Responsible Land Governance:
Towards an Evidence Based Approach
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Towards an Evidence-Based Approach

Lightning Talk

Innovative Rural Cadastre Development in Ethiopia

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Abstract

Ethiopia is a Federal Democratic Republic whose constitution and land legislation gives significant powers to its regional states. Against this background and with the support of the Responsible and Innovative Land Administration Project (REILA), the Ministry of Agriculture and Natural Resources (MoANR), which is responsible for managing and administering the rural land sector, developed an IT strategy in order to find the most suitable solution to harmonise rural land administration in the country. This strategy paved the way to building and developing the National Rural Land Administration System (NRLAIS).

The development of a pilot system to implement this IT strategy was awarded to Hansa Luftbild, a geoinformation services company from Germany. It is based on FOSS components and applies the ISO Land Administration Domain Model (LADM) standard. With its innovative and cost-effective architecture and modular "tool-kit" approach it is independent of a fully functioning internet infrastructure and can be easily adapted to cater for different legal requirements of the Ethiopian regional states, which is on the base of NRLAIS technical specification (LAUD, 2015).

The actual system development were commenced in April 2015. A prototype was delivered in December 2016, and by the end of April 2017 the system is expected to be ready for scaling up after system trials and rigorous testing at six different pilot offices in two regions (Tigray and SNNP) of the nine regions of Ethiopia. The trials cover also the Ministry's central office in Addis Ababa. The trial phase is giving additional opportunities to improve the system before its broader scaling up which is expected to start in the 2nd half of 2017.

NRLAIS represents all the processes of rural land administration which are carried out at the respective administrative levels from the central Federal Ministry of Agriculture and Natural Resources down to the district (woreda) and their respective sub-districts (kebele). Accordingly, its functionality is different at each level. At the central level the IT solution aggregates the data and information from the lower regional level in order to support the federal decision making, policy and reporting about all the regions. The IT solution at the regional level provides advanced data processing and management of cadastral parcel data, which is aggregated from the zones and districts (woredas) within that region. The system has the capability at the zonal level to view and carry out administrative tasks on data aggregated from the relevant districts. The IT solution at the district / woreda level is the core of the NRLAIS with functions to register and manage land holding rights.

The NRLAIS is developed such that the storage of all data, i.e. geometries and associated textual information, is in a PostGIS back end and is accessed either through a QGIS or a web-based front end. The web front end is called ExperMaps, which consists of several open source software tools, such as node.js, and communicates to a geoserver in order to provide the relevant OGC services. The lowest administrative level, the so-called kebele or sub-district, is the window to the system. At this level applications are received and data collected in order to make the land administration process convenient to the land holders, i.e. the local farmers. The IT solution is also providing a mass registration tool for systematic land registration and a robust data migration tool to convert existing land records, which were captured in different formats, to the NRLAIS.

Key Words:

Land Information System, LADM, Cadastre, System Design, FOSS

1. Introduction

Following the enactment of the 1994 constitution, Ethiopia has adopted a federal state structure which devolved much of its legislative, juridical and executive powers to the nine semiautonomous regions. The 1994 constitution clearly states the right to ownership of urban and rural land is vested with the state; citizens occupy land through possession rights held as perpetual use rights in the rural sector and as fixed term leases in urban areas. The tenure system is evolving differently in the rural and urban sectors, with different federal proclamations governing development and reforms progressing at different speeds in different regions.

Rural land is held by individuals through perpetual use rights, i.e. these are possession rights which can be considered as equivalent to long term leases held in perpetuity (without a fixed termination date) which can be transferred through inheritance. Recent legislation also allows exchange and sublease of land, allowing a secondary market to emerge. In practice, the secondary market is yet to emerge in the rural sector and the emphasis is still on the first registration process (first and second level certificates). Land matters are expedited through executing agencies established at the regional, zonal, woreda and kebele levels. In four regions of Ethiopa (Tigray, SNNP, Oromiya and Amhara) significant progress has been made in the issuing of certificates to landholders in the rural sector, with an estimated 85% of holding rights now issued out of a total estimated to be 13 million rural landholdings and 50 million parcels.

In Ethiopia, rural land registration has historically been divided into “First level Registration”, and “Second level Registration”. The first level registration process included the identification of the land holder and his/her neighbours as well as an estimation of the holding size. A Land Holding Book, which lists the parcels held by that person, was issued. This registration process was a response by the Ethiopian Government to existing tenure insecurity and has been commended in several international publications (cf. Deininger et al 2007).

The second level registration completes the process by adding a spatial or cadastral component, a parcel map with the exact boundaries and area size of the respective parcel. The rationale is that in a situation of growing population and pressure on land only the complete textual, legal and spatial registration information can provide full tenure security and reduce land conflicts.

The Rural Land Administration and Use Directorate (RLAUD) of the Ethiopian Ministry of Agriculture and Natural Resource (MoANR) was established in 2011 to be responsible for regulation and coordination of all rural land administration processes across the entire territory of the Federal Republic of Ethiopia.

Each of the nine regional states is responsible for the implementation of the land administration services within its region based on the federal laws and regulations. This situation has resulted in different regions implementing the land administration system in slightly different ways. Some regions are very much in advance of others in terms of numbers of parcels registered and the level of service provision.

2. Project Background

In an effort to both accelerate land registration and promote standardization of procedures, RLAUD decided to develop and implement the National Rural Land Administration Information System (NRLAIS). The initial development serves also to test if the option proposed by the IT strategy of MoANR is viable and if the developed system, which is to be tested at pilot sites, can provide a platform or toolkit to be put into operation, with some modifications, in any of the nine regions.

The REILA Project is a bilateral development project funded by the Government of Finland and implemented by NIRAS International Consulting. At the federal level the project provides technical assistance to RLAUD as well as to the Agricultural Investment Support Directorate (AISD) in the MoANR and to the Ethiopian Mapping Agency (EMA). REILA aims to improve the institutional capacity in RLAUD and to contribute to harmonized land administration procedures in Ethiopia with appropriate legal and technical framework developments. With regard to the heterogeneous land legislation situation the MoANR asked the REILA project to develop an IT strategy to identify a viable way to harmonise digital land information in the country. The strategy, completed in 2012, provides a migration path from existing systems in the Regional National States to a new national system based on a common set of standards, and a data model to be implemented in all regions (noting that regions may further develop their own systems as long as in compliance with NRLAIS).

After an international tender, RLAUD awarded the pilot system development to Hansa Luftbild, a geoinformation services company from Germany.

3. Objective / Purpose of NRLAIS

The main objective of the NRLAIS was to develop and implement a land administration information system which can be used with adaptation, if required, by all nine federal regions of Ethiopia. The initial system is currently being tested and trialed at pilot sites in two regions. The NRLAIS is being deployed and operationally tested in several configurations located as follows:

a) at the Ministry headquarters in Addis Ababa

b) at two regional headquarters (Tigray and SNNPR)

c) within each of the two chosen regions, at a zonal office and at a woreda office.

The system has been designed such that additional zones and woredas, can be brought on line progressively within the pilot regions, as well as new regional installations configured and installed over time. The NRLAIS embraces all of the land administration functions which are carried out at each of the federal, regional, zonal and woreda level. The required functionality is different at each level, and the NRLAIS has effectively the following versions

- CENLAIS - the central IT system for the aggregation of data and information to support decision making and national policy development support which covers all regions of Ethiopia
- REGLAIS – the IT system for the operation at regional level with advanced data processing capabilities and management of cadastral parcel data as well as managing all zones / woredas within that region
- ZONLAIS –the system capable of viewing and carrying out administrative actions at the zonal level
- WORLAIS – the IT system located at the woreda level to manage possession/holding rights; cadastral parcel data; and manage the linkages and updates.

The NRLAIS is supported by two further components:

- MASSREG – a mass land registration system with technical tools for systematic (mass) registration (combined first and second level certification). This will build on the pilot 2nd level registration pilots taking place in Ethiopia.
- a set of NRLAIS standard operating procedures for carrying out sporadic transfers and other transactions

Central to the NRLAIS development was the “toolkit” approach to managing the functionality at the different levels with the ability to customise the toolkit for different regions. For example, some regions require administrative functions at the zone level, others do not.

The pilot system was developed in such a way that it could be adopted by any of the other regions which are not part of the pilot regions, and in order to be their land administration system.

4. System Requirement Specification

The system requirements specification / requirements analysis was conducted first on the basis of the project terms of reference. The main focus was to clarify the requirements which directly affect the technical system as documented within technical documentations which are NRLAIS business process reengineering (HansaLuftbild, 2016b) and system requirement specification (HansaLuftbild, 2016a). The analysis and specifications covered the following main topics:

- Previous work related to rural land administration
- Stakeholders
- Legal framework (national and regional)
- Situation verification in 4 Ethiopian regions (Tigray, SNNPR Amhara and Oromia)
- Situation verification at the Ethiopian Agriculture Investment Land Administration Agency
- Current business processes in relation to NRLAIS
- Existing IT infrastructure at the pilot sites
- Migration of existing land administration data
- Updating procedure related to the Ethiopian Rural Land Administration System (RLAS)
- Issuance and delivery of landholding certificates related to RLAS
- Clarification of open issues related to the requirements specified in the terms of reference
- Definition of requirements (functional / non functional)

After carrying out the requirements analysis the domain and conceptual model were determined. For the real property and cadastre domain, the ISO standard 19152, “Land Administration Domain Model (LADM)” was used as the basis for the specification of the NRLAIS conceptual (Oosterom, 2009). LADM was adapted to the requirements of the rural land administration sector of Ethiopia. Figure 1 shows an overview of conceptual data model which was applied in NRLAIS.

The data model was structured as four main packages plus one support package. These packages were:

- Party
- Administration
- Source
- Spatial
- Auxiliary classes

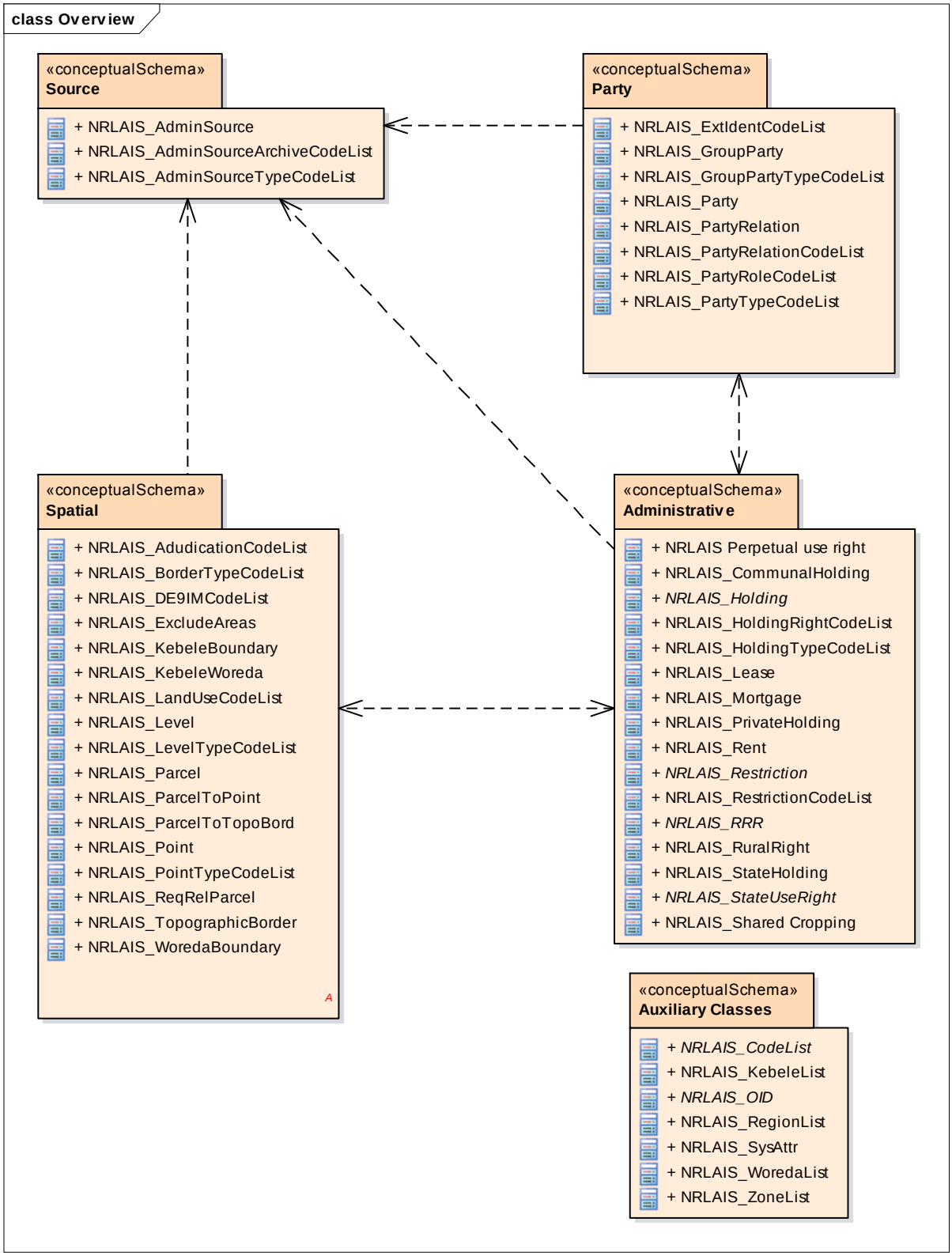

Figure 1: Overview of the NRLAIS conceptual data model (Hansa Luftbild, 2016)

The “Auxiliary Classes” package was used to model common structures such as code lists or common attribute sets. In contrast to the standard LADM, the admin Source concept was modelled in a separate package which was titled “Source” and was not part of the administration package as practiced in different projects (Rohan Bennett, Abbas Rajabifard, Mohsen Kalantari, Jude Wallace, 2015). The reason for this change was that the source package was defined as the conceptual link to the archive which was associated to all other main packages. The conceptual model for NRLAIS was therefore a tailored implementation of LADM, i.e. not all concepts of LADM were implemented. For example, the versioning of objects as defined by LADM was not implemented, as defined in the standard, because NRLAIS uses a different approach for parcel history and versioning as shown in Table 1.

Name	**Description**
NRLAIS_Inventory	This area contains the actual valid state of NRLAIS. Information in this area is legally valid in the present
NRLAIS_History	This area contains previously valid states of NRLAIS. Information in this area was legally valid in the past
NRLAIS_Transaction	This area contains the states, which become valid after a transaction is completed and approved. This state is only temporarily available during a transaction. Information in this area becomes legally valid in the future.

Table 1: NRLAIS model for the database schemas (Hansa Luftbild, 2016)

The three schemas shown in Table 1 each contains the same domain specific information; and therefore, the class model on the level of the conceptual model is identical.

The history of a parcel starts with a transaction. All data involved in a transaction is first transferred to the beginning of the transaction from NRLAIS Inventory to NRLAIS_History. The changes are then applied to NRLAIS Transaction.

After the transaction is completed and confirmed, the new state of the data is transferred from NRLAIS Transaction to NRLAIS Inventory thus becoming the new valid legal state.

If a transaction is not confirmed then the temporary state in NRLAIS Transaction and the saved state in NRLAIS_History will be removed and NRLAIS returns to the state it was in before the transaction was initiated.

The security aspects of the system were also handled during the requirements specficiation. This covered data security regarding the protection of data against loss, damage and unauthorized access, and data integrity with reference to correctness of data in relation to the conceptual data model.

During requirements specification twenty one system use cases were identified and documented. These are listed in Table 2.

Use Case No.	Name
1.	Transfer of a usage right
2.	Add rent/shared cropping right
3.	Add/remove/update party
4.	Change party role
5.	Add/ remove relationships between parties
6.	Add/remove/update group party
7.	Add newly ascertained right
8.	Add/remove/change mortgage
9.	Edit parcel (split)
10.	Edit parcel (merge)
11.	New registration of parcel
12.	Boundary correction
13.	Add/Remove perpetual usage right (PUR) to/from a holding
14.	Add/Remove state usage right (SUR) to/from a holding
15.	Change holding type
16.	Add a parcel to a holding
17.	Information retrieval
18.	Create cadastre and property rights information extract
19.	Issue of certificate
20.	Replacement of certificate
21.	Approve changes

Table 2: System use cases identified during the requirements specification of NRLAIS (Hansa Luftbild, 2016)

Figure 2 and Figure 3 show two sample diagrams of the system use cases 1 and 8, respectively, which are listed in Table 2.

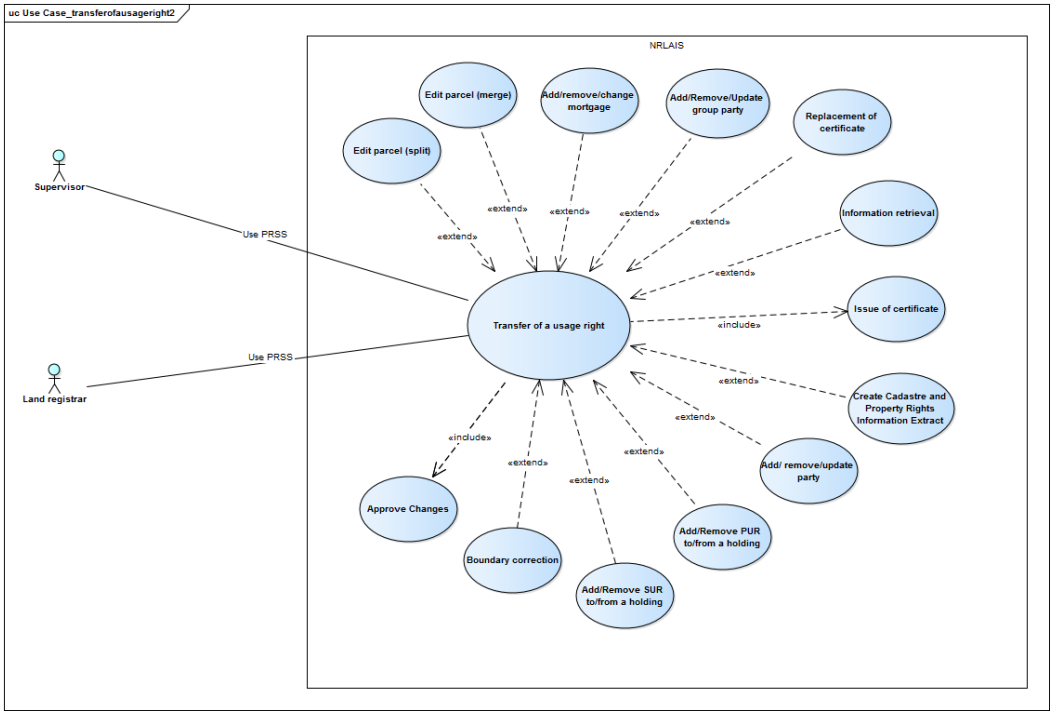

Figure 2: Use case diagram of the "Transfer Usage Right" case (Hansa Luftbild, 2016)

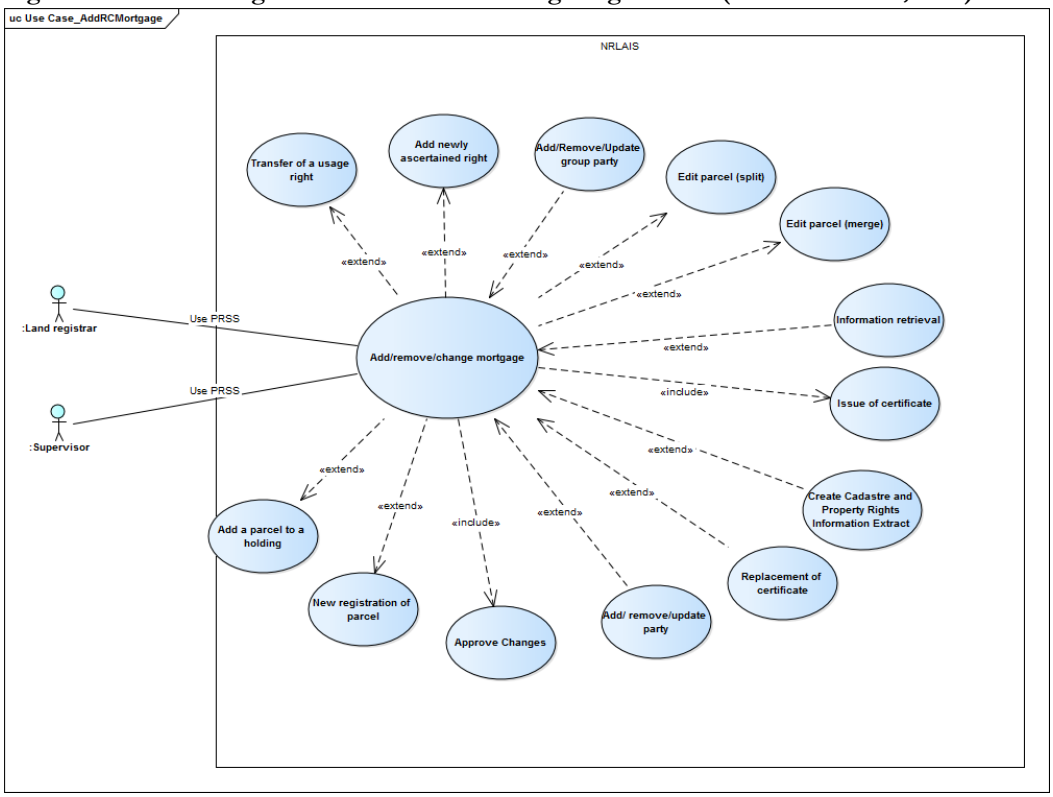

Figure 3: Use case diagram of the 'Add/remove/change mortgage' case (Hansa Luftbild, 2016)

The identified system use cases were based on the technical specifications of the terms of reference. Table 3 lists the required transaction types of the WORLAIS configuration mapped to the relevant use cases given in Table 2.

Transaction type	**Relevant use cases**
1. Modifications to Use Rights, Responsibilities or Restrictions to land	
a. Inheritance	1,13,14
b. Gift	1,13,14
c. Exchange	1,13,14
d. Divorce	1,13,14
e. Rent	2
f. Encumbrances	8
g. Add or remove disputed status	Any use case from 1 to 12
2. Modifications to Land Holders	
a. Create holder	3,13,14
b. Change holder status (e.g. non-active/active, addition/removal of guardianship, death)	3, 4, 5, 15
c. Change holder personal details (name, residence marital status)	3
d. Changes to holder lists	6,15
3. Modifications to Land Parcels	
a. Parcel extent	
i. Formation / creation of new parcel,	7, 11
ii. Subdivision,	9
iii. Amalgamation / Merging	10
b. Parcel lease (commercial tracts)	2
4. Modifications to holdings	
a. Addition/removal of parcel to holding list	16
b. Addition/removal of holder in holding list	13,14
c. Redistribution of holding (disaggregation)	1, 5, 6, 13,14
d. Split/Merging of holdings	6,15
e. Confirm holding status	15
5. Other transactions	
a. Redistribution	13,14,16,
b. Change of land use	2
c. Expropriation	13, 14

d.	Ex-Officio changes	Any use case from1 to 12
6.	Reporting and Information Provision	
a.	Provide information about individual registered holdings or parcels	18
b.	Provide reports and maps for administration and planning, etc.	Any use case from18 to 20

Table 3: Transaction types of the WORLAIS configuration mapped to the relevant system use cases (Hansa Luftbild, 2016)

5. System Architecture

NRLAIS as a national system is required to provide functionalities for different administrative levels, ie from district to central. The system requirements were associated to the three specified system levels of NRLAIS, which are WORLAIS, ZONLAIS, REGLAIS and CENLAIS. Therefore, the NRLAIS was designed on the basis of different components and subsystems which adhere to the toolkit approach as designed in the System Design Description(HansaLuftbild, 2016c). These subsystems are:

- Web information provision subsystem (WIPSS)
- Property registration subsystem (PRSS)
- Cadastre maintenance subsystem (CMSS)
- Process subsystem (PSS)
- Database (DB)
- Document management subsystem (DMSS)
- Service level

Figure 4 shows the system overview of the NRLAIS at the different organisational levels, i.e. CENLAIS, REGLAIS, (ZONLAIS) and WORLAIS, in relation to the afore-mentioned subsystems. The different transaction types which can be carried out on NRLAIS are conducted with the PRSS and the CMSS by the end user.

WORLAIS is an integrated land administration system and the productive system of NRLAIS. It allows the management and the maintenance of property rights and cadastral information. All transaction relevant processes such as the management of property rights and cadastral data are carried out by the WIPSS, CMSS, PRSS and PSS subsystems. At the backend, the inventory, transaction and history databases allow the transaction data management and archiving, which is controlled by the PSS system. WORLAIS data can be exported and aggregated to match the requirements of the REGLAIS.

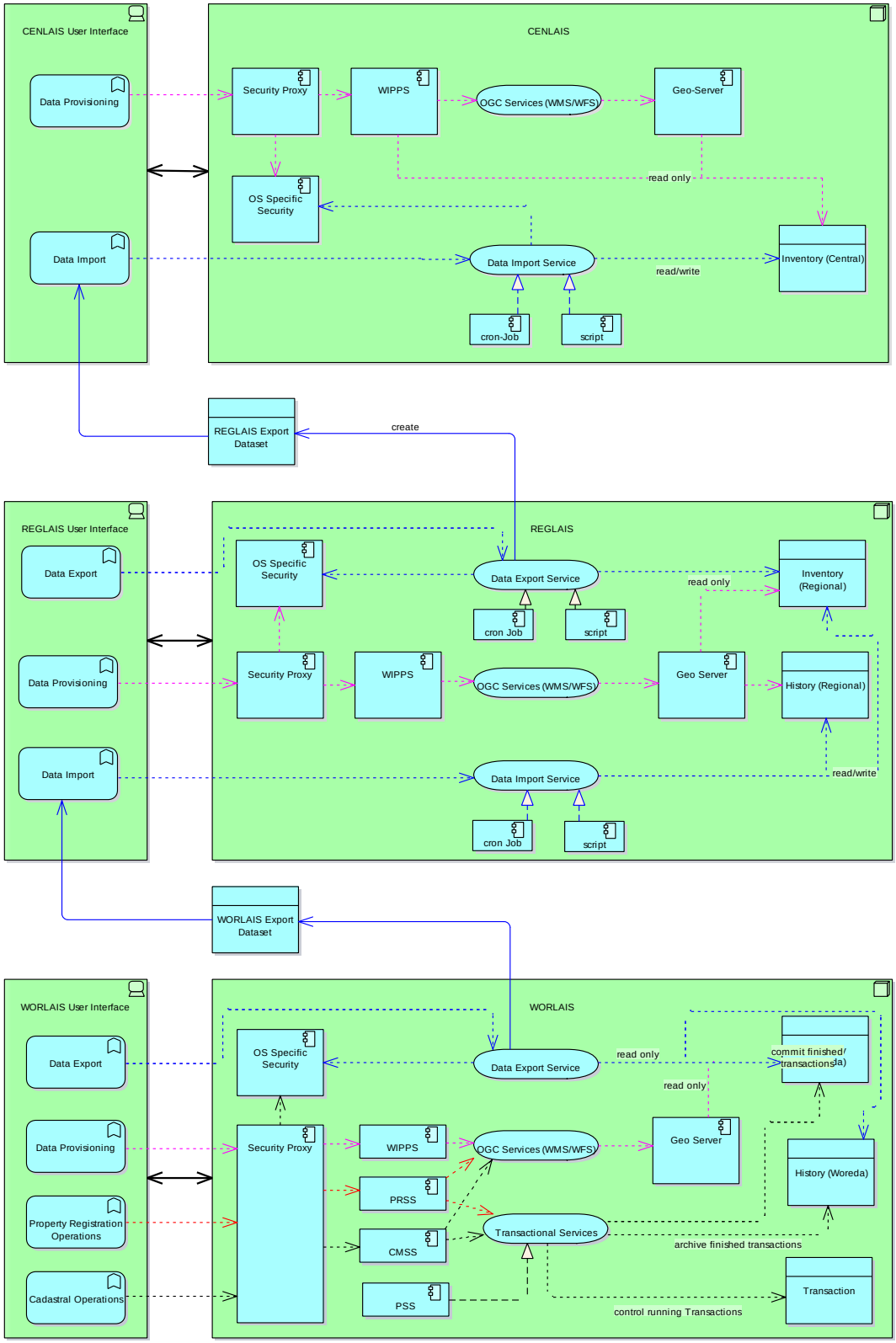

Figure 4: System overview of NRLAIS from Woreda (District) to federal level (Hansa Luftbild, 2016)

Data from the districts (woredas) serve as an information source within REGLAIS, no transactions are conducted above the woreda level. The information service is provided by WIPSS and PSS. In addition, data can be archived at the regional level. The data exchange to national / central applications at the CENLAIS level is conducted by import and export functionalities in WORLAIS and REGLAIS. CENLAIS serves as an information system only and has no data archiving functionality implemented in it. On the basis of the NRLAIS requirements the extent of functionality of each of the six subsystems is gradually reduced from the woreda level to the central / national level, as e-governance of cadastre (Hull & Whittal, 2013). The system use cases, which were identified during the requirements specification, were mapped to the subsystems of the NRLAIS as is shown in Table 4.

Use Case	**Name**	**Covered in System / Subsystem**
1.	Transfer of a usage right	WORLAIS - PRSS
2.	Add rent/shared cropping right	WORLAIS - PRSS
3.	Add/remove/update party	WORLAIS - PRSS
4.	Change party role	WORLAIS - PRSS
5.	Add/ remove relationships between parties	WORLAIS - PRSS
6.	Add/remove/update group party	WORLAIS - PRSS
7.	Add newly ascertained right	WORLAIS – PRSS
8.	Add/remove/change mortgage	WORLAIS – PRSS
9.	Edit parcel (split)	WORLAIS – PRSS; WORLAIS - CMSS
10.	Edit parcel (merge)	WORLAIS – PRSS; WORLAIS - CMSS
11.	New registration of parcel	WORLAIS – PRSS; WORLAIS - CMSS
12.	Boundary correction	WORLAIS – PRSS; WORLAIS - CMSS
13.	Add/remove perpetual usage right (PUR) to/from a holding	WORLAIS – PRSS
14.	Add/remove state usage right (SUR) to/from a holding	WORLAIS – PRSS
15.	Change holding type	WORLAIS – PRSS
16.	Add a parcel to a holding	WORLAIS – PRSS; WORLAIS - CMSS

17.	Information retrieval	CENLAIS-, REGLAIS-, ZONLAIS-, WORLAIS-WIPSS
18.	Create cadastre and property rights information extract	WORLAIS – PRSS
19.	Issue of certificate	WORLAIS – PRSS
20.	Replacement of certificate	WORLAIS – CMSS
21.	Approve changes	CENLAIS-, REGLAIS-, ZONLAIS-, WORLAIS-PSS

Table 4: System uses cases identified during the requirements specification mapped to the subsystems of NRLAIS (Hansa Luftbild, 2016)

Figure 5 shows the overview of the different subsystems and services vis-à-vis the NRLAIS.

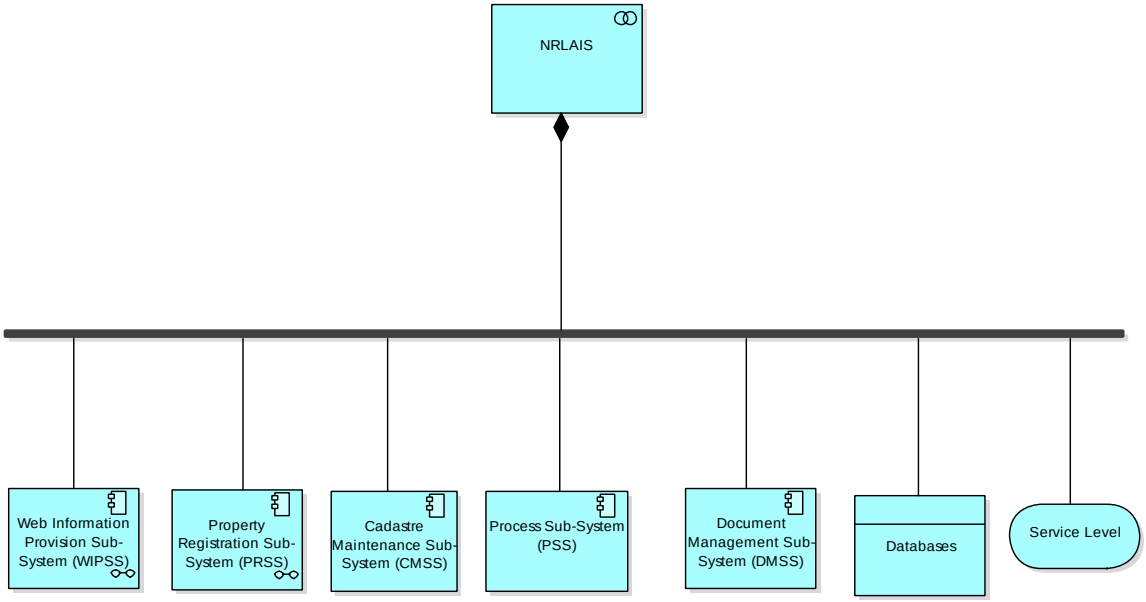

Figure 5: Overview of the different subsystems and services of NRLAIS (Hansa Luftbild, 2016)

International standards and a best practices approach were applied in the design and the development of the NRLAIS. These standards were:

- Standard web architecture
- Standard programming languages such as JavaScript (ECMAScript 5) or Python
- SQL
- Web standards such as HTML, HTTP, XML, SOAP
- UML
- LADM

6. System Development and Operational Acceptance Testing

- NRLAIS Development

Hansa Luftbild developed the entire NRLAIS system with open source software. The advantages of open source are manifold for the client. These are:

- The application can be installed on as many nodes as needed, without license costs.
- Reduced costs for base software. The system can operate on Linux. For example, if all 800 sites run two servers each, then the cost of the server operating system will be significantly more if proprietary software should be used.
- Due to the availability of the source code, the translation of tools like QGIS into local Ethiopian languages is possible.
- Stable and community driven development processes. PostgreSQL for example has been under continuous development since 1997 without interruption.

Table 5 lists the open source software components, which were used in the development and implementation of the NRLAIS:

Name	**Usage**
PostgreSQL	Database management system. PostgreSQL was used on all levels of the NRLAIS for storage of structured and semi-structured data
PostGIS	Extension for PostgreSQL was used to handle spatial data.
QGIS	Desktop GISwas used in the NRLAIS for high-end editing, visualisation and analysis of geospatial data.
GDAL/OGR	Converting different GIS formats
Geoserver	Geoserver used on all levels of the NRLAIS for OGC compliant services such as WMS or WFS
MapProxy	MapProxy used as proxy to encapsulate WMS requests for performance and security reasons
ExperMaps	Basis for web based geospatial clients in the NRLAIS
node.js	Application environment
Python	Customisation of QGIS

Table 5: List of open source software used in the development of NRLAIS (Hansa Luftbild, 2016)

The system components / subsystems of the NRLAIS were developed on the basis of the system requirements and the system design. They are physically independent but logically dependent on each

other and are connected to each other at database level. They were implemented according to their specific purpose.

The following paragraphs describe the development of the subsystems, where each subsystem has its own specialized graphical user interface to handle different types of data and to fulfill the corresponding tasks.

- Database

The NRLAIS database architecture was separated into three different types of databases:

- the main database contains current processed data and is the source for information requests,
- the transaction database deals with the transaction data from the initialization of a new transaction until it reaches its finished status as an accepted or rejected transaction process, and
- the archive database files regularly conducted transaction processes and the content of the main database

The databases of the NRLAIS were implemented in PostgreSQL with the extension PostGIS, **Error! eference source not found.** shows the application structure of the DB.

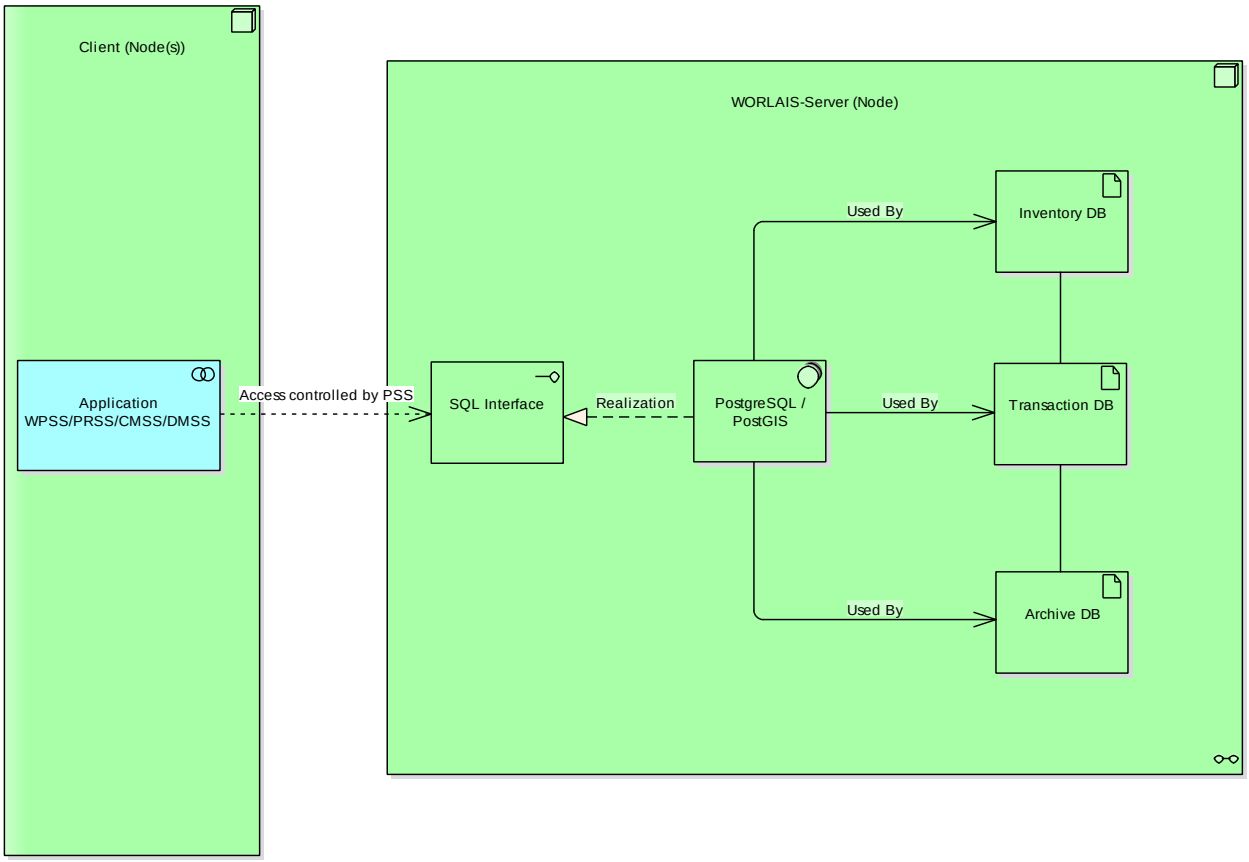

Figure 6: Application structure of the database DB (Hansa Luftbild, 2016)

- **WIPSS**

The Web Information Provision Subsystem (WIPSS) was developed as a read only service, which accesses the land register and the cadastre database. The subsystem was implemented on top of ExperMaps, a webGIS developed with open source software. Figure 7 shows the application structure of the WIPSS.

- **PRSS**

The Property Registration Subsystem (PRSS) was implemented as a web application, which is responsible for the maintenance of the land register. It was implemented as an extension of ExperMaps with node.js server as a backend. For the user interface, additional implementation in JavaScript was carried out to support AJAX (Asynchronous JavaScript and XML) capabilities. This eliminated the need for installation or configuration on the client side of the PRSS. Future changes will be able to be performed easily at low maintenance and administration costs. PRSS includes ExperMaps for displaying the geometry (spatial data). The communication with the NRLAIS server components and service level were implemented with web-service techniques.

PRSS is capable of performing transactions on the land register, reading directly from the main database. All transactions will be handled by a transaction manager, a tool which manages the transaction process. PRSS selects and locks the data need for a transaction. During the transaction, the data remains unchanged in the main database and is identified as a transaction. Changes made by the PRSS during a transaction are stored in a separate area of the database, i.e. in the transaction database. When changes to the data are completed then these changes are passed on via the transaction manager to the main database for application to the land register. This procedure ensures the integrity of the database at any time by committing the changes by one instance rather than many instances. The PRSS has limited functionality for maintaining the cadastre and covers first level registration only. The transaction handling is here carried out in the same way as a transaction on the land register. A transaction can therefore combine changes in the land register as well as in the cadaster. Figure 8 shows the application structure of the PRSS.

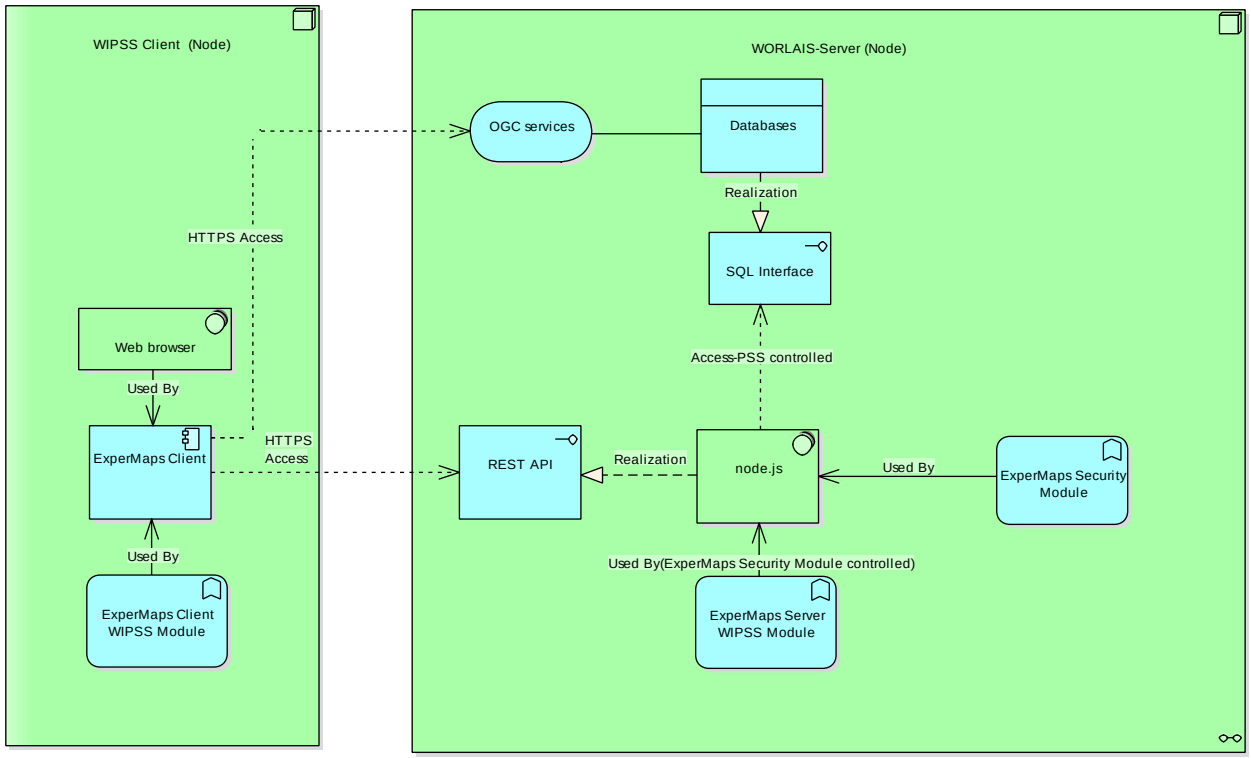

Figure 7: Application structure of the WIPSS subsystem (Hansa Luftbild, 2016)

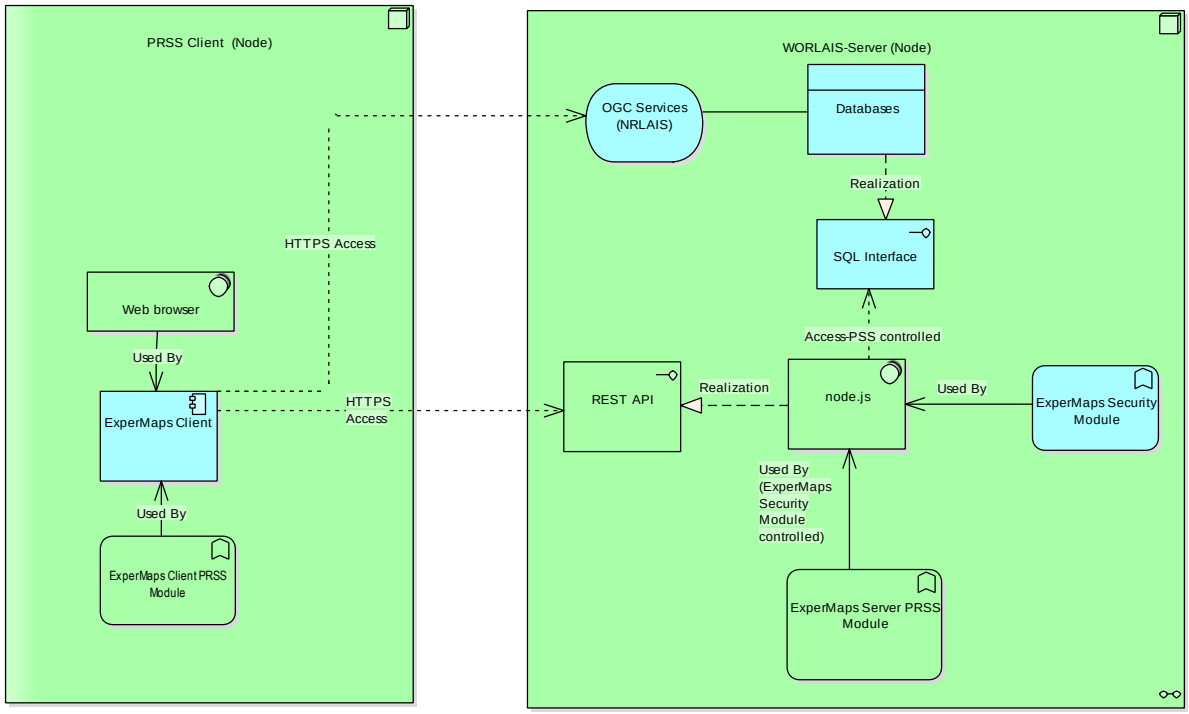

Figure 8: Application structure of PRSS subsystem (Hansa Luftbild AG, 2016)

- **CMSS**

The Cadastre Maintenance Subsystem (CMSS) client was implemented as a customized application inside QGIS. QGIS is a user friendly open source desktop geospatial information system which provides a lot of functionalities including a special cadaster application. This application, which was implemented in Python as a plugin in QGIS, allows the management of cadastre functionalities. QGIS was configured in the main at the user interface level in order to provide those functionalities and elements only, which are necessary for the CMSS.

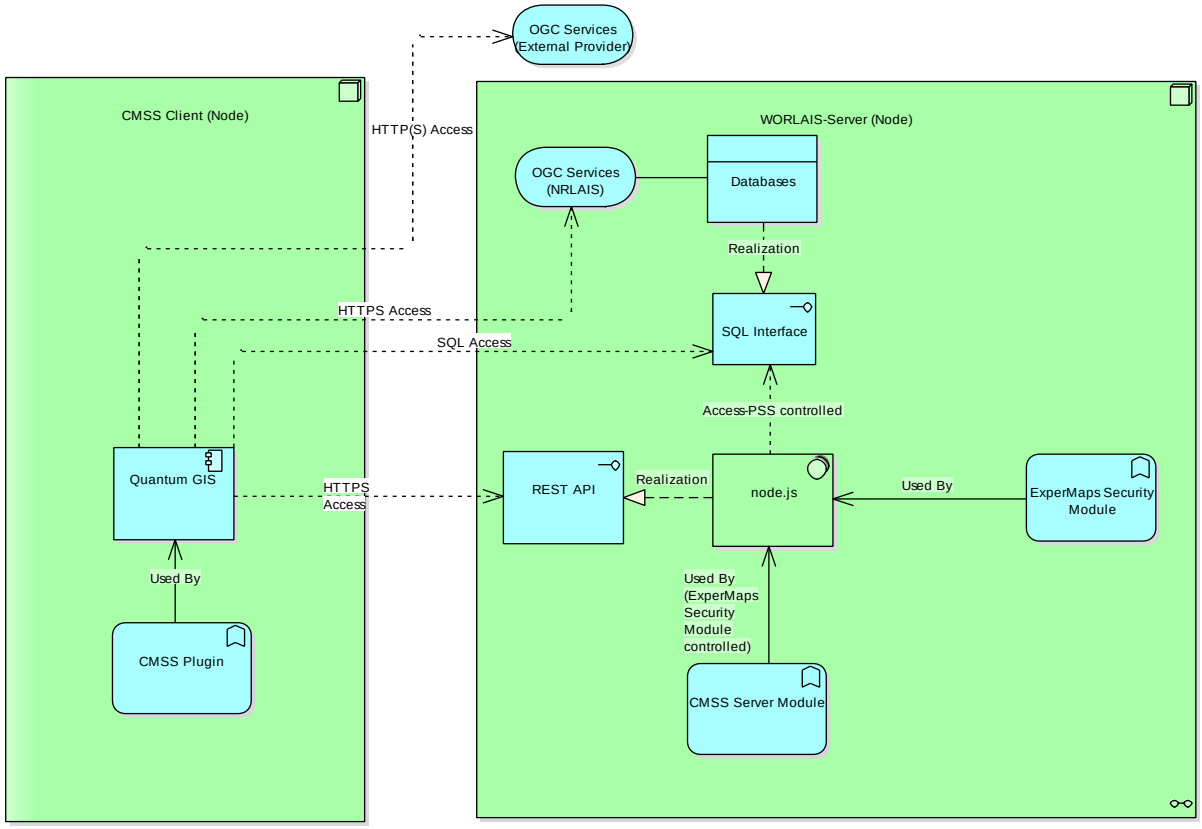

Figure **9** shows the application structure of the CMSS.

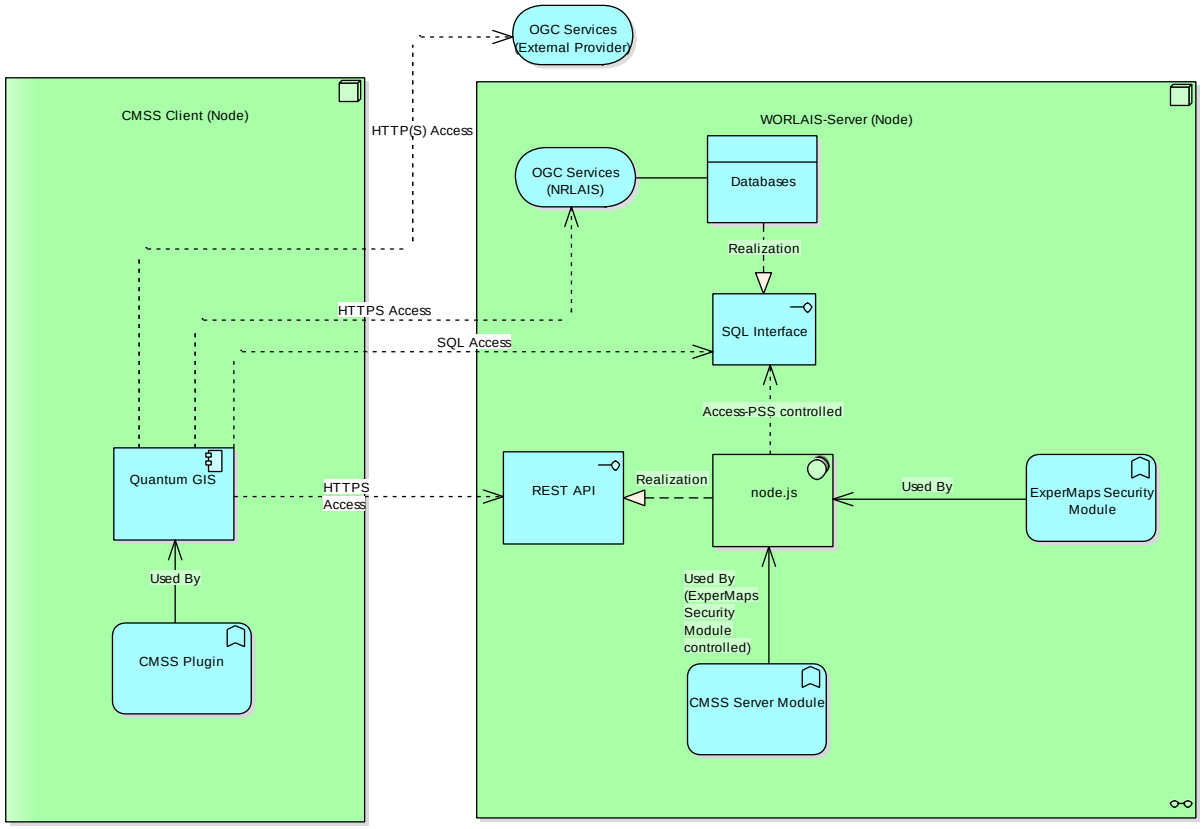

Figure 9: Application structure of the CMSS subsystem (Hansa Luftbild, 2016)

- **DMSS**

The Document Management Subsystem (DMSS), an archive system, was implemented as an interface for web-based indexing and document retrieval services. The documents can be stored either in the document management server or in the file system while the index is stored in the central database. The DMSS was

implemented with open source software and is located at the district (woreda) level.

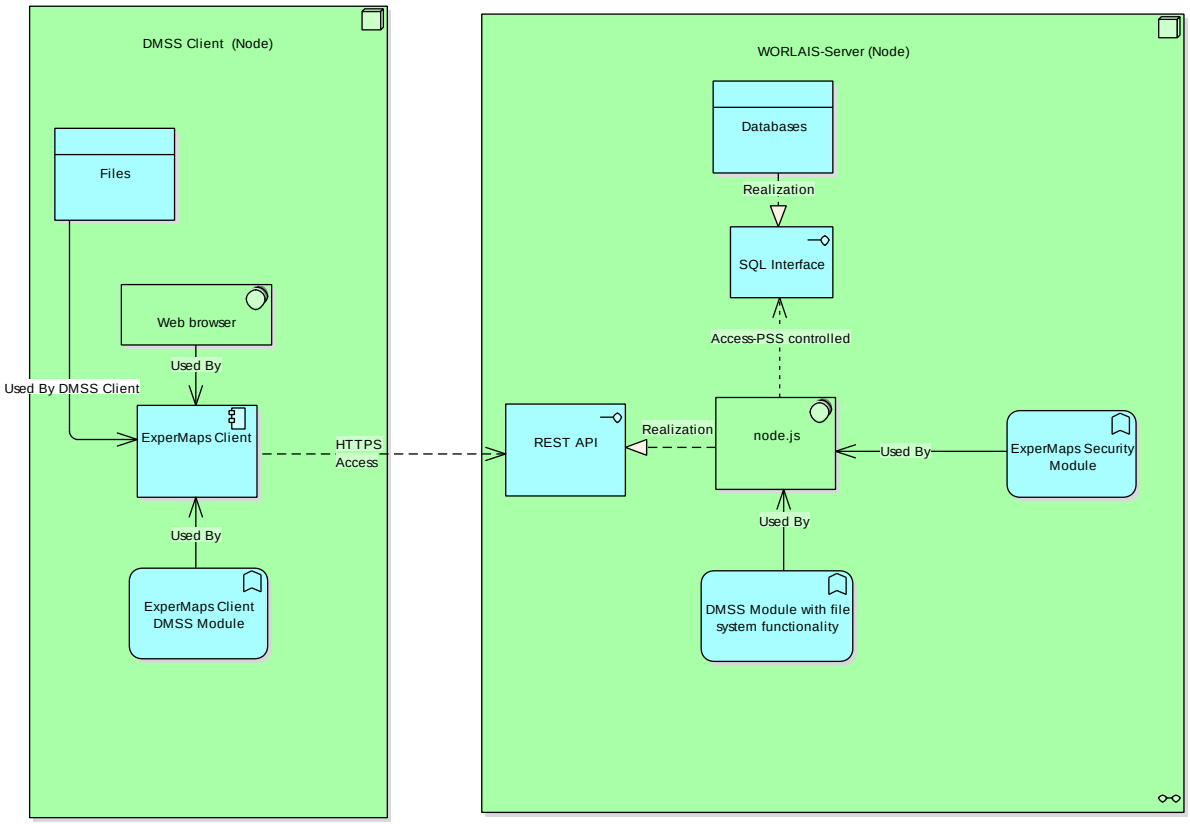

Figure **10** shows the application structure of the DMSS.

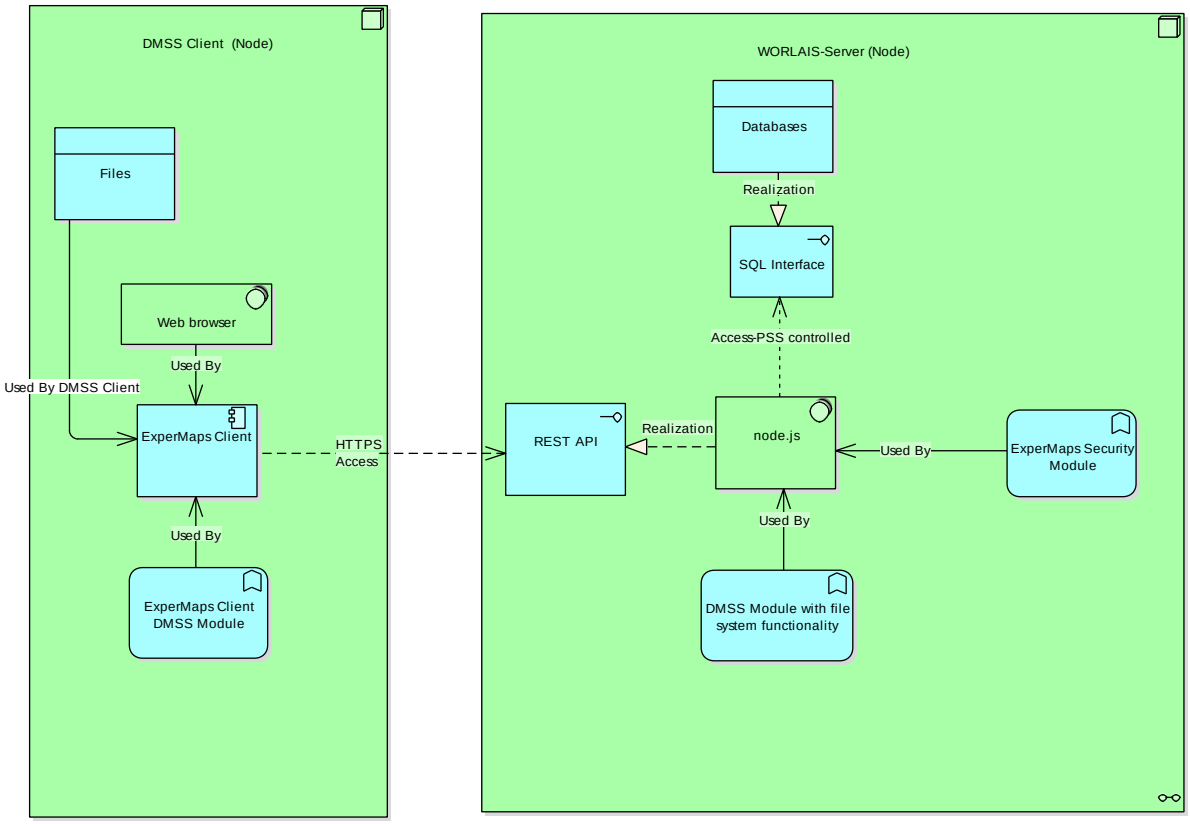

Figure 10: Application structure of the DMSS subsystem (Hansa Luftbild, 2016)

- **PSS**

The Process Subsystem (PSS) is a web application responsible for process management at the server level. It handles data processes and security issues during the transactions. The data of the processes are stored in the main database. This subsystem was implemented on the node.js / ExperMaps platform. For the user interface, additional implementation in JavaScript was carried out in order to support AJAX (Asynchronous JavaScript and XML) capabilities. The PSS is the initial interface of the NRLAIS. Its purpose is to create and maintain the processes. A process combines several tasks on the land register and the cadastre. Examples of such processes are sporadic land registration, or transfer of usage rights. Single tasks are carried out in the PRSS and the CMSS. In the context of the NRLAIS a process is defined as a transaction. The PSS provides functionalities to manage the following processes:

- Create a process. This would be the action performed at the sub-district level (i.e. kebele level) in order to submit an application.
- Status management. A process goes through a defined set of states. Some states are changed automatically by the system due to events being triggered inside the system, or are carried out by the user.

- Commit or rollback the process. For example when the process is completed, all changes to the cadastre and the land register are permanently stored in the database.

Figure 11 shows the application structure of the PSS.

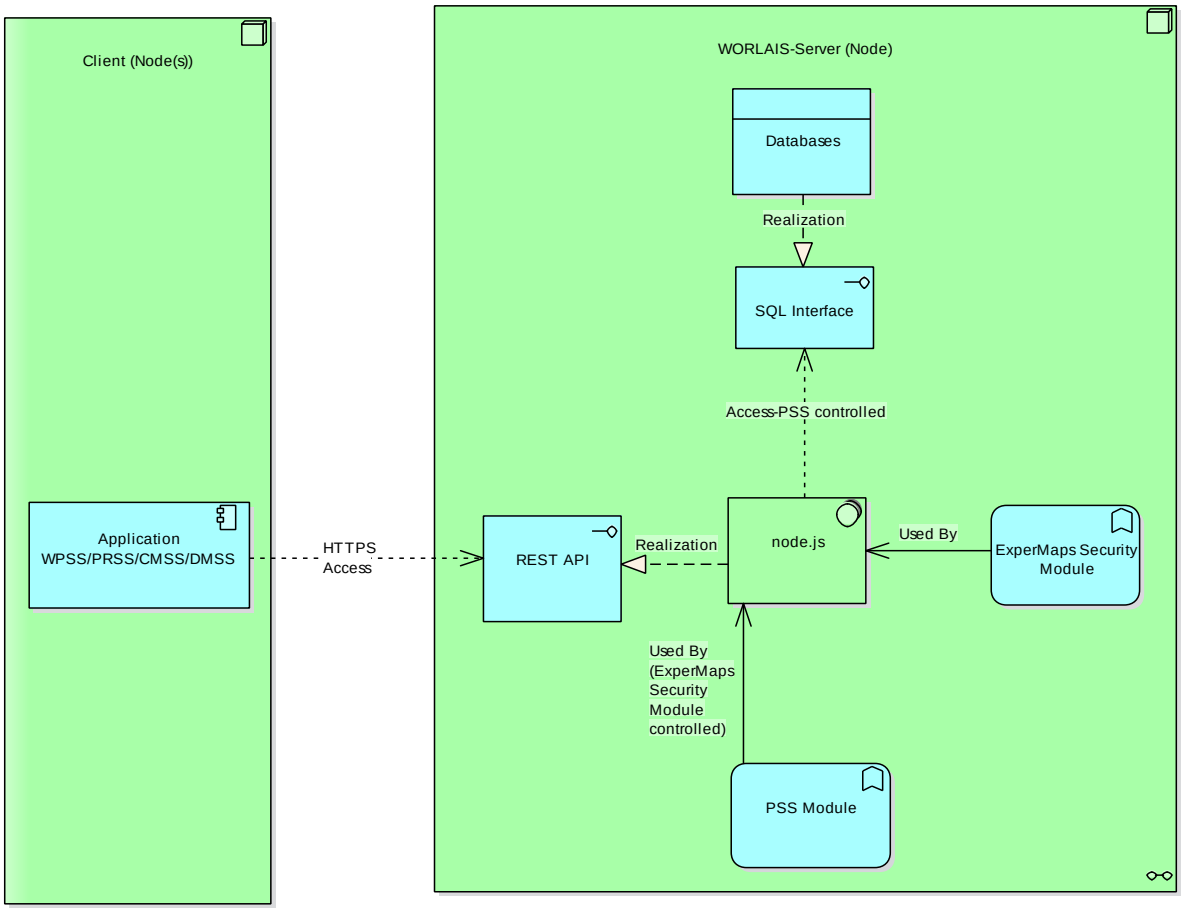

Figure 11: Application structure of the PSS subsystem (Hansa Luftbild, 2016)

- **Service level**

The service level provides web services for accessing the data in the land register and the cadastre.
For the spatial data the services are OGC compliant, these are the WFS (Web Feature Service) and the WMS (Web Map Service) services. These services were implemented using the Geoserver open source platform.

Other services were implemented on the node.js platform and are accessible via REST (Representational State Transfer) web services. Figure 12 shows the application structure of the service level of the NRLAIS.

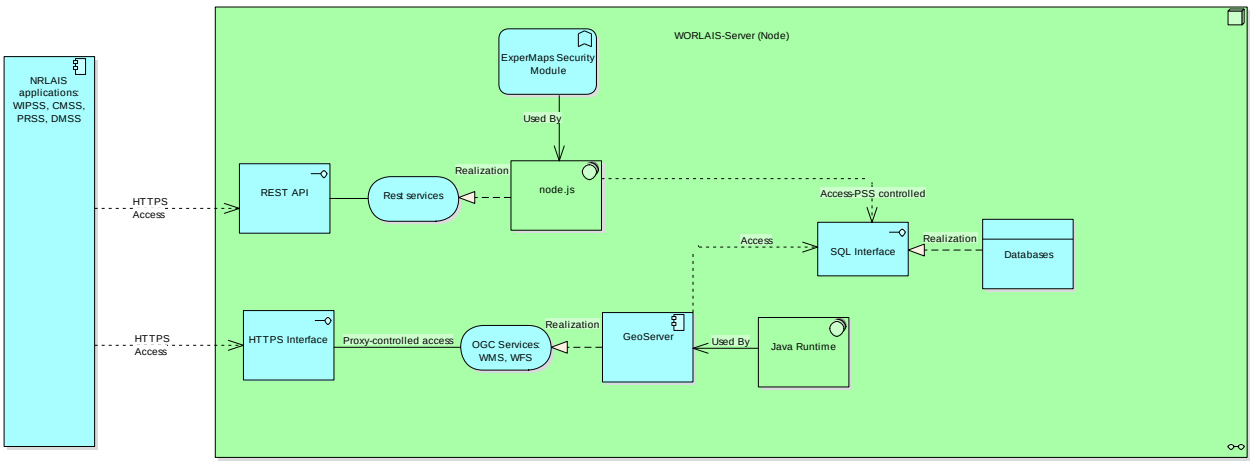

Figure 12: Application structure of the service level (Hansa Luftbild, 2016)

The technical specification of NRLAIS includes a mass land registration software component, named MASSREG. The basis of MASSREG was the software iMASSREG or interim MASSREG, which had been developed by DFID funded Land Investment for Transformation (LIFT) programme in Ethiopia using open source software (QGIS, PostgreSQL and Glassfish Java application server) and is currently being used as an interim solution while waiting for the completion of NRLAIS.

As stated MASSREG will be used for the initial systematic or mass registration of rural land. After mass registration the legal data and the spatial data will be migrated to the NRLAIS core system.

iMASSREG had most of the functionalities of MASSREG software which were specified in the terms of reference of the project. The missing functionalities were incorporated in the software and thus transforming iMASSREG into the required MASSREG.

7. NRLAIS Operational Acceptance Testing

The NRLAIS development encompassed the development of a system which is being deployed and operationally tested in several configurations at different administrative levels, i.e. at the Ministry's headquarters in Addis Ababa, at two regional bureaus (in Tigray and SNNP) mandated with the land administration tasks and at one woreda office in each of these two regions.

Currently the system prototype is being testing at the headquarters of the Ministry. However, in accordance with the NRLAIS technical specifications an operational acceptance testing plan has been prepared. This plan allows the testing of the fully integrated NRLAIS at the central, regional and woreda level for a period of at least 4 weeks. The test is a progressive test for each the NRLAIS component:

a. WORLAIS and MASSREG
b. REGLAIS and ZONLAIS

c. CENLAIS, and
d. an overall operational acceptance test of the entire system

User acceptance testing (UAT) is being carried out by taking the existing RLAUD land administration manual and transaction procedures as a primary base. Sixty test scenarios were prepared to verify the functionalities of the NRLAIS.

The pilot implementation will be completed with a final acceptance test which is performed by the testing and quality assurance team which consists of members from REILA and RLAUD, who are supported by the system developer. The following tasks are carried out in order to accept the system:

- review of technical documentations
- review of the source code and data structure to ensure their fidelity to the accepted technical documents
- testing the roll-back procedures
- system performance testing that include testing of the stability of the system and that the system is bullet-proof to user input mistakes.
- responsiveness tests of the system.

The final acceptance of the NRLAIS will trigger its transition to an operational system. In addition, after the NRLAIS acceptance Hansa Luftbild will prepare a post-pilot implementation support plan which covers the time after the warranty period. This plan will include the adaptation of the NRLAIS by any of the Ethiopian regions in order to serve as the harmonised national land administration information system.

8. Network Infrastructure

Communication infrastructure is needed because NRLAIS consists of several geographically separated components that need to exchange data. Since it is not advisable and legal to build communication lines privately, especially for the NRLAIS, the only option to satisfy the data communication need is to use the available communication infrastructure which the Ethiopian government has already built and is being expanded continuously. Data centers will be used to host large back end components of the NRLAIS. These centers are different from simple servers because they provide more reliability and availability as they are equipped with back up devices, redundant power sources and better connectivity.

According to the existing communication infrastructure the NRLAIS pilot implementation at the SNNP region and the Tigray region will use periodic offline replication. The offline replication is used for the communication between woreda – zone, zone – region and region – central. The transport of the offline replica can be done via the existing network. This process can be done automatically. The frequency of

replication is selectable (1 to 7 days). The NRLAIS is prepared for switching to an online replication when the infrastructure is able to support a stable network communication in the future. The switch to online can be carried out during the post-pilot phase. Figure 13 shows a simplified version of the communication infrastructure of the NRLAIS.

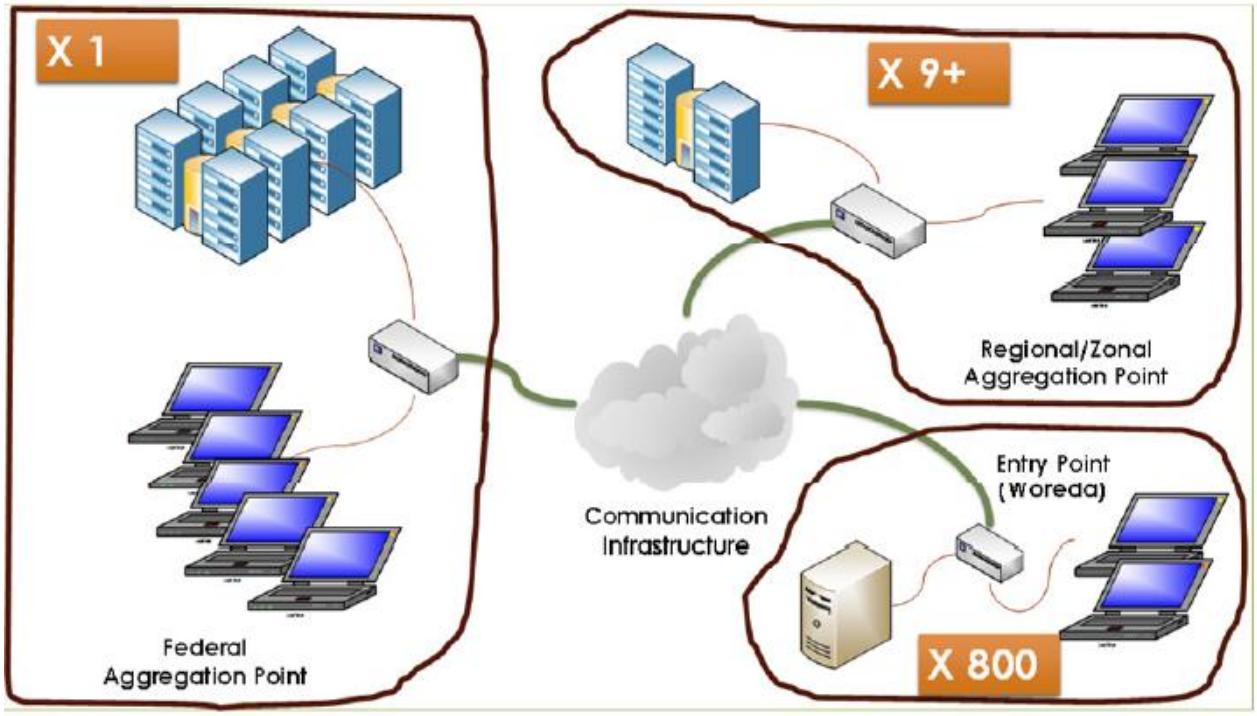

Figure 13: Simplified version of communication infrastructure of NRLAIS (Hansa Luftbild, 2016)

9. Migration of Existing Data

Data migration within the NRLAIS context is the process of transferring existing land holding data from different sources into the NRLAIS database. It has the potential to reduce the cost of producing the data that the NRLAIS will need by reusing existing digital land administration data. Several projects with the goal of collecting systematic land data on rural land holdings had been carried out throughout Ethiopia in the last 14 years. It has been found that these projects use varying data formats across and sometimes within projects. All in all six data formats were identified and evaluated as being suitable for migration. However, not all these six formats can be migrated to the NRLAIS database directly, i.e. without manually editing them to ensure a minimum level of quality and completeness prior to migration.

The existing range of candidate data formats was studied in order to use these as input data for migration to the NRLAIS. On the basis of the study specific tools and procedures were developed to perform the

actual migration of data from each specific data format to the NRLAIS database. Figure 14 shows the flow diagram for the data migration procedure to the NRLAIS database.

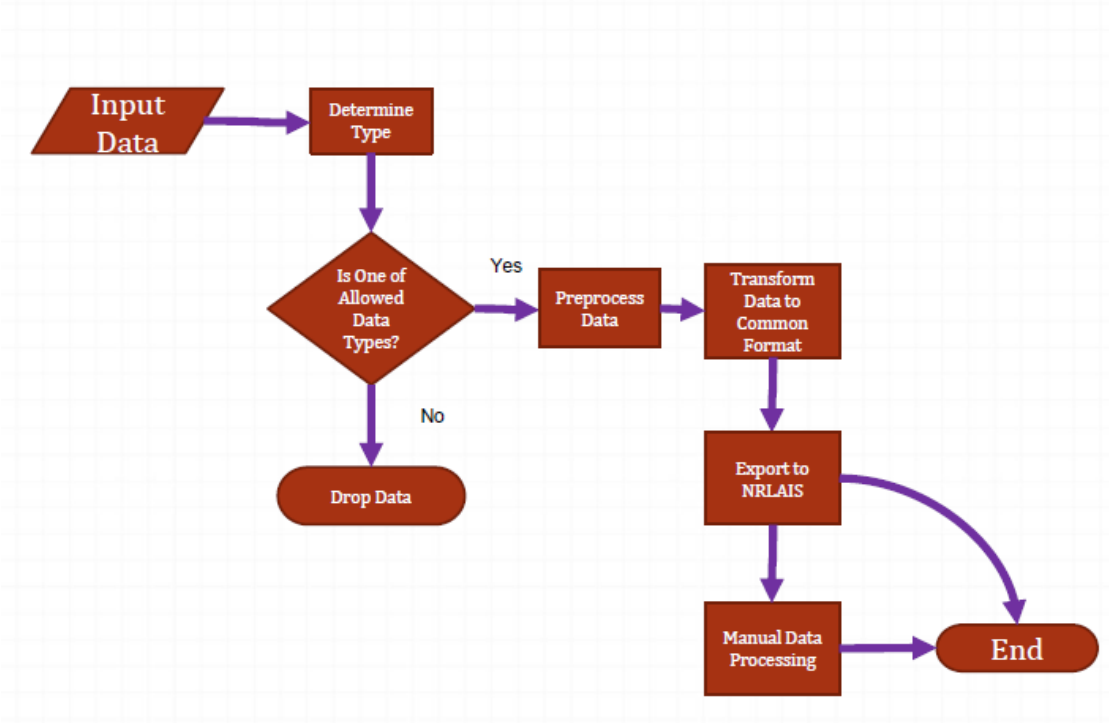

Figure 14: Flow diagram of NRLAIS data migration procedure (Hansa Luftbild, 2016)

10. Innovative Elements of NRLAIS Pilot Development

Many geospatial system products are designed and evaluated irrespective of their suitability, user satisfaction and sustainability before users on a wider scale become familiar with the software (Ullah, Mengistu, Van Elzakker, & Kraak, 2016). NRLAIS was designed to be a usable (effective, efficient and satisfactory) and sustainable cadastral system that can represent the cultural, security, legal and privacy issues of the rural land holders of Ethiopia. Hence, NRLAIS is a key strategic development within the land administration sector in Ethiopia that can provide the functionally to manage the rural land administration and information services. It is also a key element of the national ICT strategy for the standardization of the rural land administration and developed to the pilot status inconsideration of further customization.

NRLAIS is innovative in terms of its system architecture by representing all the processes of rural land administration processes at the different administrative levels (Zone, Woreda and Kebele). This approach will make it possible to adapt and customize the system for the slightly differing legislations and administrative structures in the regional states of Ethiopia.

Even though the NRLAIS development will initially be deployed and installed at the pilot sites, the system functionality is considered complete and fully caters for the legal and administrative needs of the system development with all its phases from the requirement analysis, business process reengineering, system design and architecture to the implementation that cover the whole system and not just some components.

Basically, the central concept to NRLAIS is a "toolkit" approach to manage the functionalities of the system at different levels, with the ability to customize for the needs of different regional states. As a result, the system was developed in such a way that it can be adopted by any of the regional states in order to serve as their land administration system. At the end of the day NRLAIS will consist of a set of Regional State Rural Land Administration Information Systems (REGLAIS) administered at regional level but implemented at whatever level appropriate for the IT infrastructure and human resources available in the concerned regional state. These REGLAIS systems conform to the standards which are laid down nation-wide by MoANR so that compatible data can be extracted at national level for RLAUD and ultimately for other users through the National Spatial Data Infrastructure.

NRLAIS is based solely on open-source components which removes the financial burden of license and basis software costs and adds the freedom to adapt the system to any future need without license restrictions. Moreover it allows to reuse and extend the fully accessible source code of mature OSS projects like QGIS for efficient implementation of NRLAIS functionality. Moreover, OSS makes stable and community driven development processes possible. PostgreSQL for example is under continuous development since 1997 without interruption. Because of the status of internet connectivity the pilot implementation of NRLAIS will use periodic offline replication. But the system is prepared to switch to an online replication if the infrastructure is able to support a stable network communication.

Further NRLAIS was designed in consideration of the current situation, but also has in mind future demands. Accordingly its sub-systems are tailored to their specific purpose. CMSS for instance focuses on processing spatial data, whereas PRSS deals with non-spatial data. So, each sub-system have specialized graphical user interfaces to handle different data and to fulfill the corresponding tasks. Although the sub-systems are relatively independent, they depend on each other and are connected at the database level. Especially, the service level subsystem provides different services of NRLAIS and allows a communication between service level and application level. The web services access the land register and cadastre system component of NRLAIS, hence in future this subsystem will act as a pipe to integrate other land registration demands, for instance the registration of investment land.

11. Conclusion

Ethiopia through the Ministry of Agriculture and Natural Resources has commissioned a private company to develop and implement the national rural land administration system (NRLAIS). This system is developing and being implemented using free open source software following the toolkit approach. The NRLAIS applies the ISO Land Administration Domain Model (LADM) standard. With its innovative and cost-effective architecture and modular approach it is independent of a fully functioning internet infrastructure and can easily be adapted to cater for different legal requirements of the Ethiopian regional states. The innovative development of the NRLAIS was built with the intention to harmonise the rural land administration in the country. The required functionalities are different at each land administrative level of the NRLAIS. The system will benefit the rural communities in improving their tenure security with particular attention to vulnerable groups, and will contribute to improving their livelihoods and support the conservation of natural resources in accordance with the legal framework of the Ethiopian Government.

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Terms, Acronyms and Abbreviations

FOSS	Free and Open-source Software
ISO	International Organization for Standardization
Kebele	Smallest administrative unit in the country, similar to a village. One kebele contains 3000 – 5000 land parcels, there are more than 13,000 kebeles in the country
LADM	Land Administration Domain Model
NRLAIS	National Rural Land Administration Information System
OGC	Open Geospatial Consortium
OSS	Open-source software
REILA	Responsible and Innovative Land Administration Project
RLAUD	Rural Land Administration & Utilization Directorate
SNNP	Southern Nations, Nationalities, and Peoples' Region
Woreda	Administrative unit similar to a district. There are around 570 Woredas in Ethiopia