Piling up reactive nitrogen and declining nitrogen use efficiency in Pakistan: a challenge not challenged (1961-2013)

Sajjad Raza\textsuperscript{1,2}, Jianbin Zhou\textsuperscript{1,2,7}, Tariq Aziz\textsuperscript{3,4}, Muhammad Rahil Afzal\textsuperscript{3}, Muneer Ahmed\textsuperscript{1,2,5}, Shahbaz Javaid\textsuperscript{6}, Zhujun Chen\textsuperscript{1,2}

\textsuperscript{1}College of Natural Resources and Environment, Northwest A&F University, Yangling, 712100, Shaanxi, China
\textsuperscript{2}Key Laboratory of Plant Nutrition and the Agri-Environment in Northwest China, Ministry of Agriculture, Yangling 712100, Shaanxi, China
\textsuperscript{3}Institute of Soil & Environmental Sciences, University of Agriculture, Faisalabad 38040, Pakistan,
\textsuperscript{4}School of Plant Biology, University of Western Australia, 35 Stirling Highway, Crawley, WA, Australia
\textsuperscript{5}Faculty of Agriculture, Lasbela University of Agriculture, Water and Marine Sciences, Uthal 90150, Balochistan, Pakistan
\textsuperscript{6}Animal Sciences Institute, National Agricultural Research Centre, Islamabad 45500, Pakistan
\textsuperscript{7}Author to whom any correspondence should be addressed.

Supplementary Information

Fig. S1. Changes in the consumption, production and trade of synthetic N fertilizer in Pakistan from 1961 to 2013 (IFA 2016)
### Table S1. Agricultural intensification in Pakistan during 1961-2013

| Variables | 1961-1965 | 2009-2013 (%) | References |
|-----------|-----------|--------------|------------|
| Population | Population (1000) | 48366 | 173764 | 259 | FAOSTAT 2016 |
|           | % Rural Population | 78 | 64 | -18 | FAOSTAT 2016 |
|           | Population Density (km²) | 64 | 229 | 258 | World Bank 2016 |
| Agriculture Surface | Agricultural Area (1000 ha) | 36208 | 35760 | 1 | FAOSTAT 2016 |
|           | Arable Land (1000 ha) | 31056 | 29924 | -4 | FAOSTAT 2016 |
|           | Permanent Crops | 152 | 836 | 450 | FAOSTAT 2016 |
|           | Pastures | 5000 | 5000 | 0 | FAOSTAT 2016 |
| Intensification Indicators | Agricultural Tractors (10³ Units) | 6.5 | 450* | 6823 | World Bank 2016 |
|           | % Irrigated Land over Agricultural Land | 31 | 56 | 81 | FAOSTAT 2016 |
|           | Nitrogen Fertilizers (TgNyr⁻¹) | 0.065 | 3.17 | 4777 | IFA 2016 |
|           | Energy Production (EJ) | 0.14 | 1.96 | 1300 | GOP 2013 |
| Yields (ton ha⁻¹) | Wheat | 1 | 3 | 200 | FAOSTAT 2016 |
|           | Rice | 1 | 3 | 200 | FAOSTAT 2016 |
|           | Maize | 1 | 4 | 300 | FAOSTAT 2016 |
|           | Orange | 1 | 11 | 1000 | FAOSTAT 2016 |
|           | Sugarcane | 34 | 54 | 59 | FAOSTAT 2016 |
| Livestock | Cattle (10⁶ heads) | 14 | 36 | 157 | FAOSTAT 2016 |
|           | Buffalo (10⁶ heads) | 7 | 31 | 343 | FAOSTAT 2016 |
|           | Sheep (10⁶ heads) | 11 | 28 | 155 | FAOSTAT 2016 |
|           | Goat (10⁶ heads) | 10 | 62 | 520 | FAOSTAT 2016 |
|           | Horse (10⁶ heads) | 0.4 | 0.4 | 0 | FAOSTAT 2016 |
|           | Chickens (10⁶ heads) | 13 | 352 | 2608 | FAOSTAT 2016 |
| Import of Feed | Maize (10³ tons) | 2 | 23 | 1050 | FAOSTAT 2016 |
|           | Soybean (10³ tons) | 0 | 0.03 | 0 | FAOSTAT 2016 |
|           | Soybean Cakes (10³ tons) | 0 | 420 | - | FAOSTAT 2016 |
|           | Barley (10³ tons) | 0.6 | 3 | 400 | FAOSTAT 2016 |
| Trade | Import (10⁶ tons) (420 commodities) | 1.08 | 4 | 270 | FAOSTAT 2016 |
|           | Export (10⁶ tons) (420 commodities) | 0.56 | 7 | 1150 | FAOSTAT 2016 |
|           | Value Import (10⁶ $) (Agricultural Products) | 152 | 5423 | 3468 | FAOSTAT 2016 |
|           | Value Export (10⁶ $) (Agricultural Products) | 165 | 4291 | 2501 | FAOSTAT 2016 |
|           | Agriculture Contribution GDP (%) | 42 | 25 | -40 | FAOSTAT 2016 |
| Diet | Protein Consumption (kgNcap⁻¹yr⁻¹) | 3.29 | 3.76 | 14 | FAOSTAT 2016 |
|           | Animal Protein Consumption (kgNcap⁻¹yr⁻¹) | 0.88 | 1.51 | 72 | FAOSTAT 2016 |
|           | Proportion Animal Protein (%) | 27 | 40 | 48 | FAOSTAT 2016 |
| Energy Consumption | Total Energy Consumption (EJ) | 0.30 | 2.81 | 837 | GOP 2013 |
|           | Total Energy Import (EJ) | 0.12 | 0.85 | 608 | GOP 2013 |

*Estimated value
Fig. S2. Import, export and overall net N import of crop and livestock products used in Pakistan
Table S2. Fertilizer use by different crops in Pakistan (2010-11)

| Crop Types       | Fertilizer Consumed | Quantity (Gg) | Share (%) |
|------------------|---------------------|---------------|-----------|
| Cereals          | Wheat               | 1351          | 43        |
|                  | Rice                | 346           | 11        |
|                  | Maize               | 141           | 4.5       |
|                  | Other Cereals       | 25            | 0.8       |
| Oilseeds         |                     | 31            | 1         |
| Fiber Crops      |                     | 629           | 20        |
| Sugar Crops      |                     | 251           | 8         |
| Roots/Tubers     |                     | 19            | 0.6       |
| Fruits           |                     | 110           | 3.5       |
| Vegetables       |                     | 63            | 2         |
| Other Crops      |                     | 176           | 5.6       |
| Total Fertilizer Consumed | 3143           | 3% (of world) |           |

Source: (Heffer 2013)
Fig. S3 Import and export of N (GgNyr⁻¹) by Pakistan with the world
Fig. S4 (a) Map of Pakistan depicting the spatial distribution of \(\text{NO}_3\) in groundwater samples throughout the country (n=458), (b) Inverse-distance-weighting grids of \(\text{NO}_3\) in groundwater samples collected throughout the country (n=458). Both maps reprinted from Podgorski et al\textit{2017} © 2017 The Authors, some rights reserved; exclusive licensee American Association for the Advancement of Science Distributed under a Creative Commons Attribution Non Commercial License 4.0 (CC BY-NC).

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