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Estimating the gross nitrogen budget under soil nitrogen stock changes: A case study for Turkey

Fethi Şaban Özbek *, Adrian Leip

European Commission – Joint Research Centre, Institute for Environment and Sustainability, Italy

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ABSTRACT

The method to estimate the Gross Nitrogen Budget proposed by Eurostat and the OECD was developed under the assumption of no changes in soil nitrogen stock, due to the lack of available data. We estimated the national and regional nitrogen budgets of agriculture in Turkey, calculated according to the recommended methodology at the level of administrative regions. Results suggest that changes in soil nitrogen stocks are likely for some regions. In such cases, the method warns that its estimated indicators (gross nutrient surplus and nitrogen use efficiency (NUE)) are not valid. We propose two different approaches to improve the Eurostat/OECD method, based on assumptions of minimum and maximum NUE, and on regressing the N-input and N-output relationship for regions without obvious soil nitrogen stock changes. Our results show that both approaches give reasonable results for all regions, including those for which the Eurostat/OECD method failed. The results also suggest that soil nitrogen accumulates in some regions and depletes in others. Results give a range of 6–93 kg N ha^{-1} yr^{-1} (mean 35 kg N ha^{-1} yr^{-1}) for the Gross Nitrogen Surplus, and a range of 49–82% (mean 62%) for the NUE.

1. Introduction

Nitrogen (N) is an important source of nutrition for plants. While N deficiency negatively affects plant growth, N surplus (NS) can negatively impact environmental quality and human welfare (Sutton et al., 2013, 2011a,b). These impacts include negative effects on biodiversity, eutrophication, nitrate accumulation in waters, acidification, nitrous oxide emissions (with effects on global warming and the depletion of the stratospheric ozone layer), and risks to human health due to exposure to ozone and particulate matter (Smil, 2011; Sutton et al., 2011a). The agricultural sector is an important source of the N that ends up in ground- and surface waters and the atmosphere (Erisman et al., 2013; Fowler et al., 2013; Sutton et al., 2011a,b). N deficiency, NS and N use efficiency (NUE) in agricultural production are estimated on the basis of agricultural N budgets (e.g. OECD, 2001; Oenema et al., 2003; Leip et al., 2011b; CAPRI, 2013; Eurostat, 2013a). An accurate quantification of the NS and the NUE is crucial in order to identify the possibilities of achieving a resource-efficient agri-food chain (see e.g. EC, 2014, 2011). In Europe, the Gross Nutrient Balance is considered to be a priority agri-environmental indicator (EC, 2006) that is of relevance for both water- and air-quality policies.

The N budget is one of the 28 agri-environmental indicators determined by Eurostat (EC, 2006), and is also one of the mandatory indicators to be compiled within the "Common Monitoring and Evaluation Framework" of the European Commission's Rural Development Policy (EC, 2013). Assessments of N budgets are also carried out by the European Environment Agency (EEA, 2012) and the Organisation for Economic Co-operation and Development (OECD, 2013). N budgets are not only useful as indicators of the environmental pressure of agriculture at the national scale – they also help to improve our understanding of agricultural production systems by quantifying farm, land or soil N-budgets using local and regional data (e.g. Barry et al., 1993; Weissbach and Ernst, 1994; Brouwer, 1998; Grignani et al., 2005; Panten et al., 2009; Leip et al., 2011b). To our knowledge, the NS and NUE have not yet been estimated for Turkey at the regional level.

Eurostat has developed a new methodology for quantifying gross N budgets (Eurostat, 2013b; hereafter referred to as GNB), to be applied by EU countries. This Eurostat GNB methodology, which updates the previous guidelines (OECD and Eurostat, 2007), is based on the land budget method (Leip et al., 2011b). It yields valid results only under conditions where there are no substantial changes in soil N stocks. Data on soil N stock changes are scarce, and no general guidance exists for their estimation at the regional or national level (Eurostat, 2013b).

* Corresponding author at: Via Fermi 2749, TP 266/023, I-21027 Ispra (VA), Italy. Tel.: +39 0332 78 9611; fax: +39 0332 78 9364.
E-mail address: fethi.ozbek@jrc.ec.europa.eu (F.Ş. Özbek).

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The purpose of this study is twofold: first, to develop a method that allows for the estimation of the GNB under conditions of changing soil N stocks; and second, to apply the method to provide the first quantification of N values for the 26 sub-regions of Turkey for the period 2007–2011.

2. Materials and methods

2.1. Study region

According to the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT, 2012a), the total utilised agricultural area (UAA) in Turkey in 2009 accounted for 0.8% of the total agricultural land of the world. The UAA in Turkey is about 20% of the UAA of the European Union (EU), and mineral fertiliser consumption is about 10% that of the EU (FAOSTAT, 2012a). Turkey has high numbers of livestock; for example, it has more goats and poultry than any country of the EU, and the 2nd and 3rd highest numbers of sheep and cattle compared to EU Member States (FAOSTAT, 2012b).

Turkey has four different climate zones: (i) a continental climate in the Interior, Eastern and Southeastern Anatolia regions; (ii) a Mediterranean climate in Western Anatolia and the southern coast of Anatolia; (iii) a Marmara (transition) climate in Istanbul and around the Sea of Marmara; and (iv) a Black Sea climate in the Black Sea region of northern Turkey.

In Turkey, the N removed by crops and fodder per ha (the main output variable in GNB calculations), the mineral fertiliser used, and the number of cattle per ha (the main input variables in GNB calculations) vary considerably between the regions. The differences between these variables are shown in Fig. 1(a)–(c).

2.2. Default GNB methodology (GNB-Eurostat)

We first estimated the GNB on the basis of the methodology suggested by Eurostat (2013b). In the following, we refer to this approach and the derived indicators as GNB-Eurostat, $NS_{eurostat}$, and $NUE_{eurostat}$. A summary of the methodology and data sources for N inputs and outputs used in this study are presented in Table 1. NS is estimated by subtracting the total amount of N contained in the outputs from the total amount of N contained in the inputs, and the result is divided by the reference area A_{ref}. A_{ref} is the total UAA, comprising arable land, permanent cropland, and utilised perment grassland. NUE is estimated as the ratio between the total N in the

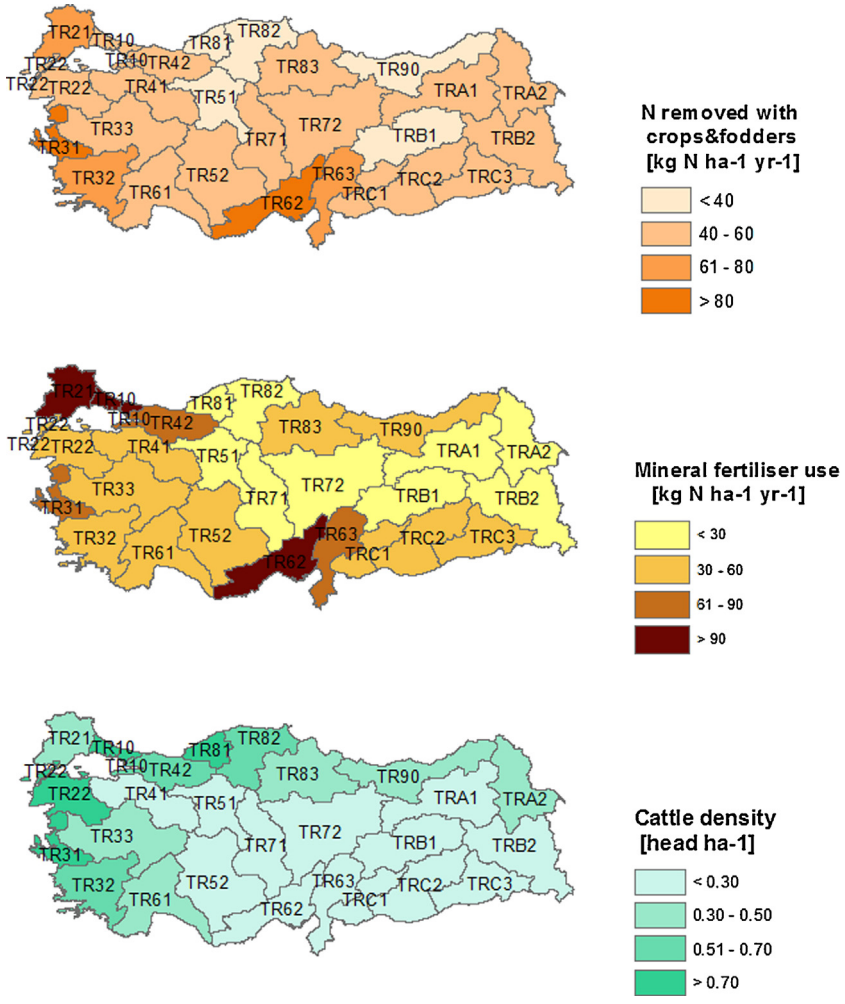

Fig. 1. Selected data required for the quantification of the Gross Nitrogen Budget at the regional scale, averaged over the period 2007–2011: (a) N removed with crops and fodders; (b) mineral fertiliser use; (c) cattle density.
Region codes: TR10: Istanbul; TR21, TR22: West Marmara; TR31, TR32, TR33: Aegean; TR41, TR42: East Marmara; TR51, TR52: West Anatolia; TR61, TR62, TR63: Mediterranean; TR71, TR72: Central Anatolia; TR81, TR82, TR83: West Black Sea; TR90: Eastern Black Sea; TRA1, TRA2: Northeast Anatolia; TRB1, TRB2: Central-east Anatolia; TRC1, TRC2, TRC3: Southeast Anatolia.