EÖTVÖS LORÁND UNIVERSITY

FACULTY OF INFORMATICS

DEPARTMENT OF CARTOGRAPHY AND GEOINFORMATICS

Modelling, Validation and Updating an Old Cadastral map Using GNSS and UAV

(Case Study: Said Ahmadan Village, Qaladizah District, Al Sulaymaniyah Governorate, Iraq-Kurdistan Region)

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Title of the master's thesis: Modelling, Validation and Updating an Old Cadastral Map Using GNSS and UAV

Problem description: Old cadastral maps in the Iraqi-Kurdistan region are not validated and updated for a long time. The purpose of this research is to validate and update an old cadastral map for the first time through the establishment of a precise geodetic control point for the study area and image acquisition by using UAV as well as describing geodetic problems in Kurdistan region.

I undertake the consultation to the above topic.

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Abstract

Recently, surveying technology was developed; more sophisticated and accurate instruments were produced such as Global Navigation Satellite System (GNSS)-Receiver, Photogrammetry drones and laser scanning where they can be utilized for surveying large and wide Areas within less time and accurate for locating land properties, making or updating Cadastral maps.

Kurdish people and their land have always been a target by different regimes of Iraq. For instances, their villages have been destroyed, or their demography has been changed. In the Iraqi-Kurdistan region, there are some old cadastral maps of villages prepared in the previous regimes of Iraq. These maps are hardcopy and analogue with a specific scale and accuracy, and they do not have spatial reference and attribute data. Despite that, we can find many problems from the perspective of cartography.

The core purpose of this research is to validate, update, and modelling for old cadastral map Said Ahmadan village by utilizing the latest modern survey and mapping technology GNSS system for establishing geodetic control points around the area and Phantom-4 professional Aircraft for image acquisition. Furthermore, Digital Elevation Model (DEM)such as Digital Terrain Model (DTM), Digital Surface Model (DSM), hill shading and contour lines of topography shall be used to depict terrain, as well as the accuracy of the orthophoto, will be assessed.

Keywords: Cadastral Maps, GNSS, UAV, Validation, Updating, DTM

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List of Abbreviations

BM:	Benchmark
CAD:	Computer-Aided Design
DEM:	Digital Elevation Model
DTM:	Digital Terrain Model
DSM:	Digital Surface Model
DJI:	Da Jiang Innovations
DCDB:	Digital Cadastral Database
GPS:	Global Position System
GNSS:	Global Navigation Satellite System
GIS:	Geographic Information System
GCP:	Ground Control Point
GSD:	Ground Sampling Distance
LIS:	Land Information System
MSL:	Mean Sea Level
RTK:	Real-Time Kinematic
RMS:	Root Mean Square
UAV:	Unmanned Aerial Vehicle
WGS:	World Geodetic System

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1. Introduction

Due to the current developments in updating geodata, especially 3D data and cadastral data as a basis for GIS and mapping, there is a demand which for a fast and efficient surveying method that combines data acquisition with additional information such as images, 3D models of buildings and infrastructure, and elevation Modell. (Manyoky et al., 2010).

The cadastral map illustrates the boundary of an area, frequently with directions, lengths, and extents to determine and register of properties. Furthermore, it can include many facilities such as infrastructure, sanitation or any additional features associated with land-use. Uncertainty has been a considerable and detectable in cadastral maps and geographic sciences for over a decade (Taylor – Francis 2002).

Updating cadastral maps can be considered as a continuous process with no end. As the urban area in all countries has witnessed daily changes in terms of urbanization and growth in population. Cadastral maps of Iraq cannot serve municipal requirements because they have not been updated in the last five to six decades and they do not reflect the reality of the ground anymore (Imzahim Alwan, 2018). Iraqi cadastral maps were referenced to Clark 1866, which was the first local geodetic system during the1930s, then a new system called English System or Nahrwan67 appeared concerning Clark 1880 (Geokart –Poland, 1977).

The purpose of this research is to achieve a high precision cadastral map by establishing a high precision geodetic control points for the hard copy map (Figure 1). To do so, high precision and modern survey equipment used, as well as the old map will georeference and digitize to validate. The accuracy and updating cadastral maps is an important subject to resolve legal disputes before the courts, especially in the Kurdistan region updating cadastral maps is an essential task of authorities and administrative due to the demographic impact of successive regimes of Iraq on Kurdish citizens and villages.

Updating Cadastral maps purpose is to recreate and update the limits of ownership or description of the land, whether that land belongs to the ownership of individuals or public ownership of the state, as well as resolving property disputes, takeovers or land got by individuals. (A. AL-Hameedawi et al., 2017).

1.1 Problems of Old Cadastral Maps

The problem of old cadastral maps in Iraqi Kurdistan region mainly divided into the following:

- **Geometrical Problem**: Old cadastral maps as a base map; they do not have a spatial reference system. Despite that, the quality of data and data collection method is unclear.
- **Attribute data problem**: There is no database or attribute table to show ownership, type of land use and elevation surface data
- **Cartographic mistakes**: some elements of maps are absent in these maps such as reference grid and neat line, author, projection and source of data.

Since these maps are analogue, not updated for many decades, and there is not an administrative unit to perform this task yet.

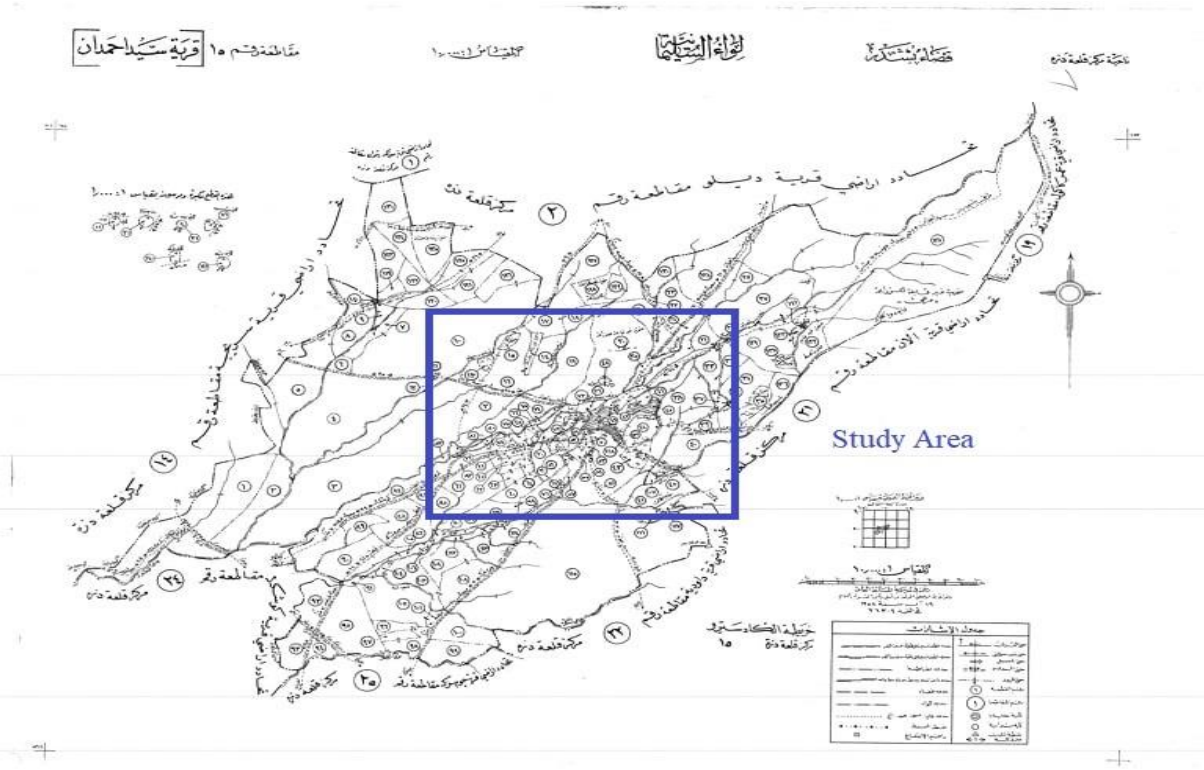

Figure 1: Old Cadastral Map of Said Ahmadan and Surroundings (Source: Local Agriculture Administrative).

1.2 Cadastral Surveying and mapping

Surveying defined as an art and science of measuring relative positions of features (natural or human-made) on the earth's surface and presentation of this information graphically or numerically. (Bannister et al., 1998).

According to (Holmberg, 2006). definition. There are different kinds of surveying, ranging from geodetic, control, plane, topography, hydrography and cadaster surveying.

Cadaster surveying defined as a survey that creates, restores and establishes the property of lines. (Holmberg, 2006). While according to (Louw, 2004) definition, cadaster surveying can further be defined as determination, demarcation, surveying, and mapping of the property boundary.

The cadastral map is a plan showing graphical information of relative position and edge of surveyed parcels of land within an area. (Louw, 2004).

1.3 Surveying Techniques

Over the last 30 years, dramatic changes and developments in surveying techniques and methods can be noticeable, from traditional optical instruments to new sensor platforms.

(Scaioni et al., 2014). Mainly, two broad categories of surveying techniques and methods can be classified, namely field survey technique (Ground survey method) and photogrammetric survey technique (Aerial photography method). (Dale- MC Laughlin, 1999).

Over the years, cheap and simple methods such as tapes, optical square, and theodolite to more complex instruments like Total station have been used in the ground surveying. Later, development in the technology has been an increase in utilize of more sophisticated Real-Time Kinetic GPS/GNSS systems as they offer more efficiency and accurate data. (Larsson,1991).

Photogrammetry is a science and technology of getting reliable spatial information through the interpretation of photographs. photogrammetry offers the solution to measure in distances whereby direct measurement is impossible, impractical or uneconomical. (Bannister et al., 1998).

Over the last few years, rapid developments of robotic systems allowed us for utilizing of uncrewed aerial vehicles as a photogrammetric data acquisition platform.

These autonomously flying UAV systems built with different sensors for navigation, positioning, and mappings such as still-video cameras, Lidar system, and others. (Manyoky et al. 2011).

All these developments of surveying instruments and approaches help us to create digital maps for cadastral purposes with the required accuracy. Furthermore, these digital maps are useful to prepare a combined plan and build a database about the title deeds parcel identifiers and ownership permanence and many other details such as the area, some districts and the privies background details. Also, the digital maps can easily be georeferenced with different land-use maps and added to the master plan of the city or region. (Rojgar Ismael et., al 2019)

1.4 GNSS

Application of GNSS is gradually obtaining popularity in the field of geodesy, land and cadastral surveying. (S., Gleason, 2009) GNSS (Global Navigation Satellite System) is a constellation of satellite positioning systems that are now operating or planned. Among them, GPS (Global Position System) is very well-Known and broadly used (Alkan et, al 2015) According to (NovAtel Inc. 2015). GNSS system consists of:

- **Global Position System (United States)** is the first GNSS system, launched in the late 1970s by the united states; it uses a constellation of 27 satellites, covers all the world
- **GLONASS(Russia):** it operated by the Russian government, launched in 1993 consists of 27 satellites in orbit and provide data for global coverage
- **Galileo (European Union): produc**ed by the European Union, it uses for civilian and commercial the first full operational capability of satellites launched in 2014
- **BeiDou (China):** is a Chinese navigation satellite system, regional service operation started in 2012, the system is consists of 35 satellites
- **IRNSS (India):** it is the Indian Regional Navigation Satellite System that covers India and the surroundings. The full constellation of seven satellites with continuous development.
- **QZSS (Japan):** its QZSS is a regional navigation satellite system refers to Japan and the Asia-Oceania region. The QZSS system planned to be deployed by 2018.

Currently, **two techniques** are commonly used in GNSS positioning: Real-Time Kinematic (RTK) and Static measurement. (GNSS Positioning Techniques, 2020)

Real-Time Kinematic (RTK)

It is a differential GNSS technique which provides high positioning performance in the proximity of a base station. RTK is working based on the use of carrier measurements and the transmission of corrections from the base station; this method requires a base station, one or several rover users and a communication channel with the base to broadcast information to the users in real-time.. (Wikipedia Contributors, Aprile 2020)

Static Method

In this technique, the receiver remains fixed during the period of observation (occupation time). Occupation time range usually 10 minutes to 6 hours. The receiver removes or models GNSS system errors to get a high level of position accuracy from a single receiver to converge to decimeter accuracy to resolve any local biases such as satellite geometry and multipath error. (An introduction to GNSS, 2015).

1.5 Computerization of Cadastral maps

The cadastral map is a fundamental data that prescribes parcel numbers, land boundaries, classification of land and ownership of land parcels. It aims to tackle and guarantee legal property boundaries and determine the area and perimeter of land use. It is a serious matter regarding the property right of every citizen. Therefore, establishing and providing a highly effective and efficient computer-based cadastral service is an essential task.

Computerization of cadastral maps leads to reduce of duplication maintaining cadastral maps for many years can easily convert maps from one scale to another and brings cadastral maps on to the same coordinate as large scale topographic maps, thereby facilitating Land information system (LIS)/GIS applications. (Asma- Afrah, 2011).

It is crucial to establish digital cadastral databases (DCDB), and an organization in the private sector or institutions must administer the system to maintain and distribute the updates. (Williamson and Enemark, 1994)

2. Research Area Description

The area of interest of this study is Said Ahmadan village - Halsho Sub-district – Qaladiza district – Al Sulaymaneyah Governorate - Iraqi Kurdistan region

2.1 Iraqi Kurdistan region general view

Iraq is located in the Middle East, Turkey to the north, the Islamic Republic of Iran to the east, the Persian Gulf to the southeast, Saudi Arabia and Kuwait to the south, and Jordan and the Syrian Arab Republic to the west.

Kurdistan region, as a single autonomous region in Iraq, has its parliament and government since 1992.With a population of 5.2 Million. Despite that, Kurdistan is the cradle of harmony, stability, co-existence, acceptance, pluralism, and solidarity for all nations, ethnics (Chaldeans, Assyrians, Syrians, Turkmen, Yazidis, Arabs and Kurds living together in harmony and currently Kurdistan is a place for the gathering of asylum seekers of inner cities and neighbouring countries(Nechirvan Barzani,2019).

Kurdistan region consists of four governorates (Erbil, Sulaymaneyah, Duhok, and Halabja) cover approximately 40,000 square kilometres. The Kurdish language is of Indo-European origin and is among the family of Iranian languages, such as Persian and Pashto, and is distinct from Arabic. The two main dialects are Sorani and Kurmanji. The capital and Kurdistan Regional Government is Erbil, a city known in Kurdish as Hawler. The Citadel in Erbil is considered the world's oldest continuously inhabited settlement. (Kurdistan Regional Governorate official website,2019)

2.2 City study view

Al Sulaymaneyah governorate is located in the northeast of Iraq, bordering Iran to the east and sharing internal borders with Erbil, Kirkuk, Diyala and Salah Al-Dinn. The city was founded in 1784 by a Kurdish prince Ibrahim Pasha Baban, who named it after his father 'Sulayman pasha'.(Sulaymaniyah…)

Al Sulayamenyah Governorate is composed of 11 Districts: Sulaymaneyah, Ranya, Dokan, Penjwin, Sharbazher**, Pshdar(Qaladizah),** Halabja, Kalar, Darbandikhan, Chamchamal and, Sharazoor. (UNAMI, 2003).

The research area is located in **Pshdar** (**Qaladizah**) **36°11′00″N 45°07′40″E** Which is means "Castle of Two Rivers" from the Kurdish words Qala= castle, dw= two and ze= river. In the south-west of the city, there is a Castle between two rivers, the town located the border of Iran about 10 miles from the Iran border. **Qaladizah** consists of five sub-districts which are Halsho, Hero, Zharawa, Esewa, and Nawdasht. (Qaladizah…).

Said Ahmadan administratively belongs to **Qaladizah,** where located in the north of town. The name of the village belongs to a pilgrim **Said** in Arabic (سيد) means (Boss) in English, and Ahmadan is an Arabic name (احمد) (Figure 2). The purpose of choosing this area:

- The familiarity of the researcher with the study area, as well as providing data and supporting by local authorities and administrative.
- The study area has a rich civilization, where there was a place to live many ethnics and different groups before coming to Islam, as well as the village has a famous citadel where archaeological teams are working on it.
- The geographic location of the study area is close to the city centre, and it has a large area for agriculture, these all led to the village become grew, and the community becomes more extensive and more abundant in residential compare to its neighbours
- The study area is one of the attractive places for many visitors and tourists, especially in the springtime.

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Figure 2: UAV image of the village (Source: Image acquisition using UAV)

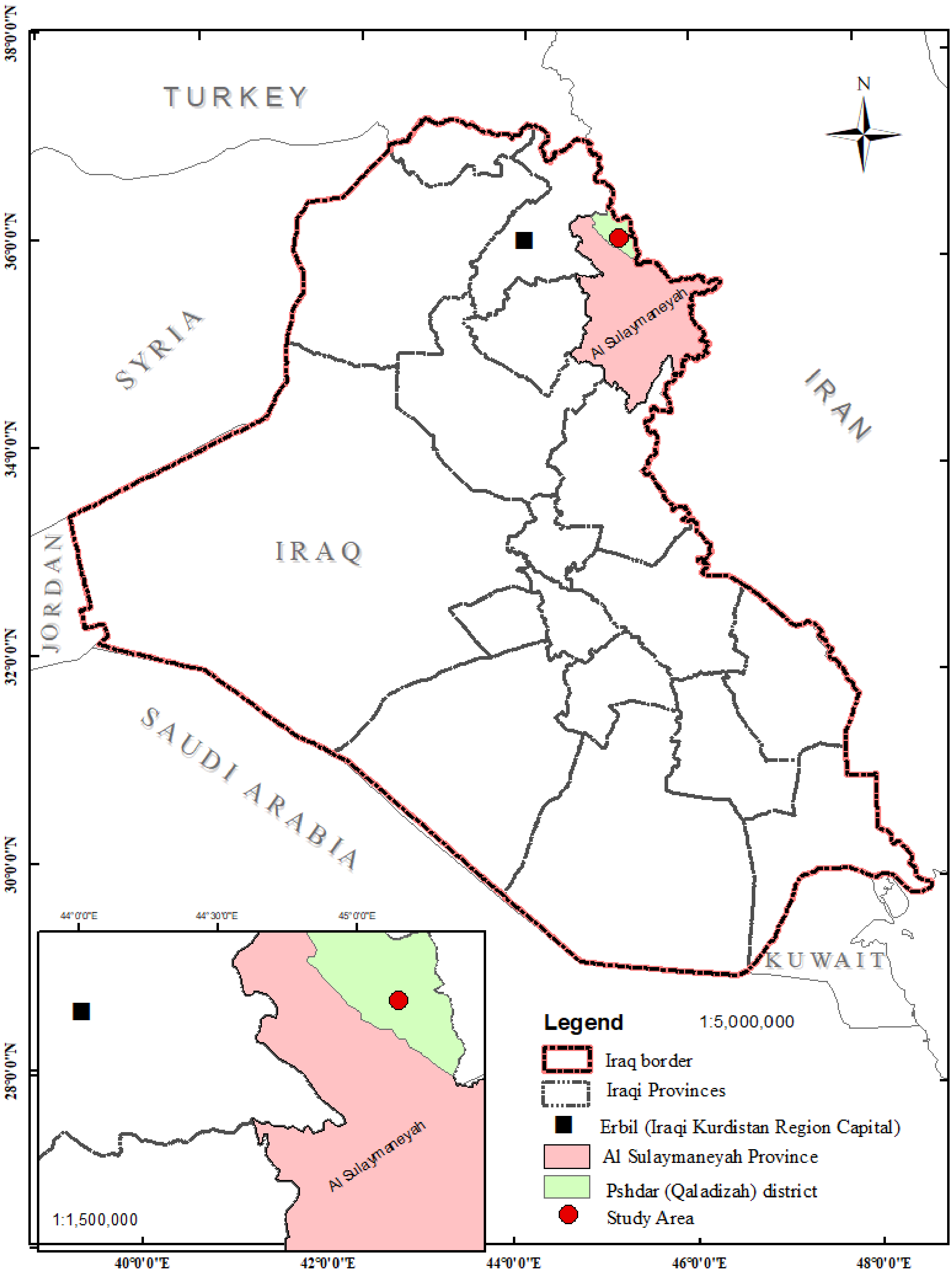

Figure 3: Study Area

2. Research Methodology

The overall workflow adopted in this research mainly consists of administrative, field working and lab work, as summarized below in (Figure 4).

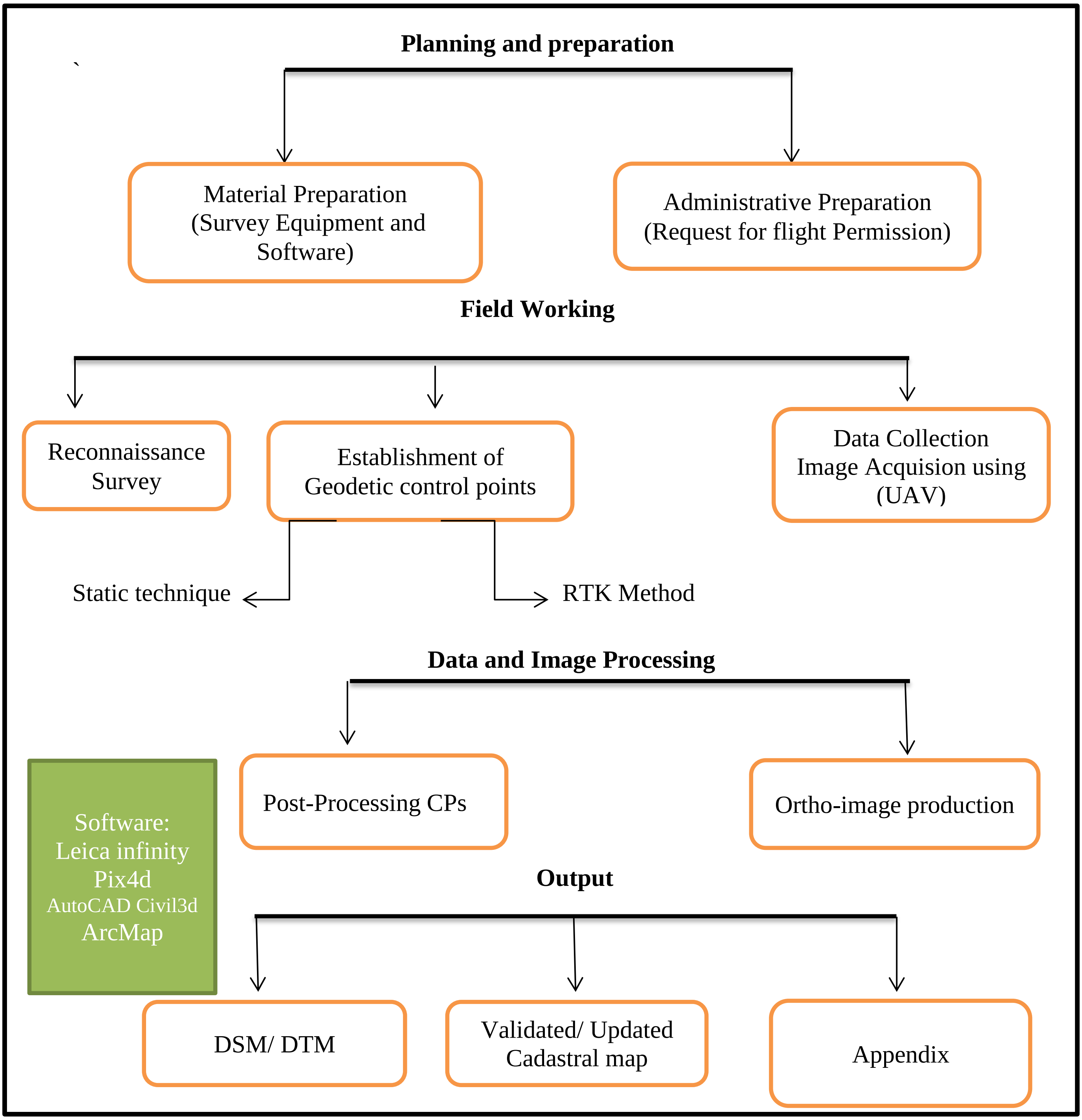

Figure 4: Flow chart of Methodology

3.1 Pre-Survey and administrative preparation

- Instruments, Software

Regarding permission for utilizing UAV, meeting and discussion were conducted with local security and administrative involved. Using such a modern and accurate drone in the Kurdistan region, especially in a research area is located in the border, Iraq-Iran is not an easy thing without permission, a set of equipment was taken from Mr Juan with its software's for the practical part of the research. In Kurdistan region, only a few of surveyors have this package of hardware and licensed software as shown in Table 1.

Table 1: List of equipment and software

Category	Name	Purpose	Source
Equipment	DJI phantom profissional	Image Acquision	Mr.Juan
	HI Target V 30 plus	Geodetic Control points	
	Laptop Dell (Intel Core i7 ,Ram 8Gb)	Data Processing	
	Smart Phone iphone x plus	Image Acquision	
Software	Leica infifnity 3.0.1	Office work	
	Pix 4D Mapper Pro		
	ArcGIS		
	AuoCAD Civil 3d 2018		

Reconnaissance survey

For preparation data acquisition and locating GCPs, a reconnaissance visit to obtain an overview of the area conducted. The primary purpose is to:

- Getting familiar with the area such as land-use and land cover, How to get there and how much time we need to arrive?
- Meeting and discussion with local people to get historical information and suggestions.
- Find the best place for the distribution of CPs and GCPs to cover the whole area. Significant attention paid to find an appropriate location for CPs, in order to avoid demolishing

Geodetic Considerations

To understand Geodetic problems in the Kurdistan region, we should define some items such as illustrated in (Figure 5).

Datum: Datum is a reference system of ellipsoidal shape which was fitted to the geoid. There are two types of datum, local datum (fit onto the territory of a country) and the global ones (fit onto the whole earth). Since the Iraqi-Kurdistan region has no local datum, Global reference system World Geodetic System (WGS)[1] Ellipsoid 1984 used.

Geoid: it is an equipotential surface of the gravity field, where approximately Mean Sea Level (MSL). The local geoid model is necessary for each country to obtain precise vertical positioning, since all geodetic measurements are strictly concerning the actual gravity field, and this gravity is the difference from point to point. Iraq has not a geoid model. We use the Earth Gravitational Model 2008 (EGM08)[2], it is at present the most precise global geopotential model of the earth's external gravity field (WenBin –Jiancheng, 2012)

Furthermore, the lack of network geodetic control points w cities is one of the problems of topographic surveying within the region.

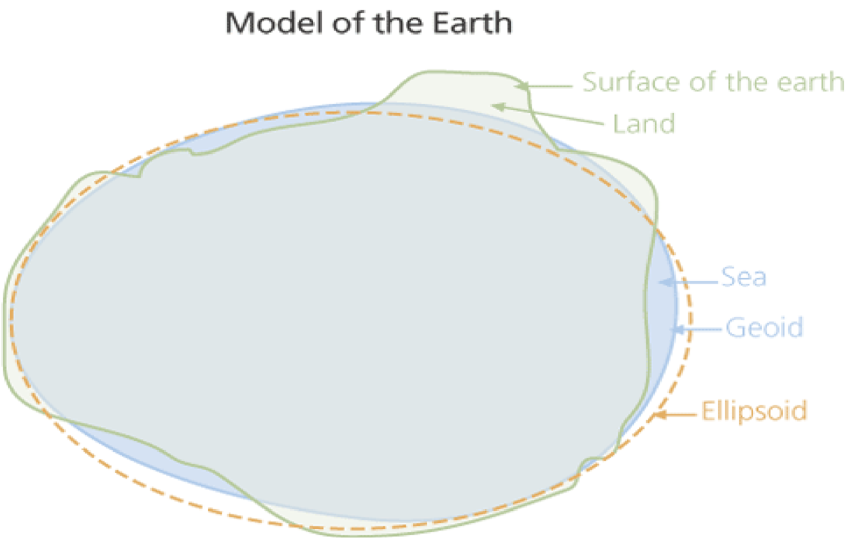

Figure 5: Earth surface model

[1] Ellipsoid WGS1984: is a Global reference system for geospatial information and is the reference system for the Global Positioning System (GPS).

[2] EGM2008: The official Earth Gravitational Model EGM2008 has been publicly released by the U.S. National Geospatial-Intelligence Agency (NGA) EGM Development Team.

3.2 Establishment of Geodetic Control Points

Three permanent control points installed to cover the entire area. The primary purpose of these control points is to establish a geodetic network for the study area, as well as these points can be used for future urban development and surveying projects. A cubic steel frame size (30*30*30) cm installed in the excavated area and poured with concrete, as shown in (Figure 6). GNSS-Receiver will set up on a control point to collect data. Besides, the nearest Continuously Operating Reference Station(CORS)[1] to the study area will be used to post-processing the static point. Later, the static point will be used as a reference to establish control points and ground control points for image acquisition

Figure 6: Establishment of Geodetic control points

HI- Target GNSS Equipment

GNSS HI-TARGET V30+ GNSS equipment used for measuring geodetic control points. The equipment can track 440 satellite signals channels simultaneously. Also, well-designed in multi-constellation GNSS engine (GPS, GLONASS, BDS, Galileo, QZSS and SBAS) with a precision of 2.5mm for horizontal and 5mm vertical position in static mode. Besides that, it can work up-to-10 hours. Furthermore, the equipment built on a Linux system and 8G storage internal memory. Specifications and pictures illustrated in (Figure7)

[1] Continuously operating Reference Station (CORS) network, managed by NOAA'S National Geodetic Survey (NGS) that provide GNSS data to improve the precision of three-dimensional positioning. CORS can enhance post-process coordinates both horizontally and vertically (Source: https://catalog.data.gov/organization/noaa-gov.)

PERFORMANCE SPECIFICATIONS

Satellite Signals Tracked Simultaneously

Channels	440
GPS	L1, L2, L5
BDS	B1, B2, B3
GLONASS	L1, L2
Galileo	E1, E5A, E5B
QZSS	L1, L2, L5
SBAS	L1

POSITIONING PERFORMANCE

High-precision static GNSS Surveying

Horizontal	2.5mm + 0.5ppm RMS
Vertical	5mm + 0.5ppm RMS

Real Time Kinematic (RTK)
Single Base

Horizontal	8mm+1ppm RMS
Vertical	15mm+1ppm RMS

Network RTK

Horizontal	8mm+0.5ppm RMS
Vertical	15mm+0.5ppm RMS
Initialization time	Typically 2-10s
Initialization reliability	Typically > 99.9%

Figure7: HI-TARGET V30 PLUS and specifications (source: equipment manual)

Static Measurement

After establishing the control points, and waiting for two days due to rainy weather, On 21, Feb 2020 the equipment was set up on a control point, named(BM1) a place of no obstacles considered. Static mode configured on BM1 to logging data for 50 minutes started from 11:30 Am till 12:27 Pm as shown in (Figure 8). The GNSS-Reciever configured to track satellite constellations of GPS and Glonass on the ellipsoid WGS 1984. The purpose of this mode is to have a point in the study area in the accuracy of millimetres.

Figure 8: Static measurement of BM1

3.3 Post-Processing Data

After fieldwork, office work started to post-process measured data of BM1.To do so, Leica Infinity Software[1] is used. The software shows two CORs in the Kurdistan region where they are operating continuously with their coordinates in millimetres, as shown in (Figure 9). The two CORs which ISER and ZAXO located in Erbil Duhok province respectively.

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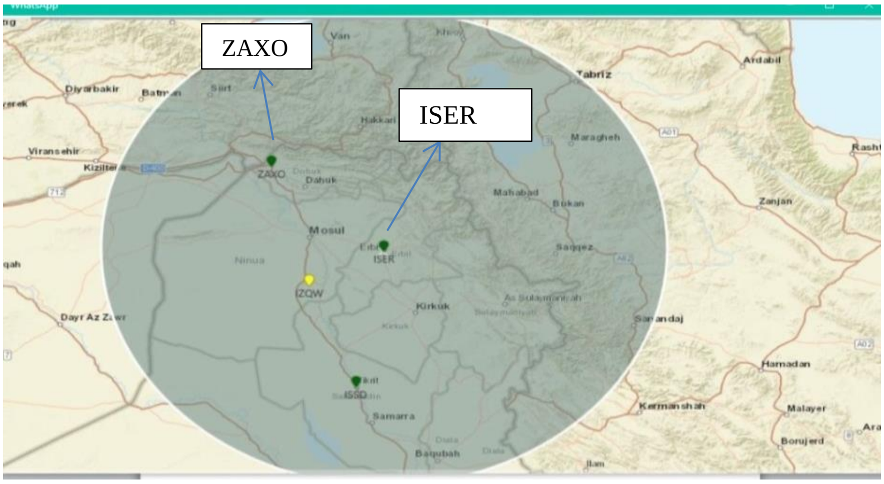

Figure 9: CORs in the Iraqi-Kudistan Region

However, the study area lies in Al Sulaymaneyah province, but there is not CORs within the province yet. So ISER station as the nearest CORs to the BM1 is used to perform post-processing and get high precision tridimensional coordinates in millimetre. As the baseline of BM1- ISER has shown in (Figure 10)

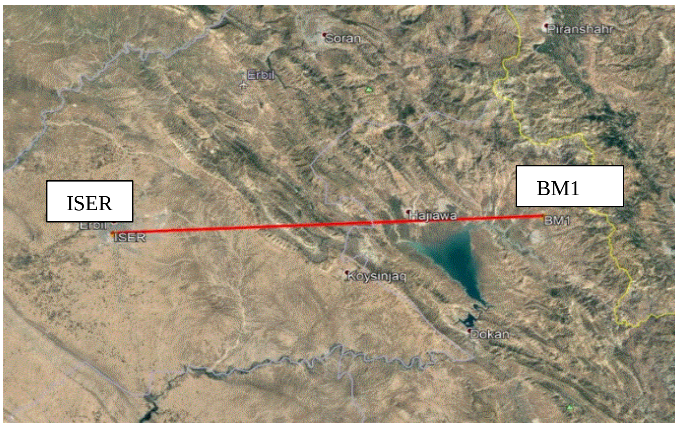

Figure 10: Baseline BM1-ISER

[1] [1] Its a geospatial office software, designed to manage, process, analyze and quality check field survey measured data, including GNSS data, total stations and Unmanned Aerial Vehicles (UAVs). https://leica-geosystems.com/products/gnss-systems/software/leica-infinity

How ever, Before post-processing BM1, GNSS-Receiver measurement data of BM1 is shown in Table 2.

Table 2: BM1 data before post-processing with ISER

Station Id: BM1

Antenna IGS Name:	V30	Occupation Mode:	Static	Point Role:	Control
Receiver Name:	V30	Start Time:	02/21/2020 11:37:23	Satellite System:	GPS/GLONASS
Receiver Serial Number:	10224348	End Time:	02/21/2020 12:28:13	Sampling Rate:	1.00 sec
Ant. Height:	1.8107 m	Duration:	00:50:50		
WGS84 Latitude:	36° 13' 47.16" N	WGS84 Cartesian X:	3,633,244.3986 m	Easting:	513,350.0424 m
WGS84 Longitude:	45° 08' 54.80" E	WGS84 Cartesian Y:	3,652,133.8852 m	Northing:	4,009,443.5499 m
Ellip. Height:	726.2930 m	WGS84 Cartesian Z:	3,749,216.7716 m	Ortho. Height:	712.6740 m

ISER data imported online from the source below to the software for 24 hours, as shown in Table 3.

Table 3: ISER data (Source: https://www.ngs.noaa.gov/cgicors/CorsSidebarSelect.prl?site=iser&option=Logfile)

Station Id: ISER

Antenna IGS Name:	TRM57971.00	Occupation Mode:	Static	Point Role:	Control
Receiver Name:	TRIMBLE NETR5	Start Time:	02/21/2020 02:59:42	Satellite System:	GPS/GLONASS
Receiver Serial Number:	4807K53513	End Time:	02/22/2020 02:59:12	Sampling Rate:	30.00 sec
Ant. Height:	0.0000 m	Duration:	23:59:30		
WGS84 Latitude:	36° 09' 35.47" N	WGS84 Cartesian X:	3,708,161.0760 m	Easting:	411,037.1721 m
WGS84 Longitude:	44° 00' 39.38" E	WGS84 Cartesian Y:	3,582,297.9590 m	Northing:	4,002,131.8982 m
Ellip. Height:	431.3272 m	WGS84 Cartesian Z:	3,742,781.5110 m	Ortho. Height:	420.1443 m

The main parameters configured in the software as below:

- **Cut-Off angle**: the minimum acceptable satellite elevation angle above the horizon. This angle is applied while post-processing to avoid multipath error, ionospheric and tropospheric delay values. post-processing baseline ISER-BM1 cut-off angle= 10°
- **Frequency Band**: GNSS frequencies referred to as Bands. All GNSS frequencies fit into either L1, L2, L5, or L6 for post-processing we applied bandsL1/L2
- **Sampling Rate**= 30.0 sec it means that the receiver calculated the coordinate of the point in each 30.0 sec. Sample rate should be assigned appropriately High sample rate means more data but more computation and more battery power
- **Satellite System**: The software configures to uses satellite constellation of GPS/GLONASS

The final post-processed data of BM1 is shown in Table 4. Later, this accurate data will be used as a reference station to measure the GCPs while imaging acquisition through RTK mode or future urban planning development

Table 4: Results of BM1data

Coordinates

	Reference - ISER	Rover - BM1		Reference - ISER	Rover - BM1
Point Role:	Control	Fixed PP			
WGS84 Latitude:	36° 09' 35.47" N	36° 13' 47.13" N	Easting:	411,037.1721 m	513,350.1952 m
WGS84 Longitude:	44° 00' 39.38" E	45° 08' 54.81" E	Northing:	4,002,131.8982 m	4,009,442.8096 m
WGS84 Ellip. Height:	431.3272 m	726.0089 m	Ortho. Height:	420.1443 m	712.3900 m
WGS84 Cartesian X:	3,708,161.0760 m	3,633,244.4382 m			
WGS84 Cartesian Y:	3,582,297.9590 m	3,652,134.1402 m			
WGS84 Cartesian Z:	3,742,781.5110 m	3,749,216.0060 m			

Quality of post-processing BM1 result:

The quality report of the baseline BM1-ISER is summarized as follows, However the rest of the quality report of post-processing BM1 attached in Appendix 1

Δ Latitude: 0° 04' 11.66"	SD Δ Latitude: 0.0012 m
Δ Longitude: 1° 08' 15.43"	SD Δ Longitude: 0.0011 m
Δ Height: 294.6817 m	SD Δ Height: 0.0029 m
ΔX: -74,916.6378 m	SD ΔX: **0.0018 m**
ΔY: 69,836.1812 m	SD ΔY: **0.0020 m**
ΔZ: 6,434.4950 m	SD ΔZ: **0.0019 m**
Slope Dist.: 102,620.6488 m	SD Slope Dist.: 0.0011 m

The coordinate system for post-processing BM1 shown in Table 5

Table 5: Coordinate system for Post-Processing BM1

Coordinate system report	
Ellipsoid:WGS 1984	**Projection**
Semi-Major Axis (a): 6,378,137.0000 m	Universal Transverse Mercator
Reciprocal Flattening (1/F): 298.2572235630	Zone Number: 38
	Central Meridian: 45° 00' 00.00" E
	Hemisphere: North
Geoid Model: EGM2008	
Ellipsoid: WGS 1984	**South-West Corner**
Apply on Local Side: No	Latitude: 28° 00' 00.00" N
Coordinate Type: Geodetic	Longitude: 38° 00' 00.00" E
Interpolation Type: Bi-quadratic	
North-East Corner	**Spacing**
Latitude: 38° 00' 00.00" N	North-South: 0° 02' 30.00"
Longitude: 49° 00' 00.00" E	East-West: 0° 02' 30.00"

3.4 Image Acquisition

Data collection for image acquisition in the field carried out after the following two criteria fulfilled:

1- Post-Processing BM1 with CORs (ISER).

2- Permission letter from local security authorities to use UAV

On 24 Feb 2020, the researcher visited the study area with two assistants to carry out data collection and image acquisition. First of all, we marked out four GCPs on the ground; the GCPs logo designed by Photoshop and printed in flex paper (1*1) meter square in black and white colour to be noticeable during image georeferencing (Figure 11). The GCPs distributed in a way that identified and be visible, as well as to get the visibility of a sufficient number of satellites to the GNSS receiver without any obstruction while measuring their coordinates. The GCPs are visual markers; they will be helpful to increase the absolute accuracy of the drone survey by fitting the model with the geodetic coordinate system

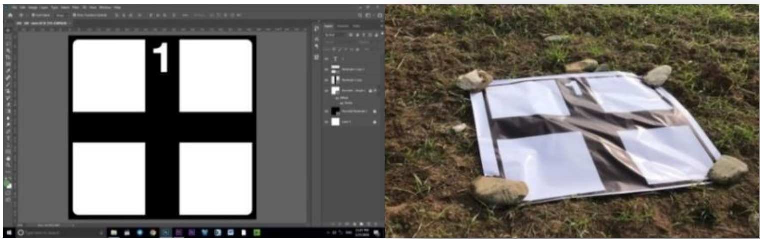

Figure 11: Designing and distribution of GCPs

The second step is measuring four GCPs, and two CP (Control Point) through using GNSS HI-Target equipment, RTK method, where the rover is fixed and levelled to measure each point for 2 minutes as shown in (Figure 12). GNSS-Receiver base placed and levelled on BM1 and one rover for measuring the CPs and GCPs. In total, 6 points, including one station, measured in the morning in cloudy weather. The survey carried out roughly in one hour. In a way that, one of the assistances was left with the base to keep it safe, then measuring the pre-marked points by placing the rover in the middle of the markings one by one

Figure12: RTK measurement of CPs and GCPs

The final step of field working is launching the UAV. To do so, DJI Phantom 4 Professional unpacked, the rotary unit of the drone and wings with a perspective lens camera attached in the platform as shown in (Figure 13).then the UAV and smartphone iPhone S set up and connected to Pix4d Mapper application to control the vehicle. The flight mission planned and some parameter for the flight mission configured, such as flight altitude= 100m, side overlap of %70 and front overlap of %80.Besides that, DJI Phantom 4 Pro can resist 10m/s wind speed, max ascent speed and descent speed 6m/s and 4m/s respectively. The vehicle uses the Constellation of satellite signal GPS/Glonass for the positioning system.

Furthermore, it has a Max Service Ceiling above Sea Level 19685 feet (6000 m). One of the most characteristics of the camera of this type of vehicle is camera shooting 4K video at up to 30 frames per second and capturing 12-megapixel photos with an enhanced sensor gives greater clarity, lower noise and better pictures than any previous camera before. Camera Gimbal features and specifications of the vehicle illustrated in Table 6 and Table 7.futher specifications of the vehicle is hovering accuracy range which is ±0.1 m for vertical (with Vision Positioning) and ±0.5 m (with GPS Positioning) while for horizontal is ±0.3 m (with Vision Positioning) and ±1.5 m (with GPS Positioning).

The UAV has four battery for, once the battery of the vehicle is getting low, the drone get back to the launching point automatically to replace the battery. However, the study area was not too large and covered in 40 minutes of flying.

Above all, the flight environment requirements considered. Such as the aircraft not recommended in severe weather conditions like speed exceeding 10m/s, snow, rain, and fog.

Currently, the UAV system is one of the rapid survey methods for cadastral maps due to its flexibility and efficiency in capturing the surface of an area from a low flight altitude. Besides, further information orthoimage, elevation models and 3D objects can easily extract from UAV images.

Figure 13: Unpacking and launching UAV

Table 6: Gimbal specifications Phantom 4 Pro (Source: Phantom 4 Pro specifications)

Stabilization	3-axis (pitch, roll, yaw)
Controllable Range	Pitch: -90° to +30°
Angular Vibration Range	±0.02°

Table 7: Camera specifications (Source: Phantom 4 Pro specifications)

Sensor	1/2.3" CMOS Effective pixels:12.4 M
Lens	FOV 94° 20 mm (35 mm format equivalent) f/2.8 focus at ∞
ISO Range	• • 100-3200 (video) • • 100-1600 (photo)
Electronic Shutter Speed	8 - 1/8000 s
Image Size	4000×3000
Video Recording Modes	UHD: 4096×2160 (4K) 24 / 25p

Research Limitations and problems

- Having an accurate geodetic control point in millimetres and image processing with 1cm requires expensive materials (equipment and software) with potential capacities.
- Flight permission from security authorities was another obstacle I faced. As the village located on the border of Iraq-Iran, and the entire territory was unstable in the security situation and politically due to assassination of the high commander of Iran in Iran by the United States.
- Weather condition, as the practical part of the research, was in wintertime and it is not applicable to use the GNSS-receiver and drone in windy, rainy and snowing weather.

4. Data Analysis and Results

4.1 UAV

Data Analysis and image processing include the process of obtaining an orthomosic for the study area and the accuracy of the data. 1.045 km square of the area covered, 311 out of 311 images calibrated and Geolocated with an average GSD[1] Of 1.56cm.

For extracting three–dimensional digital surface or terrain models and orthophotos, UAV flights at low altitude create 3D models with much higher spatial resolution compared to remote sensing technology; To do so, UAV collected many overlapping pictures to make orthophotos (Orthomosaic), and the images matched and Geolocated through Pix4D Mapper[2]. The interior orientation parameters of the camera (focal length, lens distortion parameters, the position of the principal point) estimated through a self-calibration process, i.e. Bundle block adjustment was not possible to pre-calibration in the field. After this self-calibration, photogrammetric results such as Othomosaic and Digital Surface Model (DSM) generated with the resolution 1 x GSD (3.23 [cm/pixel]) as shown in (Figure 14). the obtained orthophoto is a georeferenced UTM projection mosaic of all the captured images together in a digital format.

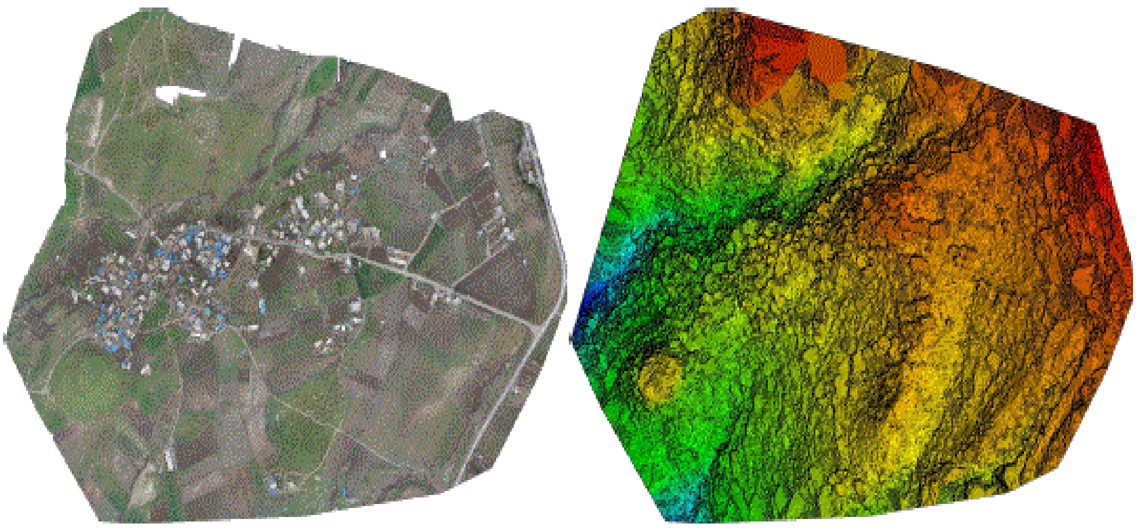

Figure 14: Orthomosaic and the corresponding sparse Digital Surface Model (DSM) before densification.

[1] Is the distance between two consecutive pixel centers measured on the ground the bigger the value of the image GSD, the lower the spatial resolution of the image and the less visible details (Source: https://support.pix4d.com/hc/en-us/articles/202559809-Ground-sampling-distance-GSD)
[2] Photogrammetry software for professional drone mapping (source:Pix4D.com)

Digital Terrain Model (DTM)

DTM generated through a triangulation method with the resolution 5x GSD (3.23 [cm/pixel]). Red colour shows the highest terrain elevation while blue colour displays the lowest elevation of the terrain in the south-west of the study area as illustrated in Figure 15. The DTM created from DSM after the process of removing vegetation, buildings and other human-made features.

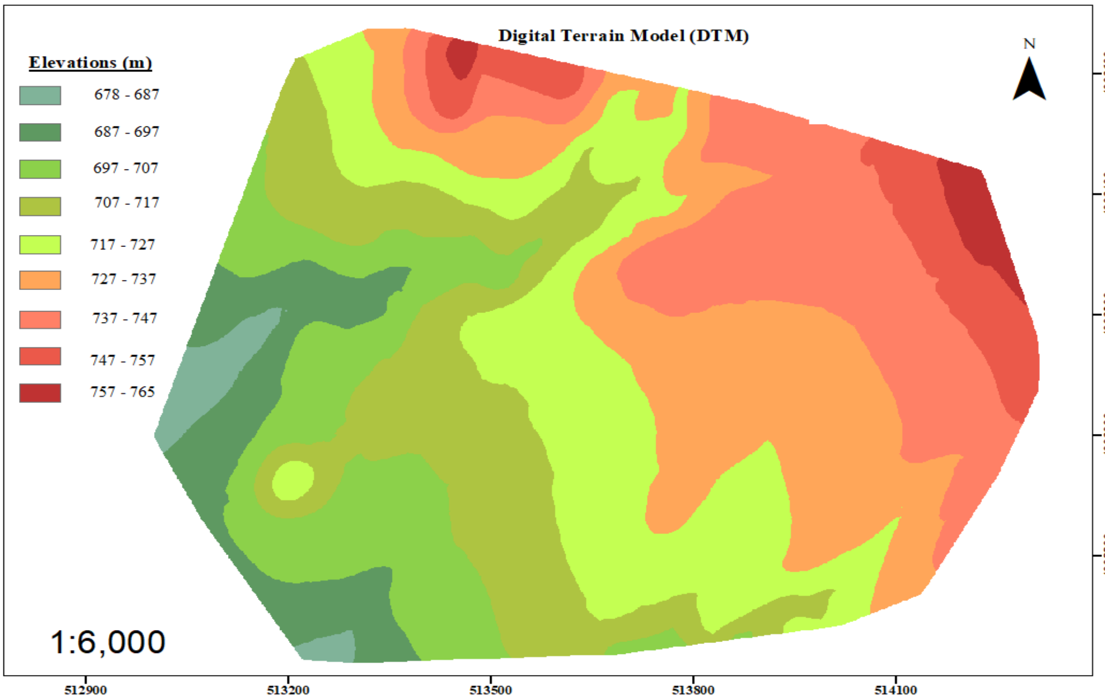

Figure 15: Digital Terrain Model

4.2 Orthoimage Accuracy

During processing by pix4dmapper, Quality report generated as attached in Appendix 2. 4GCPs were used for Geolocation with RMS Error 0.012m in X-axis, 0.014m in the Y-axis and0.012m in Z-axis, as shown in Table 8. When it comes to the accuracy of drone maps, two accuracies emerge, Relative (Local) and absolute (global), where relative accuracy is the accuracy of points of the map relative to each other. For instance, if a distance between two points measures 5m in the real world, it also measures 5m on the map. On the other hand, absolute accuracy is the accuracy of a point on the map to a fixed geodetic coordinate system in the real world.

For the obtained orthophoto, mean of relative geolocation variance accuracy of images X= 5m, Y= 5m and Z= 10 in percentage as shown in Table 9

Another error of the drone maps is orientation angles between the image coordinate system and the projected coordinate system.

Table 8: GCPs accuracy

GCP Name	Accuracy XY/Z [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]	Verified/Marked
0 (3D)	0.020/ 0.020	-0.000	0.000	-0.000	0.015	3 / 3
1 (3D)	0.020/ 0.020	0.000	-0.000	0.000	0.036	6 / 6
2 (3D)	0.020/ 0.020	0.012	-0.017	0.016	0.017	4 / 4
3 (3D)	0.020/ 0.020	-0.014	-0.015	0.047	0.016	3 / 3
Mean [m]		0.015	-0.014	0.014		
Sigma [m]		0.012	0.014	0.012		
RMS Error [m]		0.012	0.014	0.012		

The Geolocation RMS error of the orientation angles in degree is (Omega) is the rotation around the X-axis= 0.015, (Phi) is the rotation around the

Y-axis= 0.014 and (Kappa) is the rotation around the Z-axis= 0.013

Table 9: Relative Geolocation accuracy of the images

Relative Geolocation Error	Images X [%]	Images Y [%]	Images Z [%]
[-1.00, 1.00]	88.41	67.55	100.00
[-2.00, 2.00]	98.68	91.06	100.00
[-3.00, 3.00]	100.00	100.00	100.00
Mean of Geolocation Accuracy [m]	5.000000	5.000000	10.000000
Sigma of Geolocation Accuracy [m]	0.000000	0.000000	0.000000

GCPs and CPs final processed list of coordinates shown in Table 10

Table 10: Geodetic data of CPs and GCPs

Points ID	Easting	Northing	Ellipsoid height	Orthometric height	Geoid Separation
GCP1	513350.1952	4009442.8096	726.0089	712.1443	13.6242
GCP2	513235.9674	4008944.3801	720.4670	706.8986	13.5684
CP1	514084.9027	4008268.1059	757.9230	744.3680	13.5550
GCP3	513954.0437	4008434.4959	716.9860	703.4231	13.5629
CP2	513786.2447	4008888.9973	729.2590	715.6625	13.5965
GCP4	514185.7136	4009557.4834	761.7360	748.0497	13.6863

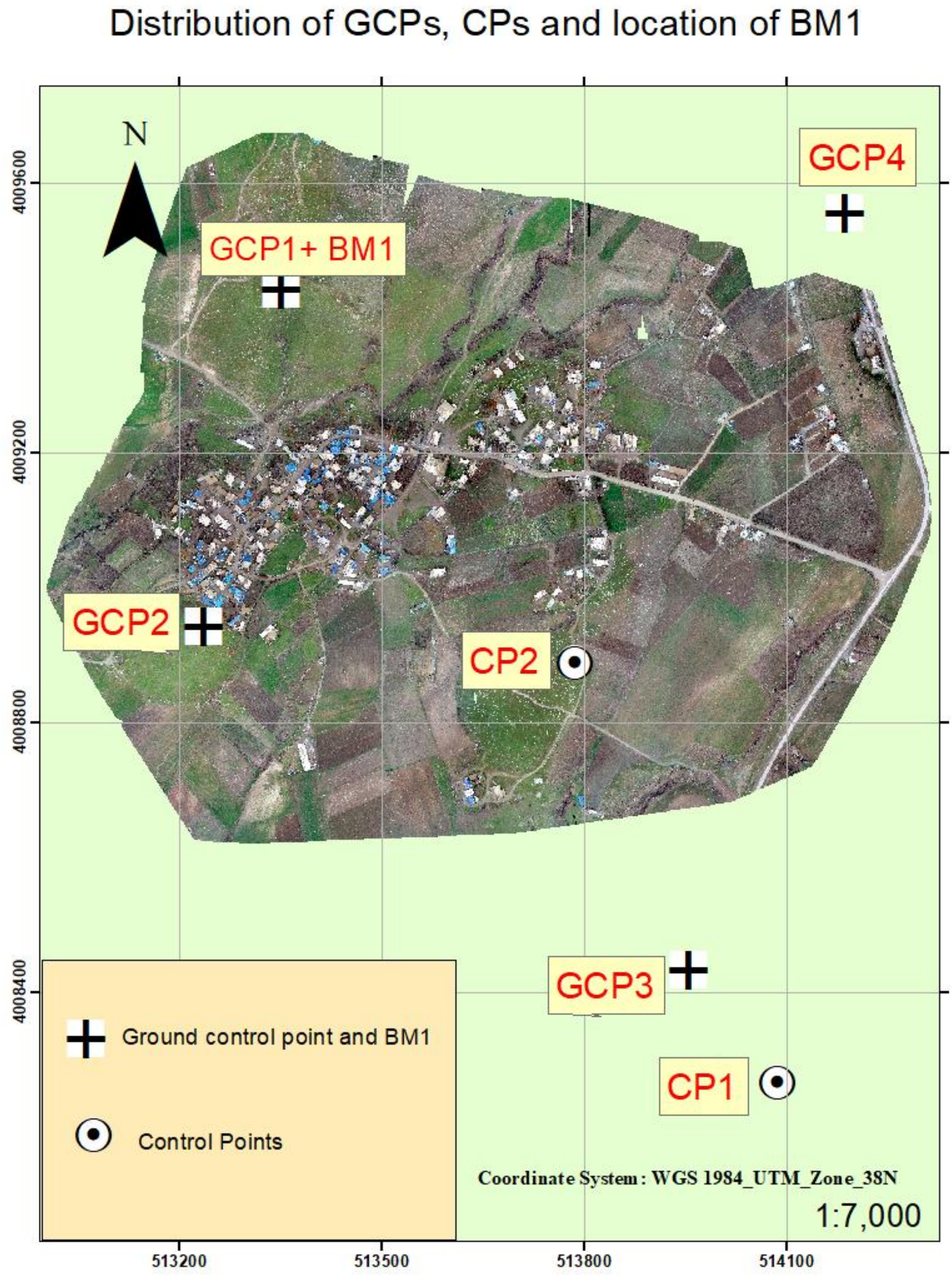

Figure 16: Distribution of GCPs, CPs and BM1

4.3 Overall Results

The main objectives of this research are the establishment of geodetic control points with an accuracy of millimetres and creating a model, validation and updating an old cadastral map in the Kurdistan region with the latest modern survey UAV. Based on this technology, first of all, features such as roads, built-up area and parcels of the old map digitized as illustrated in Figure7. For the old map, as it is not a digital map, it has no attribute table. Consequently, we cannot get the number of households, parcel owner.

When it comes to the orthophoto due to the high resolution and level of detail of the UAV orthophoto enables additional features to be visible and allows the opportunity for creating a new vector dataset such as main road, local roads and built-up area as illustrated in Figure 18.

We could digitize the built-up area with 209 households including hospital, school and mosque. The updated map will be helpful for decision –making in various urban planning activities

Eventually, the village appears that to be extended and become enlarged, the main reason is due to the closeness from the city centre (**Qaladizah**)and the second one is the fertility of its agricultural land.

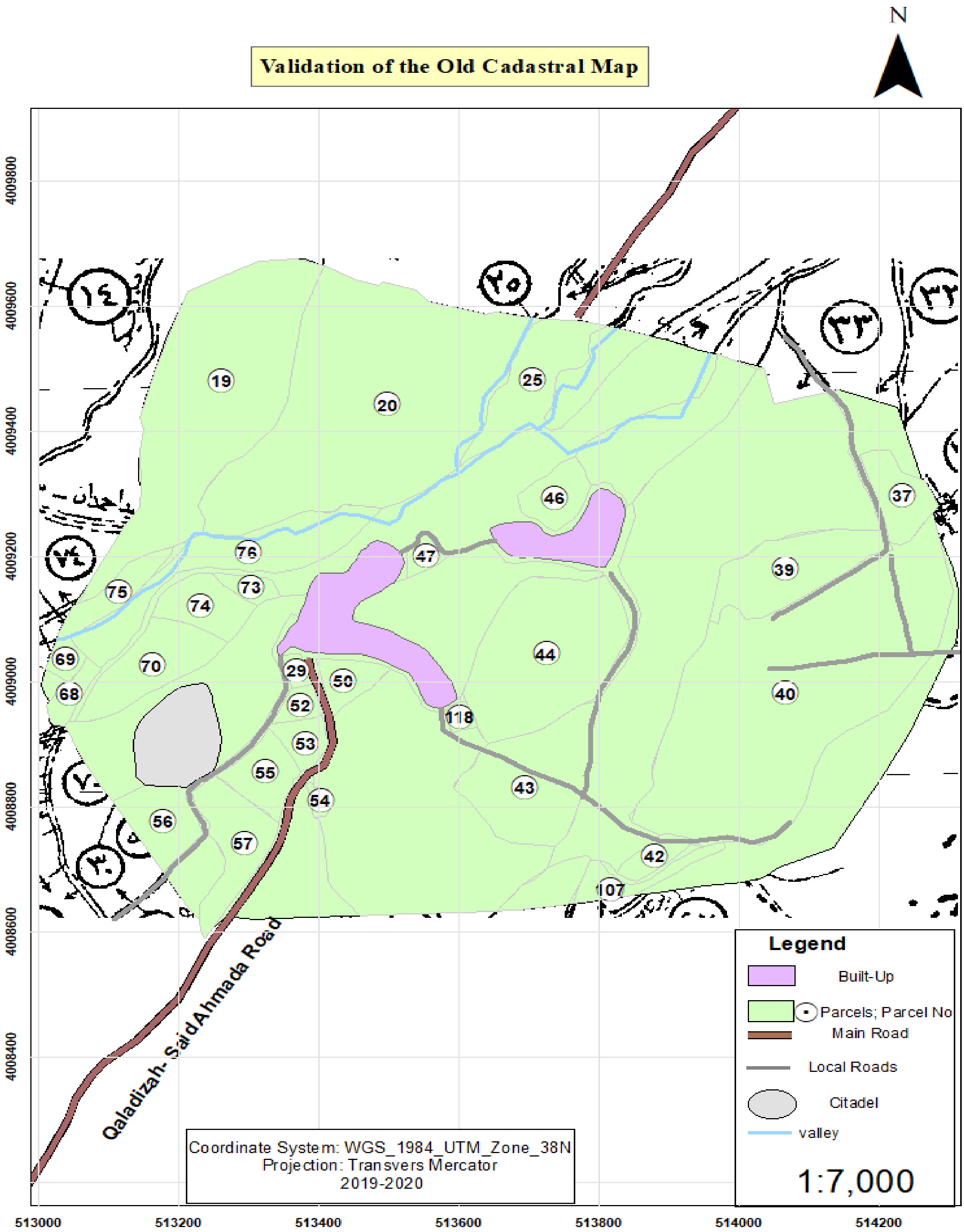

Figure 17: Validation of the Cadastral map

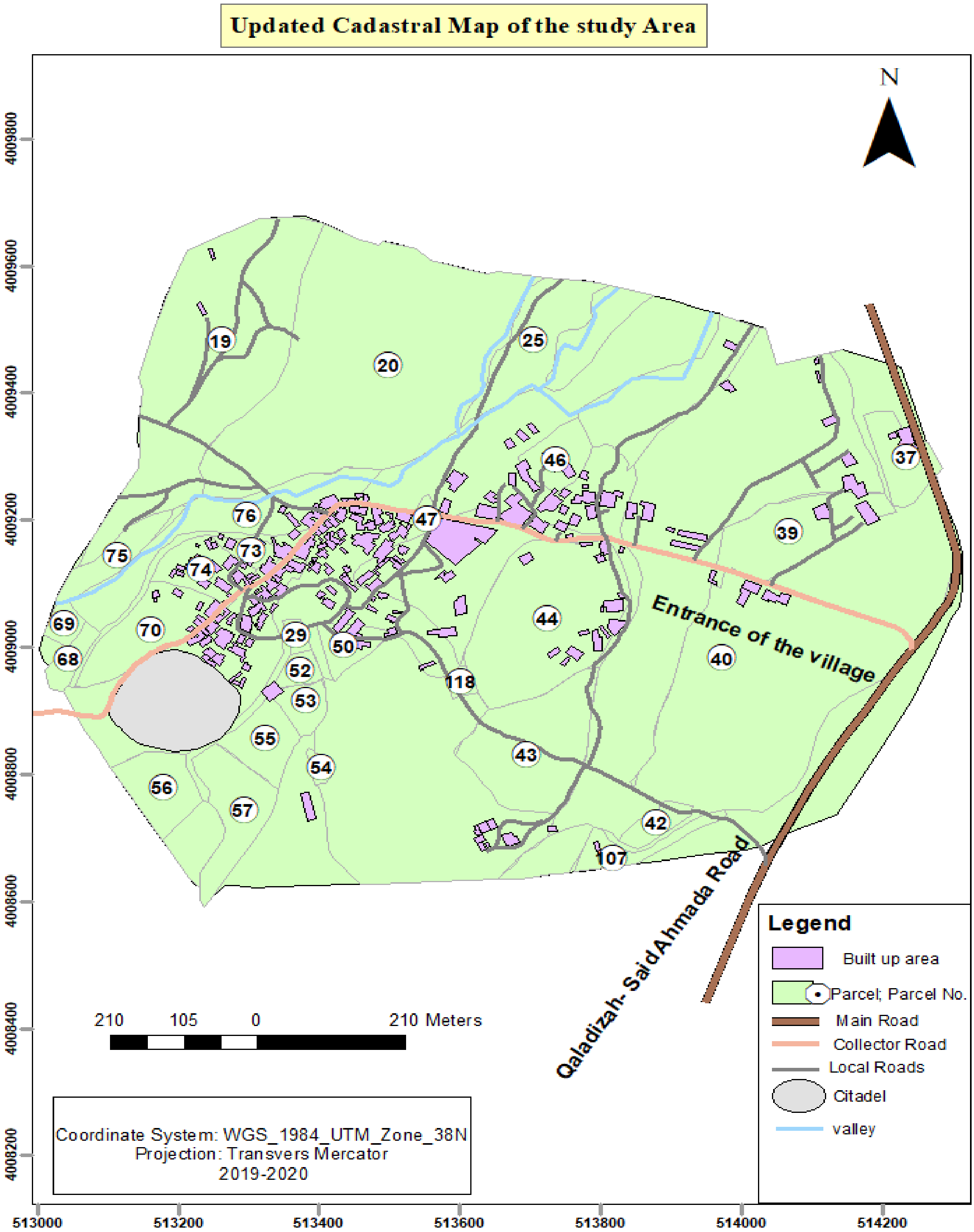

Figure 18: Updated Cadastral Map

5. Conclusion and Recommendations

5.1Conclusions

The aim of this research to establish high precision geodetic control through GNSS and post-processing geodetic data with the nearest reference station to the study area and to obtain and orthophoto georeferenced image. The UAV can result in a much more detailed map such as further information of the area like land use, or vegetation has to be documented in the map. This work demonstrates that high precision of geodetic control points and UAVs provide promising opportunities to create a high-resolution and highly accurate orthophoto.

With the UAVs, not only the orthophoto will obtain, but we can also get the Digital Surface Model(DSM) and Digital Terrain Model(DTM) which is useful to surface analysis such as hill shading, slopes and contour lines which are helpful for urban and construction project.

The vital role of GCPs in improving the accuracy of the obtained orthophoto; the geolocation accuracy without GCPs is relatively low. Moreover, this can be resolve through establishing a high –quality geodetic control points that include GNSS static measurement, post-processing and RTK measurement for GCPs data collection in the field. Thus, due to the high resolution of the UAV orthophoto, new features can be easily extracted, and various outputs can be produced. Therefore, UAVs are currently more suitable for map updating projects over a limited study area and incremental map updating. The advantage of UAV systems is the capability to quickly observe large areas at low flying altitudes within a specific time.

Finally, Digitization of the cadastral map is very critical and sensitive for providing useful, reliable, and qualitative cadastral services, especially in the disputed area. Among various types of maps, cadastral maps are being involved in the rights of property and because of its sensitivity, skilled and well knowledge of digitizers; preferably surveyors and cartographers can work qualitatively

5.2 Recommendations for Further Research

Recommendations summarized in the following points:

- Creating technical unit and administrative office from professional and technician people in to create a national survey office responsible for geodetic control and technical service provision in every office to validate and update all cadastral and old maps of the Iraqi-Kurdistan region, utilizing modern survey techniques (GNSS and UAV) to create high-resolution and accurate orthophoto.

- Computerizing updated maps through creating a GIS layer with corresponding attribute data for all cadastral sectors. Such as Id code, area, name of ownership, type of land use. Furthermore, creating a GIS server and geodatabase and web GIS in the ministry of planning order to sharing of the maps between the offices.

- Making a national guideline and framework for surveying and drawing of cadastral maps to uniformity of spatial reference, scale, map projection, database, archiving and updating of cadastral maps.

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1120–68th Avenue N.E. Calgary, Alberta, Canada T2E 8S5
www.novatel.com.

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Last but not least; I want to extend many thanks to my family: my parents Ahmed Ibrahim and Hamin Ismael for supporting me spiritually throughout my life. Particularly during these two years abroad while I am a single boy of my family.

Appendix

Appendix 1: Observations model and processing

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CH-9435 Heerbrugg
St. Gallen, Switzerland

Phone: + 41 71 727 3131
Fax: + 41 71 727 4674

- when it has to be **right**

GNSS Processing Report

Report created: 02/22/2020 10:25:10

Project Details

General		Customer Details		Master Coordinate System	
Project Name:	BM-01 Said Ahmadan Village	Customer Name:	-	Coordinate System Name:	UTM84-38N
		Contact Person:		Transformation Type:	None
Owner:		Number:		Residual Distribution:	None
Lead Surveyor:		Email:		Ellipsoid:	WGS 1984
Date Created:	02/22/2020 11:53:34	Skype:		Projection Type:	UTM
Last Accessed:		Website:		Geoid Model:	EGM2008
Application Software:	Infinity 3.0			CSCS Model:	-

Path: C:\Users\s\Documents\Leica Geosystems\Infinity\Projects\BM-01 Said Ahmadan Village\BM-01 Said Ahmadan Village.iprj
Size:
Comments:

Baseline ISER - BM1

Processing Parameters (02/21/2020 11:37:23 - 02/21/2020 12:28:13)

Data	Selected	Used	Comments
Cut-Off Angle:	10°	10°	
Frequency:	Automatic	L1/L2	
Sampling Rate:	Use All	30.00 sec	
Satellite System:	GPS/GLONASS/Galileo/Beidou	GPS/GLONASS	
Ephemeris Type:	Broadcast	Broadcast	
Antenna Calibration Set:	NGS Absolute	NGS Absolute	

Processing Strategy		
Solution Type:	Phase Fixed	Phase Fixed
Solution Optimisation:	Automatic	Iono Minimised
Frequency to use in Iono Minimised:	Automatic	L1/L2
Tropospheric Model:	VMF with GPT2 model	VMF with GPT2 model
Ionospheric Model:	Automatic	Computed
Allow Widelane Fix:	Automatic	Automatic

General Settings	
Min. Distance for Iono Minimised:	3 km
Possible Ambiguities Fix up to:	500 km
Min. Duration for Float Solution (static):	00:05:00

Frequency:	L1/L2	GDOP:	1.6 - 2.5	GPS SVs:	8/8
Solution Optimisation:	Iono Minimised	PDOP:	1.2 - 1.9	GLONASS SVs:	7/7
Solution Type:	Phase Fixed	HDOP:	0.6 - 0.9	Beidou SVs:	-
		VDOP:	1.0 - 1.6	Galileo SVs:	-
				QZSS SVs:	-

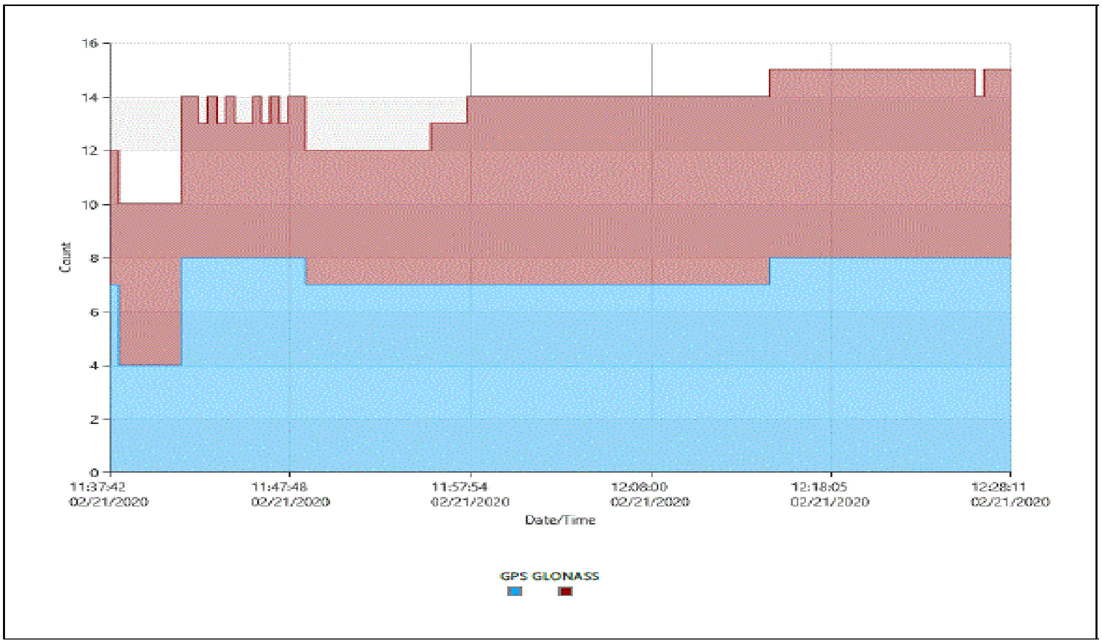
Ephemeris Type:	
GPS	Broadcast
GLONASS	Broadcast

Processing Info (02/21/2020 11:37:23 - 02/21/2020 12:28:13)

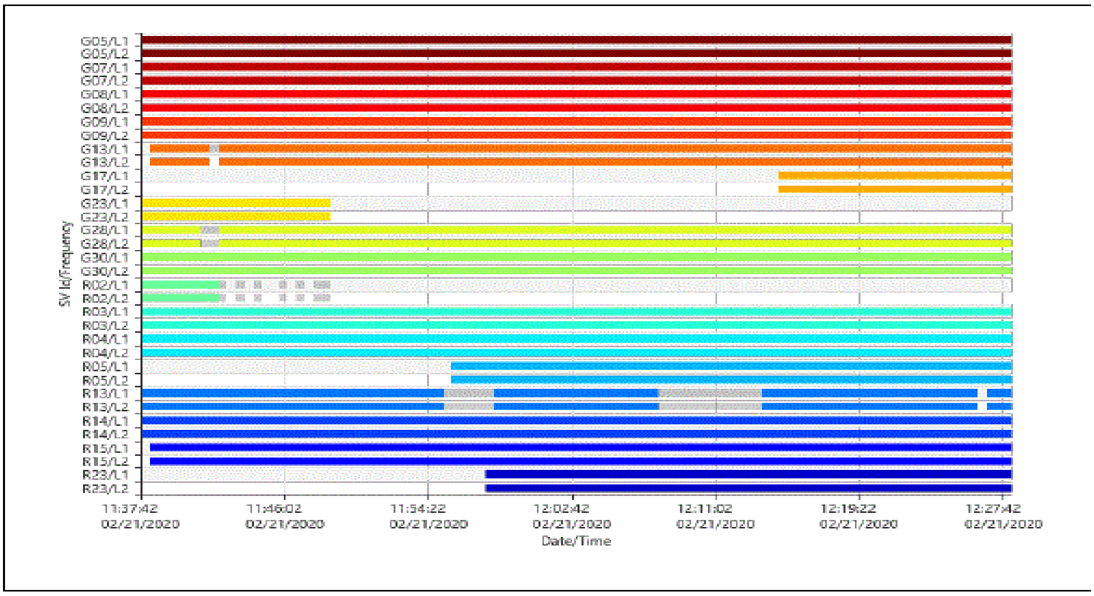
Processed Date/Time: 03/19/2020 10:25:41

Satellites

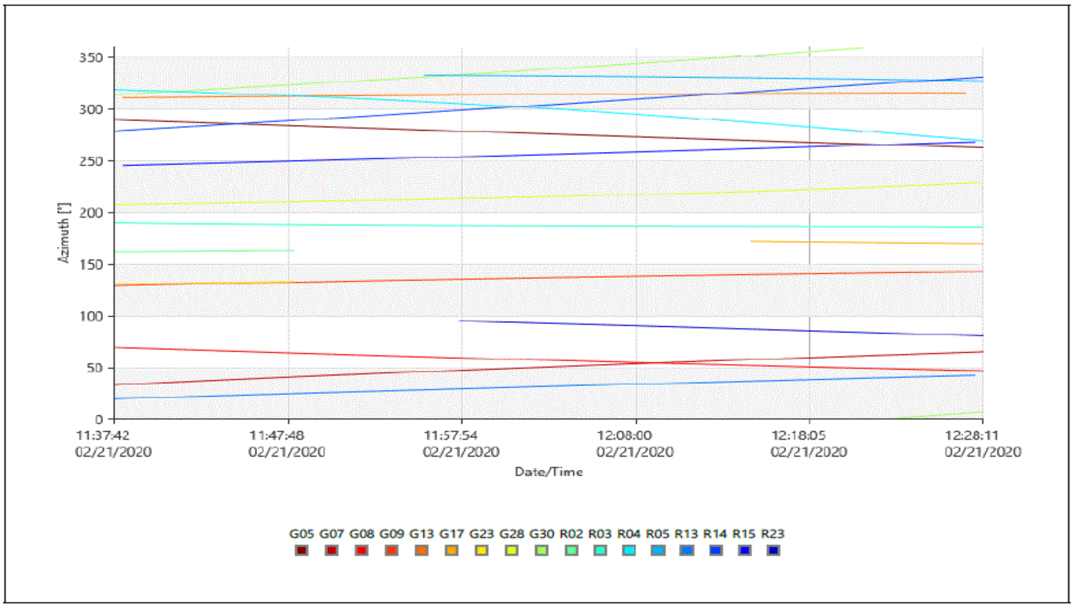
Satellite System	Used	Manually Disabled
GPS	G05 G07 G08 G09 G13 G17 G23 G28 G30	-
GLONASS	R02 R03 R04 R05 R13 R14 R15 R23	-



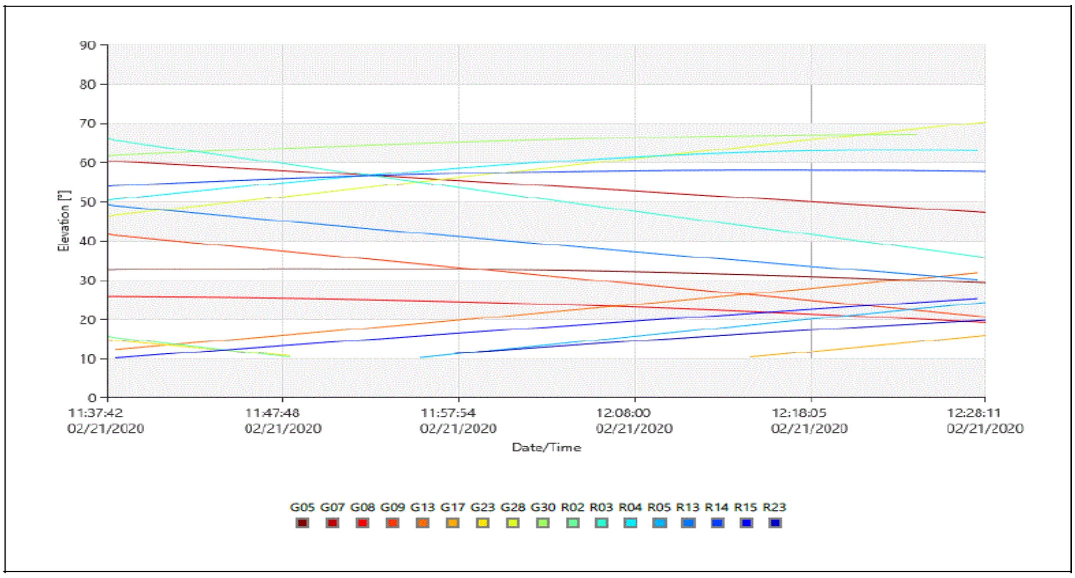
Signals Tracked



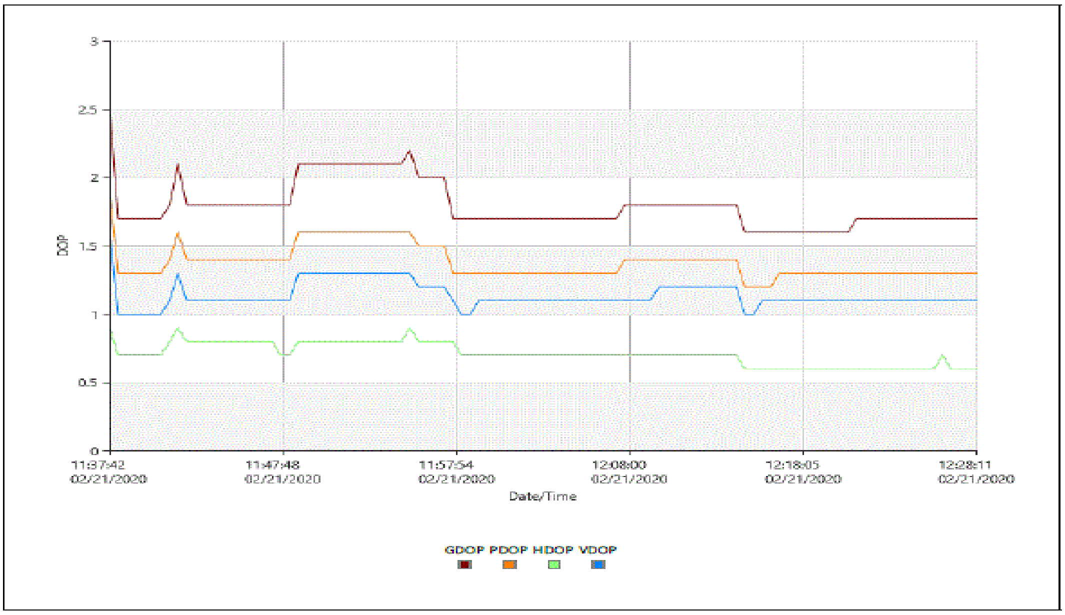
Azimuth



Elevation



DOP



Observation Statistics

Common Epochs: 102

GPS Observations

Frequency	Used	Rejected
L1	760	3
L2	760	2

GLONASS Observations

Frequency	Used	Rejected
L1	627	25
L2	627	25

Ambiguity Statistics

Number of Ambiguities	GPS	GLONASS
Fixed	22	23
Total	23	37
Independently fixed	63	62
Possible independently fixed	63	63

Average time between independent fixes: 00:00:30

% of Epochs	GPS		GLONASS	
	L1 [%]	L2 [%]	L1 [%]	L2 [%]
Fixed	99.74	100.00	96.13	98.92
Not fixed	0.26	0.00	3.87	1.08
Not fixed - contradiction	0.00	0.00	0.00	0.00
Not fixed - missing phase	0.00	0.00	0.00	0.00

Status	From Epoch	To Epoch	Duration
Fixed	02/21/2020 11:37:42	02/21/2020 12:28:12	00:50:30

Computed Ionospheric Model

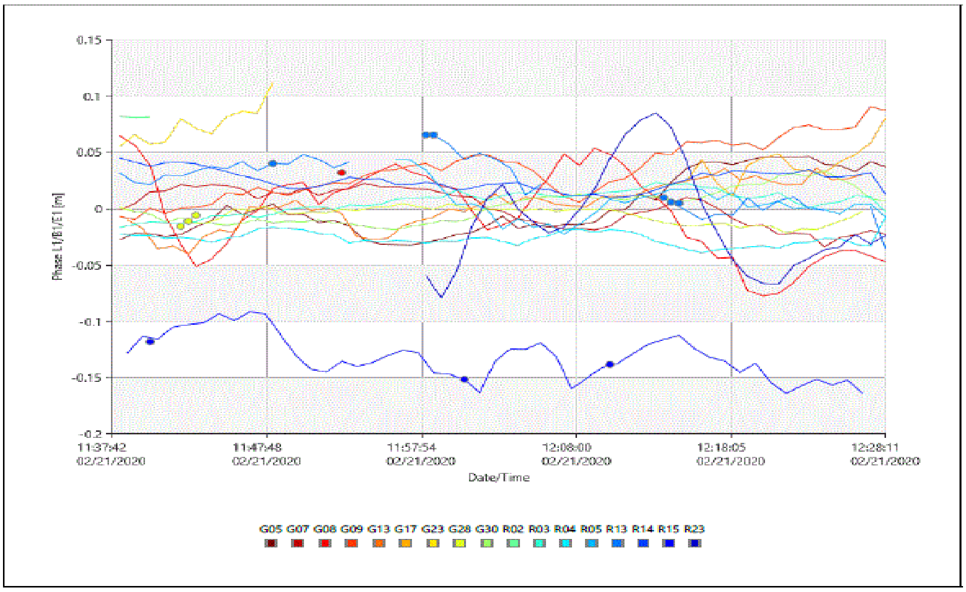
Models: 1
Sampling Rate: 30 sec
Height of Single Layer: 350 km

Model 1

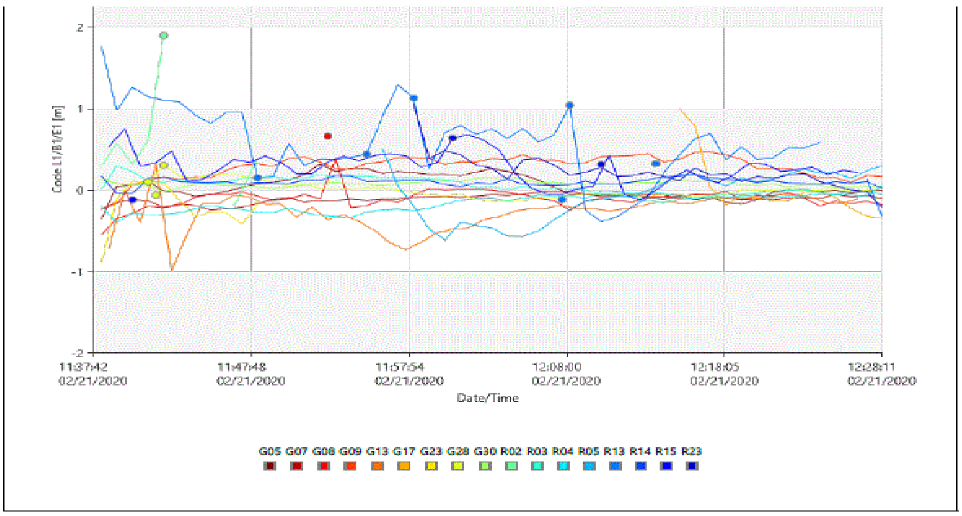
Origin Latitude: 36° 09' 35.47" N
Origin Longitude: 44° 00' 39.38" E
Origin Date/Time: 02/21/2020 08:59:35

Deg. Latitude	Deg. Time	Value	RMS
0	0	0.6793315234	0.0032581661
0	1	0.3201758281	0.0036768742
0	2	-0.0700527190	0.0014345442
1	0	-0.0952147676	0.0020883283
1	1	-0.0521350996	0.0015323139

Residuals



Tracking Status



Phase Residuals L1/B1/E1 - Single Differences

Appendix 2: Quality report

Quality Report

Generated with Pix4Denterprise version 4.4.12

Help to analyze the results in the Quality Report

Additional information about the sections

Click here for additional tips to analyze the Quality Report

Summary

Project	OmerHeroe-Said Ahmadan
Processed	2020-03-02 11:31:55
Camera Model Name(s)	FC6310_8.8_5472x3648 (RGB)
Average Ground Sampling Distance (GSD)	1.56 cm
Area Covered	1.045 km^2 / 104.4911 ha / 0.40 sq. mi. / 258.3369 acres
Time for Initial Processing (without report)	04m:12s

Quality Check

Images	median of 4059 keypoints per image	✓
Dataset	302 out of 311 images calibrated (97%), all images enabled	✓
Camera Optimization	0.7% relative difference between initial and optimized internal camera parameters	✓
Matching	median of 1510.11 matches per calibrated image	✓
Georeferencing	yes, 4 GCPs (4 3D), mean RMS error = 0.0156 m	✓

Preview

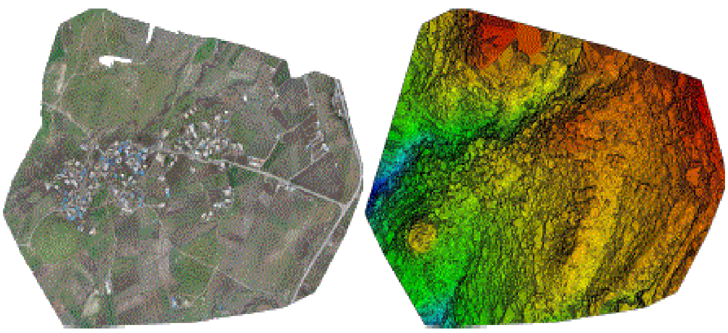


Figure 1: Orthomosaic and the corresponding sparse Digital Surface Model (DSM) before densification.

Initial Image Positions

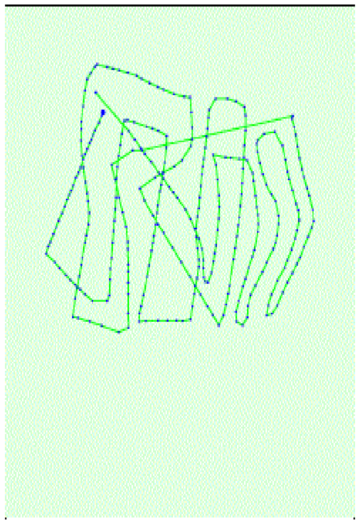
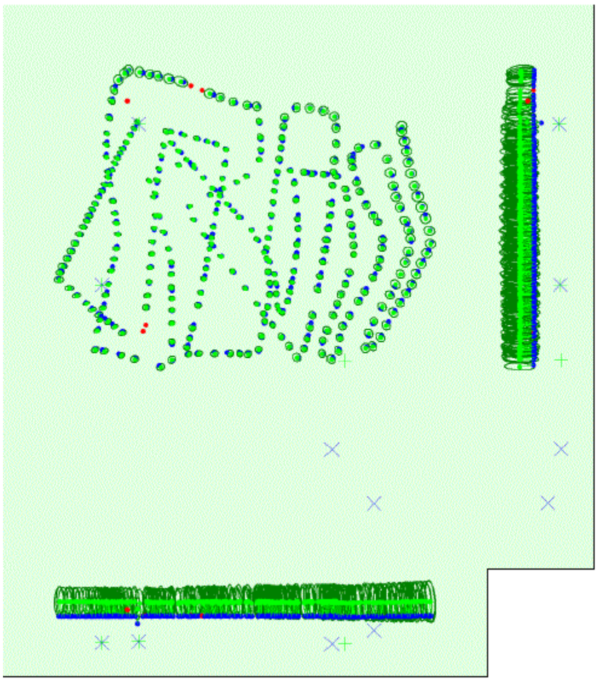
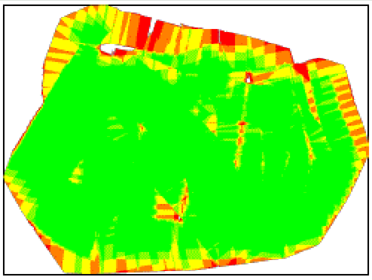


Figure 2: Top view of the initial image position. The green line follows the position of the images in time starting from the large blue dot

Computed Image/GCPs/Manual Tie Points Positions

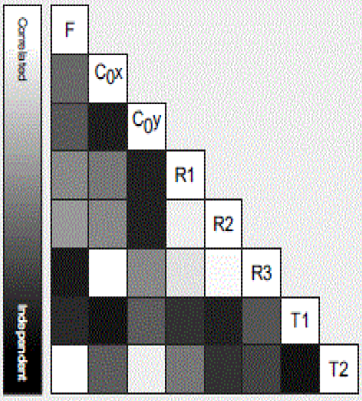


Uncertainty ellipses 100x magnified

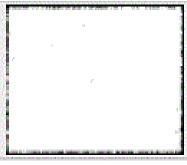


Number of overlapping images: 1 2 3 4 5+

Figure 4: Number of overlapping images computed for each pixel of the orthomosaic.
Red and yellow areas indicate low overlap for which poor results may be generated. Green areas indicate an overlap of over 5 images for every pixel. Good quality results will be generated as long as the number of keypoint matches is also sufficient for these areas (see Figure 5 for keypoint matches).



The correlation between camera internal parameters determined by the bundle adjustment. White indicates a full correlation between the parameters, ie. any change in one can be fully compensated by the other. Black indicates that the parameter is completely independent, and is not affected by other parameters.



The number of Automatic Tie Points (ATPs) per pixel, averaged over all images of the camera model, is color coded between black and white. White indicates that, on average, more than 16 ATPs have been extracted at the pixel location. Black indicates that, on average, 0 ATPs have been extracted at the pixel location. Click on the image to the see the average direction and magnitude of the re-projection error for each pixel. Note that the vectors are scaled for better visualization. The scale bar indicates the magnitude of 1 pixel error.

Bundle Block Adjustment Details

Number of 2D Keypoint Observations for Bundle Block Adjustment	476371
Number of 3D Points for Bundle Block Adjustment	179407
Mean Reprojection Error [pixels]	0.015

Internal Camera Parameters

FC6310_8.8_5472x3648 (RGB). Sensor Dimensions: 12.833 [mm] x 8.556 [mm]

EXIF ID: FC6310_8.8_5472x3648

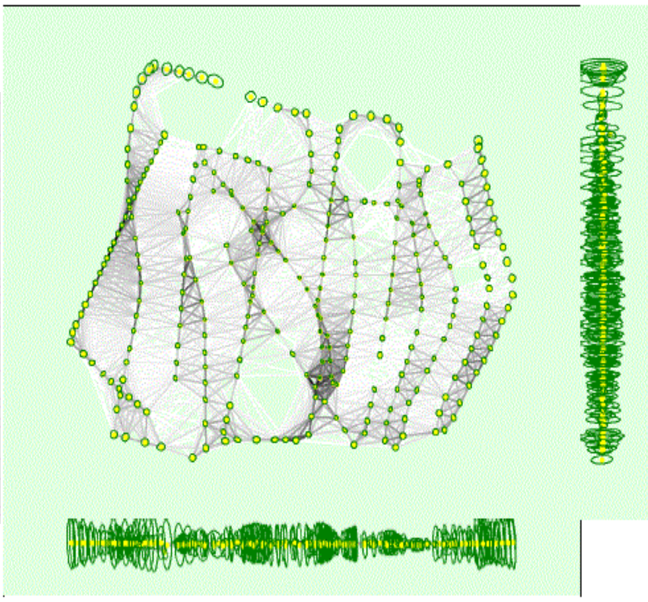
	Focal Length	Principal Point x	Principal Point y	R1	R2	R3	T1	T2
Initial Values	3752.229 [pixel] 8.800 [mm]	2736.000 [pixel] 6.417 [mm]	1824.000 [pixel] 4.278 [mm]	0.000	0.000	0.000	0.000	0.000
Optimized Values	3725.909 [pixel] 8.738 [mm]	2726.918 [pixel] 6.395 [mm]	1869.535 [pixel] 4.385 [mm]	0.002	-0.003	0.005	0.001	-0.000
Uncertainties (Sigma)	12.749 [pixel] 0.030 [mm]	0.548 [pixel] 0.001 [mm]	0.469 [pixel] 0.001 [mm]	0.000	0.001	0.001	0.000	0.000

2D Keypoints Table

	Number of 2D Keypoints per Image	Number of Matched 2D Keypoints per Image
Median	4059	1510
Min	2819	236
Max	5389	2838
Mean	4090	1577

3D Points from 2D Keypoint Matches

	Number of 3D Points Observed
In 2 Images	122926
In 3 Images	28910
In 4 Images	12387
In 5 Images	6792
In 6 Images	3745
In 7 Images	2101
In 8 Images	1120
In 9 Images	745
In 10 Images	333
In 11 Images	178
In 12 Images	98
In 13 Images	47
In 14 Images	13
In 15 Images	10
In 16 Images	2



Uncertainty ellipses 100x magnified

Number of matches 25 109 219 329 438 548 658 767 877 987

Figure 5: Computed image positions with links between matched images. The darkness of the links indicates the number of matched 2D keypoints between the images. Bright links indicate weak links and require manual tie points or more images. Dark green ellipses indicate the relative camera position uncertainty of the bundle block adjustment result.

Absolute Geolocation Variance

Min Error [m]	Max Error [m]	Geolocation Error X [%]	Geolocation Error Y [%]	Geolocation Error Z [%]
-	-15.00	0.00	0.00	0.00
-15.00	-12.00	0.33	0.33	0.00
-12.00	-9.00	2.32	5.63	0.00
-9.00	-6.00	1.99	8.94	0.00
-6.00	-3.00	5.63	12.25	0.66
-3.00	0.00	40.07	22.19	47.68
0.00	3.00	38.41	26.16	46.03
3.00	6.00	6.62	10.93	5.63
6.00	9.00	3.64	5.30	0.00
9.00	12.00	0.99	7.95	0.00
12.00	15.00	0.00	0.33	0.00
15.00	-	0.00	0.00	0.00
Mean [m]		0.012	0.013	-0.014
Sigma [m]		0.014	0.013	0.012
RMS Error [m]		0.012	0.013	0.015

Min Error and Max Error represent geolocation error intervals between -1.5 and 1.5 times the maximum accuracy of all the images. Columns X, Y, Z show the percentage of images with geolocation errors within the predefined error intervals. The geolocation error is the difference between the initial and computed image positions. Note that the image geolocation errors do not correspond to the accuracy of the observed 3D points.

Geolocation Bias	X	Y	Z
Translation [m]	0.012	0.015	-0.015

Bias between image initial and computed geolocation given in output coordinate system.

DECLARATION

I, undersigned *OMER AHMED IBRAHIM* (NEPTUN CODE: *FFCT0M*), declare that the present master's thesis is my original intellectual product in full and that I have not submitted any part or the whole of this work to any other institution. Permissions related to the use of copyrighted sources in this work are attached.

I AGREE to the publication of the accepted master's thesis in pdf form on the website of the Department of Cartography and Geoinformatics.

Budapest, *15, May 2020*

(signature of the student)