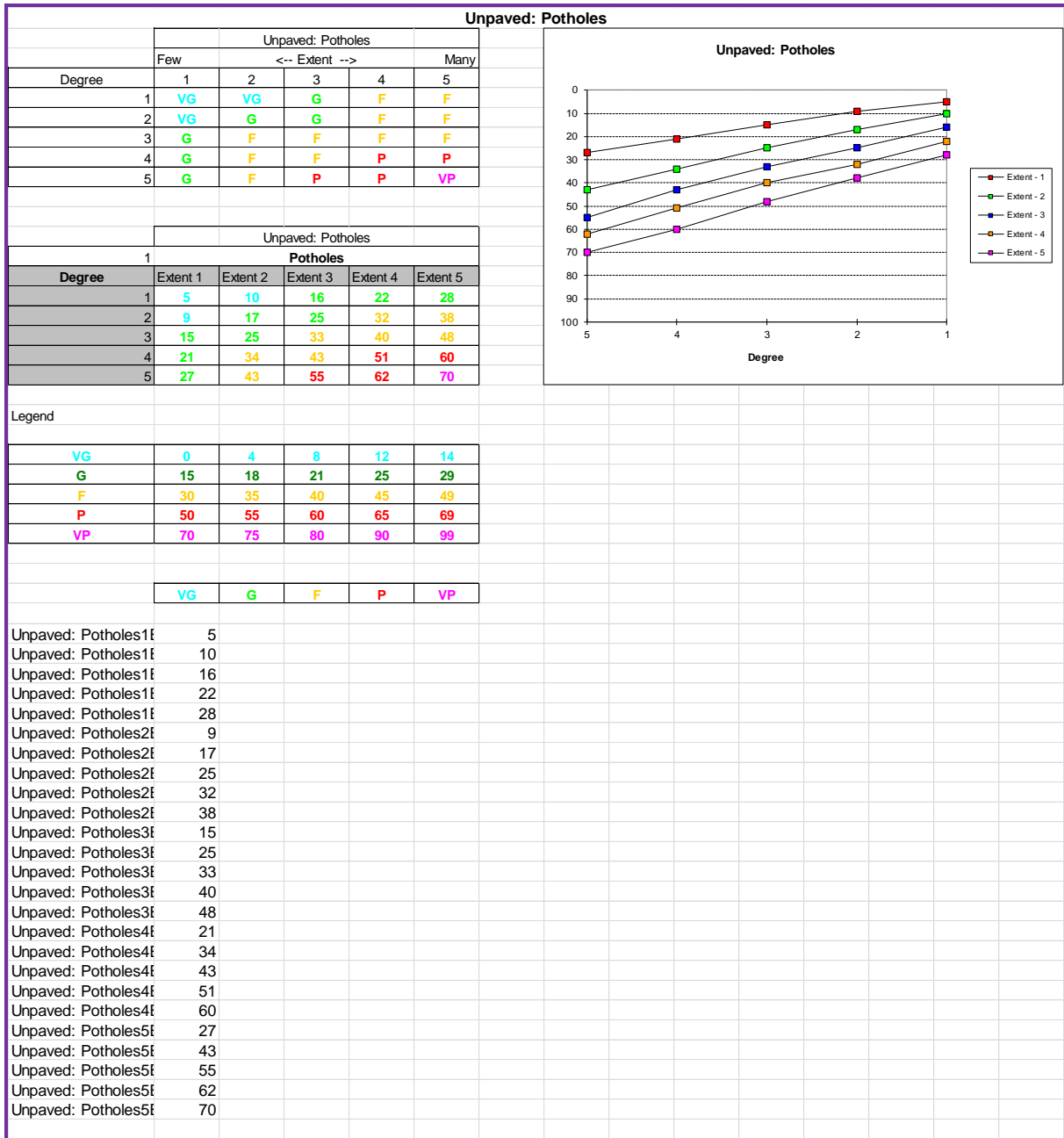
Figure A18.1

| Visual Condition Index   |        |        |              | VCI       |                    |
|--------------------------|--------|--------|--------------|-----------|--------------------|
| DEFECT                   | Degree | Extent | Deduct value | Sorted    | Index contribution |
| Unpaved: Potholes        | 4      | 4      | 51           | 51        | 51.0               |
| Unpaved: Corrugations    | 3      | 1      | 14           | 15        | 3.0                |
| Unpaved: Rutting         | 2      | 2      | 7            | 14        | 1.4                |
| Unpaved: Loose Material  | 1      | 5      | 9            | 14        | 0.7                |
| Unpaved: Stoniness Fixed | 2      | 4      | 9            | 11        | 0.6                |
| Unpaved: Stoniness Loose | 2      | 2      | 11           | 9         | 0.5                |
| Erosion Long             | 2      | 1      | 8            | 9         | 0.0                |
| Erosion-Transverse       | 3      | 1      | 14           | 8         | 0.0                |
| Riding Quality           | 2      |        | 0            |           |                    |
| Trafficability           | 1      | 4      | 0            |           |                    |
| SAFETY                   | 2      | 4      | 15           |           |                    |
| Drainage on              | 1      |        | 0            |           |                    |
| Drainage off             | 1      |        | 0            |           |                    |
| Material type            | 1      |        | 0            |           |                    |
| Material quality         | 1      |        | 0            |           |                    |
| Maximum size             | 1      |        | 0            |           |                    |
| Grading                  | 1      |        | 0            |           |                    |
| PI                       | 1      |        | 0            |           |                    |
| Layer thickness          | 1      |        | 0            |           |                    |
| Exposed subgrade         | 1      |        | 0            |           |                    |
| Subgrade quality         | 1      |        | 0            |           |                    |
| Calculated               |        |        |              | VCI       | 43                 |
|                          |        |        |              | Condition | Poor               |
| <b>VCI coefficient</b>   |        |        |              |           |                    |
| 1.00                     | 1      |        |              |           |                    |
| 0.20                     | 2      |        |              |           |                    |
| 0.10                     | 3      |        |              |           |                    |
| 0.05                     | 4      |        |              |           |                    |
| 0.05                     | 5      |        |              |           |                    |
| 0.05                     | 6      |        |              |           |                    |
| 0.00                     | 7      |        |              |           |                    |
| 0.00                     | 8      |        |              |           |                    |

Enter Deg (0-5) and Ext (0-5) . Only Degree for RQ, Trafficability , Safety and rest of red

Figure A18.2 shows one of the calculations sheets, in this case potholes on unpaved roads.

Figure A18.2



## Annex 19

### Example of DashCam guidelines (Kenya)

#### Guidelines for use of Dash-Cam, Kenya

##### Refer to user's manual for full instructions:

- Note: Ensure that the vehicle windscreen is clean at all times.

##### VIDEO MODE

- Set resolution of the images to suit situation, (highest resolution is recommended)
- Set exposure and white balance, i.e. for brightness (bright sunlight/overcast/etc.)
- Set audio on/off – if you want to record condition verbally the audio can be used
- Set date and time stamp for Kenya (default is GMT), and make sure it is set to 'ON' ('ON' is the default)
- Set loop recording time (default is 3 minutes, this means that files will be recorded as a series of 3 minute files, but can be downloaded and viewed as one continuous file).
  - NOTE: When 32GB disk is full it will start recording again from the beginning, so the data will need to be downloaded when the disk is full and the disk cleaned, or another card inserted. Card will be full at approximately 4 hours of continuous recording, so data should be downloaded twice per day, or every 3.5 hours.
  - NOTE: Card should be re-formatted every few days to ensure reliability of data.
- G-Sensor – leave ON
- Motion detection – leave OFF
- Number Plate – Enter the registration number of the vehicle, this will then show on the recorded video
- Driver Fatigue Warning – leave OFF
- GPS stamp – Leave ON, this will then show coordinates on the video
- Compass – leave ON
- Password – it is possible to set a password to protect use of the camera, recommended that this is **not** used at this time as it should be accessible to a range of staff
- Speed units – Select for KMH or MPH, in Kenya KMH is used

##### PHOTO MODE

Unlikely to be needed as the Road-Lab software will be used in parallel which allows the assessor to take geo-referenced photos. Recommended that the dash-cam is used for video only, as photos can be extracted from the video itself.

##### SET-UP Menu

Follow recommendations in manual

##### CAPACITY

Maximum resolution: 1920 x 1080 HD @ 3 fps or 2.0 MB/s

Maximum capacity: for 32GB card, 240 mins (4 hours) recording at 1920 x 1080

**Viewing Files:** Video program and manual can be downloaded from CD that was provided with the camera.

## **Annex 20**

### **Training photos from Uganda and Zambia**

**Figure A20.1 Zambia – Classroom Training**



**Figure A20.2 Zambia – Classroom Training**



**Figure A20.3 Zambia – Field visit**



**Figure A20.4 Uganda – Classroom Training**



**Figure A20.5 Uganda Classroom Training**



**Figure A20.6 Uganda Field trip**



**Figure A20.7 Uganda Field trip**



## Annex 21: Updated Workplan



## Annex 22: Progress towards ReCAP logframe outputs

| Intervention Logic   | Indicator  | Next Milestone Target Date (from Inception Report) | Next Milestone Target (from Inception Report)                           | Comment. (Risks, challenges, will Targets be achieved, and on time?)   | Achievement <sup>1</sup> |   |
|--|--|--|---|--|--------------------------|---|
| <p>Outcome:<br/>Sustained increase in evidence base for more cost effective and reliable low volume rural road and transport services, promoted and influencing policy and practice in Africa and Asia</p> | <p>1. SUSTAINABILITY: Partner Government and other financiers co-funding research with ReCAP.<br/>Contributions in kind (K) and Core Contributions (C)</p> | March 2017   | All countries on board but Kenya unable to commit sufficient resources. | Kenya has lack of funds, AFCAP agreed to supplement training costs,  | This reporting period    | 4 countries committed                   |
|  |  |  |   |  | Cumulative to date       | As above                                |
|  | <p>2. Concrete examples of change (applied or formally adopted), influenced by ReCAP research that will be allied to #km of road in focus countries.</p>   | Too early to identify change                       | March 2017, ground truthing should be complete                          | Ground truthing is still delayed in Kenya, local resource arrangement is a challenge, despite funding being confirmed. | This reporting period    | Some countries have allocated resources |
|  |  |  |   |  | Cumulative to date       | As above                                |
|  | <p>3. Number of citations in academic articles of ReCAP peer reviewed articles and/or working papers, conference papers etc.</p>                           | Not due until end of project                       |   |  | This reporting period    | None                                    |
|  |  |  |   |  | Cumulative to date       | None                                    |

<sup>1</sup> Evidence to be attached to the report submission.

| Intervention Logic   | Indicator  | Next Milestone Target Date (from Inception Report) | Next Milestone Target (from Inception Report) | Comment. (Risks, challenges, will Targets be achieved, and on time?) | Achievement <sup>1</sup>     |             |
|--|--|--|---|--|------------------------------|-------------|
| <p>Output 1:<br/>RESEARCH and UPTAKE:<br/>Generation, validation and updating of evidence for effective policies and practices to achieve safe, all-season, climate-resilient, equitable and affordable LVRR and transport services in African and Asian countries.</p> <p>(Low Volume Rural Roads :<br/>LVRR / TS – Transport Services)</p> | <p>1.1 LVRR: Number of peer reviewed papers generated from ReCAP supported or related LVRR research projects made available in open access format.</p> | <p>May 2017</p>                                    | <p>May 2017</p>                               |  | <p>This reporting period</p> | <p>None</p> |
|  |  |  |   |  | <p>Cumulative to date</p>    | <p>None</p> |
|  | <p>1.2. TS: Number of peer reviewed papers generated from ReCAP supported or related LVRR research projects made available in open access format.</p>  | <p>May 2017</p>                                    | <p>May 2017</p>                               |  | <p>This reporting period</p> | <p>None</p> |
|  |  |  |   |  | <p>Cumulative to date</p>    |             |

| Intervention Logic | Indicator  | Next Milestone Target Date (from Inception Report) | Next Milestone Target (from Inception Report) | Comment. (Risks, challenges, will Targets be achieved, and on time?)   | Achievement <sup>1</sup> |      |
|--------------------|--|--|---|--|--------------------------|------|
|                    | <p>1.3 Engineering Research: National policies, manuals, guidelines and/or research outputs that have been fully incorporated into Government/Ministerial requirements, specifications and recommended good practice as a result of ReCAP engineering research (including climate change adaptation and AfCAP and SEACAP adaptations).</p> <p>To include introduction of new policies and modification to existing policies.</p> | May 2017   | May 2017                                      | Guidelines will be complete by May 2017, but it will take a lot longer for them to be incorporated into government policy. | This reporting period    | None |
|                    |  |  |   |  | Cumulative to date       | None |
|                    | 1.4 TRANSPORT SERVICES Research: National policies, regulations and/or practices for rural transport services  | May 2017   | May 2017                                      | This depends on what high-tech solutions are taken forwards by the countries. Even after the research it will take time to | This reporting period    | None |

| Intervention Logic | Indicator  | Next Milestone Target Date (from Inception Report) | Next Milestone Target (from Inception Report) | Comment. (Risks, challenges, will Targets be achieved, and on time?) | Achievement <sup>1</sup> |  |
|--------------------|--|--|---|--|--------------------------|--|
|                    | <p>modified or introduced as a result of ReCAP research (including road safety and gender and AFCAP and SEACAP research )</p> <p>To include introduction of new policies and modification to existing policies.</p>  |  |   | incorporate into government policy                                   | Cumulative to date       | None   |
|                    | <p>1.6. LVRR and TS information generated for dissemination, and disseminated, that is not peer reviewed. Total to include research papers, final research reports, workshop reports, manuals and guidelines.</p> <p>CHECK IF THIS IS TO BE PART OF Service Provider Reporting</p> | Trial report due in Feb/March 2017                 | March 2017                                    |  | This reporting period    | All ground truthing done except for Kenya, Training done in 2 countries, analysis complete in 1. |
|                    |  |  |   |  | Cumulative to date       | As above   |

| Intervention Logic   | Indicator  | Next Milestone Target Date (from Inception Report) | Next Milestone Target (from Inception Report) | Comment. (Risks, challenges, will Targets be achieved, and on time?)   | Achievement <sup>1</sup> |   |
|--|--|--|---|--|--------------------------|---|
| Output 2:<br>CAPACITY BUILDING: The building of sustainable capacity to carry out research on low volume rural roads, and rural transport services in African and Asian countries.                         | 2.1. African / Asian experts or institutions taking lead roles in ReCAP Research Projects.                             | May 2016   | March 2017                                    | Local partners have been brought in, but funding an issue for some.  | This reporting period    | Other institutions have been brought in to partner the local team, either Universities or Remote Sensing Centres. They will play a key role in the project.   |
|  |  |  |   |  | Cumulative to date       |   |
|  | 2.3. Research projects with female researcher inputs at senior technical level.  | October 2016                                       | March 2017                                    | Involvement of women is dependent on availability, but Uganda have shown good initiative in identifying women in senior roles. | This reporting period    | In Uganda four of the team of six are women and three will play a senior technical role. In Zambia there is one woman on the team, but not in a lead role. Ghana team is yet to be determined. Kenya have not yet done ground truthing. |
|  |  |  |   |  | Cumulative to date       | As above  |
| Output 3:<br>KNOWLEDGE: Generated evidence base of LVRR and transport services knowledge is widely disseminated and easily accessible by policy makers and practitioners (including education and training | 3.2. ReCAP generated knowledge presented and discussed at high level international development debates and conferences | April 2017   | May 2017                                      | If project is delayed the T2 conference may be missed, but planning to host a workshop,  | This reporting period    | None  |
|  |  |  |   |  | Cumulative to date       | None  |
|  | 3.3.ReCAP generated  | April 2017   | Held  |  | This reporting period    | None  |

| Intervention Logic | Indicator   | Next Milestone Target Date (from Inception Report) | Next Milestone Target (from Inception Report) | Comment. (Risks, challenges, will Targets be achieved, and on time?) | Achievement <sup>1</sup> |      |
|--------------------|---|--|---|--|--------------------------|------|
| institutions).     | knowledge disseminated through significant workshops and dedicated training, virtually or physically, that are rated by participants as effective.. |  | workshop at ICTA conference in October 2016   |  | Cumulative to date       | None |
|                    |   |  |   |  |                          |      |

### Annex 23: Participant Data

Training has been carried out in Zambia and Uganda. Training is scheduled for Ghana and Kenya in March 2017.

| Name | Position | Organisation | Gender | Contact details |
|------|----------|--------------|--------|-----------------|
|      |          |              |        |                 |
|      |          |              |        |                 |
|      |          |              |        |                 |

#### Capacity Building Recipients

| Name | Position | Organisation | Gender | Contact details |
|------|----------|--------------|--------|-----------------|
|      |          |              |        |                 |
|      |          |              |        |                 |
|      |          |              |        |                 |

## **Annex 24: Partner Contribution**

Partner countries are in the process of compiling their expenditure on resources to this project. The final figures will be provided in the final trials report.