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Mapping the Cultural Tourism Complex of Nagari Pariangan Using UAV and Geographic Information Systems

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ABSTRACT

The development of spatial data utilization has increased dramatically in the past decade. This is related to the widespread use of Geographic Information Systems (GIS) and the advancement of technology in acquiring spatial data. High-tech tools like UAVs (Unmanned Aerial Vehicles) are increasingly integrated with Geographic Information Systems (GIS) and other surveying and mapping technologies, and are therefore used in various surveying, mapping, and spatial analysis projects. One of the advantages of UAVs is that the captured data can be processed through software, producing images with high spatial and temporal resolution. The use of this technology demonstrates that mapping can be performed using photographic data. The purpose of this research is to analyze and map the distribution of cultural tourism sites in detail using UAV and GIS in Nagari Tuo Pariangan, Tanah Datar Regency. Based on the results of the research, it can be concluded that data collection was carried out using a DJI Mavic Pro drone, capturing 228 aerial photos which were then exported into orthophotos. Orthophotos function as a reference for the distribution map of cultural tourism sites. In addition, a database was created, integrating spatial (geographic) and non-spatial (attribute) data, containing the necessary information for tourism objects, such as the owner's name, year of construction, function, and history of the object. There are 31 cultural tourism objects in Nagari Pariangan, Tanah Datar Regency, consisting of 8 Rumah Gadang (traditional houses), 11 Surau (small mosques), 3 hot spring pools, 3 stone inscriptions, 1 hot spring pool, 1 Tuo Pariangan Mosque, 1 river, 1 Tabuik Mosque, and 1 Saruang Hall. Most of these cultural tourism objects are well-maintained by their owners, while a small number are neglected due to a lack of adequate human resources.

Keywords: GIS, UAV, Surveying and Mapping, Spatial Analysis, Cultural Tourism Sites

1. Introduction

Nagari Tuo Pariangan is a traditional village renowned for its natural beauty and well-preserved culture. This village is located in the Tanah Datar Regency, West Sumatra, and has been chosen as one of the most beautiful villages in Indonesia. The tourism potential of Nagari Tuo Pariangan includes its stunning natural scenery, rich cultural heritage, and numerous historical relics. The village also houses the oldest mosque in Tanah Datar, called Al Ishlah Mosque, along with various other monuments and historical sites. Nagari Tuo Pariangan has areas that are difficult to reach by conventional mapping methods. The steep terrain and complex contours pose challenges for manual mapping [1].

Given the steep terrain of the area, the use of UAVs in hard-to-reach locations allows us to cover large areas more efficiently [2-3]. Previously, the mapping of the cultural tourism complex had not been carried out

comprehensively. The lack of accurate data and information regarding cultural, historical, and tourism infrastructure features can be an obstacle to effective tourism management and promotion [4]. Mapping using UAV assistance can help collect more complete and detailed data. The mapping of the cultural tourism complex is also important for conservation purposes and the preservation of cultural heritage [5-8].

However, the development of spatial data utilization has increased drastically in the past decade. This is related to the widespread use of Geographic Information Systems (GIS) and advancements in technology for acquiring spatial data. High-tech tools such as UAVs (Unmanned Aerial Vehicles) are becoming more integrated with GIS and other surveying and mapping technologies, and are therefore used in various surveying, mapping, and spatial analysis projects [9-10]. One of the advantages of UAVs is that the captured data can be processed by software to produce images with high spatial and temporal resolution [12]. The use of this technology demonstrates that mapping can be done using photographic data [13]. The purpose of this research is to analyze and map the distribution of cultural tourism points in detail using UAV (Unmanned Aerial Vehicle) and GIS (Geographic Information Systems) in Nagari Tuo Pariangan, Tanah Datar Regency. The benefits of this research, overall, are to provide spatial information such as a map of the distribution of cultural tourism objects in the Nagari Pariangan complex area, and to facilitate the identification and classification of economic and cultural potentials in Nagari Pariangan.

2. Reseacrh Methodology

This research aims to identify the distribution of cultural tourism sites and uncover the history of each tourism object in Nagari Pariangan, Tanah Datar Regency. The study employs UAVs and Geographic Information Systems (GIS). This research is a quantitative descriptive study, with data collection conducted through direct field surveys using standardized measuring tools, questionnaires, and observations that generate numerical data. The research location is in Nagari Pariangan, Pariangan Subdistrict, Tanah Datar Regency, West Sumatra Province, with an area of approximately 10 hectares. The map coordinates are -0.443659, 100.494930. The research location is shown in Figure 1.

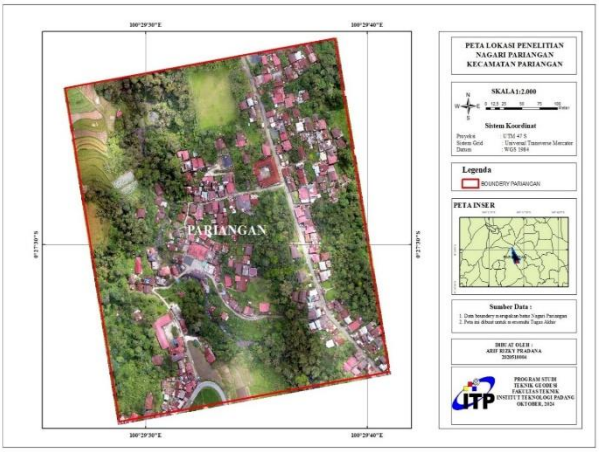


Figure 1. Research Location

This research was conducted in several stages, as indicated by the flowchart in Figure 2 where the hardware *and* software required during the research and data processing for this study was show in Table below. The explanation of the flow diagram is as follows:

1. The GNSS survey is a measurement step using the static method for creating four GCP which were processed using Trimble Business Central to obtain the coordinates for the GCPs. The purpose of using GCPs is that they are a determining factor for the geometric accuracy of the processed imagery (orthophoto), The NTRIP measurements for the ICP were conducted for ten points, which will later be used for orthophoto accuracy testing.
2. The initial step in the photogrammetry phase is to define the AOI (Area of Interest) with an area of 10 hectares. Next, premarking is conducted, which serves as markers for the GCP within the AOI. After the premarking and AOI have been established, the next step is to plan the UAV flight according to the previously determined AOI. The flight is then carried out with the following parameters: Flight Altitude of 110 meters, Side Overlap of 70%, Front Overlap of 80%, Mapping Flight Speed of 7 m/s, and GSD (Ground Sampling

Distance) of 2.18 cm/px. Aerial photos are taken vertically to maximize the quality of the images. For processing the aerial photos, Agisoft Metashape software is used, which will later be exported in the form of orthophoto format.

3. Photo geotagging is the process of adding geographic location information (geolocation) to photos after they have been taken.

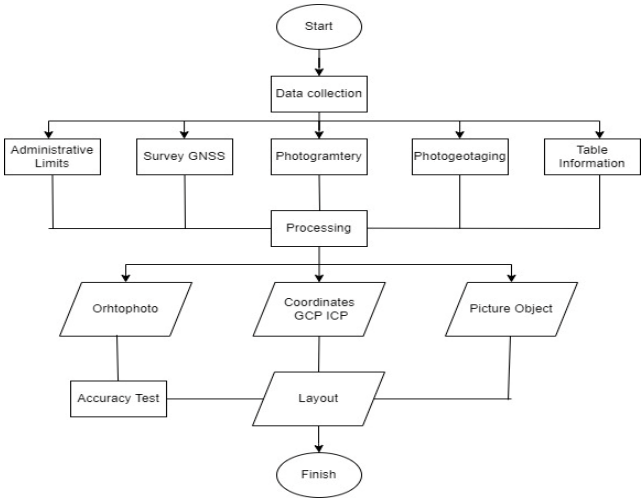


Figure 2. Research Flow Diagram

Table 1. Types of Hardware

Hardware	Utility
Laptop Asus TUF Gaming A15	Report Writing and Data Processing
Drone DJI Mavic Pro	To capture aerial photographs
Handphone IPhone XR 128GB	To capture marking data
Geodetic GPS	To capture coordinate data

Table 2. Types of Software

Software	Utility
Agisoft Metashape	For processing aerial photograph data
Google Earth Pro	To view the research location in a rough manner
TBC	For processing GNSS data
Microsoft Word	For report preparation
SW Maps	For capturing photo data.
ArcGIS	For database processing.
QGIS	To make the database online.

3. Results and Discussion

Results of Static GNSS Data Processing

The results of processing RINEX data from static measurements, which have been processed using Trimble Business Center (TBC) software, will produce coordinate data. The coordinate system used is the Universal Transverse Mercator (UTM) with units in meters. The resulting GCP coordinate data serves as reference points for ICP measurements and aerial photographs. Static data for creating GCP was collected over 1 hour, with a total of 4 GCP points using a GNSS geodetic GPS CHC i50 device. The resulting GCP points were tied to the CORS BIG Padang Panjang at a distance of approximately 13 km. The processing of this static data resulted in coordinates for *Easting, Northing, Elevation, Easting Error, Northing Error, and Elevation Error* with *a solution type of fixed*, *a 5-second interval*, and an *elevation mask of 10°*. The highest error was found at GCPSWH, with an *Easting error* of 0.070, a *Northing error* of 0.056, and an *Elevation error* of 0.468.

Table 4. The results of the GCP coordinates.

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)
GCPTK	666028,431	0,059	9949208,631	0,049	845,640	0,370
GCPSWH	665947,572	0,070	9949437,780	0,056	859,119	0,468
GCPLP	666108,097	0,050	9949480,957	0,043	861,281	0,377
GCPRMH	666206,730	0,065	9949382,893	0,051	849,466	0,462
panj	653518,392	0,000	9948448,176	0,000	721,150	0,000

Results of NTRIP GNSS Measurements

The GNSS measurements using the NTRIP method were conducted in the Nagari Pariangan complex area, which served as ICP points for orthophoto accuracy testing, with a sample size of 10 points. Measurements were carried out after obtaining the orthophoto results from the Agisoft Metashape processing, and the ICP points were marked by copying the coordinate points as a reference for accuracy testing in the field. These points were then compared with the ICP points measured in the field.

Table 5. Sample GNSS NTRIP measurement results

POINT	X	Y	Z	INFROMATION
P1	666135.214	9949552.421	861.548	In front of the field gate.
P2	666189.584	9949400.396	846.462	At the corner of the road intersection.
P3	666151.115	9949396.394	847.947	Near the Balai Saruang.
P4	666222.261	9949300.947	839.132	At the corner of the road intersection.
P5	666242.454	9949259.486	835.935	Near the grave of Tantejo Gurhano.
P6	666249.671	9949232.833	834.743	At the corner of the road intersection.
P7	666105.197	9949251.452	825.102	Near the bathing steps.
P8	666035.611	9949220.751	843.894	School fence
P9	666093.236	9949148.802	838.809	Near the billboard.
P10	666065.078	9949305.197	823.363	At the corner of the fish pond.

Results of Aerial Photo Accuracy Testing

In Table 6, the horizontal accuracy obtained using ICP (Iterative Closest Point) is shown, with a value of 0.613 meters. The results of this accuracy test were derived using the ICP coordinates and the coordinates of the orthophoto, which were digitized using the accuracy testing formula described in the research methodology.

Table 6. Result CE90

Horizontal Accuracy Test (CE 90) Aerial Photos of Nagari Pariangan							
POINT	FIELD COORDINATES (TM3 Zona 47.2)		PHOTO COORDINATES (TM3 Zona 47.2)		Square		
	X	Y	X	Y	(XL-XF)2	(YL-YF)2	DX2+DY2
ICP 01	666136.514	9949552.621	666136.333	9949552.744	0.0328588128792	0.0150197724841	0.047878585
ICP 02	666191.199	9949399.406	666191.207	9949399.337	0.0000709637760	0.0047375343171	0.004808498
ICP 03	666151.805	9949395.294	666151.986	9949395.573	0.0329037832199	0.0781005806357	0.111004364
ICP 04	666224.077	9949299.047	666224.082	9949298.862	0.0000302280035	0.0342495945061	0.034279823
ICP 05	666245.054	9949257.286	666244.944	9949257.161	0.0121952266275	0.0156793521381	0.027874579
ICP 06	666251.680	9949229.233	666252.091	9949229.286	0.1691685125412	0.0027614963480	0.171930009
ICP 07	666105.162	9949249.152	666105.351	9949248.876	0.0358447129070	0.0763461716428	0.112190885
ICP 08	666036.210	9949218.851	666035.216	9949218.220	0.9887180016460	0.3984224020608	1.387140404
ICP 09	666093.236	9949144.502	666093.070	9949144.678	0.0276128012376	0.0309459355254	0.058558737
ICP 10	666064.578	9949303.097	666064.646	9949303.045	0.0046215523330	0.0026647037285	0.007286256
					Sum		**1.962952139**
					Mean		**0.163579345**
					Root (RMS)		**0.404449434**
					Akurasi Horizontal (CE90%)		**0.613752017**

In Table 7, the LE90 calculation is used to determine the map scale based on BIG Regulation No. 14 of 2014 regarding the accuracy of RBI maps, using the formula: LE90 = 1.6499 x RMSEz. The result obtained for LE90 in this data is 2.500 meters.

Table 7. Result LE90

Vertical Accuracy Test (LE 90) Aerial Photo of Nagari Pariangan				
Titik	**FIELD COORDINATES (TM3 Zona 47.2)**	**PHOTO COORDINATES (TM3 Zona 47.2)**	**Square**	
	ZL	ZF	ΔZ	ΔZ^2
ICP 01	861.548	860.906	0.6420000000001	0.4121640000001
ICP 02	846.462	847.504	-1.0420000000000	1.0857640000001
ICP 03	847.947	848.924	-0.9770000000000	0.9545290000000
ICP 04	839.132	837.305	1.8270000000000	3.3379290000000
ICP 05	835.935	837.147	-1.2120000000001	1.4689440000003
ICP 06	834.743	836.021	-1.2779999999999	1.6332839999998
ICP 07	825.102	823.225	1.8770000000000	3.5231289999998
ICP 08	843.894	840.755	3.1390000000000	9.8533210000001
ICP 09	838.809	840.903	-2.0940000000001	4.3848360000002
ICP 10	823.363	822.409	0.9540000000001	0.9101160000001
			Sum	**27.5640160000003**
			Mean	**2.297001333**
			Root (RMS)	**1.515586135**
			Akurasi Vertikal (LE90%)	**2.500565565**

Results of Aerial Photo Processing

A total of 228 aerial photos were captured in a single flight at an altitude of 110 meters, with a Front Overlap of 80% and a Side Overlap of 70%. The resulting aerial photos were processed using Agisoft Metashape, resulting in an orthophoto. An orthophoto is an aerial image that has been geometrically corrected to have a uniform and accurate scale. This orthophoto is tied to 4 different GCP points within the aerial photo area. The resulting orthophoto is shown in Figure 3.

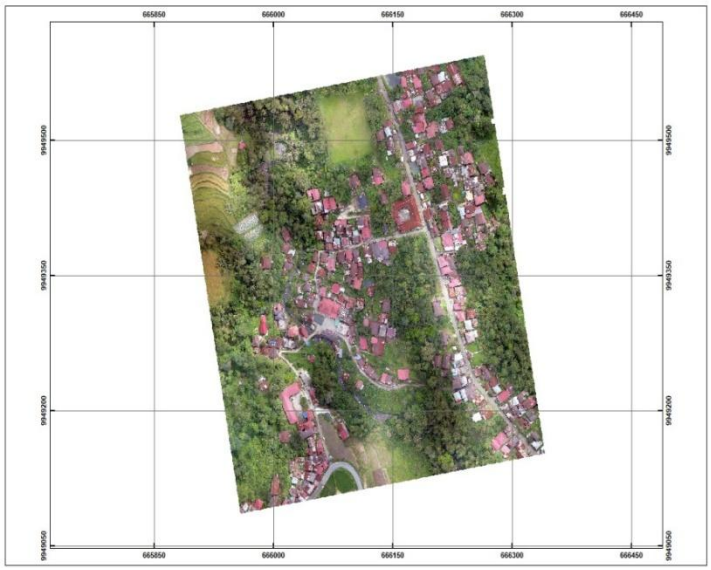


Figure 3. Orthophoto

Results Database

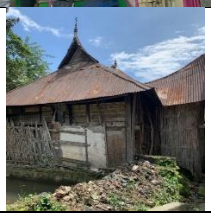
From the results of photogrammetry and field observations, information was obtained regarding the building owners and cultural tourism objects such as Masjid Tuo Pariangan, Batu Prasasti, Kuburan Panjang, Kolam Rangek Rajo, Rumah Gadang, and Surau. The necessary information gathered includes the building owners, year of construction, building function, number of rooms, and the history of the buildings, which has been summarized in the following format Table 8.

Table 8. Result Database

No	Name Object	Information	Figure
1	Mosque Ishlah Pariangan	The Tuo Pariangan Mosque was first built in 1803 and has 2 rooms, namely the micrat and the free room. This mosque was built through mutual cooperation by the community which reflects the values of togetherness in Minangkabau culture.	
2	Inscription Agam	Batu Lantak Tigo was created in the 13th to 14th century AD during the reign of King Adityawarman, and it features inscriptions in Sanskrit. This stone measures 1.6 meters in height, 2.6 meters in width, and 1.6 meters in thickness, with a distance of 70 meters between each stone.	
3	Inscription Lima Puluh Kota	Batu Lantak Tigo was created in the 13th to 14th century AD and served as a marker for the formation of the region and the early dissemination of customs and communities.	
4	Inscription Pariangan	Batu Lantak Tigo was created in the 13th to 14th century AD during the reign of King Adityawarman and features inscriptions in Sanskrit. It is located in Luhak Limo Puluah Kota and Luhak Agam. This stone is also often referred to as Tungku Tigo Sajarangan.	
5	Rangek Rajo Pool	This pond was built around the 18th century during the reign of Rajo (King) Pariangan, who was one of the first kings in Minangkabau. The owner of this pond is a local resident who holds the title Datuak Rajo Api.	
6	Grave Tantejo Gurhano	According to local folklore, Rajo Tantejo was of tall stature, which allowed him to build his palace while sitting down. He is said to be the founder of Istano Basa Pagaruyuang. The grave measures 25 meters in length and 7 meters in width; however, local residents mention that if measured in detail, the length of the grave can change over time.	

7	Men's hot water taps	This hot spring was built in 1958 by local residents, and its origin is located in Nagari Guguak Tinggi Pariangan.	
8	Women's hot water taps	The origin of this hot spring is located in Nagari Guguak Tinggi Pariangan. Due to the mystical properties of the spring, a skilled person redirected it by covering the source with a black cat, causing the spring to emerge or explode in Nagari Pariangan, near the Masjid Tuo Pariangan.	
9	Lower women's hot water tap	According to researchers, this hot spring is formed due to geothermal activity, where hot water naturally emerges from the Earth's crust. This activity occurs near an active volcano, namely Mount Marapi.	
10	Balai Saruang	As of 2024, the Balai Saruang is managed by Datuak Koto and was established in 1930. It consists of a single room, which is why it is referred to as Balai Saruang.	
11	Rumah Gadang Datuak Gaga	The Rumah Gadang Datuak Gaga was built in 1940 as a communal living space for an extended family or clan, typically consisting of several generations.	
12	Rumah Gadang Datuak Kayo	The Rumah Gadang Datuak Kayo was built in 1812, and each family living in the Rumah Gadang has a blood connection through the maternal line.	
13	Rumah Gadang Datuak Panduko	The Rumah Gadang Datuak Panduko has three rooms and contains a sacred sword that can only be seen by individuals who have had verses recited to them by Datuak Panduko.	

14	Rumah Gadang Datuak Pangulu	The Rumah Gadang Datuak Pangulu was built in 1809 and features distinctive characteristics, such as a reception area at the entrance for hosting wedding ceremonies, with rooms lined up at the back. Additionally, Rumah Gadang Datuak Pangulu consists of three rooms.	
15	Rumah Gadang Datuak Pono	The Rumah Gadang Datuak Pono was built in 1816 and consists of three rooms.	
16	Rumah Gadang Datuak Suri Maharajo	The Rumah Gadang Datuak Suri Maharajo was built in 1820 and consists of three rooms.	
17	Rumah Gadang Masyarakat	The Rumah Gadang Masyarakat was built in 1960 as a communal living space for an extended family or clan, with each family having a blood connection through the maternal line. This Rumah Gadang consists of three rooms. Inside, there is an old photograph of the mosque from around the 1990s.	
18	Rumah Gadang Perorang	The Rumah Gadang Perorang was built in 1962 and consists of three rooms. However, in the present day, this Rumah Gadang has become abandoned due to issues related to clan disputes..	
19	Surau Angko Ampek	Surau Angko Ampek is a place for learning spiritual knowledge, often referred to as "terikat." Individuals who study here are prohibited from associating with others to ensure their knowledge remains intact; if they socialize, their knowledge will be nullified for 40 days. In addition to being a place for spiritual learning, Surau Angko Ampek also serves as a site for studying Islamic religious teachings. This surau was established in 1958, consists of three rooms, and is managed by Haji Abdul Manam.	

20	Surau Datuak Gaga	Surau Datuak Gaga was built in 1938 and features three rooms across two floors. Generally, surau serves as a place for learning traditional knowledge, such as studying Kato Nan Ampek, Minang proverbs, and engaging in discussions and consensus-building.	
21	Surau Datuak Kayo	Surau Datuak Kayo was built in 1820 and consists of three rooms. It serves as a place for learning traditional customs, including food preparation (tukang pantan) and the practice of welcoming sumando in Minangkabau culture.	
22	Surau Datuak Maka	Surau Datuak Maka was built in 1930 and consists of three rooms. Additionally, this surau serves as a place for single men to stay, including those who have divorced in their marital relationships.	
23	Surau Datuak Pono	Surau Datuak Pono was built in 1931 and consists of three rooms. Generally, surau serves as a place for learning traditional knowledge, including studying Kato Nan Ampek, Minang proverbs, and engaging in discussions and consensus-building.	
24	Surau Datuak Rajo Api	Surau Datuak Rajo Api was built in 1932 and consists of three rooms. Generally, surau serves as a place for learning traditional knowledge, including studying Kato Nan Ampek, Minang proverbs, and engaging in discussions and consensus-building.	
25	Surau Datuak Sinaro	Surau Datuak Sinaro was built in 1939 and consists of three rooms. Generally, surau serves as a place for learning traditional knowledge, including studying Kato Nan Ampek, Minang proverbs, and engaging in discussions and consensus-building.	
26	Surau Datuak Suri Dirajo	Surau Datuak Suri Dirajo was built in 1935 and consists of three rooms. Generally, surau serves as a place for learning traditional knowledge, including studying Kato Nan Ampek, Minang proverbs, and engaging in discussions and consensus-building.	

27	Surau Dusun Tigo Luak	Surau Dusun Tigo Luak was built in 1934 and consists of three rooms. Additionally, this surau serves as a place for single men to stay, including those who have divorced in their marital relationships.	
28	Surau Gadang	Surau Gadang was built in 1932 and consists of three rooms. Generally, surau serves as a place for learning traditional knowledge, including studying Kato Nan Ampek, Minang proverbs, and engaging in discussions and consensus-building..	
29	Surau Tabiang	Surau Tabiang serves as an official TPA (Taman Pendidikan Al-Qur'an) for children to study and learn religious teachings, and it remains active to this day.	
30	Tabuik Masjid	In the context of Minangkabau, Tabuik is a celebration brought by the Muslim community from India who follow the Shia sect in the 19th century.	
31	River	The river flows from upstream to downstream, originating from the direction of Mount Marapi.	

Layout

The map of cultural tourism objects in Nagari Tuo Pariangan was created using ArcGIS software, with a layout that adheres to cartographic principles. This map includes a legend that provides information on buildings, vegetation, graves, traditional houses (Rumah Gadang), suraus, inscriptions (Prasasti), mosques, hot springs, and roads. The map has a scale of 1:3000, using the UTM Zone 47S coordinate system and WGS 1984 datum, with units in meters.

The map contains several photos that provide a visual representation of the types of buildings found in Nagari Tuo Pariangan. Additionally, in the bottom right corner, there is a broader location map that shows the position of Pariangan in West Sumatra. This location is known as one of the oldest villages and a center of Minangkabau civilization, with traditional architecture that has been well-preserved.
In the main section of the map, the layout of important buildings in Nagari Tuo Pariangan is displayed, such as the Rumah Gadang (traditional Minangkabau house), surau (place of worship), mosque, and several historic inscriptions and graves. Some of the buildings featured on the map are also accompanied by photos, providing a visual representation of these objects. This includes cultural landmarks such as Surau Limo Kaum, Rumah Gadang Datuk Perpatiah, and Makam Simpang. In the bottom right corner of the map, there is a broader

administrative area map, showing the location of Nagari Tuo Pariangan within the context of Tanah Datar Regency and its surroundings. Overall, this map offers a practical guide for visitors looking to explore the cultural richness and history of Nagari Tuo Pariangan, which is known as one of the most beautiful villages in the world due to its distinctive architectural heritage and profound historical significance in Minangkabau culture

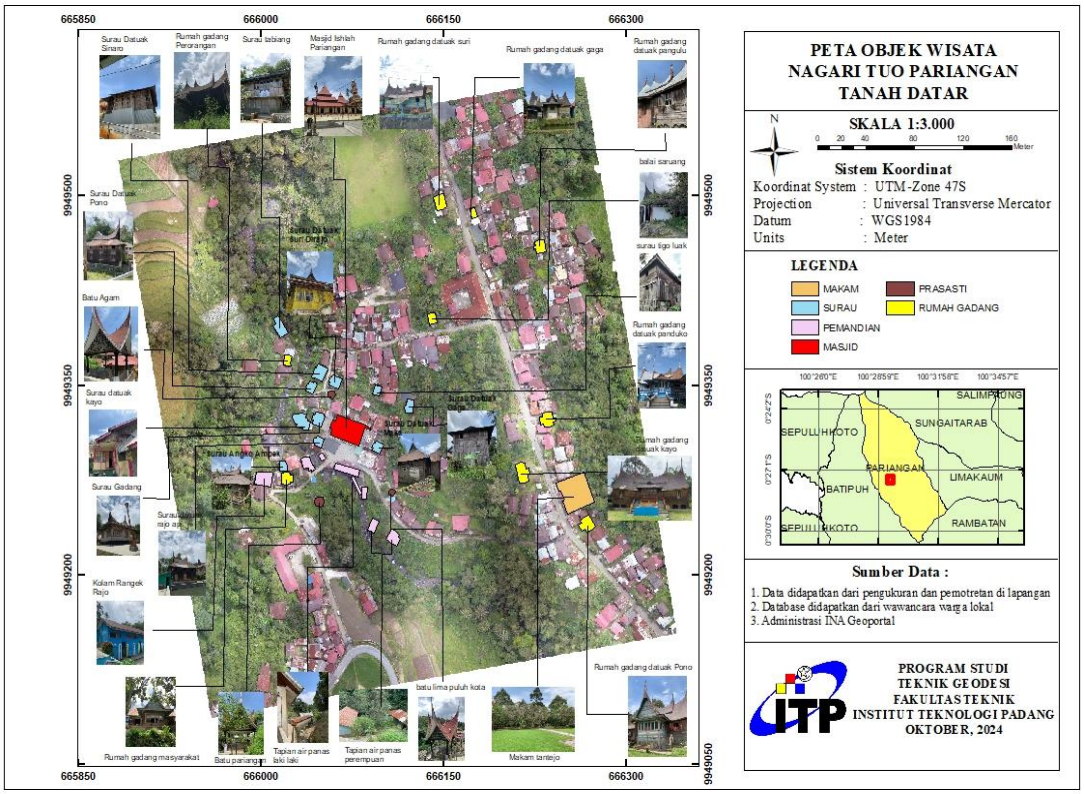


Figure 7. Result Layout

4. Conclusion

Based on the results of the conducted research, it can be concluded that data collection using the DJI Mavic Pro drone resulted in 228 aerial photos, which were then exported into an orthophoto. The orthophoto serves as a reference for the map of cultural tourism object distribution. Additionally, a database was collected in the form of a digital dataset that integrates spatial (geographic) and non-spatial (attribute) data, containing the necessary information for each object, such as the owner's name, year of creation, function, and history of the object. There are 31 cultural tourism objects in Nagari Pariangan, Tanah Datar Regency, including 8 Rumah Gadang, 11 suraus, 3 hot springs, 3 inscriptions (Batu Prasasti), 1 hot spring pond, 1 Masjid Tuo Pariangan, 1 river, 1 Tabuik Masjid, and 1 Balai Saruang. Most of the tourism objects are well-maintained by their owners, while a small portion is neglected due to a lack of qualified human resources.

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