Figure 9 shows the functionalities and qualities of the different applications for tenure data collection:

Figure 9: Overview Comparative Solutions

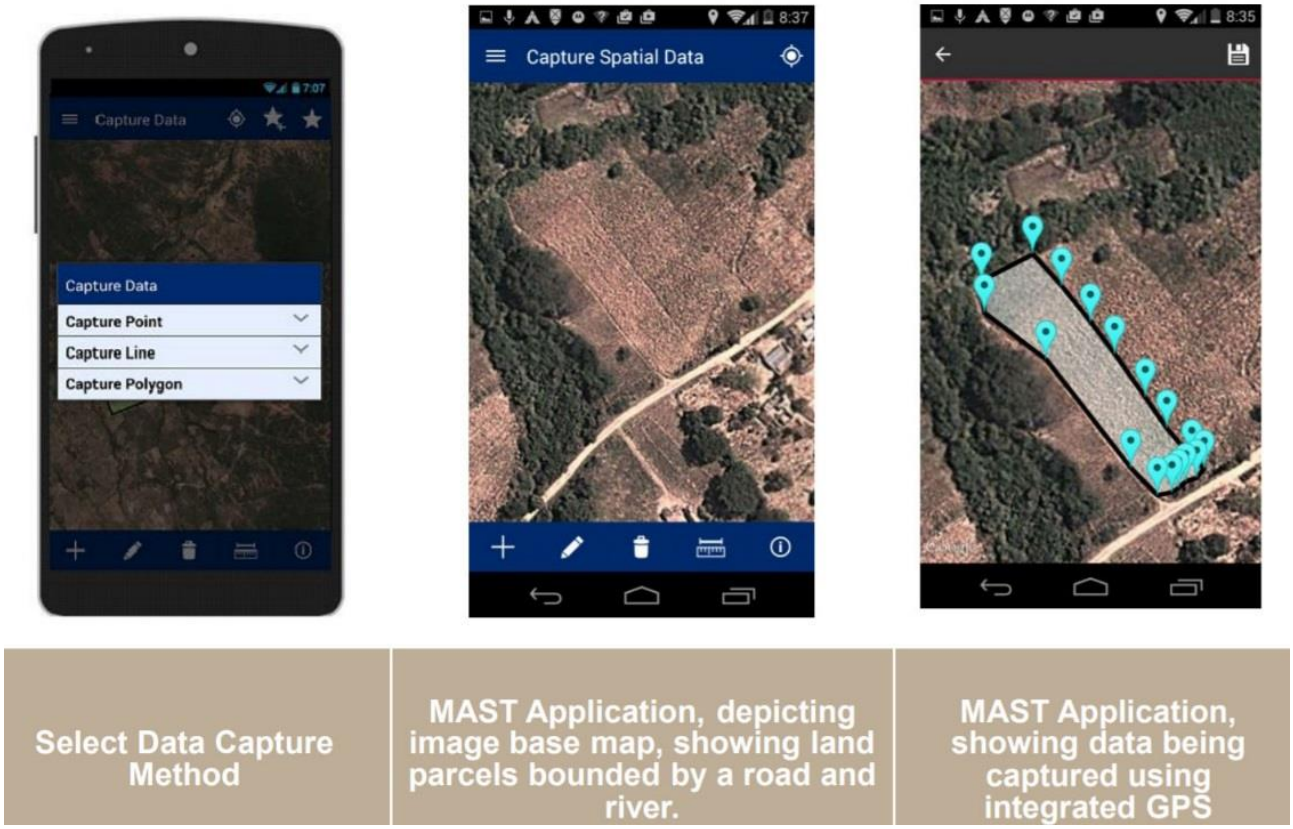
Green	Available	SOLA OT	Cadasta	MAST	STDM	ODK
Yellow	Partly available					
Red	Not available					
Functionality						
Workflow management						
› Dispute handling						
Property management						
› Systematic Registration						
Spatial unit management						
Map spatial information						
Manage rights and right holders						
Digital document management						
Search, retrieve and display						
Reporting						
System Qualities						
Security						
Maintainability/Flexibility						
› System administration						
› Survey form templates						
› Multiple languages						
Other						
› Multiple operating systems						
› E-mail notifications						
› Data import/export						
› Offline use of data						
› Downloadable Installers						
› Host Web data server						
› Support						

- MAST, CADASTA, ODK and SOLA OT perform similar functions based on a similar architecture (server – mobile device synchronisation). STDM offers similar functions but on different platforms and devices (Desktop based).
- SOLA OT has a more sophisticated architecture than MAST and STDM, with much better security and more advanced mapping tools available in the mobile application.
- Cadasta, Mast and STDM describe the use of survey grade GPS receivers connected to a mobile device to improve accuracy of measured coordinates, which are less affordable by communities.
- STDM, MAST and to a certain degree SOLA OT require/rely on a project office and on GIS expertise to advance the data collection work; there is a need for specialists and trainers to set the data collection project and team up.
- Cadasta is hosting one (1) server for all client/partners.
- SOLA, Cadasta and STDM are capable of providing support and training.

1.2.8 Mobile Applications to Secure Tenure (MAST)

Mobile Applications to Secure Tenure (MAST[9]) is an USAID development for tools that use mobile devices and a participatory approach to map and document land and resource rights (see Appendix H.1).

Figure 10 Impression MAST[10]



- MAST software is not available via downloadable installation programs, no demo environment is available. Software developers will always be required to deploy MAST; the sources[11] need to be compiled (for server and mobile app), which requires (senior) software developer knowledge of several technologies (e.g. java IDE, Maven, Android SDK etc.). "*Without knowledge of these it would be difficult for the user to setup the source code and configure to work in debug environment*". The information and instructions on GitHub are limited.

- MAST also provides a simple registration module to administer land records after they have been formalized through a community mapping process: e.g. registration transactions including sales, leases, mortgages, gift, and parcel splits. This registration module is called TRUST, developed for district land offices to manage collected records produced by MAST. Trust is not available in MAST source code on GitHub, it is unclear whether it is available as open source.

[9] https://www.land-links.org/tool-resource/mast-technology/
[10] source http://ansaf.or.tz/wp-content/uploads/2016/05/MAST-PROJECT-FOR-AG-POLICY-2-23-2016.pdf
[11] https://github.com/Mastusaid

- MAST was developed originally for specific project in Tanzania. It was not developed as a generic solution as for example SOLA OT was. Deployments from this version to other countries are based on this Tanzania version. The software architecture has been reported to have issues.

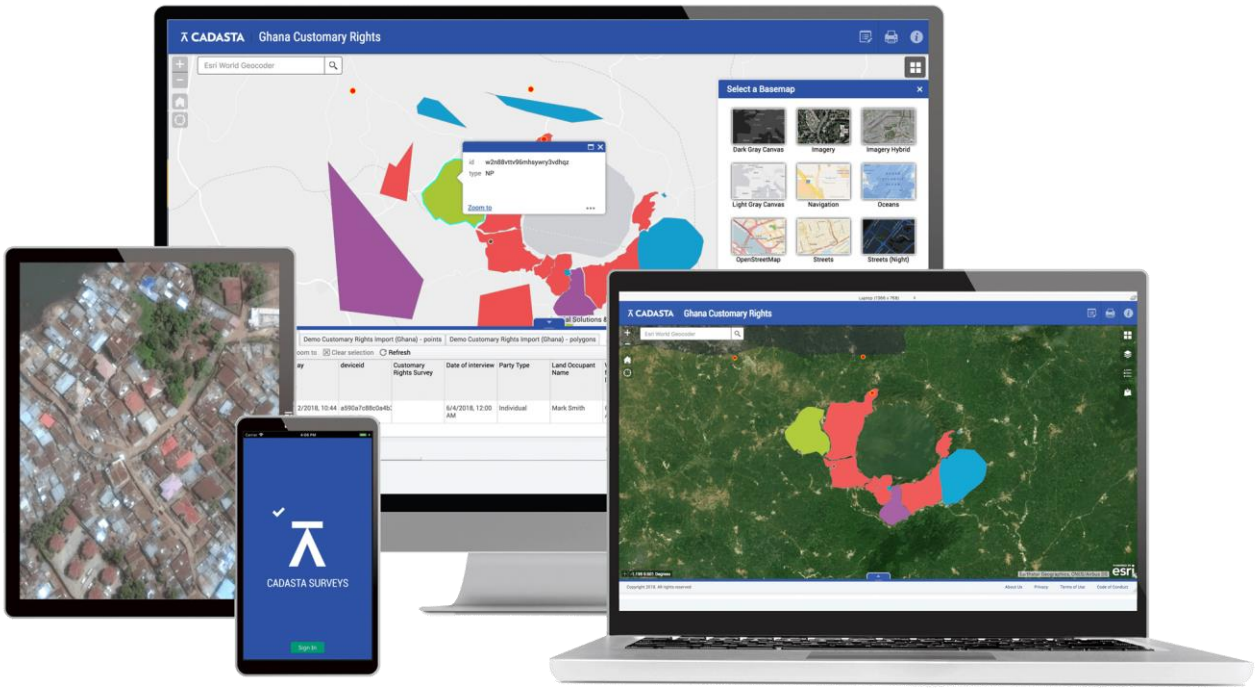
- If a project requires higher GPS accuracy than is available on board a mobile device, MAST can use external GPS devices to capture coordinate locations with more precision; note that this comes with a cost for these external GPS devices.

- MAST is published as open source, but seems to have been just "*dumped on the internet*".

1.2.9 Cadasta

Since 2015, the Cadasta Foundation develops and promotes the use of simple digital tools and technology to capture, analyse and share land and resource rights information, using a full open source stack with tools such as ODK / GeoODK Collect Mobile Application (data collection), QGIS (Desktop GIS) and plugins, PostgreSQL (database). This is labelled the Cadasta Platform 1.0, see Appendix H.2 for a copied description of the Cadasta platform 1.0 elements.

Figure 11: Cadasta Platform[12]



- Since mid-2018, Cadasta 2.0 is introduced, based on the ESRI[13] platform and tools: "*Key learnings from the past two years of working with partners have highlighted a number of needed improvements. To most efficiently address these limitations, we are partnering with Esri…*", and: "*The Cadasta team will be working to onboard all new and existing partners to the Cadasta Platform 2.0 as we begin to transition over to the Esri environment*". Cadasta reported to be currently (November 2018) halfway in making this transition.

- In the context of an approach based on open source tools and open source communities, Cadasta concluded that large scale solutions (e.g. a data collection exercise with hundreds of data collectors) cannot properly be supported by a platform based on open source tools. The uptake, contribution and support by an open source community didn't really materialise (see section 1.4.6).

[12] source https://cadasta.org/platform
[13] https://www.esri.com

- Cadasta issued an RFP to identify a partner for the elements/software for platform 2.0 and consequently selected ESRI. Concerns with regard to data privacy, security, control in ESRIs cloud-based services, have been handled in the agreement between Cadasta and ESRI; the data remains to be the sole property of the relevant partners.

- A license pricing was negotiated with ESRI for their products and services as part of platform 2.0. Cadasta's commitment is to ensure that communities, local NGOs, and customary groups (usually lacking funds) managing less than 10,000 parcels will retain free access and use of the platform. Grants are available to support these groups with training, configuration and customisation services. Organisations with larger datasets and (commercial) project setups, will be billed for a cost recovery of the data storage, and services will be billed at a daily rate.

- Cadasta is available via Google Play store (last update September 2017); technical information[14] last updated July 2017.

- Cadasta is hosting a dedicated webserver[15], physically at Cadasta's premises, offering cloud services for organizations collecting land and resource rights of individuals and communities, and will continue doing that based on the following tools offered (i.e. software as a service [SaaS]):

  - Data Collection Tools:
    - ESRI Survey 123[16]
      - ODK based, only point geometry, white labelled[17]
    - ESRI Data Collector[18]
      - all geometry types, require more advanced mapping skills
  - Use of base maps:
    - Esri Basemaps.
    - Digital Globe satellite imagery.
    - OpenStreetMap.
    - Esri StreetMaps.
  - Project Manager, a web application providing functionality with regard to workflow, data review, quality control, map viewing, digitising, reporting, and exporting data.
  - Operations Dashboard.
  - Advocacy, storytelling on the data with story and thematic maps.
  - New developments with regard to workflow/workforce management and geo-tagged photos is rolled out.

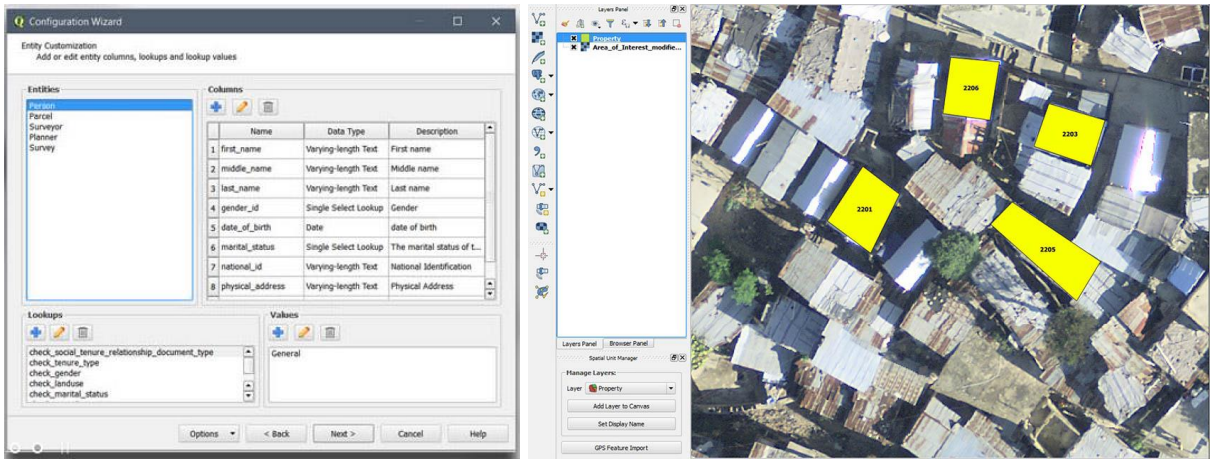
- Cadasta offers support during Cadasta platform project setup and definitions, e.g. training, configuration, special reports, as well as custom development.

[14] https://docs.cadasta.org
[15] https://platform.cadasta.org/dashboard/
[16] https://survey123.arcgis.com/
[17] i.e. branded as Cadasta product
[18] https://doc.arcgis.com/en/collector/

1.2.10 Social Tenure Domain Model (STDM)

The Social Tenure Domain Model (STDM[19]) is an information tool, developed and maintained by Global Land Tool Network (GLTN[20]) as part of their GLTN land tools, "*to bridge the gap between formally registered land and land that is not registered. It is a pro-poor, participatory and affordable land tool for representing a person-to-land relationship along the land rights continuum*" (see Appendix H.3 for more details).

Figure 12: impression STDM[21], a QGIS Desktop GIS plugin



- STDM operates on "client" computers (laptop, desktop) as a plugin to QGIS[22] Desktop GIS (running on operating systems Windows, Mac OS x, Linux); it does *not* operate on mobile devices.
- STDM data is meant to operate on "client" computers with local PostgreSQL database. A central database could be used, but is not part of the standard vision.
- Being a QGIS plugin, STDM is developed in Python program language[23]. Currently, STDM only works on the before last release of QGIS (before version 3); GLTN is working on STDM 2.0 which is a major upgrade that will work QGIS 3.
- A significant degree of flexibility/configurability is offered in STDM.
- Offline data collection is provided through the Open Data Kit (ODK) technology on mobile devices (one of the additions to the latest version).
- Access to external GPS devices is also being considered.
- Activity by open source community seems to be limited.

[19] https://stdm.gltn.net/
[20] https://www.gltn.net/
[21] https://stdm.gltn.net/features/
[22] https://www.qgis.org/en/site/
[23] https://www.python.org/

1.2.11 Open Data Kit (ODK[24])

Open Data Kit (ODK[25]) is a *set* of tools *developed/maintained by University of Washington and a large community of developers, implementers and users. The tools help organizations author, field, and manage mobile data collection solutions*. The architecture consists of a server (ODK aggregate server) which receives information collected (offline) in the field with mobile devices, based on a questionnaire/form:

- ODK is based on (multiple) XLSForms[26] and XForms, an open form standard, to define forms/questionnaires for use in in web and mobile data collection platforms. XForms offer a considerable flexibility in the definition of questionnaire, its questions and their sequence, rules and constraints, default values, and other features that guide and at same time constrain the enumerator.

- ODK is mainly focused at collection of individual questionnaires and offers more flexibility in that than SOLA OT and MAST, Cadasta is partly based on ODK. ODK is a set of tools that can support many distinct use cases, SOLA OT/CS is tailored towards one specific use case: the parcel based field data collection and *moderation*.

- ODK primarily has a focus on initial, first registration (moderation capabilities in ODK are limited). However, the open source community seems to be heading towards a full bi-directional information exchange between server and mobile devices.

- The training of enumerators, operating the mobile devices in the field, is minimal (because of flexibility in designing guiding forms/questionnaires).

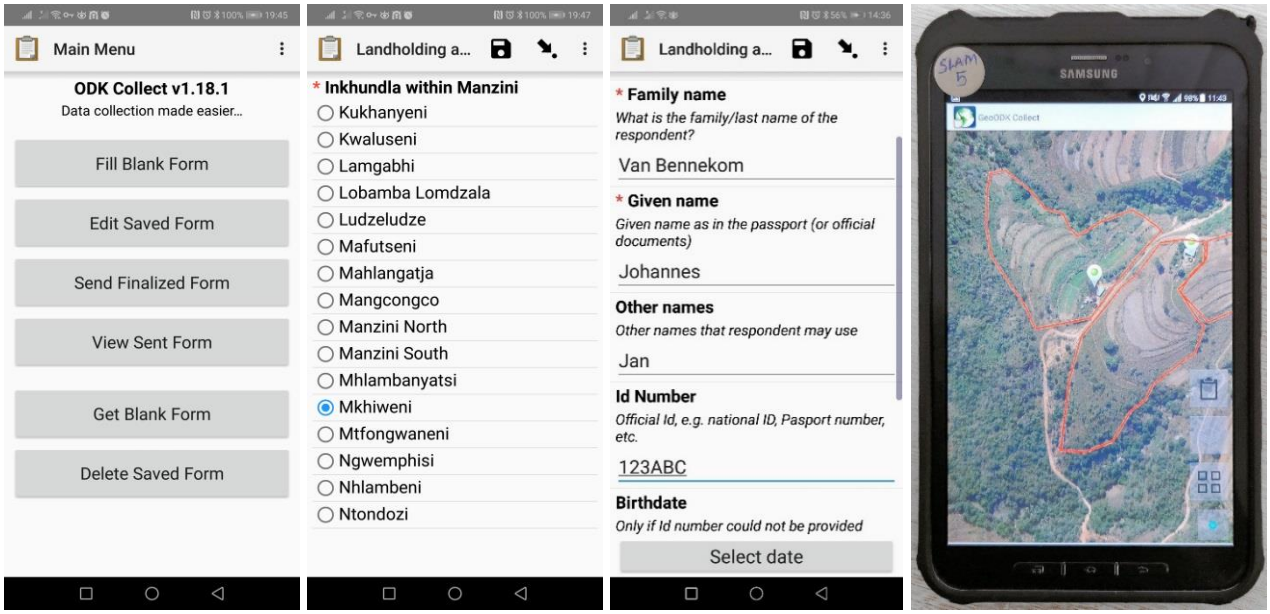
- Specialist expertise in setting up the environment (hosting server, database, edit environment) and defining the questionnaires (in XLS and XForm format) is required.

  ODK tools are only supported on mobile devices with Android operating system.

- ODK has a large, seemingly active, open source community, used in many products and projects (e.g. in STDM, Cadasta, ESRI's Survey 123, FAO's Pan Africa Bean Research Alliance (PABRA) program[27]).

[24] https://docs.opendatakit.org/collect-intro/
[25] https://opendatakit.org/
[26] http://xlsform.org/en
[27] http://www.fao.org/3/I9162EN/i9162en.pdf

Figure 13: Impression ODK and GeoODK Collect (Eswatini/Swaziland)



Example ODK implementation

In Eswatini (Swaziland) a deployment of open source ODK tools was done to collect data on the basis of a questionnaire with 6 sections and 50 information elements on homesteads and households, with several geometries (points and polygons) on homestead fields and community areas. The mobile devices, deployed with GeoODK and ODK Collect (operated by local field teams) are synchronising field collected data with a central server (i.e. an ODK Aggregate web application using a PostgreSQL database). The data clean-up and quality control was performed by local GIS operators, with QGIS Desktop GIS operating on the PostgreSQL database:

- The complete (specialist) setup and deployment of ODK tools was done with 2-3 weeks setup (involving customisation and configuration of questionnaires by senior international IT expert), and 2 weeks guidance/maintenance of the architecture.

- Both ODK and SOLA OT were evaluated by the client, and a choice was made for ODK, mainly because ODK was found to be more flexible to exactly implement the client's requirements.