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Spatial Land Records System using Geospatial Techniques: a case study of a Mid-Sized Village in Pakistan

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Master thesis, 30 credits, in Geographical Information Systems

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Abstract

In any country, land ownership and land records management are prime objectives of any land record management authority. These issues are of key importance in Pakistan for land individuals as well as for land record management authorities. Currently, land records and revenue maps are maintained by the land revenue officers manually and are available in outdated form. The Land revenue maps are made manually on paper-based fabric that has no proper standards regarding preservation, updating and integration of revenue textual information available in different scattered registers. This results in an increasing number of litigations regarding land issues. The land records management system does not exist digitally at all in the country for preservation, updating and integration of revenue records and land administration faces difficulties in land transactions, mutation, taxation, land disputes, land tenures and land rights. Some efforts to develop a standardized management information system are in progress regarding the conversion of manual revenue records into digital form but ultimately not resolved the specific objective. The need of the day is the creation of a comprehensive Spatial Land Record System (SLRS), for the preservation, updating and integration of the revenue records. Geospatial technology was used for the development of SLRS, which will not only secure land records but also be beneficial for land records management scientifically. The land revenue maps are treated as base maps, which were scanned, geo-referenced and digitized by using the High-Resolution Satellite Imagery (HSRI). The revenue textual information available in different scattered registers was integrated with the land parcels and updated the sub-khasra information (missing in land revenue maps) as per the field book (contains the details of measurements; length, width and area). Parcel Fabrication Model was adopted for the preservation of the dimensions of land parcels. The user-friendly web-based GIS interface was developed for the visualization of land records information which will be helpful for land administration. The SLRS utilizing geospatial technology is a way forward for the land record management authorities and departments to streamline the land records and update their old system. This will enhance the transparency of the service delivery system across the board.

Keywords: Geography, Geographic Information System, GIS, Geospatial Technology, Parcel Fabric,

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ABBREVIATIONS

BOR	Board of Revenue
CNIC	Computerized National Identity Card
E&T	Excise & Taxation Department
e-LA	e-Land Administration
ESRI	Earth System Research Institute
GCPs	Ground Control Points
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
HRSI	High-Resolution Satellite Image
LIS	Land Information System
LRS	Land Record System
PBS	Pakistan Bureau of Statistics
RHZ	Register Haqdaran Zameen
PLRA	Punjab Land Record Authority
PMU	Project Management Unit
PRSP	Poverty Reduction Strategy Paper
SLRS	Spatial Land Records System
SOP	Standard Operating Procedure
TM	Thematic Mapper
URL	Uniform Resource Locator
ZTBL	Zarai Taraqiati Bank Limited

1. INTRODUCTION

1.1 Background and Motivation

Land is referred to as any component of planet Earth and an important key element of human life (M.S.Ahsan, 2016). Land has different concepts concerning different people; a lawyer states that land is used for physical measurements for collection of revenue and ownership rights, while an agriculturalist considers that land as an area, used for the cultivation purpose (Ratcliffe, 1976) and a developer describes that land as a corporeal medium permitted to manipulate for investment purposes (Latu, 2009).

Pakistan is an agriculture country and 24% Gross Domestic Product (GDP) of country depends on agriculture. Almost 45.1% of employed population takes advantage from agriculture (PBS, 2018). Government of Pakistan's Strategy for Reducing Poverty (December 2003) illustrated the importance of agriculture for poverty reduction and sustainable economic progress (BOR, 2014).

Pakistan is at 5th number in population, among the largest countries in the world (Beef2Live, 2020). In Pakistan, laws and regulations related to land are formulated at federal level and implemented at provincial level. This top-down approach causes some confusion between federal and state authorities (Mirza and Adeel, 2012). In Pakistan, no land management authority exists at federal level and authorities exist at provincial level to division, district and tehsil' offices. A tehsil is an administrative sub-division of a district and district is a sub-partition of a division and no connection with federal government. The Board of Revenue (BOR) is the supreme authority at province level, for management of land records and functioning the land issues manually.

Land occupancy and managerial problems are significant issues and have huge concerns for landowners in record keeping and other administrative issues like; prejudice of land allocation, duration uncertainty, troubles and enrollment processes, which are complex and interconnected (BOR, 2014). These issues occur due to the non-availability of digital records in land management authorities.

Mostly, manual maps are paper-based and on inappropriate scales. There was no standard to develop and preserve handmade cadastral maps. It turn causes measurement issues and increases disputes among landowners and stakeholders. Therefore, land record authorities are facing problems like land selling, tax collection, land disparities, land mutations and land privileges due to a lack of digital record and technology.

In Pakistan, a lot of work has been done in the field of Land Information System (LIS). This system has its roots from an old conventional system of land documentation and evidence that it is somehow complex, old and extremely contradictory system as compared to present innovative advancements (Ali et al, 2012).

Cadastral maps are primarily available in paper forms and general research represented a deficiency of criterion from such paper mapping, outcomes with outdated knowledge (Ali, 2012). Presently, all the land records have not yet been digitalized, and it is a big deal to digitize 190 million manual land records in Pakistan.

Geographical Information System (GIS) was introduced and developed standard methods to disseminate geospatial data (Alesheikh, et.al. 2002). The process of evolution in geospatial technology continues to fulfill the needs for professionals to manage land records. Initially, an appropriate land possession makes it possible to shift property timely and lends a helping hand in resolution of disparities. It is a need for impartial and equitable property taxation to be accessed easily by people (ESRI, 2007). Transforming cadastral maps into digital forms is a very difficult task. However, cadastral modeling is very useful for agricultural management and aims to summarize attributes & spatial data and to display information in a single portal (Kalantari, 2005).

Geospatial technology is a system that acquires and handles positional data regarding Earth. GIS, Global Positioning System (GPS) and Remote Sensing (RS) are based on geospatial technologies (Encyclopedia, 2019) and must be used to preserve land records in digital form. There is a dire need for such a system to secure and land records data and to access and visualize it geographically. Therefore, development of Spatial Land Record System (SLRS) using geospatial technology is the need of hour for development of digital cadastre to secure, manage, access and visualize geographically.

According to the International Federation of Surveyors, LRMIS is a package that is based on information related to land and attracted to manage land information in secure form (FIG, 1995). It is necessary for land administration to function the process of land registration by using transparent administrative techniques. Therefore, the use of geospatial technology is very important in preservation of terrestrial documentation in digital form and benefits include accuracy of information, correctness of data and measurements.

Cadastral maps (musavees) and land record registers ought to be dealt as basic ones for every land-associated data to develop SLRS by use of geospatial technology. These land records are converted into digital form and linked geographically to develop a digital cadastre.

Parcel Fabric is an ArcGIS elaboration and secured a regulatory surface of interconnected parcels (Ana, 2014). It is used for the extraction of dimensions of individual land parcel (khasra and sub-khasra) and audited with manual records. The ultimate database is analyzed critically and developed analytical layers for development of SLRS of study area. Web-based GIS interface is developed for accessing land records information and visualization purposes. This interface will be helpful for land management to provide the services in a transparent way.

This SLRS gave an e-administration concept for land history and land records management. This research has evolved into a methodology to develop digital cadastre for SLRS using geospatial technology and proposed to land record authorities for management of land records digitally. It will reduce land records issues, which came from manual management of land records. It will also provide translucent land management systems and ensure socio-economic lawfulness. The purpose of High-tech system is to plan methods relating to computerization, checking, upgradation, confirmation and unification of data and examining the outcomes by the usage of geospatial techniques.

In other words, my study is focused on methods related to conversion of manual data into digital format and digitization of manual land records by using geospatial techniques. Manual land records include perpetual changes in divergence to digital records and revenue officer updated daily, these manual changes regarding land sale and purchase in the revenue registers. This old, outdated method takes so much time regarding updating, increasing the chances of manual mistakes, uncertain, unapproachable and dispersed attribute information and there is no integration with spatial data. Spatial Land Record System (SLRS) will provide the efficiency in conversion of manual records into digital format and helpful in an efficient updating, computing, and auditing the land record information from digital cadastre as proposed in this study.

1.2 Research Objective

General objective of my research work is to develop a cost-effective methodology where digitalization and spatial techniques are used to form digital cadastre and preserve the dimensions of individual land parcels of a mid-sized village in Pakistan. The updating of the digital cadastre and its audit with manual cadastre is also a core objective.

1.3 Research Questions

The following questions were explored and addressed during the development of proposed methodology to SLRS.

- How well will the dimensions and boundaries of land parcels be preserved in a digital cadastre?
- How should land records be updated and new records be treated? What are the proposed routines?
- How should attribute data be integrated into the digital cadastre? What are the proposed practices?
- How could the digital cadastre be available and accessible in a Web-based GIS Interface

1.4 Justification

The studies conducted by Pakistani researchers; Ali 2013, Zahir 2010, Johum 2012, Kamran 2016, Adeel 2010, and M.S. Ahsan 2016 had their own scope of study and did not cover all my research objectives due to limitations, deficiencies and difficulties. The digitalization of land record attribute data is not enough for land record management and missed component of integration of attribute data geographically. In previous studies, there is no system or mechanism available for recording dimensions of land parcels and updating land parcels information. There is a lack of a centralized enterprise system for land record administration resulting in the transparency of the service delivery mechanism.

My research covers the missing portions in former studies and suggests such methods relating to digitization by using geospatial techniques to form digital cadastre for proposed system and preserve the dimensions of land parcels. This system is a proposal for land record authorities to develop similar SLRS to achieve transparency in service delivery system of land management.

1.5 Expected Outcomes

The following are the outcomes of my research study.

- Digital cadastre (Land parcel boundaries with dimensions of lines of land parcels)
- Delineation of revenue boundaries; square, musavee, khewat and khetuni from.
- User friendly Web-based GIS interface

2. LITERATURE REVIEW

Land represents physical properties demonstrated by the surface of the earth (Wyatt et al, 2003). It is the most essential part for any nation because most economic assets like; industry, housing, infrastructure, etc. depend on agricultural land and agriculture is largely dependent on the fertility of the land. It has different categories and classifications regarding ownership and usage. Land ownership relates to the title of land and represents the land's legal right to the individual body. Public land relates to the land of state or government bodies and private land is the land possessed by individual or private entities other than government bodies.

2.1 Administrative History of Land Records in Sub-Continent

The land record history in the sub-continent is very old and the Land Record System (LRS) was established by Sher Shah Soori in 1540. In Pakistan, first land revenue act was introduced in 1967, and the land revenue rule of Pakistan was developed in 1968 (Kamran, 2016). The major agrarian reform was followed by Zulfikar ali Bhutto in 1977(Gazdar, 2009). The land record history in the sub-continent is shown in figure A1 of Appendix A.

The administrative hierarchy starts in descending order from country to Mauza/Village, but the land records in Pakistan are maintained at the province level. The administrative hierarchy and its functions are expressed in Appendix A. Each administrative zone has a relevant revenue administrator for administrative purposes and all revenue matters are dealt with by the Board of Revenue (BOR) at the province level (Zahir, 2010). Land administration, assessment, record maintenance and preparation of cadastral maps are the main functions of the BOR and have manual procedures to prepare, manage, update and archive the cadastral record (PLRA, 2019).

The patwaries (revenue officer) are at the lowest rank in the revenue administration and have to store and maintain the revenue record manually in the revenue registers (PLRA, 2019). They are the legal authority to conduct surveys, collect taxes, assist in land-related issues, the mutation process and keep records related to crop disease (Tariq, 2011).

The revenue records are the archive registers and cadastral maps and are used for land administration purposes. There are 50 million (approximately) landowners in Pakistan who own 190 million land records which is not in digital form (Adeel, 2010). In Punjab province, approximately 8,000 Patwaries maintain the land records of twenty million landowners (PLRA, 2019). Most of the attribute data are converted into digital format in Punjab but spatial component is missing. The cadastral maps are being prepared on handmade paper and pieces of cloth (Latha or Kapra) manually as shown in figure A4 of Appendix A. Many irregularities and the absence of standards are not followed to keep the record secure (Ali, 2012). The handmade maps are not up to scale and are damaged during disasters like floods and earthquakes (Dale et al, 1999). The

revenue data are maintained in the manual form at the time of settlement which includes cadastral maps; musavies/latha and 17 different registers (Adeel, 2010). The purpose of the record sets is given in Table A1 of Appendix A.

In Pakistan's land revenue system, many local expressions are included in land records. Some cadastral terminologies are given in Table A2 of Appendix A. The land is measured in specified units in Pakistan (M.S.Ahsan, 2016). Some measurement units with their equivalent units and SI units are given in Table A3 of Appendix A.

2.2 Existing Research

The region of Bangladesh is the same as in Pakistan. The research titled "Land Information System (LIS) for Land Administration and Management in Bangladesh" highlighted the major issues of land management and administration (Shafiq-Ur-Rahman and Kasphia, 2009). Multiple research related to Land Record System (LRS) were conducted in Pakistan and observed the issues of land records management which are the same as in Bangladesh.

In Pakistan, to simplify the LRS, a few efforts have been made for the computerization of land records to ascertain the transparency in the land market (Qazi, 2006). The land records are managed on a traditional system which is not digital, and a few efforts have been made to convert the registers data into digital, while cadastral maps were not converted into digital.

A few published research was investigated to analyze the problems, limitations and gaps. The comparison among previous research is as follows: -

A report developed by Ali Raza Bhutta in 2014 titled" Punjab-Land Records Management and Information System" debated the history and description of land records, their digitization, as well as land use software development (BOR, 2014). In 2013, Ali conducted research "Developing a framework to apply total quality management concepts to land administration", to highlight the institutional and practical facets of Pakistan's land administration authorities. He suggested possible strategies related to quality management and emphasized the importance of the integration of land records using geospatial technology (Ali, 2013). The research titled "Assessing Usefulness of High-Resolution Satellite Imagery in GIS-based Cadastral Land Information System" pointed out the significance of Remote Sensing data in the Land Information System (LIS). This study focused on the adoption of high-resolution spatial imageries like Quick Bird and GPS for the cadastral survey methodologies (Ali, 2012). Ali and Zahir also highlighted the importance of high-resolution imageries like SPOT-5 and Quick Bird in land record management and cadastral mapping (Ali and Zahir, 2012). In 2010, "Land Administration System in Pakistan-Current Situation and Stakeholder's Perception" by Zahir Ali and Abdul Nasir, highlighted the history of Pakistan's current cadaster system and their associated shortcomings (Zahir, 2010). In another

study, a complete theoretical concept regarding the use of geospatial techniques for land record computerization was explained in "Land Records Archiving Using Geospatial Techniques". These previous studies lacked the component of spatial integration with relevant attribute data which was covered in the present study (Kamran, 2016).

In 2012, Johum Fatima and Muhammad Adeel conducted research titled" Design and Development of Digital Cadastral Database in the Context of Pakistan" and proposed a comprehensive database model for land administration in Pakistan, which was based upon theoretical concepts and lacked practical implementation (Johum, 2012). Adeel pointed out the significance of GIS tools for the development of land record management and cadastral mapping (Adeel, 2010). He also recommended the use of open-source software. The research titled" Integrated geospatial evaluation of manual mapping: a case study of Pakistan", adopted the fishnet tool method using ArcGIS to support the use of spatial technology in cadastral mapping practices to avoid validation errors among datasets (M.S. Ahsan, 2016). This recommended method was only feasible for land parcels in square shapes but not possible for the irregular shapes.

It was concluded from the few research that there is a dire need for modern tools and geospatial technology for the changing scenarios of land administration to ensure transparency. The previous studies did not cover the whole part of land record computerization using geospatial technology and there is no unique computerization system available for effective land record administration. The use of geospatial technology is a mandatory requirement for the 21st century and my research has focused on innovations, which were not covered in previous studies.

2.3 Land Record Management Information System in Punjab

LRMIS system is not efficient in Pakistan and maintenance of land records is suffered due to the non-availability of governance principles in the country. Many developments and trial projects were initiated to manage land archives but did not provide sufficient solution. There were four initial developments incorporated by the Punjab government that had either failed and abandoned or were partially successful. The reason for the failure of the initiative is due to a lack of comprehensive software for data entry because it was developed in-house and a stand operating procedure (SOP) was not followed to manage the land records. In the next phase, Management Information System (MIS) software was developed for the digitization of manual land records registers and used for the service delivery and 18 districts of Punjab were digitized by the end of 2011. This project improved the excellence of service delivery in land record management, land transaction and linkage of the NADRA database of landowners via biometric system was a unique example of the Punjab government. (BOR, 2014).

2.3.1 Punjab Land Record Authority (PLRA)

The Government of Punjab took another initiative and established Punjab Land Records Authority (PLRA) under the administrative control of BOR to automate land record process and ascertain the quality control in transparency and in provision of better service delivery to the public. The future approach of PLRA is to transform manual land records management into an efficient, accountable, secure and transparent system by adopting integrated methods (PLRA, 2019).

According to the PLRA, there are 25,709 revenue estates in Punjab and most of the records from registers have been digitized. The main achievements of PLRA are 24/7 online availability of revenue record information, Digital PLRA android application and digitization of cadastral maps of three districts but did not link with the MIS online information. The explanation is given in PLRA achievements of Appendix A.

2.4 Use of Geospatial Technology in Land Records

In 21st century, geospatial technology is very helpful to convert manual land records into digital. This technology provides solutions such as strategy planning, decision making, meeting the transparency level and analytical modeling in the management of land records qualitatively and efficiently. It is essential to develop a comprehensive Spatial Land Record System (SLRS) using geospatial techniques for the mid-sized village in Pakistan. This system can be used as a multi-purpose tool to ascertain the transparency in the land record at the administrative level.

Martin Ralphs and Peter Wyatt described the theoretical and practical concepts regarding the development of LIS. They emphasized the improvements of LIS in the United Kingdom (UK) considering the struggle and economic transition stage of other countries. Emerging technologies like computers are used for the management of land records and processed information. The importance of GIS is identified and highlighted in managing the real property system and potential applications (Wyatt et al, 2003).

In geospatial technology, Parcel Fabrication Model is a very useful tool for cadastral mapping in a systematic way and efficient management of land records with limited resources. It became quite important at local and global levels. Parcel fabric model is used to record the direction and accurate measurement of every land parcel (Ana, 2014).

2.5 Parcel Fabric

The Parcel fabric model consists of a continuous surface of connected parcels and is defined by vector format (polygon, line and point). The Polygon's features are defined by boundary lines in

series, and record dimensions in a attribute table. These dimensions of lines against each parcel must match the recorded sizes of lines on the survey plans (ArcGIS, 2018).

Parcel Fabric is represented in ArcGIS extension and ESRI datasets, to manage cadastral data, which permits the storage, preservation and editing of data on real estate. The advantages of the parcel fabric are retrieving the historical parcels and station of a cadastral land parcel (Ana, 2014). In 2010 cadastral fabric was retitled to parcel fabric by ESRI, and associate tools are transformed and editing technology from an extension product to a part of ESRI software (Geodata, 2006). Parcel fabric of the ESRI data model provides the solution to issues like; precision, maintenance, storage and updating of legacy data within the parcel fabric cadastre (Linda, 2013).

2.5.1 Parcel Fabric Dataset

Parcel fabric is a set of feature classes with connected tables in a geo-database that form a network of parcel boundaries (ESRI, 2018). The parcel fabric geo-database structure is given in Appendix A. The Parcel fabric geo-database structure includes elements; lines, points, polygons, control points, plans, parcel fabric jobs, accuracies and adjustments are briefed in table A4 of Appendix A.

2.5.2 Parcel Fabric Concept

The theory of parcel fabric suggests a well-organized database and information on parcels can be simply accomplished to trace the parcel history. The history of the parcel is very significant for the value and legal position in the course of adjustments (Badea, 2013). A parcel fabric is created under a feature dataset and inherits its spatial reference from the feature dataset.

The ways; Archive, Periodical and Transactional, on which parcel history can be tracked (Ana, 2014) and expressed in Parcel History of Appendix A;

2.5.3 Benefits of Parcel Fabric

The main benefits of parcel fabric (Sidewell, 2021) are given as.

- Effectively manage parcel database and provide better measurement approach
- Keep historical records
- Improve the spatial integrity of the database
- Incorporate best practices for the management of cadastral data
- Produce better maps with improved data accuracy
- Promote data sharing with other agencies

2.6 e-Land Administration (e-LA)

Current cadastral data prototypes are outdated and not digitally acceptable due to integration issues of MIS data and geographical data. There is a need for an e-LA system for land records management. The role of cadastral-related data is most important to estimate the revenue collection, tax of land with comprehensive and inclusive information, to meet up-to-date government essentials. e-LA is established and holistically service delivery is achieved to improve the management of land records. e-LA not only provides the cost-effective and operative method of data modeling for cadastral mapping but also developed the standard linkages for the handling of detailed information from the data developers. Figure 2.1 illustrates the role of modeling data management. (Kalantari, 2005).

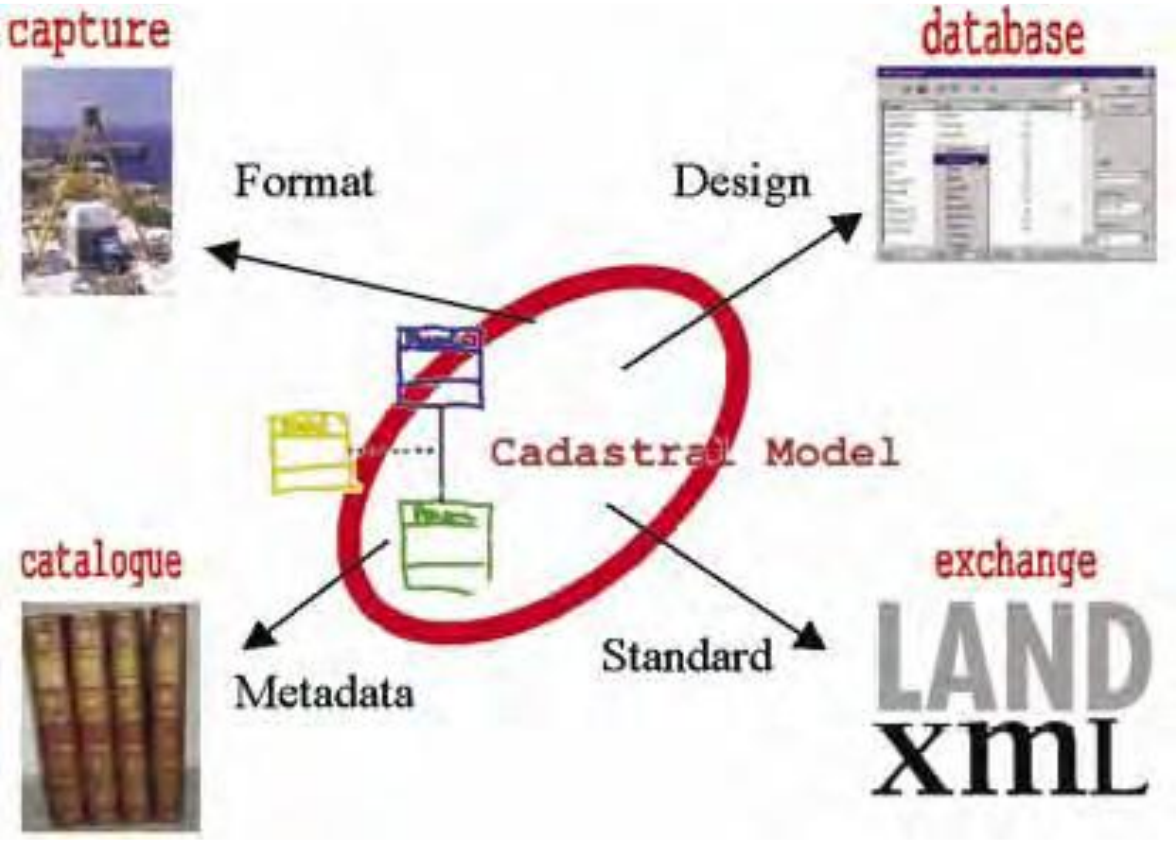


Figure 2.1: Role of Modelling of Data Management (Kalantari, 2005)

Spatial data and attributes need to be integrated into the active decision support system and must be up to date for the achievement of accurate analysis (Meyer, 2004).

The Internet has become very dominant in recent years and is taking the leading role in the provision of information in an efficient way to consumers. Web-based GIS interfaces provide the best way to present spatial and non-spatial information. Therefore, web GIS technology is used in land record management to facilitate the service delivery system (Amit, 2015).

Web GIS is an effortless and cost-effective technology to disseminate spatial data (Albert Osei, 2006). The geospatial data is published on the Web GIS portal and provides an online platform to access that information remotely from other worldwide users to manage and analyze the spatial data. OGC is the abbreviation of Open Geospatial Consortium and includes numerous standards of interfaces for information sharing and interoperability among web GIS systems. Various spatial data formats are treated via Geography Markup languages (GML) interfaces. Web Map Service (WMS) interface provides a simple HTTP interface of geo-database (Abbas, 2007; Erh-Sang Lu, 2002 and G.H.B.Souza, 2008). There are some commercial web GIS packages like; ESRI, ArcIMS and Geomedia on the market and some open-source web GIS packages; Geoserver and MapServer. These are freely available and can be used to publish geo-spatial data to be accessed remotely (Amit, 2015).

2.7 ArcGIS Server

ArcGIS Server is Earth System Research Institute (ESRI) software. It enables us to present geographic data through web services. It is a superior software suite termed ArcGIS Enterprise and allows organizations to install geographic information onto the web (E-Education, 2018).

ArcGIS Server is software used for the visualization of accessible geographic information. Any user can view geographic information via the internet through web services. GIS information can be viewed on smartphones, Tablets, laptops, desktop workstations and other related devices through ArcGIS Server (ArcGIS, 2018).

Therefore, ArcGIS server will be used locally to develop the suggested web-based GIS Interface.

3. DATA AND METHODOLOGY

This section begins by outlining the sources of data used in this study, associated metadata, and the preliminary data management process. It then describes the methodology of the development of a spatial land record management information system and the application of geospatial technology to carry out the vector data development in ArcGIS.

3.1 Study Area

The study area consists of mid-sized village "Chak No.311-WB" having area 1,439.33 acres (5.82 km). It is situated 14.5 km away in the North-East of Dunyapur city and 33.4 km away in the south-West of Lodhran City. It falls in the premises of Patwar Circle 301-WB, Qanungo 12-L, Tehsil Dunyapur and District Lodhran of Punjab province. It is located between 29°50.14' N to 29°52.49' N and 71°48.59'E to 71°50.05' E. The adjacent villages are; Chak No.289/WB in the North, Chak No.291/WB in the East, Chak No.313/WB in the South-East and Chak No. 309/WB in the West as shown in figure 3.1. The reason for the selection of this study area is the availability of spatial data (cadastral maps and textual information) and ancillary data.

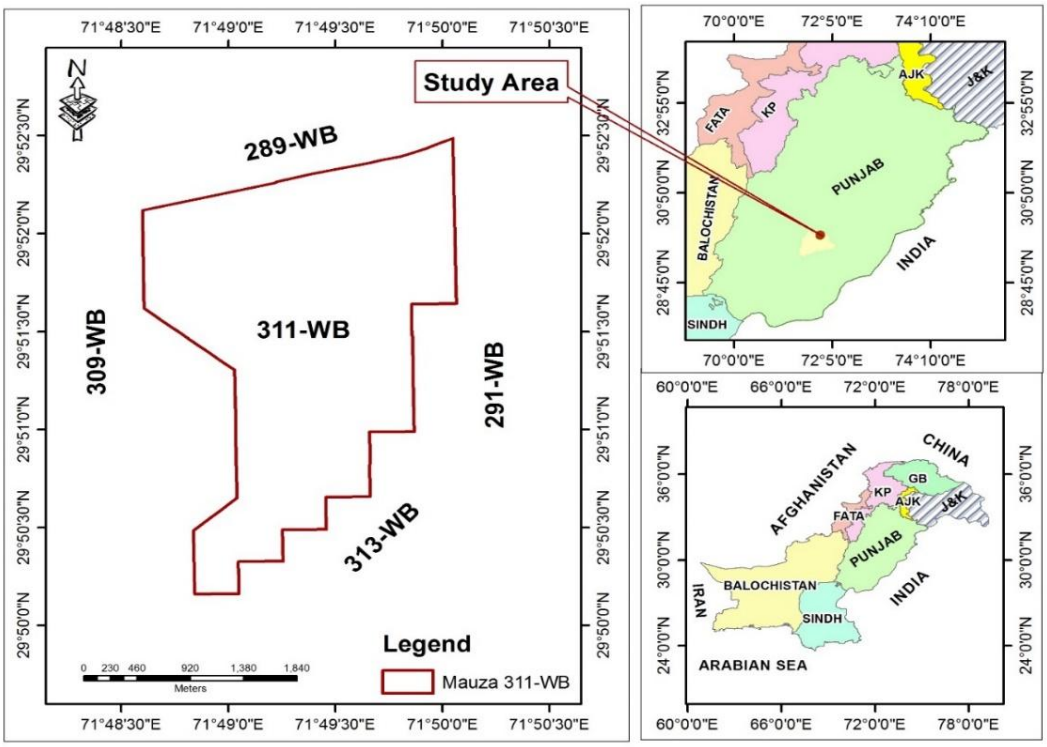


Figure 3.1: Location Map of Study Area

The Top-Down approach of the administrative hierarchy from the province to Chak No. 311-WB (AOI) is shown in figure 3.2.

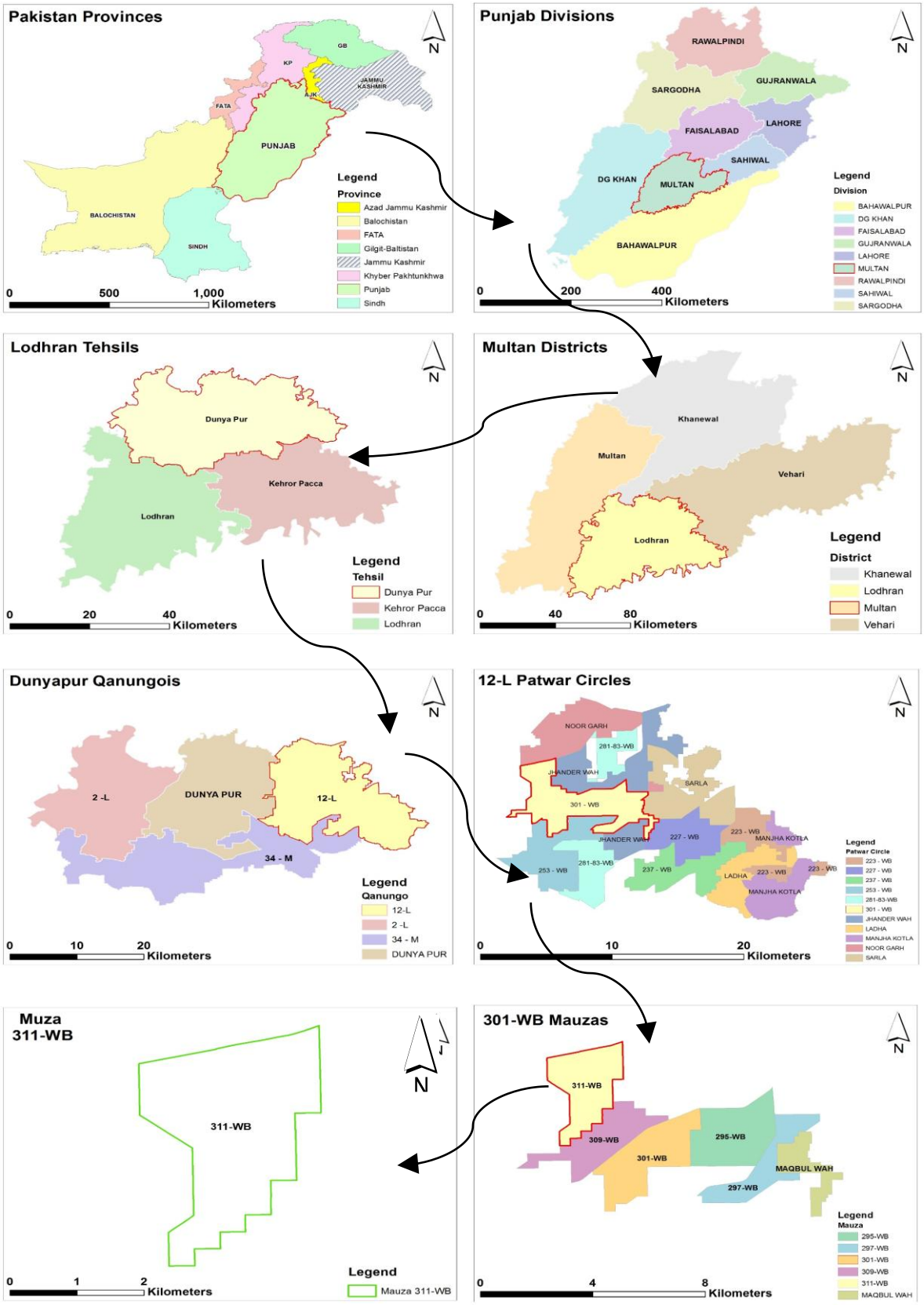


Figure 3.2: Top-Down approach of study area; Mauza 311/WB

3.2 Data Formats and Sources

The sources of spatial and non-spatial data used in this study and other associated metadata are mentioned in table B1 of Appendix B. The data encompasses the following fundamental formats for geographic data.

- Spatial Data: The spatial data consists of raster and vector data.
    - Raster Data: Satellite Imagery, Revenue data (Cadastral Maps).
    - Vector Data (Point, line or polygon) e.g., administrative boundaries, land parcels (polygon), land parcels' dimensions (line), field survey (points).
- Non-Spatial Data: Land record attribute information (Registers data) and census data.

A common map projection system called Universal Transverse Mercator (UTM) is used for spatial data for precise calculation and accurate positioning. The projection system: UTM 42 N with Datum WGS 1984 is used for all vector and raster spatial data.

3.3 Methodology

The use of geospatial technology has changed the paradigm for manual handling of land records like cadastral surveys and mapping. The methodology proposed for research was based on cadastral mapping through geospatial technology and based on previous research (Tuladhar 2005; Prudhvi et al., 2008; Ali, 2012; Sengupta et al., 2013 and Rao et al., 2014) to some extent and not an ordinary digitization of cadastral maps (Demir and Coruhlu, 2008). This study included the process of spatial data development from the handmade cadastral maps, and it also incorporated the element of recording of dimensions of sides of land parcels, integration of registers data with the land parcels data, auditing the analyzed information and remotely visualization of digital cadastre. The methodology was turned around the assimilation of geospatial technology to migrate paper-based and manual cadastral mapping into an automated, validated and standardized digital form as shown in the methodology flow chart figure 3.3.

Data acquisition includes field data and satellite imagery. The field data comprises revenue data and field survey data, while revenue data includes Registers' Data and Cadastral Maps (Musavies). The information like; Ownership record, size of the land parcel, Khewat and Khetuni, etc. were recorded from the manual registers and developed the non-spatial database to integrate with spatial data.

The scanned cadastral maps of the study area were collected from the Urban Unit. These maps were scanned via Roller scanner and Manual scanner based on the condition of the maps. The explanation is given in section 1 scanning of cadastral Maps of Appendix D. These maps were processed to make a mosaic map and removed unnecessary information to preserve the study area.

This mosaic map was georeferenced by using the Ground Control Points (GCPs) collected from the field and high-resolution satellite imagery with a spatial resolution of 0.46 meters.

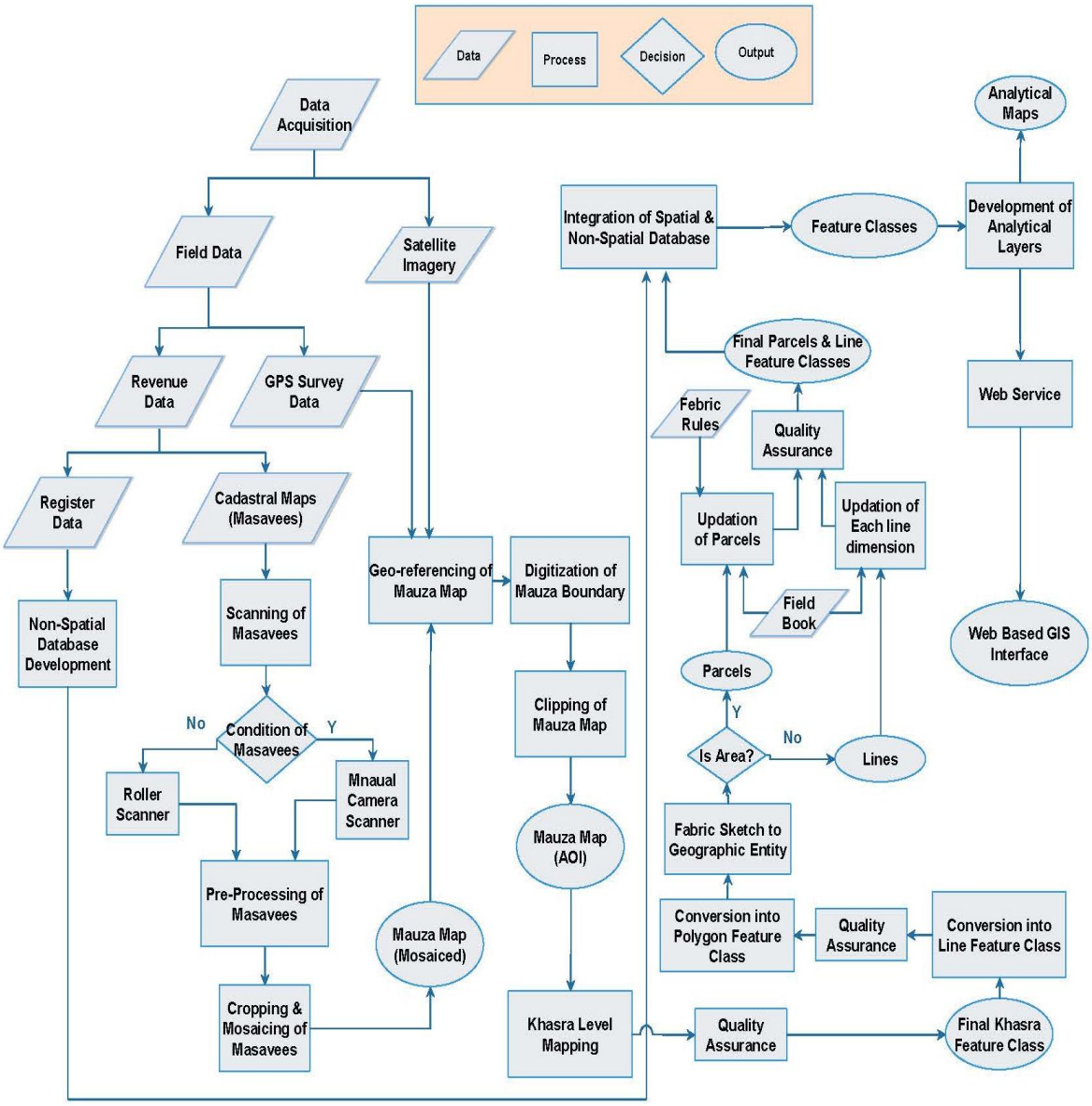


Figure 3.3: Methodology Flow Chart

The study area boundary (mauza boundary) was demarcated by using the georeferenced mosaic mauza map and unwanted information was detached to preserve the study area.

Khasras boundaries (land parcels) were demarcated from the final study area map and retrieved the information; khasra, square, mausavee name, etc, and incorporated geographically with individual land parcel. The land parcels were made qualitatively by applying the topology in ArcGIS software and rectified the errors to make error free data.

To make the parcel fabrication, the final land parcels were converted into line features and transformed into polygon features. Topological rules were applied to make it qualitative for the parcel fabrication model and tool "Fabric Sketch to Geographic Entity" was applied to develop the error-free data (land parcels and parcels lines) in the parcel fabric model. These land parcels and lines were updated by applying the parcel fabric rules by using the field book data (registers data) and again quality assurance was ensured for final error free data (land parcels and lines data).

The non-spatial database was integrated geographically with land parcels using the unique key and dimensions information were linked with land parcels' lines. Audited the size of the land parcels and dimensions, resulted in a GIS environment with the registered data and field data.

The final data was analyzed critically and analytical layers; land parcels, square, Musavee, Khatuni, khewat and dimensions of lines were generated. Multi-analytic maps were developed from analytical layers, and a web-based GIS interface was developed to access and view the data in an interactive mode.

The segment explanation as mentioned in methodology flow chart is given as;

3.3.1 Satellite Imagery

The satellite Imagery, having spatial resolution of 0.46 meters, was acquired from The Urban Unit for research work. The sensor of satellite imagery is World View-2 satellite, and the characteristics are given in table B2 of Appendix B. This imagery was used for geo-referencing of the final mosaic map and extraction of features.

3.3.2 Field Data

The field data is comprised of revenue data and field survey data. The revenue data consists of cadastral maps and land record registers.

3.3.2.1 Field Survey Data

Global Positioning System (GPS) receiver (GPS 60TM)) was used for collection of GCPs of existing boundary pillars (local name as Sarhede) and boundary marks for the geo-referencing of cadastral maps. The GPS receiver had tempted error which was fixed during processed of surveyed data. The technical specification of the GPS gadget is given in table B3 of Appendix B.

3.3.2.2 Revenue Records

The revenue records consist of cadastral maps and the registers' data.

- **Cadastral Maps**

Cadastral maps and registers' data of the study area were collected from Board of Revenue (BOR), Government of Punjab and observed these maps were generated in the year 1963-64. These cadastral maps consist of an index map and eight individual maps (musavies). The scale of all cadastral maps is 1 inch (721.82 meters) equal to 220 feet (40 Karam). The index map shows the whole study area as shown in figure 3.4. Each map has a specific Urdu language name and highlights that 4 Alaf and 4 Bey Musavies (cadastral maps) reflect the index map area as shown in figure 3.5a.

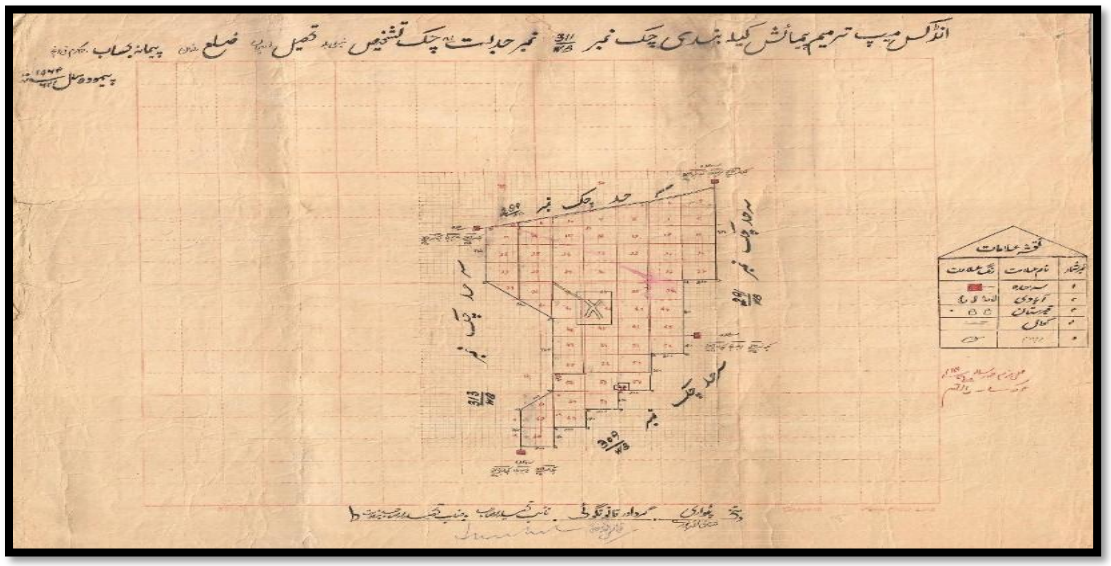


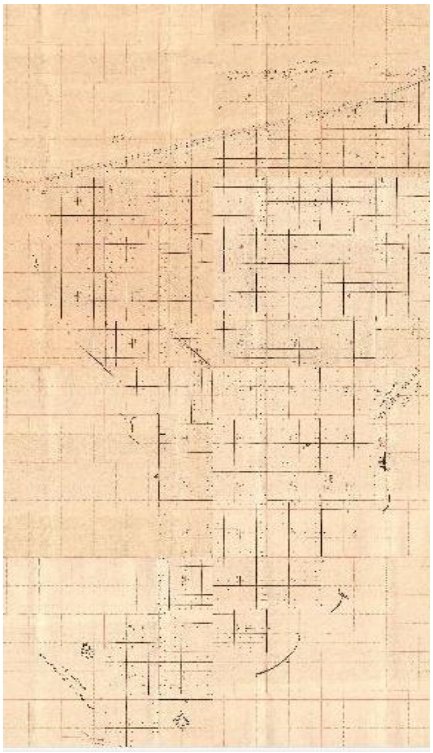
Figure 3.4: Index Map of Study Area

- **Land Record Registers**

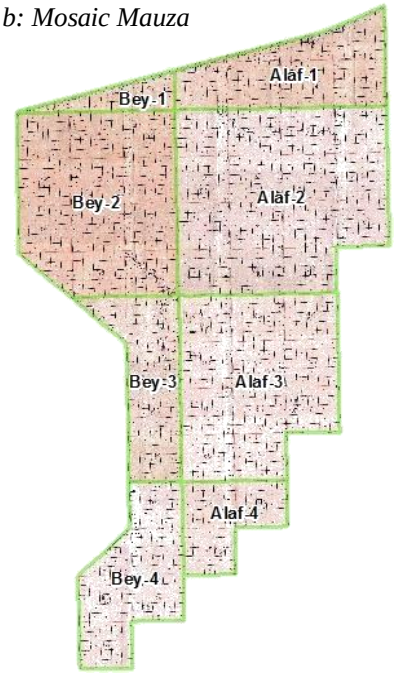
The land ownership, cultivation, mutation, possession, lease, and shajra nasab information were recorded from different manual registers by the land revenue officer (Patwarie). The description of land record registers is given in Appendix C. The revenue registers data was scanned by using a Bookeye scanner as shown in figure D2 of Appendix D. The information available on the registers; RHZ, field book, etc. were converted into digital format and linked with the geometry of the land parcels.

3.3.3 Pre-Processing of Musavies

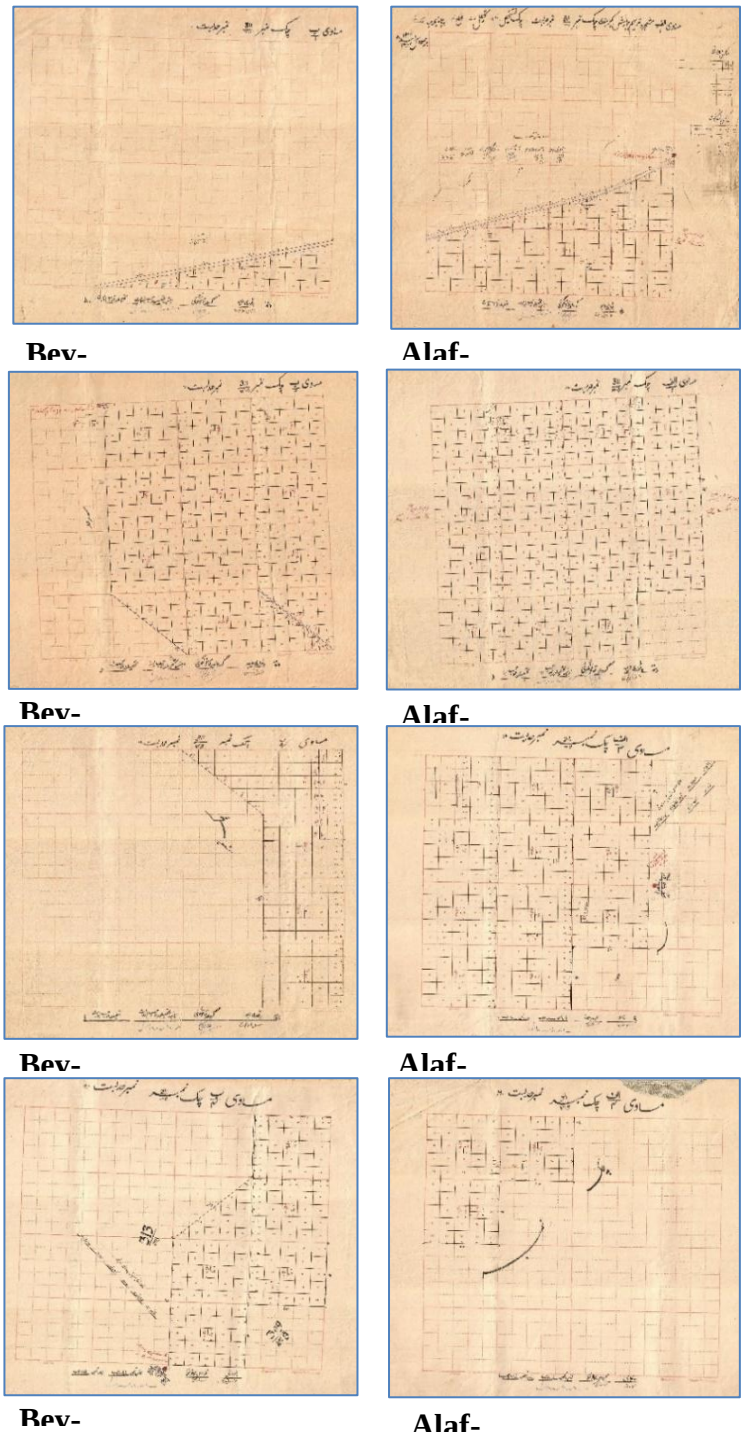
The study area consisted of eight individual cadastral maps (Musavies). These were renamed, cropped and mosaicked in MATLAB. The cropping and mosaic MATLAB algorithms were processed to complete the jigsaw puzzle for the final mosaic map as shown in figure 3.5b.



b: Mosaic Mauza



c): Final subset of Mauza Map with Musavee boundary



a): Musavies of Study area

Figure 3.5: a) Musavies of study area, b) Final Mosaic Map & c) Final subset of Mauza Map with Musavee boundary

3.3.4 Geo-referencing of Final Mauza Map

The final mauza map has no spatial reference, therefore, it was geo-referenced in ArcGIS 10.3 software by using the high-resolution satellite imagery (HRSI) and GCPs collected from the field activity as suggested in the previous research to develop cadastral measuring techniques (Ali, 2012). In this concern, 11 geospatial references were assigned on the final mosaic map using high-resolution satellite imagery and Ground Control Points (GCPs) to ascertain the better accuracy of features. The 2nd order transformation was used for geo-referencing to get better accuracy of geo-referenced mosaic map. The SI unit "meter" was used for input measurements to estimate Root Mean Square Error (RMSE). The RMSE was estimated 0.000060097 m, which is less than one meter and reflected that good positional accuracy of geo-referenced data was achieved.

3.3.5 Final Subset of Mauza Map (Area of Interest)

Digitization is a process of converting existing features from cadastral maps into a vector (digital) format. On-screen digitization process was used to demarcate village boundary of study area. Final subset of the Mauza map as per digitized area of interest (AOI) was extracted in ArcGIS using the Spatial Analyst tool "Extract by Mask" and removed un-wanted area as shown in figure 3.7c.

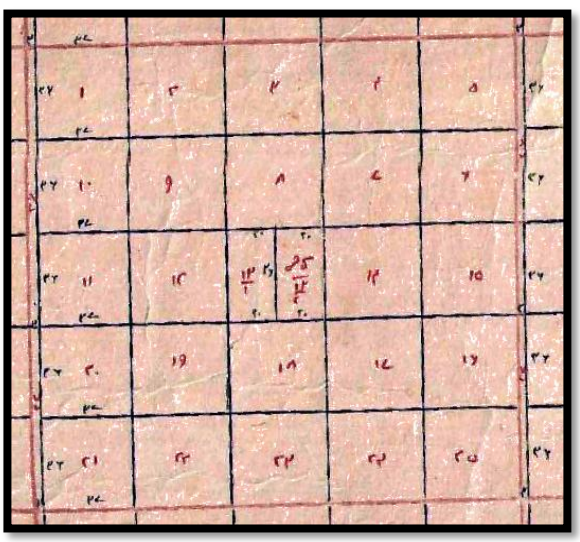
3.3.6 Khasra Level Mapping

The final extracted mauza map consisted of squares, khasra and sub-khasra boundaries with labeling of information and dimensions of sides of land parcel. It was digitized in ArcMap to store the geometry of land parcels (khasra and sub-khasra) and recorded attribute information (square number, khasra number, sub-khasra number and name of Musavee, dimensions of sides of land parcel). One of the basic challenges faced was to read the vernacular mentioned on the final mauza map because labeling information was in Arabic language and caused confusion at some times. This issue was resolved after consultation with revenue experts and revenue registers' data. The khasra as per cadastral map, overlay with digitized features and only digitized features without a cadastral map are shown in figures 3.6a, 3.6b and 3.6c respectively. In order to ascertain 100% qualitative error-free data, topology was applied and removed the overlapped areas and gap errors. Further, these land parcels were merged into 66 squares features based on square number recorded from finalized area.

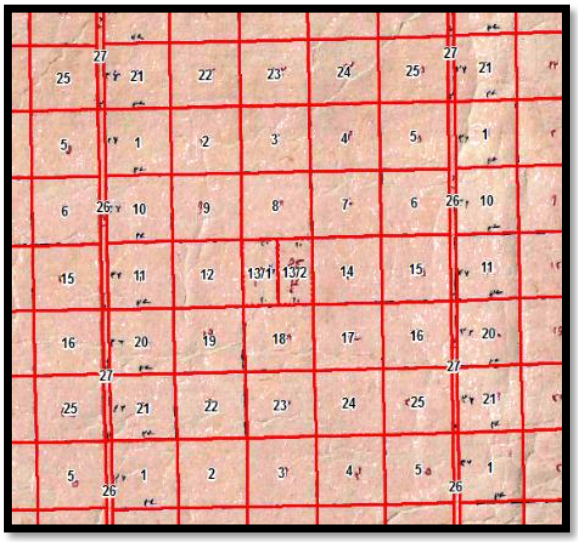
3.3.7 Fabric Sketch to Geographic Entity

To store the dimensions of the sizes of land parcels, Parcel Fabric tool was used to develop parcel fabric models. Parcel Fabric is an ArcGIS extension that is used for cadastral data management and stores a continuous surface of connected parcels. It resolves the issues of generation of separate lines with associated sizes and land parcel information can be managed easily.

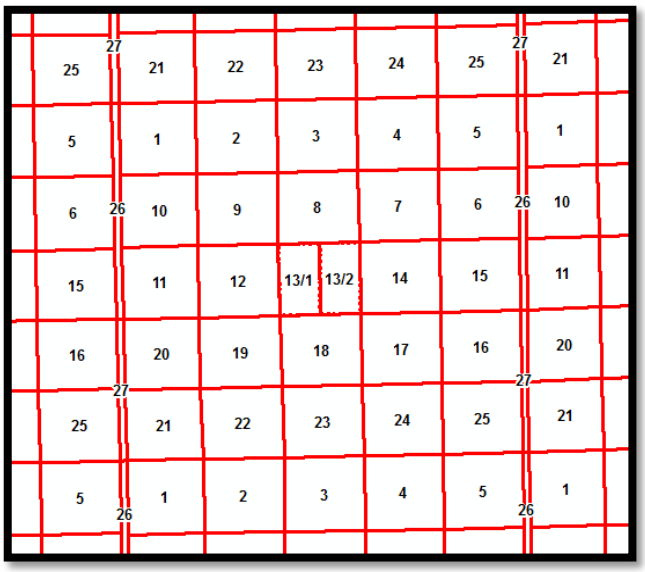
In this research work, methodology of parcel fabrication model was based on approach; "Parcel Fabric – A good possibility for management of Geospatial Cadastral Data" (Ana, 2014) and



a): Khasra and sub-khasra Scanned Musavee Map



b): Musavee map with overlay of Digitized Khasras and sub-khasras



c): Digitized Khasras & Sub-Khasras

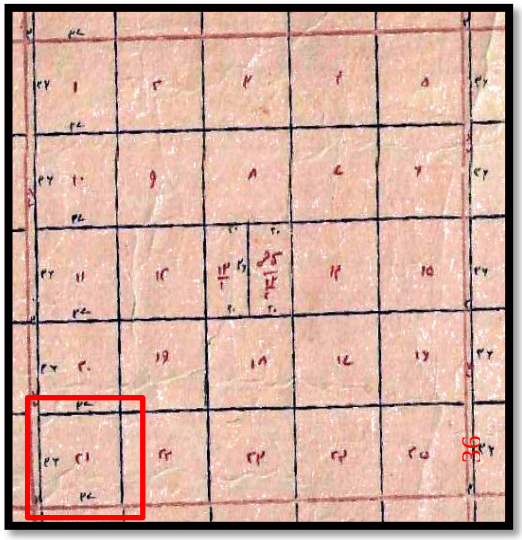
Figure 3.6: Khasras and sub-khasras of Scanned Musavee map vs Digitized khasras and sub-khasras

gave a full concept to develop parcel fabrication model. Khasra and sub-khasra features were converted into line features to develop parcel fabric models. These lines features were generalized and split at vertices. Dimension field was incorporated in the database of spatial features to store measurements of sides of land parcels. Topology was applied to ensure the quality of spatial data as per the standards of the parcel fabric model (Badea, 2004). Topology including 8 topological rules as mentioned in Appendix E was applied to line feature class and rectified errors and further

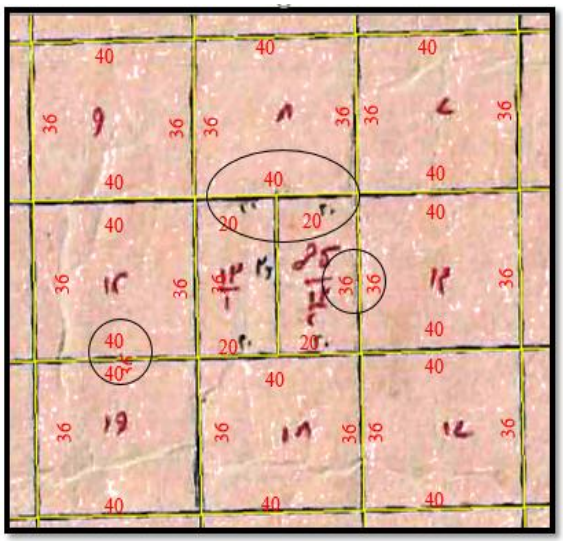
converted into the new khasra polygon feature class. Again, topology included six topological rules as given in Appendix E, were applied to the new_khasra_polygon & khasra_lines feature and errors were rectified to ensure accuracy of output data and ready for parcel fabric model. The spatial data: new khasra polygons and khasras' line features were stored in a blank geo-database. The geo-database structure detail is given in section 3 of Appendix D. The output of parcel fabrication model resulted that 1,605 khasra polygons and 6,508 khasras' lines being generated. It ensured that the increase in lines in Parcel fabric model was due to addition of adjacent lines (sharing boundary lines) of two land parcels considered a double line.

3.3.8 Updating of Khasra & Sub-Khasra

Cadastral maps are very old and not updated till now. Meyer, 2004, proposed that the cadastral records must be updated to specified standards and on a regular basis. Therefore, register data; Tatima (a division of land record) Field book (new and old), Girdawri and Register Haqdaran Zamin (RHZ) as mentioned in Appendix C, were used for updating of boundary and lines dimensions of khasra & sub-khasra. The revenue information was also updated from registers' data, including the dimensions (measurements of sides) of land parcel (khasra). The revenue system depends on measurements of land parcels because the dimensions of lines of individual land parcel reflects its area as shown in figure 3.7a. Individual khasra feature includes its dimensions of lines as 36 Karam (198 feet) x 40 Karam (220 feet). Karam unit is used for measurement of dimensions of lines of land parcels, where one Karam is equal to 5.5 feet (1.68 meter). The line's dimension of the individual land parcel, on a cadastral map, may represent two lines of adjoining land parcel. Figure 3.7b highlights the dimensions in red text which are represented by two overlapping lines with unique khasra numbers.



a): Dimensions (Red Box) of land parcel on Handmade Musavee Map



b): Digitized Lines' Dimensions of land parcels on Musavee map

Figure 3.7: Dimensions of land parcel on Handmade Musavee Map vs Digitized Dimensions

khasras were updated based on information present in the Field book & RHZ registers. To divide the concerned khasra parcels into two parcels or multiple parcels, "Parcel Division" was used in the parcel fabric tool by used of true direction tool; starting from the "North or South" or "East or West" and unwanted parcels were deleted after division and updated the attribute information. To merge the concerned khasra parcels in one parcel "Merge" option was used in the parcel fabric tool and updated the attribute information. These tools are very useful regarding Tatima cutting in land administration. Then topology was applied final to ascertain 100% quality of the final parcels and lines feature classes and other necessary quality checks as mentioned in section 4 of Appendix B, were also authenticated**.**

3.3.9 Non-Spatial Database Development and Integration with Spatial Data

BOR developed a MIS system of attribute information available in the land record registers but did not link with the geographical features as discussed in section 2.3 of Chapter 2. This linkage is necessary for geospatial technology as suggested in previous research; Data offers connections to more comprehensive information (Meyer, 2004). Therefore, attribute information (khewat number, khatuni number, number of owners, ownership, cultivator status, khasra number, total land area, types of land (nahri area, gair mumkin area, banjer qadeem and banjer jadeed) mentioned in Appendix C, were recorded from RHZ in excel format and unique IDs, were assigned to each entry for relationship with geographical features. Kkhasra level spatial data and non-spatial database were integrated based on unique IDs.

3.3.10 Ground Truthing / Field Verification

The positional accuracy and attributes information accuracy were verified in field activity with consultation of revenue officials and audited information with help of revenue available records.

3.3.11 Development of Analytical Layers

Analytical layers were prepared based on attribute information stored with geometry of khasra & sub-khasra after development of the spatial and non-spatial databases and generated multiple analytical maps.

The following feature classes were developed;

- Khasra and Sub-khasra feature class
- Square boundary feature class
- Musavee boundary feature class
- Mauza boundary feature class
- Khewat Boundary feature class
- Khatuni Boundary feature class

- Field Verification Point feature class
- Village Boundary
- Khasras 'Dimensions feature class
- Different Analytical Layers: land type based on possession, ownership and gair mumkin

3.3.12 Web-Based GIS Interface

Kalantari, 2005 suggested that E-LA does not only provides a cost-effective and operative method of data modeling for cadastral mapping but also develops standard linkages in handling of detailed information from data developers and expressed to disseminate geospatial data with less effort, web GIS plays an important role (Nutan, 2014). Alesheikh pointed out that web GIS will enhance communication among the users who understand maps and spatial data (Alesheikh, 2002). The departments: PMU and BOR have already developed software for management and maintenance of attribute data of land records but there is no spatial linkage of land parcels with spatial geometry. Therefore, a web GIS system is necessary for the 21st century.

The spatial data of my research area is ready for development of Web Based GIS Interface and interactive maps. Web-based GIS interface "Spatial Land Record System (SLRS)" was developed by publishing the data through ArcGIS Server. It provides an ArcGIS online map viewer and ESRI-enabled facilities. It can be configured as per requirement and can be accessed on a local server. It provides metadata and spatial data. Data can be viewed in multiple data rendering formats, ArcGIS JavaScript, ArcGIS Online map viewer, Google Earth, ArcMap and ArcGIS Explorer.

This study provides attribute data with spatial data of analytical layers in such a way that data can be searched/queried through Web-based GIS Interface Spatially and associated attribute information of individual land parcels.

The details of attribute and neighborhood of land parcel can be visualized in the developed GIS web interface. It provides the land revenue record in a much more readily accessible and useable format than manual land record.

4. RESULTS

Significant anomalies in area and length measurements of land parcels were identified from manual land records after the conversion of manual land records into digital form. The analytical layers: khasra and sub-khasra, square, musavee, khewat, khetuni, land types based on ownership, gair mumkin, possessions, ZTBL borrowed loan, and lines' dimensions were developed and prepared thematic maps. Web-based GIS interface was developed through ArcGIS Server for visualization and analyses of spatial data of land records remotely.

4.1. How well will the dimensions and boundaries of land parcels be preserved in a digital cadastre?

Eight musavies (cadastral maps) were scanned using a manual scanner to preserve better resolution (300 DPI) of scanned musavies as discussed in section 1 Scanning of Cadastral Maps of Appendix D and processed to make the final mauza map of the study area through Metalab algorithm. This final map was geo-referenced and digitalized the land parcels to form the digital cadastre. The lines' dimensions of land parcels were preserved through parcel fabrication model.

4.1.1. Land Parcels and Sub-Land Parcels' Statistics

The officially notified study area as per land records registers is 1,439.33 acres (11,514 kanal and 13 marlas), whereas one acre is equal to 4046.856 square meters in SI unit and number of rectangular blocks are 66. These blocks were further sub-divided into individual land parcels (khasras & sub-khasras). The total number of khasras and sub-khasras is 1,682.

The estimated area after conversion of cadastral map into digital, is 1,440.92 acres (11,527.33 Kanal), approximately as shown in table F1 of Appendix F and resulted that 0.11% increase in area. The total land parcels as per musavies are 1,605, while total land parcels as per field book (2010-11) are 1,681 as shown in table F2 of Appendix F. This illustrates that the revenue records' ownership was not up to date and did not match with another revenue record due to manual management. Musavies-wise area information with an overlay of square boundary, khasras and sub-khasras is shown in table F2 of Appendix F.

Musavee Bey-1 has the least land area of 33.67 acres (269.30 Kanal), square no. and khasra & sub-khasra information, while musavee Alaf-2 has the maximum land area of 375.17 acres (3,001.38 Kanal). Musavies wise area percentage distribution is shown in figures 4.1 & 4.2 respectively.

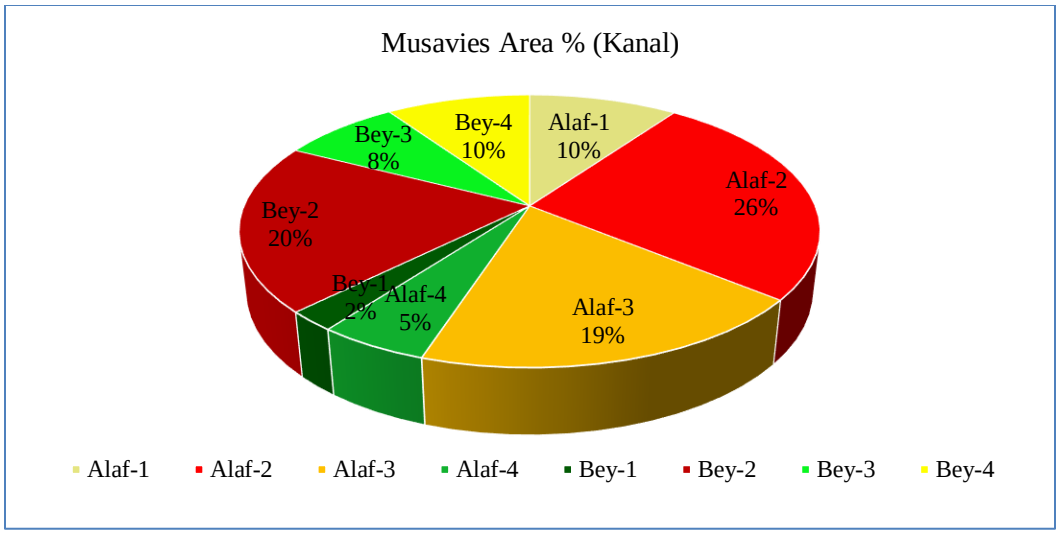


Figure 4.1: Musavee Wise - Area Percentage Distribution

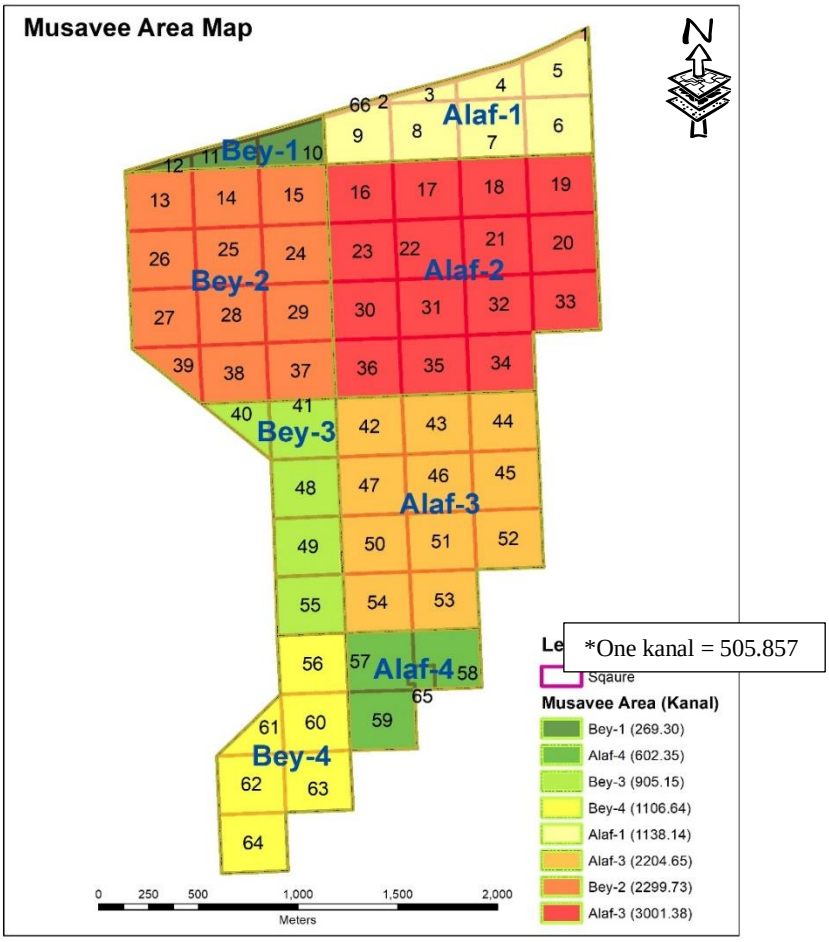


Figure: 4.2: Musavee Wise – Area Map

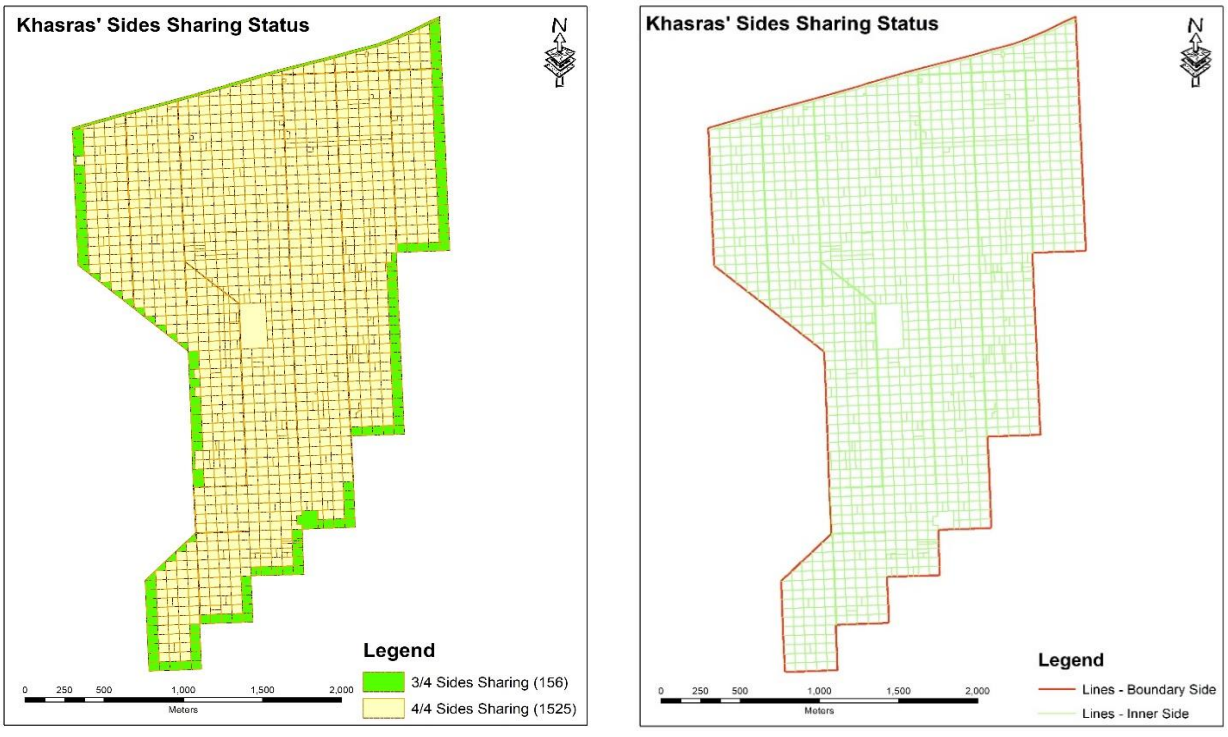
The area summary of individual squares and analysis as per musavies (before updating) and as per field book (after updating) is given in table F3 of Appendix F.

4.1.2. Land Parcels Lines' Dimensions Statistics

One objective of my research was to develop the lines' dimensions of each khasra land parcel through a parcel fabrication model to preserve lines' dimensions of land parcels in a digital cadastre. The advantage of parcel fabrication is that every single line's dimension of each khasra (leaving the boundary ones) is shared between its adjacent khasras on a cadastral map. This was stored in a database in such a way that line's dimensions are represented by two overlapping lines with unique IDs. Even in this case, different dimensions of shared side of adjacent khasras are also stored in that database separately as per cadastral map.

Khasra land parcels comprise of 1,681 polygon features and are converted into 3,575 lines features. These lines are converted into 7,119 parcel fabric lines, and store separate sides of individual unique khasra land parcel.

It is resulted that all four sides of 1,525 khasra land parcels out of 1,681, are sharing sides with adjacent land parcels, while three out of four sides of 156 khasra land parcels are sharing sides with adjacent land parcels as shown in figure 4.3a. 168 lines facing the study area boundary, are not shared with any other land parcel and consist of a single side of individual land parcel within study area as shown in red tone in figure 4.3b.



a) Khasras' Sides Sharing Status *b) Lines Boundary side vs Lines inner side*

Figure 4.3: Khasras' Sides Sharing Status

Karam is the basic unit used in the revenue record in Pakistan, which is equal to 5.5 feet (1.68 meter), so this unit is used for the measurement of the length of lines. The total dimensions' length of 7,119 lines of 1,681 khasra land parcels is 2,47,898 karam as per revenue records, while the total length of all sides in GIS is 2,48,016.60, which is 0.048% higher than the dimensions' length of revenue record.

The summary statistics of dimensions' length of individual musavies are given in table 4.1.

Table 4.1: Statistics of Musavies Wise - Lines' Dimensions

Musavee Name	Lines Count	Dimensions Length (karam*) Revenue Record	Dimensions Length (karam*) GIS	Difference %
Alaf-1	758	27,168	27,169.20	0.004%
Alaf-2	1,828	63,963	63,959.95	-0.005%
Alaf-3	1,322	45,522	45,614.02	0.202%
Alaf-4	375	12,401	12,443.78	0.345%
Bey-1	174	5,396	5,347.79	-0.893%
Bey-2	1,434	49,722	49,670.31	-0.104%
Bey-3	593	20,338	20,369.46	0.155%
Bey-4	635	23,388	23,442.09	0.231%
Grand Total	**7,119**	**247,898**	**248,016.59**	**0.048%**

*One karam is equal to 1.68 meters.

Musavee Alaf-2 has the highest lines count (1,828) and dimensions length (63,963 karam) as shown in red in figure 4.4 and Bey-1 has the least lines count (174) and dimensions length (5,396 karam) as shown in green. The dimensions' length concerning the square is also calculated and it was observed that square number 3 has the least lines count (3) with dimensions' length (93 karam) while square number 37 has the maximum lines count (167) with dimensions' length (5,343 karam). The count of sides with dimensions 36 karam and 40 karam are 3,167 and 2,316 respectively. The khasra number 66 of square number 66 has the longest dimension length 1,372 karam.

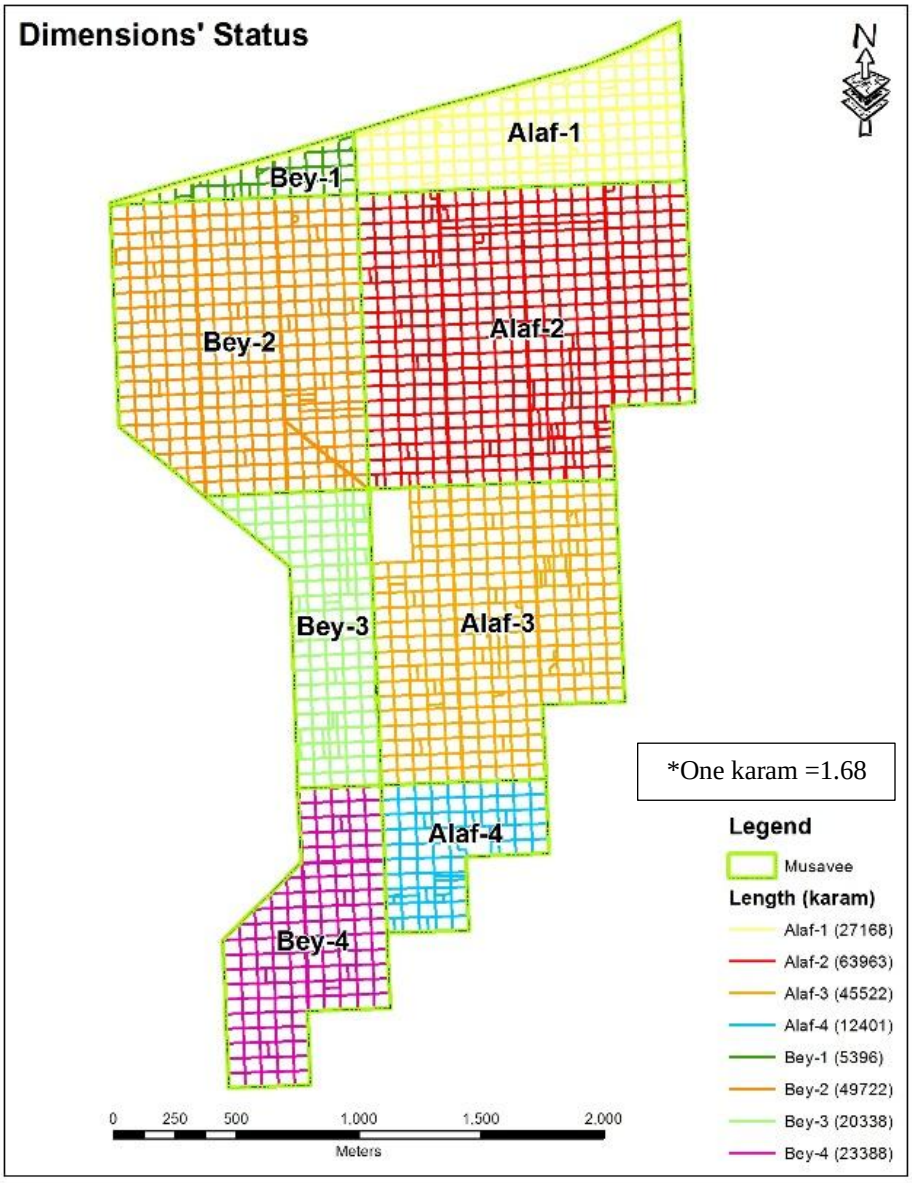
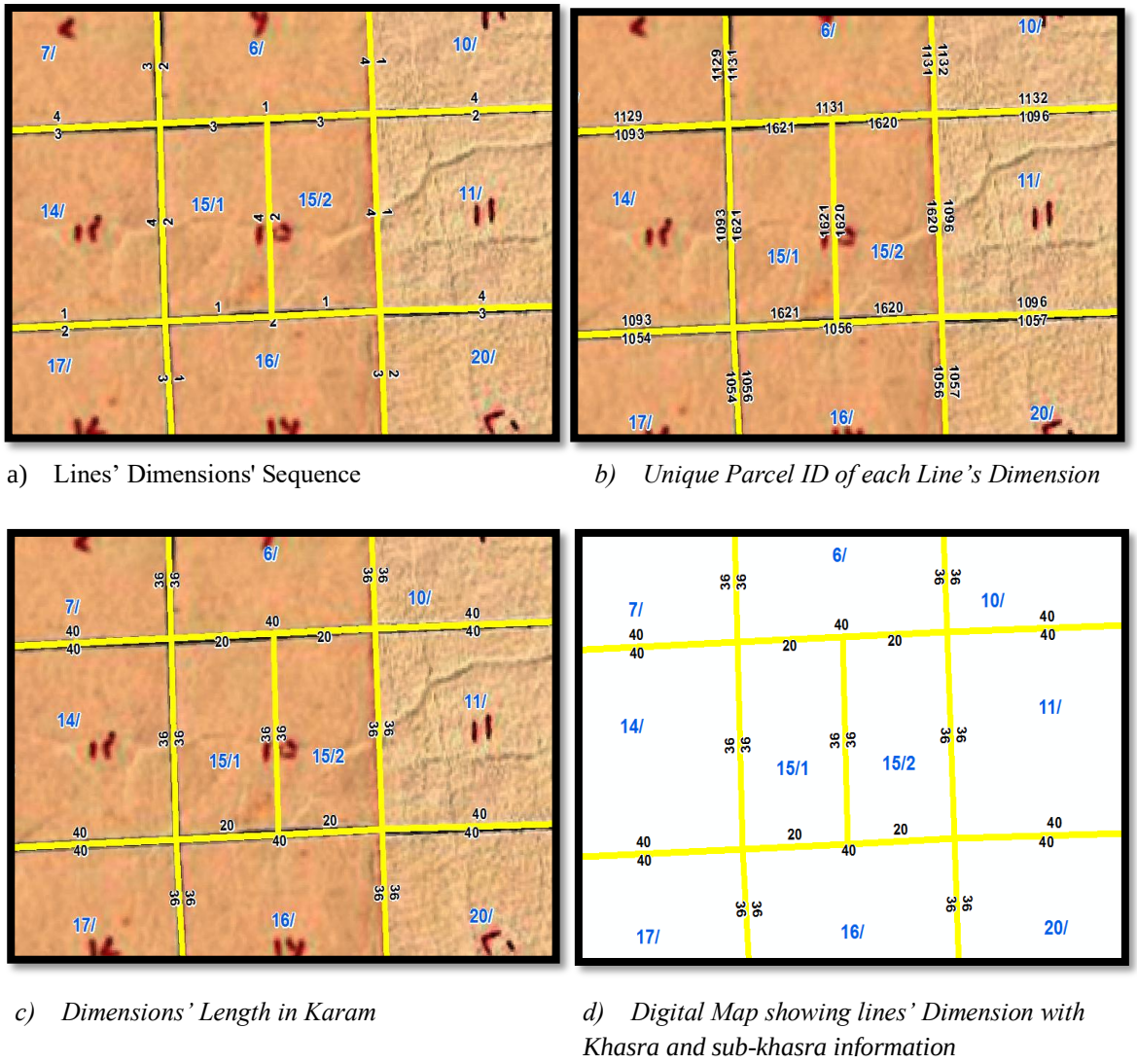


Figure 4.4: Musavee Wise Lines' Dimensions Status

The dimensions of all sides of each khasra land parcel are entered manually from cadastral maps & field book registers. These lines' dimensions were audited after conversion into a GIS environment. The sequence of dimensions lines, generated in parcel fabrication, is clockwise, i.e. 1 represents to South, 2 represents to West, 3 represents to North and 4 represents East. The unique parcel ID was assigned to all lines of parent land parcels. Sub-khasra numbers 15/1 & 15/2 of khasra number 15 of square number 24 are shown in figure 4.5a, this khasra land parcel has no division on musavee, but existed in the manual record. The unique parcel ID (1621) of the parent khasra land parcel of each line's dimension, length of each side, and digital presentation of khasra number 15 of square number 15 are shown in figures 4.5b, 4.5c and 4.5d respectively. This digital map clearly shows the lines' dimensions of each side with khasra and sub-khasra information. The development of digital cadastre is one of the objectives of this research.



a) Lines' Dimensions' Sequence

b) Unique Parcel ID of each Line's Dimension

c) Dimensions' Length in Karam

d) Digital Map showing lines' Dimension with Khasra and sub-khasra information

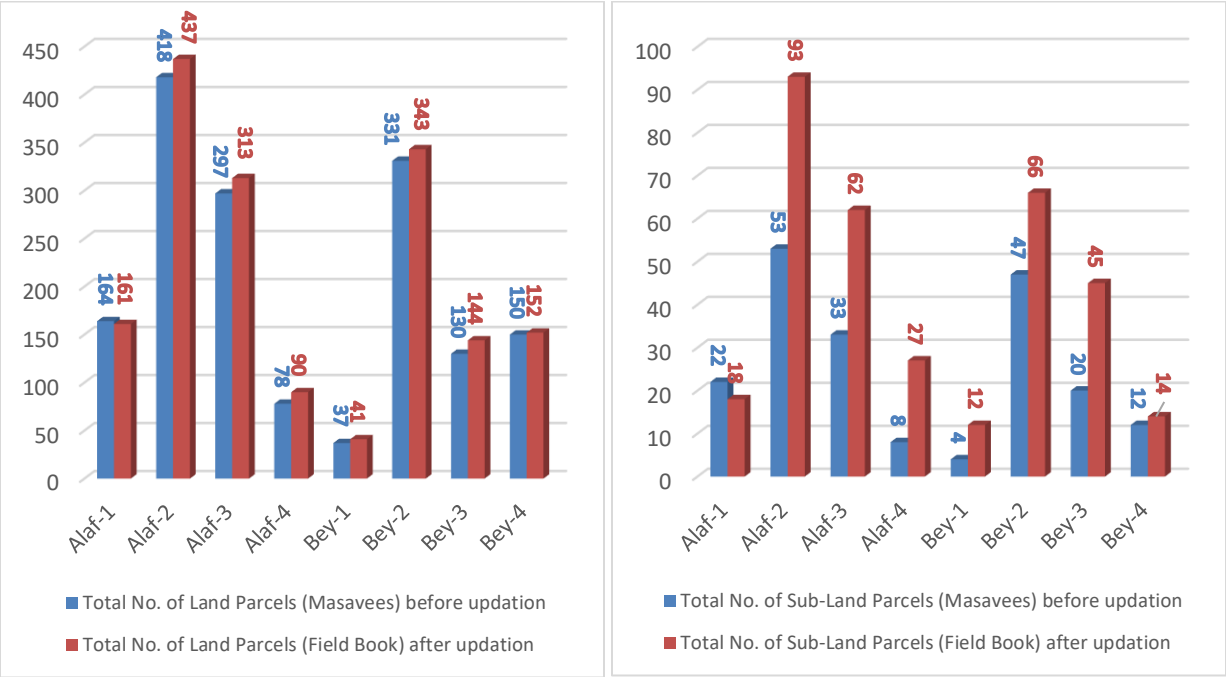
Figure 4.5: Representation of Lines' dimension Sequence, Unique ID, Length information and Digital Map of Khasra Number 15 of Square No.24

4.2. How should land records be updated, and new records be treated? What are the proposed routines?

The updating of land records information was integrated through parcel fabrication model. This model preserves information of updated parcels and stores archive information. It also provides a mechanism to merge or split the land parcels.

It is estimated that total number of khasras and sub-khasras as per musavies (before updating) and as per field book (after updating) are different. The increase in khasras and sub-khasras are 76 and 138 respectively, while total number of musavies, square numbers and areas are same before and after field book updated record as shown in table F2 & table F3 of Appendix F. It has resulted that

the change in count of khasras is due to a change of land ownership in revenue records. The sub-khasras (sub-land parcels) are further division within khasra (land parcel). The interesting thing is that the number of khasras decreased in musavee Alaf-1 from 164 to 161 and sub-khasra parcels from 22 to 18, while other musavies have increased in khasra and sub-khasras. This is considered that it is due to a change of ownership record. Musavee Alaf-2 has a maximum increase in khasras from 418 to 437 and sub-khasras from 53 to 93 as shown in table F4 of Appendix F. Similarly, total number of khasras and sub-khasras of individual square numbers as per musavies (before updating) and as per field book (after updating) are shown in table F5 of Appendix F. Musavee wise change in khasras (land parcels) and sub-khasras (sub-land parcels) before & after updating are shown in figures 4.6a and 4.6b respectively.



a): Change in Land Parcels before & after updating b): Change in sub-Land Parcels before & after updating

Figure 4.6: Musavee wise change in khasra (land parcels) and sub-khasra (sub-land parcels) before & after updating

Each observation before and after updating can be seen geographically. It was observed that 1,525 khasras out of 1,605 khasras remained unchanged; nine khasras were merged, while 71 khasras were sub-divided after updating. The behavior of merged land parcels and split land parcels after and before updating, at zoom level and full extent of study area are shown in figure 4.7 and figure 4.8 respectively.

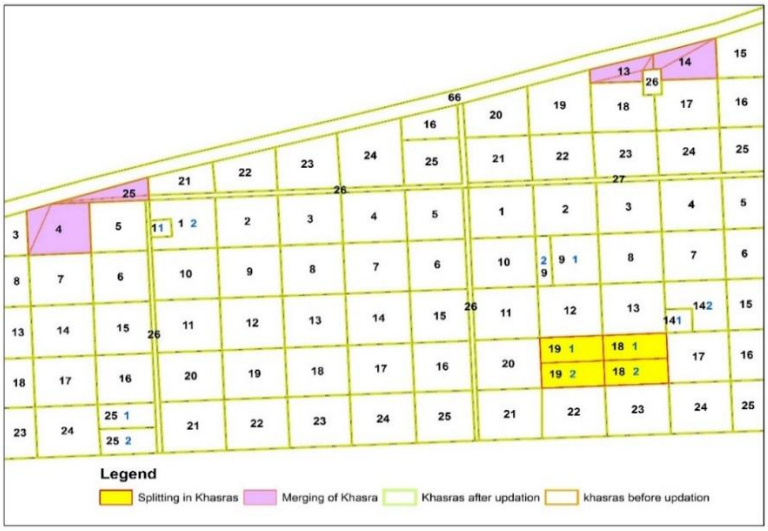


Figure 4.7: Merged and Split Land Parcels before and after updating (Zoom View)

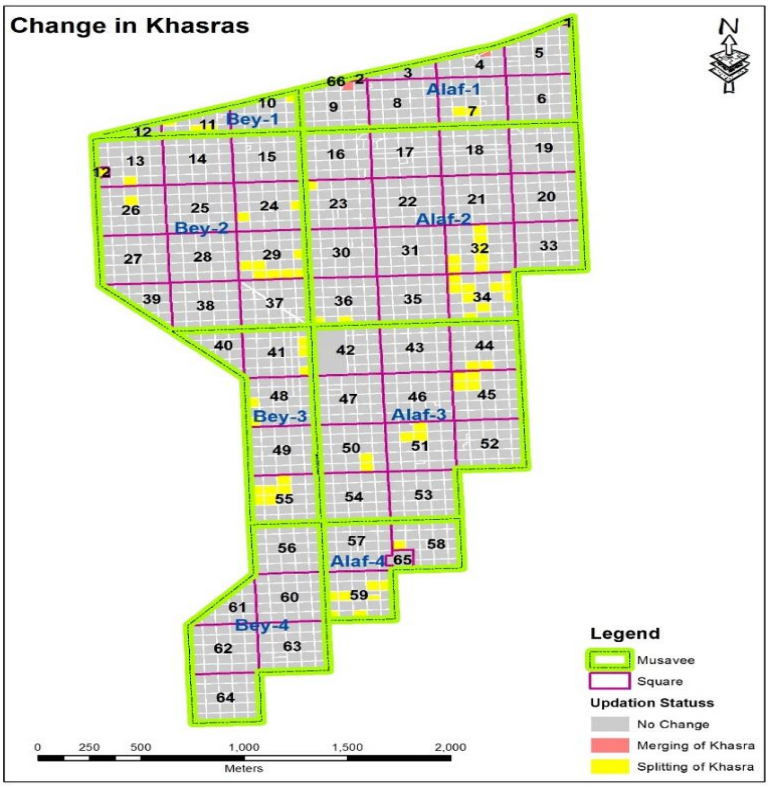


Figure 4.8: Merged and Split Land Parcels after updating (Study Area)

4.2.1. Development of Digital Musavee

The digital musavee was developed after the conversion of digital cadastre and updating of land records information by use geospatial technology. In this study, different kinds of analytical layers were prepared based on information available in the digital cadaster.

For example, the digital map of square number 24 is shown in figure 4.9, which highlights the square boundary and khasra & sub-khasra boundary with dimensions' length. Square number 24 consists of 25 khasras with six sub-khasras having 126 lines count and total dimensions' length is 4,358 Karam. This digital map represents lines' dimensions in karam of each side with khasra and sub-khasra information, which was one of my objectives of this research. Similar digital musavee concerning other squares and musavies can be generated. This digital data can be further used for khasra level crop estimation and digital Girdawri.

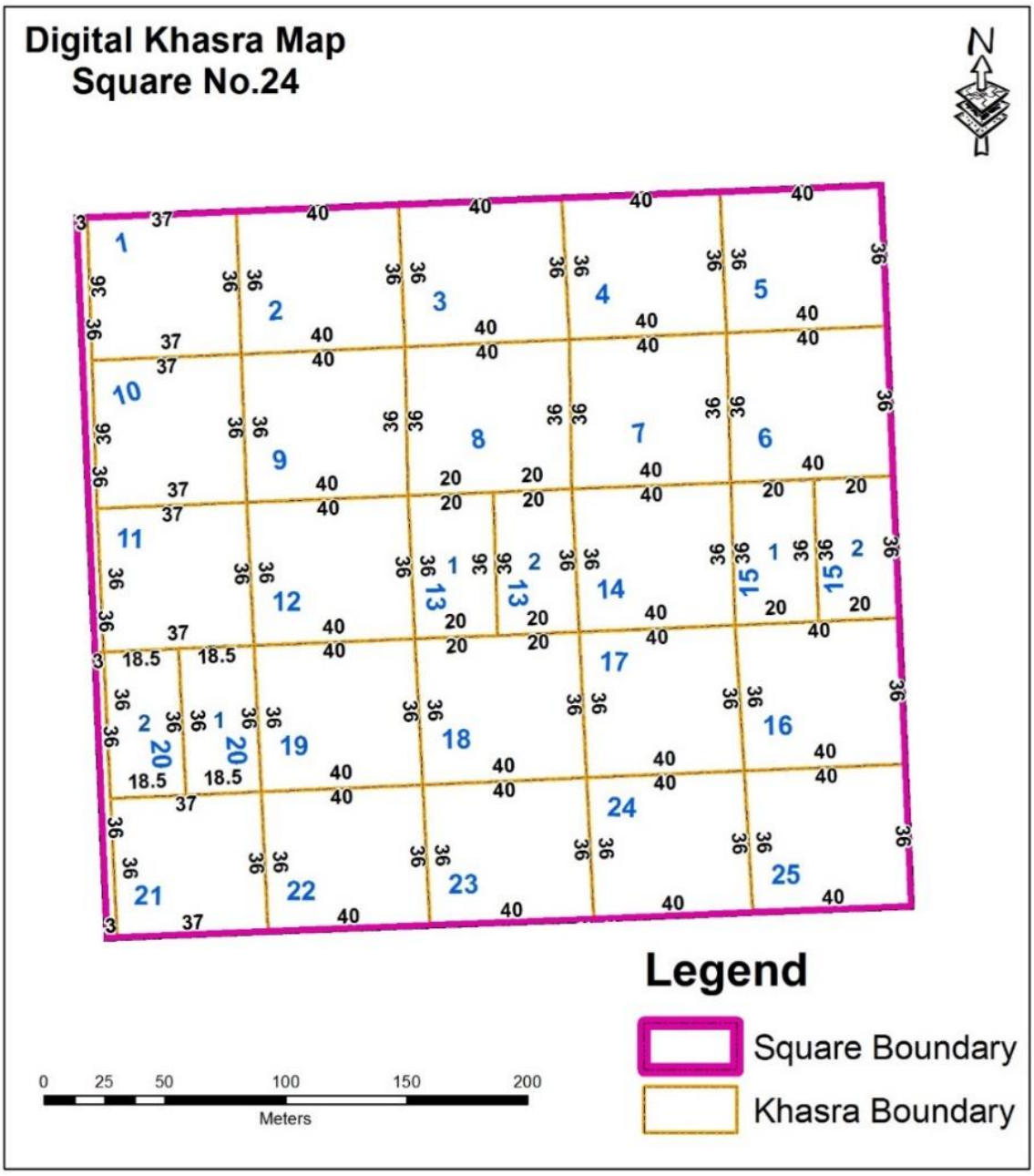


Figure 4.9: Digital representation of Khasra Map of Square Number 24

4.3.How should attribute data be integrated into the digital cadastre? What are the proposed practices?

In the manual record, the revenue information; khewat, khetuni, khasra & sub-khasra, land areas; nahri, gair mumkin, banjer jadeed, banjer qadeem, benaam and Zarai Taraqiati Bank Limited (ZTBL) loan information were recorded manually in revenue registers. In my research work, this information was transferred into digital format and was linked with spatial data. All data in the field book is only textual information and was missing the geographical linkage, which is covered in my study. The land record analysis based on khewat, khetuni, gair mumkin, ownership land type, land possessions based on cultivation and ZTBL loan information are given below.

4.3.1. Khewat Wise Land Record Statistics

Khewat information is summarized and compared with the Register Haqdaran Zameen (RHZ) and identified the misrepresentation entries in manual revenue record. Khewats counts were calculated by searching each khewat entry from the web portal of PLRA and audited with digital cadastre. The summary statistics of individual khewat is given in table F6 of Appendix F and geographical representation is shown in figure 4.11. The further categories of land areas; nahri area, gair mumkin and banjer qadeem are highlighted. It is identified that total khewats count increased from 152 to 166 and landowners increased from 152 to 761, which is due to a change in ownership of landowners. The total area of all 166 khewats is 10,822.6 Kanal instead of 11,517.05 Kanal. Khewat 1/1 consists of 199 khasras and sub-khasras has the highest land area 1,460.35 Kanal. This kind of analysis is possible due to the conversion of manual field book information into digital format and linked geographically. Some khewat has no difference in land area, i.e. khewat no.5 has the same total land area in RHZ and PLRA, which consists of 15 khasras and sub-khasras of square number 15 of Bey-2 musavee as shown in figure 4.10.

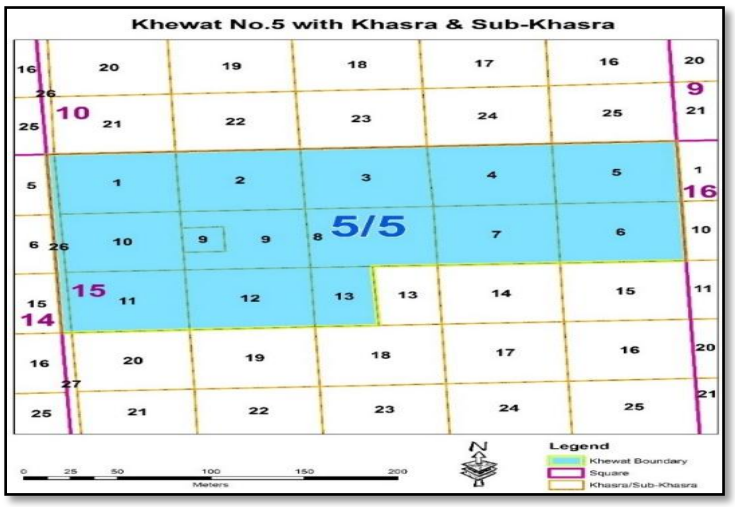


Figure 4.10: Khasras & sub-khasras of Khewat Number 5

The discrepancies were identified in khasras information such as five khasras; 35/27, 28/27, 43/27, 55/27 and 63/27 exist in RHZ but are not identified on the map, three khasras; 10/26, 30/26 and 36/26 have no information in RHZ. The khasra numbers; 11/23/1 & 11/23/2 are available in RHZ but did not divide on cadastral map. The summary of discrepancies in khasras is shown in table 4.2.

Table 4.2: Summary of Discrepancies in Khasras

Khasra Count	Khasras' Discrepancies	Remarks
1682	Total Land parcels (RHZ)	Total Land parcels (RHZ)
-5	35/27, 28/27, 43/27, 55/27 and 63/27	available in RHZ but not on Musavee
+3	10/26, 30/26, 36/26	available on Musavee but not in RHZ
+1	11/23/1, 11/23/2	available in RHZ but not divided
1,681		**Grand Total**

The detail of the five khasras was not available on musavies map and existed in khal (water path) type of gair mumkin land type. The description of each khasra is shown in table 4.3.

Table 4.3: Summary of missing Khasras on Musavee Map

Khewat No.	Khetuni No.	Land Parcels (Field Book)	Total Area in Kanal* (RHZ)	Total Gair Mumkin Area in Kanal* (RHZ)	Type of Gair Mumkin Land
7/7	37	35/27	1.8	1.8	Khal
21/21	79	28/27	1.2	1.2	Khal
52/51	141	43/27	1.8	1.8	Khal
63/62	159	55/27	1.8	1.8	Khal
93/93	267	63/27	1.2	1.2	Khal
Grand Total			**7.8**	**7.8**	

*One kanal is equal to 505.857 square meters

The area and khasras count discrepancies were noted in khewat Numbers; 33/32, 39/38, 93/93, 124/129, 125/116, 128/119, 129/120, 138/131 and 145/138 as highlighted in table F7 of Appendix F. The geographical representation of these khewats is shown in figure 4.11.

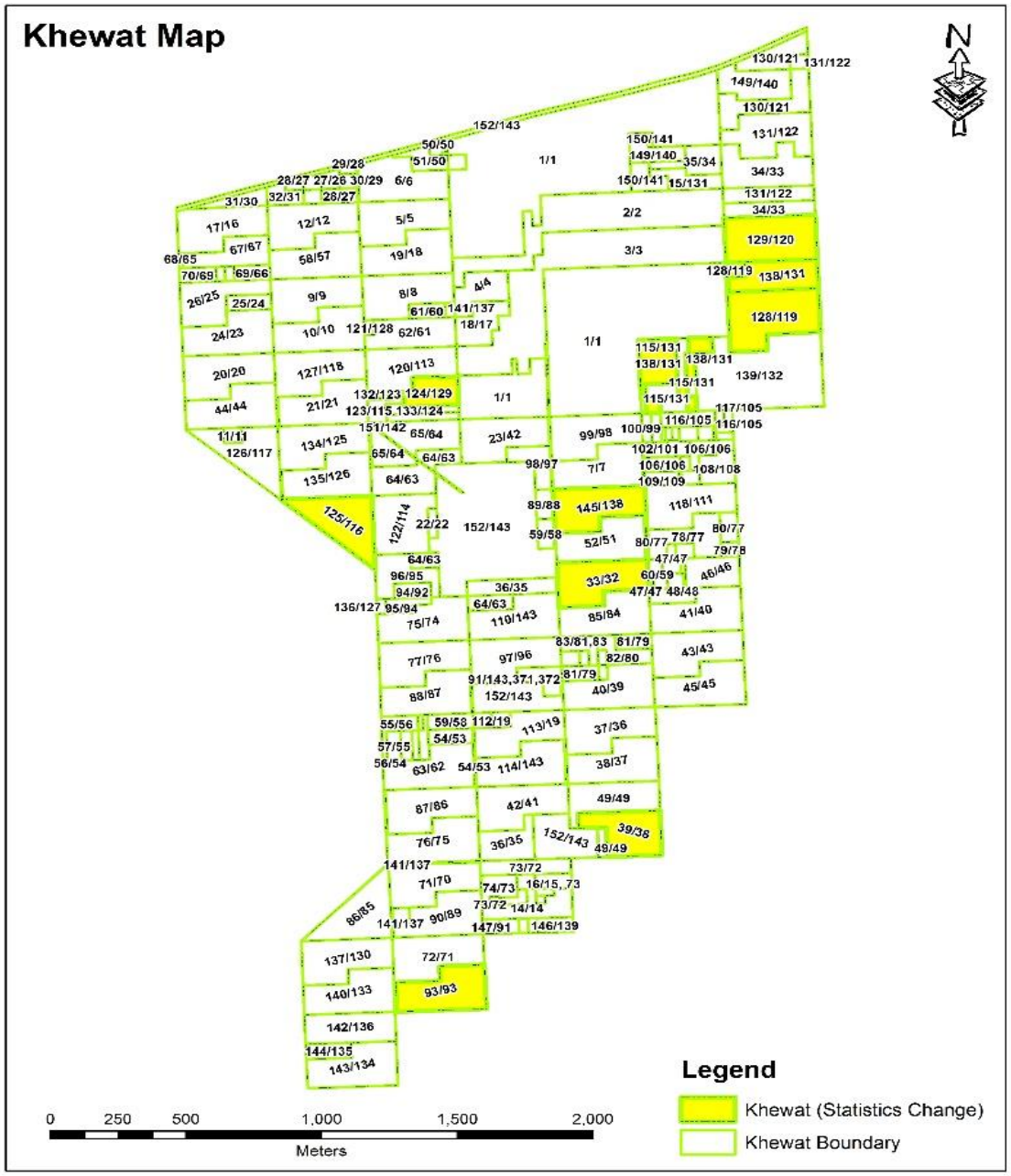


Figure 4.11: Khewats map highlighting Changes

Khewat No. 39/38 has no information regarding divided khasra of parent khasra number 13, while sub-khasra is available map. Similarly, another khewat has wrong summarized area information of all khasras recorded in RHZ.

For example, the total summarized area of all 14 khasras of khewat number 145/138 is 100 Kanal in RHZ as shown in figure 4.12, and after audited, area is 100.6 Kanal. It resulted that 0.6 kanal area information is not found in RHZ. Similarly, khewat number 125/129 includes wrong area

information of khasra number 40/9, which is geographically four kanal instead of eight Kanal as shown in figure 4.13.

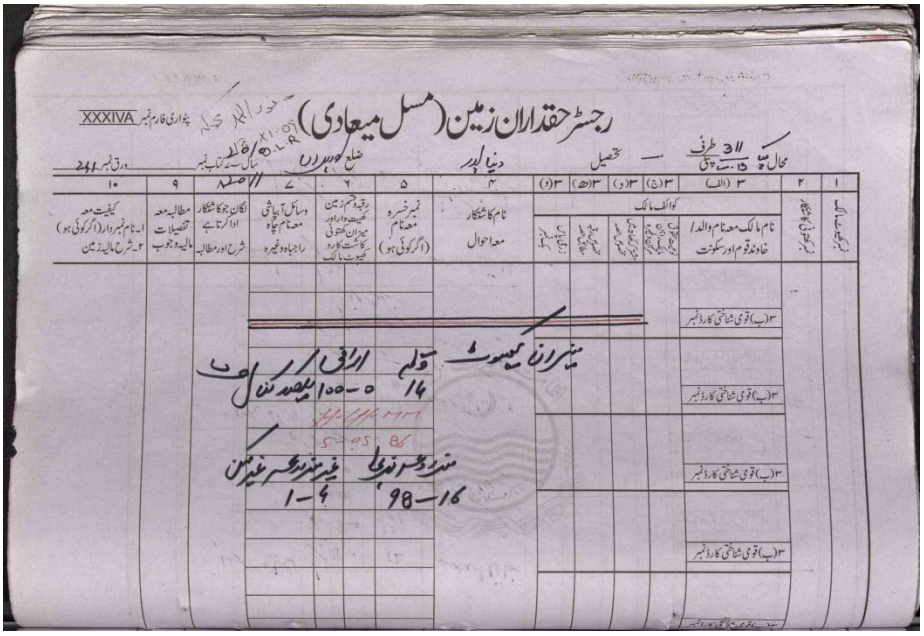


Figure 4.12: Summarized Statistics of Khewat No.145/138 of RHZ

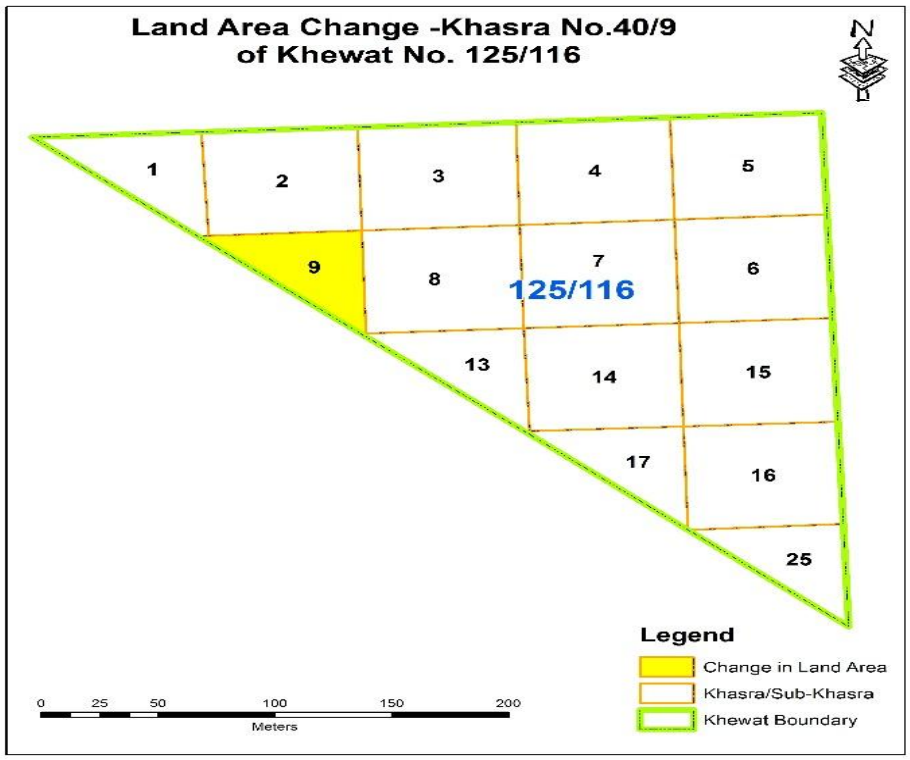


Figure 4.13: Change in Land Area of Khewat Number 125/116 vs RHZ

4.3.2. Khetuni Wise Land Record Statistics

The khetuni wis statistics were also summarized after integration of information available in RHZ with geographically. The summary statistics of each khetuni is given in table F8 of Appendix F. The geographic representation of khetunies is shown in figure 4.14 and identified that total khetunies are 472 in RHZ, while notified total khetunies are 477. The discrepancies in khasras and land area information were also identified, for example, three khasras were missing the khetuni information in RHZ.

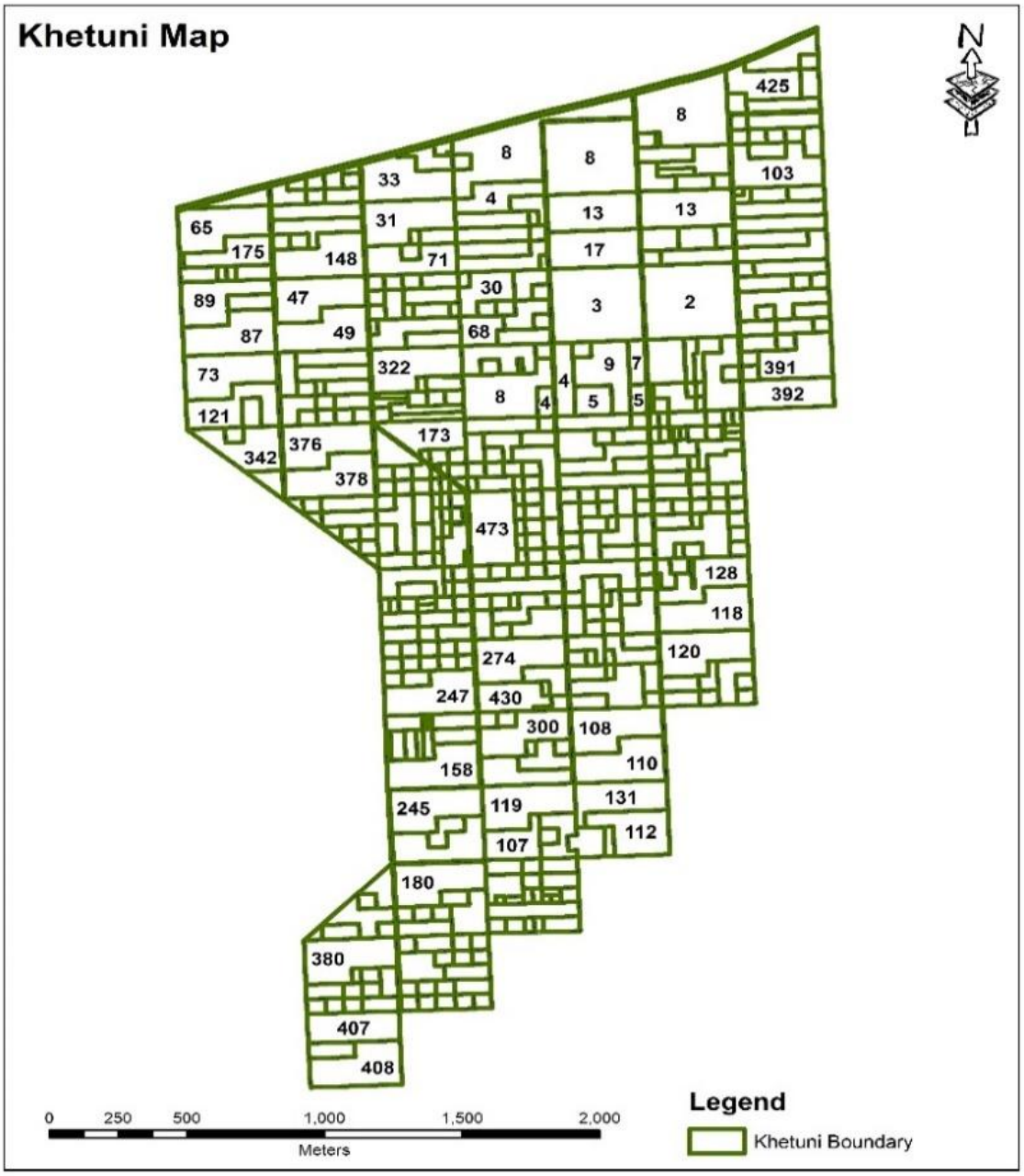


Figure 4.14: Khetuni Map after the integration of records from RHZ

The land area of individual land type of gair mumkin was also identified and highlighted in table F8 of Appendix F. It resulted that Khetuni number 8 has the highest land area of 660.65 Kanal and total Nahri area 654.4 Kanal, while three khetuni have minimum land area 0.5 Kanal. Khetuni number 473 has the highest gair mumkin area 100 Kanal and khetuni number 433 has the maximum banjer qadeem area 31.6 Kanal, while only one Khetuni has 7.2 Kanal area of Benaam.

4.3.3. Gair Mumkin Land Type Statistics

The summary of Gair Mumkin land type statistics is mentioned in table F9 of Appendix F & percentage distribution of land type is shown in figure 4.15. Total summarized 19 categories of gair mumkin types of area is 748 Kanal and identified that each category of gair mumkin land type has different area information and khasra count. For example, Abadi consists of 149 khasras with maximum land area 370.25 Kanal and Khal consist of 107 khasras with land area 125.25 Kanal. Only one graveyard is present in the study area, which consists of six khasras with land area 52 Kanal.

It was identified that each gair mumkin land type consists of combined khasras, such as Nehri Land type includes 1,282 khasras with Gair Mumkin area 18.2 Kanal, nahri area 8,773.8 Kanal, banjer jadeed area 2 Kanal, banjer qadeem area 163.4 Kanal and benaam area 7.4 Kanal. The geographical representation of each gair Mumkin land type is given in figure 4.16.

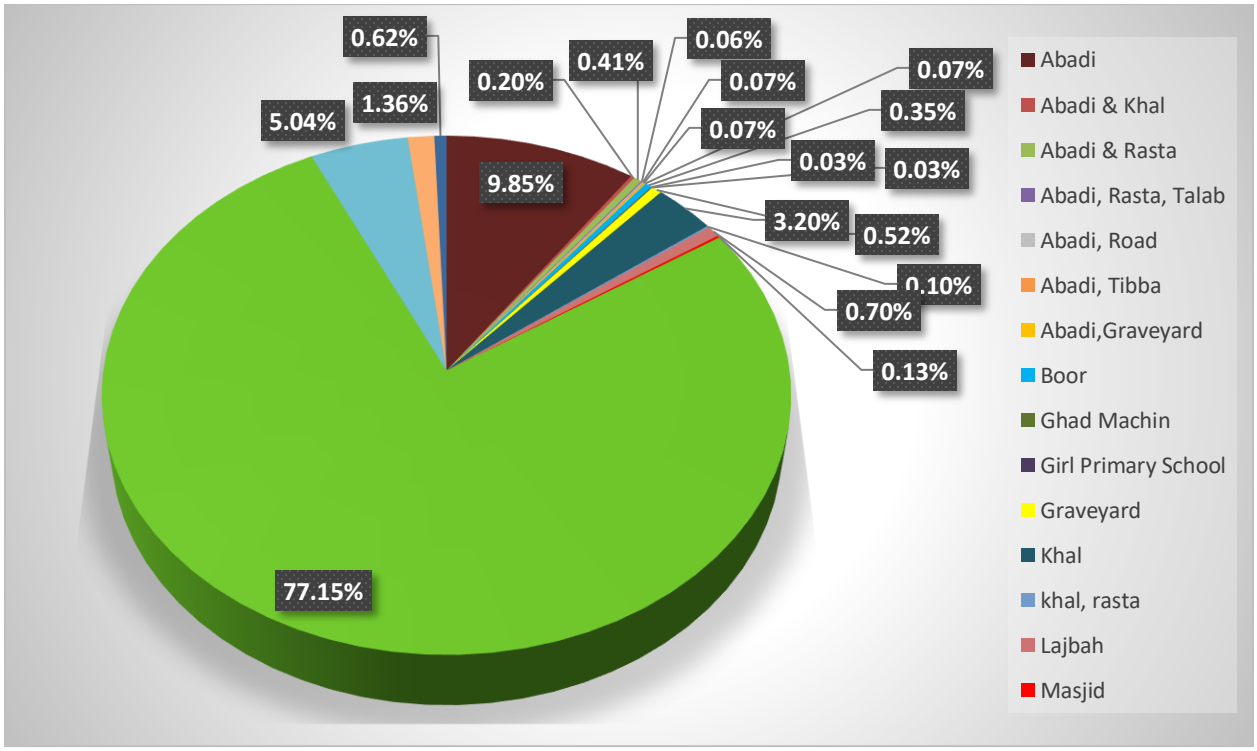


Figure 4.15: Gair Mumkin Land Type Area Percentage Distribution

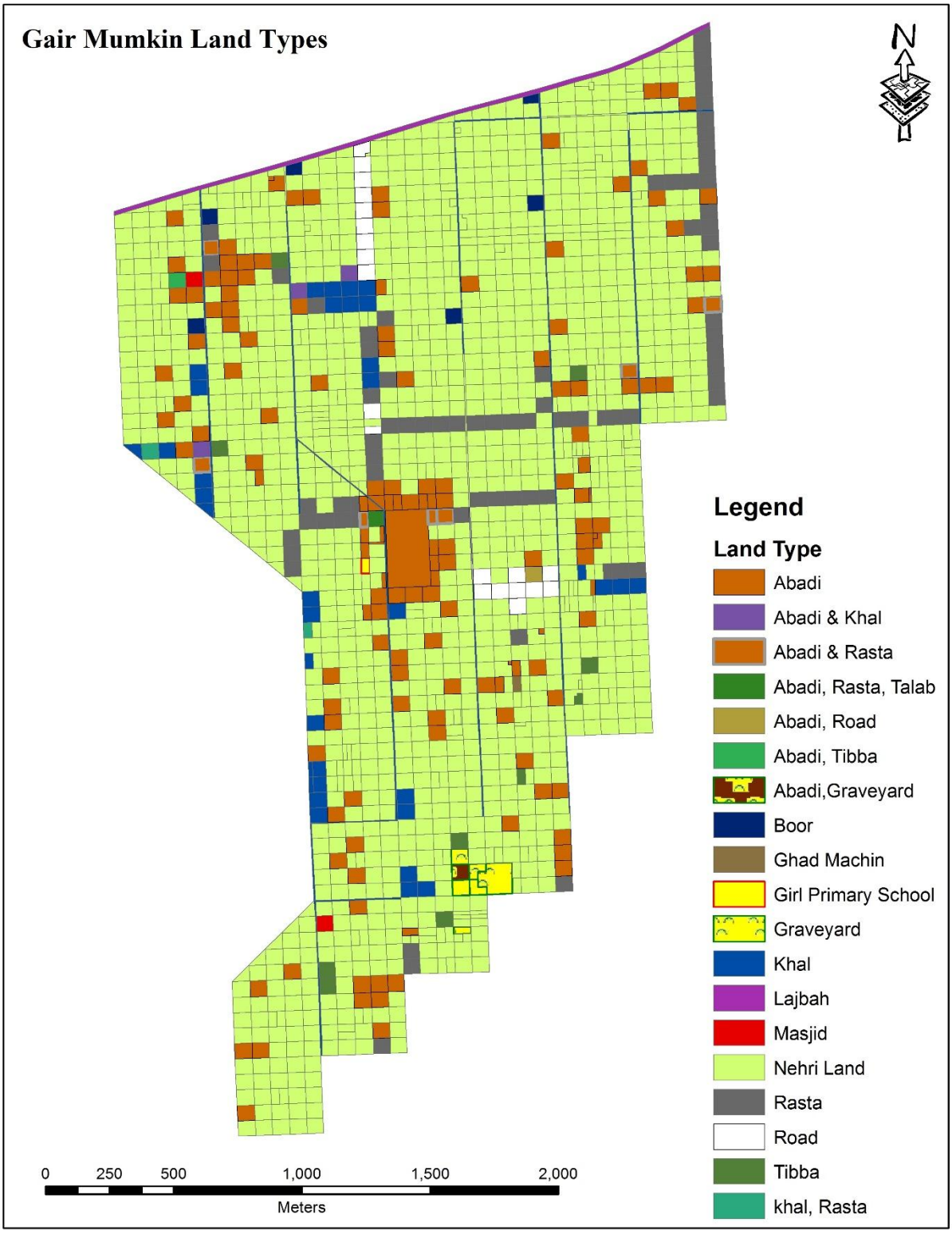


Figure 4.16: Geographical view of Gair Mumkin Land Types as per RHZ

4.3.3.1. Land Type' Khasras Statistics

The khasras count of land types; nehri, gair mumkin, banger qadeem and benaam were also calculated after integration of information from RHZ as given in table F10 of Appendix F. It was noted that nehri land, gair mumkin land, banjer qadeem and benaam land comprise of 1,258, 101, 14 and 1 khasras and sub-khasras respectively, while 307 khasras are contained mixed land types; banjer qadeem & gair mumkin (19 khasras), banjer qadeem & banjer jadeed (1 khasra), nahri land & gair mumkin (284 khasras), nahri land & banjer qadeem (1 khasra) and nahri land, banjer qadeem & gair mumkin (2 khasras). The percentage distribution of khasras of individual land type is shown in figure 4.17.

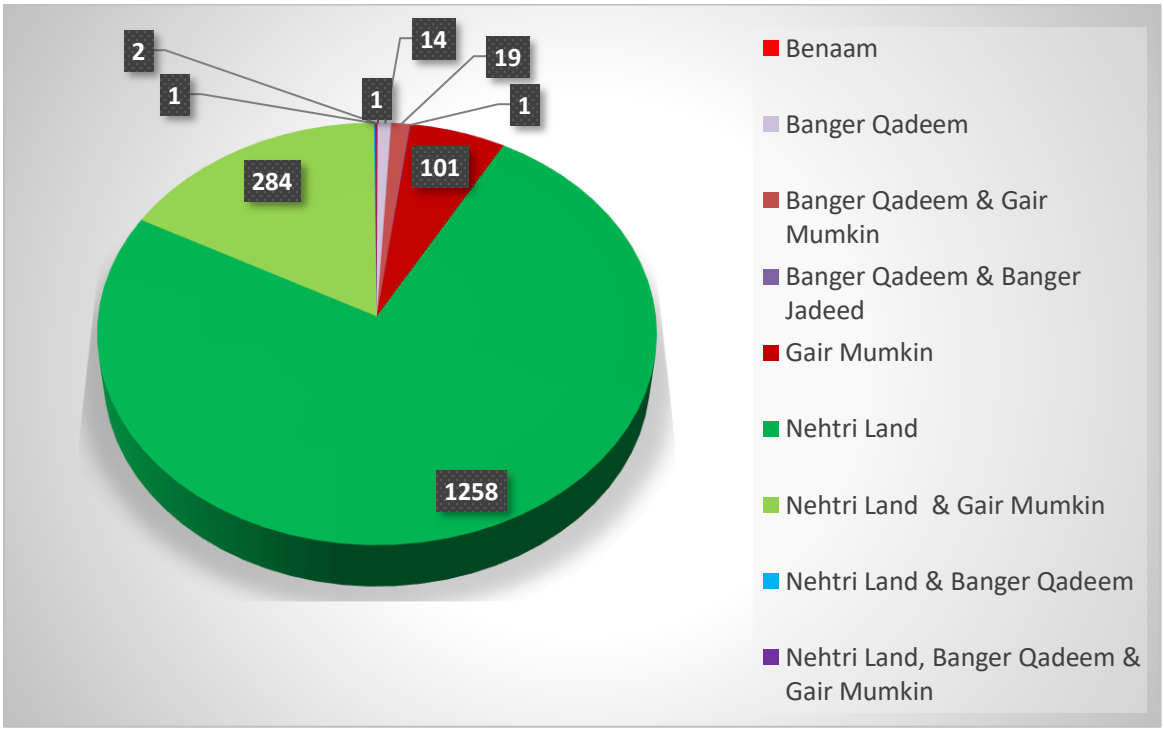


Figure 4.17: Percentage distribution of Khasras based on Land Type

Khasras count of land types; nahri, gair mumkin, banjer qadeem, are 1,545, 406 and 37 respectively, while banjer jadeed and benaam are contained only one khasra. it is noted that major portion of land category of gair mumkin and banjer qadeem was covered with Abadi as highlighted in figure 4.18 and comparison with imagery is shown in figure 4.19.

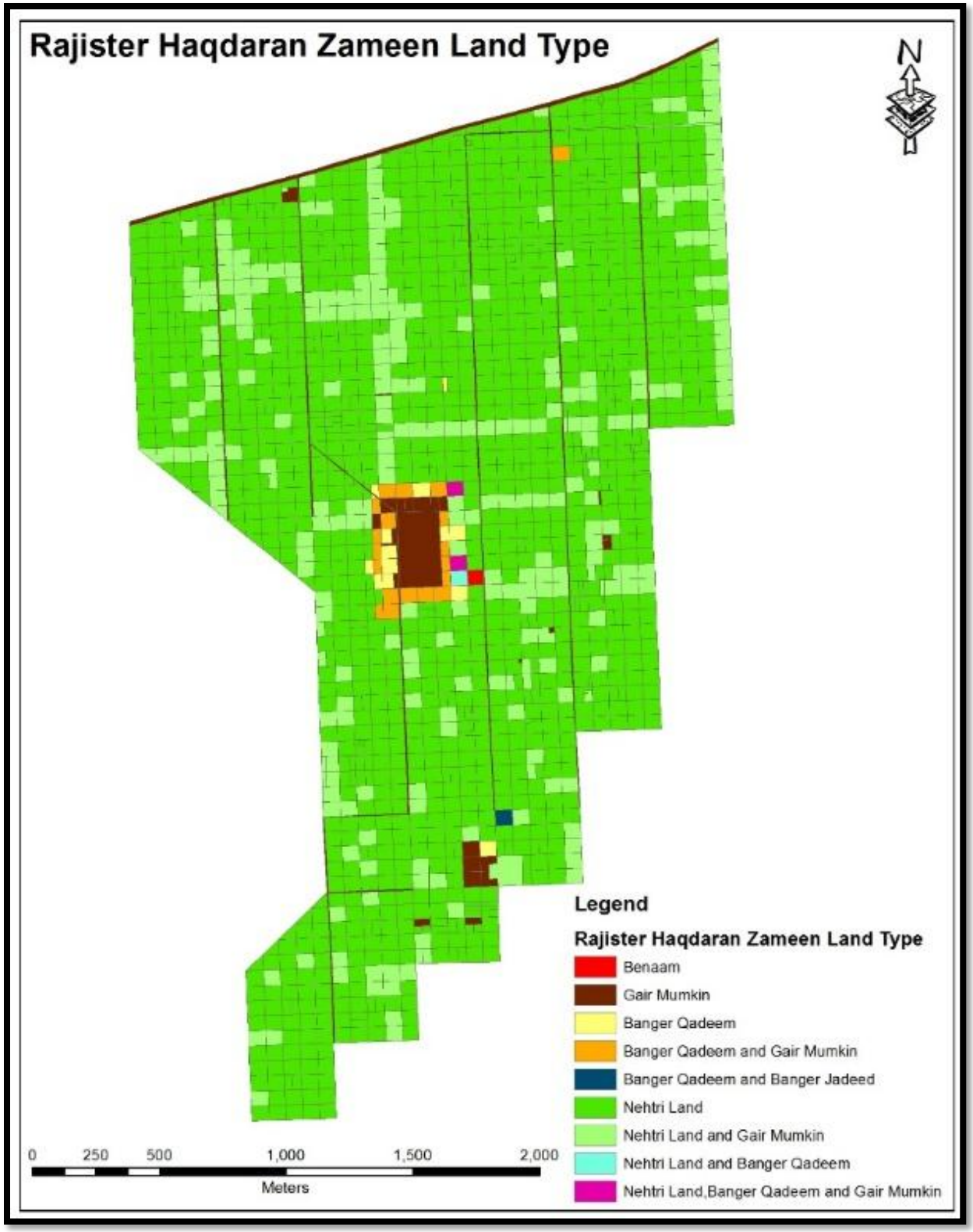


Figure 4.18: Geographic representation of khasras based on Land Types

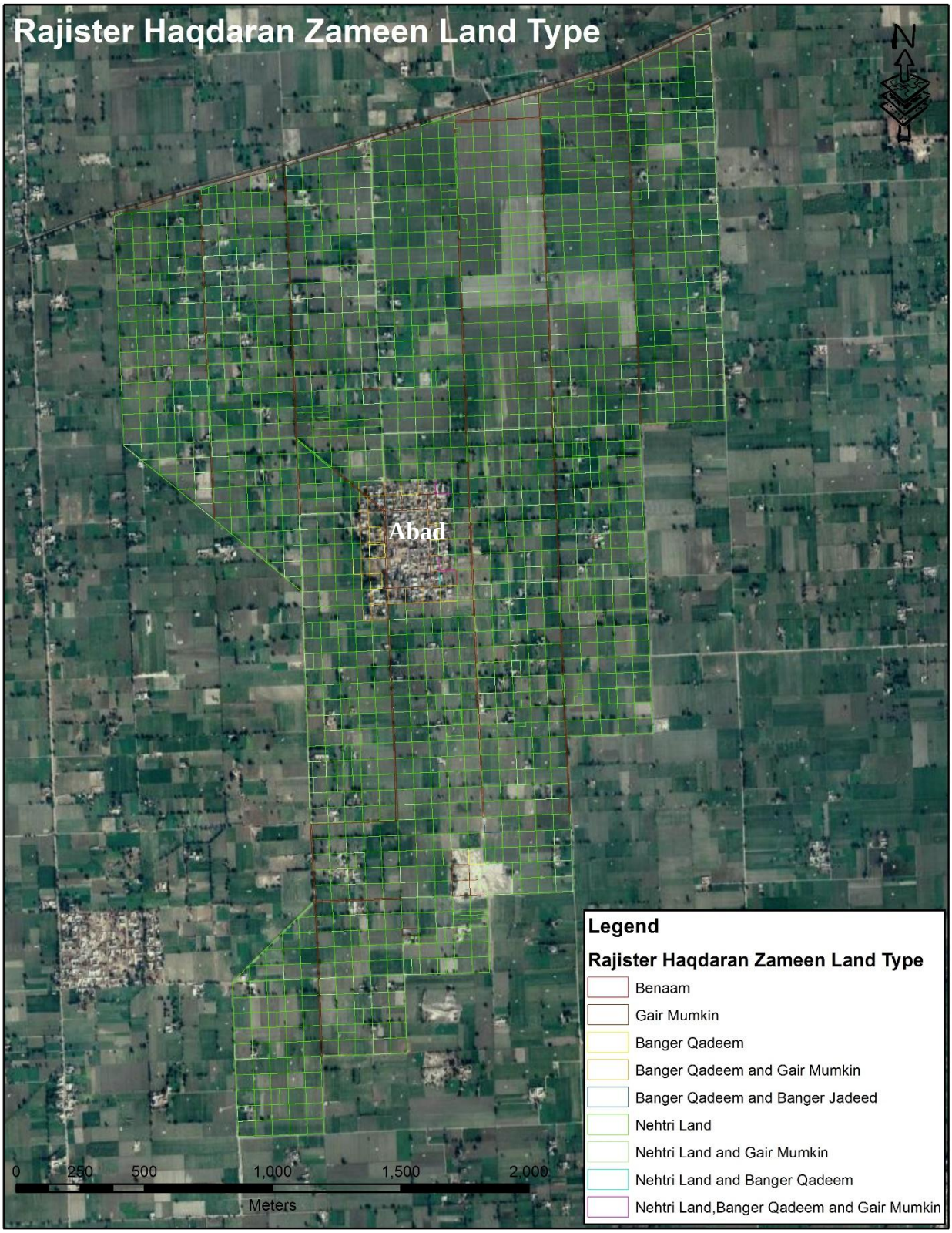


Figure 4.19: Geographical representation of Khasras based on Land Types overlay with Satellite Image

4.3.4. Ownership's Land Type Statistics

The land type characteristics based on ownership were recorded from RHZ and linked with khasra geometry. Summary statistics is given in table F11 of Appendix F and percentage distribution of individual ownership's land type is shown in figure 4.20. The geographical representation of each land type based on ownership is shown in figure 4.21a. It was identified that ownership area 10,897.9 Kanal of 1,586 khasras is mentioned in RHZ and resulted that government land area of 65 khasras is 354.35 Kanal and no ownership record of 27 khasra is available, while these kharas have maximum gair mumkin land types; Abadi and khal as highlighted on satellite view as shown in figure 4.21b.

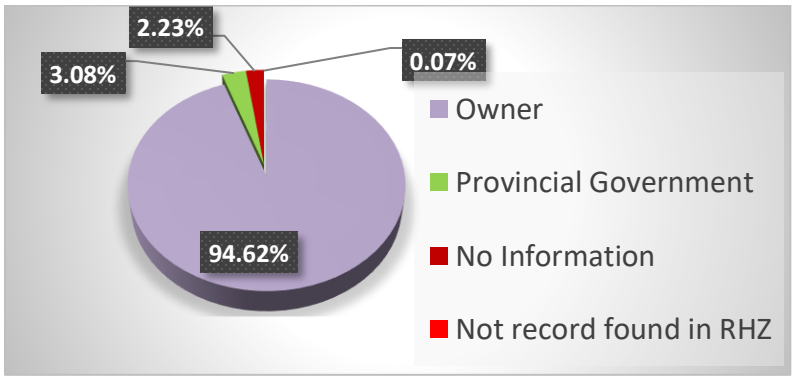
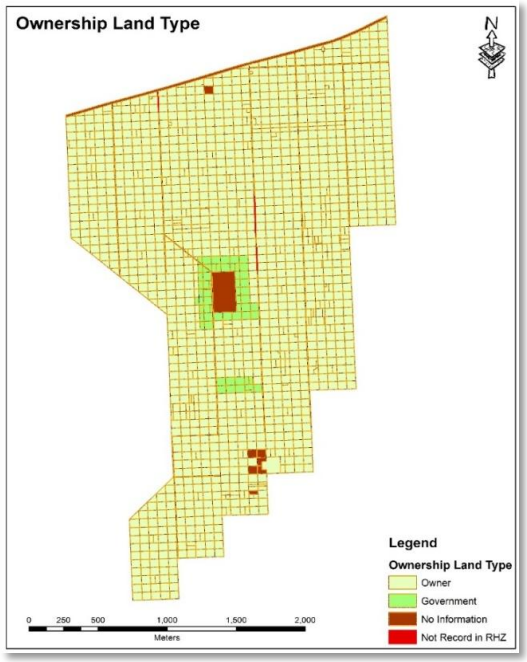
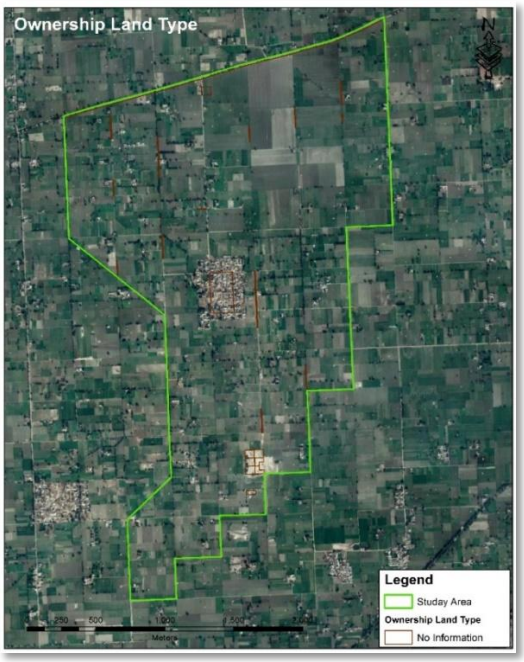


Figure 4.20: Ownership' Land Type area Percentage Distribution



a) Geographical view of Ownership's Land Type



b) Khasras with no ownership information is showing Abadi and Khal with Satellite View

Figure 4.21: Geographical view of Ownership's Land Type

4.3.5. Cultivation Land Possession Statistics

The land possessions based on cultivation characteristics were also recorded from RHZ and integrated with geometry of individual khasra feature. The statistics of land type based on possession is given in table F12 of Appendix F and percentage distribution is shown in figure 4.22. It is noted that Nehri land and Gair Mumkin land areas are 2,825.85 Kanal and 2,873 Kanal, while banjer qadeem land type has area of six Kanal.

Khasras distribution was also checked and observed that 1,122 khasra belongs to not-self category of cultivation type, while 23 khasra belongs to self and not-self category. Cooperative societies and schemes include 15 and 3 khasra respectively. The geographical view of land type based on possessions pattern is shown in figure 4.23.

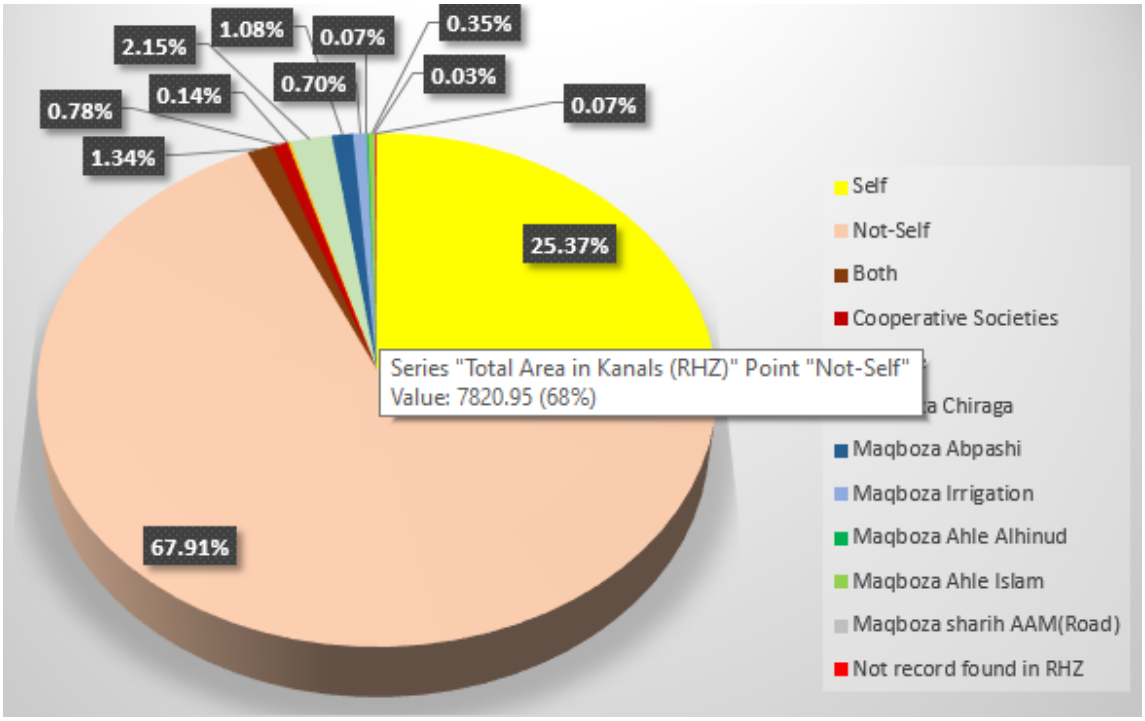


Figure 4.22: Percentage Distribution of Land Type based on Possessions

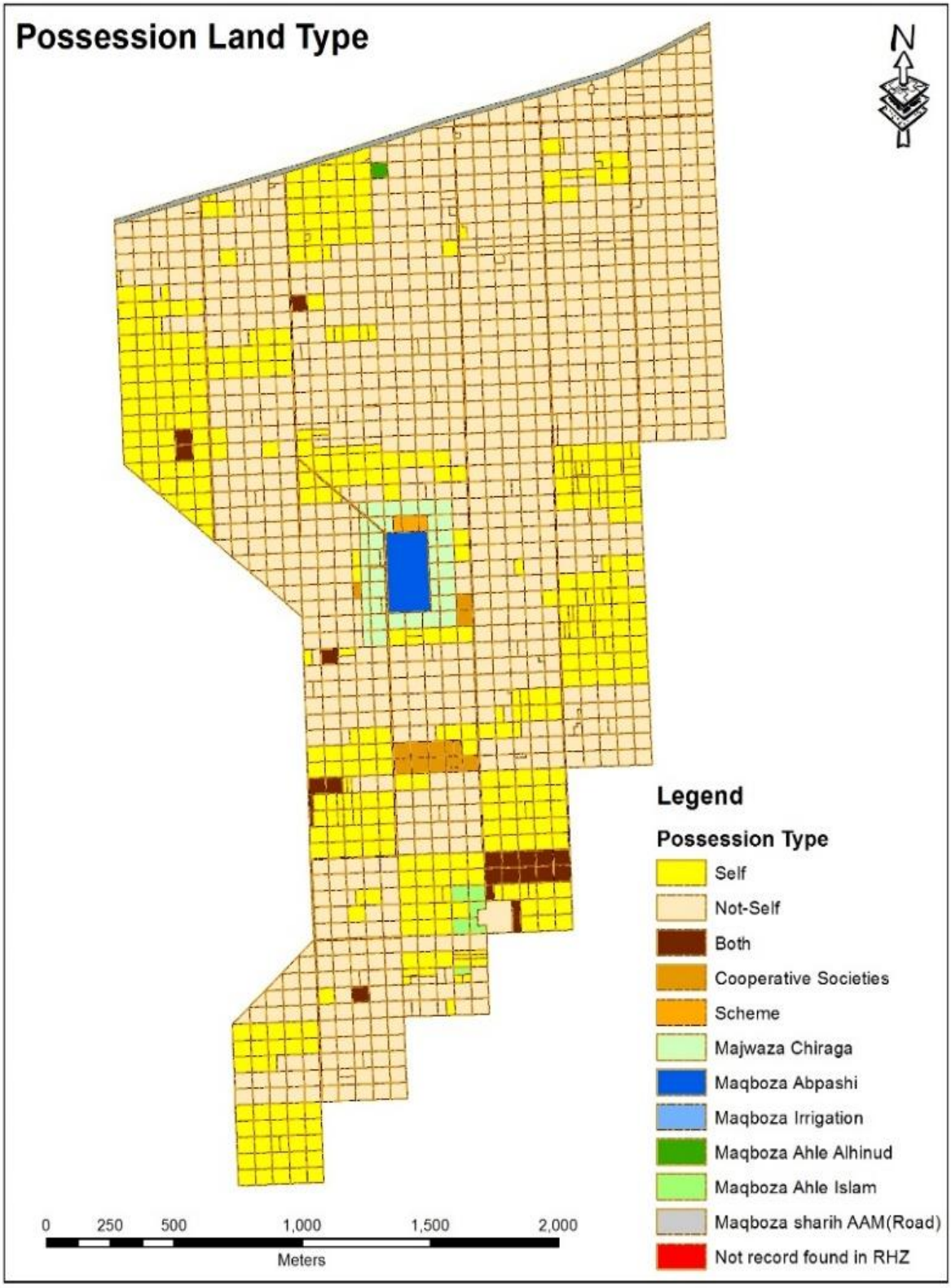
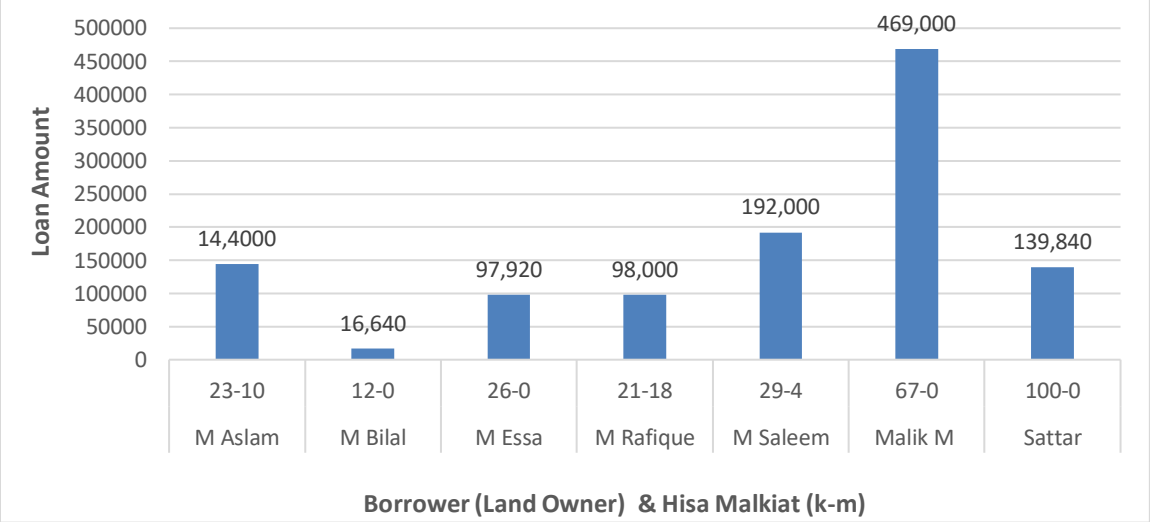


Figure 4.23: Geographical view of Land Type based on Possessions

4.3.6. ZTBL Certificate of Release of Charge

Landowners who borrowed amount from Zarai Taraqiati Bank Limited (ZTBL) against agriculture land (Hisa Malkiat) for purpose of cultivation their land are shown in table F13 of Appendix F, and recorded from certificate "Release of Charge" by ZTBL of mutation register.



**k-m means kanal and marla, one kanal is equal to 505.857 square meters*

Figure 4.24: Loan amount vs Borrowers (Landowners) based on possession area (Hisa Malkiat)

It was noted that the total borrowed amount was PKR. 11,57,400/- by seven landowners and identified that ZTBL's certificate had no exact information regarding total land area of landowners. For example, no khasra information and wrong entry of khewat number are observed. Mr. Bilal (ZTBL No. 347) borrowed the least money, PKR. 16,640/- against land area of 12 Kanal, while Malik M (ZTBL No.168) borrowed maximum amount of PKR. 4,69,000/- against land area of 67 Kanal as shown in figure 4.24. The geographical view of borrowed loans against land information within khewat is shown in figure 4.25.

The reason for performing this kind of analysis will be helpful for ZTBL for cross-verification of land information provided by the landowners. The existing practice for verification of land information may be a difficult task and did not produce transparency.

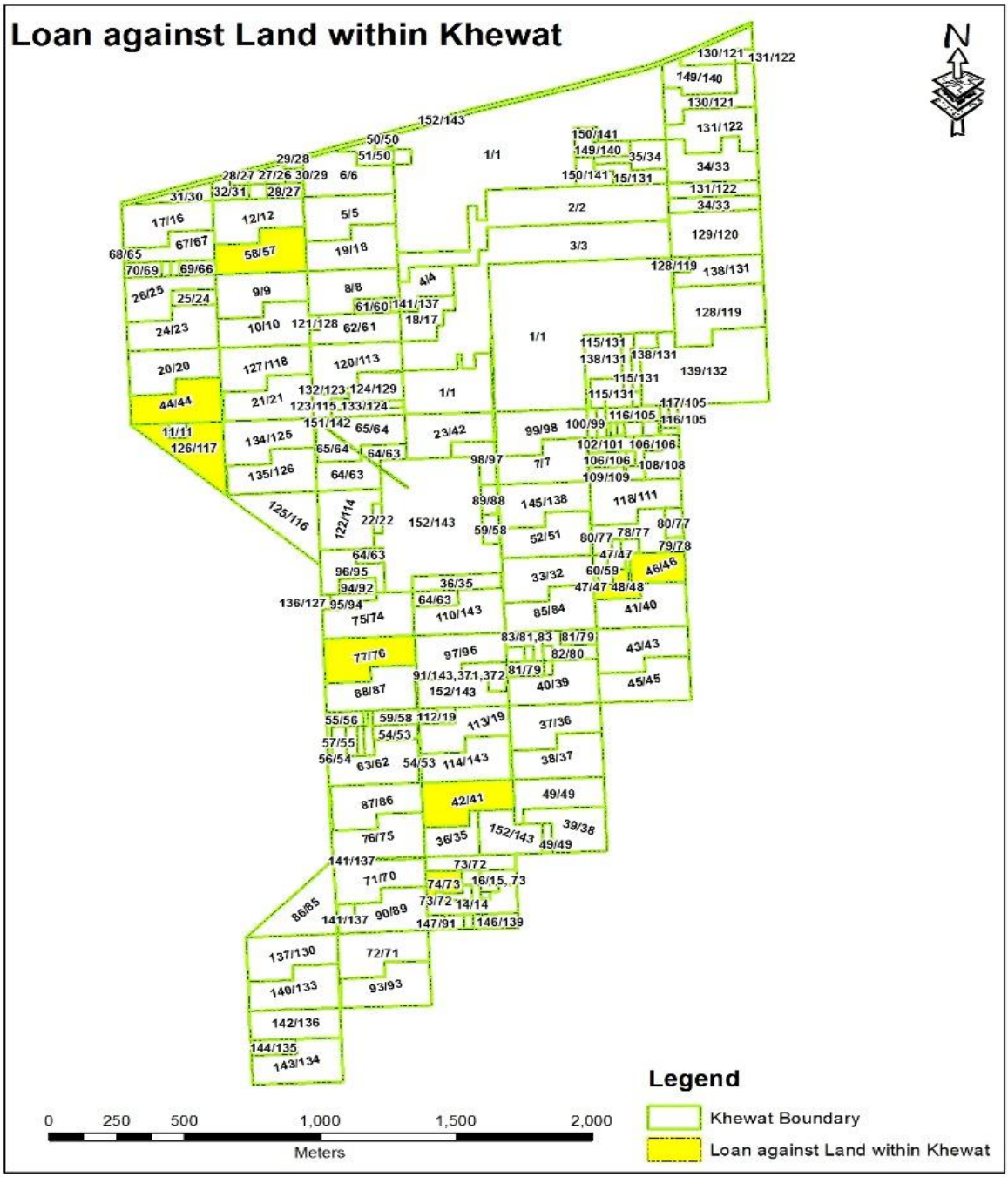


Figure 4.25: Geographical view of Loan against land area within Khewat

4.4. How could the digital cadastre be available and accessible in Web-based GIS Interface?

The main and last objective of my research was to develop a web-based GIS interface for land record data access and visualization. Spatial data layers of study area was prepared under this research and uploaded on Map server. All spatial data: Musavies, satellite image, and vector layers

linked with registered data, can be accessed and visualized through web-based GIS services local link.

The data along with metadata can be accessed and visualized in different data rendering formats, ArcGIS Online map viewer Google Earth, ArcMap and ArcGIS Explorer.

Data view in "ArcGIS Map" viewer is shown in figure 4.26. ArcGIS Map service provides legend detail, Base Map, and sharing option; measurement tool and additional tools can also be added. Layer on and off functionality is available in this map service. It also provides functionality of exploring, analyzing, querying, and sharing maps. It also provides metadata descriptions of each layer and attributes information of individual layer can be viewed as per user requirement.

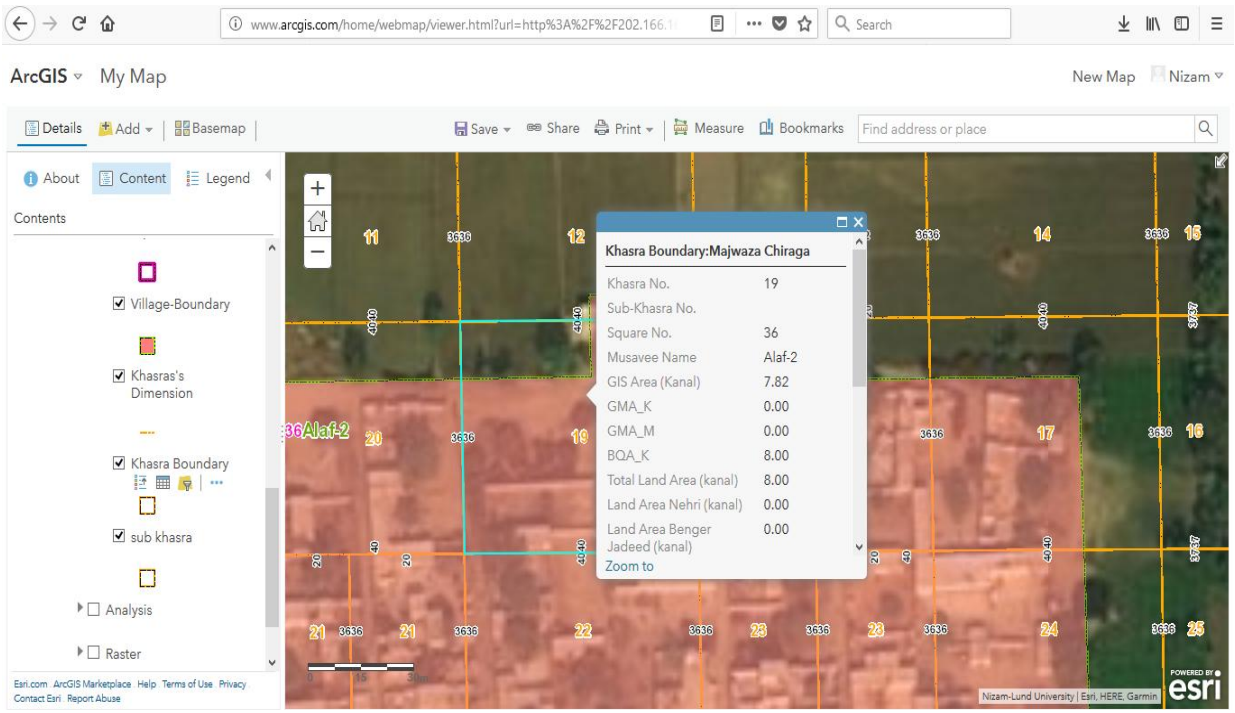


Figure 4.26: Sample View of Web-based GIS interface

The analytical layers: khasra and sub-khasra, square, musavee, khewat, khetuni, land types based on ownership, gair mumkin and possessions, ZTBL borrowed loan and lines' dimensions of each side of individual khasra can be accessed and visualized through this GIS-based web interface.
This GIS-based web interface offers a more efficient and sophisticated way to access land record information and visualization of different land record layers. It may be benefited to land record authorities in managing land records as compared to traditional manual methods. This proposed system is a pilot proposal for land record management authorities as learned from my experience with land record authorities. The land record authorities may develop this kind of proposed system on a provincial or regional level.

5. DISCUSSIONS

During the research work, a participatory approach was used. Many meetings were conducted with major stakeholders like BOR, PLRA and The Urban Unit regarding the availability of data, feedback, and resources. Technical input was also discussed for the betterment of land records in detail. The researcher also consulted workflow and methodology with colleagues, friends and professionals and critical reviews were taken. This research work was appreciated by departments as well as my colleagues, friends and professionals. They proposed that land record authorities may develop this kind of proposed SLRMIS on a provincial or regional level.

The research questions of this study were discussed in detail as given below;

5.1 Preservation of Dimensions of Land Parcels and Boundaries

First research question "How well will the dimensions and boundaries of land parcels be preserved in a digital cadastre?" was based on main objective of my research and mainly discussed methodology of development of boundaries and preservation of dimensions of sides of land parcels. Parcel fabrication method was adopted for preservation of lines' dimensions of khasras and sub-khasras. The Urban Unit officials said that cadastral maps were scanned through manual scanner to preserve maps with high resolution (300 DPI) and to achieve better accuracy of resemblance of features on musavies with ground reality. It was also discussed that roller scanners were not used due to bad condition of musavies. The departments' officials were satisfied with quality scanning of musavies and ensured that all features were prominent and readable on scanned musavies. All steps of methodology flow chart were followed and appreciated by concerned departments' officials.

My research objective was to preserve the lines' dimensions of individual land parcels, updating and integration of records from registered data and development of web-based GIS interface for accessing and visualization of land record information.

There is not any efficient and unique computerization system available for land records management till now. The existing research did not cover the whole part of land record computerization as proposed in my research, which is the requirement of 21st century to convert manual land records into digital cadastre. There was no solution available in former studies, conducted within Pakistan as discussed in section 4.1.2 of chapter 2, to preserve lines' dimensions of land parcels because every researcher had different objectives and scope of study. They did not suggest the preservation of lines' dimensions of land parcels. M.S Ahsan 2016 proposed the usage of a fishnet tool in ArcGIS to convert cadastral maps into digital maps. The methodology used in his research was helpful only for square land parcels and my study area mainly consisted of irregular shapes of land parcels along with regular land parcels and lacked detailed process of

preservation of lines' dimensions of land parcels. Therefore, lines' dimensions of land parcels were recorded through parcel fabrication model.

It was also observed in previous research that existing maps were prepared manually and did not prepare on a standard scale. The area estimated in GIS format is considered more authentic and provides the proper standards for scale measurements. The parcel fabrication model provides the sharing lines' dimension concept along two adjacent land parcels and performed desired results based on musavee, square, khewat and khetuni, etc. This concept is very useful for land administration departments and other stakeholders. The boundaries; square, musavee, khewat and khetuni were also preserved from khasra and sub-khasra land parcels.

The preservation of lines' dimensions of land parcels proposed in this study will be very helpful for land revenue management and may reduce area and dimensions measurement issues coming from manual land records management. This will create a positive impact for the management of land records to ascertain transparency and to provide service delivery in an efficient way.

5.2 Updating and Preservation of New Records

The 2nd research question "How should land records, be updated and new records be treated? What are the proposed routines?" was discussed regarding updating of land records from information available on registers and preservation of new records and audit of records. There was no mechanism available for updating manual maps in the revenue department and concerned revenue officer updates on Latha as per requirements. The former studies did not cover the answer to this question and missed the concept of updating land records and integration of attribute information geographically.

This question consists of two parts; first is updating of existing digital khasras and sub-khasras using parcel fabrication method with help of field book information. The merging and splitting of land parcels in parcel fabrication model was a unique method. It will be a very beneficial and important part of future Tatima cutting (a further division of land) for land record administration. Multiple discussion was carried out with departments and resulted in an increase in khasras and sub-khasras land parcels due to changes in ownership of land records during sale and purchase.

In second part of research question, new record was preserved through parcel fabrication model as archive data, which is an advantage of parcel fabrication model. The merging and splitting of land parcels, and archive history of parent land parcels, were also maintained. The information of individual khasra and sub-khasra was captured from Register Haqdaran Zameen (RHZ) and integrated for audit and analysis purposes as covered in section 4.2 of chapter 2.

This proposed concept of digital data updating, and new record preservation was valued by departments' officials during numerous discussions and suggested that this will be beneficial for land record management authorities for Tatima cutting during the process of new registration.

5.3. Integration of Attribute data in Digital Cadastre

The 3rd research question "How should attribute data be integrated into digital cadastre? What are the proposed practices?" was focused on integration of attribute data from land records' registers into digital cadastre. Integration of data was very important for delineation of khewat and khetuni boundaries. The information: khewat, khetuni, gair mumkin land type and ownership information was recorded from RHZ and integrated with khasras and sub-khasras as discussed in section 4.3 of chapter 4. The ownership, cultivation and land type information were attached to these boundaries and audited with digital records. There were multiple discrepancies that were found after summarizing statistics, which was an extremely difficult task for land record authorities from manual land records. The khewat and khetuni wise idea was also not covered in previous research and land record authorities also did not perform such type of analysis.

This idea also gave a unique perception to land records management departments and stakeholders to attain real-time analysis from digital cadastre. Furthermore, digital cadastre may be also useful for crop inspection, estimation and digital girdawri.

5.4 Accessing Digital Cadastre through Web-based GIS Interface

The last research question "How could the digital cadastre be available and accessible in a Web-based GIS Interface?" was concentrated to access and visualize digital cadastre in a web-based GIS interface. This question was one of the important outputs of research work. This interface provides access to visualize the data & metadata and analysis; musavee, khewet, khetuni, land type based on ownership, possession land type and ZTBL loan information can be extracted in a quick way, which was not possible via manual record. Searching for information on individual land parcels via manual record is a difficult task and takes a lot of time.

This concept did not cover in former studies such as Mr. Adeel 2010, observed that an extensive management information system was not part of existing studies. In PLRA web portal, khewat information is available but did not provide information of individual khasra land parcels. There is no information available for lines' dimensions of land parcel.

This discrepancy was addressed in this research by integrating land records information from registers geographically. This digital data is published as discussed in section 4.4 of chapter 4 and can be visualized and analyzed through a user-friendly web-based GIS interface.

The analytical layers: khasra and sub-khasra, square, musavee, khewat, khetuni, land types based on ownership, gair mumkin and possessions, ZTBL borrowed loan and lines' dimensions of each side of each khasra can be accessed and visualized through this interface. This system provides information related to land records in a quick & efficient way and will be helpful for the land recording authorities.

Therefore, it is noted that this kind of visualization of land record data in a GIS environment is more beneficial and sophisticated than the old conventional method of management of land records. I hope that the land record authorities may develop this kind of proposed system on a provincial or regional level.

5.5 Recommendations

This pilot research is a concept to develop a Spatial Land Records Information System for land record authorities and aligned stakeholders. It is recommended that Govt of Punjab must implement digitalization of existing land record system by use of geospatial technology and integrate manual records into digital format to develop a SLRIS as suggested in my research to provide service delivery in a transparent, quick and efficient way.

I hope the land record authorities can perform different kinds of analysis from similar systems of digital cadastre. The real challenge of land record organizations is to develop a girdawari from the manual land record, but after the development of the digital cadastre, digital girdawari can be performed easily and traceable with less time as compared to manual record. The consolidation of land records, legal implications and urban shift for blockchain association is also recommended for future development.

5.6 Future Work

The research had a narrow scope, and the following are the future suggestions for the land records.

- There should be Machine Learning and Artificial Intelligence (AI) systems developed for management of land records, to monitor and analyze the information in real time.
- Big Data analytics development is necessary for the better management of land records.
- There should be judicial analytics adopted in the future to resolve land disputes at the national level.
- Hybrid solutions will be required for distributable land records management departments/stakeholders from provincial level and centralized at federal level.

6. CONCLUSIONS

The development of "Spatial Land Record System (SLRS) using geospatial technology of a Mid-sized Village in Pakistan" is a very different and unique system through which digital cadastre was developed and resulted in solutions; preservation of lines' dimensions of land parcels, updating of new records by using parcel fabrication model and integration of registers data with digital cadastre. All the objectives were achieved fruitfully as proposed in this study. General objective was to develop a cost-effective methodology for perseveration of lines' dimensions of individual land parcels, updating new records in digital cadastre and audit the manual land records. Geospatial technology was used to achieve the objectives and found answers to all the research questions as discussed in Chapter 5. The modeling suggested by Kalantari 2005 was adopted to develop SLRS. The analysis: khetuni and khewat, ownership, land type, cultivation land type, possession and ZTBL loan analysis easily performed from digital cadastre. Web-based GIS interface is a new development to access and visualize the information of revenue records as compared to manual records. This technology provided the state of art SLRS for the management of land records from digital cadastre as compared to old conventional and outdated manual systems.

The study area is focused to mid-sized village "Chak No.311/WB" and scanned musavees maps were processed to form a mosaic map as discussed in detail methodology section 3.3. Study area mosaic map was processed using MATLAB algorithms and extracted study area map in ArcGIS desktop software. It was georeferenced by using high-resolution satellite imagery and GCPs collected from field to achieve better accuracy as per ground reality and extracted final study area. Land parcels data was digitized in ArcGIS software and Parcel Fabric tool was introduced for preservation of lines' dimensions of individual land parcels in digital cadastre. Qualitative data is necessary for parcel fabrication model, that was ensured by applying the topological rules and integrated land record registers with digitized land parcels to develop digital cadastre. It resulted that a 0.11% increase in area of khasras and sub-khasras was found in digital cadastre as compared to notified area and 0.048% increase in lines' length as compared to notified lines dimensions. The advantage of digital cadastre is to perform analysis quickly and efficiently that was not possible from manual land records. This digital cadastre has not only preserved archive history of land records but also provides timely and accurate measurements of area and lines dimensions of land parcels.

Area analysis based on musavee and square boundary were performed in the research work. The dimensions' information of individual line of land parcel was preserved and resulted that 1,525 land parcels had shared lines' dimensions of all four sides, while three sides of 156 lines of land parcels had shared lines' dimensions. The biggest advantage of parcel fabrication models is that lines of adjacent land parcels can be easily identified and has importance for land parcels for measurement purposes in land administration.

Land parcels and lines data were updated with registered data through parcel fabrication model and offered concept of splitting and merging land parcels. It was identified that nine land parcels were merged, and 71 land parcels were divided into sub-parcels. It resulted in that khasras and sub-khasras land parcels being increased from 1,605 land parcels to 1,681 after updating of information from RHZ. Notified total land parcels were 1,682 and concluded that 76 land parcels increased due to the change of ownership of land records in the mutation process. It was detected that five land parcels were present in RHZ but were not available on cadastral maps. Three land parcels were present on musavies but were not found in RHZ and one land parcel was available in RHH, which was not divided on cadastral map. It was assumed that such discrepancies were due to manual record management and supposed that revenue officers may have destroyed the record by his willpower to attain pecuniary benefits. This is a big question for land record administration in a service delivery mechanism. This study has proposed an idea to produce digital musavee from digital cadastre as shown in figure 4.9 and may be proposed to officials of land record authorities at provincial and regional levels for transparent service delivery.

The registered data was integrated with digital cadastre and performed analysis related to information; khewat, khetuni, land types based on ownership, gair mumkin and possessions, ZTBL borrowed loan and lines' dimensions of each side of individual khasra were integrated geographically and audited as discussed in section 4.3. Khewat and Khetuni boundaries were delineated and discrepancies in area, number of land parcels and sub-land parcels, ownership records, khewat and khetuni, gair mumkin land type and ZTBL loan records were also identified as discussed in section 4.3.6. It was assumed that those discrepancies were due to manual record management and is a big question for the land management authorities for handling records manually in provision of transparent service delivery.

Web-based GIS interface "SLRS" of study area was developed to view and access digital cadastre as discussed in section 4.4. Digital data developed in this research work was published and developed a web-based GIS interface, through which land records information can be accessed, viewed and performed analysis like khewat, khetuni, land type, possession, ownership and ZTBL information by exploring the suggested SLRS. This kind of visualization of land record data in a GIS environment is more beneficial and sophisticated than manual old and outdated method. In SLRS, real-time analysis like; size of individual land parcels and lengths of their sides and analysis of khasra & sub-khasra, square and musavee, khewat and khetuni can be performed in an efficient and quick way. It can be extended in future into editing like Tatima cutting, real-time integration of field data and report generation. This digital data can be further used for estimation of different types of crops and digital girdawri can also be analyzed in a better way as compared to manually. It was observed that tracking of required information from manual land records was a very difficult task, and errors were present in manual land records. These issues had been resolved via proposed Spatial Land Record System (SLRS) and changed the idea to manage land records and performed

analysis. Now digital musavee can be generated from digital cadastre as suggested in this research study and may be beneficial for revenue departments as compared to hand-made maps.

It is suggested that this system may be helpful for land record management authorities; BOR, PLRA, PULSE and other administrative zones. PLRA preserves registered attribute information and has developed the MIS system and there is no integration geographically. It was also investigated that there was no integrated system available, where digital musavee can be generated and real-time girdawri can be produced. My research work may play a catalyst to make such kind of fruitful system for land record management and may be a solution for creation of digital musavee and digital girdawari.

This research was a pilot and limited to only mid-sized village (one mauza) and may be extended to province level by the land record authorities. It is a proposed solution for the land record management authorities to develop such SLRS for provincial and regional level. Machine Learning, Big Data analytics and Artificial Intelligence (AI) are future solutions for management of land records to provide better service delivery to the public.

Now BOR and Survey of Pakistan (SOP), Ministry of Defense are planning to convert all the manual land records into a digital format using the parcel fabrication model, which is a big success of my research work. The acknowledgement letter from the PULSE department for my research is given in Appendix I.

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APPENDICES

Appendix A: Administrative History, Administrative Hierarchy, Manual Archives, Records with Purpose, Cadastral Terminology and Land Measurement Units

1. Administrative History of Land Records in Sub-Continent

The land record history in the sub-continent shows that the land record system was established by Sher Shah Soori in 1540, land record improvements were done by King Akbar in 1566, the land revenue department was established in 1863 by the British Rule and the first land law was introduced in 1876. The first land revenue act of Pakistan was introduced in 1967, and the land revenue rule of Pakistan was developed in 1968 (Kamran, 2016). The first major effort to redistribute agrarian reform was carried out in 1959 by Ayub Khan's military regime and in 1972 and 1977 agrarian reform was followed by Zulfikar ali Bhutto (Gazdar, 2009). The land record history in the sub-continent is shown in Figure A1 in Appendix A.

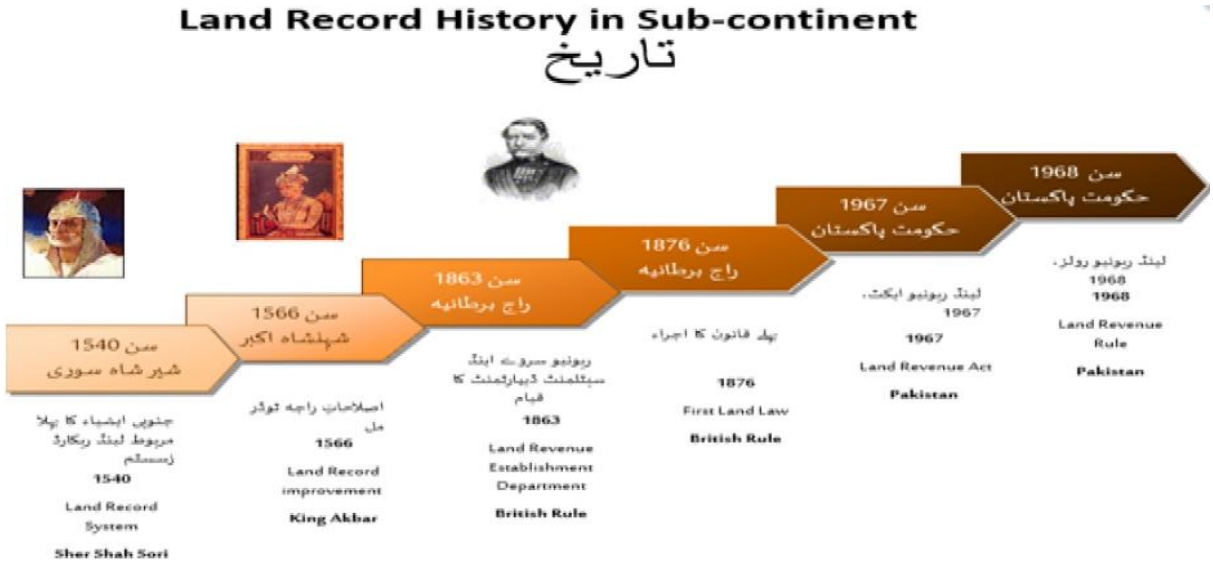


Figure A1: Land Record History in Sub-Continent (Kamran, 2016)

2. Administrative Hierarchy

The administrative hierarchy, which was developed during the British tenure is given in Figure A2.

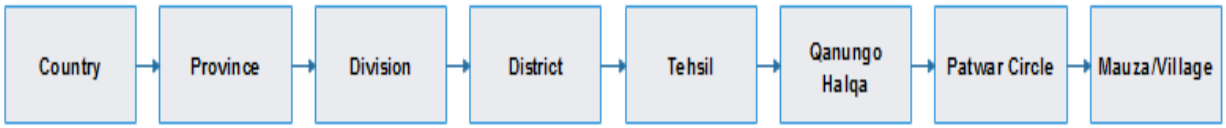


Figure A2: Administrative Hierarchy established by British (Raza, 2005)

At the province level, the administrative hierarchy starts in descending order from BOR to Patwari. The senior member is the head of BOR at the province level and empowers the commissioner as head of revenue administration at the divisional level, Deputy Commissioner is the head at the district level and Assistant Commissioner is the head at the Tehsil level. A Tehsildar is the head of the tehsil and further looks at the matters of sub-officer; Qanungo or Girdawri and Patwari (Furqan, 2019) as shown in Figure A3.

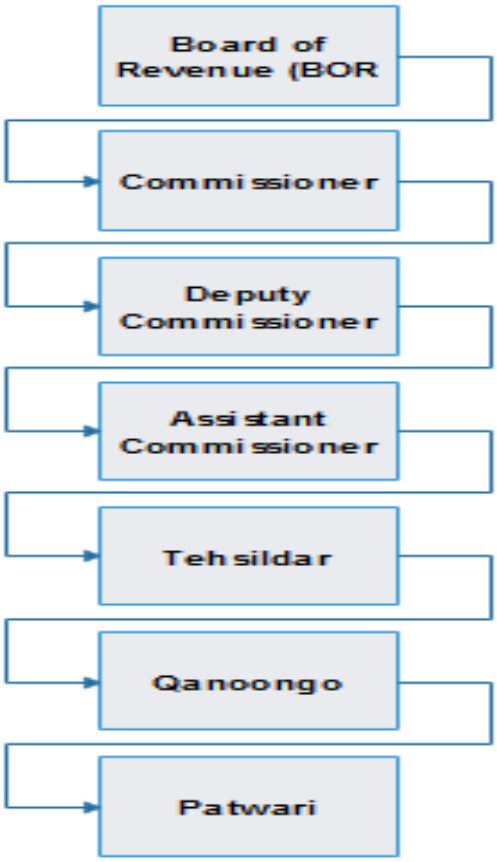


Figure A1: Revenue Administration Hierarchy in Pakistan (Furqan, 2019)

3. Manual Archives

Currently, the land record is being maintained manually by the patwari and cadastral maps are being prepared on handmade paper and pieces of cloth (Latha or Kapra) manually at the tehsil office. During this process, many irregularities and the absence of standards are found (Ali, 2012). The handmade maps are not up to the scale and are damaged during disasters like flood and earthquakes (Dale et al, 1999). Figure 2.4 demonstrates the miserable state of the manual archives.

Figure A4: Manual Records Management.

4. PLRA Achievements

The LRA achievements as discussed in section 2.3.1 are given as.

a. 24/7 Online Availability of Revenue Record Information

PLRA has developed a system to access and view the attribute information of land records online in URDU and English based on ownership and cultivator. The land information can be searched from PLRA's URL by query necessary information such as district, tehsil, Mahal (Mauza) from the dropdown options; Chewa or Name or CNIC as per user requirement. This service is available 24/7 to access the revenue record information.

b. Digital-PLRA Android Application

PLRA has launched the Android application "Digital-PLRA", can be downloaded from Google Play Store. The user can get the desired information from Digital PLRA. This application can browse the information and save it for offline access. The main features of the Android application are Land Records Search, Registration Search, Calculator, Fee Schedule, Registration Process and Online Complaint logging.

PLRA system is the only web-based information system in Punjab, which shows the attribute information of the land property but is not linked with the land parcel and geographical analysis cannot be performed.

c. Digitization of Maps

The land record registers and cadastral maps of 18 districts were scanned in 2011 under the project "Scanning and Preservation of Punjab Revenue Record". There are 36 districts in the Punjab and khasra level mapping of three districts; Lahore, Hafizabad and Lodhran under project "Services for GIS Development and Digitization of Maps (Districts: Lahore, Hafizabad & Lodhran)" were completed in 2015. There was no fiscal data (Registers Information) attached to above spatial data.

Table A1: Records with Purpose

Sr.No.	Name of Record	Purpose
1.	Shajra Parcha	Village Map
2.	Shajra Nasab	Land Holder Genealogical History
3.	Khasra Numbers	Index Numbers of Land Parcel
4.	Radeef Waar Malikaan	Alphabetical Index of Landholders
5.	Register Haqdaran e Zameen	Land tenure description of owners
6.	Haqooq-e-Chahaat-wa-Nul Chahaat	List of rights holders of water wells
7.	Wajib ul Arz	Statements of Community Customs
8.	Field book	Survey Notebook
9.	Register Girdawari	Harvest Inspection Register
10.	Register Tagrarut Kaasht	History of changes in Crop cultivation
11.	Register of Dakhil Kharij	mutation statement of Land Parcel
12.	Dhal Baacha	Government Dues' Demand
13.	Roznamcha Waqeaati	Registering of Daily events of land records
14.	Roznamcha Hidayaati	Official's instructions List
15.	Roznamcha Partaal	Register for Cross verification
16.	Laal Kitaab	Statistics Book
17.	Roznamcha Kaarguzari	Workbook

Table A2: Cadastral Terminology

Expression	**Explanation**
Mauza	It is a revenue estate and represents a specific part of the land boundary and includes multiple land parcels within one mauza of which the Patwari maintain the complete record.
Mujmili Map	The complete map of a tehsil which includes mauza boundaries, the scale is; one inch = one mile.
Shajra Parcha (Latha or Kapra)	It is the mosaicked reflection map of all musavies maps of one mauza on a big cotton cloth, prepared by the Patwari and incorporated temporal changes of land parcels by red pencil.

Musavee	It is a large-scale cadastral map of a mauza, showing parcel id (khasra number.) with dimensions, extent and square number. The scale of mausavi is 1 inch: 40 karam or 1:2500, while 1 karam is equal to 5.5 feet.
Patwari	It is the revenue officer appointed by the Government for maintaining the record of one Mauza or Village in the land revenue administration hierarchy.
Khasra Number	A khasra is the specific part of a land, represented by the unique number or survey number within a square number (Killa number) label on the musavies or latha.
Square Number	A square number is also called killa number, represented by the unique number label on the Musavee map which includes multiple Khasras
Khewat Number	Khewat refers to the ownership id (Owner ID) or Khata number of a particular land.
Khatuni Number	It refers to a unique number given by the Patwari based on the cultivator (farmer) of the part of the land.
Bandobust	The process for recording land ownership rights and land area is called bandobust or land settlement.
Field Book	It is an alphanumeric illustration of musavies where attribute information related to every land parcel (khasra) is incorporated.
Shajra Tatima	It is an annexure map created by Patwari, when any change or partition happens in a khasra (land parcel) due to land mutation.
Jamabandi/Register Haqdaran Zamin	It is the register that contains the ownership records and includes the Complete detail of each land parcel. It is prepared by Patwari at the time of settlement. It is rationalized after every 5 years.
Karam	Karam is the basic unit in land measurement, the scale is; 1 karam = 5.5 feet (1.68 Meter).
Jraib	It is a local measuring tool used for land settlement purposes. The scale of a jraib is 1 Jraib=10 Karam
Girdawri	The crop inspection of every season (kharif Crops in October and Rabi Crops in March) by the Patwari for agricultural taxation purposes.
Gair Mumkin Land	It is the land that includes settlement (Abadi), water channels (khal), road (rasta), water storage (Borr), other agglomeration of settlement (Tibba), school, graveyard, masjid, etc.

Table A3: Land Measurement Units

Unit	Equivalent Unit	SI Unit
1 Karam	5.5 feet	1.68 Meter
1 Inch	0.01515 Karam	0.0254 Meter
1 Marla	9 Square karam	2.81 Sq. Meter
1 Kanal	20 Marla	505.857 Sq. Meter
1 Bigha	4 Kanal	2023.428 Sq. Meter
1 Acre	8 Kanal	4046.856 Sq. Meter
1 Square (Muraba)	25 Acres	101171.4 Sq. Meter
1 Square Kilometer	247.1 Acres	999978.118 Sq. Meter

In Pakistan, SI unit is not used for land measurement.

5. Parcel Fabric Geo-Database Structure

The Parcel fabric geo-database structure includes elements; lines, points, polygons, control points, plans, parcel fabric jobs, accuracies and adjustments as shown in table A5. In the parcel fabric model, a parcel is continuously linked with one plan and is comprised of point, line and polygon features. The parcel polygon is a combination of individual lines, which form a closed round to describe a polygon. Each line has from and to points that are also corner points of a parcel. The Points are common between adjacent parcels and linking lines. The points of a parcel can be allocated as control points and line points (ArcGIS, 2020). The parcel fabric data model is shown in figure A5.

Table A4: Parcel Fabric Elements

Parcel Fabric Element	Explanation
Parcel Lines	Dimensions of line boundaries are preserved and stored
Parcel Points	Point coordinates (x, y, z), consequent from an adjustment of least-square is stored
Parcel Polygons	Generated from lines of the related parcel
Line Points	These are corner points of the parcel
Control points	Physical location accurate coordinates
Plans (Table)	Preserve the survey record information
Parcel fabric jobs (Table)	Parcel fabric edits' track
Accuracies (Table)	Adjustment of least square parcels' weights
Adjustment vectors (Table)	Preserve the displacement sets of vectors from the adjustment of least square

(ArcGIS, 2018)

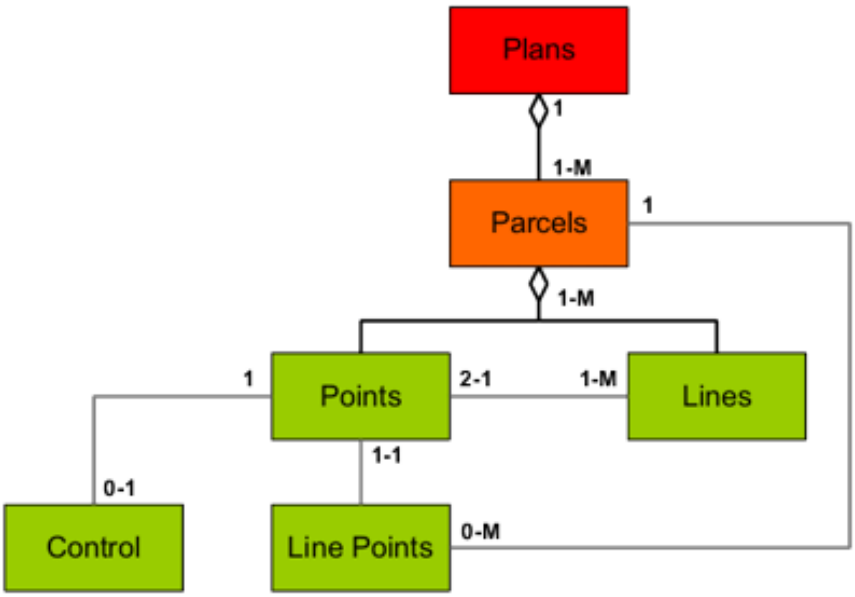


Figure A5: Parcel Fabric Data Model

6. Parcel History in a Parcel Fabric

The ways; Archive, Periodical and Transactional, on which parcel history can be tracked as discussed in section 2.5.2

- Archive

  Historical information is tracked. It is a picture of the intact geo-database at a flash in time. It is preferred that annually periodic taxation and fiscal role must be archived.

- Periodical

  Historical information is tracked and documented periodically concerning some recognized points which are in time and contain changes.

- Transactional

  This keeps a record of transactions and monitors all historical information in parcel databases and parcel plans.

Appendix B: Data Sources & Metadata, Spectral Characteristics of World View-2 satellite

Table B1: Data Sources & Metadata

Dataset	Description	Spatial Extent	Format	Coordinate System	Sources
High Resolution Satellite Image	World View-2 Image Acquired on 19 January 2017 Resolution = 0.46 m Cloud cover = 0 Off nadir = 5.11 Sun elevation = 36.80 Color Band = RGB	According to the Village Boundary	Raster ECW	PCS: UTM (Zone 42N) Datum: WGS1984	The Urban Unit
Population Census 1998 & 2017			Non-Spatial (Attribute Information): Microsoft Excel Table	N/A	PBS
Administrative Boundaries: Provinces	Boundaries of Provinces of Pakistan	Pakistan Provinces Boundary	Vector: Shapefile (.shp) (Polygon)	PCS: UTM (Zone 42N) Datum: WGS1984	The Urban Unit
Administrative Boundaries: Divisions	Boundaries of Divisions of Punjab Province	Punjab Province Boundary	Vector: Shapefile (.shp) (Polygon)	Datum: WGS1984 Datum: WGS1984	The Urban Unit
Administrative Boundaries: Districts	Boundaries of districts of Multan Divisions	Multan Division Boundary	Vector: Shapefile (.shp) (Polygon)	PCS: UTM (Zone 42N) Datum: WGS1984	The Urban Unit
Administrative Boundaries: Tehsils	Boundaries of tehsils of Multan districts	Multan District Boundary	Vector: Shapefile (.shp) (Polygon)	PCS: UTM (Zone 42N) Datum: WGS1984	The Urban Unit
Administrative Boundaries: Qanungoies	Boundaries of Qanungoies of Dunyapur Tehsil	Dunyapur Tehsil Boundary	Vector: Shapefile (.shp) (Polygon)	PCS: UTM (Zone 42N) Datum: WGS1984	The Urban Unit
Administrative Boundaries: Patwar Circles	Boundaries of Patwar Circles of Dunyapur Qanungoies	Dunyapur Qanungoies Boundary	Vector: Shapefile (.shp) (Polygon)	PCS: UTM (Zone 42N) Datum: WGS1984	The Urban Unit
Administrative Boundaries: Mauzas	Boundaries of Mauzas of 12-L Patwar Circle	12-L Patwar Circle Boundary	Vector: Shapefile (.shp) (Polygon)	PCS: UTM (Zone 42N) Datum: WGS1984	The Urban Unit

311/WB Mauza	Boundary of Mauza 311/WB	311/WB AOI boundary	Vector: Shapefile (.shp) (Polygon)	PCS: UTM (Zone 42N) Datum: WGS1984	Developed My Self
Square Boundary	Boundary of Square of Mauza 311/WB	311/WB AOI boundary	Vector: Shapefile (.shp) (Polygon)	PCS: UTM (Zone 42N) Datum: WGS1984	Developed My Self
Land Parcels Khasras/Sub Khasra Boundary	Boundary of Land Parcels (Khasra/Sub-Khasras of Mauza 311/WB	311/WB AOI boundary	Vector: Geodatabase (.GDB) (Polygon)	PCS: UTM (Zone 42N) Datum: WGS1984	Developed My Self
Lines of Land Parcels (Khasra/Sub-Khasras)	Lines of Land Parcels for Dimension	311/WB AOI boundary	Vector: Vector: Geodatabase (.GDB) (Polylines)	PCS: UTM (Zone 42N) Datum: WGS1984	Developed My Self
Revenue Record: Cadastral Maps	The Musavies of Mauza 311/WB	The Musavies of Mauza 311/WB	Raster: .JPEG	N/A	BOR
Field Survey data: GCPs	Sample GCPs	Mauza 311/WB	Vector: Shapefile (.shp) (Point)	PCS: UTM (Zone 42N) Datum: WGS1984	Self-Collected

The spectral characteristics of World View-2 satellite is given as in table B2.

Table B2: Spectral Characteristics of World View-2 Satellite

Sr. No.	Band Name	Spectral Range
1	Coastal Blue	400 nm-450 nm
2	Blue	450 nm-510 nm
5	Red	630 nm-690 nm
6	Red Edge	705 nm-745 nm
7	NIR1	770 nm-895 nm
8	NIR2	860 nm-1040 nm
9	Panchromatic	450 nm-800 nm

(earth.esa.int, 2018)

Table B3: Technical Specification of GPS 60TM

Receiver	WAAS (Wide Area Augmentation System) enabled, 12 parallel channels
Acquisition Time	Warm: Approximately 15 seconds Cold: Approximately 45 seconds AutoLocateTM: Approximately 2 minutes
Update Rate	Once per second, continuous
GPS Accuracy	Position: <15 meters, 95% typical Velocity: 0.05 meter/sec steady state
DGPS Accuracy	Position: 3-5 meters, 95% typical Velocity: 0.05 meter/sec steady state
Dynamics	Performs to specifications to 6 g's
DGPS Interfaces	NMEA 0183 version 3.01, RTCM SC-104 (for corrections) and RS-232 and USB for PC
Data Storage Life	Indefinite: no memory battery required
POI Storage	Internal: Approximately 1 MB

(GPS 60 Navigator, 2022)

Appendix C: Description of Land Record Registers

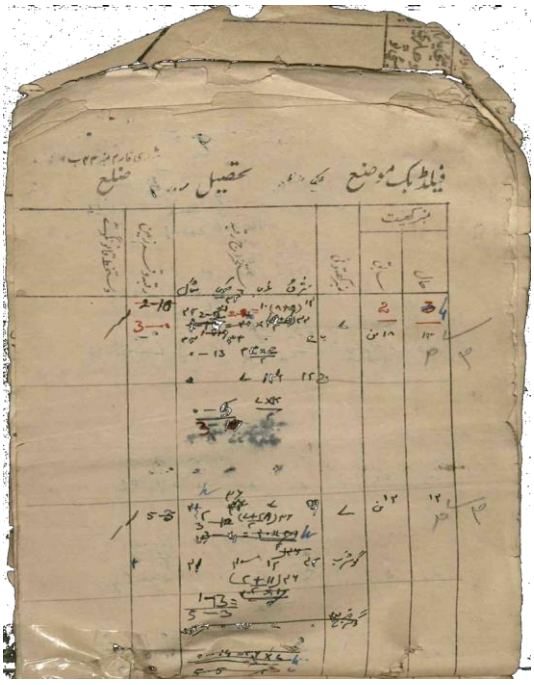
The description of Land Record Registers is given as;

- **Field Book**

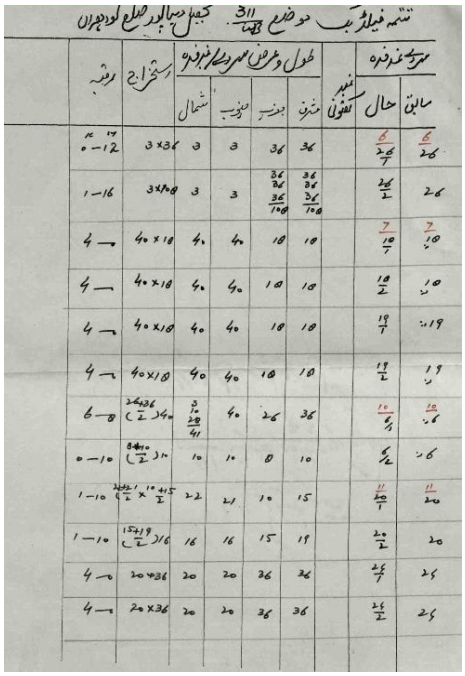
  The field book is the unique register, where the land revenue officer records the information on unique land parcels at the time of land settlement. The original field book was prepared in 1963-64 as shown in Figure C1a). The other field book "Tatima Field Book" is also recorded as shown in Figure C1b). The original field book was not in good shape and textual information was distorted. The Tatima field book was missing the khatuni information.

  The following attribute information was recorded.

  - Unique Land Parcel Number (Survey Number) Previous
  - Unique Land Parcel Number (Survey Number) Current
  - Khatuni No.
  - Dimensions of Land Parcel
  - Area of Land Parcel
  - Type of Land



C1: a) Field Book – Form No.44 Bey



C1: b) Tatima Field Book

Figure C1: Field Book Register

- **Register Haqdaran Zameen**

Register Haqdaran Zameen (RHZ) is the unique register, where the land revenue officer records the information about ownership, tenants, litigation, sale, loan and detail of tax against unique land parcels at the time of Jamabandi. It is updated every 4 years. The RHZ book was updated in 2010-2011.

The Register Haqdaran Zameen has included the following information;

- Shajra Nasib of Owners
- Index Numbers Khasras (Survey Numbers)
- Register Haqdaran Zameen
- Qanungo (Revenue Officer) Babat Part Tasdeeq (Misal Meeadi)
- Note for Change of Type of Land
- *Akheer Tasdeeq Register Haqdaran Zameen*

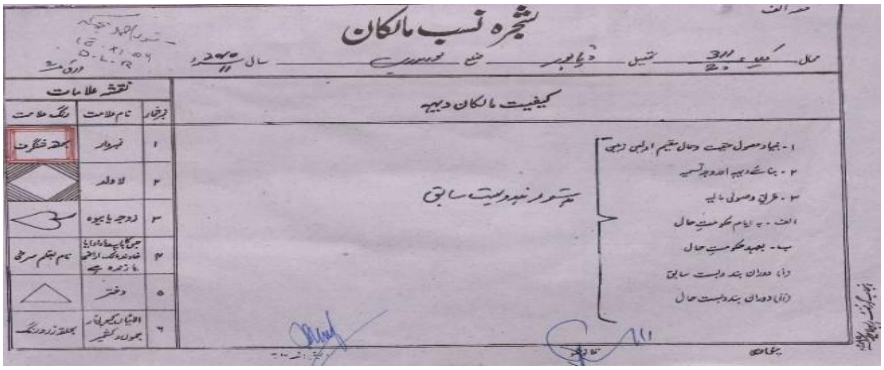


Figure C2: a) Shajra Nasib of Owners Part-Alaf

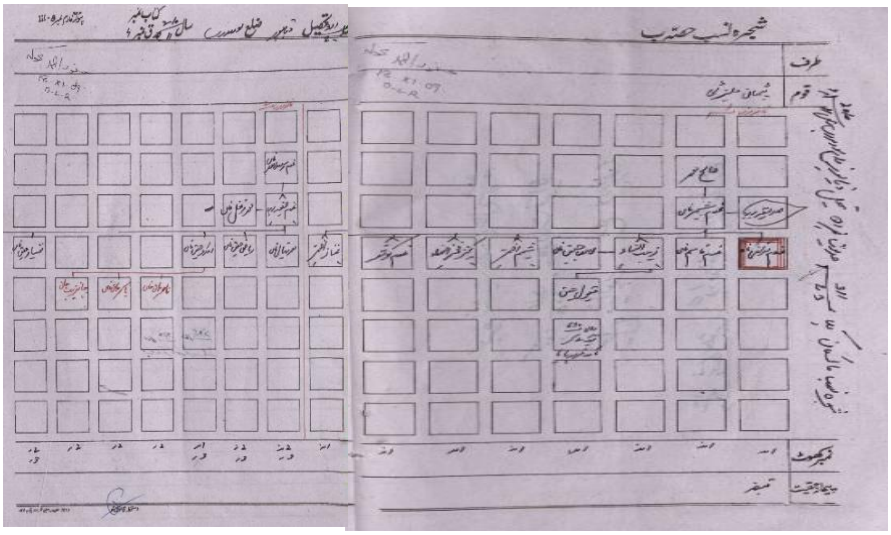


Figure C2: b) Shajra Nasib of Owners Part – Bey

Explanation

- **Shajra Nasib of Owners**

It consists of Shajra Nasib, part Alaf and part Bey. It provides information about the inheritance of the land of owners from the grandfather to their grandchildren. The symbols related to Numberdar, children, wife, grandfather/father/husband (alive), and daughter are recorded in the Shajra Nasib of Owners as shown in Figure C2a. Shajra Nasib Part-Bey consists of the information about direction, cost, and relationship blocks, Khewat Number and possession as shown in Figure C2b.

- **Index Numbers Khasras (Survey Numbers)**

It is the index and also called Patwari form no. IV. The unique land parcel numbers (khasra numbers or survey numbers) and Khatuni numbers were recorded. The text written in red represents the square number (Killa number).

The index numbers for khasras is shown in Figure C3.

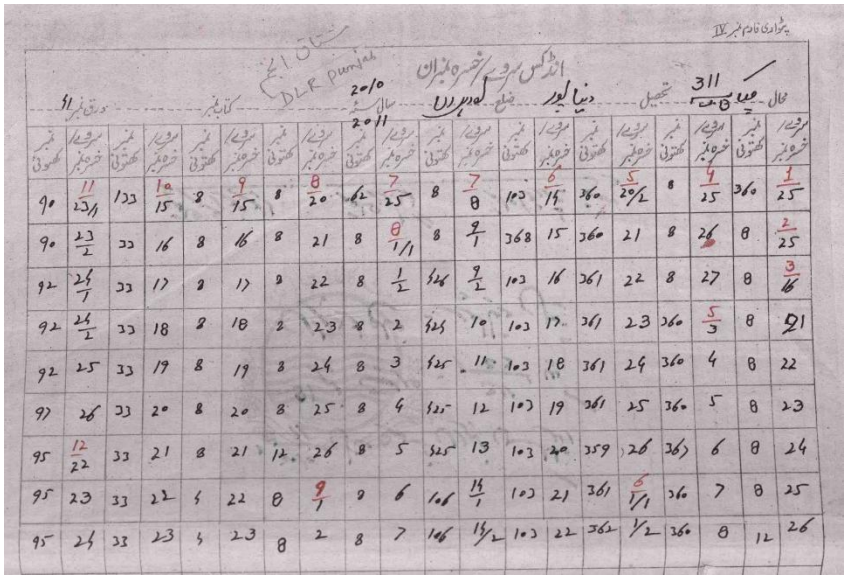


Figure C3: Index Numbers of Khasras (Survey **Numbers)**

- **Qanungo (Revenue Officer) Babat Part Tasdeeq (Misal Meeadi)**

It is a detailed document and consists of ten columns. It is also called Patwari form no. XXXIVA, on that the land revenue officer records the following information;

- Number Khewat (Owner)
- Number Khatuni (Farmer)
- Name of Owner with Father Name/Husband Name & Residence
- National Identity Card Number (NICN)
- Nature of Rights of Owner/Lessee, etc.
- Specific Part in the combined record
- Specific Area as per specific part
- Agriculture Passbook Number
- Name of Farmer with the situation
- Number Khasra with name (If any)
- Area, Type of Land and total Khatuni (Farmer) & Khewat (Owner)
- Resource with Name Chah/Rajbah etc
- Lagan (Tax) who the farmer pays, Ratio and demand
- Demand with detail of land value and answer
- Remarks (Numberdar if any)/Ratio of Land Value

The snapshot of Register Haqdaran Zameen (Misal Miadi) is shown in Figure C4.

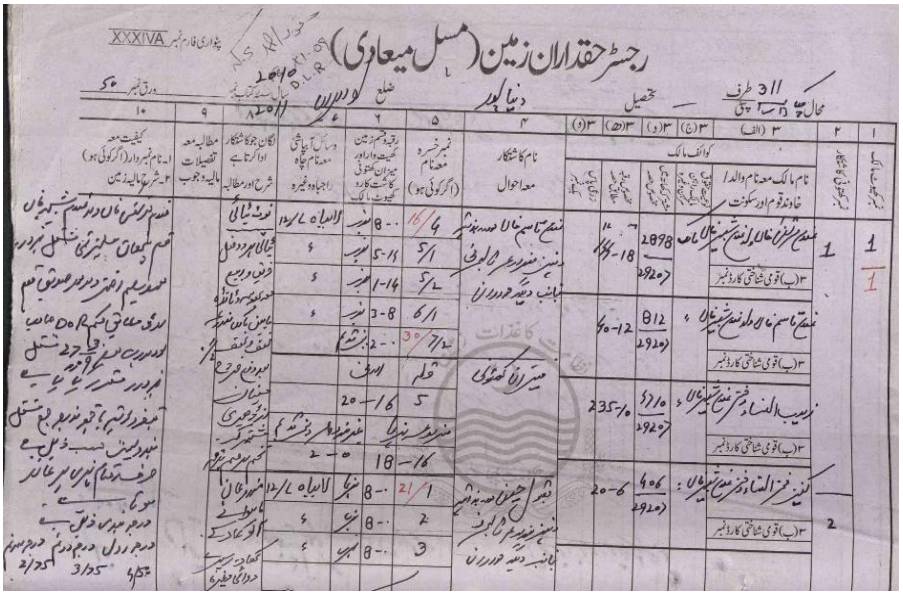
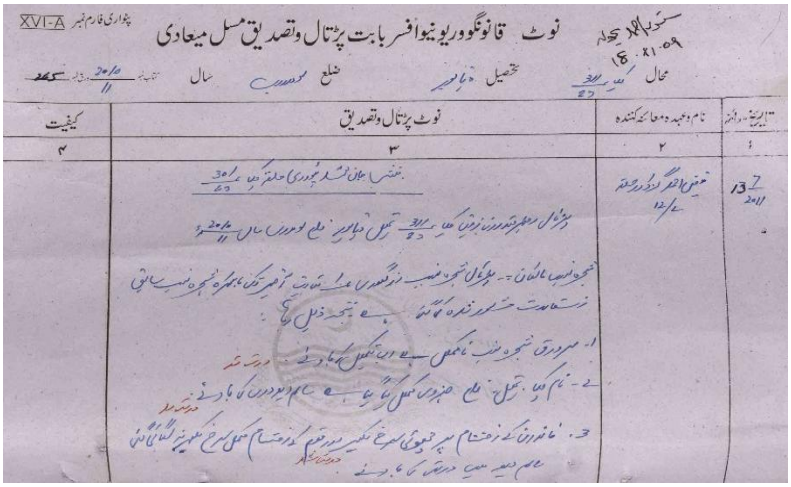


Figure C4: Register Haqdaran Zameen (Missal Miadi)

- **Qanungo (Revenue Officer) Babat Part Tasdeeq (Misal Meeadi)**

It is the document where the land revenue officer (Qanungo) verifies the information recorded by Patwari and prepares a report about the quality of the record. He mentions the errors/omission in his report. It is also called patwari form no.XVI-A as shown in Figure C5 and includes the following columns;

- Date
- Name with the designation of Record verifier
- Note for Check and balance
- Remarks


نوٹ قانونگو ریونیو افسر بابت پڑتال وتصدیق مسل میعادی

تاریخ وصولی	نوٹ پڑتال وتصدیق	نام وعہدہ معائنہ کنندہ	کیفیت
۱	۳	۲	۴

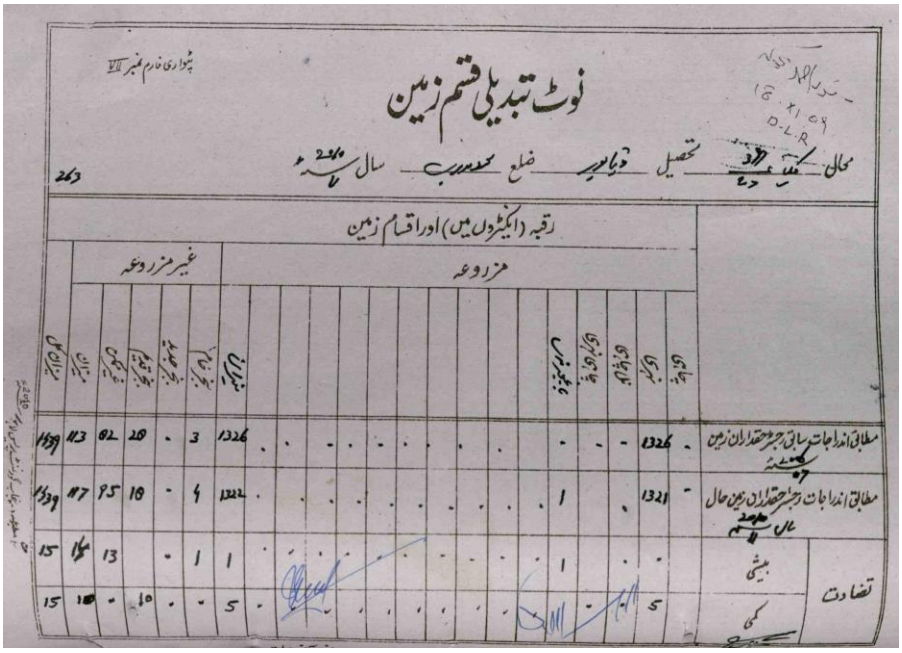
Figure C5: Qanungo (Revenue Officer) Babat Part Tasdeeq

- **Note for Change of Type of Land**

It is the document where information regarding changes in the type of land is recorded as shown in Figure C6. It is also called Patwari form no.VII and records the following information;

- Recorded information as per previous Register Haqdaran Zameen
- Recorded information as per current Register Haqdaran Zameen
- Tazadat (Errors)
    - Beshi (Increased)
    - Kami (Decreased)
- Area (in acres) and types of land (Mazroa)
    - Chahi
    - Nahri
    - Nul chahi
    - Chahi Nahri
    - Bageecha etc
    - Total
- Area (in acres) and types of land (Mazroa)
    - Banjer Kham

- Banjer Jadeed
- Banjer Qadeem
- Impossible
- Total
- Grand Total



نوٹ تبدیلی قسم زمین

Figure C6: Note for Change of Land Type

- **Akheer Tasdeeq Register Haqdaran Zameen**

It is a document on the verification information recorded by the verifier land revenue officer and consists of 9 columns as shown in Figure C7. It is also called Patwari form no.XVI and records the following information;

- Date of verification
- Location of verification
- Records that were verified
- Verification of orders Dakhil/Kharij
- Records that were compared with records in previous Register Haqdaran Zameen
- Records that were compared with records in the current Register Haqdaran Zameen
- Total Land Parcels (Khasras) that were verified with Musavee
- Dakhil/Kharij that were recorded before 30th June and not verified.

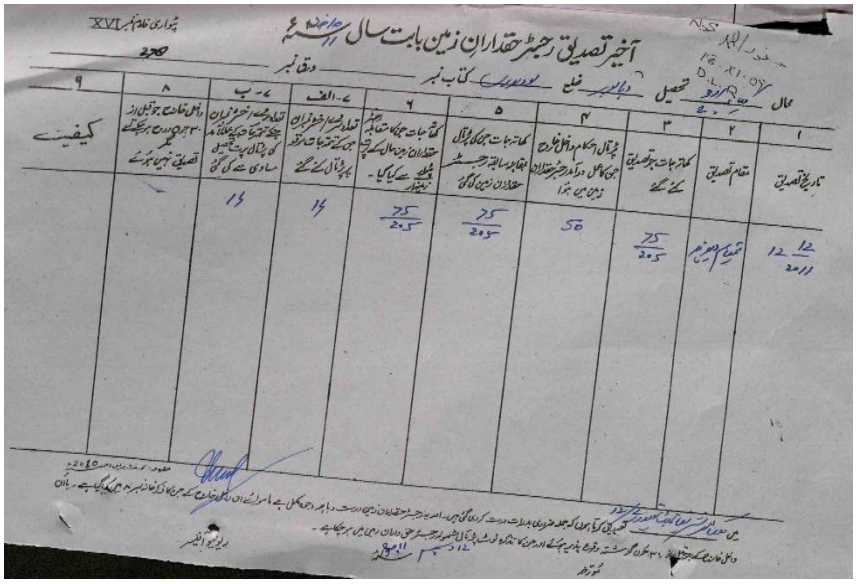


Figure C7: Akheer Tasdeeq Register Haqdaran

- **Mutation**

The mutation is the unique register, where the land revenue officer records the information about the transfer of ownership against a unique land parcel.

The Mutation register consists of the following information;

- Register Dakhil/Kharij
- Tatima Field Book & Tatima Shajra Nasib
- Certificate of Release of Charge

Explanation

- **Register Dakhil/Kharij**

  Register Dakhjl/Kharij records the information of individual land parcels whose ownership has been transferred. It is also called Patwari form no.XXXV and consists of 14 columns as shown in Figure C8.

  The following information is recorded;

  - Serial No.
  - Andraj Register Haqdaran Zameen or Last Register Dakhil/Kharij whom change is necessary
    - Number Khata Register Haqdaran Zameen

- Name of Owner with detail
- Name of Farmer with detail
- Survey Khasra Numbers with names (if any)
- Area, Land Type

- New Andraj Jawab (that will Manage)
  - Number Khata that will be recorded in the new Register Haqdaran Zameen
  - Number Khata Register Haqdaran Zameen
  - Name of Owner with detail
  - Name of Farmer with detail
  - Survey Khasra Numbers with names (if any)
  - Area, Land Type
- Type and date of Dakhil/Kharij with Bey, Rehn etc
- Malia (Fee) Dakhil/Kharij
- Report (Order), Signatures with Thumb Signs

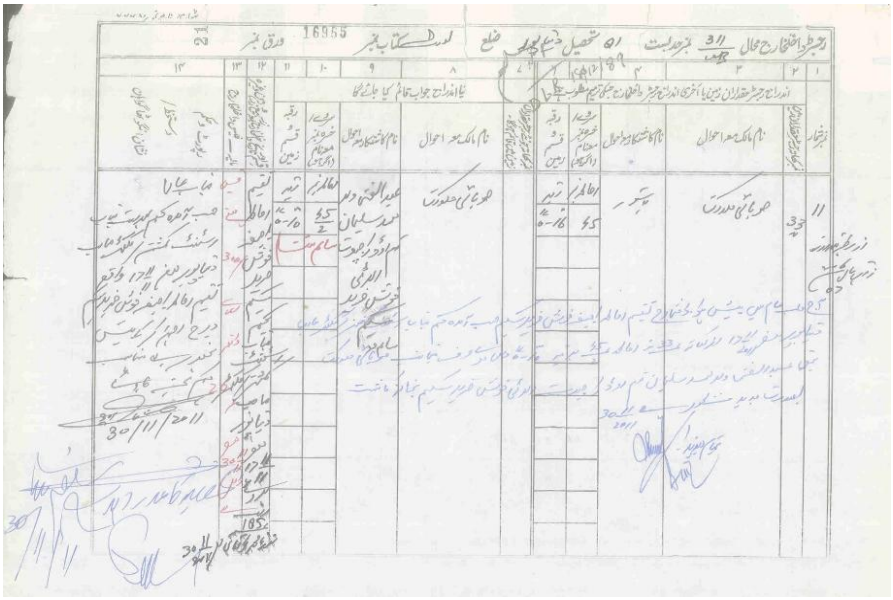


Figure C8: Register Dakhil Kharij

- **Tatima Field Book & Tatima Shajra Nasib**

It consists of two parts that are shown in Figure C9.

- Part-Alaf Tatima Field Book

This part includes the information on land parcels whose ownership has been transferred and consists of the following columns;

- Unique Land Parcel Number (Survey Number) Previous
- Unique Land Parcel Number (Survey Number) Current
- Khatuni No.
- Dimensions of Land Parcel (East, West, North, South)
- Area of Land Parcel
- Type of Land
- Remarks

- Part-Bey Tatima Shajra Nasib

This part included the manual map of land parcels whose division has been confirmed from ownership records as shown in Figure C9.

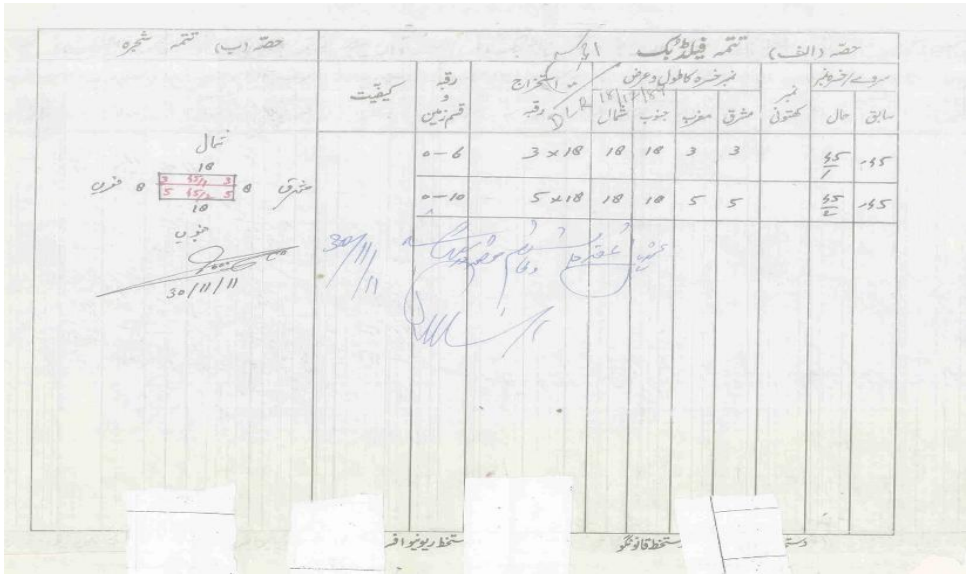


Figure C9: Tatima Field Book & Tatima Shajra Nasib

- **Certificate of Release of Charge**

This document includes the ownership information of land parcels against the payment borrowed by the landowner. Figure C10 shows the certificate of release of charge that has been issued by the Zarai Taraqiati Bank Limited (ZTBL) against agricultural land.

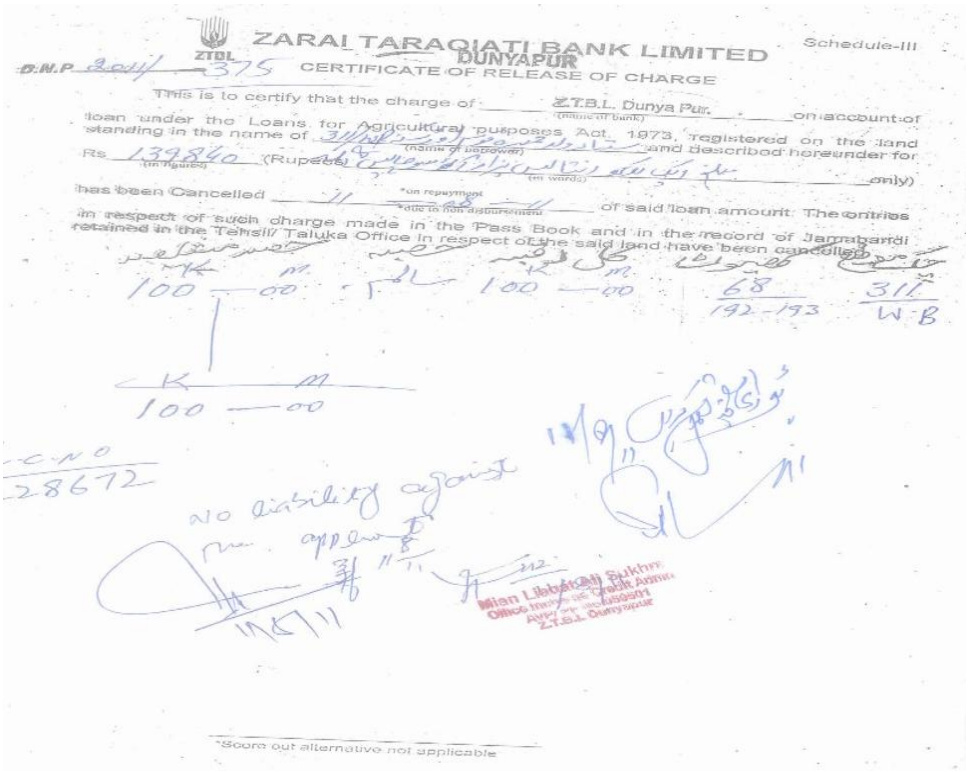

ZARAI TARAQIATI BANK LIMITED
ZTBL DUNYAPUR
Schedule-III
CERTIFICATE OF RELEASE OF CHARGE
This is to certify that the charge of Z.T.B.L. Dunya Pur. on account of loan under the Loans for Agricultural Purposes Act, 1973, registered on the land standing in the name of and described hereunder for Rs 139840 (Rupees only) has been Cancelled *on repayment *date of non disbursement of said loan amount. The entries in respect of such charge made in the Pass Book and in the record of Jamabandi retained in the Tehsil/ Taluka Office in respect of the said land have been cancelled.
100 — 00
68
192-193
311
W.B
No dishility against
Mian Liaqat Ali Sukhera
Credit Admn.
Z.T.B.L. Dunyapur
*Score out alternative not applicable

Figure C10: Certificate of Release of Charge

- **Register Tagayrat Possession, Cultivation, Tax**

This register records the information on land parcels whose possession concerning cultivation has been changed and tax information. It is also called Patwari form no.XXIV and consist of 9 individual columns shown in Figure C11.

The following information is recorded;

- Crop Name
- Date of Girdawri
- Number Khasras with area (Change of Tagayer)
- Andraj Previous
- Andraj Current
- Signature Patwari with date
- Tasdeeq from Girdawri, Qanungo with the date
- Tasdeeq from the Revenue officer with the date
- Remarks

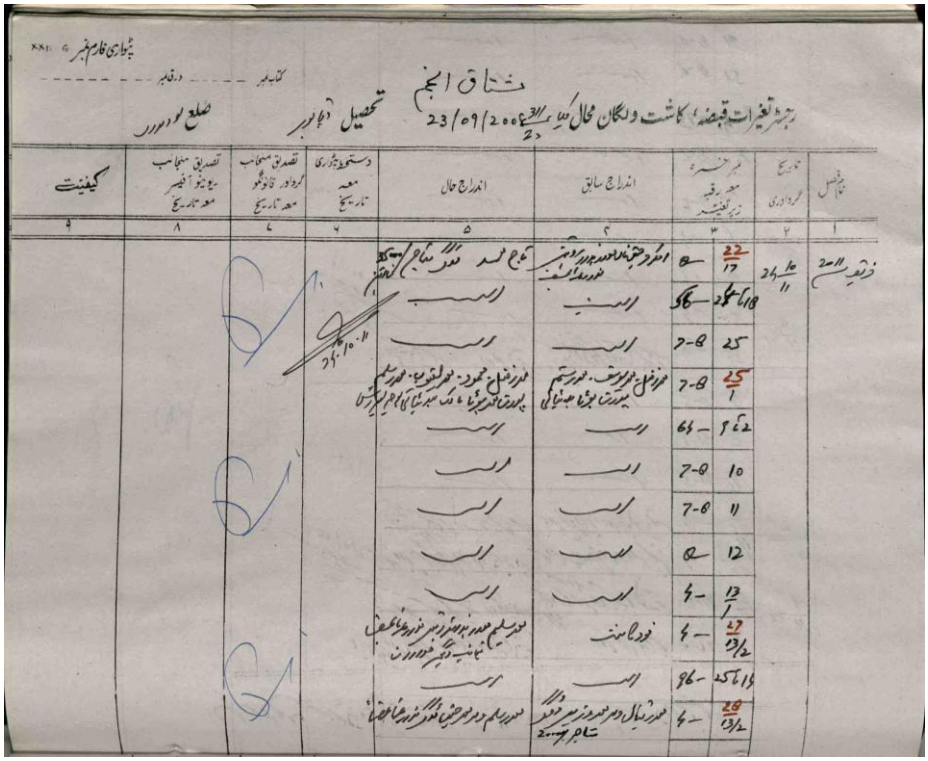


Figure C11: Register Tagayrat Possession, Cultivation Tax

Appendix D: Scanning of Cadastral Maps and Land Records, Parcel Fabric Dataset and Quality Checks of Final data

1. Scanning of Cadastral Maps

Initially, the digital copy of handmade cadastral maps locally called "Musavies", were collected from the Urban Unit. As discussed by the Urban Unit officials, 8 maps were scanned through a roller scanner and a specifically designed scanner (manual scanner) with a high resolution (300 DPI (Dots per Inch)) camera (18 Mega Pixel) to maintain better scanning output. The camera was mounted on an iron stand and two lights were installed on the left and right edges of the iron frame to support the light effects as shown in figure D1. The purpose of this manual scanner was to scan the dusty, bad condition and torn musavies to ascertain the better resolution of maps.

Figure D1: Sample of Manual Scanner

2. Scanning of Land Record Registers

The revenue registers data was scanned by using a Bookeye scanner as shown in figure D2. The purpose of this scanner is to scan such documents which are in the form of book and cannot scan each page individually.

Figure B2: Bookeye Scanner

3. Parcel Fabric Dataset

The features: control, line points, points, lines and parcels were generated during parcel fabrication model as shown in figure D3, but lines and parcel features are used for research work. The description of feature classes is given in table A4 of Appendix A.

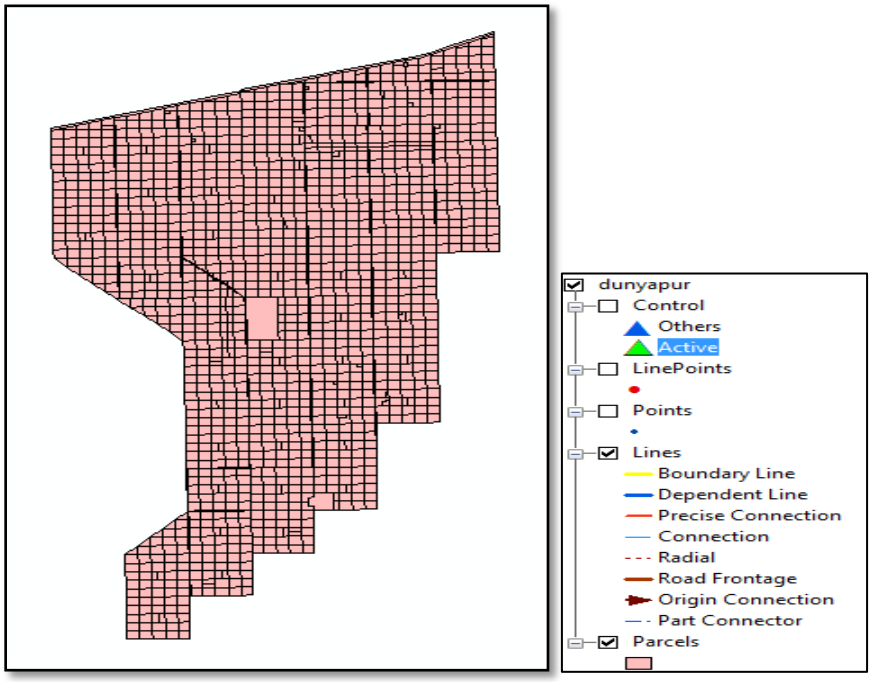


Figure D3: Feature classes after Parcel Fabrication

4. Quality Checks for final Land Parcels and Lines data

- Attribute data is entered correctly according to Musavee.
- There must be no line without dimension entry.
- The dimension to-geometric length ratio is under an acceptable limit.
- No feature must have zero length or area.
- Must have khasra number
- Must have Muraba number (not applicable in non-muraba mauzas)
- Must have a valid mauza name as per the BOR list
- Check Khasra number continuity.
- Check Square Number (muraba number) continuity.

Appendix E: Topological Rules

The following eight topological rules were applied in Parcel Fabric Model for line features of khasra and sub-khasra land parcels;

- "Must Not Overlap"
- "Must Not Intersect"
- "Must Not Have Dangles"
- "Must Not Have Pseudo Nodes"
- "Must Not Self-Intersect"
- "Must Not Self-Overlap"
- "Must be Single Part"
- "Must Not Intersect or Touch Interior"

The following six topological rules were applied for development of new khasra polygon and khasra line feature class in the parcel fabrication;

- "Must Not Self-Overlap"
- "Must Not Self-Intersect"
- "Must be Single Part"
- "Must Not Intersect or Touch Interior"
- "Must be covered by Boundary of New_Khasra parcels"
- "Boundary Must be Covered by Khasra_Lines"

Appendix F: Results

Table F1: Area Summary of Musavies before Updating

Musavee Name	No. of Musavee	Total No. of Square Boxes	Total No. of Land Parcels	Total No. of Sub-Land Parcels	Total Area in Acres*	Total Area in Kanals*
Alaf-1	1	10	164	22	142.27	1138.14
Alaf-2	1	15	418	53	375.17	3001.38
Alaf-3	1	11	297	33	275.58	2204.65
Alaf-4	1	4	78	8	75.29	602.35
Bey-1	1	4	37	4	33.67	269.30
Bey-2	1	12	331	47	287.47	2299.73
Bey-3	1	5	130	20	113.14	905.15
Bey-4	1	6	150	12	138.33	1106.63
Total	**8**	**67**	**1605**	**199**	**1440.92**	**11527.33**

*One acre = 4046.856 Square meters, and one Kanal = 2023.428 Square meters

Table F2: Area Summary of Musavies after Updating

Musavee Name	No. of Musavee	Total No. of Square Boxes	Total No. of Land Parcels	Total No. of Sub-Land Parcels	Total Area in Acres*	Total Area in Kanals*
Alaf-1	1	10	161	18	146.33	1170.61
Alaf-2	1	15	437	93	375.17	3001.38
Alaf-3	1	11	313	62	275.58	2204.65
Alaf-4	1	4	90	27	75.29	602.35
Bey-1	1	4	41	12	33.67	269.30
Bey-2	1	12	343	66	287.47	2299.73
Bey-3	1	5	144	45	113.14	905.15
Bey-4	1	6	152	14	138.33	1106.63
Total	**8**	**67**	**1681**	**337**	**1440.92**	**11527.33**

*One acre = 4046.856 Square meters, and one Kanal = 2023.428 Square meters

Table F3: Area Summary of Squares

Square Number	Total No. of Land Parcels (Musavies)	Total No. of Sub-Land Parcels (Musavies)	Total No. of Land Parcels (Field Book)	Total No. of Sub-Land Parcels (Field Book)	Total Area in Acres*	Total Area in Kanals*
1	1		1		0.22	1.78
2	2	2	1		0.35	2.79
3	7		7		5.32	42.55
4	18	5	15		11.73	93.83
5	25	2	25	2	21.12	168.95
6	28	3	28	4	25.00	200.03
7	27	4	29	8	24.86	198.85
8	27	2	27	2	24.95	199.60
9	28	4	27	2	22.99	183.89
10	19		20	2	16.37	130.95
11	13	2	16	8	10.40	83.17
12	5	2	5	2	2.84	22.71
13	27	4	28	6	24.88	199.05
14	28	2	28	2	25.14	201.12
15	29	4	29	4	25.23	201.81
16	32	8	31	7	25.06	200.49
17	36	16	34	14	25.24	201.89
18	30	10	30	10	25.27	202.17
19	30	6	29	5	25.19	201.53
20	28	3	28	3	24.96	199.67
21	25		25		25.23	201.85
22	26		26		25.30	202.40
23	27	2	28	4	24.94	199.49
24	28	2	30	6	25.00	199.97
25	28	2	28	2	25.06	200.51
26	26	2	27	4	24.98	199.81
27	26	2	26	2	24.93	199.45
28	27	2	27	2	25.00	200.00
29	28	2	38	20	24.89	199.12
30	27	2	27	2	24.70	197.57
31	26		26		25.14	201.15
32	25		32	14	24.93	199.46
33	26		27	2	25.18	201.44
34	26	2	38	24	24.69	197.56
35	27	2	27	2	24.83	198.68
36	27	2	29	6	24.51	196.05
37	41	23	39	16	24.86	198.87
38	28	2	28	2	24.74	197.94

Square Number	Total No. of Land Parcels (Musavies)	Total No. of Sub-Land Parcels (Musavies)	Total No. of Land Parcels (Field Book)	Total No. of Sub-Land Parcels (Field Book)	Total Area in Acres	Total Area in Kanals
39	15		15		12.76	102.09
40	15		15		12.61	100.88
41	31	10	34	16	25.08	200.64
42	17		17		24.88	199.02
43	27	2	27	2	25.12	200.96
44	27	3	29	7	25.00	199.97
45	26	2	32	12	25.26	202.06
46	29	4	29	4	25.13	201.01
47	29	4	29	4	25.07	200.55
48	30	6	32	10	25.05	200.41
49	27	2	28	2	24.99	199.91
50	28	2	32	9	24.69	197.54
51	30	6	34	14	24.92	199.37
52	28	6	28	6	25.23	201.86
53	28	2	28	2	25.17	201.39
54	28	2	28	2	25.12	200.92
55	27	2	35	17	25.41	203.31
56	28	2	28	2	25.53	204.25
57	26	2	26	2	24.75	197.96
58	24	2	25	4	22.17	177.36
59	27	4	38	21	24.83	198.67
60	27	2	29	4	25.00	200.03
61	15		15		12.58	100.65
62	26	2	26	2	25.03	200.25
63	28	4	28	4	25.33	202.66
64	26	2	26	2	24.85	198.79
65	1		1		3.54	28.36
66	1		1		9.79	78.34
Grand Total	**1605**	**199**	**1681**	**337**	**1440.92**	**11527.33**

*One acre = 4046.856 Square meters, and one Kanal = 2023.428 Square meters

It is noted that square numbers; 1, 2 and 66 consist of only one khasra and belong to two musavies Alaf-1 & Bey-1. Square number 1 has the least area of 0.22 acres (1.78 kanal), but square no. 56 has a maximum land area of 25.53 acres (204.25 Kanal). Square number 41 consists of 41 khasras as per musavies (before updating) and 37 as per the field book (after updating). The 44 squares have the approximately same area, and 12 squares have different area information.

Table F4: Musavee wise summary statistics of khasra and sub-khasra before and after field book Updating

Musavee Name	Total No. of Land Parcels (Field Book) after Updating	Total No. of Land Parcels (Musavies) before Updating	Change in Khasra	Total No. of Sub-Land Parcels (Field Book) after Updating	Total No. of Sub-Land Parcels (Musavies) before Updating	Change in Sub-Khasra
Alaf-1	161	164	-3	18	22	-4
Alaf-2	437	418	19	93	53	40
Alaf-3	313	297	16	62	33	29
Alaf-4	90	78	12	27	8	19
Bey-1	41	37	4	12	4	8
Bey-2	343	331	12	66	47	19
Bey-3	144	130	14	45	20	25
Bey-4	152	150	2	14	12	2
Total	**1681**	**1605**	**76**	**337**	**199**	**138**

Table F5: Summary of Squares before and after field book Updating

Square Number	Total No. of Land Parcels (Field Book) after Updating	Total No. of Land Parcels (Musavies) before Updating	Change in Khasra	Total No. of Sub-Land Parcels (Field Book) after Updating	Total No. of Sub-Land Parcels (Musavies) before Updating	Change in Sub-Khasra
1	1	1	0			
2	1	2	-1		2	-2
3	7	7	0			
4	15	18	-3		5	-5
5	25	25	0	2	2	0
6	28	28	0	4	3	1
7	29	27	2	8	4	4
8	27	27	0	2	2	0
9	27	28	-1	2	4	-2
10	20	19	1	2		2
11	16	13	3	8	2	6
12	5	5	0	2	2	0
13	28	27	1	6	4	2

Square Number	Total No. of Land Parcels (Field Book) after Updating	Total No. of Land Parcels (Musavies) before Updating	Change in Khasra	Total No. of Sub-Land Parcels (Field Book) after Updating	Total No. of Sub-Land Parcels (Musavies) before Updating	Change in Sub-Khasra
14	28	28	0	2	2	0
15	29	29	0	4	4	0
16	31	32	-1	7	8	-1
17	34	36	-2	14	16	-2
18	30	30	0	10	10	0
19	29	30	-1	5	6	-1
20	28	28	0	3	3	0
21	25	25	0			
22	26	26	0			
23	28	27	1	4	2	2
24	30	28	2	6	2	4
25	28	28	0	2	2	0
26	27	26	1	4	2	2
27	26	26	0	2	2	0
28	27	27	0	2	2	0
29	38	28	10	20	2	18
30	27	27	0	2	2	0
31	26	26	0			
32	32	25	7	14		14
33	27	26	1	2		2
34	38	26	12	24	2	22
35	27	27	0	2	2	0
36	29	27	2	6	2	4
37	39	41	-2	16	23	-7
38	28	28	0	2	2	0
39	15	15	0			
40	15	15	0			
41	34	31	3	16	10	6
42	17	17	0			
43	27	27	0	2	2	0
44	29	27	2	7	3	4
45	32	26	6	12	2	10
46	29	29	0	4	4	0
47	29	29	0	4	4	0
48	32	30	2	10	6	4
49	28	27	1	2	2	0
50	32	28	4	9	2	7
51	34	30	4	14	6	8

Square Number	Total No. of Land Parcels (Field Book) after Updating	Total No. of Land Parcels (Musavies) before Updating	Change in Khasra	Total No. of Sub-Land Parcels (Field Book) after Updating	Total No. of Sub-Land Parcels (Musavies) before Updating	Change in Sub-Khasra
52	28	28	0	6	6	0
53	28	28	0	2	2	0
54	28	28	0	2	2	0
55	35	27	8	17	2	15
56	28	28	0	2	2	0
57	26	26	0	2	2	0
58	25	24	1	4	2	2
59	38	27	11	21	4	17
60	29	27	2	4	2	2
61	15	15	0			
62	26	26	0	2	2	0
63	28	28	0	4	4	0
64	26	26	0	2	2	0
65	1	1	0			
66	1	1	0			
Grand Total	**1681**	**1605**	**76**	**337**	**199**	**138**

Khasras and sub-khasras records were summarized for estimation of information based on square numbers. It was observed that there was no change in khasras and sub-khasra count of 24 squares numbers, but khasras & sub-khasra count decreased by seven square numbers, which was the result of merged parcels based on change of ownership in field book record. The khasras count decreased from 27 to 26 of square number 13 but there was no change in sub-khasra count, but sub-khasra count were increased from 3 to 4 and no change in khasra count. It was also observed that 23 squares have different scenarios regarding increased khasras & sub khasras count, square number 34 had a maximum increase in khasras information from 26 to 38 and sub-khasras count from 2 to 24.

Table F6: Summary of Khewat as per Register Haqdaran Zameen

Khewat No.	Total No. of Land Parcels (Field Book)	Total Area in Kanals* (GIS)	Total Area in Kanals* (RHZ)	Total Nahri Area in Kanals* (RHZ)	Total Gair Mumkin Area in Kanals* (RHZ)	Total Banjer Jadeed Area in Kanal* (RHZ)	Total Banjer Qadeem Area in Kanal* (RHZ)	Total Benaam Area in Kanal* (RHZ)
1/1	199	1456.02	1460.35	1420.4	37.95	0	2	0
2/2	42	262.51	261	256.05	4.95	0	0	0
3/3	56	366.88	365	353.4	11.6	0	0	0
4/4	7	51.75	51	44.5	6.5	0	0	0
5/5	15	101.11	100	97.2	2.8	0	0	0
6/6	13	99.79	102.45	96.45	6	0	0	0
7/7	13	95.96	98.2	96.95	1.25	0	0	0
8/8	14	100.65	100	90.95	9.05	0	0	0
9/9	14	101.41	100	93.95	6.05	0	0	0
10/10	14	99.10	100	94.8	5.2	0	0	0
11/11	1	8.01	8	7.75	0.25	0	0	0
12/12	14	100.83	100	93.7	6.3	0	0	0
13/13	2	6.08	10	10	0	0	0	0
14/14	8	52.94	54	53.75	0.25	0	0	0
16/15, 73	6	16.24	16	16	0	0	0	0
17/16	13	99.62	99.75	97.75	2	0	0	0
18/17	7	50.89	53	50.5	2.5	0	0	0
19/18	14	100.70	100	95.8	4.2	0	0	0
20/20	13	100.58	100	96	4	0	0	0
21/21	13	97.52	98.8	97.8	1	0	0	0
22/22	2	7.93	8	8	0	0	0	0
23/42	13	97.75	100	100	0	0	0	0
24/23	13	99.12	100	97.5	2.5	0	0	0
25/24	3	20.27	20	20	0	0	0	0
26/25	11	80.42	80	77.75	2.25	0	0	0
27/26	4	30.37	23.15	23.15	0	0	0	0
28/27	4	22.76	23.55	23.55	0	0	0	0
29/28	1	3.55	3.9	3.9	0	0	0	0
30/29	2	7.49	8	6.2	1.8	0	0	0
31/30	5	22.71	22.95	22.95	0	0	0	0
32/31	5	19.00	19.15	18.4	0.75	0	0	0
33/32	14	100.89	100.6	96.65	3.95	0	0	0
34/33	19	135.85	136	128.2	7.8	0	0	0
35/34	7	39.28	40	40	0	0	0	0
36/35	13	92.72	91.4	89.15	2.25	0	0	0
37/36	14	101.29	100	96.8	3.2	0	0	0
38/37	14	100.10	100	96.2	3.8	0	0	0
39/38	12	84.37	84	81.5	2.5	0	0	0
40/39	15	98.59	100	93.2	6.8	0	0	0
41/40	13	99.99	100	100	0	0	0	0
42/41	13	101.51	100	99	1	0	0	0
43/43	15	102.17	100	98.2	1.8	0	0	0

44/44	13	98.86	100	97.5	2.5	0	0	0
45/45	13	99.69	100	100	0	0	0	0
46/46	10	75.85	75	72.5	2.5	0	0	0
47/47	3	10.33	10	10	0	0	0	0
48/48	2	3.02	3	2.5	0.5	0	0	0
49/49	13	92.99	92	79	5	2	6	0
50/50	1	6.17	6.4	5.9	0.5	0	0	0
51/50	4	22.88	23.1	22.6	0.5	0	0	0
52/51	13	99.39	98.2	94.7	3.5	0	0	0
53/52	1	8.21	8	7.5	0.5	0	0	0
54/53	4	22.11	20	19.4	0.6	0	0	0
55/56	4	20.55	20	17.5	2.5	0	0	0
56/54	5	20.68	20	20	0	0	0	0
57/55	5	20.55	20	19.5	0.5	0	0	0
58/57	14	100.29	100	91.8	8.2	0	0	0
59/58	6	36.04	34.8	34.2	0.6	0	0	0
60/59	4	12.87	12	12	0	0	0	0
61/60	3	15.53	16	16	0	0	0	0
62/61	11	76.04	76	74.3	1.7	0	0	0
63/62	13	97.97	98.2	94.2	4	0	0	0
64/63	20	107.96	108.05	104.25	3.8	0	0	0
65/64	16	96.32	96.3	95.5	0.8	0	0	0
66/68	1	3.94	4	4	0	0	0	0
67/67	8	58.10	58.25	56.25	2	0	0	0
68/65	1	1.77	1.75	1.75	0	0	0	0
69/66	3	19.63	20	17.75	2.25	0	0	0
70/69	2	15.98	16	16	0	0	0	0
71/70	14	98.19	100.1	90.5	9.6	0	0	0
72/71	14	104.38	100	90.2	9.8	0	0	0
73/72	9	50.13	50	50	0	0	0	0
74/73	5	25.74	26	22.2	3.8	0	0	0
75/74	15	99.88	100	96.95	3.05	0	0	0
76/75	14	103.91	100	96.8	3.2	0	0	0
77/76	14	100.67	100	96.3	3.7	0	0	0
78/77	9	65.16	64	61	3	0	0	0
79/78	1	7.74	8	7.5	0.5	0	0	0
80/77	3	19.43	20	19.5	0.5	0	0	0
81/79	5	32.37	32	30.4	1.6	0	0	0
82/80	7	31.74	32	30.4	1.6	0	0	0
83/81,83	4	20.35	20	19.55	0.45	0	0	0
84/82	1	8.19	8	7.5	0.5	0	0	0
85/84	15	100.12	100	95.75	4.25	0	0	0
86/85	15	100.65	100	99.5	0.5	0	0	0
87/86	14	100.33	100.1	92.5	7.6	0	0	0
88/87	14	99.24	100	94.7	5.3	0	0	0
89/88	4	22.58	22.8	21.05	1.75	0	0	0
90/89	13	92.91	92	90.4	1.6	0	0	0
91/143,371,372	6	27.46	28.55	27.35	1.2	0	0	0
92/90	1	4.00	4	4	0	0	0	0
93/93	14	98.28	99.4	97.9	1.5	0	0	0
94/92	2	16.37	16	16	0	0	0	0

95/94	3	15.77	16	16	0	0	0	0
96/95	8	55.91	56	55.5	0.5	0	0	0
97/96	14	99.53	100	95.3	4.7	0	0	0
98/97	5	33.60	36	36	0	0	0	0
99/98	14	102.71	100	98.8	1.2	0	0	0
100/99	3	10.91	10.65	10.65	0	0	0	0
101/100	3	11.08	10.75	10.75	0	0	0	0
102/101	2	10.81	10.5	10.5	0	0	0	0
103/102	3	10.50	10.4	9.4	1	0	0	0
104/103	3	10.54	10.7	10.7	0	0	0	0
105/104	2	10.58	11	11	0	0	0	0
106/106	6	38.06	38	37.5	0.5	0	0	0
107/107	1	0.92	1	0	1	0	0	0
108/108	6	36.21	38	38	0	0	0	0
109/109	3	21.79	23	22	1	0	0	0
110/143	14	99.83	100	95.95	4.05	0	0	0
111/110	1	8.34	8	8	0	0	0	0
112/19	1	8.26	8	8	0	0	0	0
113/19	12	84.93	84	82.8	1.2	0	0	0
114/143	13	97.50	98.2	97.2	1	0	0	0
115/131	9	45.74	49.75	48.85	0.9	0	0	0
116/105	5	32.20	32	31	1	0	0	0
117/105	1	3.96	4	4	0	0	0	0
118/111	14	99.73	100	93.75	6.25	0	0	0
119/112	2	7.91	8	8	0	0	0	0
120/113	14	100.31	100	95.2	4.8	0	0	0
121/128	1	3.73	4	4	0	0	0	0
122/114	13	100.90	100	98.25	1.75	0	0	0
123/115	2	8.12	7.9	7.4	0.5	0	0	0
124/129	8	48.39	49.05	48.3	0.75	0	0	0
125/116	15	100.88	100	98.5	1.5	0	0	0
126/117	14	94.08	92	83.5	8.5	0	0	0
127/118	14	102.48	100	96.2	3.8	0	0	0
128/119	21	145.22	144	138	6	0	0	0
129/120	16	121.47	120.6	115.3	5.3	0	0	0
130/121	18	108.60	108.9	103.4	5.5	0	0	0
131/122	21	143.51	144	137.8	6.2	0	0	0
132/123	3	7.86	8.1	7.6	0.5	0	0	0
133/124	5	17.72	18	18	0	0	0	0
134/125	14	100.01	100	96.7	3.3	0	0	0
135/126	13	96.69	98.8	97.3	1.5	0	0	0
136/127	1	3.98	4	3.75	0.25	0	0	0
137/130	13	101.15	100	96	4	0	0	0
138/131	24	156.68	150.25	141.3	8.95	0	0	0
139/132	33	252.92	256	240.1	15.9	0	0	0
140/133	13	99.11	100	97.5	2.5	0	0	0
141/137	3	12.96	12	11.4	0.6	0	0	0
142/136	10	79.62	80	80	0	0	0	0
143/134	13	98.72	100	98	2	0	0	0
144/135	3	20.45	20	20	0	0	0	0
145/138	14	101.57	100.6	99.4	1.2	0	0	0

146/139	3	24.04	20	20	0	0	0	0
147/91	2	7.57	8	7.5	0.5	0	0	0
148/50	1	0.46	0.5	0.5	0	0	0	0
149/140	13	95.45	94.9	84.9	4	0	6	0
15/131	5	31.55	32	31	1	0	0	0
150/141	4	26.00	26	26	0	0	0	0
151/142	4	15.76	16	15	1	0	0	0
152/143	83	624.38	631.45	110.25	364.4	0	149.4	7.4
(No Khewat no.)	3	7.42	7.8	0	7.8	0	0	0
Grand Total	**1681**	**11527.33**	**11517.05**	**10596.25**	**748**	**2**	**163.4**	**7.4**

*One Kanal = 2023.428 Square meters

Table F7: Discrepancies highlighted in Khewat

Khewat No.	Total No. of Land Parcels (Field Book)	Total Summarize Area in Kanals (RHZ)	Total Area in Kanals (RHZ)	Total Nahri Area in Kanal (RHZ)	Total Gair Mumkin Area in Kanal (RHZ)	area difference	Remarks
33/32	14	100.6	100	96.65	3.95	0.6	Increase in Area w.r.t RHZ
39/38	12	84		81.5	2.5	0	Khasra No. 13 not have sub-parcel in RHZ but map have 2 sub-parcels 13/1,13/2
93/93	14	99.4	100	97.9	1.5	0.6	Khasra No. 63/27 not identified on map but increase in Area w.r.t RHZ
124/129	8	49.05	48.05	48.3	0.75	0.6	Increase in Area w.r.t RHZ
125/116	15	100		98.5	1.5	0	Khasra 40/9 have false area in RHZ
128/119	21	144	144.6	138	6	0.6	Decrease in area w.r.t RHZ
129/120	16	120.6	100	115.3	5.3	0.6	Increase in Area w.r.t RHZ
138/131	24	150.25	150.25	141.3	8.95	0	Decrease in Area w.r.t RHZ
145/138	14	100.6	100	99.4	1.2	0.6	Increase in Area w.r.t RHZ

*One Kanal = 2023.428 Square meters

Table F8: Summary of Khetuni

Khetuni No.	Total No. of Land Parcels (Field Book)	Total Area in Kanals (GIS)	Total Area in Kanals (RHZ)	Total Nahri Area in Kanal (RHZ)	Total Gair Mumkin Area in Kanal (RHZ)	Total Banjer Jadeed Area in Kanal (RHZ)	Total Banjer Qadeem Area in Kanal (RHZ)	Total Benaam Area in Kanal (RHZ)
0	3	7.42	7.8	0	7.8	0	0	0
1	5	21.12	20.8	18.8	0	0	2	0
2	25	201.85	200	199	1	0	0	0
3	25	199.59	197	193.35	3.65	0	0	0
4	19	143.49	143.4	139.4	4	0	0	0
5	6	46.33	46.8	45.4	1.4	0	0	0
6	1	8.22	8	8	0	0	0	0
7	3	21.99	22.2	18.55	3.65	0	0	0
8	91	651.40	660.65	654.4	6.25	0	0	0
9	10	79.91	80	79.5	0.5	0	0	0
10	4	32.13	32	32	0	0	0	0
11	4	31.87	32	32	0	0	0	0
12	6	18.12	17.5	0	17.5	0	0	0
13	38	247.73	245.9	245.65	0.25	0	0	0
14	1	7.31	7.4	7.4	0	0	0	0
15	1	4.85	5	3	2	0	0	0
16	2	2.61	2.7	0	2.7	0	0	0
17	17	102.56	101.9	101.9	0	0	0	0
18	3	23.35	23.4	23.4	0	0	0	0
19	1	7.59	7.4	7.4	0	0	0	0
20	4	31.88	32	32	0	0	0	0
21	5	32.48	32	32	0	0	0	0
22	6	37.04	36	34	2	0	0	0
23	7	53.65	54	53.75	0.25	0	0	0
24	1	8.12	8	4	4	0	0	0
25	4	27.80	26.4	26.15	0.25	0	0	0
26	3	23.17	23.4	23.4	0	0	0	0
27	1	7.19	7.4	7.4	0	0	0	0
28	1	7.23	8	8	0	0	0	0
29	3	4.84	5.1	0	5.1	0	0	0
30	7	51.75	51	44.5	6.5	0	0	0
31	14	99.41	98.2	97.2	1	0	0	0
32	1	1.70	1.8	0	1.8	0	0	0
33	13	99.79	102.45	96.45	6	0	0	0
34	5	37.18	39.4	38.15	1.25	0	0	0

35	2	15.38	15.4	15.4	0	0	0	0
36	6	43.40	43.4	43.4	0	0	0	0
38	1	8.06	8	7.5	0.5	0	0	0
39	1	7.41	7.4	5.65	1.75	0	0	0
40	1	8.07	8	7.5	0.5	0	0	0
41	2	15.98	16	15.75	0.25	0	0	0
42	1	7.53	7.4	5.4	2	0	0	0
43	2	15.77	16	15	1	0	0	0
44	1	4.06	4	4	0	0	0	0
45	4	31.95	31.4	30.15	1.25	0	0	0
46	1	1.83	1.8	0	1.8	0	0	0
47	13	99.14	98.2	93.95	4.25	0	0	0
48	1	2.26	1.8	0	1.8	0	0	0
49	14	99.10	100	94.8	5.2	0	0	0
51	1	8.01	8	7.75	0.25	0	0	0
52	1	8.12	8	6	2	0	0	0
53	6	47.44	46.8	44.8	2	0	0	0
54	6	43.01	43.4	42.9	0.5	0	0	0
55	1	2.27	1.8	0	1.8	0	0	0
56	2	6.08	10	10	0	0	0	0
57	1	2.08	2	2	0	0	0	0
58	1	7.75	8	8	0	0	0	0
59	1	3.90	4	4	0	0	0	0
60	5	39.21	40	39.75	0.25	0	0	0
61	2	7.90	8	8	0	0	0	0
62	1	7.84	8	7	1	0	0	0
63	2	15.81	16	16	0	0	0	0
64	6	16.24	16	16	0	0	0	0
65	13	99.62	99.75	97.75	2	0	0	0
66	1	7.99	8	8	0	0	0	0
67	1	8.14	8	8	0	0	0	0
68	5	34.76	37	34.5	2.5	0	0	0
69	2	15.77	16	15.5	0.5	0	0	0
70	1	8.18	8	8	0	0	0	0
71	10	75.43	74.8	72.3	2.5	0	0	0
72	1	1.33	1.2	0	1.2	0	0	0
73	13	100.58	100	96	4	0	0	0
74	6	42.57	42.8	42.8	0	0	0	0
75	2	15.81	16	16	0	0	0	0
76	2	15.43	16	15	1	0	0	0
77	2	15.81	16	16	0	0	0	0
78	1	7.89	8	8	0	0	0	0
80	2	7.93	8	8	0	0	0	0

81	1	7.19	8	8	0	0	0	0
82	4	31.89	32	32	0	0	0	0
83	3	19.76	20	20	0	0	0	0
84	1	8.19	8	8	0	0	0	0
85	2	14.96	16	16	0	0	0	0
86	2	15.76	16	16	0	0	0	0
87	13	99.12	100	97.5	2.5	0	0	0
88	3	20.27	20	20	0	0	0	0
89	11	80.42	80	77.75	2.25	0	0	0
90	2	15.39	8	8	0	0	0	0
91	2	14.98	15.15	15.15	0	0	0	0
92	4	22.76	23.55	23.55	0	0	0	0
93	1	3.55	3.9	3.9	0	0	0	0
94	2	7.49	8	6.2	1.8	0	0	0
95	5	22.71	22.95	22.95	0	0	0	0
96	4	18.15	18.4	18.4	0	0	0	0
97	1	0.85	0.75	0	0.75	0	0	0
98	1	3.71	4	4	0	0	0	0
99	6	48.98	48	46	2	0	0	0
100	3	23.66	24	23.25	0.75	0	0	0
101	3	23.67	23.4	23.4	0	0	0	0
102	1	0.86	1.2	0	1.2	0	0	0
103	12	93.97	94.2	89.3	4.9	0	0	0
104	5	39.14	39.4	38.9	0.5	0	0	0
105	2	2.74	2.4	0	2.4	0	0	0
106	7	39.28	40	40	0	0	0	0
107	13	92.72	91.4	89.15	2.25	0	0	0
108	13	100.30	98.8	96.8	2	0	0	0
109	1	0.99	1.2	0	1.2	0	0	0
110	13	98.58	98.2	96.2	2	0	0	0
111	1	1.52	1.8	0	1.8	0	0	0
112	12	84.37	84	81.5	2.5	0	0	0
113	9	59.70	60	56	4	0	0	0
114	2	14.39	14.8	13.8	1	0	0	0
115	1	7.24	7.4	7.4	0	0	0	0
116	2	15.63	16	16	0	0	0	0
117	1	1.63	1.8	0	1.8	0	0	0
118	13	99.99	100	100	0	0	0	0
119	13	101.51	100	99	1	0	0	0
120	15	102.17	100	98.2	1.8	0	0	0
121	11	82.80	84	81.5	2.5	0	0	0
122	2	16.07	16	16	0	0	0	0
123	6	47.72	48	48	0	0	0	0

124	1	8.21	8	8	0	0	0	0
125	2	16.11	16	16	0	0	0	0
126	1	7.84	8	8	0	0	0	0
127	3	19.81	20	20	0	0	0	0
128	10	75.85	75	72.5	2.5	0	0	0
129	3	10.33	10	10	0	0	0	0
130	2	3.02	3	2.5	0.5	0	0	0
131	13	92.99	92	79	5	2	6	0
132	1	6.17	6.4	5.9	0.5	0	0	0
133	4	22.88	23.1	22.6	0.5	0	0	0
134	3	24.26	24	23	1	0	0	0
135	2	14.81	14.8	14.8	0	0	0	0
136	2	16.14	16	16	0	0	0	0
137	2	15.91	16	14.5	1.5	0	0	0
138	2	11.65	11.4	10.9	0.5	0	0	0
139	1	8.45	8	8	0	0	0	0
140	1	8.16	8	7.5	0.5	0	0	0
142	1	8.21	8	7.5	0.5	0	0	0
143	3	19.75	19.4	19.4	0	0	0	0
144	1	2.35	0.6	0	0.6	0	0	0
145	4	20.55	20	17.5	2.5	0	0	0
146	5	20.68	20	20	0	0	0	0
147	5	20.55	20	19.5	0.5	0	0	0
148	13	98.72	98.8	91.8	7	0	0	0
149	1	1.57	1.2	0	1.2	0	0	0
150	2	14.58	14.8	14.8	0	0	0	0
151	3	20.14	19.4	19.4	0	0	0	0
152	1	1.32	0.6	0	0.6	0	0	0
153	4	12.87	12	12	0	0	0	0
154	3	15.53	16	16	0	0	0	0
155	3	23.84	24	23.75	0.25	0	0	0
156	7	50.95	50.8	50.55	0.25	0	0	0
157	1	1.24	1.2	0	1.2	0	0	0
158	13	97.97	98.2	94.2	4	0	0	0
160	1	3.89	4	4	0	0	0	0
161	1	8.19	8	8	0	0	0	0
162	3	11.65	11.65	11.65	0	0	0	0
163	1	7.53	8	8	0	0	0	0
164	3	11.56	11.45	10.95	0.5	0	0	0
165	2	11.30	11.4	11.4	0	0	0	0
166	1	7.50	7.4	7	0.4	0	0	0
167	1	7.77	8	8	0	0	0	0
168	1	8.07	8	7.5	0.5	0	0	0

169	2	11.92	12	11.75	0.25	0	0	0
170	1	7.90	8	8	0	0	0	0
171	1	8.12	8	8	0	0	0	0
172	2	2.56	2.15	0	2.15	0	0	0
173	16	96.32	96.3	95.5	0.8	0	0	0
174	1	3.94	4	4	0	0	0	0
175	8	58.10	58.25	56.25	2	0	0	0
176	1	1.77	1.75	1.75	0	0	0	0
177	1	3.94	4	4	0	0	0	0
178	2	15.69	16	13.75	2.25	0	0	0
179	2	15.98	16	16	0	0	0	0
180	13	95.41	95	90.5	4.5	0	0	0
181	1	2.77	5.1	0	5.1	0	0	0
182	2	17.58	16	15	1	0	0	0
183	1	8.43	8	7	1	0	0	0
184	1	7.38	8	8	0	0	0	0
185	1	7.77	8	7	1	0	0	0
186	6	43.61	42.8	41.8	1	0	0	0
187	1	7.92	8	7.5	0.5	0	0	0
188	1	8.05	7.4	3.9	3.5	0	0	0
189	1	3.63	1.8	0	1.8	0	0	0
190	2	15.95	16	16	0	0	0	0
191	1	8.12	8	8	0	0	0	0
192	2	16.10	16	16	0	0	0	0
193	2	2.09	2.2	2.2	0	0	0	0
194	1	3.85	3.8	3.8	0	0	0	0
195	1	4.03	4	4	0	0	0	0
196	5	25.74	26	22.2	3.8	0	0	0
197	1	7.37	7.4	6.4	1	0	0	0
198	1	7.71	8	8	0	0	0	0
199	1	8.24	8	8	0	0	0	0
200	1	4.19	4	4	0	0	0	0
201	3	16.12	16	15.75	0.25	0	0	0
202	2	15.73	16	16	0	0	0	0
203	2	15.39	15.4	15.4	0	0	0	0
204	3	23.11	23.4	23.4	0	0	0	0
205	1	2.01	1.8	0	1.8	0	0	0
206	3	20.36	20	18	2	0	0	0
207	10	80.06	78.8	78.8	0	0	0	0
208	1	3.49	1.2	0	1.2	0	0	0
209	1	8.41	8	8	0	0	0	0
210	1	7.95	8	8	0	0	0	0
211	1	7.95	8	8	0	0	0	0

212	1	8.24	8	6	2	0	0	0
213	1	7.71	8	8	0	0	0	0
214	1	7.70	8	8	0	0	0	0
215	1	7.57	7.4	7.4	0	0	0	0
216	1	7.31	7.4	7.4	0	0	0	0
217	1	7.68	8	8	0	0	0	0
218	1	8.17	8	8	0	0	0	0
219	1	8.41	8	8	0	0	0	0
220	2	12.21	12	11.5	0.5	0	0	0
221	1	1.35	1.2	0	1.2	0	0	0
222	9	65.16	64	61	3	0	0	0
223	1	7.74	8	7.5	0.5	0	0	0
224	2	11.67	12	11.5	0.5	0	0	0
225	1	7.76	8	8	0	0	0	0
226	4	31.65	31.4	30.4	1	0	0	0
227	1	0.72	0.6	0	0.6	0	0	0
228	6	31.09	31.4	30.4	1	0	0	0
229	1	0.65	0.6	0	0.6	0	0	0
230	4	20.35	20	19.55	0.45	0	0	0
231	1	8.19	8	7.5	0.5	0	0	0
232	6	37.87	38.2	36.25	1.95	0	0	0
233	1	7.95	8	8	0	0	0	0
234	2	12.04	12	11.5	0.5	0	0	0
235	1	8.14	8	8	0	0	0	0
236	1	8.05	8	8	0	0	0	0
237	2	16.38	16	16	0	0	0	0
238	1	7.91	8	8	0	0	0	0
239	1	1.78	1.8	0	1.8	0	0	0
240	4	24.18	24	24	0	0	0	0
241	1	7.93	8	8	0	0	0	0
242	1	7.83	8	8	0	0	0	0
243	2	15.96	16	16	0	0	0	0
244	7	44.75	44	43.5	0.5	0	0	0
245	13	97.76	95	92.5	2.5	0	0	0
246	1	2.58	5.1	0	5.1	0	0	0
247	13	97.15	98.2	94.7	3.5	0	0	0
248	1	2.08	1.8	0	1.8	0	0	0
249	4	22.58	22.8	21.05	1.75	0	0	0
250	1	8.13	8	8	0	0	0	0
251	1	8.09	8	8	0	0	0	0
252	5	35.63	35.4	34.4	1	0	0	0
253	5	38.69	40	40	0	0	0	0
254	1	2.38	0.6	0	0.6	0	0	0

255	5	26.84	27.35	27.35	0	0	0	0
256	1	0.63	1.2	0	1.2	0	0	0
257	1	4.00	4	4	0	0	0	0
258	2	15.42	16	15	1	0	0	0
259	1	8.15	8	8	0	0	0	0
260	3	19.84	20	20	0	0	0	0
261	1	7.98	8	7.5	0.5	0	0	0
262	1	8.24	8	8	0	0	0	0
263	1	7.94	8	8	0	0	0	0
264	1	7.62	7.4	7.4	0	0	0	0
265	2	15.12	16	16	0	0	0	0
266	2	7.97	8	8	0	0	0	0
268	2	16.37	16	16	0	0	0	0
269	1	7.93	8	8	0	0	0	0
270	1	3.86	4	4	0	0	0	0
271	1	3.98	4	4	0	0	0	0
272	6	40.03	40	39.5	0.5	0	0	0
273	2	15.89	16	16	0	0	0	0
274	13	98.39	98.8	95.3	3.5	0	0	0
275	1	1.14	1.2	0	1.2	0	0	0
276	5	33.60	36	36	0	0	0	0
277	2	15.36	15.4	15.4	0	0	0	0
278	1	7.91	8	8	0	0	0	0
279	1	7.45	7.4	7.4	0	0	0	0
280	5	36.91	36	36	0	0	0	0
281	4	32.14	32	32	0	0	0	0
282	1	2.94	1.2	0	1.2	0	0	0
283	3	10.91	10.65	10.65	0	0	0	0
284	3	11.08	10.75	10.75	0	0	0	0
285	2	10.81	10.5	10.5	0	0	0	0
286	3	10.50	10.4	9.4	1	0	0	0
287	3	10.54	10.7	10.7	0	0	0	0
288	2	10.58	11	11	0	0	0	0
289	6	38.06	38	37.5	0.5	0	0	0
290	1	0.92	1	0	1	0	0	0
291	6	36.21	38	38	0	0	0	0
292	3	21.79	23	22	1	0	0	0
293	1	8.18	8	8	0	0	0	0

Khetuni No.	Total No. of Land Parcels (Field Book)	Total Area in Kanals (GIS)	Total Area in Kanals (RHZ)	Total Nahri Area in Kanal (RHZ)	Total Gair Mumkin Area in Kanal (RHZ)	Total Banjer Jadeed Area in Kanal (RHZ)	Total Banjer Qadeem Area in Kanal (RHZ)	Total Benaam Area in Kanal (RHZ)
294	7	54.24	54.8	54.55	0.25	0	0	0
295	1	7.50	7.4	7.4	0	0	0	0
296	4	28.16	28	26	2	0	0	0
297	1	1.76	1.8	0	1.8	0	0	0
298	1	8.34	8	8	0	0	0	0
299	1	8.26	8	8	0	0	0	0
300	11	83.72	82.8	82.8	0	0	0	0
301	1	1.21	1.2	0	1.2	0	0	0
302	9	66.58	66.8	65.8	1	0	0	0
303	4	30.92	31.4	31.4	0	0	0	0
304	9	45.74	49.75	48.85	0.9	0	0	0
305	2	16.31	16	15	1	0	0	0
306	1	8.20	8	8	0	0	0	0
307	1	3.96	4	4	0	0	0	0
308	1	3.73	4	4	0	0	0	0
309	1	3.96	4	4	0	0	0	0
310	2	4.13	4	0	4	0	0	0
311	1	7.54	8	8	0	0	0	0
312	1	7.89	8	8	0	0	0	0
313	1	7.99	8	7	1	0	0	0
314	1	8.36	8	8	0	0	0	0
315	1	7.83	8	7.75	0.25	0	0	0
316	1	8.10	8	8	0	0	0	0
317	1	7.86	8	8	0	0	0	0
318	1	7.66	8	8	0	0	0	0
319	2	16.33	16	15	1	0	0	0
320	2	16.04	16	16	0	0	0	0
321	2	7.91	8	8	0	0	0	0
322	13	98.35	98.2	95.2	3	0	0	0
323	1	1.96	1.8	0	1.8	0	0	0
324	1	3.73	4	4	0	0	0	0
325	2	16.35	16	16	0	0	0	0
326	1	4.02	4	3.75	0.25	0	0	0
327	5	39.78	40	39.5	0.5	0	0	0
328	5	40.74	40	39	1	0	0	0
329	1	7.39	7.4	7.4	0	0	0	0
330	1	0.73	0.5	0	0.5	0	0	0

Khetuni No.	Total No. of Land Parcels (Field Book)	Total Area in Kanals (GIS)	Total Area in Kanals (RHZ)	Total Nahri Area in Kanal (RHZ)	Total Gair Mumkin Area in Kanal (RHZ)	Total Banjer Jadeed Area in Kanal (RHZ)	Total Banjer Qadeem Area in Kanal (RHZ)	Total Benaam Area in Kanal (RHZ)
331	1	7.95	8	7.5	0.5	0	0	0
332	1	7.88	8	8	0	0	0	0
333	1	8.03	8	8	0	0	0	0
334	2	14.89	15.25	15	0.25	0	0	0
335	1	3.95	4	4	0	0	0	0
336	2	5.69	5.8	5.8	0	0	0	0
337	3	23.97	24	23.5	0.5	0	0	0
338	2	15.88	16	15.5	0.5	0	0	0
339	9	53.04	52	51.5	0.5	0	0	0
340	1	7.99	8	8	0	0	0	0
341	3	16.35	16	15.5	0.5	0	0	0
342	11	77.73	76	68	8	0	0	0
343	4	31.32	32	32	0	0	0	0
344	1	7.93	8	8	0	0	0	0
345	4	26.76	26.2	26.2	0	0	0	0
346	4	32.79	32	30	2	0	0	0
347	1	3.68	1.8	0	1.8	0	0	0
348	8	62.71	62.8	60.05	2.75	0	0	0
349	1	7.48	7.4	7.4	0	0	0	0
350	3	23.36	24	23.75	0.25	0	0	0
351	2	15.95	16	16	0	0	0	0
352	2	16.77	15.4	15.4	0	0	0	0
353	2	15.34	15.4	15.4	0	0	0	0
354	3	3.61	3	0	3	0	0	0
355	5	39.52	39.4	36.4	3	0	0	0
356	4	31.91	32	32	0	0	0	0
357	6	48.03	47.4	46.9	0.5	0	0	0
358	1	2.00	1.8	0	1.8	0	0	0
359	1	4.54	3.35	2.35	1	0	0	0
360	11	68.49	68.15	67.15	1	0	0	0
361	5	28.00	30	26.5	3.5	0	0	0
362	1	7.57	7.4	7.4	0	0	0	0
363	4	32.02	32	31.75	0.25	0	0	0
364	1	7.71	8	8	0	0	0	0
365	1	7.80	8	8	0	0	0	0
366	1	7.96	8	8	0	0	0	0
367	1	7.64	8	7.75	0.25	0	0	0

Khetuni No.	Total No. of Land Parcels (Field Book)	Total Area in Kanals (GIS)	Total Area in Kanals (RHZ)	Total Nahri Area in Kanal (RHZ)	Total Gair Mumkin Area in Kanal (RHZ)	Total Banjer Jadeed Area in Kanal (RHZ)	Total Banjer Qadeem Area in Kanal (RHZ)	Total Benaam Area in Kanal (RHZ)
368	5	37.31	37.2	36.7	0.5	0	0	0
369	2	16.08	16	14	2	0	0	0
370	3	18.10	18.2	16.2	2	0	0	0
371	1	7.47	7.4	7.4	0	0	0	0
372	2	1.41	1.2	0	1.2	0	0	0
373	2	7.53	7.6	7.6	0	0	0	0
374	1	0.32	0.5	0	0.5	0	0	0
375	5	17.72	18	18	0	0	0	0
376	13	97.85	98.2	96.7	1.5	0	0	0
377	1	2.15	1.8	0	1.8	0	0	0
378	13	96.69	98.8	97.3	1.5	0	0	0
379	1	3.98	4	3.75	0.25	0	0	0
380	13	101.15	100	96	4	0	0	0
381	8	57.74	52	47.65	4.35	0	0	0
382	2	7.88	8	7.5	0.5	0	0	0
383	8	50.52	50.25	46.75	3.5	0	0	0
383.1	1	7.79	8	8	0	0	0	0
384	1	7.95	8	8	0	0	0	0
385	3	24.11	23.4	23.4	0	0	0	0
386	1	0.68	0.6	0	0.6	0	0	0
387	1	7.44	7.4	4.4	3	0	0	0
388	1	8.99	8	8	0	0	0	0
389	1	7.56	8	4	4	0	0	0
390	1	7.22	7.4	7.4	0	0	0	0
391	18	141.24	144	138	6	0	0	0
392	10	77.51	78.8	78.3	0.5	0	0	0
393	1	2.96	2.4	0	2.4	0	0	0
394	2	15.52	16	16	0	0	0	0
395	2	15.06	16	16	0	0	0	0
396	1	7.81	8	7	1	0	0	0
397	1	8.16	8	8	0	0	0	0
398	1	8.11	8	8	0	0	0	0
399	1	8.20	8	6.5	1.5	0	0	0
400	1	7.98	8	8	0	0	0	0
401	2	16.01	16	16	0	0	0	0
402	1	8.11	8	8	0	0	0	0
403	1	4.15	4	4	0	0	0	0

Khetuni No.	Total No. of Land Parcels (Field Book)	Total Area in Kanals (GIS)	Total Area in Kanals (RHZ)	Total Nahri Area in Kanal (RHZ)	Total Gair Mumkin Area in Kanal (RHZ)	Total Banjer Jadeed Area in Kanal (RHZ)	Total Banjer Qadeem Area in Kanal (RHZ)	Total Benaam Area in Kanal (RHZ)
404	1	4.03	4	4	0	0	0	0
405	1	7.52	7.4	7.4	0	0	0	0
406	1	1.41	0.6	0	0.6	0	0	0
407	10	79.62	80	80	0	0	0	0
408	13	98.72	100	98	2	0	0	0
409	3	20.45	20	20	0	0	0	0
410	1	7.31	8	8	0	0	0	0
411	1	7.49	7.4	7.4	0	0	0	0
412	1	8.23	8	8	0	0	0	0
413	1	7.84	8	8	0	0	0	0
414	2	16.08	16	16	0	0	0	0
415	1	8.01	8	8	0	0	0	0
416	1	7.87	8	8	0	0	0	0
417	2	11.47	12	12	0	0	0	0
418	2	16.63	16	16	0	0	0	0
419	1	7.96	8	8	0	0	0	0
420	1	2.68	1.2	0	1.2	0	0	0
421	3	24.04	20	20	0	0	0	0
422	2	7.57	8	7.5	0.5	0	0	0
423	1	0.46	0.5	0.5	0	0	0	0
424	1	8.08	8	0	2	0	6	0
425	12	87.37	86.9	84.9	2	0	0	0
426	4	26.00	26	26	0	0	0	0
427	4	15.76	16	15	1	0	0	0
428	3	12.62	13.7	13.7	0	0	0	0
429	1	1.36	0.6	0	0.6	0	0	0
430	8	56.58	57.15	55.15	2	0	0	0
431	2	11.11	11.4	0	0	0	4	7.4
432	1	7.33	7.4	7.4	0	0	0	0
433	6	32.03	32.6	0	1	0	31.6	0
434	1	8.09	8	0	2	0	6	0
435	1	3.91	4	0	4	0	0	0
436	1	8.04	8	0	2	0	6	0
437	1	4.11	4	0	1	0	3	0
438	1	7.50	8	2	6	0	0	0
439	1	4.06	4	0	4	0	0	0
440	1	7.64	8	2	1	0	5	0

Khetuni No.	Total No. of Land Parcels (Field Book)	Total Area in Kanals (GIS)	Total Area in Kanals (RHZ)	Total Nahri Area in Kanal (RHZ)	Total Gair Mumkin Area in Kanal (RHZ)	Total Banjer Jadeed Area in Kanal (RHZ)	Total Banjer Qadeem Area in Kanal (RHZ)	Total Benaam Area in Kanal (RHZ)
441	1	3.91	4	0	4	0	0	0
442	1	7.81	8	0	2	0	6	0
443	1	7.64	8	0	1	0	7	0
444	1	7.63	8	0	5	0	3	0
445	2	7.08	7.2	0	7.2	0	0	0
446	1	1.93	2	0	2	0	0	0
447	1	1.01	1	0	1	0	0	0
448	1	1.98	2	0	2	0	0	0
449	1	4.22	4	0	1.5	0	2.5	0
450	1	8.10	8	0	2	0	6	0
451	1	3.95	4	0	3.5	0	0.5	0
452	1	7.71	8	2	6	0	0	0
453	1	7.83	8	2	6	0	0	0
454	1	7.89	8	0	0	0	8	0
455	1	3.95	4	0	2	0	2	0
456	1	7.87	8	0	0	0	8	0
457	1	7.95	8	2	1	0	5	0
458	1	7.42	7.4	0	5	0	2.4	0
459	2	11.45	11.4	0	4.5	0	6.9	0
460	1	4.19	4	0	1	0	3	0
461	1	7.22	7.4	0	6.4	0	1	0
462	1	7.80	8	4	0	0	4	0
463	1	3.99	4	0	2	0	2	0
464	1	7.82	8	0	0	0	8	0
465	1	3.92	4	4	0	0	0	0
466	3	7.59	7.5	0	0	0	7.5	0
467	1	4.22	4	0	1	0	3	0
468	3	7.85	5.6	0	5.6	0	0	0
469	1	8.15	8	0	8	0	0	0
470	1	28.36	28	8	20	0	0	0
471	6	39.63	40	0	32	0	8	0
472	1	8.03	8	8	0	0	0	0
473	1	99.89	100	0	100	0	0	0
474	3	15.71	16	0	16	0	0	0
475	1	78.34	81	0	81	0	0	0
476	5	6.49	8.35	0	8.35	0	0	0
477	2	3.48	3.75	0	3.75	0	0	0

Grand Total	**1681**	**11527.33**	**11517.05**	**10596.25**	**748**	**2**	**163.4**	**7.4**

*One Kanal = 2023.428 Square meters

Table F9: Summary of Gair Mumkin Land Type

Land Type	Khasra Count	Total Gair Mumkin Area in Kanal (RHZ)	Total Area in Kanals (RHZ)	Total Nahri Area in Kanal (RHZ)	Total Banjer Jadeed Area in Kanal (RHZ)	Total Banjer Qadeem Area in Kanal (RHZ)	Total Benaam Area in Kanal (RHZ)
Abadi	149	370.25	1134	690.95	0	72.8	0
Abadi & Khal	3	7.25	23.4	16.15	0	0	0
Abadi & Rasta	7	16	47.4	28.9	0	2.5	0
Abadi, Rasta, Talab	1	6.4	7.4	0	0	1	0
Abadi, Road	1	1	8	7	0	0	0
Abadi, Tibba	1	2	8	6	0	0	0
Abadi,Graveyard	1	8	8	0	0	0	0
Boor	6	1.85	40.6	38.75	0	0	0
Ghad Machin	1	0.25	4	3.75	0	0	0
Girl Primary School	1	1	4	0	0	3	0
Graveyard	6	52	60	8	0	0	0
Khal	107	125.5	369.1	243.6	0	0	0
khal, rasta	2	0.75	12	11.25	0	0	0
Lajbah	1	81	81	0	0	0	0
Masjid	2	0.75	15.4	14.65	0	0	0
Nahri Land	1282	18.2	8885.5	8773.8	2	84.1	7.4
Rasta	79	32.1	580.95	548.85	0	0	0
Road	21	13.15	156.8	143.65	0	0	0
Tibba	10	10.55	71.5	60.95	0	0	0
Grand Total	**1681**	**748**	**11517.05**	**10596.25**	**2**	**163.4**	**7.4**

*One Kanal = 2023.428 Square meters

Table F10: Summary Khasra Count based on Land

RHZ Land Type	Nahri Land	Banjer Qadeem Land	Banjer Jadeed Land	Gair Mumkin Land	Benaam Land	**Grand Total**
Benaam					1	**1**
Banjer Qadeem		14				**14**
Banjer Qadeem & Gair Mumkin		19		19		**19**
Banjer Qadeem & Banjer Jadeed		1	1			**1**
Gair Mumkin				101		**101**
Nehtri Land	1258					**1258**
Nehtri Land & Gair Mumkin	284			284		**284**
Nehtri Land & Banjer Qadeem	1	1				**1**
Nehtri Land, Banjer Qadeem & Gair Mumkin	2	2		2		**2**
Grand Total	**1545**	**37**	**1**	**406**	**1**	**1681**

Table F11: Summary based of Ownership Land Type

Land Ownership Type	Khasra Count	Total Area in Kanals (RHZ)	Total Nahri Area in Kanal (RHZ)	Total Gair Mumkin Area in Kanal (RHZ)	Total Banjer Jadeed Area in Kanal (RHZ)	Total Banjer Qadeem Area in Kanal (RHZ)	Total Benaam Area in Kanal (RHZ)
Owner	1586	10897.9	10494.00	387.90	2	14	0
Provincial Government	65	354.35	94.25	111.30	0	141.4	7.4
No Information	27	257	8.00	241.00	0	8	0
No record found in RHZ	3	7.8	0.00	7.80	0	0	0
Grand Total	**1681**	**11517.05**	**10596.25**	**748.00**	**2**	**163.4**	**7.4**

*One Kanal = 2023.428 Square meters

Table F12: Summary based on Cultivation Possession Land Type

Cultivation Possession Type	Khasra Count	Total Area in Kanals (RHZ)	Total Nahri Area in Kanal (RHZ)	Total Gair Mumkin Area in Kanal (RHZ)	Total Banjer Jadeed Area in Kanal (RHZ)	Total Banjer Qadeem Area in Kanal (RHZ)	Total Benaam Area in Kanal (RHZ)
Self	441	2922.2	2825.85	90.35	0	6	0
Not-Self	1122	7820.95	7531.65	287.3	0	2	0
Both	23	154.75	136.5	10.25	2	6	0
Cooperative Societies	15	90.25	76.25	2.6	0	4	7.4
Scheme	3	16	0	16	0	0	0
Majwaza Chiraga	47	248.1	18	92.7	0	137.4	0
Maqboza Abpashi	17	124.25	0	124.25	0	0	0
Maqboza Irrigation	1	81	0	81	0	0	0
Maqboza Ahle Alhinud	1	8	8	0	0	0	0
Maqboza Ahle Islam	6	40	0	32	0	8	0
Maqboza sharih AAM(Road)	2	3.75	0	3.75	0	0	0
Not record found in RHZ	3	7.8	0	7.8	0	0	0
Grand Total	**1681**	**11517.05**	**10596.25**	**748.0**	**2**	**163.4**	**7.4**

*One Kanal = 2023.428 Square meters

Table F13: Summary of Landowners borrowed Loan from ZTBL

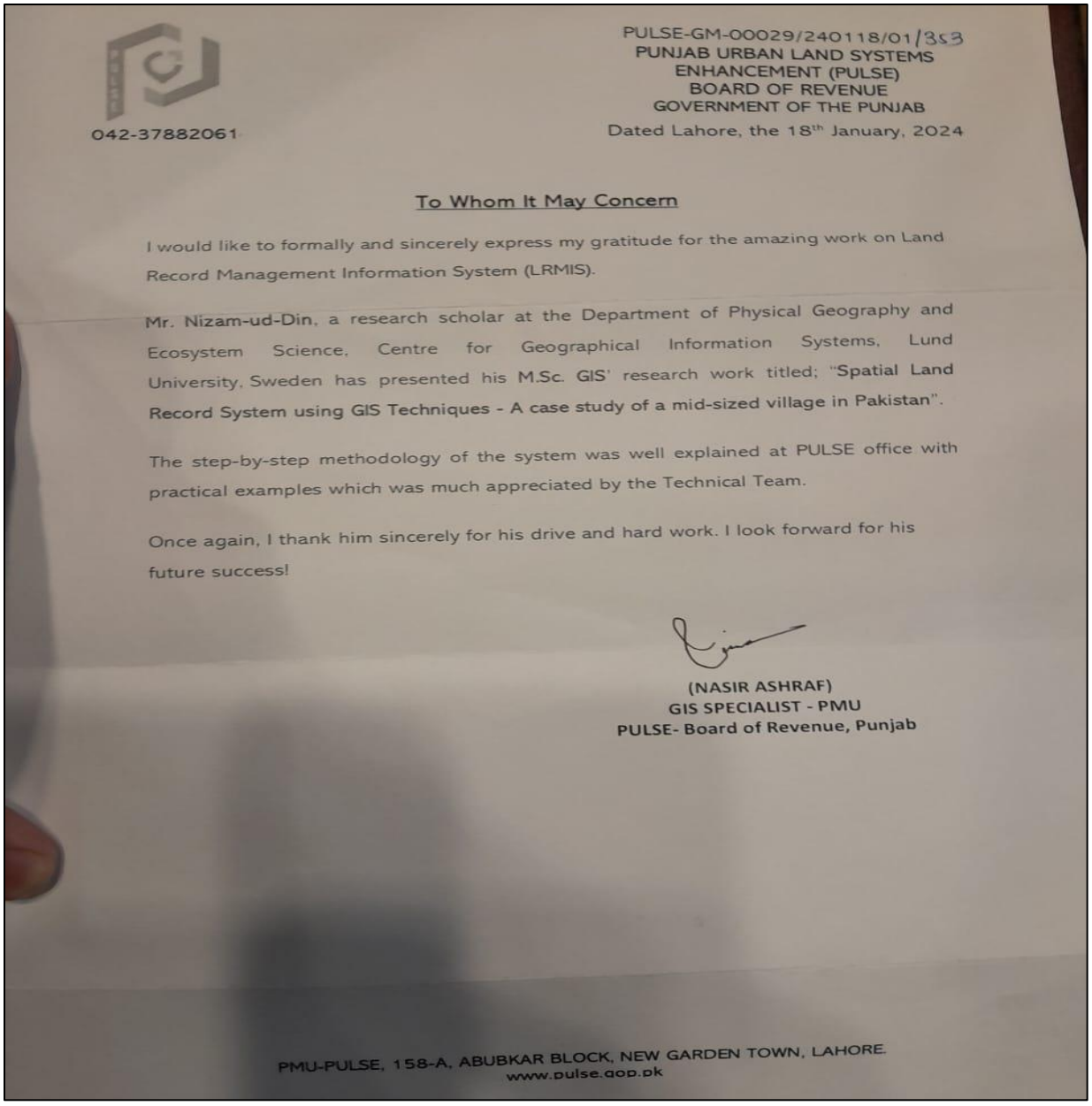
ZTBL Certificate No.	Borrower Name	Khewat No. (Bank Certificate)	Khewat No. (RHZ)	Khetuni	Total Raqba (K-M)*	Hissa Malkiat (K-M)*	Hissa	Loan
347	M Bilal	42/115-114	77/76		100-0	12-0	240/2000	16640
545660	M Essa	73	74/73		26-0	26-0		97920
375	Sattar	68/192-193	58/57		100-0	100-0		139840
168	Malik M	68	46/46		67-0	67-0		469000
545868	M Rafique	46		119	21-18	21-18	438/1500	98000
245878	M Saleem	44	44/44	112,113	29-4	29-4		192000
545856	M Aslam	117	126/117	290 to 289	92-0	23-10	470/1840	144000

*K means kanal and M means marla, and one Kanal = 2023.428 Square meters

Appendix I: Acknowledgment from PULSE, department of Board of Revenue

I have presented my research work to the PULSE department, and officials of PULSE has appreciated research work methodology. PULSE is digitizing cadastral data of whole Punjab as per proposed methodology.

The acknowledgement letter from PULSE is attached.



042-37882061

PULSE-GM-00029/240118/01/353
PUNJAB URBAN LAND SYSTEMS
ENHANCEMENT (PULSE)
BOARD OF REVENUE
GOVERNMENT OF THE PUNJAB
Dated Lahore, the 18th January, 2024

To Whom It May Concern

I would like to formally and sincerely express my gratitude for the amazing work on Land Record Management Information System (LRMIS).

Mr. Nizam-ud-Din, a research scholar at the Department of Physical Geography and Ecosystem Science, Centre for Geographical Information Systems, Lund University, Sweden has presented his M.Sc. GIS' research work titled; "**Spatial Land Record System using GIS Techniques - A case study of a mid-sized village in Pakistan**".

The step-by-step methodology of the system was well explained at PULSE office with practical examples which was much appreciated by the Technical Team.

Once again, I thank him sincerely for his drive and hard work. I look forward for his future success!

(NASIR ASHRAF)
GIS SPECIALIST - PMU
PULSE- Board of Revenue, Punjab

PMU-PULSE, 158-A, ABUBKAR BLOCK, NEW GARDEN TOWN, LAHORE.
www.pulse.gop.pk

Figure A: Acknowledgement Letter from PULSE

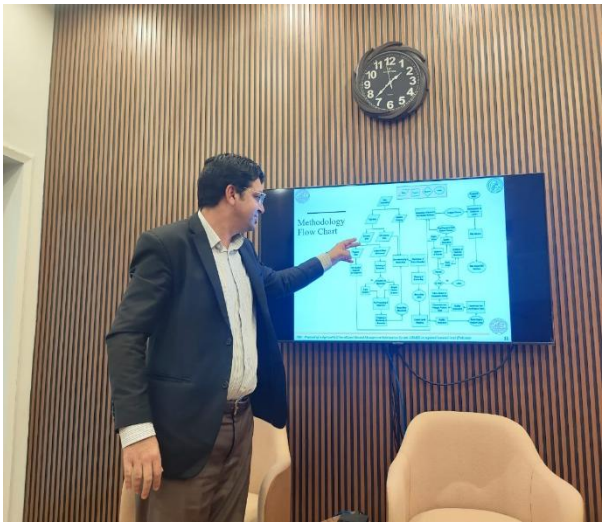


Figure B: Presentation to PULSE officials

Department of Physical Geography and Ecosystem Science

Master Thesis in Geographical Information Science

1. *Anthony Lawther:* The application of GIS-based binary logistic regression for slope failure susceptibility mapping in the Western Grampian Mountains, Scotland (2008).
2. *Rickard Hansen:* Daily mobility in Grenoble Metropolitan Region, France. Applied GIS methods in time geographical research (2008).
3. *Emil Bayramov:* Environmental monitoring of bio-restoration activities using GIS and Remote Sensing (2009).
4. *Rafael Villarreal Pacheco:* Applications of Geographic Information Systems as an analytical and visualization tool for mass real estate valuation: a case study of Fontibon District, Bogota, Columbia (2009).
5. *Siri Oestreich Waage:* a case study of route solving for oversized transport: The use of GIS functionalities in transport of transformers, as part of maintaining a reliable power infrastructure (2010).
6. *Edgar Pimiento:* Shallow landslide susceptibility – Modelling and validation (2010).
7. *Martina Schäfer:* Near real-time mapping of floodwater mosquito breeding sites using aerial photographs (2010).
8. *August Pieter van Waarden-Nagel:* Land use evaluation to assess the outcome of the programme of rehabilitation measures for the river Rhine in the Netherlands (2010).
9. *Samira Muhammad:* Development and implementation of air quality data mart for Ontario, Canada: A case study of air quality in Ontario using OLAP tool. (2010).
10. *Fredros Oketch Okumu*: Using remotely sensed data to explore spatial and temporal relationships between photosynthetic productivity of vegetation and malaria transmission intensities in selected parts of Africa (2011).
11. *Svajunas Plunge:* Advanced decision support methods for solving diffuse water pollution problems (2011).
12. *Jonathan Higgins:* Monitoring urban growth in greater Lagos: A case study using GIS to monitor the urban growth of Lagos 1990 - 2008 and produce future growth prospects for the city (2011).
13. *Mårten Karlberg:* Mobile Map Client API: Design and Implementation for Android (2011).
14. *Jeanette McBride:* Mapping Chicago area urban tree canopy using color infrared imagery (2011).

15. *Andrew Farina:* Exploring the relationship between land surface temperature and vegetation abundance for urban heat island mitigation in Seville, Spain (2011).
16. *David Kanyari*: Nairobi City Journey Planner: An online and a Mobile Application (2011).
17. *Laura V. Drews:* Multi-criteria GIS analysis for siting of small wind power plants - A case study from Berlin (2012).
18. *Qaisar Nadeem:* Best living neighborhood in the city - A GIS based multi criteria evaluation of ArRiyadh City (2012).
19. *Ahmed Mohamed El Saeid Mustafa:* Development of a photo voltaic building rooftop integration analysis tool for GIS for Dokki District, Cairo, Egypt (2012).
20. *Daniel Patrick Taylor*: Eastern Oyster Aquaculture: Estuarine Remediation via Site Suitability and Spatially Explicit Carrying Capacity Modeling in Virginia's Chesapeake Bay (2013).
21. *Angeleta Oveta Wilson:* A Participatory GIS approach to *unearthing* Manchester's Cultural Heritage '*gold mine'* (2013).
22. *Ola Svensson:* Visibility and Tholos Tombs in the Messenian Landscape: A Comparative Case Study of the Pylian Hinterlands and the Soulima Valley (2013).
23. *Monika Ogden:* Land use impact on water quality in two river systems in South Africa (2013).
24. *Stefan Rova:* A GIS based approach assessing phosphorus load impact on Lake Flaten in Salem, Sweden (2013).
25. *Yann Buhot:* Analysis of the history of landscape changes over a period of 200 years. How can we predict past landscape pattern scenario and the impact on habitat diversity? (2013).
26. *Christina Fotiou:* Evaluating habitat suitability and spectral heterogeneity models to predict weed species presence (2014).
27. *Inese Linuza:* Accuracy Assessment in Glacier Change Analysis (2014).
28. *Agnieszka Griffin:* Domestic energy consumption and social living standards: a GIS analysis within the Greater London Authority area (2014).
29. *Brynja Guðmundsdóttir:* Detection of potential arable land with remote sensing and GIS - A Case Study for Kjósarhreppur (2014).
30. *Oleksandr Nekrasov:* Processing of MODIS Vegetation Indices for analysis of agricultural droughts in the southern Ukraine between the years 2000-2012 (2014).
31. *Sarah Tressel:* Recommendations for a polar Earth science portal in the context of Arctic Spatial Data Infrastructure (2014).
32. *Caroline Gevaert:* Combining Hyperspectral UAV and Multispectral Formosat-2 Imagery for Precision Agriculture Applications (2014).

33. *Salem Jamal-Uddeen:* Using GeoTools to implement the multi-criteria evaluation analysis - weighted linear combination model (2014).
34. *Samanah Seyedi-Shandiz:* Schematic representation of geographical railway network at the Swedish Transport Administration (2014).
35. *Kazi Masel Ullah:* Urban Land-use planning using Geographical Information System and analytical hierarchy process: case study Dhaka City (2014).
36. *Alexia Chang-Wailing Spitteler:* Development of a web application based on MCDA and GIS for the decision support of river and floodplain rehabilitation projects (2014).
37. *Alessandro De Martino:* Geographic accessibility analysis and evaluation of potential changes to the public transportation system in the City of Milan (2014).
38. *Alireza Mollasalehi:* GIS Based Modelling for Fuel Reduction Using Controlled Burn in Australia. Case Study: Logan City, QLD (2015).
39. *Negin A. Sanati:* Chronic Kidney Disease Mortality in Costa Rica; Geographical Distribution, Spatial Analysis and Non-traditional Risk Factors (2015).
40. *Karen McIntyre:* Benthic mapping of the Bluefields Bay fish sanctuary, Jamaica (2015).
41. *Kees van Duijvendijk:* Feasibility of a low-cost weather sensor network for agricultural purposes: A preliminary assessment (2015).
42. *Sebastian Andersson Hylander:* Evaluation of cultural ecosystem services using GIS (2015).
43. *Deborah Bowyer:* Measuring Urban Growth, Urban Form and Accessibility as Indicators of Urban Sprawl in Hamilton, New Zealand (2015).
44. *Stefan Arvidsson:* Relationship between tree species composition and phenology extracted from satellite data in Swedish forests (2015).
45. *Damián Giménez Cruz*: GIS-based optimal localisation of beekeeping in rural Kenya (2016).
46. *Alejandra Narváez Vallejo:* Can the introduction of the topographic indices in LPJ-GUESS improve the spatial representation of environmental variables? (2016).
47. *Anna Lundgren:* Development of a method for mapping the highest coastline in Sweden using breaklines extracted from high resolution digital elevation models (2016).
48. *Oluwatomi Esther Adejoro:* Does location also matter? A spatial analysis of social achievements of young South Australians (2016).
49. *Hristo Dobrev Tomov:* Automated temporal NDVI analysis over the Middle East for the period 1982 - 2010 (2016).

50. *Vincent Muller:* Impact of Security Context on Mobile Clinic Activities A GIS Multi Criteria Evaluation based on an MSF Humanitarian Mission in Cameroon (2016).
51. *Gezahagn Negash Seboka:* Spatial Assessment of NDVI as an Indicator of Desertification in Ethiopia using Remote Sensing and GIS (2016).
52. *Holly Buhler:* Evaluation of Interfacility Medical Transport Journey Times in Southeastern British Columbia. (2016).
53. *Lars Ole Grottenberg*: Assessing the ability to share spatial data between emergency management organisations in the High North (2016).
54. *Sean Grant:* The Right Tree in the Right Place: Using GIS to Maximize the Net Benefits from Urban Forests (2016).
55. *Irshad Jamal:* Multi-Criteria GIS Analysis for School Site Selection in Gorno-Badakhshan Autonomous Oblast, Tajikistan (2016).
56. *Fulgencio Sanmartín:* Wisdom-volkano: A novel tool based on open GIS and time-series visualization to analyse and share volcanic data (2016).
57. *Nezha Acil:* Remote sensing-based monitoring of snow cover dynamics and its influence on vegetation growth in the Middle Atlas Mountains (2016).
58. *Julia Hjalmarsson:* A Weighty Issue: Estimation of Fire Size with Geographically Weighted Logistic Regression (2016).
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