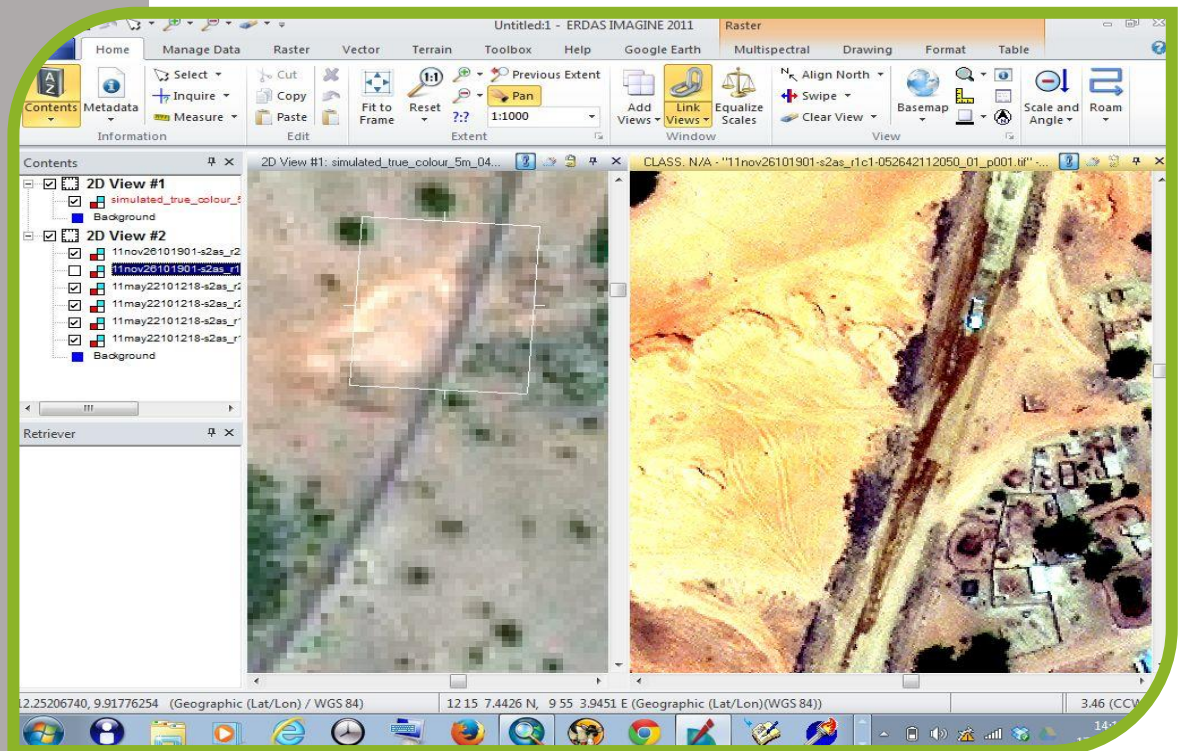# The use of appropriate high-tech solutions for road network and condition analysis, with a focus on satellite imagery

Scoping study for Tanzania involvement

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AFCAP Project Reference Number. GEN2070A

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The views in this document are those of the authors and they do not necessarily reflect the views of the Research for Community Access Partnership (ReCAP) or Cardno Emerging Markets (UK) Ltd for whom the document was prepared

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See www.research4cap.org

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Acronyms, Units and Currencies

AfCAP	African Community Access Partnership
ARMP	Annual Road Maintenance Plan
CERSGIS	Centre for Remote Sensing and Geographic Information Services
DFID	Department for International Development
DROMAS	District Road Management System
DRSRS	Department of Resource Surveys and Remote Sensing
GIS	Geographical Information System
GPS	Global Positioning System
IRI	International Roughness Index
LGA	Local Government Authority
OSM	Open Street Map
PO-RALG	President's Office – Regional Administration and Local Government
QGIS	Quantum Geographic Information System
RAI	Rural Access Index
RAMS	Road Asset Management System
RCMRD	Regional Centre for Mapping of Resources for Development
ReCAP	Research for Community Access Programme
SDI	Surface Distress Index
Tanroads	Tanzania Roads Authority
UAV	Unmanned Aerial Vehicle
UK	United Kingdom

Contents

1. Executive Summary

This study is designed to assess the possibility of including Tanzania in the current phase of the high-tech solutions project. The Team Leader of the project visited Tanzania between 19th and 24th March 2017 to make this assessment. Meetings were held with the main Tanzania and Donor stakeholders. The Tanzania Road Fund Board identified a key problem as a lack of information on the rural road networks of Tanzania; a common issue in Africa. The Road Fund Board has to allocate maintenance funds to the implementing bodies based on information provided by those bodies. A set formula is used to allocate funds, but the information provided is not complete and its reliability has been questioned.

There are three possible areas where the high-tech solutions project could help with the specific needs of the Road Fund; confirming road lengths, checking road conditions and providing detailed up-to-date maps. There would also be an opportunity to see if the technology is compatible with the DROMAS 2 database. These solutions could be trialled during the present phase of the project with a short training from the project, and some counterpart input from the main stakeholders in Tanzania.

Further recommendations have been made for the involvement of Tanzania in any future phases of the project, although this would depend on the final results of the current phase and the avoidance of any duplication with other initiatives in Tanzania. It is important that any inputs are appropriate and useful for the stakeholders of all roads in Tanzania.

2. Introduction

This scoping study was commissioned by AfCAP as part of the GEN2070A high-tech solutions project, which is researching high-tech solutions for increasing knowledge of local road networks in Africa. An important part of this project is to develop a methodology and guideline for assessing road condition using very high resolution satellite imagery. It is this aspect that is the focus of the scoping study, although other high-tech aspects will be considered if found to be appropriate.

The scoping study is designed to assess the possibility of including Tanzania in the current phase of the project to test the technologies for use in providing information that would be useful for the Tanzania Road Fund Board to increase their knowledge of the network. There is also a task to assess the suitability of Tanzania as a partner in any future phase of the project, possibly as a country where the technology could be rolled out on a larger scale.

The scoping study was carried out by the Team Leader from TRL, who visited Tanzania between 19th March and 24th March 2017. An internal visit was made to Dodoma on 20th March, returning the following day. During the Dodoma visit meetings were held with the President's Office Regional Administration and Local Government (PO-RALG), representatives of the Road Fund Board and staff from the DROMAS 2 project (see Section 3.2). A short field visit was also made to district and urban roads in and around Dodoma.

In Dar es Salaam the Team Leader presented the current project to stakeholders from DFID, Road Fund Board and World Bank, at DFID offices. The findings of this scoping study will be considered by AfCAP for the inclusion of Tanzania in the project, as noted above.

3   Background

Tanzania has a large road network, estimated at more than 143,000km, including all classified and unclassified roads. The strategic road network is well documented and inventories are established, including lengths, structures and road furniture. The urban, district and feeder road network is less well documented.

The total classified road network in Tanzania is estimated to be 86,472km, as established by the Road Act 2007, leaving more than 56,500km of road as unclassified.

3.1   Road management

The main organisations involved in road maintenance and construction in Tanzania are:

- Road Fund Board: The Road Fund Board is an independent body that was established by an act of parliament and consists of 9 members, four from the public sector and five from the private sector. The Board has tenure for 3 years, renewable once, and is responsible for providing road maintenance funds to the main road agencies in Tanzania. It advises the Minister of Works on sources of road and fuel tolls, how the rates should be collected and adjusted, and on the regulations for collection of road and fuel tolls to ensure adequate and stable flow of funds to road operations.

- Tanroads: This authority is responsible for the maintenance and development of the trunk and regional road network in Tanzania. The Ministry of Works maintains the national road network through Tanroads. This network consists of approximately 33,891km, comprising 12,786km of trunk roads and 21,105km of regional roads. Of these approximately 11,000km are paved, the remainder are unpaved.

- PO-RALG: It is estimated that there are approximately 53,000km of classified urban, district and feeder roads under the responsibility of the PO-RALG. The majority of these roads are unpaved. These roads are gazetted and receive maintenance funding, but there are a further 56,500km of road, approximately, that would be under the PO-RALG, but are unclassified and consequently receive no maintenance funds from the Road Fund.

A study was commissioned in 2006 to define which district roads should be classified and which should not, leading to the figures shown above. Despite this, it is recognised that the figures may not be accurate and current. The study was conducted more than 10 years ago and the network is constantly changing. There is also some doubt over the accuracy and fairness of the original study and PO-RALG believes that some of the unclassified roads should be given classified status. This translates into a lack of knowledge of the district road network in Tanzania, which the Road Fund Board is keen to address.

The Road Fund Board allocates maintenance and development funds across the whole network, in the following proportion:

- TanRoads   70%
- PO-RALG   30%

The road condition assessment in Tanzania is carried out on the basis of a three level system, using 'Good', 'Fair' and 'Poor'. The Road Fund Board is not allowed to allocate funds to 'Poor' roads, as roads in poor condition are considered to need rehabilitation, the funds for which must be found from Treasury or elsewhere. There is an exception to this rule for

roads where a small amount of spot patching on an unpaved road would bring the road back to a 'Fair' condition, with a funding limit of 5%. The formula for determining the funding allocation to roads is key to ensuring that the correct roads receive necessary funds, so an accurate and up to date inventory and condition assessment of roads is essential for this formula to work.

3.1.1   Tanroads

Tanroads carries out condition surveys on their roads using a laser Deflectometer and Falling Weight Deflectometer on paved roads, and visual inspections on unpaved roads. At present this is carried out for all roads approximately every 2 to 3 years. Tanroads previously used a Bump Integrator to determine roughness, but that has now been superseded by the Deflectometer, which provides a laser profile of the roads and their environment. This information is used to allocate funds between the roads maintained by Tanroads.

3.1.2   PO-RALG

Of the 30% allocated to PO-RALG roads, 90% is allocated to maintenance and 10% to rehabilitation or development activities. The allocation of funds is made on a basis of road length and condition, using a formula to determine which roads receive funding and in what proportions.

However, the Road Fund Board have some concerns over the accuracy of the road network data for urban, district and feeder roads, both in terms of basic information including road length and road condition. The Road Fund Board specifies that road condition surveys will be undertaken every 6 months on this network, which should provide current information on a regular basis. However, this frequency is very high and must be very challenging to achieve for the local administrations. Due to the logistics and resources required, it is assumed that driven surveys are not carried out on all roads every 6 months. Enquiries suggest that condition surveys are in many cases estimated, based on recent local knowledge and some visual inspection. The most recent condition survey was carried out in December 2016.

3.2   DROMAS 2

A database is being developed to assist PO-RALG in managing their network. This database is called the District Road Management System version 2 (DROMAS 2) and is in the process of being populated. The database includes road network and mapping features, as well as providing information for the Annual Road Maintenance Plan (ARMP) and contract management tools. Network features include:

- Road name, code and class
- Road length and dimensions
- Pavement type and construction status
- Structures such as bridges, culverts, retaining walls and side drains
- Road furniture

These details can be entered as attributes, but photographs can also be linked to the database.

Road condition is collected visually as a general condition, but specifically the International Roughness Index (IRI) and Surface Distress Index (SDI) are also collected, along with a speed rating and traffic information.

DROMAS 2 is an on-line facility, which works with other applications such as QGIS (a freely available GIS program), Google Maps and SW-Maps. A hand-held GPS is used to collect the road centre-line, which is likely to be accurate to between 3m and 10m laterally. GPS information on the road alignment is collected and adjusted to match the road alignment as can be seen on the mapping software that is used. This process requires the district staff to drive every road in order to collect this information and provide an accurate road length and inventory of assets.

DROMAS 2 is still in the process of being developed, and faces some challenges ahead in terms of collecting the full inventory for roads and presenting it in a way that the Road Fund Board needs. DROMAS 2 is committed to including all of the classified and unclassified roads maintained by PO-RALG, and a target has been set to gain basic inventory information on all of these by June 2017. To gain full inventory information and mapping data will take some time beyond this.

The Road Fund Board has also requested that a Planning Module be included in DROMAS 2. This is in the process of being developed. Proposals how to include DROMAS 2 in this study are included in the recommendations.

3.3   Prioritisation

At present the Road Fund Board needs to have more, and better quality, information on the Local Government Authority (LGA) network in order to fairly prioritise the funding of urban, district and feeder roads. At present the Road Fund Board is sceptical of the details provided by the inventory survey carried out in 2006, as mentioned before, and is not yet ready to fully accept the inventory details from DROMAS 2, as it is still incomplete. Without full inventory information it is possible that the Road Fund Board may inadvertently be funding maintenance on unclassified roads.

The Road Fund Board therefore believe that there is a need to check all aspects of the road network for completeness and accuracy, but more specifically the length of roads, their status and their condition should take priority. With this in mind the Road Fund Board is launching a tender for a comprehensive inventory and condition survey for all rural roads that will include a re-classification exercise for all roads in the country. The potential use of satellite imagery and high-tech solutions can assist in this project, and further suggestions will be made in the recommendations.

4   Other high-tech initiatives in Tanzania

The World Bank is also supporting infrastructure in Tanzania. One example is the 'Tanzania Open Data Initiative', also supported by DFID, which is committed to providing open source data for all aspects of infrastructure through their Geo-node website. The project has also merged data from Tanroads and PO-RALG roads to produce a map of all roads in the country. This is freely available to download from the Geo-node website and can be found through: http://162.243.57.235/layers/geonode:merged_tanroads_pmo_master . The data can be accessed through QGIS software. Each road has attributes attached to it, which will

show length, condition and a number of other factors, where populated. It is assumed that this is the most up to date information on roads, but this would need to be checked with Tanroads and PO-RALG.

Another current project is called 'Ramani Huria', also supported by World Bank and DFID. This was implemented to map areas vulnerable to flooding in Dar es Salaam. It used GPS and Unmanned Aerial Vehicles (UAVs), along with teams of local community volunteers, students from Ardhi University and others to help with the mapping. The project uses OpenStreetMap (OSM) as a base map for the work, which is also built up using crowdsourcing from local volunteers. In addition a project is being carried out to map the urban areas of Zanzibar, which has been extended to cover the whole island, using a similar methodology. Again OSM, QGIS and other freeware is used to make the project as appropriate and sustainable as possible.

The Rural Access Index (RAI) has also been implemented in Tanzania under ReCAP with DFID funding. A new methodology was proposed, using more high-tech solutions, and has been trialled in eight pilot countries, which includes Tanzania. The report can be seen using this link: http://documents.worldbank.org/curated/en/367391472117815229/pdf/107996-REVISED-PUBLIC-MeasuringRuralAccessweb.pdf. The very high resolution imagery used by the high-tech solutions project should be useful in identifying how far people live from the road, and the methodology used on the 'Ramani Huria' project would also be useful in terms of identifying households.

The Road Fund Board is negotiating a loan from the World Bank for approximately US$300M, to develop the rural road network in Tanzania. DFID is expecting to fund the project preparation for this planned investment.

5   AfCAP High-Tech solutions project

This project is still in the trials period and not all of the data has been collected and analysed. However, there are some relevant examples from the project that can be used to recommend how to move forwards with Tanzania as a partner country. To do this it is necessary to consider the basic information on the prevailing environment in Tanzania and its road network.

Tanzania was considered as a potential partner country at the start of the high-tech solutions project in 2016, but Kenya was selected instead because there was a requirement to look at a desert area with minimal vegetation, which is only present in Kenya (see the vegetation map of East Africa in Appendix 1 and in the following link http://eusoils.jrc.ec.europa.eu/Esdb_Archive/EuDASM/Africa/images/maps/download/afr_veg_ea.jpg). Also there is at present no government based remote sensing centre in Tanzania, although the Ministry of Lands has been considering it for some time. In Kenya the Department of Resource Surveys and Remote Sensing (DRSRS) exists, plus the Regional Centre for Mapping of Resources for Development (RCMRD) is based in Nairobi. These details can be seen in Appendix 1 of the Desk Study Report on the AfCAP website http://www.research4cap.org/Library/Workmanetal_TRL_2016_UseAppropriateHighTechSolutionsforRoadNetworkConditionAnalysis_PRDeskStudy_AfCAP_GEN2070A-v161007.pdf

5.1 Road Environment in Tanzania

The important features of Tanzania are:

- Overall area of Tanzania is 947,300km^2, land area is 885,800km^2. There are also significant areas with no maintained roads, such as mountains, forest and parks.
- Population: 53.47 million (2015)
- Geography: Overall fairly flat, with Rift Valley and some mountains.
- Altitude: 0 - 5,892m (Mount Kilimanjaro)
- Climate: Semi-tropical, with some arid areas (see Figure 1). Dry season: June to November, with a period in February that remains dry with minimal rainfall.
- Vegetation cover: Medium in most areas (see Appendix 1). Much of Tanzania is woodland and savanna, with some dry bushland and some forest.

Figure 1 – Climate map of Tanzania
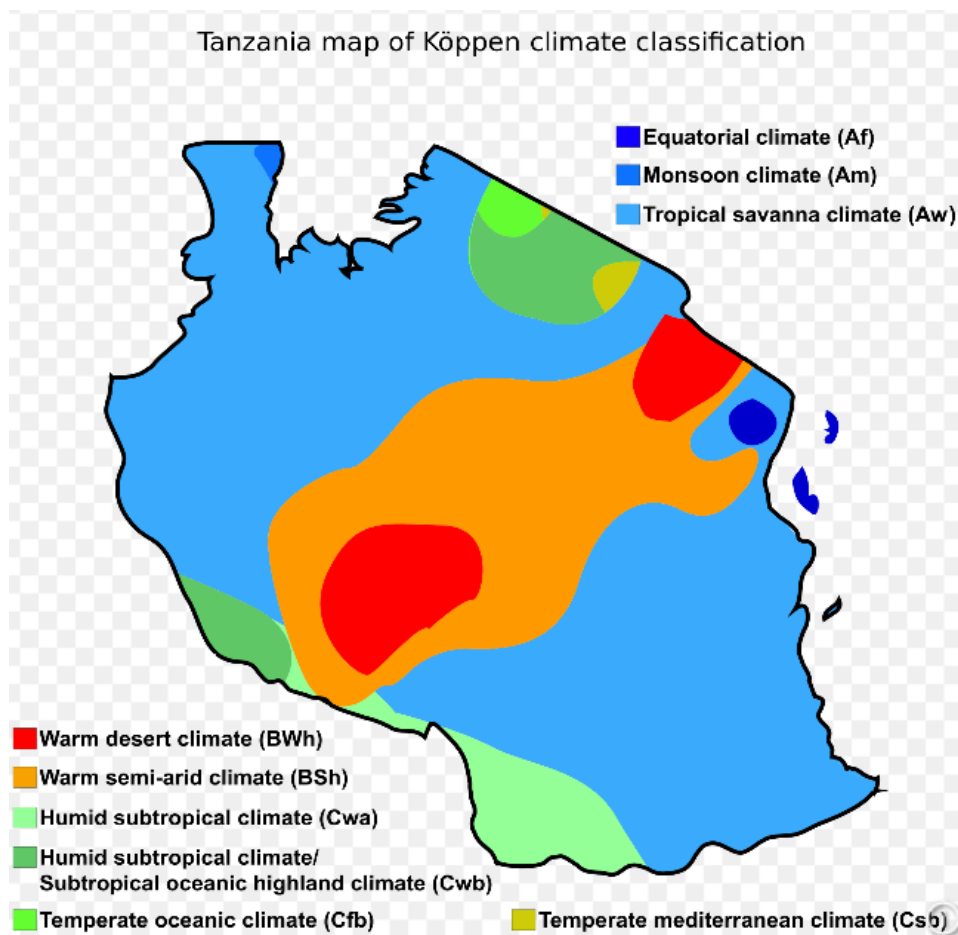
Source: Wikipedia

5.2 Trials under the high-tech solutions project

So far under the high-tech solutions project three countries have started to report results, Zambia, Uganda and Ghana. In terms of maintenance and condition assessment, Ghana is the most similar to Tanzania as it also uses a three level condition assessment system:

'Good', 'Fair' and 'Poor'. Initial results indicate that the condition assessment in Ghana is more accurate than in the countries where a five level condition assessment system is used. This was expected, but also presumes that a similar accuracy could be achieved in Tanzania.

In addition Ghana has a very tropical climate, which resulted in less clarity in the imagery, and the vegetation cover is high, so it was more difficult to identify features along the road, such as side drains, culverts and other structures. It is expected that clearer imagery will be available and roadside features will be more visible for Tanzania. In Ghana CERSGIS proved to be an active and competent partner to the Ministry of Roads and Highways, which was an important factor in achieving good results.

In terms of other high-tech solutions, the project has considered the use of UAVs, so with the experience in Tanzania of the World Bank, it may be that this technology can have a use in any further phases of the project. At present UAVs are designed more for capturing areas, rather than linear details such as roads, but the technology is evolving very rapidly and may be appropriate for network assessment in the future. There is significant research being undertaken in this area in the USA, which has approximately 2 million km of unpaved roads. An example of this is the research from Michigan Tech University: http://integratedglobaldimensions.com/unpaved .

6   Conclusions

A number of conclusions can be drawn from the information collected during the visit to Tanzania for this scoping study. They are summarised below:

- The classification of rural roads needs to be reviewed, in order to ensure that all important roads are eligible to receive funding for maintenance

- The inventory of rural roads is not complete. This includes road length and condition, which are very important factors in determining the funds that are allocated by the Road Fund Board for maintenance of roads.

- The requirement for 6 monthly condition inspections is intensive, and may lead to unreliable information if the districts do not have sufficient resources to carry out full surveys.

- There is the likelihood that some of the inventory information held on rural roads is not accurate. The baseline survey/review that was undertaken in 2006 apparently had some errors, and it has not been reviewed or corrected since.

- DROMAS 2 is providing a comprehensive inventory and condition database, but it will be some time before it is completed.

- The Road Fund Board is concerned that the information on which they base their funding allocation is not accurate, so they would like to check and update the information on which it is based.

7   Recommendations

The AfCAP funded high-tech solutions project has researched how to develop maps and assess road condition for paved and unpaved rural roads in four countries. The recommendations shown here will be linked to the results of the project so far, to focus on the requirements of Tanzania in terms of mapping, inventory establishment and condition assessment.

The immediate requirements of the Road Fund Board in Tanzania can be summarised as:

- The need for accurate road lengths to allow the formula for allocation of funds to be applied appropriately

- Accurate maps to locate the classified and unclassified roads on the network

- Reliable road conditions based on recent information; it would be useful for the Road Fund Board if this information could be auditable

7.1   Recommendations for current phase

Any inputs from Tanzania into the current AfCAP High-tech solutions project should not cause any delay to its planned outputs. Given the requirements of the Road Fund Board and the results of the high-tech solutions project so far, the following recommendations can be made:

- Carry out a trial in Tanzania, focused on the specific requirements of the Road Fund Board. This trial will not be linked specifically to the existing trials in the other four countries involved in the high-tech solutions project; but it will be designed to test the feasibility of providing information that is specific to the needs of the Roads Fund.

    In order to carry out a trial such as this it will be necessary to procure very high resolution imagery for Tanzania. The dry season in Tanzania is from June to November, with February often being dry as well, so there are two options for the trial. One is to carry out the trial when the dry season starts in June, the second is to use archive imagery for the trial and base it on the condition surveys undertaken in December 2016, using archive imagery.

    Option 1: This would involve carrying out ground truthing and tasking new imagery for the chosen area at the start of the dry season in June/July 2017. This would be more expensive, use more resources for ground truthing (which will not have been budgeted for by local organisations) and would take more time. However, the ground truthing would be more reliable as it could be audited using dashboard cameras and IRI apps.

    Option 2: The latter option would require an area that has both reliable condition surveys from December 2016 and archive imagery from around the same time period. This will be cheaper, would use less local resources and could be started immediately. Airbus DS have checked the availability of recent available Pleaides imagery already acquired. There appears to be sufficient imagery available (161 acquisitions this year alone). As the imagery is more than 2 months old it should be possible to procure as archive imagery and will therefore be cheaper.

It would be preferable to follow option 2 as this would be more cost effective, should be possible to arrange within the scope of the current project and could be implemented reasonably quickly. It will be necessary to consult local stakeholders in order to identify a suitable area, with the DROMAS 2 team being probably the most likely to have up to date information on condition surveys and knowledge on the reliability of the information provided.
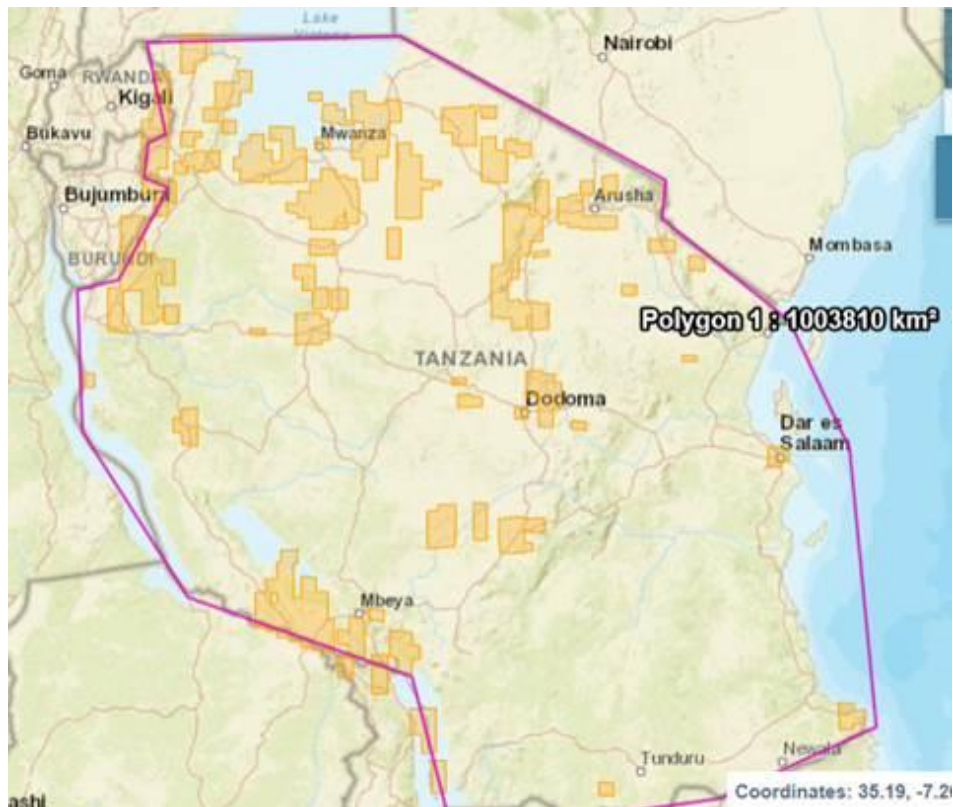
The available imagery from 2017 is shown in Figure 2, below,:

Figure 2: 2017 Pleaides imagery
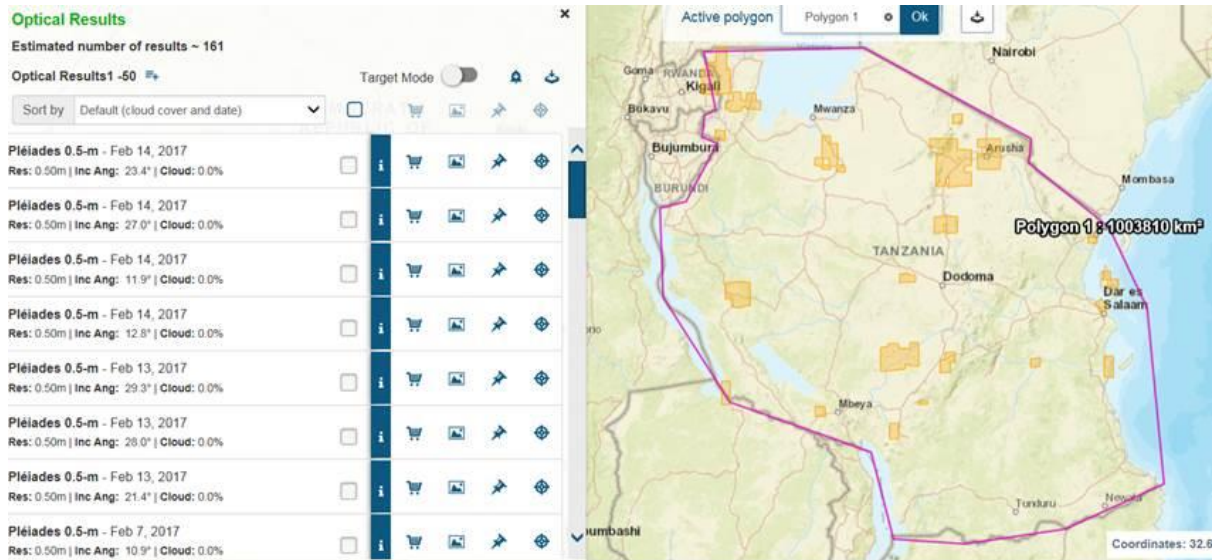
The complete archive of Pleiades imagery is shown in Figure 3:

Figure 3: Archive of Pleaides imagery

It would of course be necessary to find an image that contains a number of PO-RALG maintained roads, but it is anticipated for the available imagery that this would be possible. If an area similar to the trials in the other partner countries is used, the cost would be as shown below, see Figure 4:

Figure 4: Possible Area of Interest (AoI) in Tanzania
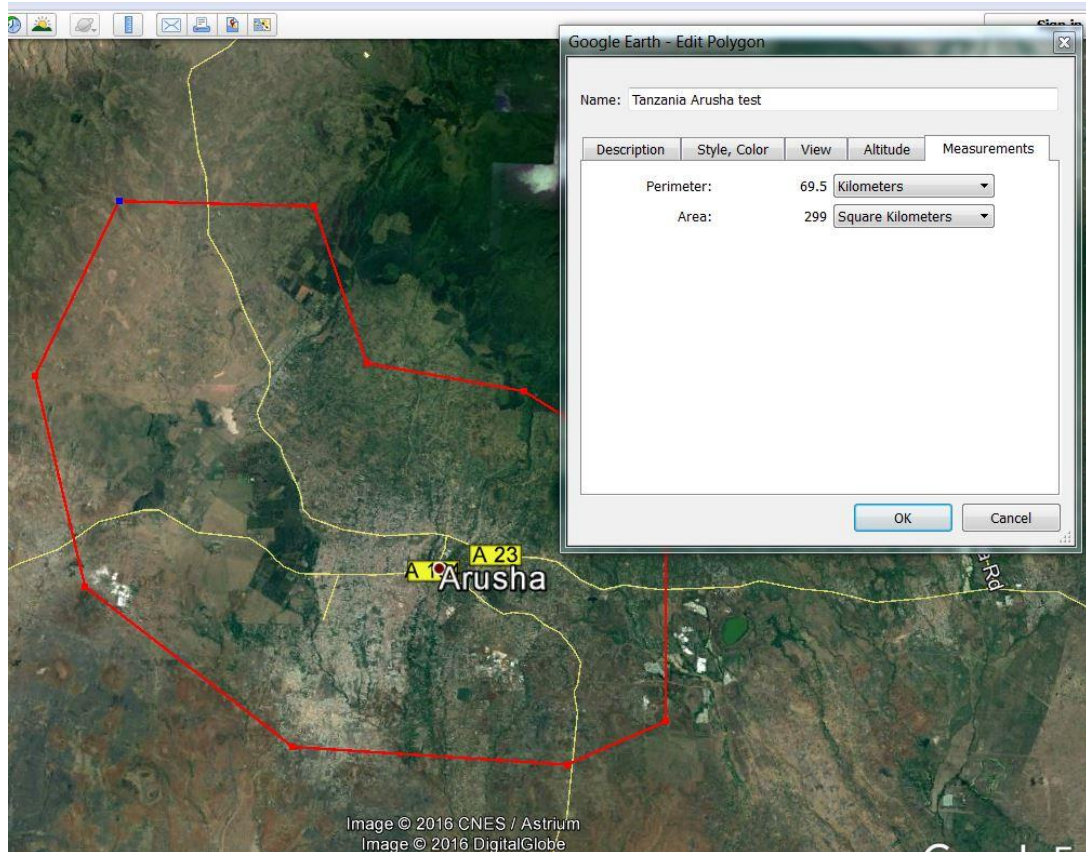
The area shown above is included in the 2017 Pleiades imagery capture, so would be readily available. According to the DROMAS database it would include urban, feeder and collector roads, so a range of roads could be studied. The area shown is approximately 300km^2. For this area the costs would be approximately:

− For tasked imagery €17 per km^2: Assuming a 50% discount, a tasked acquisition would be approximately €2,550 (£2,217 at an exchange rate of £1/€1.15)

− For archive imagery €10 per km^2: Assuming a 50% discount, an archive acquisition would be approximately €1,500 (£1,304 at an exchange rate of £1/€1.15)

The trial will therefore focus mainly on the accuracy of the inventory collected, especially the road lengths. It is recommended that a short training be carried out, along similar lines to the training to be undertaken in Kenya. This will give the participants a basic understanding of the methodology for undertaking assessment from satellite imagery. It would be necessary to form an assessment team who would need to be trained in QGIS and image interpretation. In order to check the road lengths it will be necessary for the team to digitise a number of roads from the satellite imagery in QGIS, and check the lengths against the existing inventory held

by PO-RALG. This is a relatively simple and quick process. This will provide an insight into the accuracy of the existing network road lengths.

- The process above will be similar for options 1 and 2. It will essentially provide a base map for the trial area, which can then be used in DROMAS 2, along with the imagery that can be used as the base image. This can then be compared to the existing base imagery and maps used in DROMAS 2 to see if it would be an improvement to the existing system. It is very likely that the imagery will be an improvement over Google maps as it is higher resolution and more recent, plus it may be possible to identify some features on the road, such as bridges and culverts. Another benefit of using DROMAS 2 is that the manipulation of data and maps will be greatly facilitated as DROMAS 2 is GIS based. The main project will recommend that the system be housed in a GIS based program or database due to this reason, so the fact that DROMAS 2 is operational in Tanzania makes it the obvious choice for this trial.

- The third aspect would be to test the feasibility of assessing the condition of the network, as estimated from the satellite imagery. If archive imagery is used, as in option 2, the area would need to be carefully selected so that the condition surveys from December 2016 can be relied on to be accurate. A spot check of some roads may be necessary, taking into account that conditions may have altered slightly from December 2016.

Tanzania uses a three level condition assessment system, as described in Section 3, above. This is similar to the system used in Ghana, which is likely to produce the highest level of correlation between the ground truthing and satellite assessment of road condition (initial results show between 80% and 100%). The three level system is simpler and more likely to provide accurate results.

The assessment team would assess the condition of the roads that were digitised in the mapping exercise, above. When the condition has been determined and entered into the attributes table of the digitised roads, it can then be compared to the existing road condition as provided to Road Fund Board in December 2016. As the most recent condition surveys were carried out in December 2016, it would be desirable to procure imagery as close to that date as possible, so that the conditions can be compared on the same baseline. Enquiries suggest that the data may have been largely estimated, but the project is focused on using locally produced ground truthing. This will be the most recently available data, but some ground truthing spot checks may be necessary to validate the information. It is recognised that December is still in the wet season, so it may be necessary to use imagery from January or February 2017, which is more likely to be cloud free. Imagery will be procured as close to the date of the condition surveys as possible.

- The participants in the above trial would be determined by the Road Fund Board, but it is recommended that the main participants are from Road Fund Secretariat, PO-RALG and DROMAS 2, with representation from Tanroads as well. In previous trials a local remote sensing partner has also been included in the training and assessment in order to provide the GIS and image interpretation expertise and make the system more sustainable. In the case of Tanzania it is recommended that the Urban and Spatial Planning unit of Ardhi University is included. They have been working with

the World Bank on the projects mentioned above and would be keen to be involved, following a meeting with them on 24th March 2017.

For previous training events a team of two (GIS/image interpretation specialist and a road maintenance expert) has been assigned to train up to 8 participants, in order to ensure that each individual receives enough attention to fully understand the process. In reality up to 12 participants have attended, which has meant that the trainers have not been able to fully support all participants at all times during the training. We recommend that the principle of up to 8 participants is maintained, but if more people are to be trained then an additional trainer can be assigned.

The most cost effective option would be to use RCMRD to carry out the training. They are based in Nairobi and are involved in the training for the Kenya team. It may be necessary to include some input from the TRL team, in order to ensure that the road condition aspects are fully understood. It may be possible to arrange this via video conference, or if there are sufficient funds in the provisional sum a short visit could be arranged.

The location of the training would be decided by the Road Fund. Although the Road Fund Board and PO-RALG are located in Dodoma, it may be more convenient to hold the training in Dar es Salaam as Ardhi University may not have funds for travel, plus Tanroads and RCMRD will be located in Dar es Salaam. In line with AfCAP principles it is expected that the local partners provide some contributions to activities such as training, so it would be appropriate if the Road Fund Board or PO-RALG could provide facilities for the training. The input of RCMRD could be procured by AfCAP.

- The high-tech solutions project is intending to hold a workshop at the forthcoming T2 conference in Zambia, in May 2017. If this input is agreed, it would be beneficial for a representative from Tanzania to attend that workshop in order to share experiences with the other countries and to gain a better understanding of how the technologies could be used in Tanzania in any future phase of the project.

Summary:

In summary it is recommended that a trial be carried out to test the specific aspects that the Road Fund Board has identified as priority, namely road lengths, mapping and road conditions. The most cost effective and fastest way to do this is to use the recent condition surveys from December 2016 and archive satellite imagery. The imagery, training and other logistics could be managed from the Provisional Sum budget, whilst a small amount of additional time would be required from TRL and Airbus to facilitate the trial and analyse the results. Additional high-tech options would be available to be used, such as mobile phone IRI measurement and dash-cameras, to provide a baseline record of the road. It may also be possible to use UAVs if they are available locally to gain more information on areas where the satellite imagery does not provide enough detail, such as large structures.

7.2   Recommendations for future involvement

The recommendations for future involvement of Tanzania in the high-tech solutions project will depend on the results of the trials, as described in 5.2 above. However, the likely benefits and involvement can be predicted, assuming that the trial is successful.

The first consideration will probably be the cost effectiveness of the system, compared to the information it will provide. It would be necessary to procure tasked imagery for most of the country, however this could be a focused acquisition as was done in Kenya, where areas with no roads are omitted. A detailed study of the network would be necessary to do this accurately, but it can be assumed that:

- Of the total area of Tanzania, 947,300km^2, only the land area 885,800km^2 is of interest.

- Only the national road network is of interest, so roads within national parks and game reserves (approx. 100,000km^2) are not required.

- Mountainous areas with no roads can be omitted.

- Densely forested areas with no roads can be omitted.

In this case the land area of 885,800km^2, less the area of protected areas of 100,000km^2, leaves about 785,500km^2. We can assume that the mountainous and forested area may exclude another 100,000km^2, leaving a total of approximately 685,000 km^2 to be procured. This could be reduced further if very careful image acquisition was made (as in Kenya), but this would have to be offset against the time and effort it would take to achieve this.

Therefore at a rate of 17 Euros per km^2, the cost would be €11,645,000. Due to their involvement in the project, Airbus have provided a discount of 50% on imagery procured for the project. Assuming Airbus involvement and a similar discount, the price could be brought down to €5,822,500 – or approximately £5,000,000. This would need to be compared to the funds provided to LGAs to carry out the regular condition inspections, which when discussed in Dodoma with PO-RALG and Road Fund Board representatives, would probably be approaching this figure. Further details on these costings would need to be investigated, and for large areas of acquisition it may be possible to negotiate further with suppliers. Alternatively, if other government agencies are interested in imagery for the non-roads areas, it may be possible to negotiate a rate for the whole country and share the cost between agencies. Please note that the areas and costs above are estimated and will require further investigation to confirm.

It is important that the project does not duplicate other work that is being undertaken in Tanzania. The trial outlined above has been designed to test a specific output for the Road Fund Board that has not been addressed to date. However, there is considerable funding planned in the future for the roads sector in Tanzania, with DFID and World Bank involved. The details of these inputs are not yet finalised, but the Road Fund Board can liaise with AfCAP on the most appropriate involvement that does not duplicate resources.

The potential outputs also need to be appropriate. For example it is the ambition of the Road Fund Board to collect full inventory and condition information for the whole network. If the satellites methodology is to be used for part of this, the Road Fund Board need to be sure that the outputs are of high enough accuracy and quality for their needs, and that the type of data collected is in line with existing data collection. It should also be noted that the DROMAS 2 program will eventually collect this data, so it would be advisable to see how this technology can be used in association with DROMAS 2, rather than duplicate what it is already doing.

Most of these questions cannot be answered until the first phase of the high-tech solutions project is complete and the results have been analysed. The final report will identify the most appropriate situations for each technology, and where/how they can be integrated or used to complement each other, based on the situation present in each country and how cost effective the system would be.

Given the potential issues above, the high-tech solutions project could provide the following added value to the Road Fund Board operations:

- High quality maps that can be used to digitise the length of roads accurately.

- The ability to quickly assess a high quantity of road details, specifically length, surface type and other dimensions.

- An assessment of road condition, based on visual indicators. At present this is being undertaken manually, but DFID are arranging a pilot to test the feasibility of developing this as an automated process. This would reduce the subjectivity of the process and allow the assessment to be carried out more quickly and hopefully with higher accuracy. There would be scope to build this research into the next phase of the project.

All of the above functions can be carried out using other technologies, so it would be necessary to check that the technology is not being duplicated and that it is appropriate for the use to which it is being put. It may be that the system can be used to provide a quick assessment of road lengths and condition, for example, in order to provide a better idea of the rural network and allow planning of other interventions to be confirmed. It should also be noted that the condition assessment of structures is limited to what can be seen on the satellite imagery, but other high-tech solutions may be able to provide more information, such as UAVs. This will be included in the reports for the main project.

Appendix 1: Vegetation map of East Africa
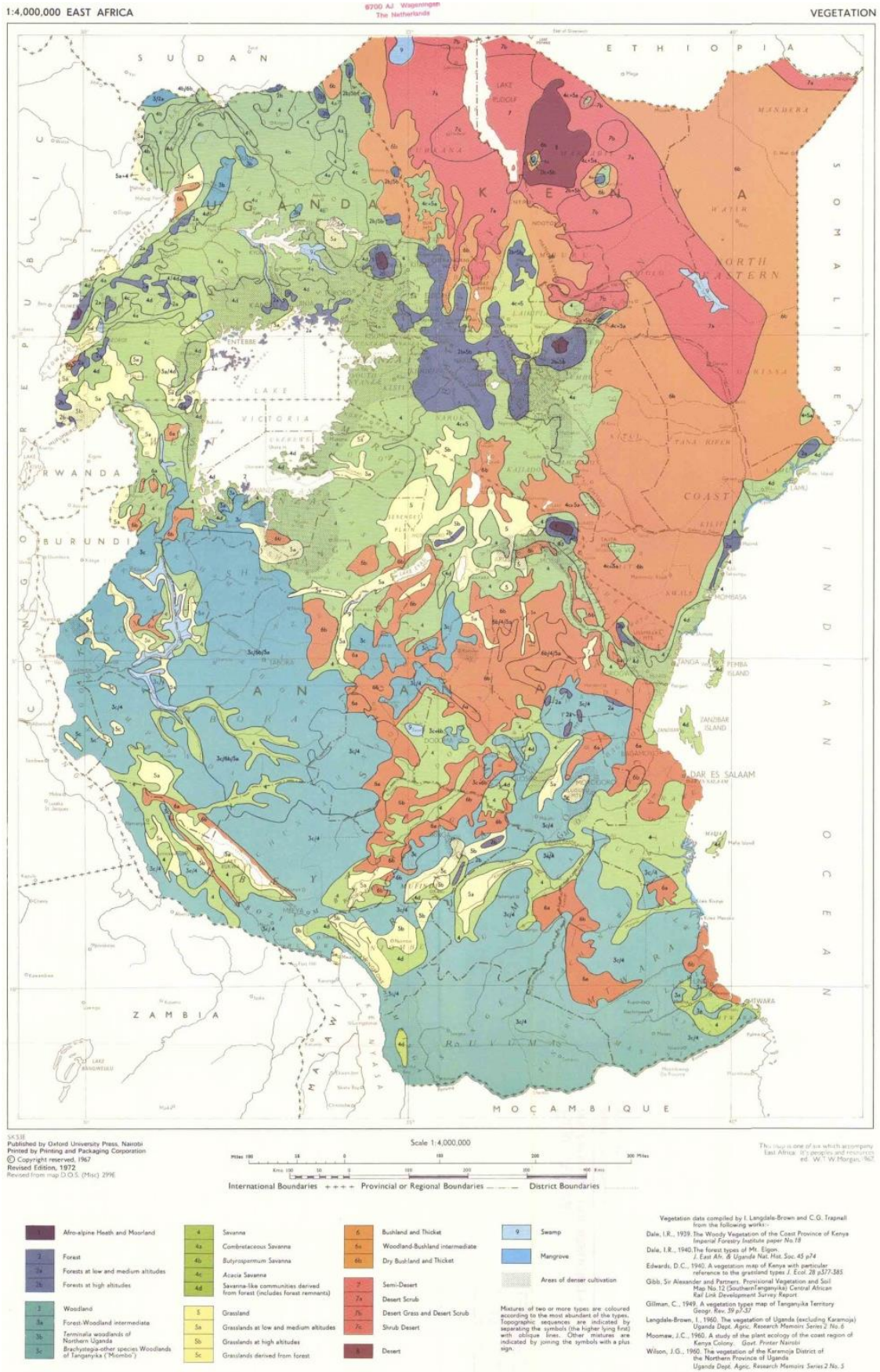
Source: Oxford University press, Nairobi