Soil-Plant Tranfer Factors in Forest Ecosystems

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TRANSFERFAKTOREN IN WALDÖKOSYSTEMEN

Zusammenfassung

Im Rahmen einer umfassenden Studie wurden Einflußgrößen des Boden-Pflanze-Transfers von ^{137}Cs in Waldökosystemen untersucht.
Die TF-Werte weisen oft erhebliche artabhängige Unterschiede auf, was zum Teil mit der Wuchsform der verschiedenen Pflanzengruppen und ihrer Wurzeltiefe zusammenhängt.
Bei ausdauernden Pflanzen wie Bäumen (*Picea abies*) und Zwergsträuchern (*Vaccinium myrtillus*) wurde eine ausgeprägte Altersabhängigkeit der ^{137}Cs - Transferfaktoren in Triebe verschiedener Jahrgänge nachgewiesen, junge Pflanzenteile weisen höhere Cäsiumkonzentrationen auf als alte, verholzte Triebe.
Eine Korrelationsanalyse (Spearman Rangkorrelationskoeffizienten) von physikalisch - chemischen Bodenparametern und den TF-Werten zeigt eine signifikante Beeinflussung des Boden-Pflanze-Transfers durch die organische Substanz, genauer durch den Humifizierungsgrad und das Verhältnis von extrahierbaren Fulvo- zu Huminsäuren des Bodenhumus.

TRANSFER FACTORS IN FOREST ECOSYSTEMS

Abstract

Within the scope of an extended study about ^{137}Cs behaviour in forest ecosystems several parameters were found to influence soil-plant transfer factors.
TF - values of different plant species cover a range of two magnitudes. This is partly due to variations in rooting depth of plants and specific physiological adaptations of nutrient supply.
Perrenial plants like trees (*Picea abies*) and dwarf shrubs (*Vaccinium myrtillus*) showed a distinct age - dependency of ^{137}Cs - transfer factors. In young plant parts caesium concentration is higher than in old, more lignified twigs.
A correlation analysis of physico-chemical soil parameters and TF-values to forest vegetation showed, that soil organic matter, especially the degree of humification and the ratio between extractable fulvic to humic acids are important influencing factors of ^{137}Cs transfer from forest soils to plants.

SOIL - PLANT TRANSFER FACTORS IN FOREST ECOSYSTEMS

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Introduction:

In 1993 carrying on an Austrian monitoring program of ^{137}Cs behaviour in forest ecosystems about 80 soil and 200 plant samples were collected in Weinsberger Wald (spruce forest ecosystem in Lower Austria).

Soil contamination was determined by analysing thin-layer - profiles and pooled samples. Concerning vegetation, in addition to an overview of ^{137}Cs contamination special topics like seasonality and cycling phenomena were investigated.

For radiological assessment of forest ecosystems it is necessary to provide comparable and reproduceable data on the main processes. Therefore, plant / soil concentration ratios are calculated on dry matter basis and related to the litter layer only (see fig. 1). TF-values of forest plants are known to be highly dependent on rooting depth and aging effects. Young plant parts show higher ^{137}Cs-concentrations because their tissues are less lignified and rich in sap (WYTTENBACH et al. 1993, NIMIS et al. 1988, HAFFELDER 1993).

In forest soils organic matter highly influences binding and plant transfer of radiocaesium. Chemical parameters of humus quality are considered to be closer related to the soil-plant transfer than the humus content.

Material & Methods - Site description:

The investigation area is situated in Weinsberger forest (Lower Austria, 48°23'N, 15°03'E, 900 m altitude; precipitation 910 mm a^{-1}). The soils are classified as Dystric Cambisols.

In the litter layer pH-values of 3.2 were determined, in deeper soil horizons the values increase to 3.6 (A/B horizon). The average distribution of soil texture fractions was 44%

sand, 29% silt and 27% clay. Humus content decreases from 70% in the litter layer to 20-30% in Ah horizon and 10% in A/B-horizon (10-20 cm depth of mineral soil). The optical densities are highest in the mineral horizons and amount to 2700 OD g^{-1} humus (400 nm) in A/B horizon.

^{137}Cs - soil inventory (0-25 cm from surface) determined in pooled samples reached values between 41.5 - 84 kBq m^{-2} (median value: 61.9 kBq m^{-2}).

^{137}Cs concentrations showed a distinct vertical decrease in the investigated soil layers :

litter (5-0 cm): 2997 ± 502 Bq kg^{-1}
Ah1 (0-5 cm): 127 ± 257 Bq kg^{-1}
Ah2 (5-10 cm): 191 ± 134 Bq kg^{-1}
A/B (10-20 cm): 56 ± 34 Bq kg^{-1}

Spearman - correlation coefficients were calculated for all 4 soil layers and many physico - chemical parameters (pH, texture fractions, cation exchange capacity, base saturation, exchangeable cations, organic matter content etc.). Only coefficients significant at least at the 0.05 probability level were taken into account ($\alpha_{\text{two sided}} = 0.05$ (9 observations): $r > 0.68$, BAHRENBERG et al. 1990).

Results and Discussion:

A significant decrease of TF - values from youngest to older shoots was found for both conifer trees (*Picea abies,* see fig. 2a) and dwarf shrubs (*Vaccinium myrtillus*, see fig. 2). In each case the TF - values could be calculated by an exponential regression term. For *Picea abies* the TF - values for 1 to 4 years old needles are expressed by the regression term $y = 24.50 * e^{-2.47} + 0.85$ ($R^2 = 0.56$, see fig. 2 a). For *Vaccinium myrtillus* the slope of the regression of 1 to 4 years old shoots is slightly steeper than in the case of conifer needles (data: $y = 5.4 * e^{-1.55} + 0.68$; see fig. 2). Although the R^2 reaches only 0.50, the curve represents a very good fit to the median values respectively. Thus the median turns out to be an useful estimate to describe the natural interconnection between transfer value and age of plant parts.

By using SPEARMAN correlation coefficients a close relation of TF - values (spruce and ferns) with the fulvic - to humic acids ratio was found in the litter layer ($r = 0.82$;

see fig. 3). In the Ah - horizon TF - values are correlated with the amount of exchangeable aluminium cations in soil ($r = 0.68$, see fig. 3) and the optical density / g humus ($r = -0.75$).

In recent studies soil organic matter turned out to be an influencing factor of the binding of ^{137}Cs and plant uptake in soils of semi-natural ecosystems (GERZABEK et MOHAMAD 1993).
A high degree of humification of organic matter implicates a large number of functional groups and therefore a low cation mobility through complex formation (SCHNITZER and KHAN 1978). Thus the TF values showed a negative correlation with the degree of humification (indicated by optical density / g humus).
Under acid conditions the polymerization of humic acids is slow and disintegration processes readily occur (GERZABEK et al. 1989), therefore fulvic acids are an important humus compound in forest soils and enhance the ion - mobility.
High fractions of exchangeable aluminium are an indicator of soil acidification (GUGGENBERGER 1994), which results in a higher mobility of plant nutrients like Ca, Mg and K. This is supported by the correlation of ^{137}Cs TF - values with exchangeable aluminium ions.

Conclusions:

Only samples from plant parts of well defined age classes should be taken into account to calculate transfer factors in forest ecosystems. Concentration ratios in older plant parts can be evaluated by exponential regression.
Organic matter, especially water soluble low molecular weight fulvic acids enhance availability of ^{137}Cs to plant roots. A high degree of humification, indicated by high optical densities / g humus implicates a large number of binding sites on low mobile highly condensed molecules, which causes a decrease of soil-plant-transfer.

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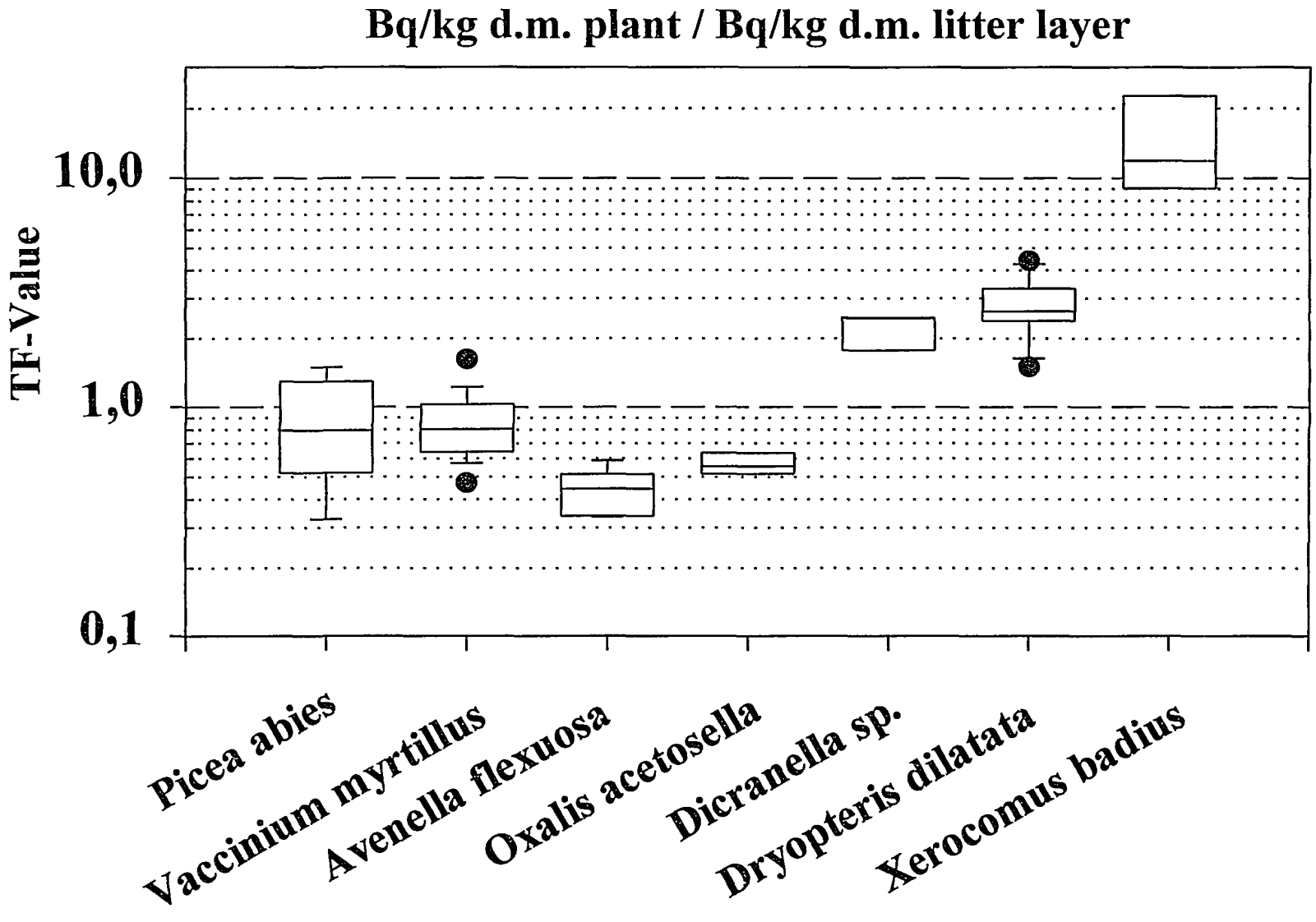
Fig. 1: Transfer Factors of Forest Vegetation



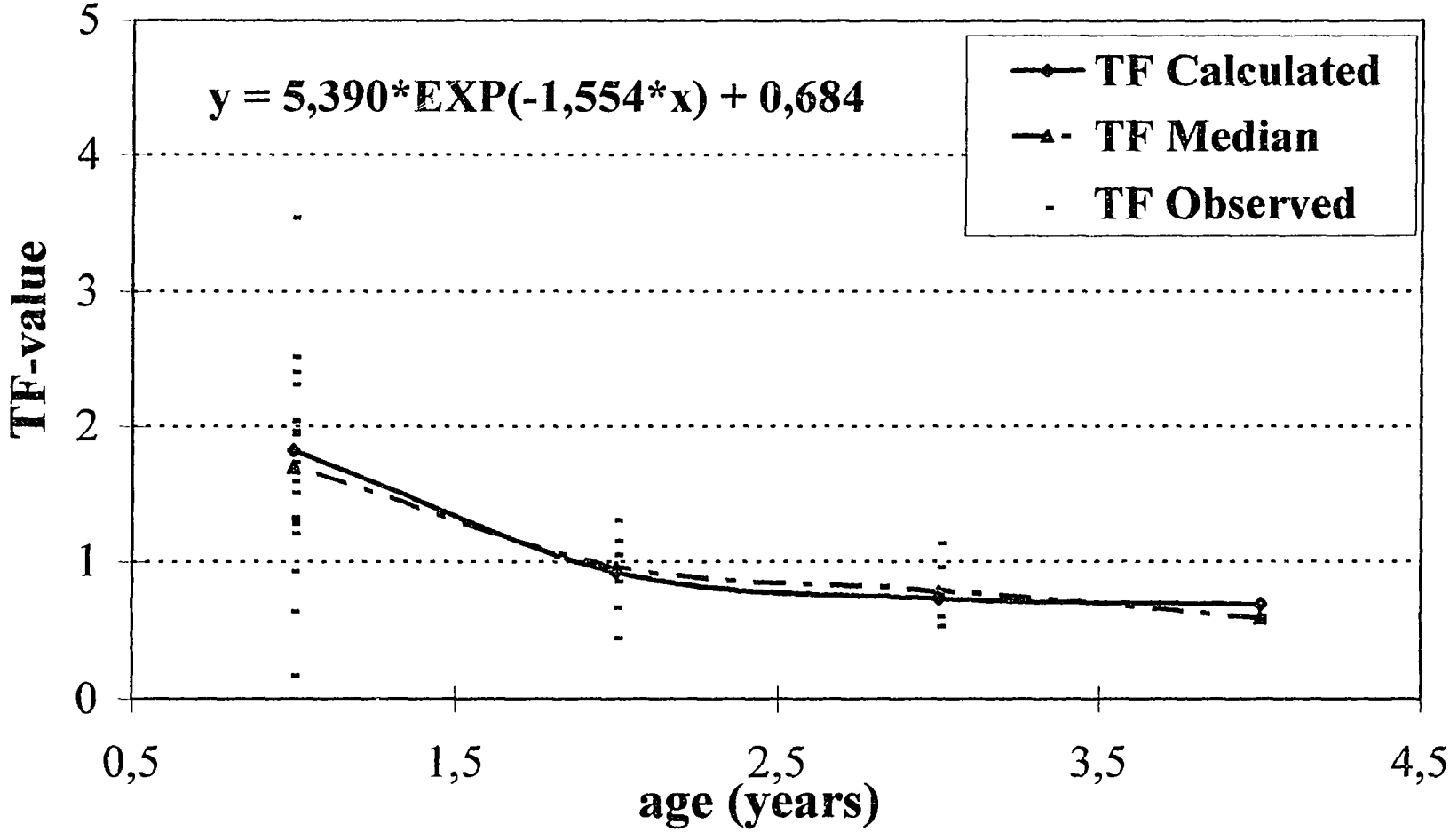


Fig. 2: Age dependency of TF-value soil-bilberry twigs

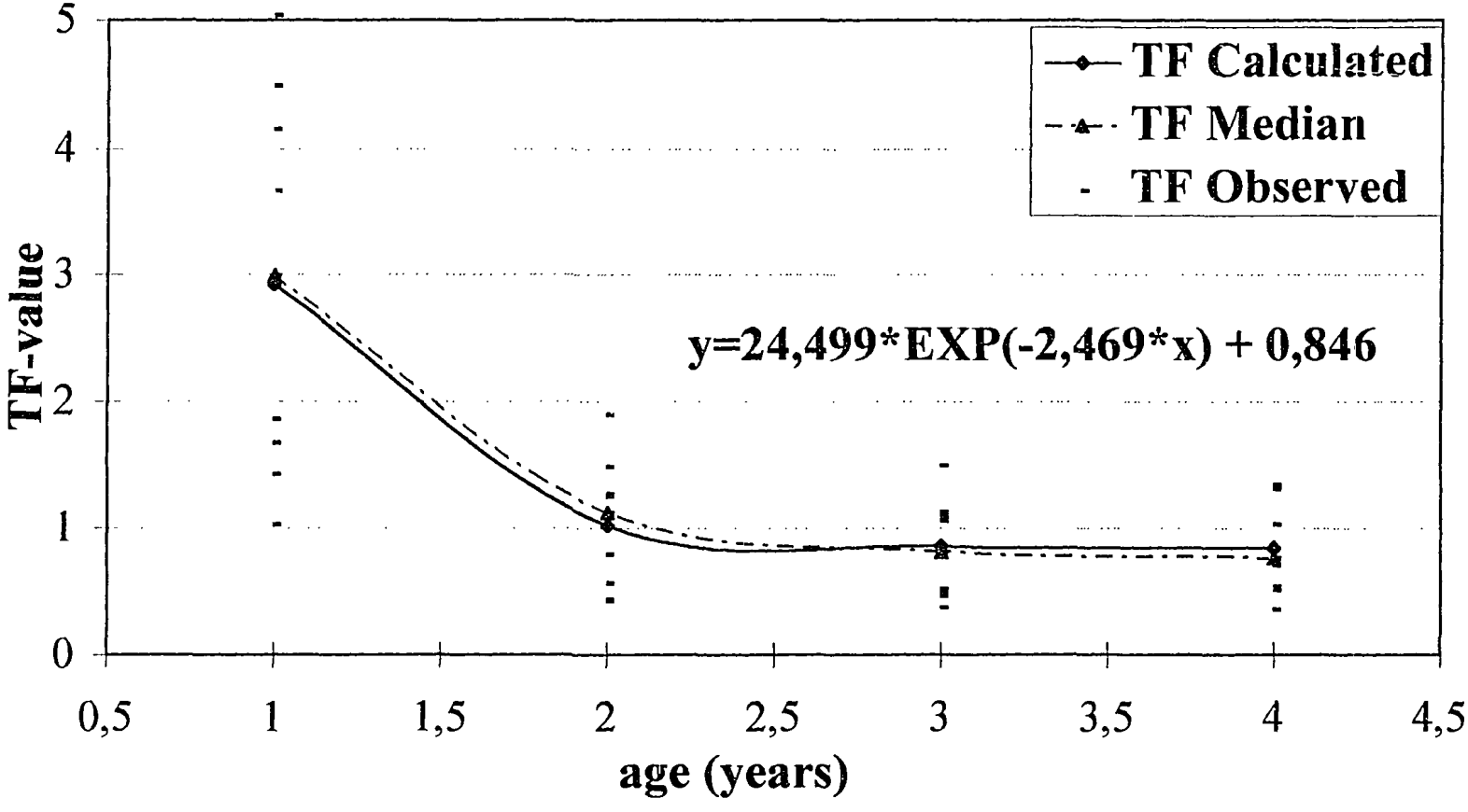


Fig. 2 a: Age dependency of TF-value soil - spruce needles

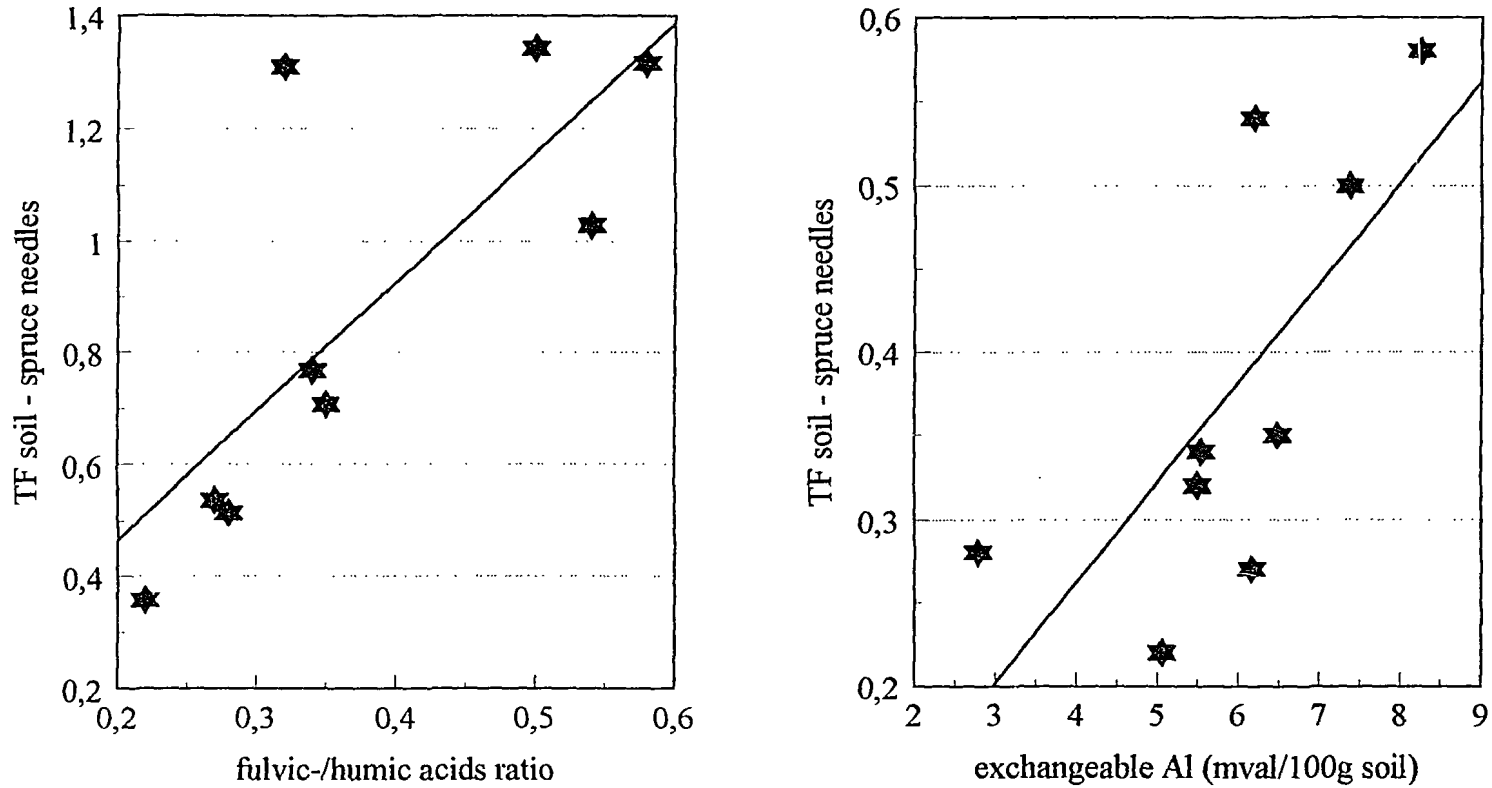


Fig. 3: Correlation of TF-values with soil parameters

a) fulvic-/humic acids ratio b) exchang. Al cations

Als Manuskript vervielfältigt.

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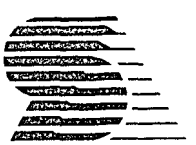

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