# HARMONIZE VARIOUS TYPES OF ECOSYSTEM SERVICES OF AGRICULTURAL DRAINAGE SYSTEMS IN THE CZECH REPUBLIC USING PREVENTIVE AND REMEDIAL NITROGEN STRATEGIES

# HARMONISER LES DIFFÉRENTS TYPES DE SERVICES DE SYSTÈMES DE DRAINAGE AGRICOLE DES ÉCOSYSTÈMES DANS LA RÉPUBLIQUE TCHÈQUE EN UTILISANT DES STRATÉGIES PRÉVENTIVES ET CORRECTIVES AZOTE

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## ABSTRACT

More than ¼ of agricultural land in the Czech Republic was artificially drained. Of a substantial share are tile drainage systems situatedin foothills of highlands; i.e. built in slopes. These systems provideseveral Ecosystem service (ES) tradeoffs lying in interaction between provisioning, regulation and supporting services. In the CR, the most serious problems with drainage systems consist inageing and neglected maintenance of this systems and high contribution on nitrogen leaching. The efficiency of two nitrogen management strategies, targeted grassing and the use of drainage bioreactor, were tested on drainage systems placed in slopes. The experiments proved that both of these measures can be used for improvement of drainage water quality and consequently may helpto harmonize ES of agricultural drained lands. The trials showed that grassing focused on recharge zone, reduced the nitrate concentration by 36%-38% and the bioreactor lowered nitrate concentrations on average by 63%.

## RÉSUMÉ

Plus de ¼ des terresagricolesdans la Républiquetchèqueaétéartificiellementdrainé. D'une part substantielle des systèmes de drainage de tuilessituées au pied des montagnes; à-dire construitedans les pentes. Cessystèmesfournissentplusieurscompromis service de l'écosystème (ES) se trouvantdansl'interaction entre l'approvisionnement, la réglementationet les services de soutien. Dans la CR, plus graves problèmes avec les systèmes de drainage les consistent envieillissementet du maintien de cettesystèmes et de haute contribution sur le lessivage de l'azotenégligés. L'efficacité des deuxstratégies de gestion de l'azote, l'engazonnementetl'utilisationciblée de drainage bioréacteur, ontététestés sur les systèmes de drainage placésdans les pentes. Les expériencesontmontré que cesdeuxmesurespeuventêtreutilisées pour l'amélioration de la qualité de l'eau de drainage et par conséquentpeutcontribuer à harmoniser les ES de terresdrainéesagricoles. Les essaisontmontré que l'enherbementciblé sur la zone de recharge, réduit la concentration en nitrates de 36% -38% et les bioréacteursréduit les concentrations de nitrates enmoyenne de 63%

**Keywords**:Tile drainage ; Ecosystem services ; Nitrate leaching ; Targeted grassing ; Bioreactor

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## 1. Introduction

Agricultural tile drainage belongs to the common worldwide measures enhancing water and air behavior in the soil. Optimal conditions for crop plants and better trafficability for farm machinery are reached by removing the excess water from soil. By draining, especially provisioning Ecosystem Service (ES) is enhanced (Cristiansen et al., 2013) bringing economic and social benefits as increase in the crop yield and living standards of local people (Schultz et al., 2007). On the other hand, some trade-offs are connected with land drainage, which lie in regulation and supporting ES services. Improvement of soil structure and health benefits are advantages of agricultural draining, while other services as e.g. the provisioning of clean water and biodiversity are rather deteriorated. Drainage systems are reported among significant factors for nutrient transport from soilto surface waters (Hirt et al., 2005). To the most leached nutrients belongs nitrogen, mainly in nitrate form, playing an important part in water quality degradation (Galloway et al. 2003).

In the Czech Republic, there were more than 1 078 000 ha of land drainage built by 1990, which cover about ¼ of the agricultural land in the CR (Kulhavý et al., 2007). Many of these system were built in the foothill areas of the Bohemian-Moravian Highland, on crystalline bedrocks. These systems are characterized by their locations in slopes, in transient zones, or at interfaces of transient and discharge zones (Doležal and Kvítek 2004). In such cases, the entire catchment (rather than the drained land itself) must be taken into account for water balance and quality studies, since a considerable portion of the drainage runoff originates outside the drained area (Zajíček et al., 2011) together with significant portion of nutrient loads (Fučík et al. 2014). Being built into slopes, these tile drainage systems represent a shortcut between recharge and discharge zones which significantly shortens the water residence time in the catchment hastens the precipitation-runoff reaction, and shortens the time to reach peak discharge during events (Robinson 1990). All above mentioned contribute to the increased N leaching by the drainage systems, which belong together with ageing of this systems, land owner – tenant relations and relatedneglected maintenance to the biggest up-to-date problems related to land drainage in the Czech Republic(Kulhavý and Fučík, 2015).

For decreasing N leaching, there exists some preventive (e.g. nitrogen application management, land or tillage management, crop rotation) and remedial strategies (e.g. controlled drainage, bioreactors and constructed wetlands) (Dinnes et al. 2002). Grassing belongs to the preventive nitrogen remedial strategies. Reducing nitrate pollution by grassland is mainly caused by the fact that grassland can absorb and use bigger amount of nitrogen in comparison to field crops and this ability remains for longer period within the year. Permanent grasslands cover the soil year round and have a big stock of active subsurface biomass in the root system, which can immobilize a significant amount of soil nitrogen. Moreoverit has bigger amount and increased activity of soil microbes, which is much higher under grassland than under field crops (Griffiths et al. 2008). Besides nitrogen remedial ability, grasslands offer other regulation and supporting ES benefits (Hönigová et al., 2012) e.g. carbon sequestration, erosion and water flow regulation. On the other hand, using too widely, it has also negative ES decreasing provisioning services, in particular crop production (Hauck et al., 2014). That's why it is recommended to use the grassing to act effectively, in relatively small spots,focused on the proper catchment areas. The effectiveness of grassing has been evaluated e.g. statictically, when Fučík et al. (2008) reported that increase of grasslandby10 % of catchment area can decrease the C90 nitrate value in waters of small water courses on average by 6,4 mg/l.

Bioreactors belong to the group of remedial N strategies. To the benefits of building bioreactors belong its small size, underground placement, low construction and maintenance costs(Christiansen et al., 2013). Nitrate removal capacity depends on the hydraulic residence time in systems and the denitrification capacity of the microbial community (Schipper et al., 2010). The exact kinetics of $NO_3$-N removal in these systems is complex, depending upon the initial $NO_3$-N concentration in water, the biomass of the denitrifier community, temperature, and carbon bioavailability (Schipper et al., 2010). Removal efficiency of nitrates is reported to vary between 25% - 75% (Christiansen et al., 2013).

The aim of this paper is to present the results of two nitrogen remedial measures: a seven-year field experiment with targeted grassing, situated in a small drained catchment´s recharge zone as well as trials with an extensively monitored denitrifying bioreactor to minimize nitrate burden in drainage and related surface waters.

## 2. Evaluation of Nitrogen removal strategies

### 2.1. Experimental grassing of recharge area

| Site | Drainage type | Period 1 land-use | | Period 2 land-use | |
|---|---|---|---|---|---|
| | | Discharge zone | Recharge zone | Discharge zone | Recharge zone |
| K1 | systematic | grassland | arable land | grassland | grassland |
| K2 | intercepting drain | --- | arable land | --- | grassland |
| K5 | systematic | arable land | arable land | arable land | arable land |
| K6 | intercepting drain | --- | arable land | --- | arable land |
| K4 | systematic | grassland | arable land | grassland | arable land |
| KL | closing outlet | grassland | arable land | grassland | arable land+grassland |

**Tab. 1: Measuring sites and land-use in their Discharge and Recharge zones**

Long term experiment with the land use change in tile drainage recharge zone was conducted in the catchment Dehtáře (57.9 ha, Bohemian-Moravian Highlands, Czech Republic). It is a locally typical small agricultural catchment, where the tile drainage acts as the only permanent runoff. Typical for the region is the position of drainage systems in slope and crystalline bedrock covered by very heterogeneoussoil cover (Zajíček et al., 2011). The water quality in sixsites with different land-use in recharge and discharge areas was monitored from 2003 to 2013 (tab.1). Samples were taken in one- or two week step. Part of recharge area with the area 4.6 ha was grassed since the hydrological year 2007. The area for grassing was chosen using the method of relative soil infiltration vulnerability determination and the delineation of infiltration vulnerable areas (Janglová et al., 2003).For evaluation the effect of this grassing, the whole monitored time was divided into period 1 - before grassing (years 2003-2006) and period 2- after grassing (years 2007-2013). All grassland in the catchment was fertilized by approximately 100 kg N/ha per season (mostly by slurry and urea); arable land, due to common crop rotation, in the amount of circa 120 kg N/ha per season.

The nitrate concentrations were strongly variable during the whole period (dependence on discharges) and in comparison of particular seasons (different precipitation course in particular season and by crops rotation). The monthly flow-weighted concentration (Cfw)$NO_3$value varied from 13 to 197 mg/l throughout the monitored period. In period 1 (before grassing the recharge zone), Cfwwere surprisingly higher in sites K1, K2 and K4 with the permanent grassland in drained area (discharge zone) than in sites collecting waters arable land (K5, K6). After grassing the K1 subsystem recharge area, some changes occurred. Approximately one year after grassing, the long-term course of $NO_3$ concentrations changed its direction and became decreasing in sites with completely (K1, K2) or partly grassed recharge zone. In sites without land–use change (K5, K6, K4), the nitrate Cfw trend remained increasing or the stagnation was found. Results of Kruskall-Wallis test evaluating the significance of nitrate concentration change showed the statistically significant decrease happened in sites with the grassed recharge zone. Decreases of 38.1% and 35.9% were detected in the systematic drainage subsystem K1 and intercepting drain K2, respectively. In the same period, an increase in nitrate concentration was detected in sites without land use change in their recharge zone. There was an increase of 10.4% in the drainage subsystem K5 with arable land in both (recharge and discharge) zones and of 7.4% in intercepting drain K6. In the subsystem K4 with grassland in the discharge zone, but arable land in the recharge zone an insignificant increase of 8.0% happened in period 2. Evaluating the whole drainage system (KL), the fall in nitrate concentrations by 14.6% was detected after grassing about 20% of this systems recharge zone area.

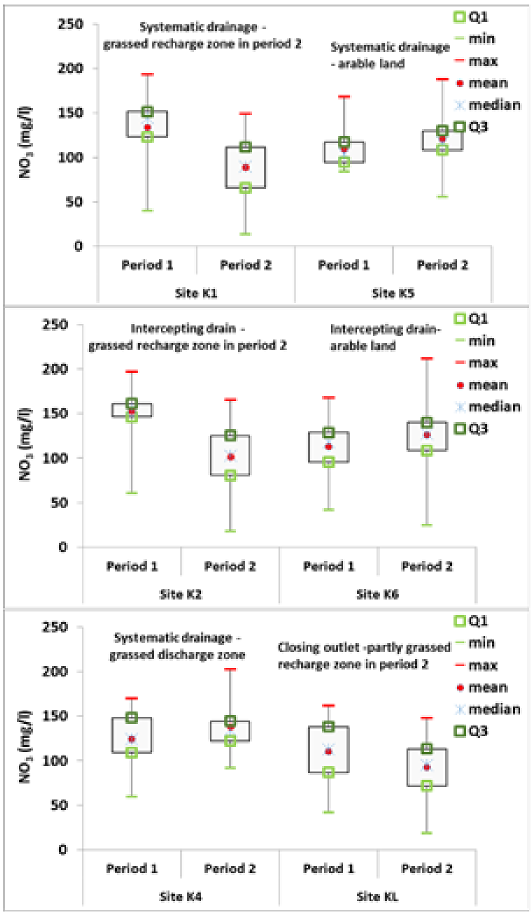


Fig. 1: Nitrate concentrations befor (period 1) and after (period 2) grassing of a part of a catchment recharge zone

### 2.2. Efficiency of the straw bioreactor

Atthe outlet of a drainage group in the Černičí catchment (Bohemo-Moravian Highlands, 135 ha, paragneiss bedrock, drainage system built in slope, was built a denitrification bioreactor (end of 2006). The fill-material of reactor was straw, the shape was block 1.2m width and 3.0m length. It was placed in the depth of the drainage outlet - 1.2 m. Samples for monitoring of nitrate concentrations were taken irregularly in the period 2006-2014. Removal efficiency of nitrates was established as difference between inflow and outflow concentrations.

The efficiency of bioreactor was relatively high (Fig. 2), when the mean and median nitrate concentrations decrease was 63% and 83%, respectively. There were only small differences between vegetation and non-vegetation seasons, the efficiency was slightly higher during vegetation season (mean 66%, median 85%) than during non-vegetation season (mean 58%, median 79%). The values of mean $NO_3$ removal efficiency were influencedby samples taken during high flow events (spring snowmelt or summer rainfall-runoff events), when the outflow water was mixed with water bypassing the bioreactor, with diluted $NO_3$ values. The efficiency of denitrification remained high during all monitored period despite the fact, that 2-3 years after construction, the discharge capacity of the bioreactor started to decrease (probably because of clogging) and the sensorial characteristics of outflow water (color and smell) deteriorated. For the future, the water residence time in bioreactor should be measured or computed and the state of straw fillcontrolled to secureappropriate functioning of the bioreactor.

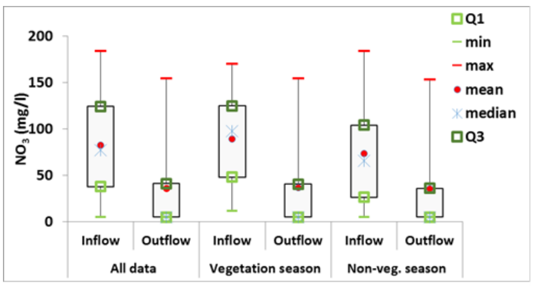


**Fig. 2: Nitrate concentrations in inflow and outflow of denitrification bioreactor**

## 3. Conclusions

The experiment proved that grassing focused on the proper catchment area (recharge zone) can be a useful tool for reducing nitrates in drainage water. While permanent grassland placed directly in the drained area (catchment discharge zone) did not show any effect, the grassing focused on the catchment recharge area demonstrated a significant decrease in$NO_3$ concentrations. The denitrification bioreactor showed high efficiency, however, an attention must be paid on well-timed renewing its fill content. Both of these nitrogen management strategies may be used for improving the quality of water leaving drainage outlets and consequently led to harmonize of ES of agricultural drained lands.

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