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| RESEARCH ARTICLE

A Comparative Analysis of Turkey's and Iran's Land Management Systems and Technological Infrastructure

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| ABSTRACT
The comparison of cadastral systems worldwide proves challenging, given the profound cultural, linguistic, technical, and social disparities among countries. This complexity extends to the examination of data, encompassing issues related to land policy, laws, regulations, ownership, management, and technology within each nation's cadastral framework, forming the foundation for numerous studies. This article delves into a comparative analysis of the cadastral systems of Turkey and Iran, two nations sharing a common geography, similar cultures, and identical religious beliefs. The focus lies on content examination, exploring historical development, organizational structure, and the comprehensive status of cadastres across both countries. The study further scrutinizes the technologies employed and the mapping infrastructure integral to each nation's cadastral system. This research offers valuable insights into the similarities and differences between these two countries, shedding light on the intricate dynamics of cadastral systems within a shared cultural and geographical context.

| KEYWORDS

Cadastral System, Turkey, Iran, Comparison

| ARTICLE INFORMATION

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1. Introduction

The land, which has been the main place of human settlement and human activities since its early days, is one of the most basic and important issues for all societies today. Throughout history, the delineation of land boundaries through measurement, valuation, and the recording of ownership has played a pivotal role in ensuring the robust functioning of states and maintaining social order. The increasing complexities arising from societal development have elevated the significance of land ownership and boundary determination, leading to the establishment of cadastral systems.

Cadastral systems materialized through land registration and associated frameworks, function as essential reservoirs of data vital for diverse aspects of society. These systems play a pivotal role in ensuring precision in construction, providing security for property ownership, and ultimately fostering sustainable development. Despite the universal inclusion of fundamental cadastral elements such as property information, property area, and boundaries, the specific functions of cadastral systems exhibit divergence among countries, shaped by their distinct challenges and priorities.

Cultural, linguistic, technical, and social differences between nations contribute to the diverse nature of cadastral systems globally. Presently, comprehensive studies hinge upon comparing data related to land policy, laws, regulations, ownership, management, technology, and mapping infrastructure, forming the bedrock for cross-cultural analyses (Ting and Williamson, 2001; Ataç, 2019).

This article aims to scrutinize and compare the current state of cadastral systems in Turkey and Iran, employing a descriptive-analytical methodology. By delving into the distinct characteristics of these systems, the study seeks to unravel insights into their individual nuances and broader implications within the context of their cultural and geographical environments.

2. Overview and Analysis of the Cadastral System in Turkey

Turkey, with an area of 780,580 km^2 and a population of about 84 million, is a country located in the northern hemisphere. This country has a 499-km border with Iran, and citizens of the two neighboring countries create heavy traffic between countries in terms of tourism and trade. About 92.3 percent of Turkey's population lives in cities (URL-1).

First of all, in order to understand the content and the current situation of the Turkish cadastral system, which consists of two components, one is map production, which defines the geometrical status of land; the other is land registration, which defines land property records. It is necessary to take a brief look into land acquisition and instruments for land recording in two periods: The Ottoman Empire period and the Turkish Republic period.

In the Ottoman property system, almost all land was possessed by the empire, and land tenure was given to people who had financially supported the military organization during the wars. These people were called "DIRLIK, and they were allowed to collect taxes from farmers who ran agricultural facilities on these lands. In this context, land records, called 'TAHRIR', were organized by the government in order to define the boundaries and areas of lands textually.

However, this system did not last long due to financial and legal reasons. Therefore, the government set up a land registration system based on legislation (titles) and an administrative network in a more Westernized concept. On May 21, 1847, "DEFTERHANE-I AMIRE KALEMI," which was the foundation of today's General Directorate of Land Registry and Cadastre and land registration, was adopted.

From the foundation of the Ottoman Empire until the Balkan Wars (1912–1913), all registrations were executed textually and supplied with a governmental guarantee for property rights, even though the lack of maps that show the geometrical status of land (position, area, and other information) became a huge problem for maintaining this guarantee. Therefore, the first cadastral work was set up in a Westernized way with a law that came into force on February 5, 1912. With this law, the aim was to survey boundaries and estimate the values and incomes of all lands, but it was not successful because of World War I.

But, after the establishment of the Republic in 1924, the Turkish cadastre entered another important and historical stage. In the real sense, cadastral work started quickly after the establishment of this period to put an end to the property confusion experienced by the people during the Ottoman Empire period.

In 1924, the General Directorate of Land Registry was established, and subsequently, by merging other cadastral units with it, this organization was renamed the General Directorate of Land Registry and Cadastre (TKGM). In 1925, "Cadastre Law" No. 658 was put into effect. At the same time, the cadastral works started in the cities of Ankara, Istanbul, Izmir, Bursa, and Konya.

In parallel, in 1926, Turkish Civil Law (#743) entered into law, which presented the "private property concept" differently than in the Ottoman period and introduced the TKGM as the custodian of the Turkish cadastre.

After World War II, agricultural machinery was started to be used on large rural lands in Turkey, and the idea of determining the legal and geometrical status of lands in rural areas came to mind. Hence, the titling law was regenerated (#5602) in 1950 and enabled the execution of cadastral work in rural areas.

In 1987, a new definition of cadastre was spelled out in the New Cadastre Law (#3402), the purpose of which was to define real estate's legal status based on the country's cadastral topographical map, demonstrating its boundaries both on land and on maps. By this definition, the methodological difference between cadastral works in urban and rural areas was removed, and a single method was adopted for all countries.

From a technical perspective, the Turkish cadastral system is dealt with in three periods, including written, linear, and digital. A written cadastre means that cadastral information is expressed in words instead of geometrical data. Cadastral maps produced in the linear cadastral period constitute an important part of the archive. In this period, cadastral maps were produced using various methods at various scales. In addition, some of these maps do not have a coordinate system; some of them have been prepared based on the local or ED50 datum. These maps consist of graphic, photoplan, photogrammetric, and classic maps. Classic maps have been produced by prismatic and tacheometric survey methods (Ataç, 2019).

Changing cadastral surveying methods led to the beginning of the digital cadastral period after the 1980s. The cadastral sheets produced with these tools bases with respect to scale, accuracy, and method are shown in Table 1.

Table1. Turkish cadastre technical archive and their accuracy (Osman et al., 2020; Yildiz and Erden, 2021)

Production Method	**Scale**	**Datum**	**Number of Maps**	**Spatial Accuracy (m)**	**Rate in Archives (%)**
Graphic	1:500 – 1:10000	None	91,804	0.5 – 5.0	17.6
Photo Plan	Miscellaneous	None	1,782	-	0.3
Photogrammetry	1:5000	ED50	81,334	1.5	15.6
Classic	1:500 – 1:5000	Local/ED50	188,389	0.25 – 1.73	36.2
Digital	1:500 – 1:1000	ED50/ITRF96	154,008	0.08	29.5
Other	-	-	4220	-	0.8
Total			521,537	-	100

Table 1 shows that the spatial accuracy of the cadastral maps ranges from 0.08m to 1.73m depending on the cadastral map type and its scale. This accuracy expresses the error limit of the maps. The error limit is defined as the acceptable difference between the boundary of the real estate on the ground and the map values calculated according to the production method and scale of the cadastral maps. The maximum spatial error (error limit) of the maps varies according to the measurement method used and the scale of the cadastral map.

Error amounts in cadastral maps produced by the photogrammetric method are calculated from the following equation:

$$ds_{max} = 0.0003 \text{ m} \times M \quad \ldots\ldots\ldots (1)$$

Since the scales of the photogrammetric cadastral maps are 1/5000, the maximum spatial error is calculated as 1.5 m according to the (1) equation. If the cadastral spatial data is generated by the numerical method, the maximum spatial error should be less than 8 cm. It is difficult to state precisely the spatial data accuracy of graphic maps. In a pilot field study conducted by Coruhlu (2007), it was found that the spatial accuracy of graphic maps ranged from 0.5 m to 5.0 m (Yildiz and Erden, 2021).
Error amounts in cadastral maps produced with prismatic and tacheometric methods are presented in Table 2.

Table2. Spatial accuracy of classic cadastral map sheets (Yildiz and Erden, 2021)

Methods	**Prismatic Method**		**Tacheometric Method**		
Scales	1:500	1:1000	1:2000	1:2500	1:5000
ds_{max} (m)	0.25	0.35	1.15	1.22	1.73

After the foundation of the Republic of Turkey, cadastral works in this country were started in the real sense. In 1973, the total area where the cadastral works should be done was determined to be 430,000 square kilometers. Of this area, 410,000 square kilometers are rural areas, and 20,000 square kilometers are urban areas. Since then, almost 99% of this cadastral target had been carried out by the year 2022, and 57.7 million parcels were registered, but only less than one percent of the incomplete parcels due to refusal of cadastral work or disputed borders still remain. Of these, 33 million (57%) are digital format parcels with ground compatibility; however, 24.7 (43%) parcels have been temporarily converted to digital format (Osman et al., 2020; Yildiz and Erden, 2021). The realization ratios of cadastral works from 1925 to 2021 are seen in Table 3.

Table 3. Realization of the Turkish cadastral works (1925-2021) (Osman et al, 2020; Yildiz and Erden, 2021)

Period	Total Turkish Area (km^2)	Completion of Cadastral Work in (Urban and non-Urban) Areas		
		Total target area (km^2) (A)	Completed area (km^2) (B)	B/A (%)
1925-1984	780,580	430,000	226,522	52.7
1985-2000			136,595	31.8
2001-2021			64,383	14.9
Total	780,580	430000	427,500	99,4

During the last two decades, Turkey has taken important steps to provide a modern cadastral system. The "Land Registration and Cadastre Modernization Project" was implemented on August 13th, 2008, with the help of a World Bank fund, and it contains five fundamental components whose aims are to improve the quality of land registration and cadastral services to regenerate and update cadastral maps standing by registration information and digital cadastre, supply institutional improvement and human resources, develop institutional policies for real estate valuation, and project management with capacity improvement.

An important part of these projects is the construction of the Turkish permanent national GNSS network (TUSAGA-AKTIF/CORS-TR), which was completed in June 2013 with the cooperation of "The Directorate of Land Registry and Cadastre" and "General Command of Mapping.".

TUSAGA-Active System (Turkish National Permanent G.N.S.S. Network-Active) provides location information at any time and places it in an area within a few seconds with centimeter accuracy. The TUSAGA Active System is made up of 146 permanent GNSS stations in Turkey and the Turkish Republic of North Cyprus (Figure 1). All stations are transmitting 24-hour-long data to the main control system at the GDLRC via the Internet.

The TUSAGA-Active-Active is used in earthquake studies, improvement of weather forecasts, military activities, mapping, navigation, construction, logistics, and similar fields (Mekik et al., 2011; Akdemir, 2022; Ulger et al., 2015).

Figure 1. TUSAGA-Active GNSS Stations (Mekik et al, 2011)

According to the strategic plan of the General Directorate of Land Registry and Cadastre (TKGM), 2D Cadastral Updating and digitization are aimed to be completed in 2023 (Yildiz and Erden, 2021).

3. Overview and Analysis of the Cadastral System in Iran

Iran, with an area of 1,648,000 km^2 and a population of about 86 million, is a country located in the northern hemisphere. A significant part of the country's territory is desert; about 74.39 percent of Iran's population lives in cities (Ataç, 2019).

For the first time, the law for deeds and property registration was passed in April 1911 by the Iranian Parliament. Subsequently, the 126-article law for deeds and property registration was passed in March 1923, according to which the Iranian Deeds and

Property Registration Organization (IDPRO) was founded, and in addition, it became the custodian of property registration. With the establishment of IDPRO, it was expected that people would be encouraged to invest because of the judiciary and legal stability, and the government would also receive taxes from transactions (Iran Cadastre Report, 2009).

The first order of the registration organization regarding the cadastre dates back to 1955; in this order, the issuance of the ownership document was subject to the preparation of the cadastral registration map, although this order was never a basis or motivation for the cadastral mapping.

The real estate registration law in the form of cadastre was approved in 1972, and based on that, it was decided to prepare maps with a scale of 1:500 for urban areas and maps with a scale of 1:1000 for the outskirts of cities by the mapping organization. In this regard, the cities of Qazvin, Mashhad, and Abbas Abad in Tehran were selected as samples. Map preparation in these cities was done using photogrammetric and ground methods (areas that were not visible in the photo). As a result, more than 80% of the maps of Qazvin and Mashhad cities were prepared, but in Abbas Abad, Tehran, due to the lack of necessary manpower in the registration organization and a lack of will and sufficient support in this regard, they were never completed.

Subsequently, the cadastral work started again in 1990 with the formation of the Technical Council. The Council decided to prepare for the cadastral plan and execution work, to outline the required cadastral equipment, to determine the relevant costs and programs for the cadastral work, and to make the cadastral plan in twenty years, which includes four five-year plans.

This council held its weekly meetings until the end of 1990 and studied and examined the following detailed issues and then made a decision:

- Examining the work done before, collecting their results, and justifying the reasons for stopping and unsuccessful implementation of cadastral work in the past;
- Technical and economic justification of the plan in the first five years;
- Preparing a general report based on the real estate registration system and explaining the objectives of modern cadastre;
- Propose to start cadastral works for three areas: south of Tehran, Qeshm Azad region, and Khorramshahr city;
- Examining and providing training for employees of the relevant department at all levels to implement and maintain cadastral works.

Based on the above considerations, the cadastral project was started by recruiting university graduates who had completed relevant secondary education in accordance with the needs of the project and also by purchasing modern surveying equipment, including a total station, GPS satellite receivers, and photogrammetric analysis devices.

Investigations show that the efforts to implement the cadastral project in 1990 were due to administrative weakness, a lack of necessary cooperation and interactions between relevant organizations (National Mapping Organization and Deeds & Properties Registration Organization), a lack of expert staff and necessary resources, a lack of the necessary technical infrastructure, etc., which could not meet the necessary expectations. On the other hand, the lack of a regular land registration system and the slowness of the land registration process caused land grabbers to usurp government land.

The above cases made it necessary to foresee a comprehensive plan for the expansion of cadastral works in the entire territory of the country (urban and non-urban areas) and to appoint a trustee institution for cadastral implementation. Finally, a draft plan was prepared under the title (Comprehensive Cadastre Law) and was approved by the Islamic Council on February 2, 2015.

According to the Comprehensive Cadastre Law, the Deed and Property Registration Organization was designated as the main institution and implementer of cadaster throughout the country. The general and important points of this law are summarized as follows:

- ✓ Creation of a national mapping network throughout the country in an integrated manner;
- ✓ Preparation of cadastral maps of all properties (public and private) as well as pastures, forests, rivers, etc;
- ✓ Modification of the organizational structure of the Deeds & Properties Registration Organization to implement cadastral works;
- ✓ Using technologies, standards, and technical and legal guidelines to achieve a modern cadastral system;
- ✓ Matching the maps with the properties on the land and creating a comprehensive land information system according to modern technologies;
- ✓ Providing security and guaranteeing government and private properties;
- ✓ Keeping the land information system up-to-date, etc., constitutes the important issue of this law;

This law has been successful in solving many ambiguities and deficiencies, but it is not free from deficiencies either. However, the review of the operational plans of the Real Estate Registration Organization in 2018–2019 and the 2020–2023 four-year plan shows that despite the efforts made, this organization has not been able to achieve the set goals.

At the same time, the non-completion of 2D cadastral works throughout the country, legal deficiencies, inconsistency between registration and cadastral data, and a lack of practical action to update maps and the land information system are among other cases that have challenged the Iran cadastral system.

Currently, cadastral works are going on in both urban and rural areas, and the maps are prepared using photogrammetry and ground methods. It should be noted that the cadastral maps of 95 percent of urban areas have been prepared and are available on scales of 1:500, 1:1000, and 1:2000. Table 4 shows the cadastral survey of urban areas until 2019 (Iran Cadastre Report, 2009; Hajinezhad and Hassani, 2021; Shakeri, 2009).

Table 4. Realization of Iran's urban cadastral works (1990-2019)

Period	**Total Iran Area (km^2)**	**Completion of Cadastral Work in Urban Area**		
		Urban area (km^2) (A)	**Completed area (km^2) (B)**	**B/A (%)**
1990 - 2004	1,648,000	12,000	2053	17.1
2005 - 2009			4043	33.7
2010 - 2019			5304	44.2
Total	1,648,000	12,000	11400	95

The accuracy of the measurements, which have been determined by the National Mapping Organization, considering the scale and methods of measurement, is shown in Table 5:

Table 5. Accuracy and measurement methods

Methods	**Land Measurements (GNSS, Total station)**		**Photogrammetry**		
Scales	1:500	1:1000	1:500	1:1000	1:2000
ds_{max} (m)	0.01 – 0.20		0.05 – 0.20		

In accordance with the article of the Comprehensive Cadastre Law and the more accurate and integrated implementation of cadastral works at the country level, the country's deeds and property registration organization started the project of the integrated property positioning network (SHAMIM) in 2016.

SHAMIM is an integrated property positioning network that is used in mapping to determine the coordinates of properties on land. This system is connected online with the Land Registry Office. In this system, in addition to the coordinates, the angles and sides of the perimeter and area are also calculated.

The accuracy of determining the location of properties using the RTK method depends on the distance of the rover from the nearest reference station and ranges from 0.01-0.20 m. The property's integrated positioning network consists of 144 stations across Iran, so these stations were installed at distances between 60 and 190 kilometers from each other. The structure of the network of integrated positioning of properties (SHAMIM) is shown in Figure 2 (URL-2).

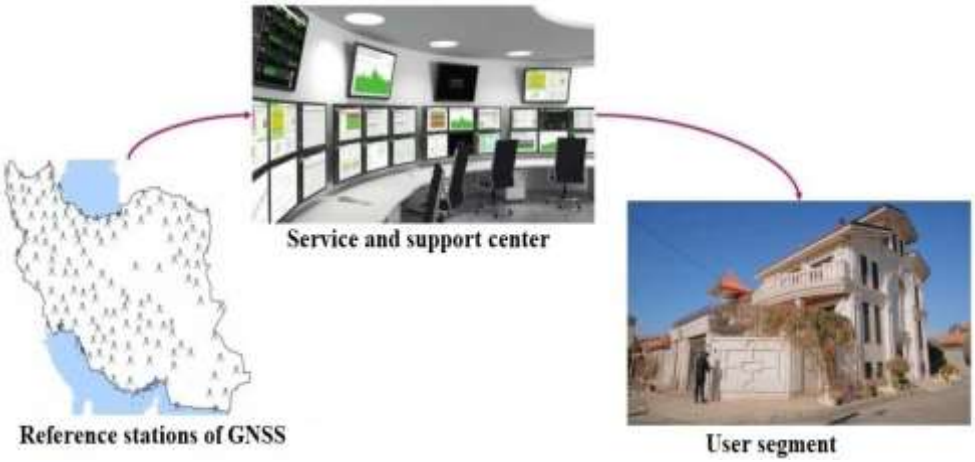

Figure 2. The structure of integrated property positioning network (SHAMIM)

4. Results and Discussion

Comparing cadastral systems around the world is a difficult task due to cultural, linguistic, technical, and social differences between countries. The comparison of the data, including issues related to the countries' land policy, laws and regulations, land ownership, land management and cadastre, the technology used, and mapping infrastructure, is the basis for many studies.

In this section, the cadastral systems of Turkey and Iran have been compared according to historical development, the complementary status of cadastral systems throughout the country, organizational structure, challenges and weaknesses, and strengths.

The start date of cadastral work in Turkey can be accepted as 1925. In 1924, the Organization of the General Directorate of Land Registry was established, and at the same time, the cadastral works were started. In Iran, the first registration of the cadastral registry was formally started about 68 years ago, namely in 1955. Based on these dates, it is seen that Turkey started its cadastral studies 30 years before Iran.

In Turkey, 2D cadastral works in urban and rural regions have been completed; currently, renovation works and work on the 3D cadastral are being carried out.

On the other hand, in Iran, urban cadastral works were started in 1990. Currently, about 95 percent of the urban cadastral works have been completed; at the same time, work on the cadastre works in rural areas is ongoing.

It should be mentioned that the cadastre is centrally managed in both countries. The General Directorate of Land and Cadastre Registration in Turkey (TKGM) and the Deeds and Properties Registration Organization (IDPRO) in Iran carry out activities related to cadastre and property registration. At the same time, cadastre and registration of land ownership are mandatory processes in both countries.

- When both countries are compared in terms of problems experienced in cadastral studies and land registration, it is determined that there are similarities in terms of management problems, lack of budget, and specialists.

In addition, the existence of an extensive legal structure, the use of different measurement methods, the reflection of the problems caused by non-coordinated produced maps, and the citizens' refusal to do cadastral work can be considered part of the current cadastral problems in Turkey.

Border disputes as a result of the differences between the accurate maps produced by the National Mapping Organization and the old maps used in the Deeds and Properties Registration Organization (IDPRO), the conflict of old rules with modern technology and strategies, the problems of transferring the data from registration books to the land information systems, and uncompleted cadastral works in rural areas can be considered part of the current cadastral problems in Iran.

- Completion of 2D cadastral works (urban and rural areas) in Turkey and urban areas in Iran, having a land information system equipped with modern technologies, a nationwide mapping network in both countries, starting 3D cadastral works, etc., are considered the strengths of both countries.

5. Conclusion

From the results of the study, it can be seen that Turkey started official and regular cadastral work about 30 years earlier than Iran. Although this country has faced various challenges in this field, with different approaches and by implementing numerous projects and contributing to the private sector in this field while accelerating this process, it has also been able to overcome the leading challenges and complete the cadastral works throughout the country. It should be mentioned that Iran has not yet completed its cadastral works in rural areas and is behind Turkey in this field.

On the other hand, forasmuch as the 2D cadastral works have been completed in Turkey, and during this process, this country has undoubtedly gained a lot of experience. Therefore, the cadastral system of this country seems to be a suitable model for those neighboring Islamic countries with similar traditions that still lack an efficient cadastral system, like Afghanistan. This work, while speeding up the cadastral work process, also prevents unsuccessful and inefficient experiences.

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