Looking forward to 2030: Nitrogen and the Sustainable Development Goals

Achim Dobermann

Rothamsted Research, Harpenden, Herts, AL5 2JQ, UK, achim.dobermann@rothamsted.ac.uk

Abstract
The new Sustainable Development Goals (SDGs) provide a framework for all countries to develop and implement roadmaps for sustainable development in all its dimensions. Agriculture contributes to many of the new SDGs and their Targets. SDG 2 on ending hunger, improving nutrition and achieving a more sustainable agriculture is among the most challenging ones to achieve. Transformative changes will be required in how food is consumed and produced. Nitrogen as the world's most important nutrient is a key currency for all that, requiring a full-chain approach to increase its overall efficiency and reducing its environmental impact. Agro-food systems in developed as well as developing countries need to become more precise in their management to achieve substantial increases in N use efficiency (NUE). A coherent, well-coordinated effort is needed for monitoring NUE at unprecedented levels of detail, using new sensing and data science technologies that are now becoming available. Many solutions exist, but they will require more investment as well as new ways of working to achieve faster and greater impact. Science should embrace an innovation culture, translating new ideas much faster into commercial technologies and actionable knowledge widely accessible to farmers and businesses along the whole nitrogen chain.

Key Words
Sustainable Development Goals, nitrogen, nitrogen use efficiency, monitoring, innovation

Sustainable Development
Seventeen Sustainable Development Goals (SDGs) were endorsed at a historic summit of world leaders in September 2015 (United Nations, 2015). Covering the period 2016 – 2030 (and beyond), they succeed the Millennium Development Goals (MDGs) and provide – for the first time – a guiding framework for all countries to develop their own roadmaps towards sustainable development in all of its dimensions. The SDGs push the envelope by bringing together a great diversity of development issues that are interconnected (Fig. 1). They are the most inclusive agenda the UN has delivered to date, with millions of people submitting input from around the globe to ensure that the SDGs, their Targets and Indicators address the key issues and are also applicable to all countries and stakeholders.

Figure 1. The 17 Sustainable Development Goals (SDGs) for the post-2015 era.
(Source: https://sustainabledevelopment.un.org/sdgs)

Many media outlets, bloggers, politicians, business leaders, activists as well as scientists have critiqued the SDGs and their 169 Targets as being unfeasible, vague, aspirational, contradictory, insufficient or even distracting from urgent priorities. I agree with much of the criticism voiced and I, like many others, had hoped for a more concise SDG framework, such as the ones proposed by the SDSN (Sustainable Development Solutions Network, 2013) or the High-Level Panel (High-Level Panel on the Post-2015 Development Agenda, 2013). But I also think that the critics are missing the key point: the SDG development process was relatively open, inclusive and transparent, which also explains the diversity of issues included. The main value of the SDGs therefore lies in providing a broadly accepted framework for policymaking, not in trying to establish a rigorous accountability mechanism. The SDGs are meant to inspire people, businesses, and whole countries to think about the future and their own actions in a more holistic manner, and change behaviours towards actions that support sustainable development in all its economic, social and environmental dimensions. They reflect an emerging awareness about what has gone wrong in our global economic system and will hopefully inspire more action at many levels.

Much work remains to be done to translate this general framework into practical solutions and actions. Scientists should play a significant role in this process by embracing the SDGs, help filling the necessary gaps in terms of more concrete targets and indicators, targeting their own research towards tackling real-world problems embedded in the SDGs, as well as supporting governments, businesses and other actors in developing suitable policy, technology and investment roadmaps.

Agriculture in the new SDG Agenda

Although the world is facing numerous challenges, agriculture was recognized as playing a key role in the new SDG agenda. At least half of the SDGs are directly or indirectly linked with agriculture and the way we produce, process and consume food (Fig. 1). SDG 2 on eradicating hunger and achieving food and nutrition security through more sustainable agriculture is among the most complex and challenging goals to achieve because it means at least six very different things:

- Agriculture that offers a viable income and livelihood for farmers and business along the whole value chain in any country.
- Agriculture that provides nutritious foods for the entire world population, including the right mix of grains, legumes, vegetables, fruits, nuts, livestock and fish products to ensure adequate supply of energy, protein with essential amino acids, micronutrients, omega-3 fatty acids etc.
- Agriculture that is resilient to future climate change.
- Agriculture that comprehensively reduces greenhouse gas emissions from energy use, deforestation, methane and nitrous oxide.
- Agriculture that reduces other environmental harms (loss of biodiversity, invasive species, freshwater depletion, soil degradation, destruction of habitat, chemical pollutants from pesticides and herbicides, etc.)
- Agriculture that sustains local landscapes, cultures, cuisines, etc.

Addressing these challenges requires transformative changes along the whole food chain as well as treating rural communities in the same way as urban communities. Success will largely depend on how consumers change and whether rural places can become attractive places to live and work, particularly for entrepreneurial and technologically savvy younger generations (Dobermann et al., 2013). A consensus is emerging that a sustainable intensification must happen in small and large farms throughout the world, although opinions differ on what exactly that means and how it can be achieved and monitored (Garnett et al., 2013; Smith, 2013). Depending on the context, improved performance may mean any or all of the following: increased profitability and productivity, high efficiency and returns from external inputs, improved crop and livestock yield stability, reduced greenhouse gas emissions, enhanced biodiversity and ecological resilience, better animal welfare, and environmental broader services provision (e.g., clean water, flood protection, recreational and cultural landscape values).

It is obvious that not all of these outcomes can be achieved at once or simultaneously everywhere, i.e. trade-offs among different outcomes are common. To enter a sustainable development path in the right order, countries will need sound policy and technology roadmaps that enable them to achieve targets of high priority. As of today, few countries have developed a clear understanding of how to make such transformative changes in complex and diverse food systems. This is an area in which science can contribute much, through methodologies and participatory processes that contribute to national policy debates.

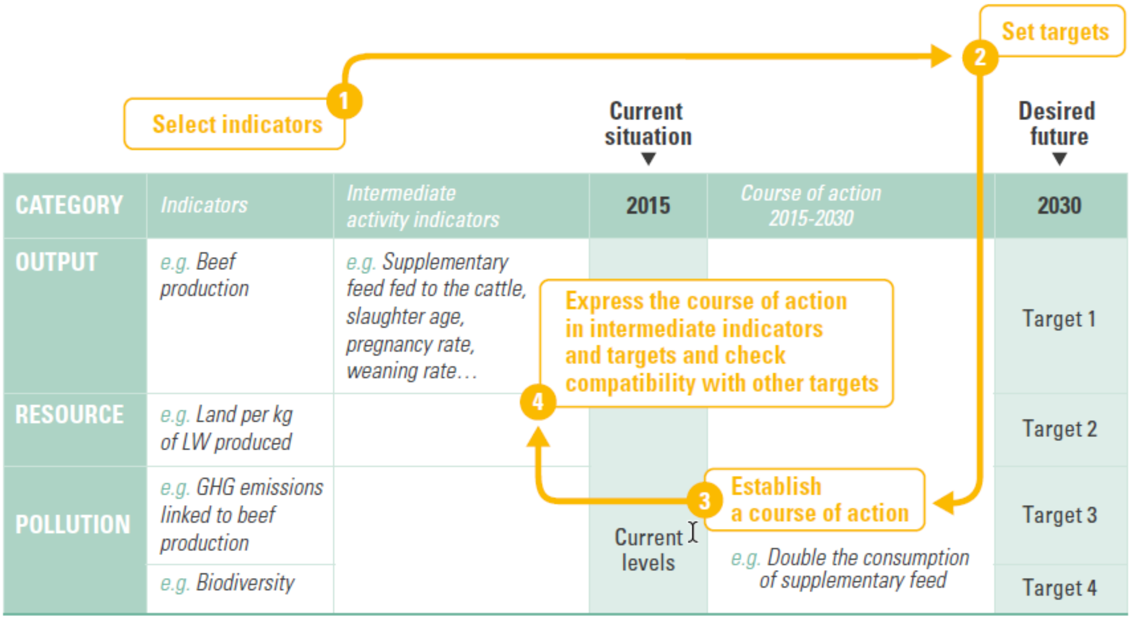

Figure 1. Illustration of the backcasting approach used in the Agricultural Transformation Pathways Initiative (Schwoob et al., 2016)

Backcasting is one approach that will be useful for sustainable development roadmapping. It denotes a process in which a target is fixed for a future date, and then a pathway towards achieving that target is identified by moving backward in time. It can also be combined with forward-analysis of scenarios, but its main focus is on participatory problem-solving, setting priorities and identifying critical pathways and steps that need to be taken in order to reach a desired outcome. Although backcasting has been used in areas such as decarbonizing energy supply (Williams et al., 2012) or sustainable city planning (Carlsson-Kanyama et al., 2007), it has received less attention in the agricultural and food sector so far. In support of the SDG implementation, we have recently launched an initiative to explore backcasting applications for agricultural transformations at sector or national scales (Schwoob et al., 2016), using a simple, transparent approach that is also easy to communicate to non-experts (Fig. 2). Considering its unique, multi-faceted role, nitrogen (N) would seem to be a particularly attractive target for applying this approach.

Nitrogen

Through its biological functions and whole life-cycle, N is a common currency for achieving SDGs 2, 6, 12, 13, 14, and 15. This re-iterates the need for applying a full-chain approach to improving N use efficiency (NUE), including technological, policy and behavioural interventions affecting the production, consumption and recycling of N (Sutton et al., 2012). It will be critical now to establish suitable roadmaps at the level of individual countries that enable policy makers, businesses and other stakeholders to plan ahead and implement the right actions.

The amount of knowledge about the N cycle has risen exponentially in the past 20 years. Thousands of scientific papers and reports on many aspects of N in agriculture and environment are published each year and the International Nitrogen Initiative (INI) itself has been active for 15 years. Yet, on a global scale, we seem to have made insufficient progress in reducing the amount of reactive N in undesirable stages of the biophysical cycles, or increasing NUE at key stages of the full life cycle, particularly NUE of fertilizer used in agricultural production. The general picture is one in which some countries have improved their NUE and agro-environmental performance, whereas in many others this has not yet happened or agricultural production is even limited by a lack of nitrogen (Lassaletta et al., 2014; Zhang et al., 2015). Consequently, targets for N or NUE, policy roadmaps and technology solutions will need to differ widely, taking into account the current baseline as well as the overall sustainable development targets and priorities. This is a responsibility the scientific community now faces. Although we may still not have enough data and knowledge to answer many questions more precisely, we have an obligation to move forward towards practical solutions and also learn and improve along the way.

Besides the actual targets, this also requires reaching agreement about indicators for NUE or other aspects of the N cycle that are related to various SDGs. Monitoring and evaluation of complex, interconnected issues poses a major challenge to the SDGs and there is a risk that wrong indicators or poor data may lead to wrong directions being taken. Agreement on indicators is a political, scientific as well as technical process with input from a diverse group of stakeholders, and it also involves communicating roles and responsibilities to diverse stakeholders. This process is still ongoing. The UN Statistical Commission has identified a first set of global SDG indicators (http://unstats.un.org/sdgs/), which, however, does not include any N indicator and also falls short in many other areas.

Hence, as a community of experts we now have an obligation to distil our wealth of knowledge about N into indicators that are meaningful, measurable and actionable, and thus also easy to understand by key public and private sector stakeholders. Encouraging efforts have recently been made to develop such indicators at farm or other scales (EU Nitrogen Expert Panel, 2015; Godinot et al., 2014; Zhang et al., 2015) and also provide clearer guidance on what to aim for (Fig. 3).

Interpretation	**Nitrogen surplus (kg/ha/yr)**		
	Cropping systems	Mixed crop-livestock systems, 1 LSU/ha	Mixed crop-livestock systems, 2 LSU/ha
Very high	>120	>160	>200
High	80-120	120-160	160-200
Modest	50-80	90-120	130-160
Low	20-50	60-90	100-130
Very low	<20	<60	<100

Figure 3. A Simple scheme for the interpretation of NUE values (input-output mass balance) of crop production systems and mixed crop-livestock production systems in Europe (EU Nitrogen Expert Panel, 2015). Proposed target values (green) require further validation. LSU is Livestock Unit (equivalent to a 500 kg dairy cow).

It has also been demonstrated how the available global NUE data (Zhang et al., 2015) can be further manipulated to create a Sustainable Nitrogen Management Index and thus become part of a broader SDG Index and Dashboard (http://www.sdgindex.org/), allowing to visualize countries' progress towards meetings SDGs (Sachs et al., 2016). Although these efforts may leave many scientific questions unanswered for the time being, it is important to move in that direction in order to support broader action.

Open Innovation

The discussion on N needs to move towards a culture of action, joint learning and true innovation. Scientists need to be at the forefront of this, demonstrating what is possible through the systematic sharing, integration and application of the world's best know-how. This will require new ways of working and also a willingness to take risks. An important way to solve problems is through practical initiatives involving new technologies, business models, institutional mechanisms and/or policies that are promising, can take place in any country, and can also generate learning elsewhere. There is a need to move to demand-driven, faster agricultural innovation systems and simplify the increasing complexity, fragmentation and poor coordination of agricultural R&D that prevails in many countries.

Many of the changes needed to achieve the SDGs cannot wait for another 20 or 30 years for a new idea to develop and have greater impact. Political, economic and social drivers may often constrain faster development and wider adoption of new technologies. However, I argue that science itself should also change in order to achieve greater impact much faster. This requires a substantial culture change at institutional levels, at the level of individual scientists, and in science funding. Demonstration of return for investment by funders often results in incremental, safe science rather than high-risk steps. The emphasis on publishing results in publications as the end goal that many scientists pursue to advance and even survive in their own careers should be replaced by a much stronger desire to take the next step of converting the results into improved products or practices. Scientists need to work in a more problem-solving and entrepreneurial manner, but we also need to reinstate a culture where the gain makes the risk worth taking and the supported means of getting at the goal allows time and mechanisms for scientists to exercise greater freedom in creative thinking, especially across disciplines. A more open innovation and open access environment will be required as opposed to secretive behaviour and intellectual property management approaches that stifle wider progress.

References

Carlsson-Kanyama A et al. (2007). Participative backcasting: A tool for involving stakeholders in local sustainability planning. Futures 40, 34-46.

Dobermann A et al. (2013). Solutions for sustainable agriculture and food systems. Technical report for the post-2015 development agenda. Sustainable Development Solutions Network (SDSN), New York.

EU Nitrogen Expert Panel (2015). Nitrogen Use Efficiency (NUE) - an indicator for the utilization of nitrogen in agriculture and food systems. Wageningen University, Alterra, Wageningen, Netherlands.

Garnett T et al. (2013). Sustainable intensification in agriculture: premises and policies. Science 341, 33-34.

Godinot O et al. (2014). SyNE: An improved indicator to assess nitrogen efficiency of farming systems. Agric. Syst. 127, 41-52.

High-Level Panel on the Post-2015 Development Agenda (2013). New global partnership: eradicate poverty and transform economies through sustainable development. United Nations, New York.

Lassaletta L et al. (2014). 50 year trends in nitrogen use efficiency of world cropping systems: the relationship between yield and nitrogen input to cropland. Environmental Research Letters 9, 105011.

Sachs J et al. (2016). SDG index and dashboards - global report. Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN), New York.

Schwoob MH et al. (2016). Agricultural transformation pathways initiative. 2016 Report. IDDRI, Rothamsted Research, SDSN, Paris.

Smith P (2013). Delivering food security without increasing pressure on land. Global Food Security 2, 18-23.

Sustainable Development Solutions Network (2013). An action agenda for sustainable development. Report for the UN Secretary General. Sustainable Development Solutions Network, New York.

Sutton MA et al. (2012). Our nutrient world: the challenge to produce more food and energy with less pollution. Center for Ecology and Hydrology, Global Partnership on Nutrient Management, INI, Edinburgh.

United Nations (2015). Transforming our world: the 2030 Agenda for Sustainable Development. Resolution 70/1 adopted by the General Assembly on 25 September 2015. New York.

Williams JH et al. (2012). The technology path to deep greenhouse gas emissions cuts by 2050: The pivotal role of electricity. Science 335, 53-59.

Zhang X et al. (2015). Managing nitrogen for sustainable development. Nature 528, 51-59.