 DOI: 10.22616/RRD.30.2024.007

THE COMPOSIT ION AND RICHNESS OF GROUND COVER VEGETATION IN DRAINED FOREST STANDS

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Abstract
Forest drainage is a common management practice, carried out in order to improve tree growth; however, the alterations in hydrological and microclimate dynamics can cause diverse changes in the characteristics of ground cover vegetation. The aim of study was to characterise the composition and richness of ground cover vegetation in drained forest stands, where the groundwater levels have been affected by the reconstruction of drainage diches. Research was conducted in the hemiboreal forests of Latvia. Three study sites were chosen, measurements of groundwater level, stand parameters and projective cover of ground covered vegetation took place in two stands which underwent reconstruction and restoration of the drainage system in 2019, and a control stand, where the drainage system had not been restored. For assessing the relationship of ground cover vegetation in relation to groundwater level and stand factors, DCA analysis was used. The differences between stands, regarding the species projective cover and species composition, were assessed by ANOSIM (Analysis of similarities). Sites, where drainage ditches were fully or partially reconstructed exhibited a greater diversity of ground cover vegetation species compared to the control stand, where no renewal of drainage ditches had occurred. Conversely, the control stand displayed a higher projective cover of the bryophyte layer. The composition of ground cover vegetation species differed amongst all studied stands, the varying stand characteristics and co-dominant tree species in canopy layer had a more pronounced influence on ground cover vegetation, making it complicated to evaluate direct impact of groundwater level.
Key words: ground cover vegetation, projective cover, drained forests, organic soils.

Introduction

Forest drainage has been practiced for over 250 years, with discussions on its impact on tree growth dating back to the middle of the 20th century (Heikurainen, 1964). By creating drainage ditches and lowering the groundwater table, soil aeration enhances, hence promoting improved tree growth and CO_2 removal for atmosphere (Lõhmus, Remm, & Rannap, 2015). Despite the regionally contradictory results, regarding greenhouse gas emissions (GHG), caused by drainage of organic soils (Tiemeyer *et al*., 2020; Lazdiņš *et al*., 2024), no significant changes in carbon (C) stock have been observed in the Baltics (Dubra *et al*., 2023). However, anthropogenic disturbances usually have a heterogeneous and complex effect on ecosystems; consequentially, in the context of drainage, variable hydrological and shading conditions are initiated. The implementation of drainage ditches tends to have an uneven influence on water table; drainage redirects water flow and develops a systematic pattern, where water levels decline as the distance from the ditch increases (Haapalehto *et al*., 2014). Additionally, changes in groundwater level can alter proximate surroundings of the stand, including microclimate and composition of ground cover vegetation (Chipman & Johnson, 2002; Paal *et al*., 2016; Sikström & Hökkä, 2016).

Forest ground cover vegetation and its diversity is an essential component of forest ecosystems, functioning as nutrient supply, along with serving as an irreplaceable habitat and shelter for various life forms (Felton *et al*., 2017; Felton *et al*., 2018; Zhang *et al*., 2018; Vélez, Martínez-Peña, & Castrillo, 2023). Furthermore, ground cover vegetation ensures improved growth conditions by balancing soil moisture and regulating soil fertility (Nilsson & Wardle, 2005; Petersson *et al*., 2019; Teixeira *et al*., 2020). The composition of understory vegetation is mainly defined by the prevailing tree species and soil type. The dominant tree species determine light intensity variation throughout growing season and the chemical composition of forest floor's organic debris (Sorenson *et al*., 2011; Petersson *et al*., 2019). Furthermore, changes in geogenic factors - nutrient availability and moisture (Chipman & Johnson, 2002), can alter the cover, abundance and diversity of individual vegetation species.

Biodiversity responses to forest drainage are multiplex and result from various interacting changes in abiotic and biotic conditions. The changes in ground cover vegetation within human-influenced landscapes are impacted by activities in the surrounding catchments, yet local disturbance history appears to have a greater influence than the broader regional context (Pellerin *et al*., 2016). The abundance of different bryophyte and lichen species are known to be affected by drainage (Remm *et al*., 2013). The species colonizing drained sites are often viewed as typical post-disturbance, successional, and adaptable – common in managed forest landscapes (Remm *et al*., 2013). To thoroughly understand the influence of forest drainage on the forest ecosystem within the study area and to compile a comprehensive overview of background information, evaluation of the understory vegetation is substantial. The aim of study was to characterise the composition and richness of ground cover vegetation in drained forest stands, where the groundwater levels have been affected by the reconstruction of drainage diches.

Materials and Methods

Description of the study area

This research was conducted in hemiboreal forests situated in the central region of Latvia (N 56° 42`; E 26 50`, EPSG: 4661) within the Veseta River catchment area, see 'Figure 1A'. The predominant tree species in this area are *Pinus sylvestris L.* and *Picea abies* ((L.) H. Karst.). Initially, the study area, characterized by organic soils (Fibric histosols), was a transitional mire within the hemiboreal vegetation zone. In 1963, a forest research station was established, the current study area was defined as *Myrtillosa turf. mel*, representing poorly acidic peat soil formed by the drainage of transitional bog. Data collection took place in three forest stands, two of which underwent reconstruction and restoration of the drainage system in 2019 e.g. 'FR' (fully reconstructed) site, see 'Figure 1D', where reconstruction of two adjacent diches was carried out, and 'PR' (partially reconstructed) site, see 'Figure 1C', where only one of the adjacent drainage diches was restored. Lastly, a control site was chosen – 'LE' (Long-established), see 'Figure 1B', where the drainage system had not been restored.

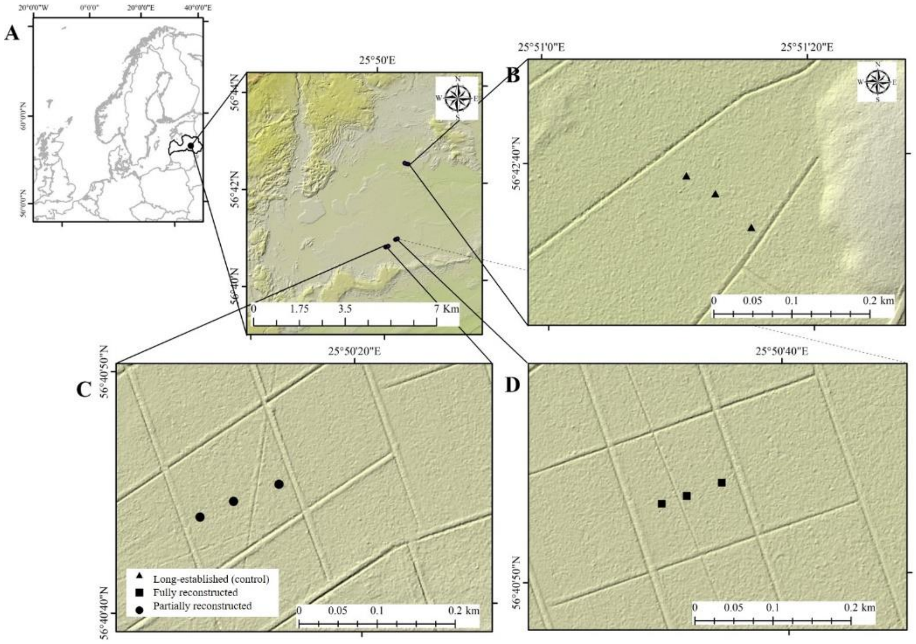

Figure 1. The location of study sites.

Data sampling

Three circular sampling plots with an area of 500 m^2 were establish in each of chosen forest stands, see 'Figure 1'; nine plots were established in total. The placement of the sample plots was arranged in a row, perpendicular to the restored ditches – so that the nearest and furthest area from the dich was characterized 'Figure 1, B, C, D'. In the case of control site, the plots are located perpendicular to the long-established ditches. Within each sampling plot, the dimensions of all trees, with diameter at breast height (DBH) greater than 6 cm, were measured.

In all plots of FR and PR sites a groundwater level measurement tool Rugged TROLL 200 Data Logger (In-Situ, Inc.) was installed (except one plot (PR1) in partially reconstructed forest stand). For the installation of the data logger, a two-meter-long plastic pipe was dug in each sample plot, in which a water level measuring device was placed. Holes were drilled in the lower part of the tube to ensure the flow of water. To ensure that the pipe would not fill up with the inflowing soil, the lower outer part of the pipe was tied with a geotextile. Each deployed data logger was set to collect groundwater elevation readings at one-hour intervals. Additionally, since the elevation and distance between the sites is relatively small, one Rugged BaroTroll 200 data logger (In-Situ, Inc.) was positioned at the land surface to monitor and record barometric pressure for all three sites. In the LE (control) site, the water level measurements were carried out manually.

In each sampling plot, the relative projective cover of ground flora was determined in 12 grid plots of size of 1 × 1 m, arranged systematically to the four cardinal directions whit a spacing of 1 m between the grid plots, see 'Figure 2'.

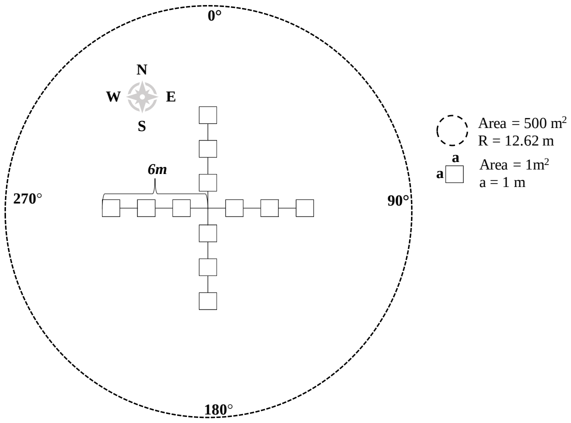

Figure 2. The scheme of study plot structure; tree stand measurement area and ground cover vegetation surveying grid.

The ground cover vegetation was divided and described within three layers: herbaceous vascular plants, woody plants (at an herbaceous layer) and bryophytes. The relative projective cover was assessed for all species individually; the total cover was allowed to exceed 100%, however, this restriction applied within the distinguished ground cover vegetation groups. The projective cover of bare soil, litter and wood debris was also determined. The ground cover vegetation survey, as well as the depth to groundwater measurements took place in 2021, in June-August and May-August time periods, respectively. The measurements of tree parameters took place in 2023; however, no chances in the structure or growth conditions had been detected.

Data analysis

The characteristics of forest stand for each plot were assessed by calculating basal area, standing stock and density of the canopy layer. Mean values for DBH and height (H) within each plot were obtained. To specify the composition of canopy layer, the proportion of each of the tree species was assessed.

In order to decribe the range of water level variation in studied forest sites, two time periods were distinguished, see 'Figure 3'. Measurements from May and June were combined as the measurements of the 'Spring' season. The measurements from July and August were assigned to 'Summer' season.

In order to describe the range of the possible water level variation, the minimal and the maximal depth to the groundwater was assessed in all study plots for both time periods. For the obtained results to be more uniform, data collected from the automatically obtained measurements were selected on the days when manual water level measurements were performed.

To gain an understanding of the composition and richness of the ground cover vegetation, the mean projective cover was obtained for vascular, woody and bryophyte layers separately. Furthermore, the mean projective cover of bare soil, litter and dead wood was assessed. For evaluating the communities of ground cover vegetation and the primary ecological gradients, DCA (Detrended Correspondence analysis) (Hill & Gauch, 1980) was utilized. The mean projective cover of the vegetation of grid plots was used as the basis for the analysis, and the downweighing of rare species was performed. For assessing the relationship of ground cover vegetation and stand factors, a matrix, containing information about the minimal and maximal depth to groundwater and taxation indices was used in DCA analysis and the variables were displayed as vectors. To find out whether there are differences between stands regarding the species projective cover and species composition, the ANOSIM (Analysis of similarities) (Clarke & Green, 1988), using *Bray's* distance, was calculated. To improve the comprehensibility and visualisation of ANOSIM results, boxplot graph was created. The statistical analysis was performed, using R software (R Core Team, 2023) and package *'vegan'* (Oksanen *et al*., 2022).

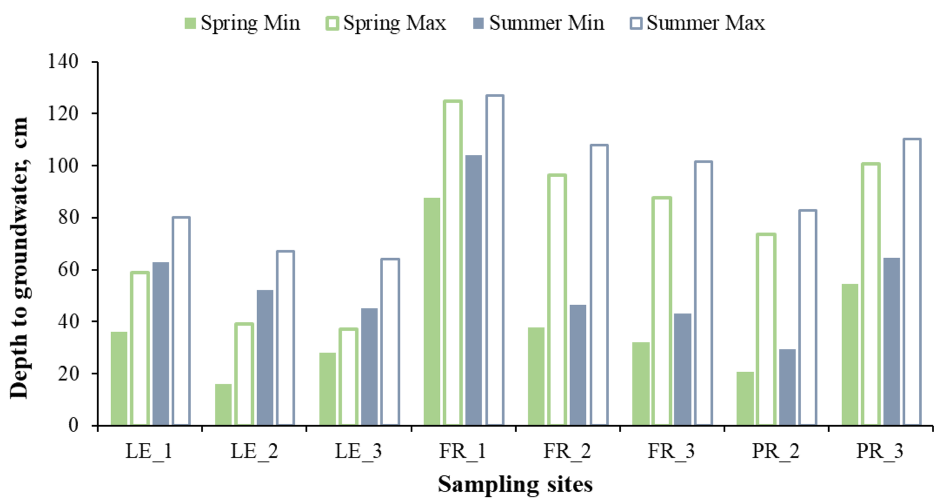

Figure 3. Comparison of the minimal and maximal depth to the groundwater level in studied stands depending on the drainage system status: LE – Long-established (control); FR – Fully reconstructed; PR – Partially reconstructed. 'Spring' period includes measurements from May to June, 'Summer' period – from July to August.

Results and Discussion

The studied PR and FR stands had rather similar mean stand volume, 107.6 and 105.8 m^3ha^{-1}, respectively; the LE (control) site had a higher mean stand volume – 275.4 m^3ha^{-1}. However, the FR stand was approximately twice as dense as the rest, with a mean of 1027 canopy trees ha^{-1}, while the PR stand had 640 and the LE (control) stand – 447 canopy trees ha^{-1}. The individual tree dimensions were more similar in the PR and FR stands, the mean DBH being 16.6 cm and 14.0 cm, and the mean tree height being 15.4 m and 13.4 m, respectively. The LE (control) site had trees of larger dimensions; the mean DBH reached 26.9 cm and the mean height of canopy trees – 23.6 m. In all three sites the canopy was dominated by *Picea abies* – 90 %, 70 % and 60 % of canopy trees in PR, FR and LE (control) site, respectively. All three study sites had an admixture of *Betula pendula*, for the PR stand a mean of 10 %, for the FR stand a mean of 30 %, but for the LE (control) stand < 10% from all canopy trees. Additionally, the LE (control) stand had an admixture of *Pinus sylvestris*, that reached a mean of 40% of all canopy layer trees.

The range of groundwater level differed among the studied forest stands 'Figure 3'; in case of all of the research sites, the lowest depth to groundwater was detected in spring season, reaching (mean ± standard deviation) 26.7 ± 10.1 cm, 37.5 ± 24.1 cm and 52.6 ± 30.5 cm on average in LE, PR and FR sites, respectively. The maximal depth to groundwater in spring season was more diverse amongst the research stands; the least amount of variation between the minimal and maximal depth to groundwater was observed in the LE (control) site, where the maximal depth to groundwater level reached a mean of 45.0 ± 12.2 cm. For the summer season, the lowest depth to groundwater was 46.9 ± 24.9 %, 53.3 ± 9.1 % and 64.6 ± 34.3 % in the PR, LE (control) and FR stands, respectively. In case of all of the studied plots, the greatest depth to groundwater was observed in the summer season, reaching a mean of 70.3 ± 8.5 %, 96.6 ± 19.5 % and 112.1 ± 13.3 % in the LE (control), PR and FR site, respectively. Overall, the greatest differences in the range of the depth to groundwater were detected in FR and PR stands, where the reconstruction of drainage diches, to some extent, took place in 2019, see 'Figure 3'.

A total of 73 different ground cover vegetation species were detected in research sites of which 48, 10 and 16 were of vascular, woody and bryophyte layer, respectively. The highest number of species was found in PR stands – 47 different species, of which 26 were vascular plant, seven were woody plant and 12 bryophyte species. Similarly, all together 41 different species were found in FR forest stand; the recording contained 30 vascular, four woody and seven bryophyte species. The lowest number of species was detected in the LE (control) stand, summing up to 33 different ground cover species of which 18, seven and eight were vascular, woody and bryophyte species, respectively. The mean projective cover of vascular plants in FR stand was 27.7 ± 7.7 %, in LE stand – 56.5 ± 7.9 % and in PR stand – 57.2 ± 15.3 %. The highest mean projective cover of woody plant species was recorded in PR stand (25.8 ± 13.3 %), followed by the LE stand (11.2 ± 5.7 %) and the FR stand (4.7 ± 4.4 %). The mean projective cover of bryophyte species in the FR stand was 49.9 ± 15.5 %, in the PR stand – 46.7 ± 12.7 % and in the LE stand – 63.3 ± 7.7 %.

Little to no projective cover of bare soil was detected in the research sites; however, the highest mean projective cover of bare soil was found in the FR stand – 0.8 ± 1.4 %. The highest mean projective cover of tree stand litter was recorded in the FR stand or 52.5 ± 12.8 %, followed by the LE and the PR stand, which had 24.4 ± 4.1 % and 17.9 ± 14.2 %, respectively. The mean projective cover of wood debris was highest in the LE stands – 1.0 ± 0.6 % and lowest in the FR stand – 0.8 ± 1.4 %.

As a result of the DCA analysis, two-dimensional graphs for both species and sampling sites were obtained, see 'Figure 4'. The eigenvalues were 0.588 and 0.248 for the first and the second axis, respectively. No overlapping of studied sample plots was detected, indicating that the species composition and stand characteristics were heterogeneous.

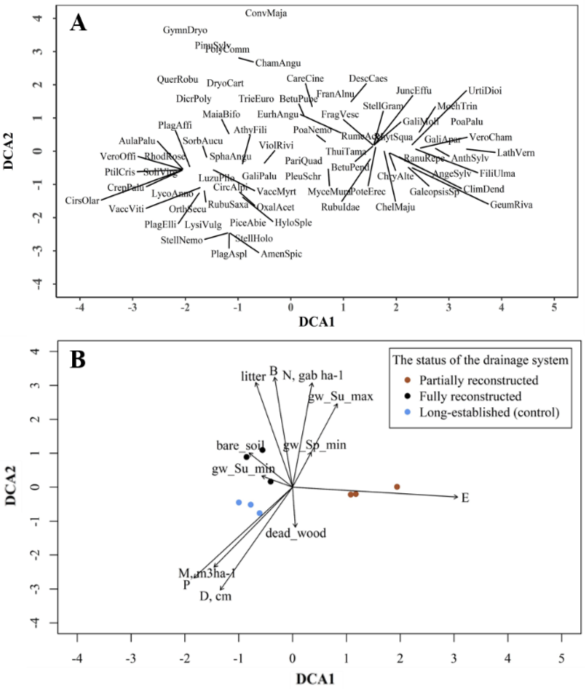

Figure 4. The image of the detrended correspondence analysis (DCA) of forest ground level vegetation species (A) and sample plots (B) according to their projective cover in forest stands where the drainage system has either been long-established (control), partially reconstructed or fully reconstructed. Species acronyms containing 8 letters (first 4 from the first and first 4 from the second scientific name) were used. Abbreviations of vector names: P – proportion of pine in canopy; E – proportion of spruce in canopy; B – proportion of birch in canopy; tree_D – mean diameter of canopy trees; M, m^3ha^{-1} – mean total stock of canopy tree per ha; N, ha^{-1} – mean number of trees per ha; gw_Sp_min – the minimal depth to groundwater in May-June period, cm; gw_Su_min - the minimal depth to groundwater in July-August period ; gw_Su_max - the maximal depth to groundwater in July-August period.

The proportion of *Picea abies* in canopy layer was positively corelated with the first axis, suggesting that the first axis reflected a gradient of either light availability or spruce needle induced acidity (or combination of both), as it has been revealed in findings of previous studies (Saetre *et al.*, 1997). Increased proportion of spruce was more characteristic to the PR plots; species associated with rather high soil moisture content, for example, *Galium Aparine*, *Urtica Dioica, Poa Palustris, Filipendula Ulmaria, Paris Quadrifolia, Geum Rivale, Veronica chamaedry, Climacium Dendroides, Angelica Sylvestris,* were more common in the mentioned plots.

The minimal depth to groundwater in summer season also had a positive correlation with first axis gradient; however, the influence was slight. The second axis was positively correlated with such factors as stand density, the proportion of *Betula pendula* in canopy layer and projective cover of tree litter. Nonetheless, the second gradient was approximately half as long as the one describing the X axis, making it difficult and discouraging to draw conclusions. However, previous research has found, that the deciduous leaf litter is less acidic (Saetre *et al*., 1997). Moreover, studies have shown that it influences the moisture of surface soil layer, advancing the growth of vascular plants and underscoring the beneficial effect of deciduous species in coniferous stands (Esteso-Martínez & Gil-Pelegrín, 2004). The scores of LE (control) plots had a slight positive correlation with the projective cover of bare soil and higher minimal depth to groundwater level. Such species as *Trientalis Europaea, Rubus Saxatilis, Dicranum Polysetum, Solidago Virgaurea, Chamaenerion Angustifolium, Circaea Alpina, Dryopteris Carthusiana, Sorbus Aucuparia, Hylocomium Splendens*, *Ptilium Crista-castrensis*, are common in various types of forest and were more associated with these plots.

In order to assess the similarity of species composition in the selected stands, ANOSIM analysis was applied. Dissimilarity rank within each group of plots was relatively low ‘Figure 5’, suggesting that the species composition and projective cover were similar within studied plots for each site group. However, the species composition varied significantly amongst study sites, as indicated by the dissimilarity R value and p value (R=0.9, p = 0.003).

The high dissimilarity of composition of ground cover vegetation in the FR, PR and LE (control) stands is likely due to distinct stand structural (stand volume, density, canopy tree species) differences, which, in recent studies, have been described as an important aspect, affecting the ground cover vegetation (Remm *et al*., 2013; Matisone *et al*., 2023), making it hard to evaluate the impact of groundwater level on species composition and richness.

Consequentially, the admixture of canopy tree species (Sorenson *et al*., 2011; Petersson *et al*., 2019) and the local stand factors, as well as the history of study sites (Pellerin *et al*., 2016) are known to have a crucial influence on composition of ground cover vegetation. However, identifying suitable research locations presents a significant challenge, this has also been pointed out by other researchers (Remm *et al*., 2013).

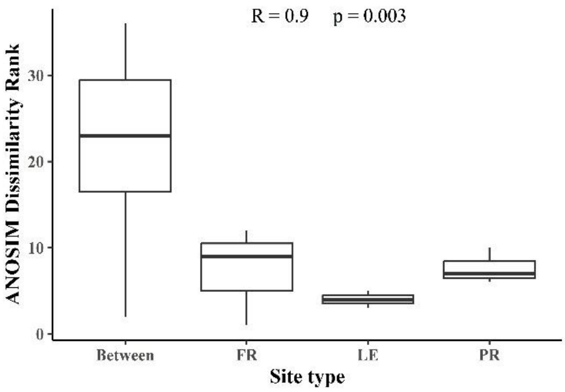

Figure 5. Boxplot illustrating the ANOSIM Dissimilarity Rank based on mean projective cover of ground cover vegetation across different site types, where the drainage system has either been long-established (LE, control) or partially reconstructed (PR), or fully reconstructed (FR). The plot displays the distribution of ranks alongside corresponding statistical values – R statistic and p-value.

Assessing the potential for possible changes of ground cover vegetation in our studied stands is important, especially for the effective planning and management of drained forests (Čakšs *et al*., 2018). The assessment of long-term impact of groundwater level on vegetation growing on organic soils after the reconstruction of drainage dich system is now possible in the studied sites, since the ground cover vegetation has now been characterized.

Conclusions

1. The composition of ground cover vegetation species differed amongst the studied sites. However, the stand factors were divergent, thus influencing the species composition and making it difficult to assess the direct impact of the groundwater level.
2. The sites with fully and partially reconstructed drainage ditches had a higher number of species, while the control stand, where no drainage dich renewal had taken place, contained a greater projective cover of bryophyte layer.
3. Admixture in canopy layer had a more distinct influence on the characteristics of ground vegetation species than that of the groundwater level.

Acknowledgements

The study was funded by European Regional Development Fund project ‘Development of a decision support tool integrating information from old-growth semi-natural forest for more comprehensive estimates of carbon balance’ (No 1.1.1.1/19/A/130)

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