Estimation of Nitrogen budget in the transboundary river catchments of Eastern Europe dominated by agroactivities

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INTRODUCTION

Agriculture, industry and other human activities have been altering Nitrogen (N) cycling leading to N imbalance at ecosystem and regional levels. This results at numerous environmental impacts on air, water and soil quality, GHG balance and ecosystem functioning (ENA, 2011). Quantification of N flows at district scale to build joint N budget is an efficient tool for identification of relevant domains to apply mitigation measures.

The aim of this study is to develop N budget for the transboundary region in East Europe to assess N flows contribution and impact on the Black Sea.

METHODS

The study region embraced the catchments of Dniester and Prut (and the Danube Delta area) with total land area of 121 897 km^2 and aquatic surface of 2 863 km^2.

To calculate N flows we used available data from different sources (national statistics, environmental monitoring and research). Estimates of EMEP, FAO, EDGAR, GRDC etc. and methodology described in ECE/EB.AIR/113 have been also taken into account.

RESULTS and DISCUSSION

In this study we tried to develop the conceptual scheme for N budget estimation at a river catchment scale, which might be applied in a transboundary watersheds within the Eastern Europe or elsewhere under limited data availability.

We conceptualized to distinguish three main categories of N flows within boundaries of the studied system: input (incoming from elsewhere to the system), output (outgoing to elsewhere from the system) and internal cycle flows (which originate/ produce and consume/ utilize within the system boundaries). Temporal boundaries were suggested to be on a calendar year basis if annual statistics are planned to be used; however, multiannual dataset use may increase the credibility of mean estimates avoiding the impact of climate- and economy-related N flow variations in a particular year. Below we present an example of the main N flows for N budget estimation made for the watersheds of Prut and Dniester (and Danube delta) in 2015 within the Towards INMS project (Fig. 1; shown results are indicative to illustrate the order of magnitudes and the availability in the region).

Input N flows

- Total N fertilizer use in the region was accounted to be 190 Gg N yr^{-1}
- Mean TN deposition was estimated as 145±8 Gg N yr^{-1} to the entire study area in 2015 (Medinets et al., 2020a), where ca. 60% were deposited in organic forms, 'oftener unaccounted' in the inventories and previous assessments
- Biological N fixation (BNF) was estimated from 13 to 54 Gg N yr^{-1}
- Around 13.5 Gg N was fixed by surface water from the atmosphere annually
- The input of N with fish stocking to the rivers was minor (0.004 Gg N yr^{-1})
- Imported forage for animals was roughly assessed as 390 Gg N yr^{-1} (under revision)
- Other N transported to the region with imported products was not estimated

We suppose that ~50% of N might come into region with 'imported' animal forage (still under revision). Synthetic N fertilizer and N deposition contributed to 24% and 18% respectively, being 2nd and 3rd large sources.

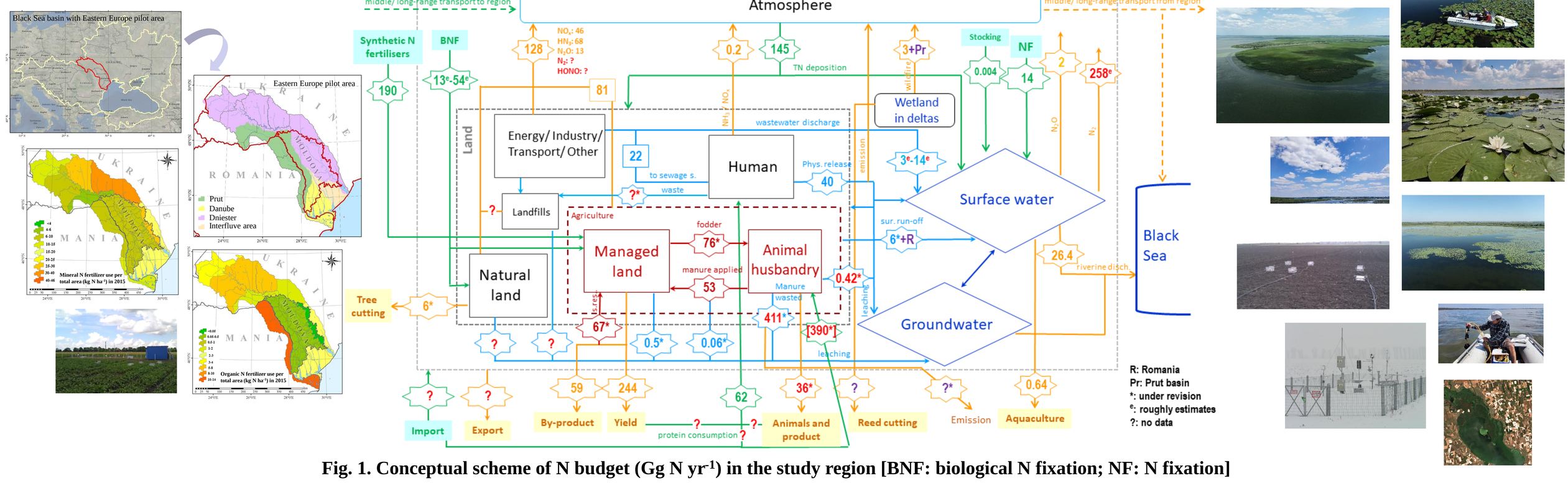

Fig. 1. Conceptual scheme of N budget (Gg N yr^{-1}) in the study region [BNF: biological N fixation; NF: N fixation]

Internal cycle N flows

Within sub-system agriculture

- Approx. 76 Gg N of fodder crops were transferred from plant growing system to animal husbandry in 2015
- Around 53 Gg N were returned to the crop and grasslands with animal manure as organic fertilizers (less than 15% of total manure produced in the region)
- Plant residues returned ca. 67 Gg N back to fields

Between land and hydrosphere

- Wastewater discharges contributed from 3 to 14 Gg N to the rivers annually
- Ca. 40 Gg N was released by population and not treated with sewage system
- Approx. 411 Gg N of animal manure might be wasted (under revision)
- The rates of N run-off and leached to the surface and groundwater were estimated as ~1 Gg N (understudied)
- Annually ca. 62 Gg N was consumed with food (animal and plant) protein by population in the region (ratio of local to imported is unknown)

Estimates of N flows between land (agriculture/ humans) and aquatic sub-systems were largely unknown due to the lack of targeted research

Output N flows

- The largest amount of N was removed form the system with crop yield (244 Gg N yr^{-1}) and by-product (59 Gg N yr^{-1})
- Losses (NO_x+NH_3+N_2O) to the atmosphere from the land-based sources (industry and agriculture) were estimated as 128 Gg N yr^{-1}; agriculture sector contributed ~63% of N-gas emissions
- Dniester riverine discharge removed ca. 26.4 Gg N to the Black Sea
- At least 3 Gg N were emitted from wetland areas due to fires
- Around 2 Gg N were emitted as N_2O form surface waters
- Freshwater aquaculture likely contributed to less than 1 Gg N removal
- Estimates of N_2 production and emission (via denitrification and anammox) were highly uncertain, but might be huge enough (up to 258 Gg N yr^{-1})
- N removal with animal product was ca. 36 Gg N yr^{-1}
- Losses to the environment from wasted manure might be equal to its amount (411 Gg N yr^{-1}) (under revision)

N losses to the atmosphere from land-based activities were comparable to crop production in Ukrainian part (if losses from manure are not taken into account)

CONCLUSION

- **The developed concept for the main N flows in a river catchment might be applied in a transboundary watersheds within the Eastern Europe or elsewhere under limited data availability to estimate N budget**
- **N losses are highly uncertain in the region due to their estimations based on unspecific emission factors developed for other regions rather than proved by robust region-specific in-situ measurements**
- **The first N budget estimation within transboundary region in East Europe covering two watersheds (Dniester and Prut) and Danube delta area in three countries showed total N input was assessed as 793 Gg N yr^{-1}, where ~50% likely derived from external sources (imported fodder; under revision). The flows within N internal cycle made around 683 Gg N yr^{-1} (again dominated by manure wasted; under revision). The total N came out from system was assessed as 805 Gg N yr^{-1} including N_2 portion (258 Gg N yr^{-1}) released from surface waters; on one hand, N_r to N_2 transition had an energetically negative effect (as N loss), on the other – environmentally positive one (as neutralization with a zero direct impact on environment)**
- **More than 26 Gg N was directly discharged to the Black Sea from the Dniester catchment**
- **Overall N budget was +12 Gg N yr^{-1}, while if only N_r accounted it made -246 Gg N yr^{-1} supposing that water bodies might play an important role in loosing N_r from the system by neutralizing it to N_2.**

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