Applied Soil Ecology xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

Short communication

Tangel humus forms – genesis and co-evolution with vegetation

Eckart Kolb*, Michael Kohlpaintner

Forest Nutrition and Water Resources, Departement of Ecology, Technical University of Munich, Germany

ARTICLE INFO

Keyword:
Tangel
Humus forms
Vegetation
Northern Limestone Alps

ABSTRACT

Tangel humus consists of thick zoogenic organic layers up to 100 cm which form directly over solid or coarse carbonate bedrock. Mineral soil horizons are absent or negligible. It develops mainly in the montane and subalpine region of the Northern Limestone Alps, where cool and moist climate, as well as slowly decomposable litter from coniferous trees and dwarf shrubs promotes the accumulation of organic material. Tangel has a high base saturation throughout the whole soil profile and shows a pH value above 5 in the transition zone to the carbonate bedrock or in the shallow mineral soil horizon.

In this publication the preconditions for the development of Tangel are described, different forms of Tangel are characterized and a differentiation from other humus forms is made. On the example of the subalpine zone in the Wetterstein Mountains the coevolution of vegetation and Tangel humus forms as well as their degradation stages are discussed.

1. General characterization and genesis of Tangel

Tangel is a humus form which consists of thick organic layers (up to 100 cm and more). It develops preferentially over solid or coarse carbonate rocks (limestone and dolomite) with high carbonate contents (Ca- and/or $MgCO_3$ > 90%) and low residual clay contents. It is mainly found in the montane up to the subalpine zone of the Limestone Alps where cool and moist climate promotes the accumulation of organic matter (OM). The vegetation associated with this climate and type of bedrock (e.g. coniferous trees, pinus mugo shrubs and plants of the heath family) additionally produces litter which decomposes slowly and therefore also favors the accumulation of OM. Fig. 1 shows a typical Tangel profile with OL, OF, a thick zoOH, an A horizon and a transition/contact zone to the solid parent carbonate rock material (A/C). It is typical that the pH in this contact zone is increasing up to pH 6 or even higher.

The overlying organic horizons (OH and OF) in contrast are significantly more acid with pH_{H2O} values even below 4. Independently of the pH and horizon the base saturation is high throughout the entire solum (usually > 85%). Especially the contact zone with the A or C horizon the OH layer shows a loose and crumbly structure. Tangel has a high water storage capacity and is the main or only reservoir of water and plant nutrients at sites where mineral soil layers are thin or missing. Relatively pure limestones and dolomites are found concentrated in the Northern and Southern Limestone Alps where we can also find the major occurrence of Tangelhumus, but it occurs also in other regions with similar bedrock and climate.

To understand the occurrence and genesis of Tangel it is important to know that there are **two pathways** in the development of soils derived from limestones (Fig. 2).

(1) Mineral soils without or with shallow organic layers develop from strongly disintegrated limestones and dolomites (pieces smaller than 6.3 cm in diameter, but mainly smaller than 2 cm) such as fine slope debris, river sediments and moraine deposits. This substrate offers a large surface which enhances weathering and the buildup of mineral soil layers. The same applies to marly limestones with lower Ca- and $MgCO_3$ contents (usually < 90%) and higher residual silicate contents. The OM delivered by initial plant communities is readily mixed with the mineral soil which promotes high pH throughout the whole solum. Plants adapted to high pH soils (eg. Carex species and graminea) develop and produce relatively easy decomposable litter which is mixed into mineral soil. pH is significantly higher in the upper soil profile compared to the soil development over high carbonate rocks. High soil pH and fast decomposable litter promotes the activity of micororganisms (MO) which prevents a major accumulation of OM (left path of Fig. 2). The developing soil types are rendzinic Leptosols and/or Cambisols.
(2) On the other hand Tangel develops over solid or coarse debris from limestones and dolomites with high carbonate contents (> 90%). Due to low residual clay accumulation there is almost no mixing of OM with the mineral soil. Frequent and sharp drying as well as water saturation (during rainy and cold seasons) of the shallow organic layer creates unfavorable conditions for decomposition

* Corresponding author.
E-mail address: kolb@wzw.tum.de (E. Kolb).

http://dx.doi.org/10.1016/j.apsoil.2017.09.040
Received 8 December 2016; Received in revised form 26 September 2017; Accepted 29 September 2017

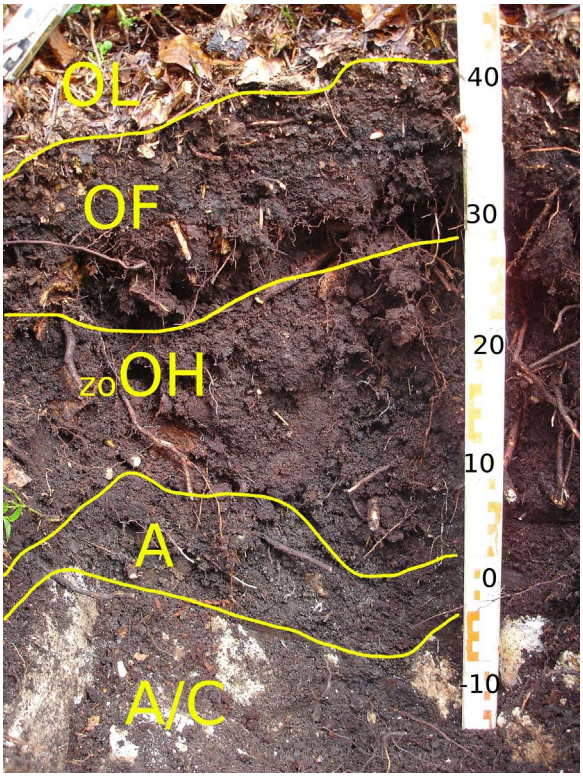

Fig. 1. Tangel humus in a mixed mountain forest (Photo: R. Baier).

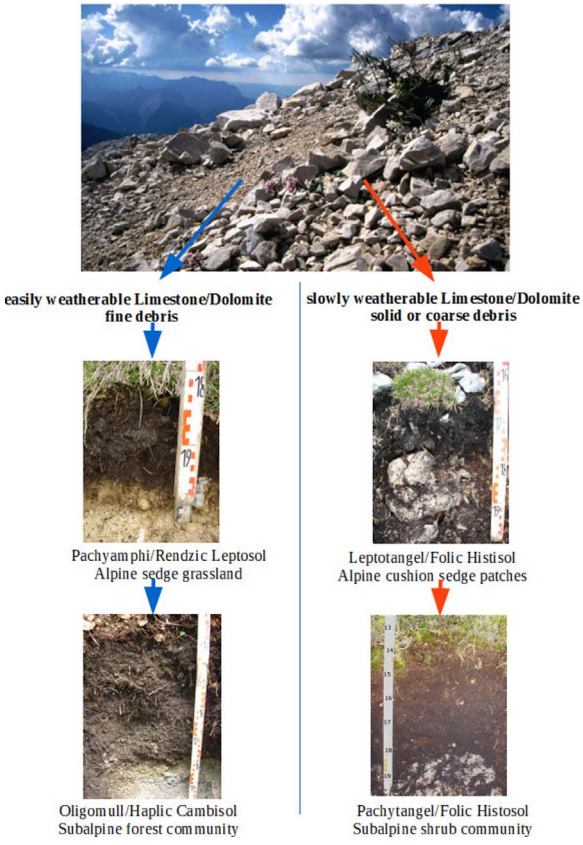

Fig. 2. Branching of the soil development on carbonate bedrock (example form the subalpine zone). Over marl and strongly disintegrated carbonate rocks mineral soils with Amphi or Mull humus forms develop (blue arrows, left side). In contrast, over solid rock or coarse debris from bedrocks with high carbonate contents (> 90%) the development of thick humus layers (Tangel) is very likely (red arrows, right side); Humus forms according to Zanella et al. (2011), soil types according to WRB (2006) (Photos: E Kolb). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

which leads to the accumulation of more OM. Colonization with sedges and other grasses increases OM production. Moisture conditions improve and plant species from the erica and pinus family can establish and shade out the low growing grass vegetation. The slowly decomposing litter of these plants species increases the accumulation of OM and decreases the pH in the organic layer which in turn hampers decomposition even more. The result is a steep pH gradient from the humus layer (pH 4 and below) to the transition zone to the parent rock material (pH up to 7). A typical Tangelhumus profile develops (right path of Fig. 2). If the solum is thick enough, high water holding capacity and nutrient accumulation within the Tangelhumus profile may even sustain forest growth with Picea abies (L. KARSTEN), Pinus cembra (L.), Larix decidua (MILL.) and further tree species.

2. Tangel humus forms – classification and differentiation from other humus forms

Few publications deal with the description and definition of Tangel. An overview is given in Kolb and Baier (2001). Thick humus layers from the Alps have been mentioned **already more than 150 years ago** (Sendtner, 1854). Ebermayer (1888) in his later days was the first who recognized the difference between these thick humus layers and mor humus. Leiningen (1908, 1909, 1912) described a separate humusform in a wide range of aspects. He used the term “Alpenhumus” (alp humus) for thick organic substrate under well growing mountain forests. The word Tangel was first used by Kubiena (1948). Bochter (1984) developed a sophisticated classification system for tangel humus based on morphological and chemical properties of the organic layers which unfortunately did not fit into the established classification system. This may be the reason why it is not used today.

Current national definitions of tangel humus in Alpine counties can be found in Ad-hoc-AG (2005), Standortskartierung (2016), Englisch and Kilian (1998), Nestroy et al. (2000), Walthert et al. (2004) and Zanella et al. (2001).

What is missing up to now is a harmonized European classification for Tangel humus (Baier and Kolb, 2005). Zanella et al. (2011) made the first approach to harmonize the European humus classification systems including Tangel.

According to Zanella et al. (2011), Tangel is present when the zoogenic organic horizons are thicker than 10 cm (zoOF and OH > 10 cm) and when they are combined with a C horizon or an A horizon which is thinner than one half of the OH horizon (A < 1/2 OH). The pH in the transition zone from OH to C or in the A horizon has to be above 5 (pH A > 5). The A horizon can be massive or biomesostructured. Therefore Tangel may be the humus form of an O-C-soil, but also of an O-A-C-soil.

With the classification system of Zanella et al. (2011) also a clear differentiation from other humus forms is possible. The main criteria are listed below:

- Amphi has a thicker biomesostructured A horizon (A > ½ OH).
- Moder has a pH_{water} lower than 5 in the A horizon (pH_{water} of A < 5).
- Mor has a non zoogenic OF horizon and a A or AE or E horizon which has a pH_{water} lower than 4.5 (presence of nzoOF and pH_{water} of A or AE or E < 4.5).

The delineation of different Tangel humus forms is easy. The single criterion is the mightiness of zoogenic OF and the OH Horizon (Fig. 3):

(1) **Leptotangel** is present if the organic zoogenic horizons are