Newton-Bhabha Virtual Centre on Nitrogen Efficiency of Whole-cropping Systems for improved performance and resilience in agriculture (NEWS India-UK)

M.A. Sutton[1], **J. Drewer[1]**, N. Raghuram[2], D. Kumar[3], A. Price[4], J.U. Smith[4], A. Bhatia[3], D. Reay[5], D. Subrahmanyam[6], A. Ahmad[7], U. Skiba[1], U. Dragosits[1], M. Vieno[1], W.J. Bealey[1], E. Carnell[1], E. Roberts[1], A. Stott[8], S. Sohi[5], A. Moring[5], J. Hillier[4], D.R. Nayak[4], R. Prasana[3], R. Singh[3], C.N. Neeraja[6], S.R. Voleti[6], R.M. Kumar[6], K. Surekha[6], S. Hooda[2], R. Babu[6], N. Jain[3], P. Pandey[3], B. Ramakrishnan[3], N. das Saha[3], H. Pathak[3]

[1] Centre for Ecology and Hydrology (CEH), Edinburgh Research Station, Bush Estate, Penicuik, EH26 0QB, Scotland, UK, www.ceh.ac.uk, juew@ceh.ac.uk
[2] School of Biotechnology, Guru Gobind Singh Indraprastha University, Sector 16C, Dwarka, New Delhi-110078, India
[3] ICAR-Indian Agricultural Research Institute, New Delhi 110012, India
[4] University of Aberdeen, School of Biological Science, Rm G43 23 St Machar Drive, Aberdeen, AB24 3UU, Scotland, UK
[5] University of Edinburgh, School of Geosciences, High School Yards, Edinburgh EH8 9XP, Scotland, UK
[6] ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad-500030, India
[7] Department of Botany Aligarh Muslim University, Aligarh-202002, UP, India
[8] Centre for Ecology and Hydrology (CEH), Lancaster Environment Centre, Library Avenue, Lancaster, LA1 4AP, UK

Abstract
NEWS India UK (Newton-Bhabha Virtual Centre on Nitrogen Efficiency of Whole-cropping Systems for improved performance and resilience in agriculture) is established to promote cooperation between the two countries that demonstrates innovative ways to improve agricultural nitrogen management, allowing increased and more resilient food production in India while reducing nitrogen losses to the environment. Here we present the structure of the Virtual Joint Centre including strategic and scientific goals and objectives as well as the activities planned to achieve these.

Key Words
Nitrogen use efficiency (NUE), agronomic NUE, biological NUE

Introduction

The need to optimize agricultural nitrogen (N) use is fast emerging as a key global challenge where international cooperation can play a transformational role. The rational is to establish a Virtual Joint Centre (VJC) that focuses on India-UK cooperation to improve **N**itrogen **E**fficiency of **W**hole-cropping **S**ystems (NEWS India-UK). The VJC builds on existing research by UK and Indian N researchers to develop and test innovative approaches to optimize N management that help meet food security goals while reducing multiple environmental threats.

The UK and Indian teams have already played a key role in development of nitrogen science for sustainable agriculture. For example, they have had a key contribution to the International Nitrogen Initiative (INI) and the United Nations Environment Programme (UNEP) 'Global Partnership on Nutrient Management' (GPNM) that provided the foundation for agreement of the Delhi (2010) and Kampala (2013) Declarations, and led to the 'Our Nutrient World' report (Sutton et al., 2013), in addition to the Indian and European Nitrogen Assessment processes (Abrol et al., 2008, Sutton et al., 2011). One of the key outcomes has been to demonstrate the major economic impact of agricultural N losses, which represent a resource loss for farmers and a major cause of water, air and soil pollution, threatening climate, health and biodiversity. 'Our Nutrient World' developed the idea of 'full chain nitrogen use efficiency' (NUEfc), showing that a 20% increase in NUEfc would lead to estimated global benefits worth US $170 billion per year, including $23 billion in N fertilizer saving (Sutton et al., 2013). It also identified ten Key Actions for improving NUEfc, including raising agronomic and biological nitrogen use efficiency (NUE).

. Until now, scientific efforts to improve agronomic NUE and biological NUE have too often been considered in isolation. This means that the potential for investigating synergies between fields has received insufficient attention. For example, how much could biotechnological and other genetic approaches contribute to improving NUEfc compared with adoption of better agronomic practices? And, what are the implications of

genetic improvement in plant ammonium (NH_4^+), nitrate (NO_3^-) and urea utilization for managing components of N losses, such as ammonia (NH_3) volatilization, nitrous oxide (N_2O) and nitrogen (N_2) emission and NO_3^- leaching?

To address such questions and to further strengthen the research of the partner countries, NEWS India-UK brings together experts in agronomic and biological NUE. In considering the whole system, we place genetic and biotechnological development in their wider agronomic context, and then consider the implications at field, farm and national scales. By taking such an integrative approach, the rationale is to incorporate all relevant contributions to improving NUEfc. In this way, more N-efficient genetic stock and novel fertilizer practices (with a special focus on rice, as having the lowest NUE and highest fertilizer use in India) provide the foundation to show what can be done at the farm scale and for India as whole. This requires consideration of all potential N sources (including from organic manures, Biological Nitrogen Fixation (BNF) and atmospheric deposition), while exploring improved spatial and temporal strategies that can help optimize N resource use. By scaling up in this way, the VJC will show how advances in N management can help develop resilience in meeting food and feed production goals, while delivering quantified reductions in Indian agricultural N emissions.

Objectives

The overall Strategic Goal of NEWS India-UK is to promote cooperation that demonstrates innovative ways to improve agricultural N management, allowing increased and more resilient food production while reducing multiple pollution threats. The Centre will strengthen the research impact of both countries, including their input to the International Nitrogen Management System (INMS), a global science support process for international N policy being developed by UNEP, INI, the UN Food and Agriculture Organization (FAO) and others.

Five Strategic Objectives contribute to this goal:

1. To establish an internationally leading program of NUE research that links the complementary strengths of the Indian and UK partners.
2. To strengthen existing and build new collaboration between UK and Indian partners, including the synergy of allied N research beyond initial scope and lifetime of the Centre.
3. To make innovative links between N research domains, e.g., plant biology, biotechnology, agronomy, biogeochemistry, spatial data analysis, environmental modelling and policy analysis.
4. To build a wider scientific basis for durable cooperation in agricultural N beyond the project, supported by use of fellowships, post-doctoral training, joint workshops and seminars.
5. To use the research programme as a platform for stakeholder engagement to foster mutual learning and feedback thereby strengthening India-UK cooperation.

The overall Scientific Goal is to show how a combination of agronomic and biological improvements can contribute to raising NUEfc at field, farm and national scales and to demonstrate by how much these improvements will reduce N losses to the environment (including NH_3, NO, N_2O, N_2, NO_3^-, etc.) and thereby contributing to increased resilience of Indian agriculture. To achieve this, the Centre includes an interdisciplinary programme linking complementary science areas and scales.

Five Scientific Objectives contribute to this goal:

1. To characterize and explain plant NUE differences, including establishment of a phenotypic ranking of Indian rice varieties for NUE supported by improved functional understanding of traits, comparing this with what can be achieved by a known genetic modification (GM) for improved NUE.
2. To compare the effectiveness of agronomic and biological approaches to improving NUE, and to assess by how much combined approaches maximize overall crop performance.
3. To quantify the relationships between NUE improvement and measured reduction in N losses, considering the different N forms and N loss pathways.
4. To test how better use of all available N resources can improve Farm NUE in rice-wheat rotations, including from organic manures, atmospheric N deposition and BNF, and to explore options for overcoming the barriers to better manure recycling.
5. To establish a national N agricultural budget for India to examine scenarios of improved N management and resilience, and the associated environmental benefits.

Activities Outline
To achieve the strategic and scientific objectives the activities are divided into five components (Figure 1).

Component 1: Plant strategies, genetics and improving plant nitrogen use efficiency combines laboratory ranking of Indian rice varieties and a GM variety with exploration of trait differences.
Component 2: Agronomic strategies to improving field-level nitrogen use efficiency integrates agronomic and genetic potential to improve NUE with field measurements of full N fluxes to quantify the link to reduced environmental impacts.
Component 3: Farm scale nitrogen strategies, maximizing the value of all N sources, addresses options to better recycle manures and N deposition, and examines the barriers to change.
Component 4: National scale nitrogen strategies and scientific synthesis compiles data and models to establish an Indian agricultural N budget and assess the potential of future options.
Component 5: Capacity Building, Training and Dissemination links across the VJC to strengthen the research integration and build a basis for durable cooperation.

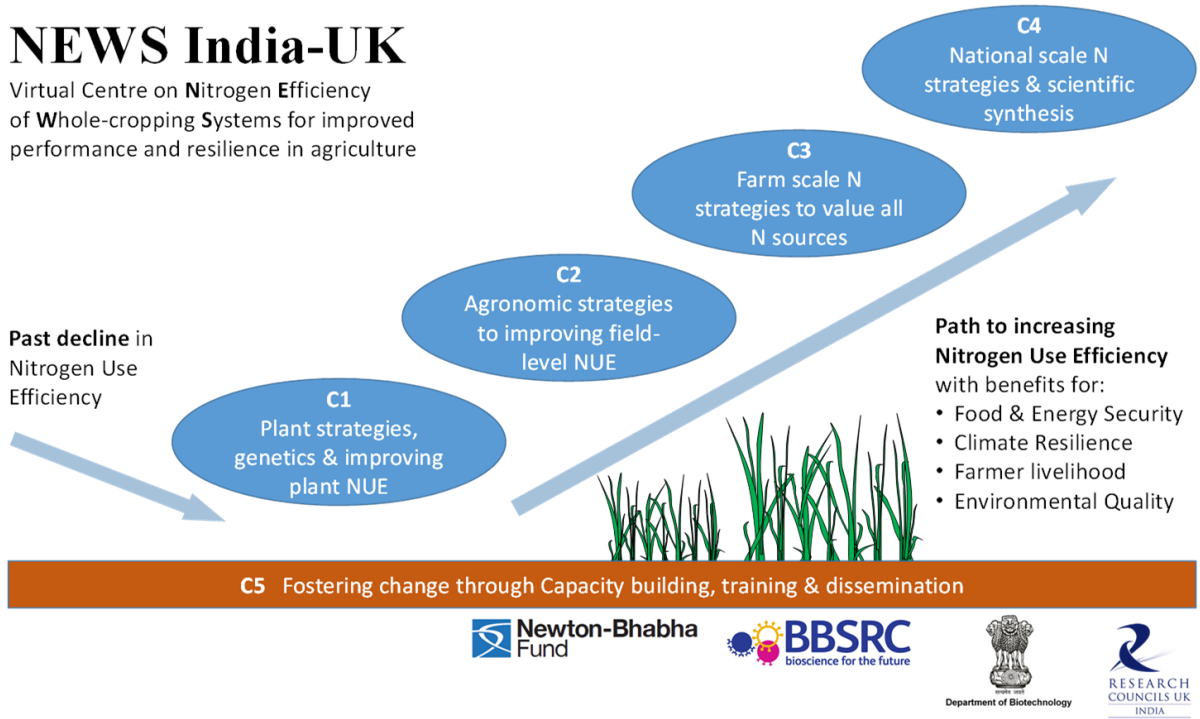

Figure 1. The NEWS India-UK virtual joint centre is structured through four research components (C1-C4) and an integrating component (C5) that addresses wider cooperation, training & dissemination.

Summary
The NEWS India-UK Virtual Joint Centre builds on existing research by UK and Indian N researchers to develop and test innovative approaches to optimize N management that help meet food security goals while reducing multiple environmental threats. NEWS India-UK also takes two important further steps. Firstly, it applies the outcomes of biological and agronomic advances in NUE at the farm scale. Secondly, it scales up the outcomes to the national scale.

Analysis of natural genetic variation, together with the opportunity that can be provided by Genetic Modification (GM) techniques, will support process studies on improving plant level NUE. At the field scale, the project will quantify full N budgets, measure all major N emissions to the air and water and demonstrate how NUE improvements translate into reduced N pollution and greenhouse gas emission.

The field scale will also bring together the options to see how a combination of genetic and agronomic improvements can maximize net benefits of better nitrogen management for higher productivity and climate resilience. The experimental datasets will then be applied, with support of case studies, to assess the farm

scale, with mathematical models used to bring information together and to consider simple tools that can support small-holder farmers for better decision making.

Finally, the national-scale work is also addressed by using models, where available statistical information for Indian agriculture is brought together with the expert understanding to develop country-level estimates and the forward look.

References

Abrol Y.P., Raghuram N. & Chanakya H.N. (Eds.) (2008) Reactive Nitrogen in Indian Agriculture, Environment and Health. *Current Science* (Nitrogen Special Issue) **94**, 1375-1477.

Delhi Declaration on Reactive N Management for Sustainable Development (2010). Presented to the Executive Body of the UNECE LRTAP Convention and UNEP Governing Council.

Kampala Statement-for-Action on Nitrogen in Africa and Globally (2013) www.initrogen.org

Sutton M.A., Howard C., Erisman J.W., Billen G., Bleeker A., Grennfelt P., van Grinsven H. & Grizzetti B. (Eds.) (2011) *The European Nitrogen Assessment.* Cambridge Univ. Press. 612 pp.

Sutton M.A., Abrol Y.P., Adhya T.K., Raghuram N., Ayyappan S., Pathak H. & 40 others (2013) *Our Nutrient World: The challenge to produce more food and energy with less pollution.* Global Overview of Nutrient Management. Edinburgh: CEH for UNEP, on behalf of the GPNM and INI.