VALUING NATURE PROGRAMME

VNP07

Joining the dots

Global Challenges and the Valuing Nature Agenda

Valuing Nature Report

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Valuing Nature Report

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Executive summary

Background

- This report provides a review of published research which elaborates synergies between the Valuing Nature Network and Global Challenges Research agendas.
- The **Valuing Nature Network** aims to improve understanding of the value of nature in both economic and non-economic terms, and improve the use of these valuations in decision making. It funds interdisciplinary research and builds links between researchers and people who make decisions that affect nature in business, policy-making, and in practice. The **Global Challenges Research Fund** aims to support research that directly contributes to the sustainable development and welfare of people in developing countries.
- A review of the United Nations Sustainable Development Goals (see Annex I) and their targets revealed a number of themes that have links to the Valuing Nature Network research agenda, specifically: the governance of natural resources; conservation of natural capital and sustainable use of ecosystems; environmentally, socially and economically sustainable agro-forestry systems; and knowledge exchange at the science-policy interface. Assessing the extent and depth of existing research in these areas, and identifying networks of current research collaboration, can enable the identification of key opportunities for advancing research into the natural environment that also seeks to address the challenges associated with international development.

Methods

- Six Official Development Assistance countries were chosen to represent geographically distinct circumstances and contexts. These were: China, Colombia, India, Burkina Faso, Kenya, and South Africa. A comprehensive literature search was conducted through the Web of Science database, using a range of search terms pertaining to Valuing Nature concepts and mechanisms. Abstracts were read and articles were categorised into one of ten predetermined thematic areas that link the Valuing Nature Network and Global Challenges Research agendas. A further note on methods is given in Annex II.

Results

China

There has been considerable and diverse research effort in China across the thematic areas, with substantial in-country research capacity having been developed. However, there are relatively few collaborative partnerships with the UK reflected in the literature.

The research emphasis is on ecosystems, their characterisation and associated services, and on urbanisation. These reflect the geographical scale and ecological complexity of the country, and rapid urbanisation due to population growth and movement from urban areas.

Burkina Faso

The research themes reflected in the literature mirror the pressures impinging on Burkina Faso, with many families struggling to avoid malnutrition, almost half the country living in poverty, and the area being prone to floods and droughts. The most common research focus is on species relevant to addressing those problems, such as trees and their role in stabilising soils, plants of relevance to human food and medicine, and soil in relation to nutrients, water and crop production. This includes the sustainable use of natural resources to protect food and water security, and generate income.

Kenya

The research focus reflects the dichotomy apparent in Kenya. On the one hand, half the population lives below the poverty line, leading to a focus on species, trees and forest systems often in relation to the services they provide in terms of food for humans and animals, medicines and firewood. On the other hand, the country has expansive wildlife parks and nature reserves which attract considerable valuable tourism. This leads to an additional focus on biodiversity conservation and the management of charismatic wildlife and habitats.

South Africa

South Africa has a very diverse climate and (super) abundant biodiversity. It is relatively economically strong, suffering from resultant environmental degradation and increased agricultural/horticultural production. There is also a large, mainly rural, proportion of the population that still rely on natural resources for food, water and shelter. The research emphasis on species is in the conservation, management and biodiversity context, and land and resource use in relation to agriculture, natural hazards and ecological restoration.

India

An overarching concern in India is to sustain its enormous and rapidly growing population, the need to manage its natural resources efficiently, effectively and sustainably. This is set against a background of a high dependency on rain-fed (monsoon-dependent) agriculture, large proportions of the population living in marginal landscapes, and many parts of the country susceptible to climate change. This was reflected in research themes on the (sustainable) use management of natural resources; forests and deforestation; water, particularly in relation to agricultural needs, drought and monsoon flooding; a large spatial scale covering whole watersheds or ecosystems, agriculture, crops and soils in particular; traditional knowledge in relation to sustainable livelihoods and economic development; climate change and increased flood risk; and remote sensing to assess and monitor ecosystems.

Colombia

The relatively small body of research in Colombia reflects the economic and social context which has been characterised by decades of armed conflict, uneven development, and lack of government presence and institutions. Despite the peace deal, social inequality and power imbalances persist, making sustainability challenging. The research themes reflecting this situation included: agriculture, particularly coffee and extensive cattle ranching; deforestation and resulting ecosystem conversion; water provision and regulation; biodiversity and carbon conservation; wetlands, in terms of fishing, hunting and tourism; governance, including resources, power, and tackling corruption; restoration, involving transdisciplinary and public-private collaborations.

Linking Valuing Nature themes with Global Goals

Ten themes clustered under four headings emerged from the six country literature reviews. We consider each below, highlighting the links with the Global Goals.

Conservation and sustainable use of natural capital (including biodiversity)

This is an overarching theme, in the context of this study we have drawn out four areas:

- **Ecosystems and ecosystem service characterisation, including conservation planning**
- **Ecological restoration**
- **Mining and hydropower**
- **Traditional knowledge**

These are particularly relevant to Global Goals 6, 7, 11–15. (We have considered a particular focus on agriculture and forestry below).
A considerable body of work explores the links between landscape structures and ecosystem service value, most frequently for provisioning and regulating services such as the sustainable supply and management of adequate and clean water (GG6), flood mitigation and prevention (GG13). There are many studies documenting unsustainable use of natural resources (e.g. water pollution, habitat fragmentation) the solutions to which are required to meet GG12, 14 and 15.

Ecological restoration which benefits multiple services would deliver broadly to many of the Global Goals if properly designed and implemented in context, particularly for some ubiquitous issues such as water supply. As the 21st century advances there are likely to be more investments in infrastructure and exploitation of resources, yet these developments need to be sustainable for the delivery of GG7 & 9.

Environmentally, socially and economically sustainable agro-forestry systems

This theme focuses on food, timber and fibre production systems, namely:

- **Agriculture, agro-forestry and fisheries (including impact and sustainability)**

This one theme underpins a number of Global Goals, including the aim to end poverty, and ensure food security and healthy lives (GG 1–3). Three Global Goals (12, 14 and 15) focus specifically on developing sustainable practices for consumption and production, the use of the oceans and the management of terrestrial ecosystems and forests. In this context, there are many studies documenting *unsustainable* use of fisheries, forests, and other ecosystems, and considerable emphasis on the need to increase productivity of land for food, biofuel and animal feed, with soil degradation and poor soil health being one particular problem. These goals sit at the interface of the Valuing Nature and the Sustainable Intensification agendas.

Mechanisms to improve the governance of natural resources

This broad theme covers three subthemes that emerged from the literature, which were:

- **Payments for Ecosystem Services, valuation and revenue**
- **Offsets**
- **Governance, management and decision making**

The governance of natural resources arguably underpins all Global Goals: those that focus on inequalities (5, 10 and 16); on sustainable management (1–3, 6–7, 12, 14–15); on economic growth (8, 9, 11); on climate change mitigation (13); and on accountability (17). This illustrates the nature of the Global Goals being an integrated whole. The research emerging in this area is greatly influenced by Country context, with government led schemes being prevalent in some cases (e.g. 'Grain for Green' in China), yet in other cases these themes do not currently appear in our searches of the literature at all. In other instances, the valuation of ecosystem services is well developed, but this is not applied into mechanisms to enhance governance of natural resources.

Resilient and sustainable urbanisation

There are two themes particularly relevant to Global Goals:

- **Natural hazards**
- **Urban sustainability**

These focus on resilient infrastructure (9) and safe, sustainable and resilient cities (11). However, although there is rapid urbanisation in most of the countries we considered, there is very little research in this area. There is a recognition that research is needed on the governance dimension of urbanisation in some countries.

Conclusions and reflections

There are strong research themes from the Valuing Nature agenda that illustrate necessary pathways to be developed for the delivery of the Global Goals. These themes also link to the Sustainable Intensification research agenda and to the climate change adaptation agenda, and more should be made of those links, and those which connect with other Research Councils. The specific context, and therefore the most likely productive emphasis for next steps, differs between the six countries examined, depending, in part, upon the current status of the environment and in national priorities. Nevertheless, both globally and nationally, there is an urgent need to start thinking about finance and accounting — as all societies and their relationship(s) with the natural environment are linked to their past, present, and future financial economies.

Many articles could be assigned to the 'governance, management and decision-making' category but seldom in terms of explicit natural capital assessment. This implies that, in terms of future development, the practical and research emphasis should move towards including natural capital assessment and accounting in order to better inform decision-making. In this context, natural capital accounting information will be needed at the national level but also at the site/organisation/project/programme level, and also perhaps at the 'instrument level' when offsets are being monitored or validated. The emerging inference is thus the need to think about 'natural capital finance' and how best to co-design systems that provide both financial and non-financial returns and also solely non-financial gains but which involve financial costs. In other words, encouraging private investment in natural capital for private and public gain through relatively new instruments like green bonds (public and private) and blended funds.

The evidence in this review suggests there has been a relatively low level of collaborative partnership between UK institutions and any of the six countries investigated around these research themes. Such collaborative partnerships would be extremely timely and could be used to emphasise and develop the links between the SDGs, practical research, and climate change adaptation priorities in particular. This would also have direct relevance to UK priorities such as the UK Climate Change Risk Assessment 2017: Evidence Report (Chapter 7) that identified risks to the UK from climate change internationally for such things as food security (food imports), food safety (pests and pathogens spreading to the UK), and human migration and political turnover overseas.

The potential for developing timely research collaborations is therefore considerable in all thematic areas examined. Important next steps would be:

- **To consider visits and meetings to main research institutes to identify research and regional priorities, building on the differences in Country context identified here.**
- **To scope out interdisciplinary research programmes of suitable size that cut across the Global Goals, to exploit the potential synergies between pathways to achieve the different goals.**
- **To ensure that any new research aims to use a multidisciplinary approach in defining problems, identifying the (fundamental/underlying) causes, and designing solutions.**
- **That co-developing and implementing innovative finance mechanisms and engaging with stakeholders should be a key part of research.**
- **That any research focussed on an action on the ground should be accompanied by financing for that action and by research/policy/practical testing.**

1. Introduction and context to review

Concepts and methods for valuing natural capital and ecosystem services provide an important context in which the challenges of achieving the Global Goals can be understood and addressed, from the starting point of interdisciplinary research into the natural environment. Details of the 17 specific Sustainable Development Goals are listed in Annex I.

People depend on the natural environment for a variety of livelihood and wellbeing benefits. These dependencies encompass access to a range of ecosystem services that are salient to the meeting of Global Challenges in general, and poverty alleviation specifically. A review of the Global Goals and their targets reveal a number of interdependent themes that have links to the Valuing Nature research agenda. There are many ways in which this review could be constructed, and additional themes of relevance to the Valuing Nature agenda (for example, the links between environment and human health, both mental and physical). Those considered here were constructed after preliminary views of the literature and for expediency, and include:

- **Mechanisms to improve the governance of natural resources**
- **Conservation and sustainable use of natural capital (including biodiversity)**
- **Environmentally, socially and economically sustainable agro-forestry systems**
- **Resilient and sustainable urbanisation**

An important thing to note here in relation to governance is the issue of finance being available (or not) to implement the recommendations arising from research. The availability of finance for subsequent implementation can clearly affect the ultimate effectiveness of research, and so considering it at the start of any work could very well increase the effectiveness of research.

The report further contextualises and elaborates the thematic areas noted above through a review of published research pertaining to a range of Official Development Assistance (ODA) countries, highlighting current research emphasis and where opportunities exist for research development. Nevertheless it should be noted that these research themes continue to have relevance in efforts to meet Global Goals in the UK. Funded under the Natural Environment Research Council's (NERC) Innovation and Impact Scheme this desk-based project specifically sought to:

- **Assess the extent and depth of Valuing Nature scholarship in ODA countries and how these map on to addressing Global Challenges;**
- **Identify and describe the networks of current and recent research collaboration that this scholarship entails, with a particular emphasis on the link between ODA countries and UK research networks;**
- **Establish opportunities for advancing the Global Challenges research with respect to Valuing Nature scholarship.**

2. General overview of Valuing Nature context to ODA countries

The Organisation for Economic Co-operation and Development's (OECD) Development Assistance Committee (DAC) list of countries and territories which are eligible to receive ODA includes 145 countries. These countries are found across all six populated continents, but vary greatly in terms of size and population density.

Whilst some of the ODA countries are highly vulnerable from an environmental perspective, due largely to their locations, the status of their soils, and the impacts of weather, others are incredibly ecologically rich and threatened primarily by human impacts. Island nations form around a third of ODA countries, and tend to be limited by their high population sizes, resource production capacity, and frequently, by their susceptibility to weather events. Social and political unrest are characteristic of many nations with high environmental insecurity (such as soil degradation or deforestation) but may also be prevalent where countries have a high dependency on markets for their oil resources. Issues around oil prices are particularly relevant for some of the larger ODA countries in Africa and the Middle East. The continent of Africa contains the majority of the world's ODA countries, both large and small, and arguably those with some of the most extreme social and environmental issues still to be overcome. The status of Africa's soils, deforestation and the resulting erosion and loss cause desertification which in many African countries is accompanied by pollution resulting from poor infrastructure linked to issues of economic under-development. The two largest ODA countries, Brazil and China are progressing towards self-sufficiency but still face considerable environmental and economic challenges in common with other ODA countries.

3. Approach to country reviews

The geographically distinctive circumstances and contexts for Global Challenges/Valuing Nature research is reflected in an account of six countries — China, Colombia, India, Burkina Faso, Kenya, and South Africa.

The reviews were conducted systematically by three researchers. Based on the Web of Science (WoS) database, relevant research articles were identified for identified for further analysis through the application of Boolean search terms in the English language and subsequent exploration of the title and abstract of the papers in realtion to both the Valuing Nature and Global Challenges agendas. Papers were categorised for analysis into 10 thematic areas, developed and mutually agreed by the reviewers. These may be grouped under the broader themes identified previously:

Conservation and sustainable use of natural capital (including biodiversity)

- **Ecosystems and ecosystem service characterisation, including conservation planning**
- **Ecological restoration**
- **Mining and hydropower**
- **Traditional knowledge**

Environmentally, socially and economically sustainable agro-forestry systems

- **Agriculture, agro-forestry and fisheries (including impact and sustainability)**

Mechanisms to improve the governance of natural resources

- **Payments for Ecosystem Services, valuation and revenue**
- **Offsets**
- **Governance, management and decision making**

Resilient and sustainable urbanisation

- **Natural hazards**
- **Urban sustainability**

The papers selected were examined in relation to the numbers published each year and the proportion of them authored by a researcher affiliated to an institution in the named country ('in-country'), or authored by researchers from an 'overseas' country, or written by a 'mixed' authorship from the named country and at least one overseas one. As well as detailing the numerous 'overseas' countries involved in authorship of the selected papers, particular attention was paid to those that had some level of UK affiliation.

In terms of the Thematic analysis, once categorised, abstracts were then reread and key 'messages, issues, and topics' were summarised (and references given) for each theme. For each country, WoS outputs were also used to produce lists of (A) the institutions in that country collaborating with UK organisations, (B) UK organisations collaborating with partners from the named country, and (C) publications arising from these joint collaborations.

The final element of analysis was to document the funding sources reported in the selected articles. Information on funding sources obtained from WoS was restricted to whatever was available from the original input of information. A further note on methods (and the production of word clouds presented in the Executive summary) is given in Annex II.

4. Joining the dots in China — Key Findings

4.1 Country context

China covers approximately 9.6 million km^2 and has a population of over 1.381 billion. It is governed by the Communist Party of China and, through economic reforms, has become one of the world's fastest-growing major economies with only 10% of the population now living in poverty. The country has urbanised significantly in recent decades and there are over 262 million migrant workers, mostly rural people seeking work in cities. China has over 160 cities, including seven 'megacities', each with a population of over one million. The country is the world's leading investor in renewable energy technologies and invests heavily in local scale renewable energy projects (e.g. hydroelectricity).

China is exceptionally biodiverse and a party to the Convention on Biological Diversity (CBD). The landscape is vast, ranging from deserts to subtropical forests, and has a climate dominated mainly by dry seasons and monsoons. At least 840 species in the country are threatened due to habitat destruction, pollution and poaching for food, fur and ingredients for Traditional Chinese Medicine (TCM). In addition to threatened wildlife, China is currently losing 4,000 km^2 per year to desertification. Environmental regulations are fairly stringent but poorly enforced and frequently disregarded in favour of economic development. China is the world's largest carbon dioxide emitter and urban air pollution is a severe health issue; water pollution is also a serious problem. Water quality, erosion, and pollution control are important issues in China's relations with other countries. In addition, climate change may worsen arid conditions in the north of the country and also affect heavily populated low-lying areas.

4.2 Overall search results

The WoS literature search generated 5,440 articles and 1,528 were considered relevant. There was a consistent increase in publications since 2000. Eight articles were published during 1991–1996, increasing to 38 in 1997–2001, 154 in 2002–2006, 443 in 2007–2011, and 885 in the last (full) years (2012–2016).

Authorship

Overall for recently published papers (2014–16, n = 485), the majority (61%) were authored solely by individuals from organisations based in China. About one-third of papers were authored by a mixture of China and overseas institutions from 33 other countries. Of these, the most commonly reported collaborative countries (from n = 208 records) were the USA (40%), Australia, Germany, and the UK (8%). Other co-authoring institutions were from twelve European countries, eight from Asia, five from Africa, plus Canada, New Zealand, Kyrgyzstan, Qatar and Nepal.

The remaining papers (n = 21, 4%) were written entirely by individuals affiliated to organisations exclusively from overseas. A total of 16 overseas countries were reported (n = 36 records). The most frequently recorded country was Germany (19%), followed by the USA (14%), the UK (11%), and the Philippines (8%). Other records were from eight further European countries, three other Asian ones, plus Russia and Australia.

In respect to the UK, from the 244 records with any degree of overseas authorship, 18 records (7%) were identified with UK institutions. Of the 208 records from publications jointly-authored between China and another country, the UK ranked fourth amongst collaborating countries (7%). Of the 36 records from publications solely authored outside China, the UK ranked third amongst overseas countries (11%).

4.3 Thematic analysis

All 485 selected publications (for the full years 2014, 2015, 2016) were grouped inductively into categories reflecting the Valuing Nature Network/ Global Challenges thematic areas. From these, brief overviews of relevant recent studies (from 2015 and 2016, n = 313) in those thematic areas that had at least 5% of the overall records within this period were given.

4.3.1 Ecosystem and ecosystem service characterisation

A total of 165 articles were assigned to this theme and 'ecosystems' were mentioned specifically in about a third of papers, mostly addressing a variety of 'ecosystem service' topics in relation to forest ecosystems, food and health provision, buffer and riparian habitat, water conservation, and rapid urbanisation. In order to improve ecosystem services and to protect national ecological security, the Chinese government has designated numerous 'national key ecological function zones' (NKEFZ).

Several papers aimed to better understand the links between landscape structures or land use and ecosystem service value (ESV). Regulating services were shown to provide more than half of the total ESV in some areas, followed by supporting, provisioning and cultural services. Fragmentation – a common feature of urbanisation – was important and patch size influenced the relationships between landscape metrics and ESV. In more natural environments (e.g. forests) many studies characterised systems – very often in terms of species' characteristics such as 'diversity', 'composition', 'richness', 'assemblage', 'redundancy', and 'extinctions'. Other themes relating to biodiversity included invasive species, depleted species richness, high anthropogenic activities associated with national economic development, overexploitation of major fisheries, water pollution, and habitat fragmentation.

4.3.2 *Payments for Ecosystem Services (PES)*

Twenty papers were reviewed under this theme, and many addressed land use issues, at various geographical scales. In most cases, 'payments' were associated with specific ecosystem services or specific geographical areas. Several studies focused on China's Sloping Land Conversion Programme (SLCP), the largest land retirement/reforestation program in the developing world. Unlike other forest policies, SLCP uses a public payment scheme directly engaging millions of (volunteer) rural households as core agents of project implementation. Research showed that decentralised approaches with more local participation were important requirements in policy implementation for PES programs like SLCP.

China initiated the 'Grain for Green' programme in 1999 as an ambitious conservation programme designed to mitigate and prevent soil erosion by 'retiring' susceptible farmland. The 'Grain-for-Blue' policy (1998) was designed to relinquish cultivated land at the periphery of water areas. Like SLCP, these are massive Chinese government programmes based on Payment for Ecosystem Services, designed to help solve the country's environmental issues. Willingness to pay and willingness to accept (that payments are required) were common themes from China and research focused on balancing what local stakeholders were willing to pay for a service with the local protection cost. Water was a common resource in relation to PES and economic valuation research.

4.3.3 *Ecological restoration*

Most of the 27 ecological restoration papers were concerned with vegetation or some aspect of soil. Used frequently, the word 'ecosystem' was generally paired with the words 'services', 'restoration', 'stability', 'health', 'regeneration', 'reconstruction', 'productivity' and 'degradation'. In terms of restoration *per se,* the most common situations reported involved vegetation, forest and wetlands. Vegetation restoration studies focused on issues such as the control of desertification, and the propagation of native tree species to restore subtropical forests. In relation to "policy-driven ecological restoration" (e.g. Government programmes such as 'Grain for Green', see PES), research was reported on such things as plant establishment and growth; the dynamics of vegetation cover; soil properties and the potential for erosion; and the effects of restoration on ecosystem services (e.g. vegetation carbon sequestration).

4.3.4 *Agriculture*

In China there seemed a clear distinction between agriculture and other forms of natural resource management and exploitation. In papers (n = 23) assigned to the agriculture theme, the most commonly cited issues were related to soil and fertilisation, yields and production. There appeared to be a strong use of field experimentation.

Agricultural products such as rice (several studies), tea, summer maize, winter wheat, rubber, and sheep were mentioned. For rice farming, issues of climate change, mechanisation, advertising, transportation networks, and demographic shifts toward urban centres were all important. There were also calls to examine China's rice policy where there was a clear need to balance the needs of production with wetland conservation and sustainable agriculture.

4.3.5 *Natural hazards*

Relatively few papers (n = 15) addressed natural hazards where the focus was mostly on 'climate change' (60%). Much climate change research focused on such things as hydro-climatic variables and runoff as a result of changes in temperature, precipitation and their spatial/temporal distributions; the effectiveness of protected area networks; drought vulnerability; irrigation; flooding; sea-level rise, and human vulnerability to climate change. There was scant mention of either 'mitigation' or 'adaptation' in these papers nor in any others describing natural hazards – the only other topic mentioned being 'fire'.

4.3.6 *Urban sustainability*

Since the implementation of market oriented economic reform in 1978, China has seen unprecedented, rapid urbanisation. Although there is limited understanding of how this might affect habitats and biodiversity, urbanisation causes significant changes in lifestyle (diet, domestic sanitation, and motorisation), and production style (agriculture, industry, and services). Urbanisation has resulted in substantial cultivated land loss, raised 'quality of life' issues, threatened food security, and degraded ecological systems. Very often urbanisation issues are explicitly considered through the lens of ecosystem services (ES) where quantifying and mapping the ES distribution patterns are used to determine which services should be protected and where investments should be directed to improve synergies and reduce trade-offs.

4.4 Research Capacity

WoS output (2014–2016) produced 24 papers from 16 Chinese institutions collaborating with UK organisations, and 18 papers from the 12 UK institutions listed as collaborating with Chinese ones. Overall, there were 16 papers with China and UK authorship.

4.5 Overview of funding streams

From the material that could be assigned unequivocally, 642 records – pertaining to 173 funding sources – were available for China. A total of 13 countries were involved in funding Chinese research and, overall, more than half of the funding sources were associated with more than one paper.

China was the most commonly cited funding source with 85% of records relating to 61% of the funding bodies. The most frequently cited funder (n = 207 records) was the National Natural Science Foundation of China, followed by Chinese Academy of Sciences (46) and then a variety of specific Ministries, other State-led funding sources, and seven Chinese universities, three Taiwanese organisations and a further six Chinese ones.

The remaining 15% of records of 67 funding sources (39%) were from overseas countries. Of these the most frequently reported was the USA with 36 records of 29 funding sources. Germany was the next most frequently reported (12 funding sources), followed by Australia (5). The UK had four funding sources: Darwin Initiative, Economic and Social Research Council (ESRC), Newcastle University, and the University Of East Anglia (1 each). Other sources were The Netherlands (3), Denmark (2), and Finland, Norway, Canada, Japan, Nepal, Philippines, and South Korea (1 each). At the continental level, there were two European funding sources, the European Union and the European Commission, and there were also two at the global level: the Consultative Group on International Agricultural Research (CGIAR) and the United Nations University.

4.6 Summary of opportunities arising for Global Challenges research

- **Ecosystems and ES characterisation —** one obvious area of research is that of linking landscape structures and ecosystem service value (ESV). A better understanding of these links could guide landscape planning, management and restoration. Numerous issues and threats affect China and addressing and remediating each offers considerable research opportunities: habitat loss and degradation, overexploitation of biological resources, alterations of hydrological regimes, eutrophication, and pollution. An overarching research theme involves disentangling the effects on ecosystems and ecological services of direct human activities and climate change, ultimately to better devise targeted management measures.

- **PES/ES valuation and revenue —** current planning lacks awareness of ecosystem service values (ESVs), focusing more on economic benefit and less on ecosystem protection. Throughout China there is a need to establish a "... real socio-economic-ecological benefit evaluation scheme for the integration of planning". There are also further research opportunities associated with current PES programmes in China and much to be learned about the collaboration between relevant government actors at different hierarchical levels, and specifically, the motivations and interests of the government actors responsible for on-the-ground implementation.

- **Ecological restoration —** less than 10% of the articles in the WoS search were assigned to this theme, so there is likely to be potential to develop research in this area which also includes decontamination and the remediation of pollution. Plans for ecological restoration projects and national policies often rely on ESVs but the effects and influences of these are hotly debated. Research opportunities arise from findings that a single ecological restoration policy cannot improve all the ecosystem functions and so integrated ecological restoration policies are probably required. There is also an urgent need to move beyond the "one-size-fits-all" approach that China has used so far in many restoration projects.

- **Agriculture (inc. agroforestry + fisheries + impacts) —** less than 10% of the articles in the WoS search were assigned to this theme, so there is likely to be potential to develop research in this area. Driven by an urgent need to produce more food whilst reducing agriculture's environmental impact, research is exploring how to maximise crop yields close to their biophysical limits for the lowest economic and environmental costs. Aiming for up to 50% increases in national agricultural yields, the government has more than tripled its investment in agricultural research, financing a national network of organisations for developing modern agricultural technology.

In the available literature relating to China, the following themes each had five percent or less of the total relevant WoS articles. Given the very limited research on this topic, there is presumably considerable potential to undertake more and some avenues are mentioned here.

- **Natural hazards —** a key challenge for water managers is how to incorporate highly uncertain information about potential climate change from global models into regional-scale water management models and tools to support local planning. Further research is also needed to address the issue that the government's current repackaging of resettlement as a climate change adaptation measure actually has the potential to amplify rather than to alleviate household vulnerability to climate change.

- **Urban sustainability —** threats to food security, the degradation of ecological systems, and a decline in ESV as a consequence of urbanisation all offer numerous research opportunities. The current lack of data and methodological issues for cultural services mean that the cultural function changes in the process of urbanisation have not been assessed, adding much uncertainty to current assessments.

- **Traditional knowledge —** in the knowledge economy, traditional knowledge is a very important resource for social progress and economic development. Traditional knowledge of Chinese medicine cannot be achieved through existing means of protection alone and so research is needed on how best to create favourable environments for its preservation and development.

- **Mining —** no WoS articles were assigned to this theme, which is surprising given the prevalence of mining in China. The country is the world's largest producer of coal, gold and most rare earth minerals, and the world's leading consumer of most mining products so there are likely to be research opportunities in this area. For example, in relation to coal mining there are possible avenues in terms of mitigation and low-carbon technologies. Such work might not be technical research *per se* but could well focus on governance and uptake for instance.

- **Governance, management & decision making —** although governance has "even become an official discourse in China", disputes have emerged over the applicability of governance theory in China. It has been suggested that the future agenda of research on Chinese governance needs to revolve around a core involving state governance, social governance, and the interaction between the two.

- **Offsets —** the WoS search generated no references to 'offsetting'. This is noteworthy as it indicates little interest in this topic to date. This could be interpreted either as evidence that the topic is not a legitimate one for research or that there is considerable potential to develop research in this area. The lack of research on offsetting might be due to the concept being as yet barely developed in the country's conservation 'culture', and therefore no organisational infrastructure existing in which to operate such schemes.

4.7 Conclusion and next steps

In China there has been a great deal of research effort directed at many of the thematic areas. A very considerable in-country research capacity has also been developed. In this context however, the evidence of this study suggests that there has been a fairly low level of collaborative partnerships involving UK institutions, and an even smaller proportion uniquely of an Anglo-Chinese nature. Yet given the considerable challenges facing China in terms of maintaining the quality of environmental resources whilst improving the quality of life of the human communities that rely on them, it seems that there is considerable potential, at least in some specific research areas, for many more such partnerships to be developed, and on a larger scale.

There is potential to conduct more research in all topic areas examined. It would certainly be possible to invest in Valuing Nature research in China to help address the Global Challenges, guide its sustainable development, and create a green economy. Important next steps would be to consider visits and meetings to the main research institutes to identify research and regional priorities.

5. Joining the dots in Colombia — Key Findings

5.1 Country context

Colombia is an extremely diverse country with six distinct natural regions: the Andes mountain range with the largest source of diversity and endemism, the Pacific coastal region, the Caribbean coastal region; the Llanos plains; and the Amazon rainforest region that has the second largest source of diversity. It also holds vast water resources across four main basins: Amazon, Orinoco, Cauca, and Magdalena. Protected areas cover 13% of the country. Colombia is regarded as a "megadiverse" country, covering 0.7% of the planet and hosting 10% of its biodiversity. However, it has been relatively understudied as the decades-long armed conflict made many areas unsafe to access. The economic and social context has been characterised by violence, uneven development, and lack of government presence and institutions. A peace deal is now being reached but social inequality and power imbalance persist, making sustainability challenging to achieve. Hence addressing such inequalities and promoting peace and sustainable development is especially relevant in the country and aligned to Global Challenges Research Fund priorities. The cessation of the conflict will also increase investment and open new opportunities for developers, thus focusing on promoting sustainable livelihoods and resilient development, as well as a green economy in Colombia is particularly timely.

5.2 Overall search results

The WoS literature search generated 329 articles and 175 were considered relevant. There was an increase in publications since the first article was published in 1997.

Authorship

39% of articles (n = 68) involved only foreign institutions, 13% (n = 22) only Colombian institutions and 48% (n = 85) a mix of foreign and Colombian institutions. These numbers show that while there is some research capacity in the country there is also potential to improve it. Links with the UK are scarce and only 7% (n = 13) of articles had authors affiliated to British institutions.

5.3 Thematic analysis

The 175 articles were grouped inductively into categories to reflect the Valuing Nature Network/ Global Challenges thematic areas. From these, brief overviews of relevant recent studies (since 2012) in each thematic area were given.

5.3.1 Agriculture

45 papers were assigned to this theme. Recent publications focussed on coffee and cattle ranching (the oldest and strongest sectors in Colombia), and oil palm production – a rapidly growing sector in Colombia. Studies suggested benefits to biodiversity, farmers, and climate change from shade coffee plantations and silvopastoral systems.

Certification within the coffee sector was also a focus of research, relating to environmental benefits and improving the wellbeing of both farmers and communities. With regards to oil palm production, less than 10% of the total palm oil producing area in Colombia is currently certified, which is below the world average of 17% (RSPO 2016). However, RSPO (Roundtable on Sustainable Palm Oil) members are increasing, showing positive momentum in terms of such things as encouraging uptake and measuring impacts in the future. The government has adopted a policy framework aimed at favoring the expansion of oil palm cultivated lands, and at the marketing, promotion, and consumption of biodiesels, yet research so far has shown that all of these instruments are likely to exacerbate natural ecosystems' loss and fragmentation. Data on biodiversity responses to this crop is limited and only starting to emerge. The socio-economic perspective of oil palm production was also discussed in the literature, in relation to employment, social equity, armed conflict and violence.

5.3.2 *Mining and hydropower*

Besides agriculture, other economically important but environmentally damaging sectors in Colombia are hydropower generation and mining. Research on both of these sectors was limited, and discussed in just five articles. One article highlighted the damage caused by mining to water resources and suggested the incorporation of mine water management into relevant undergraduate courses, training of officials to support implementation of catchment management approaches, and the empowerment of communities to recognise and negotiate solutions to mine-related risks. The impact on local subsistence activities from hydropower development was also reported on.

5.3.3 *Offsets*

Six articles discussed offsets, which are currently a requirement in Colombia. New developments should adopt the mitigation hierarchy of: (1) avoiding impacts, (2) minimising impacts, and (3) offsetting/ compensating for residual impacts. Following guidance from the Nature Conservancy (TNC), the Colombian Ministry of Environment and Sustainable Development adopted an approach whereby this hierarchy is combined with landscape-level conservation planning that enables the identification of where proposed development and conservation priorities would be in conflict and where impacts should be avoided. Recent research in this area has revealed the high transaction costs for obtaining rigorous ecological equivalence, whilst also presenting promising new software OPAL (Offset Portfolio Analyzer and Locator), "which maps and quantifies the impacts of development on habitat and ecosystem services, and facilitates the selection of mitigation activities to offset losses".

5.3.4 *Governance, management & decision making*

38 articles were assigned to this theme, and strengthening institutions emerged as a key factor to achieving sustainable development in Colombia. Research universally called for more participatory approaches to decision making, concluding that knowledge exchange between the different sectors and stakeholders is highly beneficial in all terrestrial, marine and wetland systems. Recently published articles highlighted the importance of peer-to-peer exchange, and the use of prospective structural analysis (PSA) as a strategic foresight tool to support decision making, sustainable management, and capacity building in community-based natural resource management of complex socio-ecological systems. An additional topic that emerged in governance research in Colombia is the use of scenario analysis as a tool to design responses that are innovative and anticipatory and enable a more systematic appraisal of the future in complex systems.

5.3.5 *Ecosystem and ecosystem service characterisation*

41 articles were assigned to this category, and methods for assessing/characterizing services emerged as a theme in recently published literature. Topics included carbon storage and biodiversity conservation; methods for measuring soil-ecosystem services; and the role of trees in reducing urban air pollution. Public engagement was also discussed, with studies demonstrating how participatory research and mapping techniques were used to enable analysis of ecosystem service provision in the Colombian Amazon and in the Amazonia Piedmont region.

5.3.6 *Payments for Ecosystem Services (PES)*

In Colombia, PES are supported at the national level and included in National Development Plans as a conservation strategy and way of improving quality of life for the most vulnerable communities. Fourteen articles considered PES, with some research assessing the effectiveness of schemes and conditions of success. A PES scheme in Quindio (a silvopastoral area) which ran from 2003–2008 did encourage land owners to adopt environmentally-beneficial land management practices, with benefits persisting after payments ceased, however 'Payments for Watershed Services' that attempted to involve Colombia's energy sector had limited success. Challenges to the sustainability of PES schemes were discussed which included durability, benefit sharing, and misunderstandings from farmers regarding the links between contractual commitments and forest conservation. Overall the sustainability of PES schemes was deemed uncertain.

Other research in this thematic area focused on ES valuation and associated techniques. One paper suggested that deliberative valuation methods may be too vulnerable to background inequalities among group members, and another found that willingness to pay (WTP) and willingness to give up time (WTT) estimates highlighted the high commitment of all users of cloud forest areas towards conserving the ecosystem services provided by these strategic ecosystems. A particularly interesting study valued the ES associated with the capture and storage of oceanic carbon provided by mangroves and seagrasses in a new network of marine protected areas in Colombia.

Tourism was also discussed as a means of generating revenue from natural resources. One survey indicated that tourists would be willing to pay additional money to protect the beaches of San Andres Island. However, it was reported that beach erosion could reduce tourism revenue by up to 65.6% in the island. Another innovative way to link tourism with natural and cultural heritage is through place branding, which was found to be successful in a coffee landscape and even increased dialogue between stakeholders.

5.3.7 *Ecological restoration*

Twelve articles were assigned to this theme. Colombia's government is currently the main driver of restoration projects, initiating 64% and fully financing 78% of the 119 projects in the country. The Colombian Network for Ecological Restoration (Red Colombiana de Restauracion Ecologica [REDCRE]) is actively increasing and developing several subnational nodes, showing a growing interest in restoration, which is regarded as an opportunity for transdisciplinary and public-private collaborations. However, many projects lack depth in participatory governance and adequate planning and monitoring, limiting their potential for sustainability and knowledge sharing, both of which are necessary for scaling up.

5.3.8 *Urban sustainability*

Five articles were sourced that considered urban sustainability. Research showed that green areas and urban parks can help human wellbeing in Colombia's capital city of Bogota. However, trees are unequally distributed and wealthier areas of Bogota present more and larger trees, hence particulate matter removal is proportional to socioeconomic strata. Research also revealed that increased integration and participation of people into green infrastructure and urban projects seemed beneficial for increasing sustainability and users' appreciation of urban nature.

5.3.9 *Natural hazards*

Nine articles were sourced that discussed natural hazards. Recently published papers recommend that conservation planning should encompass risk analysis and disaster prevention. One paper identified priority areas for conservation and restoration where endemic and small-range bird diversity was high, and where landslide risk was also high. It was highlighted that restoring forests in areas such as this yields benefits for both biodiversity and people.

5.4 Research Capacity

Approximately half of the articles produced by the WoS search involved at least one Colombian institution, however international institutions are often present and a minority of articles involved only Colombian institutions. This highlights that there is research capacity in the country but there is also potential to increase it. The number of publications has increased substantially in recent years, showing that with the cessation of armed conflict there is great potential to intensify research and access different regions, especially for national institutions. Most of Colombian research arises from institutions based in Bogota, the capital city.

5.5 Overview of funding streams

Prominent funding streams noted in the literature included the Gordon and Betty Moore Foundation; Community-based management of environmental challenges in Latin America (COMET-LA); CGIAR; National Fish and Wildlife Foundation; UN Development Programme – Global Environment Facility; and the Inter American Development Bank – Global Environment Facility.

5.6 Summary of opportunities arising for Global Challenges research

- **Agriculture —** apart from the coffee and cattle ranching sectors, research on the ES provided by sustainable agriculture is limited and should be conducted as a starting point to develop PES schemes. The bio control potential of fungal endophytes from an Andean ecosystem was the focus of one study, and more studies are needed to assess the importance of leaving forest and natural vegetation as a natural barrier for bio control. This could be particularly relevant for the Colombian oil palm sector, which has suffered from Rotten Bud disease. Since Colombia aims to be one of the larger producers of agrofuels in Latin America, research should also look into its sugar production. Its legitimacy is already doubtful and it is affecting communities' access to natural resources. Research that focusses on sustainable production landscapes should be interdisciplinary and work closely with stakeholders and policy makers to increase sustainable practices. Designing incentives for agroforestry, favoring smallholders, and promoting certification schemes are all tools to increase sustainability. Meanwhile, investigating the effectiveness of certification schemes in other agricultural sectors and researching how to best create green market are all priorities.

- **Mining and hydropower —** as peace becomes more consolidated, new development opportunities will bring more investments, infrastructure and exploitation of resources. Therefore more research into the impact of mining, hydropower, and infrastructure is needed, as well as on potential solutions. It is vital to engage with these sectors for sustainable planning, mitigation and incorporation of natural capital into their decision-making. It is also crucial to conduct cost-benefit analysis of conserving natural capital for businesses.

- **Offsets —** current evidence is limited and more research should be conducted. As peace is bringing new investments and business, it is particularly timely to investigate mechanisms of reducing transaction costs while achieving ecological equivalence, as well as reporting case studies of successes and failures in compensating ecological damage. It is ever more important to engage businesses and persuade them of the importance of integrating natural capital in their operations. Other challenges included ensuring conformance with the mitigation hierarchy; identifying the most environmentally preferable offsets within a landscape context; determining appropriate mitigation replacement ratios; and ensuring appropriate time and effort is given to monitor offset performance.

- **Governance, management & decision making —** it is vital to work with local actors to develop strong governance that is integrated at different scales, transparent, and participatory. Clearly-defined property rights are a crucial part of effective governance and PES schemes, and, given the many forced displacements that have occurred in Colombia, should be a key aspect of research and interventions. Equally important is to integrate and work with different policy sectors: e.g. agriculture, environment, and mining. Partnerships amongst NGOs, private organisations, communities and government are also key opportunities for fostering meaningful participation of all stakeholders in planning/management of protected areas and natural resources, improving their governance.

- **Ecosystem and ES characterisation —** since the synergies between carbon and biodiversity seem limited in the country, it is important to assess the real benefits of REDD (Reducing Emmissions from Deforestation and Degradation) strategies for biodiversity, as well as investigating the connections between biodiversity and other ecosystem services. It is also crucial to continue developing indicators to measure ES, and to conduct more participatory research in other priority areas that are not the Amazon or the Andes piedmonts to understand the value people place on natural world. The latter would enable establishing further links between conservation of natural resources and society/ wellbeing.

- **PES and revenue —** it would be useful to investigate whether there are additional PES schemes that are not reported by published literature, especially in different ecosystems from silvopastoral areas, cloud forests, and watersheds. It is also important to engage more with hydropower companies and agricultural producers since they benefit from ES (e.g. water and soil services), and design mechanisms to involve them in the protection of the natural resources they depend on. Similarly, valuing the ES provided by sustainable agriculture could be an incentive for good practice.
- **Ecological restoration —** the WoS search revealed interest and positive momentum in restoration, but very limited research. Hence there is a need to undertake more research on the effectiveness of restoration, optimal planning and decision-making, as well as participatory mechanisms and/or barriers to their implementation.
- **Urban sustainability —** urban ecosystem services should be increasingly taken into account in city planning efforts to address environmental justice issues and improve citizen welfare. It is also important to use participatory approaches for urban planning and increase participation in urban sustainability projects, as well as investigating wellbeing and its connections to urban nature in other big cities (e.g. Cali, Medellin).
- **Natural hazards —** limited research was found on this topic and there is great potential to undertake more. Establishing the links between natural resources and disaster prevention is particularly important as it would be a robust driver for their conservation.

5.7 Conclusion and next steps

There is potential to conduct more research in all topic areas examined. Since the peace deal is increasing investment and development in the country, it is ever more valuable to invest in Valuing Nature research in Colombia to help solve the Global Challenges, guide its sustainable development, and create a green economy. Important next steps would be to organise visits and meetings to the main research institutes to identify research and regional priorities.

6. Joining the dots in India — Key Findings

6.1 Country context

India, occupying 2.4% of the world's land area, is classified as a 'megadiverse' country. It hosts 7–8% of all recorded species, including over 45,000 plant and 91,000 animal species. This represents 8% of all mammalian species, 13% of avian species, 6% of reptilian species and 6% of flowering plant species. The level of endemism is also high, with 4045 endemic species of angiosperm in 141 genera belonging to 47 families, and in vertebrate groups India is ranked globally 10th for birds (69 spp.), 5th for reptiles (156 spp.), and 7th for amphibians, (110 spp.).

India also holds key importance as a centre of origin of cultivated plants and domesticated animals, with some 15 agro-climatic zones having been identified within its borders. It is regarded as the primary centre of the origin of rice, has documented 811 varieties of cultivated plants and 902 of their wild relatives, as well as many native breeds of cattle (34), buffalo (12), goats (21), sheep (39) and chickens (15).

This reflects the diversity of traditional farming systems and practices that support millions of people and the strong link between biodiversity and human wellbeing. For instance, about 300 million tribal and other locals depend on the forest for subsistence and livelihoods, 70% of India's rural population use fuelwood to meet domestic energy needs, and an estimated 100 million Indians derive their main source of cash income from forests as fuelwood, non-timber forest products (NTFPs), or construction materials. Furthermore, half of the 70 million tribal people in India, amongst the most disadvantaged in Indian society, subsist from forests.

Successive Indian governments have grown the protected area network to 102 National Parks, 527 Wildlife Sanctuaries, 57 Conservation Reserves and 4 Community Forests by 2014 — covering 166,700 km^2, or 5% of the country's geographical area (cf. England + Wales = 151,200 km^2). For India, the importance of maintaining its biological diversity in the near and long term is vital to the health and wellbeing of a large part of its population, as well as its cultural diversity and future development. With the population of India growing rapidly, and with 50% of the 1.34 billion below the age of 25, 65% below the age of 35, and the total population predicted to pass 1.53 billion people by the end of 2030 the need to understand, protect, and use these resources sustainably has never been greater.

6.2 Overall search results

The WoS search generated 2572 articles, of which 1589 were deemed directly relevant. A steady increase in published outputs was exhibited over the 26 years from 1990–2016; an approximate doubling of items every 5 years, from just 5 in 1991 to 174 in 2016.

Authorship

The proportion of publications authored soley by individuals representing Indian organisations has been roughly steady since 2000 (averaging 74%), whilst the proportion of India/Overseas co-authored publications has grown from zero to 26% in 2016. Of 343 records with any overseas authorship, 93 were identified with UK institutions, although of 230 India+overseas jointly authored publications since 1970, just 27 recorded exclusive Anglo-Indian institutional collaboration (2% of this sub-sample).

6.3 Thematic analysis

All 1589 publications were grouped inductively into categories to reflect the Valuing Nature Network/Global Challenges thematic areas. The results indicated a predominant interest in describing and evaluating natural resources, plus a central importance given to understanding agricultural practices (including agroforestry and fisheries); with these thematic areas also being disproportionately responsible for much of the overall growth in publication output.

6.3.1 Ecosystem and ecosystem service characterisation

The bulk of the 604 articles allocated to this category reported research oriented at the assessment and monitoring of ecosystems, or, in a minority of cases, with general or specific biodiversity surveys. Remote sensing using data gathered by Indian satellites figured highly in survey methodologies, with recognition of the ecological unit of the watershed being reflected in its high frequency (n = 437, 38%) recorded across the full sample. Similarly, the importance given to 'forests', India's largest land use after agriculture, is reflected in the 726 records in which the word appears, nearly half (46%) of all records.

6.3.2 Agriculture

Given that agriculture is the most important occupation for most Indian families, and contributes about 16% of GDP and 10% of the value of exports, it is unsurprising that a large proportion of the research effort, as revealed by the WoS search was directed at agriculture in one way or another. This also helps explain the high frequency of the words 'water' (548 = 35%), 'crop' (317 = 20%), and 'soil' (303 = 19%) across the sub-sample of 1589 records. Other typical publications considered land evaluations for the purpose of improving agricultural production, sustainable techniques for increasing crop productivity, aquaculture, home gardens, and agroforestry. These data appear to reflect the importance given to the high level of agro-diversity existing in India and the intimate relationship between this biodiversity and human communities.

6.3.3 Governance, management & decision making

The high frequency of the word 'management' in the sub-group records (880=55%) most probably reflects the interest in managing environmental resources in the most efficient and effective manner. In many of these instances the concern was either with existing, or recommending specific, management practices.

6.3.4 Payments for Ecosystem Services (PES)

Very few of the 179 publications allocated to this category addressed payments for ecosystem services, with published matter predominantly oriented at their valuation. The term 'ecosystem service' was encountered in 121 records – typically assessments of carbon stocks, aquatic macrophytes, and full economic costings, whilst others adopted a more integrated approach, considering the co-development of sustainable livelihood strategies.

6.3.5 Natural hazards

With such a high dependency on monsoon-dependent agriculture, and susceptibility to climatic change, the large number of records containing the word 'climate' (n = 222, 14%) and many mentioning 'flood' (n = 64, 4%) or 'drought' (n = 56, 4%) was not unexpected. There was also a clear interest in the need to develop coping strategies that integrate traditional knowledge with government and local interventions to produce solutions that address the interrelationships between water, agriculture, forests, pastures, and livestock; in other words, to place resilience at the heart of India's agricultural, environmental and conservation strategies.

6.3.6 Traditional knowledge

With 104.2 million people belonging to over 700 scheduled tribes, and nearly twice this number belonging to over 1000 scheduled castes (2011 Census), this thematic area was of particular importance in the Indian publication data. Recognition of the potential value of tribal knowledge in contributing to the sustainable livelihoods, the health of the environment, and the economic development of the nation was reflected by the 100 records (6%) primarily concerned with this form of knowledge, and the significant number of records containing the words 'traditional' (n = 283, 18%), 'medicinal' (n = 136, 9%), and 'tribal' (n=84, 5%). The importance of religious understandings to wildlife and habitat conservation was also recognised in 55 records (4%) that contained the term 'sacred grove', referencing the numerous pockets of biodiversity that hold special significance for the long-term biodiversity conservation in India.

6.3.7 Ecological restoration

Although just 28 (less than 2%) of the WoS records were categorised under this theme, the word 'restore' (including 'restore', 'restoring' and 'restoration') generated 105 records (7% of the total). There appears to be a nascent yet growing recognition that ecological restoration, designed and implemented properly, can make a valuable contribution to the alleviation of poverty through livelihood provision and by increasing wellbeing through the production of medicinal and other materials.

6.3.8 *Mining, Urban Sustainability, Offsetting*

The handful of records that dealt specifically with mining or hydropower (n=9), considered their wider environmental impact, for instance 'unsustainable sand mining'. However, some allocated to other themes included mining alongside agricultural expansion and plantations as a key cause of deforestation and environmental degradation.

The lack of references to 'offsetting' generated by the WoS search is noteworthy insofar as it points to relatively little current interest in this topic. This is possibly due to the concept being as yet barely developed in the country's conservation 'culture', but perhaps more easily explicable in terms of the nature of the society and the economy, together with the lack of physical space in which to exercise this sort of practice.

6.4 Research Capacity

There is a plethora of organisations in India involved in conducting research in the Valuing Nature Network/Global Challenges thematic areas, and together they embody a considerable amount of research capacity. They range from national government organisations and agencies, through University departments and specialist research institutes, to international, national and local NGOs. The following lists are readily available via the internet: The Directory of Environmental Organisations & Environmental Government Agencies in India, Development NGOs and International NGOs in India, and the Directory of NGOs – India. In terms of Anglo-Indian collaborations, 31 Indian and 25 UK organisations were identified as engaged in partnered activities as indicated by the mixed authored publication records (see section 6.4. main text).

6.5 Overview of funding streams

Since 1993 the Darwin Initiative has been a major funder, match-funding 45 projects that involved India, of which 30 were exclusive to India. The total monetary contribution has been over £5 million, with approximately half of this to India-only projects. The Ecosystem Services for Poverty Alleviation program (ESPA) has now all but ceased, with the last cohort of projects having focused on building upon the scientific advances and evidence generated by previous ones. Since 2011 Research Councils UK, Government of India and third parties have together invested over £200 million in co-funded research programmes tasked with enhancing the UK-India relationship in science and research – >100 UK-India research projects, involving over 90 industry partners. Other significant funders have been: the Environment Programme, Management of Natural Resources, DG Research and Innovation, European Commission 7th Framework; The Rufford Foundation, which has awarded grants to over 3000 projects in 155 countries, of which 583 have been in India; and, the World Wildlife Fund-India Small Grants Programme, which, from 2010–2016, sponsored nearly 40 projects.

6.6 Summary of opportunities arising for Global Challenges research

According to the WoS data, in India over the past 26 years the primary focus of research in the field of nature and the environment has been directed at understanding species and ecosystems, whether from the point of view of their composition, health, value, and sustainability, or their governance and management. Much of this work has been underpinned by the objectives of improving the lot of the substantial human populations that rely upon them, ensuring their long-term sustainability, and maintaining agricultural diversity whilst further understanding and realising the further economic and other values that they can generate.

The WoS search data indicate that collaborations have involved a significant number and range of participant organisations in the UK and India, although predominantly academic institutions in the UK. In terms of opportunities for Global Challenges research, the following conclusions have been drawn in relation to the different thematic categories – although there is also a great deal of interdisciplinary research that steps across the boundaries these categories imply:

- **Ecosystem and ES characterisation —** although the Indian in-country capacity in this area is strong and growing, there will continue to be topics and areas where collaboration with UK institutions can make valuable contributions to an understanding of ecosystem function. These are likely to be of a more specialist nature and/or where new techniques or technologies being developed or utilised in the UK will be of particular value to Indian counterparts (and *vice versa* of course). Consequently, where the links to enable or progress partnerships are not already present, some forum for advertising and promoting UK-based expertise and skills could be utilised.

- **Agriculture —** a considerable Indian expertise clearly exists in this thematic area, together with a great interest in 'capturing' traditional agricultural knowledge with a view to developing more productive and resilient outcomes. Anglo-Indian collaborations can perhaps make a valuable contribution to this process through a sharing of relevant expertise and technologies.

- **Governance, management & decision making —** as the volume of the WoS data indicates, this is clearly a very important thematic area and one in which some UK organisations are already engaged; notably with approaches focused on stakeholders, local communities, and participatory and collective agreements as a basis for effective management strategies. This therefore seems to be a promising candidate for further research investment.

- **PES/ES valuation and revenue —** although the idea of payment for ecosystem services does not seem to have gained much of a foothold in India, there is clearly significant interest in understanding the economic and other values provided by ecosystems, habitats and individual species, and how to conserve and sustainably utilise them.

- **Natural hazards —** the research effort made in regards to natural hazards has been very much focused around the notion of resilience and how this can be improved through various means. Key amongst these were the protection and restoration of watersheds, and the need to develop resilience at the heart of its agricultural, environmental and conservation strategies.

- **Traditional knowledge —** the extremely rich diversity of socio-ecological knowledge existing across the Indian subcontinent comprises a precious resource to be recorded, understood and drawn upon in supporting a resilience agenda. Some may prove extremely valuable in other locations and situations around the world. The need to document, preserve and share this knowledge is therefore of great importance, and it seems that UK-derived expertise in appropriate research methods and survey instruments might well prove helpful in facilitating this process.

- **Ecological restoration —** properly designed and implemented, ecological restoration can make an extremely valuable contribution to the revitalisation and preservation of existing biodiversity-rich sites, as well as to the regeneration of severely degraded ones. It can help restore ecosystem services, with the benefits of building resilience to perturbations and thereby reducing the risk and impact of natural hazards. It can also have a positive effect on human culture, wellbeing and livelihoods. As a subject likely to be of growing significance in the future, it may well be a suitable candidate topic to pursue in the context of the Global Challenges research agenda.

- **Mining, urban sustainability, offsetting —** none of these themes were of any great significance as measured by the WoS outputs. Unlike offsetting, urban sustainability is perhaps beginning to gain a foothold on the research agenda. However, mining did appear to be a topic of some interest in terms of its wider environmental impacts.

6.7 Conclusion and next steps

In India there has been a great deal of research effort directed at many of the thematic areas. A very considerable in-country research capacity also has been developed. In this context however, the evidence of this study suggest that there has been a rather low level of collaborative partnerships involving UK institutions, and an even smaller proportion that are uniquely of an Anglo-Indian nature. Yet given the considerable challenges facing the people of India in terms of maintaining the quality of environmental resources whilst improving quality of life of the human communities that rely on them, it seems that there is considerable potential, at least in some specific research areas, for many more such partnerships to be developed and on a larger scale.

7. Joining the dots in Burkina Faso — Key Findings

7.1 Country context

Landlocked Burkina Faso has a population (2014) of just over 17.3 million. The country faces high levels of food insecurity and the rapidly growing population strains resources and infrastructure, further limiting accessibility to food. Many families struggle to avoid malnutrition, especially women and children. Environmental degradation and climatic hazards like droughts disrupt socio-economic development and drive poor communities into even more poverty, increasing their vulnerability to extreme weather events. Burkina Faso is one of the poorest countries in the world and around 45% of the population live under the poverty line of US$1 per day. Most people depend on agriculture for income and food, but Burkina Faso is prone to drought and floods and experiences radical climatic variation, making agriculture very difficult and rendering crops vulnerable to insect pests.

With an increasing human population, biodiversity has become impoverished and there is increased fire frequency, overharvesting, and killing and disturbance of wildlife. Over 90% of the population depends on natural resources for their livelihood but much of the soil is structurally unstable and has low water-holding capacity. Investment in woody vegetation to counter land degradation, enhance carbon sequestration, and improve livelihoods is increasing. Water service coverage is low when considering targets under the Sustainable Development Goals (SDGs).

7.2 Overall search results

The WoS literature search generated 150 articles and 62 were considered relevant. There was an increase in publications over the last decade. Only 10 were published from 1997–2006, increasing to 21 in 2007–2011, and then 31 in the last five years (2012–2016).

Authorship

The proportion of relevant publications (n = 62) authored solely by individuals from Burkina Faso was low (n = 5, 8%) and these were only recorded in the last decade. Prior to 2007, the ten publications recorded were divided equally between those written by overseas authors or a mix of these and Burkina Faso-based authors.

Overall, the highest proportion (n = 31, 50%) of publications had mixed authorship involving Burkina Faso institutions plus those in 19 other countries. Of these, the most commonly reported was France (23%), followed by Sweden, Germany and The Netherlands, Denmark and Belgium. There were two records each of collaborations with Senegal, Mali, Kenya, Madagascar, Togo, and Indonesia, and single instances each with the USA, UK, Austria, Bali, India, and Morocco.

The remainder (42%) of the articles relating to Burkina Faso were written entirely by overseas authors. A total of 21 overseas countries were reported (n = 42 records), the most frequent being Germany (17%), followed by the USA (15%), Denmark (10%), Sweden and the UK (7% each).

There were a further 1–2 records from Togo, Kenya, Cote d'Ivoire, Ghana, Madagascar France, Italy, The Netherlands, Belgium, Hungary, Finland, Taiwan, Malaysia, Peru, and Argentina.

In respect to the UK, from the 88 records with any degree of overseas authorship, only 5 records (less than 5%) were identified with UK institutions.

7.3 Thematic analysis

All 64 selected publications (since 1970) were grouped inductively into categories to reflect the Valuing Nature Network/Global Challenges thematic areas. From these, brief overviews of relevant recent studies (since 2012, n = 31) in each thematic area were given.

7.3.1 Ecosystem and ecosystem service characterisation

Of the 34 papers in this theme, the most frequent research topic was on woodland landscapes, a focus that followed severe droughts in the 1970s and 1980s and subsequent debates about desertification. Satellite image analysis has been combined with participatory activities to classify village landscapes for assessing provisioning ecosystem services.

Forestry regrowth, and 'woodland' in general were studied in relation to carbon stocks and potential for carbon sequestration. Recent research demonstrated the complexity of current landscape changes and questioned rain as the sole primary driver of increased tree cover. Lack of data on carbon stocks in soils has hampered implementation of emission reduction mechanisms, e.g. REDD+. Studies suggested that, overall, dense shea parklands (shea *Vitellaria paradoxa* trees within cultivated fields) have real potential for carbon sequestration, as well as allowing tree-crop integration. Such parklands are important for ecosystem services provision and household subsistence, but shea trees on farms are threatened for several reasons and research is needed to develop management regimes for improved regeneration.

Most species of woody vegetation generate multiple provisioning ecosystem services. Almost all species have medicinal uses, contribute to livestock fodder, and are important for human nutrition. Fewer species were involved in regulating ecosystem services with mainly positive or no effects on soil nutrients, soil carbon and soil water content. Research has also examined the social and environmental factors influencing the utilisation of tree products by rural households for home consumption and commercialisation. Non-forest environmental products are demonstrably crucial to rural livelihoods, producing considerable 'environmental income'.

A recent assessment of bee species and their seasonal distribution now forms an important scientific basis for the establishment of management strategies for agricultural practices ensuring better productivity through pollination service provision and biodiversity conservation.

Water offers many ecosystem services and wetlands in semi-arid Africa are vital for local inhabitants and biodiversity but are prone to strong seasonal fluctuations. Groundwater over-extraction and pollution of surface water bodies have serious impacts on water resource availability and biodiversity in Burkina Faso, while climate change exacerbates the health risks of water insecurity. Several studies have used remote sensing to monitor wetlands, offering a potential early warning indicator of drought.

7.3.2 Agriculture

In some ways the distinction between agriculture, the theme of 19 papers, and other forms of natural resource management and exploitation in Burkina Faso is quite blurred, partly a result of fragmented landscapes, harsh climatic regimes, and relatively extensive resource 'exploitation'. Agriculture is often limited by resource availability and research has been undertaken on the quality of topsoil and crop yield across a range of fertiliser treatments.

Trees in agroforestry parklands (crops grown under a discontinuous cover of scattered trees) reduce erosion, provide soil cover, vital green fodder for livestock, and fruits and leaves for human consumption and income generation. Forage markets in Burkina Faso are a significant economic activity sustaining livestock where better organisation is required to reduce risks and ensure sustainability, and cotton and shea production have been studied in relation to improving soil fertility and management practices.

7.3.3 *Other themes*

Three further articles each dealing with other themes were found. **Urban sustainability:** a spatial and temporal exploration of urbanisation and land surface temperatures (LSTs), in relation to specific green infrastructure areas. **Natural hazards:** a systematic review of the literature on drought in West Africa in relation to impacts and human responses. **Ecological restoration:** evaluation of the long-term impacts of herbivore, fire, and termite activities on the regeneration of trees and woody species.

7.4 Research Capacity

WoS output (since 1970) produced only one paper from an institution in Burkina Faso which collaborated with a UK organisation, and no papers where any UK institutions were listed as sole collaborators with ones in Burkina Faso. There were no papers with Burkina Faso and UK authorship.

7.5 Overview of funding streams

Although incomplete, information on the "funding agency" was available for 64 articles. The most commonly cited funding source-country was Sweden, with almost a third of articles. Of these the most frequently cited funder was The Swedish International Development Cooperation Agency (SIDA), a government agency. Eight further articles were funded (at least in part) by five other Swedish institutions.

Other named European national funders were France and Germany (8% each) and The Netherlands. Two funding sources from the UK (3%) were cited: the Department for International Development (DFID) a government department, and the Royal Society for the Protection of Birds (RSPB), a charity. At the continental level, four articles cited EU European funders, three funders were cited from Africa, and one from the USA. At the global level, six articles had international funders, including CGIAR, the World Bank, the UN, IFS, and the FAO.

Three funders (5% of articles) from Burkina Faso were cited: the University of Ouagadougou, the Environmental Institute for Agricultural Research (INERA), and the Government of Burkina Faso.

7.6 Summary of opportunities arising for Global Challenges research

- **Ecosystem and ES characterisation —** one key research area is the improvement of data on local ecosystem services, as people depend on these for their livelihoods. Research is required to improve methods to assess potential trade-offs and synergies among services that might arise from poverty alleviation interventions. Research also needs to address the consequences of increasing aridity in Burkina Faso where farmers are increasingly vulnerable to the extremes of shifting/reduced rainfall distribution. Research is required to develop, and maximise the potential of, carbon sequestration in agroforestry systems. Research is also needed to reduce or eliminate groundwater over-extraction and pollution of surface water bodies, while climate change exacerbates the the health risks of water insecurity.

- **Agriculture (inc. agroforestry + fisheries + impacts) —** there are research opportunities associated with recent calls for production options that ensure increased and diversified agricultural productivity whilst preserving the environment. With increasing urbanisation there is more demand for livestock products and research is needed to strengthen links between livestock producers and crop farmers, and identify strategies to improve livestock productivity. Soil degradation leads to impoverished soil, hydrological instability, and reduced primary productivity so reversing it would be a vital contribution to poverty alleviation and food security. There are also research opportunities in devising and improving soil restoration techniques.

- **Governance, management, and decision making —** as less than 10% of the articles in the WoS search were assigned to this theme, there is likely to be potential to develop research in this area, although the WoS search and a more general web-search produced little in relation to this theme.

In the available literature relating to Burkina Faso, the following themes each had five percent or less of the total relevant WoS articles. Given the very limited research on these topics, there is presumably considerable potential to undertake more and some avenues are mentioned here.

- **Natural hazards —** perhaps one of the most consistent natural hazards facing Burkina Faso is that of variable climatic conditions and recurring drought. More research is needed on the effectiveness and on the unexpected effects of responses to droughts of populations, states, and NGOs, and also their interactions.

- **Ecological restoration —** one of the main areas of ecological restoration in Burkina Faso is that of reforestation. There are many research opportunities in relation to the management and regeneration of woodlands, including species selection, seedling husbandry, and planting and water retention technologies.

- **Urban sustainability —** urbanised areas and urbanisation are intimately linked with climate change and food security. The use of green infrastructure to provide ecosystem services and increase resilience has largely been overlooked in climate change and urban policies but research on the benefits of preservation of green infrastructure would be highly relevant to municipalities in Burkina Faso.

- **Traditional knowledge —** no specific references to traditional knowledge were found during the WoS search but several topics had strong connections with traditional knowledge and offer considerable research opportunities. These include ethnobotany, traditional medicine, and adaptation strategies for water management and climate change.

In the available literature relating to Burkina Faso, three themes had no articles assigned to them. This could be interpreted either as evidence that the topic is not a legitimate one for research or that there is considerable potential to develop research in this area. **Mining and hydropower —** there may be research opportunities in Burkina Faso as gold mining, for instance, plays a significant role in the country's economy, although slave/forced and child labour is common place. **Offsets —** the WoS search generated no references to 'offsetting', suggesting there is little interest in this topic to date. The concept seems as yet barely developed in the country's conservation 'culture' and so there are likely to be opportunities for research here. **PES/ES valuation and revenue —** Burkina Faso is reported to be piloting payment for environmental and ecosystem services provided by local communities to reduce pressure on forest resources. More widely, there are a number of potential options for PES including livestock production, and better utilisation of water, land and biodiversity.

7.7 Conclusion and next steps

In Burkina Faso there has been very little research effort directed at any of the Valuing Nature Network/Global Challenges thematic areas. Relatively little in-country research capacity appears to have been developed. In this context, the evidence of this study suggests that there has been a very low level of collaborative partnerships involving UK institutions, and none that are uniquely with the UK. Yet given the considerable challenges facing Burkina Faso in terms of maintaining the quality of environmental resources whilst improving the quality of life of the human communities that rely on them, it seems that there is considerable potential, at least in some specific research areas, for many more such partnerships to be developed and on a larger scale.

There is potential to conduct more research in all topic areas examined. It would certainly be possible to invest in Valuing Nature research in Burkina Faso to help address the Global Challenges, guide its sustainable development, and create a green economy. Important next steps would be to consider visits and meetings to the main research institutes to identify research and regional priorities.

8. Joining the dots in Kenya — Key Findings

8.1 Country context

Kenya covers 581,309 km^2, has a population of approximately 48 million, 53% of which lives below the poverty line and is heavily dependent on food aid. The country's climate varies from tropical along the coast and temperate inland to arid in the north and northeast. Kenya is known for its expansive wildlife reserves and national parks and the annual migration involving millions of animals attracts considerable valuable foreign tourism. Kenya's services sector contributes 61% of GDP and is dominated by tourism to coastal beaches and game reserves, the country's principal source of foreign exchange.

Agriculture, including forestry and fishing is the second largest contributor (24%) to Kenya's GDP. The agricultural sector is poorly developed and largely inefficient, and Kenya cannot guarantee food security despite there being a major irrigation sector and considerable investment. Although Kenya is the most industrially developed country in the region, manufacturing accounts for only 14% of the GDP. Kenya has an oil refinery processing imported crude petroleum, and most of its electricity supply comes from geothermal and hydroelectric sources. In 2007, the Kenyan government unveiled 'Vision 2030', an extremely ambitious economic development programme and in 2013, it launched a National Climate Change Action Plan, aiming to ensure climate change is treated as an economy-wide issue.

8.2 Overall search results

The literature search generated 658 articles and 250 were considered relevant. There was an increase in publications, particularly over the last decade. Fifteen articles were published from 1994–2001, increasing to 33 in 2002–2006, 52 in 2007–2011, and then 146 articles in the last five (full) years (2012–2016).

Authorship

Overall, the highest proportion (n = 104, 42%) of the 250 publications (2014–2016) were authored by someone from a Kenyan institution and at least one overseas co-author. Such mixed authorship involved 36 other countries, the most commonly reported (from 125 records) being the USA (20 records, 16%), the UK (13%), The Netherlands, Germany, and Belgium. Other co-authoring institutions were from a dozen European countries, five from Asia, three from South America, plus Canada, New Zealand, and Australia. Eight African countries were also involved in collaborative research, most records citing South Africa.

The remaining (n = 95, 39%) Kenyan articles were written entirely by individuals from overseas and 20 countries were reported (n = 73 records). The most frequently recorded was the USA (n = 14, 19%), followed by The Netherlands, Germany, the UK (8%), and Canada. Nine further European countries, Australia, Canada and Thailand, as well as three African ones (Ethiopia, Senegal, Tanzania) were also recorded.

In respect to the UK, from the 198 records with any overseas authorship, 22 records (11%) were identified with UK institutions. Of the 125 records from publications jointly-authored between Kenya and another country, the UK ranked second amongst collaborating countries (16 records, 13%). Of the 73 records from publications solely authored outside Kenya, the UK ranked fourth amongst overseas countries (6 records, 8%).

8.3 Thematic analysis

All 250 selected publications (for the full years since 1970) were grouped inductively into categories to reflect the Valuing Nature Network/ Global Challenges thematic areas. From these, brief overviews were given of relevant recent studies (2012–16, n = 146) in those thematic areas that had at least 5% of the overall records within this period.

8.3.1 *Ecosystem and ecosystem service characterisation*

55 articles were assigned to this category and the word 'species' was the most commonly used (53% of articles), often in relation to communities or guilds of species at the ecosystem level. Often research focused on trees but other work examined various other species and communities within forest ecosystems. Systems were often characterised in relation to preferred plant species for such things as human food, animal fodder, medicine resources, materials and firewood.

Conservation was an important perspective for many ecosystem services articles (29 records, 55%) and biodiversity conservation was considered a great challenge. Related research focused on the effects of reserve establishment and fencing on mammalian diversity, and the relationship between the human aesthetic appreciation of wildlife and attitudes towards conservation. Much research highlighted the differences in perspectives between visitors and local people.

Water was often considered the most important ecosystem service and around one-third (27%) of articles focused specifically on it. Research was often based on the understanding that the degradation of agricultural watersheds usually reduces their capacity to provide ecosystem services and affects food security. Water pollution, often from agricultural and domestic sources, threatens ecosystem services and the security of livelihoods and so improved water quality information is vital.

8.3.2 *Agriculture*

In Kenya the distinctions between agriculture and other forms of natural resource management and exploitation were fairly clear and 23 articles were classified under the agriculture theme. Most studies (65%) investigated crop 'production' and 'yield' and associated issues, often in terms of indigenous vegetables, food security, and sustainable agricultural production approaches. Soils and their properties were also very important and frequently studied (43% of articles), papers covered soil fertility, soil chemistry and microbial content, soil chemistry and macrofauna, soil security, and soil management.

8.3.3 *Governance, management & decision making*

The two most commonly occurring words in papers assigned to governance were 'management' (10 papers, 67%) and 'community/ies' (47%). There was a noticeable split between governance-themed papers dealing with issues of 'household(s)' (40%) and those of 'institution(s)' (53%). Articles citing 'households' explored how natural environment and market accessibility affect peoples' coping and adaptation strategies, and explored perceptions of individuals in terms of influence in decision-making. At the 'institutional' level, studies investigated catchments as hydro-economic systems with slowly emerging basin-wide water management institutions facing interlinked challenges, and the development of ecotourism as a model for the conservation of natural resources and improvement of local people's welfare.

8.3.4 *Forestry*

Most of the twelve forestry papers were concerned with the biodiversity associated with forests or the environmental consequences of deforestation. Some papers (25%) examined either tree biodiversity or some component of the fauna associated with forests. Several others (25%) focused on the REDD+ scheme and explored forestry-related land-use changes (e.g. afforestation, deforestation, agroforestry) in relation to water fluxes and hydrology. Other forestry articles covered research into how land use determines tree species assemblages, their associated traits and potential ecosystem services, and how forest resources significantly contribute to income generation.

8.3.5 *Payments for Ecosystem Services (PES)*

The word 'payment(s)' was commonly cited in the 11 papers assigned to this theme and most (64%) investigated some issue around conservation, wildlife, and tourism. Such topics included examination of tourism-conservation enterprises (TCEs), the willingness to accept payments for keeping land open to preserve migratory wildlife corridors, and the effects of wildlife tourism-based payments for ecosystem services on poverty, wealth inequality, and livelihoods. Other specific topics addressed through PES (2 papers, 18%, each) were related to water supply or other water-related ecosystem services, and to climate change adaptation.

8.3.6 *Fisheries*

Nine papers were assigned to the 'fisheries' theme and all dealt with issues of food security and the sustainability of fisheries. As well as fin-fish, a variety of other species/groups were investigated, including crustacean fisheries, and sea urchins which overgraze their habitats because their own predators had been fished-out. Other 'fisheries' issues included transactional sex to obtain resources amid declining access to fish, and a review of the general sustainability of coastal systems and their marine resources (including fisheries).

8.4 Research Capacity

WoS output (2012–2016) produced 17 papers from 15 Kenyan institutions collaborating with UK organisations, and 17 papers from the 15 UK institutions listed as collaborating with Kenyan ones. Overall, there were 14 papers with Kenya and UK authorship.

8.5 Overview of funding streams

From the available material that could be assigned unequivocally, 201 records – pertaining to 137 funding sources – were available for Kenya. The most commonly cited funding source country was the USA which had 53 records (26%) relating to 37 funding bodies (27%). Of these the most frequently cited funder (n = 8) was the US National Science Foundation. The next most commonly cited funders were from Kenya and the UK (each with 23 records, 11%). In Kenya, 22 sources of funding were listed and, of these, only the Kenyan Government was cited more than once. In the UK, ESRC was cited six times, NERC five times, and DFID four times. Most of the other sources were NGOs, or PhD or other research scholarships.

Apart from Kenya, six funding sources within the African continent were reported. Within Europe, 13 countries other than the UK were reported: Germany (8 sources), Switzerland (6), Belgium and The Netherlands (5 each), France (4), Austria and Sweden (3 each), Denmark and Portugal (2 each), and Finland, Liechtenstein, Luxembourg, and Norway (1 each).

Also at the national level, Canada had two funding sources and China one. At the continental level in Europe there were six funding sources, often involving the EU/EC, and at the global level there were nine funding sources, including the CGIAR Research Program, FAO, and the UN.

8.6 Summary of opportunities arising for Global Challenges research

- **Ecosystems and ES characterisation —** the largest proportion (42%) of articles in the WoS search were assigned to this theme. One likely research area is 'biodiversity conservation' which is threatened greatly by habitat degradation. A nuanced and comprehensive understanding of the dynamics of human-environment interactions associated with land use change are required to best predict how land use changes affect biodiversity and its vulnerability. There are also likely to be research opportunities in the critical evaluation of the effectiveness of different land use patterns in maintaining the diversity of native species in human-dominated landscapes, and in the exploration of human attitudes towards biodiversity conservation and the aesthetic appreciation of wildlife.

- **Agriculture (incl. impacts) —** only 15% of the articles in the WoS search were assigned to this theme, so there is likely to be potential to develop research in this area. For example, Kenyan agriculture is under pressure to produce greater quantities of food, animal feed, and biofuel on limited land resources. There is also a requirement for a greater investment in long-term research, breeding programmes, and improved seed supply sources so that underutilised fruit and vegetable crops can be competitive in the marketplace. Overall, research to inform the development of sustainable agricultural practices is clearly needed to address the persistent problems of land degradation and declining crop productivity in Kenya and throughout sub-Saharan Africa.

- **PES/ES valuation and revenue —** only 10% of the articles in the WoS search were assigned to this theme, so there is likely to be potential to develop research in this area. For example, there will be numerous opportunities to study the effects of wildlife tourism-based payments for ecosystem services on poverty, wealth inequality, and the livelihoods of local people. It is not always clear how things like wildlife tourism-based payments or the willingness-to-pay for the conservation of charismatic species actually feed into management, governance, pricing and finance on the ground. Thus, there are likely to be research opportunities for interdisciplinary work taking this valuation approach. The contribution of tourism-conservation enterprises (TCEs) such as eco-lodges to livelihoods and biodiversity conservation is dependent on the nature of the partnership arrangements between actors as well as the local, national, and international contexts in which they operate, and there are numerous opportunities here for research into PES/ES valuation and revenue.

- **Governance, management, and decision making —** less than 10% of the articles in the WoS search were assigned to this theme, so there is likely to be potential to develop research in this area. Given that there are numerous projects in Kenya explicitly seeking to promote such things as sustainable agricultural land management practices but which are doing so "often at the expense of achieving sustainable development goals", there would appear to be numerous opportunities for governance-related research.

- **Traditional knowledge —** less than 10% of the articles in the WoS search were assigned to this theme, so there is likely to be potential to develop research in this area. As recent government legislation appears to offer little or no provisions on support, access, development, let alone promotion, of traditional knowledge and cultural expressions, there are likely to be numerous research opportunities in Kenya in the coming years in relation to traditional knowledge and associated issues in relation to this legislation and its consequences.

In the available literature relating to Kenya, several themes were assigned relatively few articles. The following themes each only had five percent or less of the total relevant WoS articles. Given the very limited research on this topic, there is presumably considerable potential to undertake more and some avenues are mentioned here.

- **Natural hazards —** natural hazards affecting Kenya include drought, floods, and landslides, and their impact is compounded by poverty and lack of adequate resources to develop the affected areas, rendering the populations there more vulnerable. Research is clearly required to address these issues.

- **Ecological restoration —** Kenya has attempted to restore forest cover, but these efforts have not been sustained. Research opportunities thus include understanding why Kenya's reforestation programme has lost momentum. Research might also focus on government commitment and on stakeholder involvement, effort and 'power' – as the success of future programmes will depend on these.

- **Urban sustainability —** it has been suggested that future research should focus on the 'governance dimension' of urbanisation because this is where the biggest challenge lies. There is an increasing need for the immediate management of rapid urbanisation, given the associated rapid population movements and imbalances in socio-economic development.

- **Offsets —** there are some offset schemes operating in Kenya and these will offer potential research opportunities in areas including uptake by donors but also local impacts on such things as poverty reduction, water and food security, wildlife conservation, and local livelihoods, health and well-being.

In the available literature relating to Kenya, one theme, **Mining and hydropower,** had no articles assigned to it. This could be interpreted either as evidence that the topic is not a legitimate one for research or that there is considerable potential to develop research in this area. There may be research opportunities that consider mining and hydropower in relation to such things as the relationships between environmental exploitation and protection, as well as the social and economic consequences of 'industrialisation' and its effect on human distribution, livelihoods and wellbeing.

8.7 Conclusion and next steps

In Kenya there has been a relatively small amount of research effort directed at many of the Valuing Nature Network/Global Challenges thematic areas. Some in-country research capacity also appears to have been developed. In this context however, the evidence of this study suggest that there has been a fairly low level of collaborative partnerships involving UK institutions, and a similar proportion that are uniquely of an Anglo-Kenyan nature. Yet given the considerable challenges facing the people of Kenya in terms of maintaining the quality of environmental resources whilst improving quality of life of the human communities that rely on them, it seems that there is considerable potential, at least in some specific research areas, for many more such partnerships to be developed and on a larger scale.

There is potential to conduct more research in all topic areas examined. It will certainly be possible to invest in Valuing Nature research in Kenya to help address the Global Challenges, guide its sustainable development, and create a green economy. Important next steps would be to consider visits and meetings to the main research institutes to identify research and regional priorities.

9. Joining the dots in South Africa — Key Findings

9.1 Country context

South Africa has the second-largest economy in Africa and a population of about 56 million, about a quarter of which lives on less than 1.25 US$ a day. The South African black majority still has a substantial number of rural inhabitants, leading largely impoverished lives.

South Africa has a great variety of climatic zones, ranging from the extreme desert in the northwest to the lush subtropical climate in the east. South Africa is a party to the Rio Convention on Biological Diversity (CBD). It is biologically very diverse and holds about 9% of all known plant species. Climate change is expected to bring considerable warming and drying to much of South Africa's semi-arid regions and many rare species face extinction. South Africa has lost a large area of natural habitat to overpopulation, sprawling development, and deforestation. Only 1% of South Africa is forest, and plantations of imported non-native trees predominate. It is one of the World's worst affected countries in relation to invasion by alien species.

South Africa is a popular tourist destination, and considerable revenue comes from tourism. Eco-tourism has considerable potential to alleviate poverty through income generation and job creation. Many South Africans still rely on natural resources for food and traditional medicine, and rural populations depend on agriculture and grazing. Overgrazing often leads to the degradation of the soil. The agricultural industry contributes around 10% of formal employment and only around 3% of GDP. Due to aridity, very little land can be used for crop production. Grains and cereals are the country's most important crops and maize production is self-sufficient due to Government programmes. South Africa produces numerous fruit varieties and over 1.5 million tons of grapes are used in the country's wine industry (with over 100,000 ha of vineyards). Sugarcane is also an important export crop, and the country is the world's tenth largest sugar producer.

South Africa has a strong, innovative water industry but much less progress has been achieved on sanitation. The water sector has a policy of free basic water and Water Boards operate pipelines and sell water from reservoirs to municipalities. Mining in South Africa has contributed greatly to its advanced economy. The country is the fifth largest producer of gold, is renowned for its mineral deposits, and is the world's third largest coal exporter. South Africa is also a huge producer of iron ore.

9.2 Overall search results

The WoS literature search generated 2,445 articles and 895 were considered relevant. There was an increase in publications over the last decade. Eighteen articles were published during 1992–1996, increasing to 41 publications in 1997–2001, 110 in 2002–2006, 269 in 2007–2011, and 448 in the last five (full) years (2012–2016).

Authorship

Overall for papers published in 2014–16 (n = 269), the majority (60%) were authored solely by individuals from South African organisations. Almost one-third of papers (n = 81, 30%) were authored by a mixture of South Africa and overseas institutions from 25 other countries. Of these, the most commonly reported collaborative countries (from n = 111 records) were the USA (26 records, 23%), the UK (15%), Australia, the Netherlands, and Sweden and Germany. Other co-authoring institutions were from ten European countries, three from Asia, two from South America, plus Canada and Australia. Four other African countries also jointly-published with South Africa.

The remaining articles (n = 25, 9%) were written by individuals affiliated exclusively to overseas organisations. Thirteen overseas countries were reported (n = 32 records), the USA was the most frequent (n = 6, 19%), followed by the UK and Germany (16% each), Australia, and Sweden. Five further European countries, New Zealand, Mozambique and Nigeria also had exclusive overseas authorship.

In respect to the UK, from the 143 records of any overseas authorship, 22 (17%) were identified with UK institutions. Of the 111 records from publications jointly-authored between South Africa and another country, the UK ranked second amongst collaborating countries (17 records, 15%). Of the 32 records from publications solely authored outside South Africa, the UK again ranked second amongst overseas countries (5 records, 16%).

9.3 Thematic analysis

All 269 selected publications (for the full years 2014–2016) were grouped inductively into categories to reflect the Valuing Nature Network/ Global Challenges thematic areas. From these, brief overviews were given of relevant recent studies (from 2015 and 2016, n = 194) in those thematic areas that had at least 10% of the overall records within this period.

9.3.1 *Ecosystem and ecosystem service characterisation*

A total of 119 articles were assigned to this theme, many seemed rather general and few described or quantified specific ecosystem services explicitly. Words such as 'species', 'use', 'areas', 'natural', 'habitat', 'biodiversity', 'management', and 'conservation' were the most frequent. The latter appeared in the title and/or abstract of 62 (52%) of papers, 'biodiversity' appeared in 51%, and both words appeared together in more than half of the articles.

Several broad subject areas were found within these 'biodiversity conservation' papers. Some studies looked at the ecology and/or habitat requirements of specific species or groups of animals/plants. Others examined different habitat conditions in the 'landscape' (a word featured in 30% of papers), highlighting that landscape-scale management of conservation areas is critical to ensure the adequate protection of natural resources. Concepts such as biodiversity and spatial scale were considered in research related to wildlife tourism – an important cultural ecosystem service, benefiting regional economies and biodiversity conservation.

Several 'ecosystems' were covered by these papers, including coastal, estuarine, forest, agricultural and fynbos (a very rich, specific plant community) but the most commonly reported (mentioned in 18 papers, 15%) was 'grassland'. Similarly, several biotic aspects were covered by papers in this category, specifically water, trees, (often in relation to alien, invasive and 'exotic' species), soil, and fish communities.

9.3.2 *Governance, management & decision making*

A total of 25 papers were assigned to this category. The most commonly occurring word in these papers was 'management' (18 papers, 76%). Of these, most were either concerned with governance in relation to issues such as resources, stewardship, conservation targets and sustainability and protected areas, or with adaptive (or co-) management of resources or protected areas. The topic of 'conservation' occurred in 48% of papers, often in relation to conservation areas and private land, stewardship and participation. Governance-themed 'management' papers also dealt with water issues (17%), particularly those related to water services and associated infrastructure, water management areas, and water conservation.

9.3.3 *Ecological restoration*

Most of the 25 ecological restoration papers appeared concerned with soil or some aspects of vegetation, and so words like 'soil', 'vegetation', 'grasslands', 'clearing', 'cleared', 'cover', and 'plant' were commonly used. The word 'recovery' was used more frequently (8 papers, 44%) than was 'restoration' (28%). Apart from single studies into recovery after previous agricultural use, deforestation, or natural fire, the most commonly studied recovery scenario (5 papers) was following the removal of invasive alien plant species, particularly trees. 'Soil' was also mentioned in the context of recovery/restoration, often in relation to the removal of alien plants but also in relation to the restoration of grassland and soil quality to mitigate soil degradation.

9.3.4 *Agriculture*

Relatively few papers (n = 11) were assigned to agriculture and a wide variety of topics were covered. A variety of crops and livestock were mentioned, including maize, vineyards, sweet lupin (a fodder plant), fruit orchards, sugarcane, potatoes, sheep and beef cattle. There was also research on diversification, GM crops, and pests. Only three papers (27%) addressed 'production' (of communal livestock). Three papers (27%) focussed on farmers, and dealt with their perceptions, behaviour, tolerance of pests, crop diversification, and modes of farm management. Only two papers dealt with the issue of soil quality and enhancing fertility.

9.3.5 *Natural hazards*

Relatively few papers (n = 11) covered natural hazards and most (n = 7, 64%) addressed issues related to climate change. Most research was based on predictions and projections and several papers focused on the likely effects of climate change on floristic composition. Where papers gave perspectives on climate change, they were around possible increases in temperature and associated changes in rainfall patterns. There was scant mention of 'mitigation' or 'adaptation' in any papers dealing with natural hazards. The word 'management' was used often (6 papers, 55%) but was only explored specifically in one paper on flood management and resilience, and two on fire management. Fire was studied in three papers – not specifically as a natural hazard, but as a widely used management strategy in grasslands and wetlands to maintain vegetation structure and improve its quality.

9.3.6 *Payments for Ecosystem Services (PES)*

The word 'payment(s)' was only used in one of the 11 papers (9%) in this category and this was the only one dealing specifically with PES. The most common subject area for papers (n = 7, 70%) was based around issues of 'conservation' and 'tourism' where papers dealt with things like ecotourism revenue or willingness-to-pay to derive value from wildlife. Papers also considered paying for the control of invasive species and the economic value of water resources lost due to them. The only other issues covered were the possible role of PES within South African economic growth generally, and the pricing, valuation and "marketization" of South African diamonds.

9.4 Research Capacity

WoS output (2015–2016) produced 36 papers from 19 South African institutions collaborating with UK organisations, and 21 papers from the 16 UK institutions listed as collaborating with South African ones. Overall, there were 20 papers with South Africa and UK authorship.

9.5 Overview of funding streams

From the available material comprising 239 articles (2015–16) that could be assigned unequivocally, 378 records – pertaining to 150 funding sources – were available for South Africa. A total of 17 countries were involved in funding South African research. The most commonly cited funding source country was South Africa itself which had 228 records (60%) relating to 64 funding bodies (43%). Of these the most frequently cited funders (n = 76) were the National Research Foundation (NRF) and the Department of Science and Technology (DST), or a combination thereof. Other frequently recorded South African funding sources included the Department of Environmental Affairs, South African National Parks (Sanparks), and the Water Research Commission of South Africa. A further 54 South African funding sources were recorded on 1–3 occasions.

The most commonly cited overseas funders were from the USA (39 records, 10%), Germany and the UK (5% each). In the USA, 22 funding sources were listed, many of which were Foundations, Universities, and U.S. Government departments/ agencies. In Germany, the German Research Foundation (DFG) was reported as a funding source seven times, and the remaining nine sources were each reported 1–3 times.

In the UK, NERC was reported as a funding source on three occasions, and DFID and ESRC twice each. Ecosystem Services for Poverty Alleviation (ESPA), part of the Living with Environmental Change partnership, funded by DFID, NERC, and ESRC was also reported twice. A further ten UK funding sources were reported once each – a mixture on universities, NGOs, and charities.

Eight other European countries were reported: Sweden (8 sources), The Netherlands and Norway (3 each), Belgium and Spain (2 each), Switzerland, Italy, and Denmark (1 each). Elsewhere at the national level, three sources of funding each were based in Australia, China, and Brazil, while Japan and Canada each had one funding source. At the continental level, in Europe there were five sources of funding, mostly through the European Union/ Commission, and at the global level there were five, including the UN, UNESCO, and the World Wide Fund for Nature (WWF).

9.6 Summary of opportunities arising for Global Challenges research

- **Ecosystem and ES characterisation —** most (56%) of the articles in the WoS search were assigned to this theme. In terms of research opportunities, one obvious area is the forest biome which, although less than 1% of the country's surface cover, is one of the most vulnerable and threatened vegetation types, despite many people continuing to rely on native forest for their livelihoods. Research is also needed to develop quantitative, comparable metrics of 'success' to improve conservation interventions (which will inevitably be contested and require negotiation). Surface water supports 70% of the country's GDP, 70% of its population, and 74% of all water demand. This demand comes from agriculture, domestic, urban and industrial needs, from mining and power generation, and from forestry and ecological needs, so there are likely to be many research opportunities in South Africa in relation to surface water quality and quantity.

- **Governance, management & decision making —** only 12% of the articles in the WoS search were assigned to this theme, so there is likely to be potential to develop research in this area. There are enormous crises of confidence and service delivery problems in South African local government and, similarly, in many other areas of corporate governance. Research is thus needed to address whether the drafting of codes of good governance really make companies and institutions healthier and more sustainable, and whether or not they reduce the likelihood of departmental and corporate collapses. Considering governance to incorporate wider management and decision-making, there are also research opportunities in the fields of 'stewardship' aimed at improving sustainability and resilience of socio-ecological systems, and in fostering collaboration for land management.

- **Ecological restoration —** less than 10% of the articles in the WoS search were assigned to this theme, so there is likely to be potential to develop research in this area. For example the long-term effectiveness of ecological restoration projects is seldom reported in the scientific literature and the outcomes of restoration projects are not often used to inform practice. Coupled with the observation that case studies are rare, this suggests considerable research opportunities in this area.

- **PES/ES valuation and revenue —** less than 10% of the articles in the WoS search were assigned to this theme, so there is likely to be potential to develop research in this area. There is increasing debate in South Africa on the value of endangered species in terms of both current use and non-use values through comparisons of willingness-to-pay and consumptive use values. There are numerous species and systems where a better understanding of the value of wildlife would help to incentivise the benefits of wildlife conservation. On a broader scale, many research opportunities are raised by the assertion that Payments for Ecosystem Services (PES) are not the most appropriate instrument for conservation but might instead contribute to 'degrowth' as a transition instrument toward fostering better practices.

- **Agriculture (incl. agroforestry + fisheries + impacts) —** less than 10% of the articles in the WoS search were assigned to this theme, so there is likely to be potential to develop research in this area. For example, crop diversification could be a major co-benefit of on-going land reform in South Africa but further research is required to develop explicit strategies. In terms of increasing agricultural production through genetically engineered crops, there are several major research areas associated with longer-term agro-ecosystem interactions which require further exploration so that practical and economically viable advice can be given to farmers and regulators.

- **Natural hazards —** less than 10% of the articles in the WoS search were assigned to this theme, so there is likely to be potential to develop research in this area. Conservation planning has only recently begun to adequately account for dynamic threats such as climate change. Undoubtedly, more research is required to provide further insights to facilitate conservation planning for climate change.

In the available literature relating to South Africa, several themes were assigned relatively few articles. The following themes each had five percent or less of the total relevant WoS articles. Given the very limited research on these topics, there is presumably considerable potential to undertake more and some avenues are mentioned here.

- **Traditional knowledge —** very few specific references to traditional knowledge were found during the WoS research but several related topics were mentioned that could offer considerable research opportunities, including ethnobotany, agricultural practices, traditional medicine, and adaptation strategies for such things as water management and climate change.

- **Urban sustainability —** given the very limited research on this topic, there is presumably considerable potential to undertake more. There are numerous research opportunities associated with the current realities of South African cities and associated peri-urban areas. These include the uncontrollable rise and growth of massive informal settlements, unplanned and uncontrolled road creation and use, indiscriminate and badly-located small enterprises and services (including schools, shopping outlets, clinics), and uneconomical and *ad hoc* infrastructure distribution (including sewage, water, electricity, and telephone).

- **Mining —** there may be research opportunities in the area of mining in South Africa where mining has been the main driving force behind the history and development of Africa's most advanced and richest economy. As well as environmental impacts there are also numerous safety and political/economic issues associated with mining that would benefit from further research.

- **Offsets —** The fact that the WoS search generated no references to 'offsetting' is noteworthy insofar as it points to there being little interest in this topic to date. However, South Africa has a decade of experience designing and implementing biodiversity offsets, but without explicit national policy. There are thus research challenges to be addressed, including insufficient capacity to design and implement offsets; inconsistent decision-making; problems establishing sustainable financing mechanisms; and inadequate enforcement and monitoring.

9.7 Conclusion and next steps

In South Africa there has been a considerable amount of research effort directed at many of the Valuing Nature Network/Global Challenges thematic areas. A considerable in-country research capacity has also been developed. In this context however, the evidence of this study suggests that there has been a fairly low level of collaborative partnerships involving UK institutions, and an even smaller proportion that are uniquely of an Anglo-South African nature. Yet given the considerable challenges facing the people of South Africa in terms of maintaining the quality of environmental resources whilst improving quality of life of the human communities that rely on them, it seems that there is considerable potential, at least in some specific research areas, for many more such partnerships to be developed and on a larger scale.

There is potential to conduct more research in all topic areas examined. It would certainly be possible to invest in Valuing Nature research in South Africa to help address the Global Challenges, guide its sustainable development, and create a green economy. Important next steps would be to consider visits and meetings to the main research institutes to identify research and regional priorities.

10. Exploring the business dimension — Key Findings

A rapid review of business-relevant Valuing Nature scholarship in ODA countries, with a focus on China, Colombia, India and Sub-Saharan Africa, found that a wide range of relevant research has been published over the past five years, addressing a wide range of business sectors, and a wide range of 'types' of business opportunity.

The business sectors most frequently addressed are the agriculture and forestry sectors, with conservation business/wildlife trade and the fisheries sector also well represented. The tourism sector, and the energy, infrastructure, mining sectors and urban construction sector are less frequently addressed.

Among the sample of 115 papers, the 'types' of business opportunity most frequently addressed are product markets, followed by PES/REDD markets, with less attention to cultural services markets, offsetting markets, ecosystems knowledge economy markets, financial/legal services markets and corporate ecosystem initiatives and environmental technologies.

As regards to research of business relevance, the papers identified, and the analysis carried out, provide a useful basis to stimulate further research of relevance to certain business sectors and in relation to certain types of business opportunity in the sampled countries/regions.

UK organisations are fairly well represented in such business-relevant research in these countries/regions, though there appears to be room for capacity building to be able to address more sectors and more types of business opportunity in each country/region. The 115 papers identified, along with the affiliations of their authors, provide a useful initial directory of research competence and potential partners in the ODA countries/regions themselves, and in other countries such as the US, Australia, Germany, France and The Netherlands.

11. Conclusions and next steps

In sum, the search of WOS and review of articles showed that:

- In **China** the most common research focus was on: ecosystems, their ecological characterisation and associated services – often on large geographic scales (e.g. river basins, national); water, including lakes and wetlands; species, both individuals and communities; soil and land; development, particularly urbanisation and the role of the city; management in numerous forms and contexts; much research used the word 'natural' – often in terms of a state that has been altered by human activity or one that might be achieved through restoration. The large body of research in China addressed these topics through a myriad of studies, reflecting the massive geographic scale of the country, its ecological complexity, and the diverse anthropogenic influences on natural systems facing China as a result of population growth and movement from rural areas as a result of rapid urbanisation.
- In **Colombia** the most common research focus was on: agriculture, particularly coffee and extensive cattle ranching; deforestation and resulting ecosystem conversion; water provision and regulation; biodiversity and carbon conservation; wetlands, in terms of fishing, hunting and tourism; governance, including resources, power, and tackling corruption; restoration, involving transdisciplinary and public-private collaborations. The relatively small body of research in Colombia reflects the economic and social context which has been characterised by decades of armed conflict, uneven development, and lack of government presence and institutions. Despite the peace deal, social inequality and power imbalances persist, making sustainability challenging. There is now potential to increase investment and open new opportunities for developers, thus focusing on promoting sustainable livelihoods and resilient development.

- In **India** the most common research focus was on: the (sustainable) use management of natural resources; forests and deforestation; water, particularly in relation to agricultural needs, drought and monsoon flooding; a large spatial scale covering whole watersheds or ecosystems, agriculture and crops and soils in particular; traditional knowledge in relation to sustainable livelihoods and economic development; climate change and increased flood risk; remote sensing to assess and monitor ecosystems. The large body of research in India reflects the country's overarching concern to sustain its enormous and rapidly growing population, the need to manage its natural resources in an efficient and effective manner, and to do it sustainably in the long-term. This is set against a background of a high dependency on rain-fed (monsoon-dependent) agriculture, large proportions of the population living in marginal landscapes, and many parts of the country susceptible to climate change.

- In **Burkina Faso** the most common research focus was on: species (very often of trees and other plants in terms of human food and medicine and animal fodder) and their role in stabilizing environments; soil in relation to nutrients, water and crop production; land in terms of resources and management; and vegetation diversity, in terms of reducing erosion, enhancing water and food security, and contributing to income generation. Many families in Burkina Faso struggle to avoid malnutrition, almost half live in poverty, and the country is prone to drought and floods and radical climatic variation. Not surprisingly therefore, compared to the other countries studied here, there was a relatively narrow focus to much of the (relatively limited) research – to support the country's human population, very often at the local scale.

- In **Kenya** the most common research focus was on: species, very often communities or guilds at the ecosystem level; trees and forest systems, often in relation to services – human food, animal fodder, medicines and firewood; biodiversity conservation and management, of charismatic wildlife or habitats for local resource harvesting; local land and water use. The relatively focused research reflected the dichotomy apparent in Kenya. On one hand, around half the population lives below the poverty line and is heavily dependent on food aid and the country's agricultural and industrial sectors are poorly developed. On the other, the country has expansive wildlife parks and nature reserves which attract considerable valuable foreign tourism, the country's principal source of foreign exchange.

- In **South Africa** the most common research focus was on: species, very often specific communities of animals or plants; conservation and management, often in terms of biodiversity and/or spatial scale; much research used the word 'natural' – often in terms of habitats (particularly vegetation and water) that had been altered by human activity; land and resource use in relation to agriculture, natural hazards and ecological restoration. The large body of research in South Africa addressed these topics, often reflecting the country's very diverse climate and (super) abundant biodiversity. It is a relatively economically strong country suffering from resultant environmental degradation and increased agricultural/horticultural production. There is also a large, mainly rural, proportion of the population that still rely on natural resources for food, water, shelter and traditional medicine and have little, or no, access to effective sanitation.

In China, India, and South Africa there has apparently been considerable research effort directed at many of the thematic areas, at least those that lead to publications recorded on the WoS database. Research effort in Colombia was not insignificant but it was relatively small in Kenya and even smaller in Burkina Faso.

A very considerable in-country research capacity has been developed in China and India. There was considerable capacity in South Africa, some in Kenya and Colombia, and very little in Burkina Faso. In this context, evidence presented suggests that there has been a fairly low level of collaborative partnerships involving UK institutions and any of the six countries investigated, with probably a slightly higher proportion of collaborations between the UK and India but very low levels with Burkina Faso.

Analysis further suggests even smaller proportions of collaborations that are solely with UK institutions, levels being apparently highest with India and Colombia, followed by South Africa, they were fairly low with China, lower with Kenya and very low with Burkina Faso.

Next steps...

Given the considerable challenges facing the people of all six countries covered in this report, in terms of maintaining the quality of environmental resources whilst improving quality of life of the human communities that rely on them, it seems that there is considerable potential, at least in some specific research areas, for many more such partnerships to be developed and on a larger scale.

There is potential to conduct more research in all topic areas examined, including further business-relevant research. It would certainly be possible to invest in Valuing Nature research in all six countries explored here to help address the Global Challenges, guide sustainable development, and create green economies. Important next steps would be to consider visits and meetings to the main research institutes to identify research and regional priorities.

Overall conclusions, implications and inferences

There are strong research themes from the Valuing Nature agenda that illustrate necessary pathways to be developed for the delivery of the Global Goals. These themes also link to the Sustainable Intensification research agenda and to the climate change adaptation agenda, and the most should be made of those links which connect with other Research Councils. The specific context, and therefore the most likely productive emphasis for next steps, differs between the six countries examined, depending, in part, upon the current status of the environment and in national priorities. Nevertheless, both globally and nationally, there is an urgent need to start thinking about finance and accounting – as all societies and their relationship(s) with the natural environment are linked to their past, present, and future financial economies.

Articles could be assigned to the 'governance, management and decision-making' category but seldom in terms of implicit natural capital assessment. This implies that, in terms of future development, the practical and research emphasis here should perhaps move towards including natural capital assessment and accounting in order to better inform decision-making. In this context, natural capital accounting information will be needed at the national level but also at the site/organisation/project /programme level, and also perhaps at the 'instrument level' when offsets are being monitored or validated. The inference that emerges here is thus the need to think about 'natural capital finance' and how best to co-design systems that provide both financial and non-financial returns and also solely non-financial gains but which involve financial costs. In other words, encouraging private investment in natural capital for private and public gain through relatively new instruments like green bonds (public and private) and blended funds.

The evidence in this review suggests there has been a relatively low level of collaborative partnership between UK institutions and any of the six countries investigated around these research themes. Such collaborative partnerships would be extremely timely and could be used to emphasise and develop the links between the SDGs, practical research, and climate change adaptation priorities in particular. This would also have direct relevance to UK priorities as the UK Climate Change Risk Assessment 2017: Evidence Report (Chapter 7) identified risks to the UK from climate change internationally for such things as food security (food imports), food safety (pests and pathogens spreading to the UK), and human migration and political turnover overseas.

The potential for developing timely research collaborations is therefore considerable in all thematic areas examined. Important next steps would be:

- To consider visits and meetings to main research institutes to identify research and regional priorities, building on the differences in Country context identified here.
- To scope out interdisciplinary research programmes of suitable size that cut across Global Goals, to exploit the potential synergies between pathways to achieve the different goals.
- Any new research should aim to use a multidisciplinary approach in defining problems, identifying the (fundamental/ underlying) causes, and designing solutions.
- Co-developing and implementing innovative finance mechanisms and engaging with stakeholders should be a key part of research.
- Any research focussed on an action on the ground should be accompanied by financing for that action and by research/policy/ practical testing.

Annex I. The Sustainable Development Goals (SDGs)

The 17 Sustainable Development Goals (SDGs) are part of the United Nations "Transforming our World: the 2030 Agenda for Sustainable Development". They are also known as the Global Goals for Sustainable Development.

The unifying thread throughout the 17 SDGs and their 169 targets is the commitment to ending poverty: "Eradicating poverty in all its forms and dimensions, including extreme poverty, is the greatest global challenge and an indispensable requirement for sustainable development." notes the agenda's preamble.

The SDG framework does not distinguish between so-called "developed" and "developing" countries – the goals apply to all nations. The SDGs cover a broad range of social and economic development issues, as listed below.

Goal 1: No Poverty
Goal 2: Zero Hunger
Goal 3: Good Health and Well-Being for people
Goal 4: Quality Education
Goal 5: Gender Equality
Goal 6: Clean Water and Sanitation
Goal 7: Affordable and Clean Energy
Goal 8: Decent Work and Economic Growth
Goal 9: Industry, Innovation and Infrastructure
Goal 10: Reduced Inequalities
Goal 11: Sustainable Cities and Communities
Goal 12: Responsible Consumption and Production
Goal 13: Climate Action
Goal 14: Life Below Water
Goal 15: Life on Land
Goal 16: Peace, Justice and Strong Institutions
Goal 17: Partnerships for the Goals

Further information on the SDGs can be found at:
https://www.weforum.org/agenda/2015/09/what-are-the-sustainable-development-goals

Annex II. Brief notes on methods

1. Search criteria

A standard procedure for the comprehensive literature review reported in this work was used throughout. Literature searches were conducted through the Web of Science (WoS) © 2017 CLARIVATE ANALYTICS. The investigation was conducted with a range of Boolean search terms in the English language. A standard search query for Valuing Nature concepts and Valuing Nature mechanisms was devised as follows:

TOPIC: (natural capital OR biodiversity OR natural resource* OR ecosystem service* OR socio-ecological system*)

AND TOPIC: (threshold* OR valu* OR econom* OR offset* OR payment* OR revenue OR govern* OR institution* OR decision making OR integrated OR planning OR restoration OR knowledge exchange OR resilien* OR sustainab* OR participa* OR wellbeing OR management OR tipping point* OR natural hazard* OR natural disaster*)

AND TOPIC: (Name of Country)

This search procedure was followed for six countries covering a geographically diverse range of current NERC ODA counties of interest: China, Colombia, India, and three sub-Saharan African countries – Burkina Faso, Kenya and South Africa. The WoS database was searched as far back as 1970 and included all studies up to February-March 2017.

2. Selection processes

Based on this initial search, the first selection process for articles involved evaluations of the title and abstract to provisionally identify studies relevant to both the Valuing Nature and Global Challenges agendas. The second selection step involved reading all abstracts carefully in full and then categorising articles into one of ten thematic areas:

- **Agriculture and agro-forestry and fisheries, including impact and sustainability**
- **Mining and hydropower**
- **Offsets**
- **Governance, management and decision making**
- **Ecosystems and ecosystem service characterisation, including conservation planning**
- **Payments for Ecosystem Services (PES) (including ecosystem service valuation and general revenue from natural resources)**
- **Ecological restoration**
- **Urban sustainability**
- **Natural hazards**
- **Traditional knowledge**

3. Data acquisition and information analyses

The selected articles were then examined in relation to the numbers published each year and the proportion authored by a researcher affiliated to an institution (i) in the named country, (ii) in an 'overseas' country, or (iii) written by a 'mixed' authorship from the named country and at least one overseas one. Particular attention was paid to articles that had some level of UK affiliation. There followed a Thematic analysis whereby articles were assigned to one of the ten categories mentioned above. Once categorised, key 'messages, issues, and topics' were extracted from the abstracts and summarised for each theme. In many cases this involved a form of secondary analysis where the abstracts were searched for specific key words and phrases in order to build up a general picture of their content.

For each country, WoS outputs were used to produce lists of (A) the institutions in that country collaborating with UK organisations, (B) UK organisations collaborating with partners from the named country, and (C) publications arising from these joint collaborations. The final element of analysis was to document the funding sources reported in the articles. Available information on funding sources was inevitably restricted to whatever had been submitted to WoS but, for most countries, information was found on the funding source and the number of times it was reported in the selected articles under anaylsis.

4. Visualisation and word clouds

For the Executive summary, the most common issues mentioned in articles analysed from the WoS search and subsequent selection process were visualised in word clouds. These were generated from all words in the titles and abstracts of the selected papers for each country. In order to get 'workable' sample sizes of papers, they were arbitrarily selected as follows. For Burkina Faso, all selected articles were incorporated (1997–2016, 77 papers) in order to maximise the number of papers. For the other countries (for which considerably more papers were published), only more recent papers were included: Kenya (2012–2016, 150 papers), South Africa (2015–2016, 239 papers), China (2015–2016, 344 papers), and India (2015–2016, 219 papers). Due to a technical issue, the original WoS searches for Colombia were not available and so the full reference list given for Colombia in the Full Technical Report (see 12.2) was used (2006–2012, 71 papers). Again, technical issues meant that abstracts for India and Colombia were unavailable through WoS for this analysis, and so an internet search was undertaken to collect them again — based on the original references used in this work: India (2015–2016, 219 papers), Colombia (2006–2016, 62 papers).

The word lists thus generated were then edited to (i) remove some unnecessary and uninformative words, and (ii) restrict the overall number of words included. For all word lists, four types of word were removed: (a) the names of a country or continent, and the directional words 'north', 'south', east' and 'west', (b) common words referring to the research and analysis process e.g. 'study', 'results', 'data', and 'analysis', (c) general qualitative words e.g. 'showed', 'different', 'potential', and 'important', (d) other common words such as 'can', 'will', 'also', 'within', and 'however'.

Finally, words with a low count were removed in order to restrict the final number of words included in the word cloud. For China, all words counted twenty or more times were included. For Burkina Faso, Kenya, India, and South Africa all words counted ten or more times were included, while all words counted five or more times were included for Colombia.

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The Valuing Nature Programme is a 5 year £7M research programme which aims to improve understanding of the value of nature both in economic and non-economic terms, and improve the use of these valuations in decision making. It funds interdisciplinary research and builds links between researchers and people who make decisions that affect nature in business, policy-making and in practice. See **www.valuing-nature.net**

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