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Coordinate Systems and Map Projections Used in Mapping and GIS Activities in Turkey

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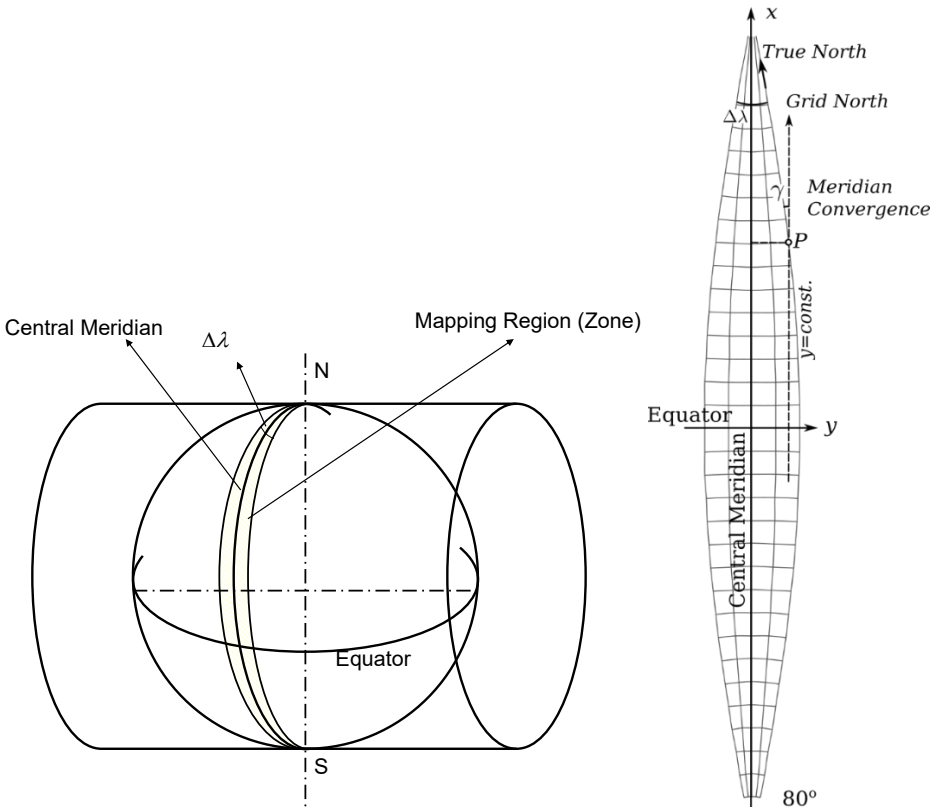
Abstract:

Map projections and coordinate reference systems (CRS) play a crucial role in mapping and Geographical Information Systems (GIS) applications. In Turkey, large-scale mapping is standardized via a juridical regulation, the Large-scale Map and Geospatial Data Production Regulation of 2018 (BÖHHBÜY, 2018). According to the regulation, the reference frame is TUREF with the GRS80 Ellipsoid, and the map projection is Transverse Mercator (TM) implemented in 3-degree zones (Figure 1). The regulation applies to official map production at scales of 1:5000 and larger. In particular, local authorities (municipalities) and nationwide governmental institutions are required to comply with it in their mapping activities. In the past, large-scale mapping was carried out using the ED50 datum and the TM projection. As a result, there are still officially valid maps and geospatial datasets in that coordinate system. However, transforming between the ED50 and GRS80 datums is challenging, mainly because ellipsoidal heights in the ED50 datum are not available. To address this, transformation models based on predicted ED50 heights have been published, which can be used within certain accuracy limits. (Aktuğ et.al.,2011).



(a) (b)

Figure 1. a) The projection principle of TM Projection, b) The plane coordinate system of a zone

In transverse cylindrical projections, the differential scale, or scale factor, increases with distance from the central meridian. The maximum increase occurs at the edges of the zone. Additionally, topographic heights also affect the scale, with significant influence at higher altitudes, starting from about 1000 m. Since topographic heights are changing up to 5000 m in Turkey, the total scale factor may exceed the acceptable limits in large-scale mapping (Bildirici et.al, 2017; Bildirici, 2023; Idrizi, 2014). In this study, an analysis was conducted by using 11400 regularly spaced points within the territory of Turkey. For the height estimation, a regional Digital Elevation Model (DEM) downloaded from the General Bathymetic Chart of the Oceans (GEBCO; URL1) was used. Its resolution is 15 arc-seconds. The results are presented in Table 1, where the maximum scale factor resulting from the projection and topography is approximately 836 ppm. For large-scale topographic mapping, these values are assumed to be high (Iliffe 2017). To diminish the scale increase, a standard scale factor (m_0) can be used. Since the 3-degree zones can be assumed narrow enough, m_0 is taken as 1. To avoid negative values, false easting and false northing coordinates are used. In the Turkish TM system, a false easting value of 500,000 m is used.

Table 1. Scale factor (SF) analysis within the territory of Turkey (Using 11400 points)

	SF by Projection	**SF by Topography**	**Total SF**
Max.	1.000225 (225ppm)	1.000792 (792ppm)	1.000836 (836ppm)
Average	1.000068 (68ppm)	1.000146 (146ppm)	1.000214 (214ppm)

The country's territory is divided into 9 zones, each 3 degrees wide in longitude. Actually, 9 different coordinate systems are in use. This is an interrupted system and has disadvantages when working areas that span two zones. In such working areas, the scale factor caused by map projection reaches maximum values. Additionally, 3-degree zones are constructed in accordance with 6-degree UTM zones (Figure 2). So, one of every 2 zone shares the same central meridian with UTM. Since $m_0 = 0.9996$ in the UTM system, the TM and UTM zones sharing the same central meridian are not the same in terms of coordinates. This fact is sometimes confusing.

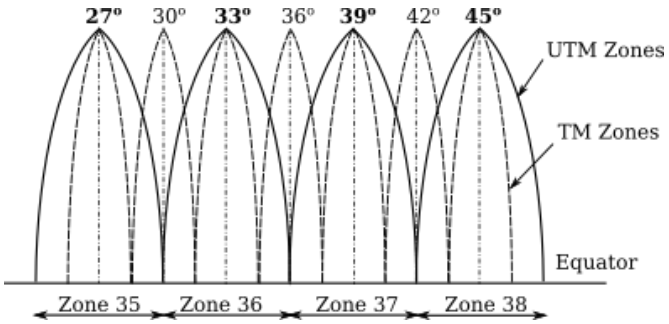


Figure 2. TM and UTM Zones

Medium-scale topographic mapping in Turkey is carried out by the Directorate General for Mapping, the National Mapping Agency, which is responsible for producing the 1:25,000, 1:50,000, 1:100,000, and 1:250,000 map series. For medium-scale mapping, the UTM system with the WGS84 datum has been in use since 2002; before that, the ED50 datum was employed. The UTM is an internationally defined coordinate reference system. The standard scale factor (m_0) is set at 0.9996, with a false easting of 500,000 m. For the southern parts of the zones, a false northing of 10,000,000 m is applied. As is well known, the UTM system encompasses 120 different coordinate systems, making it an interrupted projection system.

Both TM and UTM are interrupted systems and are not eligible for depicting the whole country. Therefore, the Lambert Conformal Conic (LCC) projection is mainly used in small-scale mapping. Current Turkey maps use LCC with standard parallels of $36°30'$ and $41°$. The central meridian is taken as $35°$. Since the maps produced are small-scale, and the projection does not cause a significant scale change, the standard scale factor is taken as 1.

Using geographic coordinates directly as a coordinate reference system is common in Turkey, as in many other countries. This is widely known as EPSG:4326. EPSG stands for the *European Petroleum Survey Group*, which developed a standard coding system for coordinate reference systems and map projections. In fact, EPSG:4326 corresponds to the equidistant cylindrical projection in the normal aspect. Although this projection is not suitable for mid- and high-latitude regions, it is sometimes used for mapping in Turkey. Such maps depict the country as compressed in the north–south direction, resulting in a misleading representation. Figure 3 illustrates the appearance of Turkey in EPSG:4326 compared with the Lambert Conformal Conic (LCC) projection.

For the mathematical background of the Transverse Mercator (TM) and Lambert Conformal Conic (LCC) projections, the following sources can be consulted: Bildirici (2023), Bugayevskiy & Snyder (1995), Snyder (1987), and Snyder (1993).

Figure 3. The appearance of Turkey in LCC and EPSG4326

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