1 SOILS WITHIN TORUŃ URBAN AREA

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Introduction

In the countryside and areas free of urbanization processes or destructive industrial forces, natural soil dominate; they are resistant to anthropogenic and technogenic impact. In urban areas, there are only remnants of natural soils, while soils radically transformed by different human activities dominate together with 'new soils', where development of particular horizons and layers is not reflected in natural conditions of the system. Sealing of soils, transformations of naturally developed soils and formation of soils from anthropogenic deposits are the main types of soil formations in urban areas (Blume 1989). Soils of urban areas are quite different complexes deserving individual consideration.

The problem of anthropogenic soil transformations is a subject of growing interest among researchers. It is difficult, however, to get detailed soil maps of only urban ecosystems (Stroganova, Prokofieva 2000).

This chapter characterizes the urban soil cover in Toruń. The identified soil units were described with special reference to soils formed and transformed as a result of anthropogenic and technogenic activity.

Study area

The city of Toruń (18°36' E and 53°01' N) covers an area of 116 km^2. It is located in the Toruń Basin (part of the Vistula ice marginal streamway) in North Poland (Fig. 1). The Toruń Basin is 20 km wide in the vicinity of the city and cover an area of 11 535 km^2.

Toruń is situated on the flat river terraces – the most important element of the relief – with small groups of dunes. Such a location does not hinder the development of the city. Of the original eleven terraces distinguished, only X, IX, VIII, VII and VI survived to our times. Their origin probably dates back to 17.0 and 14–13.5 ka BP. All the terraces,

except the floodplain, are built of sand and gravel deposits, underlain by Pleistocene boulder clay or Tertiary clay. The main problem in the spatial development of the city was the edge of terraces VIII and IX in places adjacent to terrace IV. However, during the expansion of the city and road construction, the edge has been substantially softened. Similarly, the dunes have been significantly transformed or destroyed by the construction of military, industrial or sports facilities, as well as by exploitation of dune sands (Niewiarowski, Weckwerth 2006).

Fig. 1. Location of Toruń

The largest areas in Toruń are represented by flat lands, which have developed as a result of filling of primary or secondary depressions and levelling of natural convex forms (e.g. dunes). This type of terrace transformation is evidenced by embankments. According to Fedorowicz (1993), the thickness of downtown embankments is around 2.5 to 4.0 m, or even more than 7–8 m in places of medieval moats. Outside the City Centre, the embankment thickness is relatively smaller and ranges within 1.0–2.5 m.

The average annual air temperature for the period of 1951–2000 is 7.9°C and the average total precipitation for the same period is 522.5 mm (Wójcik 2006).

The largest plant formation in the area of Toruń are forests, covering about 23% of the total urban area. The total forest area is about 27 km^2 and forest parks – 1.5 km^2 (Kozłowski 1998). Meadows cover 7% of the urban area and arable lands – about 18%.

The history of Toruń as an urban centre began on 18 December 1233 when the city rights were granted. Since then, the city has grown very rapidly. In the 13th century, it was already surrounded by city walls. In 1233, the area of the city was 20 ha and in 1264 – as much as ca. 40 ha (Fedorowicz 1993). The specific location of this city and particular role of the Vistula River as a haul road contributed to the fact that in the 14th century, Toruń was already an important trade centre of the then Polish country. It was one of the largest cities in medieval Poland (Klimek, Rymaszewski 1994).

The development of Toruń was interrupted in the 17th century by the war with Sweden. Nevertheless, the city regained its former splendour. In the late 18th century and 19th century, however, the political situation led to a complete functional transformation of Toruń – in the spatial and economic structure (Fig. 2). The extension of fortifications determined the transformation of the city into a powerful fortress. Elimination of the suburbs and a ban on house building near the fortress zone caused that for a long time there were no connections between the medieval centre and suburbs developing in the

Fig. 2. Skyline of 17–18th century Toruń, a copper engraving by Christian Daniel Pietsch

distance. This situation resulted in a trade slump and restriction on the spatial development of the city. Introduction of new architecture was possible only after the removal of certain fortification elements in 1918 (Gregorkiewicz 1983). The period of World War II did not bring any damage to the city, but after the liberation of Poland and seizure of power by the communists, Toruń has lost its role as a provincial capital in favour of the neighbouring city of Bydgoszcz.

Fig. 3. Contemporary skyline of Toruń Old Town

The next stage of Toruń development started after 1960, when decisions about the construction of two large industrial plants were taken ('Elana' chemical fibre plant and 'Merinotex' yarn spinning mill). This caused a massive influx of people from the neighbourhood that resulted in the rapid development of urban infrastructure. Since 1989, Toruń, like other cities in Poland, has undergone profound social and economic transformations.

Nowadays, the city is a co-capital of the Kuyavian-Pomeranian Province and a regional centre of investment, science and tourism. In 1997, the medieval part of Toruń was designated as a UNESCO World Heritage Site (Fig. 3). As of January 1st 2013, the population of the city was 198 383 people (source: Toruń City Council Census).

Anthropogenic transformation of the landscape and soils in Toruń

The genesis and characteristics of urban soils depend on the history of a given city. The origin of surface feature transformation in the area of Toruń goes back to the 13th century with the highest intensity in the 19th and 20th centuries. The human activity generates the development of negative and positive land forms, which contribute to specific anthropogenic relief within the city range (Podgórski 1996). Destructive morphological activity of man occurred, among others, during construction of channels and drainage ditches, levelling of surfaces, formation of pits and workings after exploitation of building material etc. Extensive destruction of e.g. dunes has been observed, which until the 13th century occurred in large numbers on all the terraces, excluding the inundation ones.

The impact of human activity led to a gradual transformation of aeolian forms and to a total elimination of small dunes. Construction of roads and streets resulted in the transformation of terraces. Furthermore, also many linear embankments developed. The thickness of surface embankments within the administrative boundaries of the city varies, depending on their age. In the medieval area of the city and in the Podgórz district, there are 2.5–4.0 m thick embankments. On the outskirts of the Old Town, their thickness increases to about 7 m. The embankments with a thickness of 1.0–2.5 m occur within the boundaries of the 19th century city (Fedorowicz 1993).

Soil units

Figure 4 presents a map with the current state of knowledge about the soil cover transformation of technogenic and anthropogenic origin in the Toruń urban area. Its first version was prepared for the SUITMA 2 conference in Nancy (Bednarek et al. 2003). A modified version of the map was published in the monograph of Toruń (Bednarek, Jankowski 2006). The soils were mapped using units distinguished as hybrids of three urban soil classifications: by Stroganova et al. (1998), Konecka-Betley et al. (1984) and Burghardt (2000). The legend of this map consists of 8 soil units: undisturbed and weakly transformed soils, urbisols, industrisols, garden soils, soils of parks and lawns, necrosols, ekranosols and constructosols. They are described below.

Undisturbed and weakly transformed soils

This unit includes urban forest and agricultural soils located within the administrative boundaries of Toruń (Fig. 4).

Urban forest soils cover about 23% of the city area. They also belong to anthropogenically transformed soils, but changes in their morphology and properties are often relatively small. Therefore, these soils can be locally classified as natural.

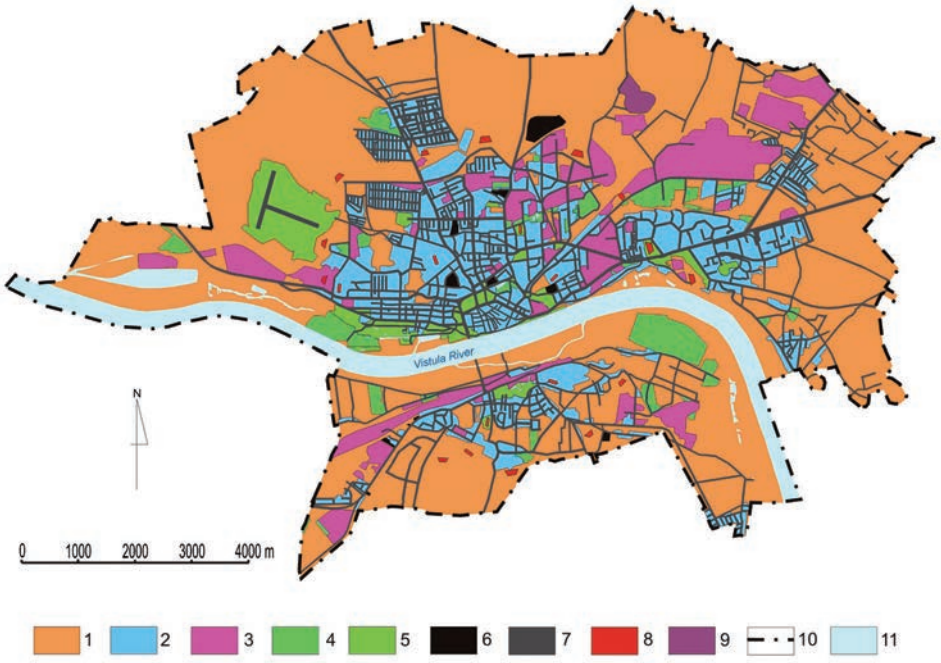

Fig. 4. The map of soils within Toruń urban area (Bednarek et. al 2003; Bednarek, Jankowski 2006; modified). Explanations: 1 – undisturbed and weakly transformed soils, 2 – urbisols, 3 – industrisols, 4 – garden soils, 5 – soils of parks and lawns, 6 – necrosols, 7 – ekranosols, 8 – constructosols, 9 – rubbish dump, 10 – administrative boundaries of Toruń, 11 – surface waters

Urban forests, occurring mostly in suburbs, show spatial and ecological continuity with forest complexes situated outside the city. Their soils developed from river terrace and dune sands (Fig. 5), covered mainly with pine stands (*Pinus sylvestris*). These sandy acid soils (Podzols, Arenosols) are characterised by low resistance to pollution. The highest degree of soil transformation is observed in the vicinity of industrial plants in the western part of Toruń.

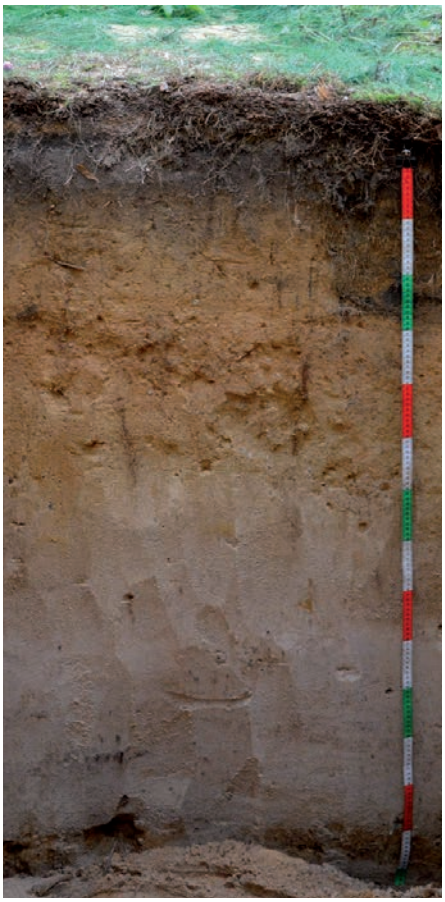

Fig. 5. Urban forest soil (Brunic Arenosol)

Fig. 6. Urban agricultural soil (Haplic Fluvisol)

The urban agricultural soils (mainly Fluvisols – Fig. 6) are used as meadows, pastures and arable lands. They cover ca. 25% of the city area, but this value constantly decreases. Like all other soil units found in urban ecosystems, urban agricultural soils are much more affected by pollution compared to soils of non-urbanized areas. Interwoven into the urban infrastructure, they are affected by large amounts of greenhouse gases and toxins emitted by factories, as well as by domestic and commercial wastewater (particularly on the northern outskirts of Toruń).

Urbisols

These soils are characterised by large quantities of artefacts in their profile, like e.g. bricks, and high horizontal and vertical variability (Fig. 7). Urbisols cover the largest area within the municipal boundaries. They include compact urban built-up areas of right-bank as

well as left-bank Toruń. The built-up areas were treated comprehensively on the map (Fig. 4), however they include also separate soil units occurring under the town squares, housing estate and street lawns. The latter are not included on the map. As mentioned above, spatial development of the city proceeded with varying intensity over the centuries. That is why urbisols formed in the urban built-up area are characterised by varying degrees of morphological transformation. The soils occurring in the Old Town and downtown were formed on a well-developed cultural layer with the urbic horizon of large thickness and high content of artefacts. Most of such soils meet the criteria of WRB Technosols. The areas of relatively new housing estates are covered with incompletely developed urbisols. The soils are often only partially technogenically transformed with still visible deeper soil horizons, which until recently were mostly natural, or agriculturally transformed. Such urbisols do not qualify as Technosols.

Fig. 7. Urbisol (Szosa Chełmińska st.)

Fig. 8. Industrisol (at the former chemical plant 'Polchem')

Industrisols

These soils occur in places of working industrial plants and in their close proximity (Fig. 8). Their typical feature is contamination with various substances – gaseous, liquid or solid. Toruń industry is concentrated in three parts of the city - western, north eastern and southern (Fig. 4). The studies of soil contamination with heavy metals and sulphur in the protection zone of the largest and most environmentally harmful industrial plants revealed an elevated content of sulphur around the 'Elana' chemical fibre factory. Within a distance of 2.6 km from the CHP plant 'Energotor', soils were strongly contaminated with cadmium, and – to a lesser extent – with zinc and sulphur (Burak 2001). However, the soil acidification caused by emission of sulphur compounds was not detected (Pokojska et al. 1999).

Garden soils

Allotment gardens in Toruń cover ca. 349 ha (3% of the total city area) and constitute significant greenery resources of the city (Fig. 4). The largest complex occurs in left-bank Toruń, in the Rudak quarter on the floodplain. The oldest, still existing allotment garden is located just outside the Old Town area. It was founded in 1928 and named after General Sikorski. It covers an area of 3.5 ha.

Garden soils in Toruń due to horticultural operations developed thick and dark humus horizons (Fig. 9), which usually meet criteria of *mollic* but not very often *hortic*, due to too low phosphorus content (Hudańska 2013).

The primary soils in particular garden complexes were different (Fluvisols, Brunic Arenosols and Mollic Gleysols). However, organic deposits of different origin and thickness were applied by garden owners. The degree of soil transformation in particular complexes depends also on the type and the level of contamination. Due to the development of the city infrastructure, gardens located in the past on the outskirts are now close to industrial areas and main traffic routes. Monitoring results for the period of 1994–1996 in 13 allotment garden complexes pointed to zinc and lead pollution. Extreme contamination with these elements was found in gardens located near the highway from Toruń to the north part of Poland (Jankowski 1995).

Soils of parks and lawns

Sometimes the soil cover in large green urban areas cannot be classified as 'artificial' soils, but instead as technogenically transformed ones (Fig. 10). Parks and housing estate lawns are included in the so-called 'arranged green'. The arranged green area in Toruń is about 226 ha, including 31 ha of historical garden installations. The soils of parks and grass plots cover 1.95% of the city area. Lawn soils are described in Chapter 3.

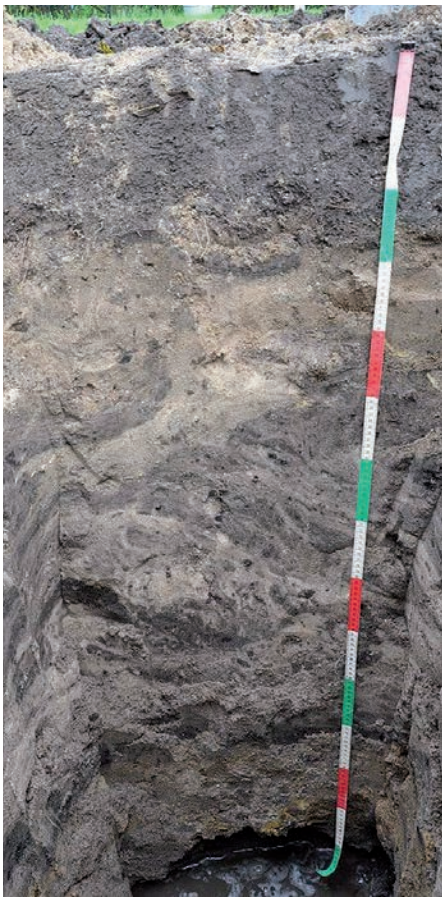

Fig. 9. Garden soil (Szczanieckiego st.)

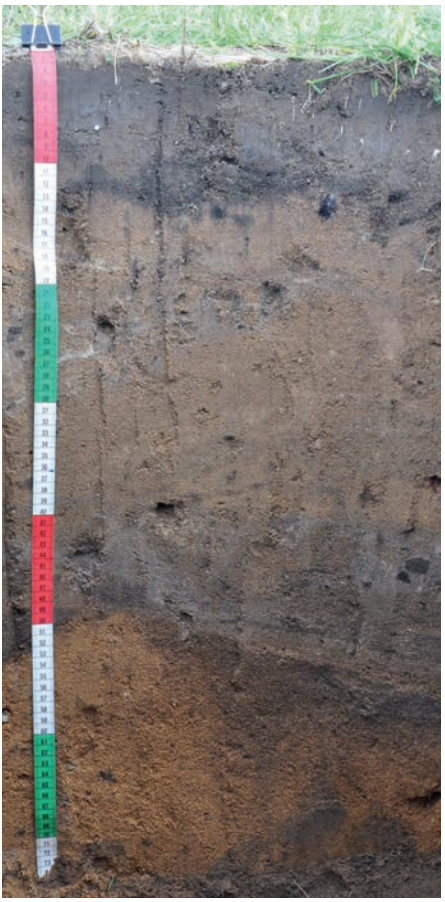

Fig. 10. Lawn soil (Lubicka st.)

Necrosols

There are 15 old, no longer used cemeteries and former graveyard grounds in the city of Toruń and 11 contemporary cemeteries, still in use. The Central Communal Cemetery is the largest one, located in the northern part of the city. It was founded in 1975 and covers an area of 59 ha. The soils occurring in the cemetery area are called necrosols (Fig. 11). According to Stroganova et al. (1998), the depth of technogenic transformations within these soil profiles exceeds 2 m. Other features of graveyard soils include the absence of natural horizons, the presence of urban layers with abrupt transitions and the occurrence of artefacts (e.g. fragments of bricks, glass, nails). This was also observed in soils of Toruń cemeteries (Charzyński et al. 2011b). The research was carried out in the above-mentioned Central Communal Cemetery and in the two oldest cemeteries – St. George cemetery

existing since 1811 and St. Jacob the Apostle Parish cemetery established in 1817. In the Polish burial tradition, graves are usually covered with large horizontal tombstones, therefore sealing is another feature to be recognized in necrosols.

Ekranosols

In contemporary cities, large areas are sealed by road and pavement coverings. In densely populated agglomerations, sealed soils cover most of their area. In Moscow, sealed soils cover 90–95% of the downtown districts, 80% in industrial districts and 60% in residential areas.

The largest homogeneous area of ekranosols in the city is located under the runway and taxiways of Toruń Aerodrome. These soils were described in Chapter 10. Furthermore, ekranosols also occur under all asphalted or cemented streets, sidewalks and alleys in

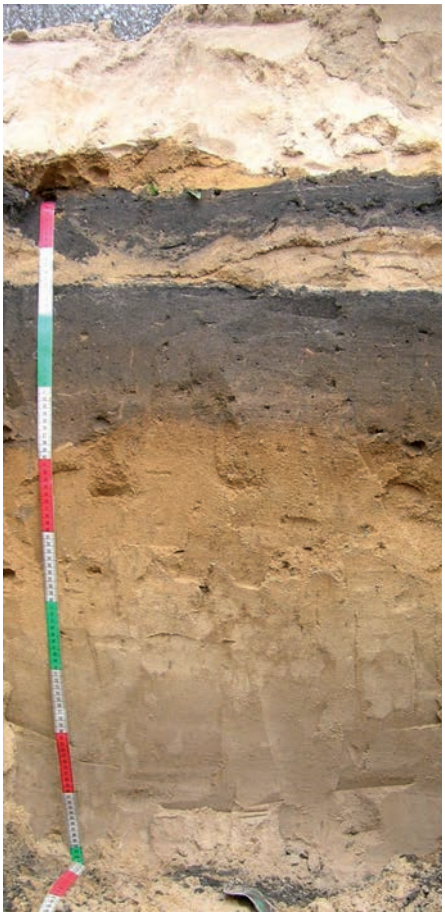

Fig. 11. Necrosol (Central Communal Cemetery)

Fig. 12. Ekranosol (Gałczyńskiego st.)

the city parks (Fig. 12). Ekranosols in Toruń are characterised by alkaline reaction, high calcium carbonate content, low organic carbon and total nitrogen content. Some profiles contain layers with a high content of phosphorus, which is related to the previous land use (Charzyński et al. 2011a).

Constructosols

Constructosols in Toruń are mainly represented by soils developed on forts or some medieval walls (Fig. 13). According to the definition by Stroganova et al. (1998) and taking into account the genesis of forts, these are artificial soil products built of several different layers of mineral material brought by man, which are enriched with mould material on the surface. The former Toruń Fortress included 15 forts built in the 19th century. Their construction was of brick with ceiling thickness above 1 m, covered with earthy (soil) deposits. The thus developed soils constituted a fort construction unit and also a substrate for plant cover, which was a significant structural part of the defence (see Chapter 18).

Fig. 13. Constructosol on walls of Dybowski Castle

Soils of eight older sport grounds can also be considered as another version of constructosols. In these areas, a thin humus horizon built of the transported material occurs over the autochthonous mineral material, which represents different parts of the natural soil profile. This humus horizon is artificially deposited to create optimal conditions for sward development. Soils of similar genesis can occur on newly formed housing-estate and street lawns. However, they are usually additionally contaminated with combustion gases, particularly near busy streets.

Summary

As evidenced by the results of long-term and multifaceted studies of soils within the Toruń urban area, the anthropogenic and technogenic factors significantly affected the primary soil cover. The present state of urban soils is a result of over 750 years of spatial development and an effect of human economic activity. Before the intensive urbanization process had started, Brunic Arenosols dominated in the described area. Nonetheless, the natural soils (undisturbed and weakly transformed), polluted to a varying degree, are still recognized within the municipal boundaries. Nowadays, about 75% of the city area consists of technogenic soils – human-transformed or man-made.

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