

TEEB Implementation in India: “Promoting biodiversity and sustainability in the agriculture and food sector project”

A background review of agriculture and biodiversity in India

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Table of Contents

List of Acronyms.....	i
Executive Summary.....	ii
1 Introduction: Snapshot of Indian agricultural production.....	1
1.1 Snapshot of biodiversity in India.....	6
1.2 Challenges to biodiversity in India	7
1.3 Challenges to sustainable agriculture in India	9
1.4 TEEB Implementation in India: Promoting biodiversity and sustainability in the agriculture and food sector project.....	12
2 Overview of national policies in agriculture and biodiversity	16
2.1 The Twelfth Five-Year Plan	16
2.2 The evolution of agricultural policy	16
2.3 Policies on biodiversity conservation in India.....	22
2.3.1 National Biodiversity Action Plan (NBAP)	22
3 Case studies on agricultural impacts in India.....	24
4 Conclusion.....	38
References	40

List of Acronyms

APMCs	Agricultural Produce Market Committees
BIOFIN	Biodiversity Finance Initiative
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
ESMERALDA	Enhancing ecoSysteM sERvices mApping for poLicy and Decision mAKing
EU	European Union
FAO	Food and Agriculture Organization
FCI	Food Corporation of India
GDP	Gross Domestic Product
INDC	Intended Nationally Determined Contribution
IPBES	Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services
MSP	Minimum support prices
NAP	National Agricultural Policy
NBAP	National Biodiversity Action Plan
NPF	National Policy for Farmers
OECD	Organisation for Economic Co-operation and Development
PDS	Public Distribution System
TEEB	The Economics of Ecosystems and Biodiversity
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCLOS	United Nations Convention on the Laws of the Sea
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation
ZBNF	Zero Budget Natural Farming

Executive Summary

1. BACKGROUND

India has achieved sustainable economic growth over the past three decades. By the early 1990s, India instituted economic liberalization measures, which included industrial deregulation, privatization of state-owned enterprises, and reduced controls on foreign trade and investment. These steps, coupled with the country's endowment of natural resources and its young and growing labour force, helped to accelerate the country's growth, which averaged nearly 7% per year from 1997 to 2017.

Over the past few decades, the manufacturing and services sectors have increasingly spearheaded the country's economic growth, while the agriculture sector's contribution has declined from more than 50% of GDP in the 1950s to 16.8% in 2017. However, **agriculture remains the mainstay of the economy and a major source of employment to nearly half of the 1.28 billion Indians. In 2016, about 54.6% of the total population was engaged in agriculture and the sector accounted for 47% of the total employment.**

India ranks second worldwide in arable land (159 million hectares); it is **second largest producer and number one exporter of rice; second top world producer of wheat; second world producer of groundnuts, fruits, vegetables; and sugarcane; first in Jute and the world largest producer of milk.** About 85.5% smallholders operate on less than two hectares mostly producing rice, wheat, pulses, spices, vegetables and other cereals. There are two major agricultural seasons in India: Kharif (summer, from April to September) and Rabi (winter, from October to March). Rice is predominantly cultivated in Kharif while wheat is Rabi's main crop.

2. PROBLEM DEFINITION: Challenges to sustainable agriculture and biodiversity in India

Globally, food systems are now the source of 60% of terrestrial biodiversity loss, 33% of soil degradation and 61% of the depletion of commercial fish stocks. The situation in India is almost consistent with these global statistics.

Addressing the negative impacts on biodiversity is critical, given that **India is one of the 17 mega-diverse countries in the world. India is well endowed with biodiversity and has been identified as one of the eight important "Vavilorian" centres of origin and crop diversity.** The country has about 8% of the total worldwide biodiversity with an estimated 49,000 species of plants, 10% of which are endemic. It boasts of faunal diversity including **25000 fishes, 197 amphibians, 408 reptiles, 1,200 birds and 350 mammals.** The southern part of India including the southern Western Ghats encompass more than 6000 species of higher plants, 2000 of which are endemic. **Of the 34-world biological 'hot spots' (areas of greater biological endemism in the biosphere), four are in India, the Eastern Himalayas, Western Ghats, Andaman and Nicobar island chain, and North East of India and part of Indo-Burma.**

As well as scoring highly on biodiversity indicators, **India is also considered as a repository for traditional knowledge of biological resources.** With respect to agricultural biodiversity, **India is a center of origin and diversity of crops, with 811 cultivated plants and 902 of their wild relatives documented in 2015.** India also contains a broad spectrum of native breeds of farm animals. According to the IUCN, **758 species of plant and animal are listed as threatened.**

In terms of drivers and pressures, **India experiences threats to biodiversity from agricultural conversion, a major driver of deforestation in some regions.** Land use change, driven by agricultural expansion, is **creating fragmentation and loss of forests, grasslands, wetlands and other habitats.** **Agricultural intensification, agrochemicals, and eutrophication from agriculture runoff are causing pressures on biodiversity both on terrestrial and marine habitats.** The pressures of livestock grazing on forests and grasslands are severe. India has the world's largest livestock population, constituting 15% of the global total in 2.4% of the global geographical area. **High density of livestock population contributes to the degradation of soils.** Of the 10 biogeographic zones of India, 9 are experiencing threats to biodiversity from agricultural and livestock activities.

In addition to agricultural impacts, several other factors have been cited as leading causes of India's biodiversity loss including **escalating population, habitat degradation and fragmentation, landscape change, pollution, climate change, invasive alien species and overexploitation of natural resources.**

On the other hand, **the agriculture sector itself is facing numerous challenges. To attain food self-sufficiency, India adopted the 'Green Revolution' strategy in the mid-1960s.** This heightened the use of modern technology, high yielding crop varieties, chemical fertilizers, irrigation facilities, and improved farm implements and crop protection measures. By the 1980s, India was largely self-sufficient in food grain production. However, the drive to increase agri-food production has had a major toll on the environment, **leading to loss of soil fertility, soil erosion, soil toxicity, diminishing water resources, pollution of underground water, salinity of underground water, increased incidence of human and livestock diseases, and global warming.**

Today, **India is one of the countries with the highest rate of greenhouse gas emissions in agriculture coming second after China.**

While agriculture is a key driver of environmental degradation, it is above all other industries, the most reliant upon a well-functioning environment. Consequently, it is vulnerable to temperature extremes, water availability, atmospheric soil and water pollution, pest and disease outbreaks, biodiversity loss, tropospheric ozone, high winds, among others.

Presently, **Indian agriculture is facing the critical challenge of feeding an escalating human population (1.25 billion) under increasingly declining soil quality, land and water scarcity and changing climatic conditions.**

Water shortage is a serious threat to sustainable agriculture in India. Irrigation, the most common alternative to rainfed agriculture, has led to alarming rates of ground water exploitation and depletion. **India's water availability per capita was over 5,000 m³ per annum but is projected to decline to 1,500 m³ by 2025.** The agriculture sector, which is the largest user of water, accounting for about 80% of the water withdrawals, is likely to be the main victim. It is projected **that India's water availability for agricultural use could decline by 21% by 2020, which would result in yield reduction of irrigated crops, especially rice.**

Although currently no major studies exist to show the effects on agriculture, **climate change still poses potential threats to the sustainability of agriculture and food security in India, especially given that about 62% of India's cropped area is rainfed.** Nonetheless, some projections have been made. For instance, a study by Singh et al. (2017), indicated that by 2050, 15% – 40% of the rainfed rice cultivating areas would be at risk of decline in climate suitability or become completely unsuitable. However, they highlighted variations across the country with the eastern and northern India being at more risk than central and western parts of the country, which could benefit from increased precipitation. **According to the Government of India (2008), every 1 °C increase in temperature reduces the Rabi crop (wheat) production by 4 – 5 million tonnes.** Overall, the agricultural system is both a driver and a victim of environmental change.

3. CURRENT SITUATION: India's national level strategies and policies

India has embraced sustainable agriculture and biodiversity conservation, through a variety of national level strategies and policies, which have evolved over time. These include **Twelfth Five-Year Plan (2012-2017) which emphasized sustainable management of natural resources and agriculture.**

In addition, **the National Agricultural Policy (NAP) 2000** sets out clear objectives and measures for all the important sub-sectors of agriculture. **Until 2020, this policy aims to attain an agricultural growth rate of more than 4% per annum through the efficient use of natural resources** and a combination of other measures. The main elements of the policy include:

- **Efficient use of natural resources, while conserving soil, water and biodiversity**
- Growth with equity, i.e. growth which is widespread across regions and farmers
- Growth that is demand-driven and caters to the domestic markets and maximizes benefits from exports of agricultural products in the face of challenges arising from economic liberalization and globalization.
- **Growth that is sustainable technologically, environmentally and economically.**

Furthermore, **the National Policy for Farmers (NPF) 2007** was implemented with the main objectives of improving agricultural productivity to improve net income of farmers. **It emphasizes increased productivity, profitability, institutional support, and improvement of land, water and support services.**

On 6 February 2014, the Government approved **the National Agroforestry Policy**, making India one of the first countries to adopt agroforestry policy. It is envisaged that **the policy will enable farmers to reap the benefit of agroforestry to meet the country's population demand for food, fodder, firewood and timber; conserving biodiversity and protecting wildlife; and holding and repairing soils, against a backdrop of shrinking land and water resources for agriculture and the threat of climate change.**

India is undertaking many steps to halt and reverse the pressures on biodiversity arising from the agri-food sector. For instance, **the promotion of organic farming through a certification scheme has seen an increase from 42,000 hectares in 2004 to 1,050,000 hectares in 2010** of area under organic farming. **India has added three million hectares of forest in the last decade through targeted programs such as Green India Mission and reformed fertilizer pricing to encourage soil biodiversity.**

India is also party to a number of international conventions that promote forest and biodiversity conservation. These include: 'Convention on Biological Diversity (CBD), 1992. **India has come up with various national strategies, legislation and administrative instruments to address the obligations under the conventions.** For instance, under the CBD (1992), **the country has implemented its National Biodiversity Action Plan (NBAP) since 2008.**

The NBAP is broadly aligned to the global Strategic Plan for Biodiversity 2011 – 2020 adopted under the aegis of the Convention on Biological Diversity (CBD) in 2010. **The plan was updated in 2014 during which time 12 National Biodiversity Targets were developed** using 20 Aichi Biodiversity Targets as a framework. In line with the Strategic Plan for Biodiversity 2011-2020 and the Aichi Targets, India's NBAP is developed with the aim of addressing the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society and reducing the direct pressures on biodiversity and promoting its sustainable use.

In its effort to address the effects of climate change in the country, **on June 30, 2008, India officially released its National Action Plan on Climate Change.** The action plan outlines several steps required to advance development and climate change-related objectives. **By 2016 India had spent Rs.157.14 crore (about US\$ 17.2 million) on Integrated Farming System activities (promoted under Rainfed Area Development – a key component of National Mission for Sustainable Agriculture under National Action Plan on Climate Change)** which covered about 32,740 ha comprising 4,245 ha of livestock based farming system, 9,727 ha of dairy based farming system, 1,609 ha of fishery based farming system, 7,408 ha of horticulture based farming system, 5,105 ha of agro-forestry based farming system, 472 ha of silvi-pasture based farming system and 4,174 ha of cropping system with peripheral plantations (Government of India, 2017).

India has also expressed interest in combating global climate change. At the 2015 United Nations Climate Change Conference, **India submitted an Intended Nationally Determined Contribution (INDC) and made a commitment to reduce the emissions intensity of its GDP by 20 to 25 percent by 2020 from 2005 level.**

4. ACCOUNTING FOR ECOSYSTEM IMPACTS AND DEPENDENCIES

Despite well intended national policies and strategic plans, there is a long road ahead to close the gap between aspiration and application. **Mainstreaming biodiversity and ecosystem values into the agri-food value chain remains a major challenge.** Consequently, **the expansion of agricultural land in India remain the key drivers to ecosystem services and biodiversity loss.**

There is increased concern on the potential environmental effects from agriculture. However, there is paucity of studies assessing environmental impacts of agri-food systems across the value chain in India. **A few studies conducted mostly at farm gate point towards significant impacts on biodiversity, climate change and natural resources.** One case study is outlined here.

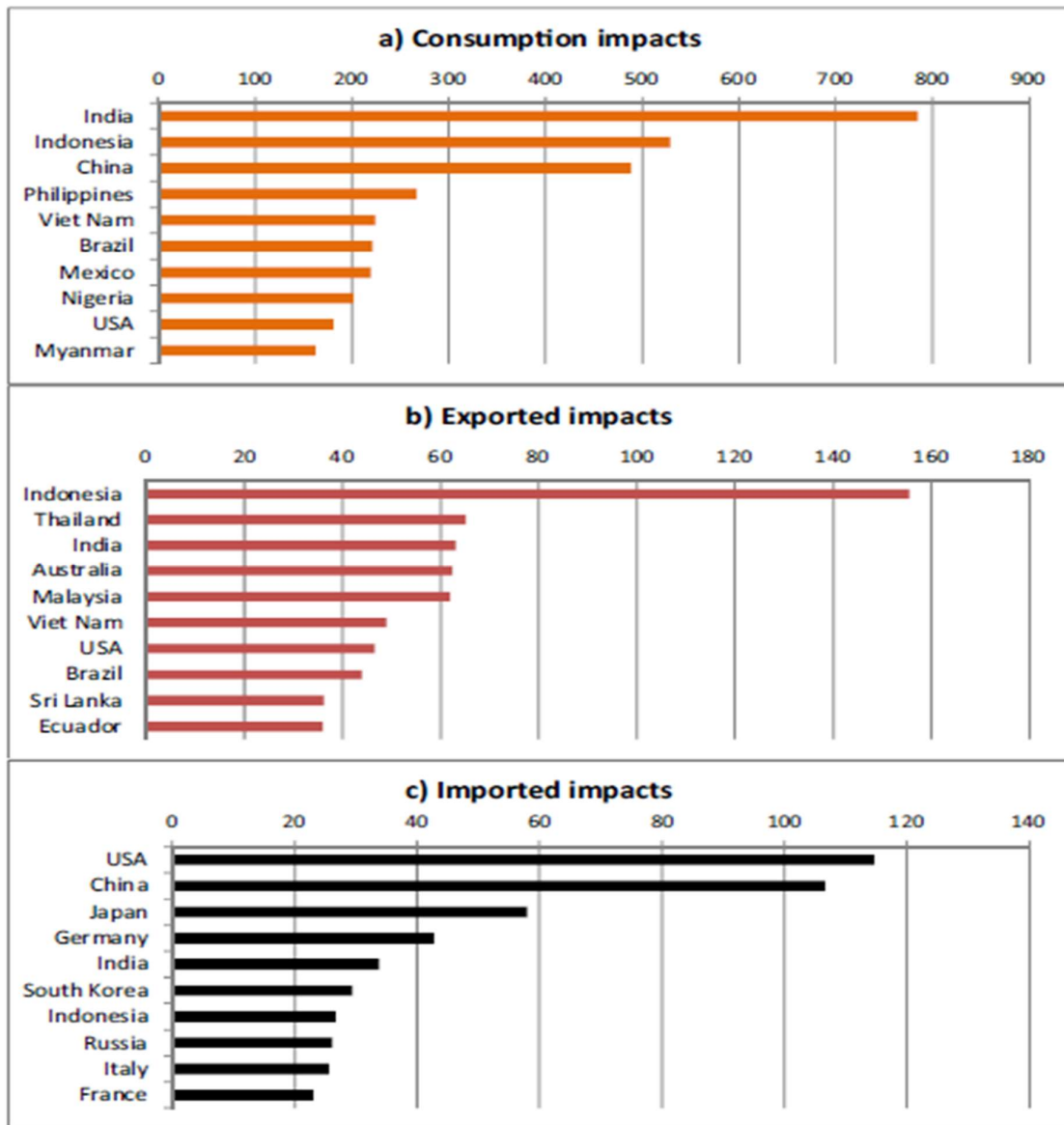
Agricultural land use to meet the demands of a growing population, changing diets, and lifestyles is a key driver of biodiversity loss in India

Biodiversity offers several benefits, including pollination and nutrient cycling, that are key to human health and the economy. Unfortunately, in the past 500 years, over 300 vertebrate species have been obliterated, and many more are under threat of extinction; and agriculture is a key driver of biodiversity loss (European Commission, 2016).

A study by Chaudhary and Kastner (2016) **employed the countryside species area relationship (SAR) model to estimate the mammals, birds, amphibians and reptiles species lost due to agricultural land use in 804 regions globally**. The study combined this measure of species lost with high spatial resolution global maps of crop yields to compute species lost per ton for 170 crops in 184 countries. Then, the study linked the impacts per ton with the bilateral trade data of crop products to calculate the land use biodiversity impacts embodied in international crop trade and consumption. Finally, the impacts per ton were multiplied by each country's volumes of current crop production (in tons) to identify which crop causes high land-use impacts. This process helped to identify the hotspots of biodiversity loss due to global agricultural land use.

The findings showed that **wheat, rice and maize land use contributed to 2,220 species lost (40% of global agricultural land use impacts)**. Such results did not come as a surprise because together these three crops occupy 40% of global cropland. Surprisingly, crops such as **sugarcane, palm oil, coconut, cassava, rubber and coffee contributed to 23% of global land use impacts**, which was quite high given that together they only occupy less than 10% of global cropland. The Figure below shows the top-ranking countries for biodiversity impacts due to consumption, exports and imports.

Top-ranking countries for biodiversity impacts due to consumption, exports and imports (Unit: number of species lost)



Source: Chaudhary and Kastner (2016, p. 198)

Regarding the **top-ranking countries for biodiversity impacts**, India is ranked **1st on consumption**, **3rd on exports** and **5th on imports**. This highlights the fact that India's footprint on biodiversity is one of the highest in the world.

5. PROJECT AIMS AND OBJECTIVES: TEEB Implementation in India, “Promoting biodiversity and sustainability in the agriculture and food sector project”

1. To complement the Indian Government’s initiatives for agriculture sustainability and biodiversity conservation, **the United Nations Environment (UN Environment), with the support of the European Union (EU), launched a four-year project for “Promoting biodiversity and sustainability in the agriculture and food sector in India.**
2. This project is in line with the Cancun Declaration adopted at the 2016 December CBD COP13 in which governments committed to mainstream biodiversity across all sectors. The project would contribute to integrating biodiversity values into national accounting and reporting systems and will encourage sectors that depend or have an impact on biodiversity to adopt integrated approaches for its conservation and sustainable use. In line with the Declaration, the project will also contribute to supporting sustainable production and consumption throughout value chains, the safe and sustainable application of technologies, and the phasing out of harmful incentives and strengthening of positive incentives.
3. **The overall objective of this project is to protect biodiversity and contribute to a more sustainable agriculture and food sector with well-functioning ecosystems.** This will be achieved by:
 - developing and applying instruments to capture the value of ecosystems services across the entire life cycle in the agri-food and the non-food agricultural raw material sectors;
 - identifying intervention options protecting biodiversity and promoting well-functioning ecosystems and by direct engagement with farmers, agri-businesses, government, and civil society (including consumers).

The example above – on the contribution of India’s footprint on biodiversity, locally **and globally**– has not been funded by the UN Environment/EU project, but **demonstrates the often-invisible externalities, impacts and dependencies between the agricultural sector and ecosystems & biodiversity**. This Executive Summary is limited to this one example, but the main report provides six such examples.

The studies presented are more limited in scope than the full TEEBAgriFood assessments that would be conducted under the current UN Environment/EU project. For instance, these analyses do not cover the **entire value chain** ‘from farm to fork’ (and including final waste management), does not consider all impacts such as **human health**, and do not present a **Theory of Change**, i.e. what can be done to intervene to switch away from the current business-as-usual scenario to an alternative – the sustainable management of agricultural landscapes.

Although ‘partial’ vis-à-vis the TEEBAgriFood Evaluation Framework, the studies described herein reveal the potential for **complex trade-off** between social- economic and environmental objectives in the Indian agri-food systems. Research into this area is still evolving, with an evaluation of possible trade-offs mainly focused at farm level or partial agri-food value chains. More comprehensive analysis of potential social- economic and environmental trade-offs is generally constrained by the complexity of the agri-food value chains and data availability. However, an understanding of these trade-off is

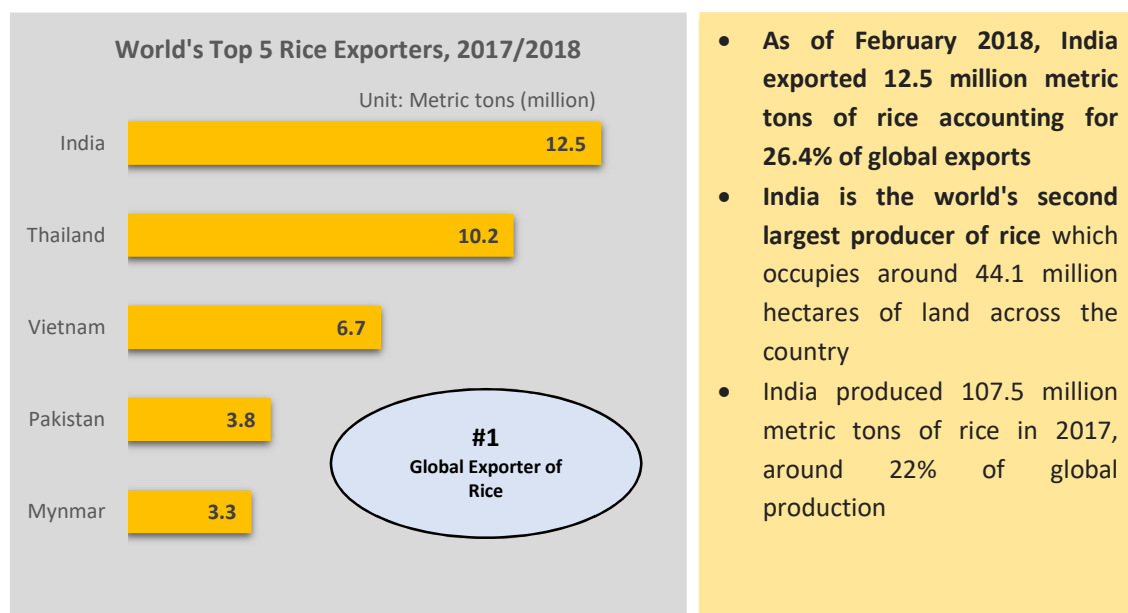
crucial for the effective implementation of the Indian green agricultural initiatives and biodiversity conservation, and this is the focus of the UN Environment/EU project.

1 Introduction: Snapshot of Indian agricultural production

Currently ranked the sixth largest economy in the world, in terms of nominal GDP, India has achieved sustainable economic growth over the past three decades. By the early 1990s, India instituted economic liberalization measures, which included industrial deregulation, privatization of state-owned enterprises, and reduced controls on foreign trade and investment. These steps, coupled with the country's endowment of natural resources and its young and growing labour force, helped to accelerate the country's growth, which averaged nearly 7% per year from 1997 to 2017 (CIA, 2017).

Over the past few decades, the manufacturing and services sectors have increasingly spearheaded the country's economic growth, while the agriculture sector's contribution has declined from more than 50% of GDP in the 1950s to 16.8% in 2017 (CIA, 2017; Deshpande, 2017). However, **agriculture remains the mainstay of the economy and a major source of employment to nearly half of the 1.28 billion Indians. In 2016, about 54.6% of the total population was engaged in agriculture and the sector accounted for 47% of the total employment.** India ranks second worldwide in arable land (159 million hectares); third in production of cereals and tea; second in groundnuts, fruits, vegetables; and sugarcane; and first in Jute (Central Statistics Office, 2017). About 85.5% smallholders operate on less than two hectares mostly producing rice, wheat, pulses, spices, vegetables and other cereals (Deshpande, 2017; Government of India, 2017). There are two major agricultural seasons in India: Kharif (summer, from April to September) and Rabi (winter, from October to March). Rice is predominantly cultivated in Kharif while wheat is Rabi's main crop (IBEF, 2018).

India is the world second largest producer and number one exporter of rice



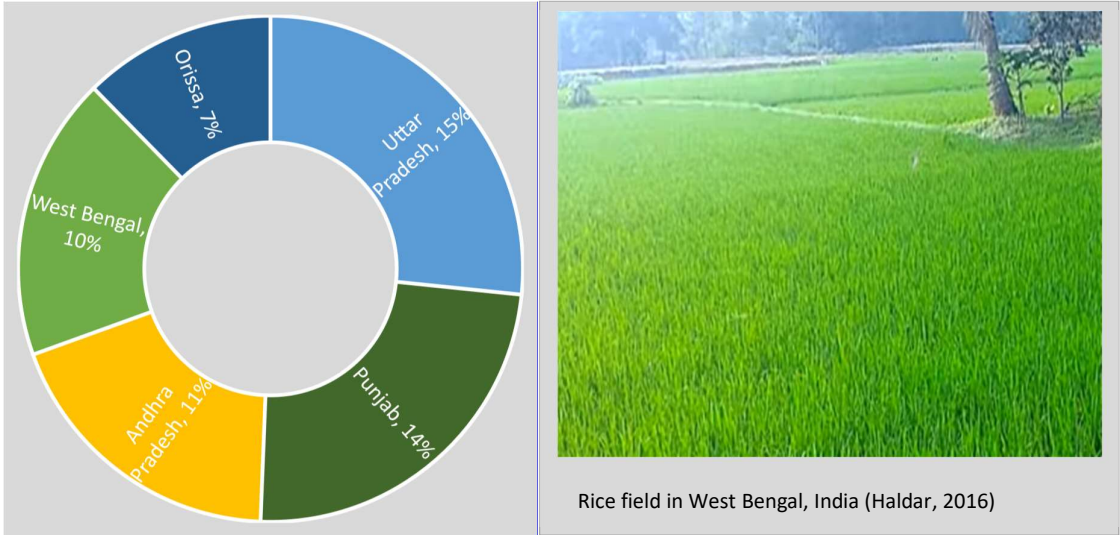
Source: (Statista, 2018; USDA, 2018)

Although India is the world's second largest producer of rice, its yield is lower than that of China, Brazil and the USA. As of 2016, rice yield in India stood at 3.7 metric tons per hectare compared to

China’s 6.9, Brazil’s 5.5 and USA’s 8.1 metric tons per hectare (FAOSTAT, 2018). Recently, India has focussed on exporting high quality and pest free rice. For instance, in 2016 India accredited 400 Pest Control Agencies to undertake fumigation with Aluminium Phosphide and 86 Rice Processing Mills to process exported rice for USA and 30 for China (Government of India, 2017).

Based on 2011 data, the following are the top five rice producing states in India: **West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab and Orissa** shown in Figure 1.

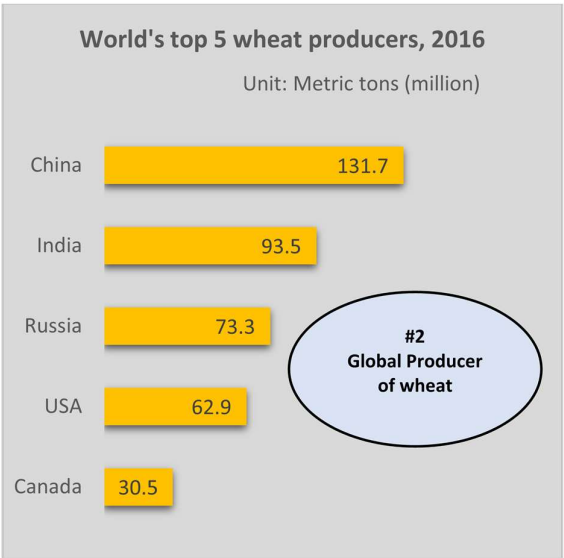
Figure 1: Distribution of regional rice production in India: The top five



Source: AIREA (2012)

India is the second top world producer of wheat

After rice, **wheat is the second most major cultivated food crop in India**. The country is a major global producer of wheat, second to china. In 2016, India's wheat farms covered a total of 30.23 million hectares, with 93.5 million metric tons produced (FAOSTAT, 2018). **About a third of wheat produced in the country is procured by the central government** mainly to cushion farmers from price volatilities. **Uttar Pradesh is the key wheat producing state in India accounting for almost one-third of the wheat** harvested followed by Punjab and Madhya Pradesh (Deshpande, 2017).



Source: FAOSTAT (2018)

India is the world largest producer of milk, in general, and second producer of cow milk

India is the world largest producer of milk, in general, bolstered by its buffalo milk producers. In terms of cow milk alone, India is second to the USA (Sheth, 2018).

The percentage share of value of output for milk in total value of livestock sector stood at 67% in 2015, representing zero percentage change since 2011 (Central Statistics Office, 2017).

According to National Dairy Development Board (2018) Uttar Pradesh is the key milk producing state in India accounting for almost 17% of the total milk produced followed by Rajasthan, Gujarat and Madhya Pradesh.



Source: FAOSTAT (2018)

India is the world largest producer of Jute

India is the world number one producer of Jute. The top five world producing countries of Jute are shown in Table 1.

Table 1. Top five world producers of Jute in 2016

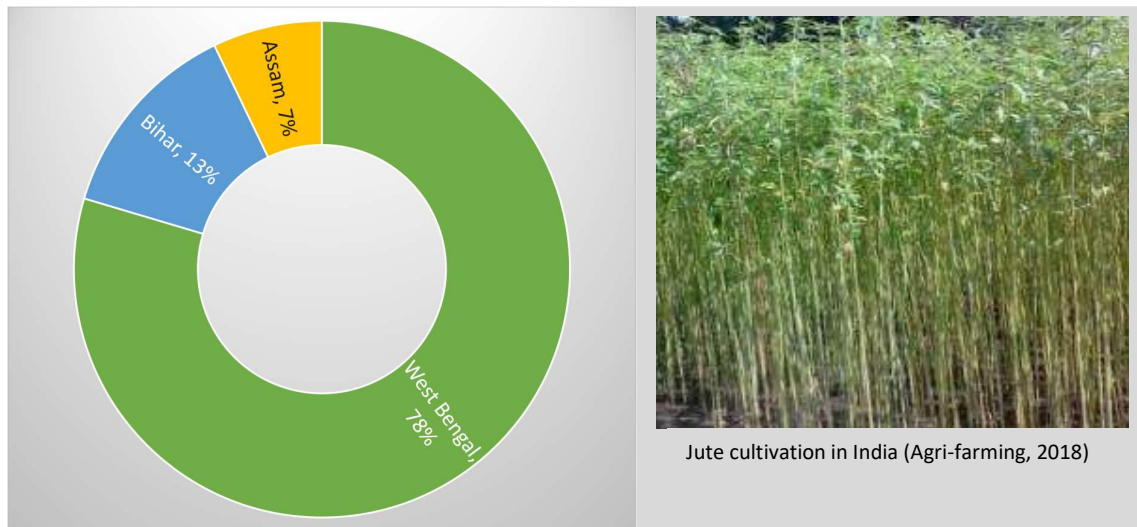
	Country	Jute production (metric tons)	Share of world total (%)
1	India	1,900,433	57.4
2	Bangladesh	1,344,000	40.6
3	China	39,703	1.2
4	Nepal	11,633	0.4
	Uzbekistan	3,709	0.1

Source: FAOSTAT (2018)

Of course, not much of the crop is produced worldwide and the output appears to be either stagnant or declining. For instance, in Bangladesh, the second world producer of Jute, output declined by 3.9% between 2015 and 2016. During the same period, Uzbekistan's output fell by about 63%. However, in India, Jute production has registered some increase, albeit insignificant, from 1.8 million metric tons in 2015 to 1.9 million metric tons in 2016 (FAOSTAT, 2018).

According to the Ministry of Textiles (2018), **Jute in India is predominantly cultivated in West Bengal, accounting for 78% of jute produced in 2015.** The other two states that produce reasonably significant amount of Jute are Bihar and Assam as shown in Figure 2.

Figure 2. Top three jute producing states in India in 2015



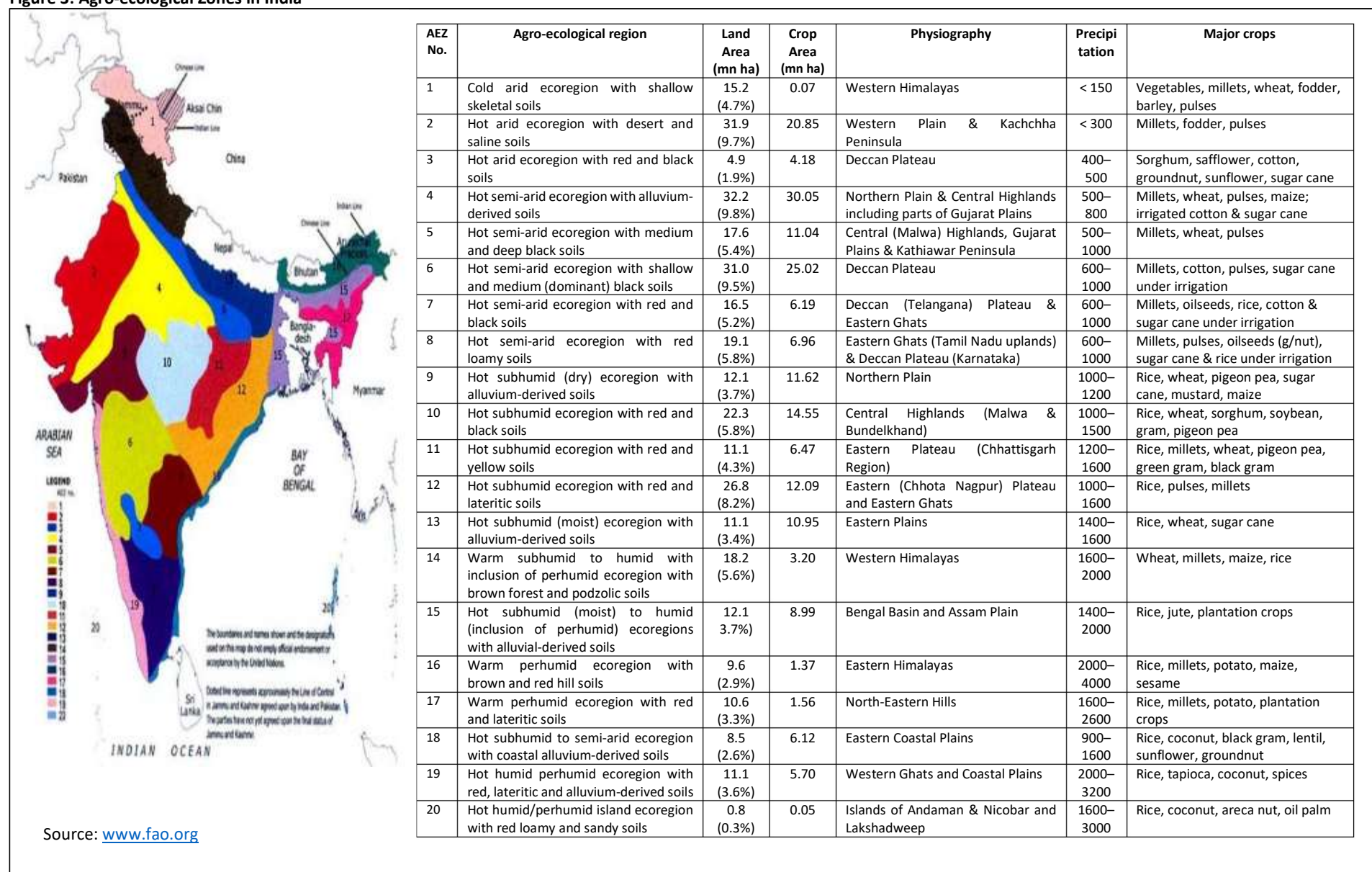
Source: Ministry of Textiles (2018)

India also produces several other crops such as groundnuts, fruits and vegetables, tea and sugarcane that put the country on the world map.



The robust Indian agriculture sector is divided into **20 Agro-ecological zones** each supporting **wide-ranging crops** depending on the climatic conditions, topography, soil conditions and precipitation as shown in Figure 3.

Figure 3: Agro-ecological Zones in India



India's robust agriculture sector is supported by its rich endowment of natural resources and biodiversity.

1.1 Snapshot of biodiversity in India

India is well endowed with biodiversity and has been identified as one of the eight important “Vavilorian” centres of origin and crop diversity, and one of the 17 mega-diverse countries in the world (MoEFCC & GIZ., 2014; Ramakrishnappa, 2003). The country has about 8% of the total worldwide biodiversity with an estimated 49,000 species of plants, 10% of which are endemic (Kumar & Asija, 2000). It boasts of faunal diversity including 25000 fishes, 197 amphibians, 408 reptiles, 1,200 birds and 350 mammals as shown in Table 2. The southern part of India including the southern Western Ghats encompass more than 6000 species of higher plants, 2000 of which are endemic (Anil et al., 2014). **Of the 34-world biological ‘hot spots’ (areas of greater biological endemism in the biosphere), four are in India, the Eastern Himalayas, Western Ghats, Andaman and Nicobar island chain, and North East of India and part of Indo-Burma** (Government of India, 2011).

Table 2: Comparison between the number of species in India and the world

Group	Number of species in India (SI)	Number of species in the world (SW)	SI/SW (%)
Mammals	350	4,629	7.6
Birds	1,224	9,702	12.6
Reptiles	408	6,550	6.2
Amphibians	197	4,522	4.4
Fishes	25,446	21,730	11.7
Flowering Plants	15,000	2,50,000	6.0

Source: UNDP (2008, p. 8)

As well as scoring highly on biodiversity indicators, India is also considered as a repository for traditional knowledge of biological resources¹. With respect to agricultural biodiversity, India is a center of origin and diversity of crops, with 811 cultivated plants and 902 of their wild relatives documented in 2015². India also contains a broad spectrum of native breeds of farm animals³. According to the IUCN, 758 species of plant and animal are listed as threatened⁴.

¹ Convention on Biological Diversity. Country Profiles – India. Available at, <https://www.cbd.int/countries/profile/default.shtml>

² India's Fifth National Report to the Convention on Biological Diversity. Ministry of Environment and Forests, 2014. Available at, <https://www.cbd.int/reports/nr5/>

³ ibid

⁴ International Union for Conservation of Nature (IUCN). *Red List of Threatened Species*. Available at, <http://www.iucnredlist.org/>

1.2 Challenges to biodiversity in India

Globally, food systems are now the source of 60% of terrestrial biodiversity loss, 33% of soil degradation and 61% of the depletion of commercial fish stocks (UNDP, 2016). The situation in India is almost consistent with these global statistics.

In terms of drivers and pressures, India experiences threats to biodiversity from agricultural conversion, a major driver of deforestation in some regions⁵. Land use change, driven by agricultural expansion, is creating fragmentation and loss of forests, grasslands, wetlands and other habitats⁶. Agricultural intensification, agrochemicals, and eutrophication from agriculture runoff are causing pressures on biodiversity both on terrestrial and marine habitats⁷. The pressures of livestock grazing on forests and grasslands are severe. India has the world's largest livestock population, constituting 15% of the global total in 2.4% of the global geographical area⁸. High density of livestock population contributes to the degradation of soils⁹. Of the 10 biogeographic zones of India, 9 are experiencing threats to biodiversity from agricultural and livestock activities¹⁰ as shown in Figure 4.

In addition to agricultural impacts, several other factors have been cited as leading causes of India's biodiversity loss including **escalating population, habitat degradation and fragmentation, landscape change, pollution, climate change, invasive alien species and overexploitation of natural resources** (Anil et al., 2014; MoEFCC & GIZ, 2014). Figure 4 shows ten biogeographical zones in India and a summary of how numerous factors affect biodiversity in these zones.

⁵ India's Fifth National Report to the Convention on Biological Diversity. Ministry of Environment and Forests, 2014. Available at, <https://www.cbd.int/reports/nr5/>.

⁶ India's Fifth National Report to the Convention on Biological Diversity. Ministry of Environment and Forests, 2014. Available at, <https://www.cbd.int/reports/nr5/>.

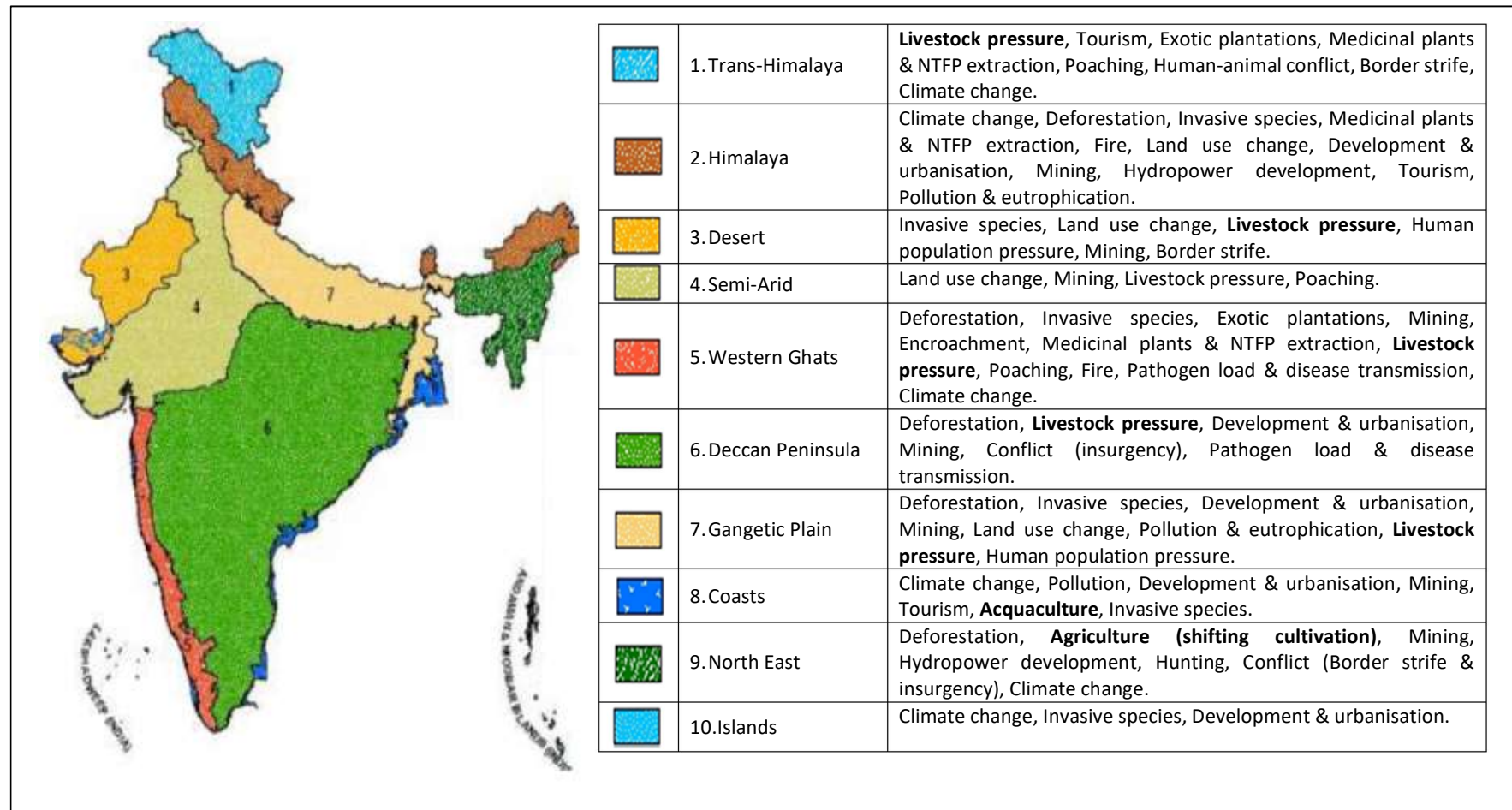
⁷ India's Fifth National Report to the Convention on Biological Diversity. Ministry of Environment and Forests, 2014. Available at, <https://www.cbd.int/reports/nr5/>.

⁸ India's Fifth National Report to the Convention on Biological Diversity. Ministry of Environment and Forests, 2014. Available at, <https://www.cbd.int/reports/nr5/>.

⁹ *ibid*

¹⁰ *ibid*

Figure 4: India's biogeographical zones and how various factors affect biodiversity in these zones



Source: S. Arora (2016)

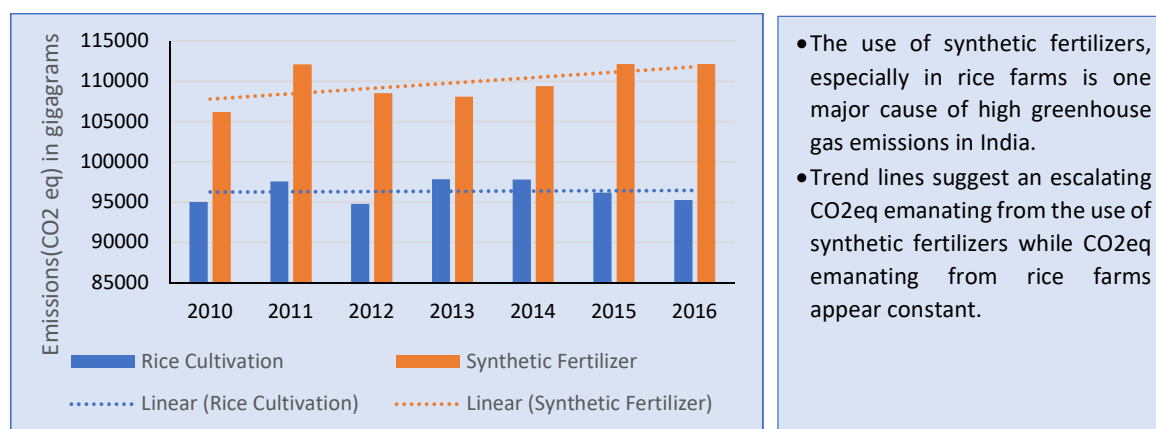
India is undertaking many steps to halt and reverse the pressures on biodiversity arising from the agri-food sector¹¹. For instance, **the promotion of organic farming through a certification scheme has seen an increase from 42,000 hectares in 2004 to 1,050,000 hectares in 2010** of area under organic farming¹². **India has added three million hectares of forest in the last decade through targeted programs such as Green India Mission and reformed fertilizer pricing to encourage soil biodiversity**¹³.

1.3 Challenges to sustainable agriculture in India

To attain food self-sufficiency, India adopted the ‘Green Revolution’ strategy in the mid-1960s. This heightened the use of modern technology, high yielding crop varieties, chemical fertilizers, irrigation facilities, and improved farm implements and crop protection measures (Sing, 2000). By the 1980s, India was largely self-sufficient in food grain production (Acharya, 2009). However, the drive to increase agri-food production has had a major toll on the environment, **leading to loss of soil fertility, soil erosion, soil toxicity, diminishing water resources, pollution of underground water, salinity of underground water, increased incidence of human and livestock diseases, and global warming** (Rahman, 2015).

Today, **India is one of the countries with the highest rate of greenhouse gas emissions in agriculture coming second after China** (FAO, 2015) as shown in Figure 5.

Figure 5: Greenhouse gas emissions in India (2010 – 2016)



Source: FAOSTAT (2018)

Presently, **Indian agriculture is facing the critical challenge of feeding an escalating human population (1.25 billion) under increasingly declining soil quality, land and water scarcity and changing climatic conditions.**

¹¹ India's Fifth National Report to the Convention on Biological Diversity. Ministry of Environment and Forests, 2014. Available at, <https://www.cbd.int/reports/nr5/>.

¹² ibid

¹³ ibid

Agriculture is driving its own demise

Agriculture is a key driver of environmental degradation. It is directly responsible for approximately 10 – 12% of global greenhouse gas (GHG) emissions and indirectly for roughly another 10%. It is the main driver of land use change and associated biodiversity loss, uses 92% of global fresh water and approximately 20% of primary energy.

Besides causing environmental damage, agriculture is, above all other industries, reliant upon a well-functioning environment. It is vulnerable to temperature extremes, water availability, atmospheric soil and water pollution, pest and disease outbreaks, biodiversity loss, tropospheric ozone, high winds, among others.

The global agricultural system is thus both a driver and a victim of environmental change.

Source: Gathorne-Hardy (2013, p. 37)

Impact of water scarcity on agriculture

Water shortage is a serious threat to sustainable agriculture in India. Irrigation, the most common alternative to rainfed agriculture, has led to alarming rates of ground water exploitation and depletion (Misra, 2014). **India's water availability per capita was over 5,000 m³ per annum but is projected to decline to 1,500 m³ by 2025.** The agriculture sector, which is the largest user of water, accounting for about 80% of the water withdrawals, is likely to be the main victim. It is projected that **India's water availability for agricultural use could decline by 21% by 2020, which would result in yield reduction of irrigated crops, especially rice** (Indian Agricultural Research Institute, nd).

Impact of climate change on agriculture

Some generic climate change-related variables have been documented in India. For instance, increases of about 0.4 °C of surface air temperatures have been observed over the past Century, especially in west coast and central India. A trend of increasing monsoon seasonal rainfall has been observed along the west coast, northern Andhra Pradesh and north-west India (10%-12% of the normal) over the past Century. Lastly, over the past 40 years, annual rises in the sea level of between 1.06 mm and 1.75mm have been estimated (Government of India, 2008). However, the World Bank (2011) report presents a much grimmer picture by stating that **India is highly vulnerable to climate change due to a combination of; (i) high levels of poverty, (ii) population density, (iii) high reliance on natural resources, and (iv) an environment already under stress (for instance water resources).**

In early June 2015, for more than 10 days, temperatures in Patna, along the Ganges, surpassed long-term average temperatures, that were already very high, by 2° C, with maximum temperatures of 44° C (UNEP, 2016)

Although currently no major studies exist to show the effects on agriculture, **climate change still poses potential threats to the sustainability of agriculture and food security in India, especially given that about 62% of India's cropped area is rainfed.** Nonetheless, some projections have been made. For

instance, a study by Singh et al. (2017), indicated that by 2050, 15% - 40% of the rainfed rice cultivating areas would be at risk of decline in climate suitability or become completely unsuitable. However, they highlighted variations across the country with the eastern and northern India being at more risk than central and western parts of the country, which could benefit from increased precipitation. The projections by Singh et al. (2017) seem to augur well with the estimates by Joshi et al. (2011) suggesting that India's averaged temperature could exceed a threshold value of 2 °C by the early 2030s and 3 °C between 2040 and the early 2050s. Joshi et al. (2011) echo the concern regarding crop productivity that **yields of tropical wheat are expected to decrease significantly should local temperature exceed 3 °C above pre-industrial levels**, regardless of whether adaptive measures such as planting different crop varieties are pursued. **According to the Government of India (2008), every 1 °C increase in temperature reduces the Rabi crop (wheat) production by 4 – 5 million tonnes.**

A study by Negi et al. (2017) to understand the **people's perception regarding climate change in Uttarakhand, Western Himalaya** found out the following: (i) 80% of the respondents were aware of the climatic changes in the region; (ii) **90% acknowledged the erratic rainfall patterns**; (iii) **80% attested to shifts in crop maturation**; (iv) **85% acknowledged the increase in pests and diseases** in crops and (v) **86% attested to decrease in forest resources. Decrease in water availability and change in agrobiodiversity** were some of the other indicators that most of the respondents agreed to. **Drought and insufficient rainfall are likely to make grazing land less hospitable, cultivation of fodder less predictable, and water for livestock or crops harder to come by** (MacDonald & Iyer, 2012).

In its effort to address the effects of climate change in the country, **on June 30, 2008, India officially released its National Action Plan on Climate Change** (Government of India, 2008). The action plan outlines several steps required to advance development and climate change-related objectives. These steps are packaged in eight missions as shown Table 3.

Table 3: Eight missions of India's National Action Plan on Climate Change

Mission	Objective
National Solar Mission	To encourage the development and use of solar energy for power generation and other uses.
National Mission for Enhanced Energy Efficiency	To ensure energy consumption decreases in large energy-consuming industries.
National Mission on Sustainable Habitat	To promote energy efficiency as a core component of urban planning.
National Water Mission	To achieve 20% improvement in water use efficiency through pricing and other measures.
National Mission for Sustaining the Himalayan Ecosystem	To prevent melting of the Himalayan glaciers and protect biodiversity in the Himalayan region.
Green India Mission	To achieve afforestation of 6 million hectares of degraded forest lands and expand India's forest cover from 23% to 33%.
National Mission for Sustainable Agriculture	To enhance agricultural productivity especially in rainfed areas focusing on integrated farming, water use efficiency, soil health management and synergizing resource conservation.

National Strategic Climate Change	Mission Knowledge for	on	To gain a better understanding of climate science and promote private sector initiatives to develop adaptation and mitigation technologies through venture capital funds.
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By 2016 India had spent Rs.157.14 crore (about US\$ 17.2 million)¹⁴ on Integrated Farming System activities (promoted under Rainfed Area Development – a key component of National Mission for Sustainable Agriculture) which covered about 32,740 ha comprising 4,245 ha of livestock based farming system, 9,727 ha of dairy based farming system, 1,609 ha of fishery based farming system, 7,408 ha of horticulture based farming system, 5,105 ha of agro-forestry based farming system, 472 ha of silvi-pasture based farming system and 4,174 ha of cropping system with peripheral plantations (Government of India, 2017).

India has also expressed interest in combating global climate change. At the 2015 United Nations Climate Change Conference, **India submitted an Intended Nationally Determined Contribution (INDC) and made a commitment to reduce the emissions intensity of its GDP by 20 to 25 percent by 2020 from 2005 level¹⁵.**

In addition, **India has embraced sustainable agriculture and biodiversity conservation, through a variety of national level strategies and policies**, which have evolved over time. These include the Zero Budget Natural Farming (ZBNF)¹⁶; Mizoram Organic Farming Act, 2004¹⁷; Scheme on Labelling of Environmental Friendly Products (ECO-Mark)¹⁸; Seeds Act, 2004¹⁹; Environment (Protection) Rules, 1986²⁰; Food Safety and Standards (Contaminants, Toxins and Residues) Regulations, 2011²¹; Agricultural Produce Act, 1937²²; National Forest Policy, 1988²³ and Protection of Plant Varieties and Farmers' Rights Act²⁴; and Biological Diversity Act, 2002²⁵ and Some of these are covered in more detail in the next chapter.

1.4 TEEB Implementation in India: Promoting biodiversity and sustainability in the agriculture and food sector project

4. To complement the Indian Government's initiatives for agriculture sustainability and biodiversity conservation, **the United Nations Environment (UN Environment), with the support of the European Union (EU), launched a four-year project for "Promoting biodiversity and sustainability in the agriculture and food sector in India.**

¹⁴ 2015-2016 Reserve Bank of India data available at: <https://www.rbi.org.in/scripts/PublicationsView.aspx?id=17923>

¹⁵ <http://envfor.nic.in/sites/default/files/press-releases/revised%20PPT%20Press%20Conference%20INDC%20v5.pdf>

¹⁶ <http://www.fao.org/3/a-bl990e.pdf>

¹⁷ Can be found: <https://www.informea.org/en/legislation/mizoram-organic-farming-act-2004-act-no-6-2004>. Assessed Nov 2017

¹⁸ Can be found: <https://www.informea.org/en/legislation/resolution-ministry-environment-and-forests-approving-scheme-labelling-environmental>. Assessed Nov 2017

¹⁹ Can be found: <https://www.informea.org/en/legislation/seeds-act-2004>. Assessed Nov 2017

²⁰ Can be found: <https://www.informea.org/en/legislation/food-safety-and-standards-contaminants-toxins-and-residues-regulations-2011>. Assessed Nov 2017

²¹ Can be found: <https://www.informea.org/en/legislation/seeds-act-2004>. Assessed Nov 2017

²² Can be found: <https://www.informea.org/en/legislation/agricultural-produce-grading-and-marking-act-1937-act-no-1-1937>. Assessed Nov 2017

²³ Can be found: <https://www.informea.org/en/legislation/national-forest-policy-1988>. Assessed Nov 2017

²⁴ Can be found: <https://www.informea.org/en/legislation/protection-plant-varieties-and-farmers-rights-act>. Assessed Nov 2017

²⁵ Can be found: <https://www.informea.org/en/legislation/biological-diversity-act-2002>. Assessed Nov 2017

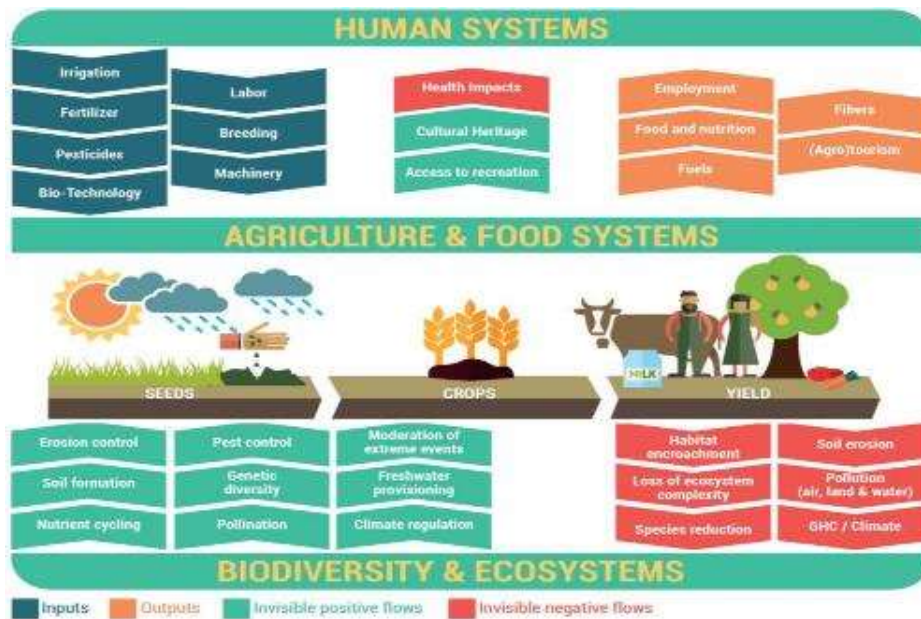
5. This project is in line with the Cancun Declaration²⁶ adopted at the 2016 December CBD COP13 in which governments commit to mainstream biodiversity across all sectors. The project would contribute to integrating biodiversity values into national accounting and reporting systems and will encourage sectors that depend or have an impact on biodiversity to adopt integrated approaches for its conservation and sustainable use. In addition, and in line with the Declaration, the project will contribute to supporting sustainable production and consumption throughout value chains, the safe and sustainable application of technologies, and the phasing out of harmful incentives and strengthening of positive incentives.
6. **The overall objective of this project is to protect biodiversity and contribute to a more sustainable agriculture and food sector with well-functioning ecosystems.** This will be achieved by:
 - developing and applying instruments to capture the value of ecosystems services across the entire life cycle in the agri-food and the non-food agricultural raw material sectors;
 - identifying intervention options protecting biodiversity and promoting well-functioning ecosystems and by direct engagement with farmers, agri-businesses, government, and civil society (including consumers).
7. The TEEBAgriFood Framework²⁷ will be used to assess the sectors for the EU Partner countries in scope. The focus in this action is capturing the value of ecosystems services, protecting biodiversity and promoting well-functioning ecosystems of the framework. The action aims to be comprehensive, from farm to fork (i.e. across the entire value chain). The Framework allows decision-makers (regulators, agri-business and farmers) to see explicitly any trade-offs that arise through the application of different measures, as compared with Business-As-Usual (BAU).
8. The rationale for the development of the TEEBAgriFood Evaluation Framework, is to provide a comprehensive and universal framework that captures all the positive and negative impacts and externalities across the entire agri-food value chain. It is a frame of reference that can enable us to answer the question “what we should value, and why?” It can be used to evaluate a policy question, a business question or an accounting question²⁸. The TEEBAgriFood schematic (Figure 6) below provides a visual illustration of some of the impacts and externalities that might be omitted were we not to apply a holistic and comprehensive evaluation framework.

²⁶ <http://www.cbd.int/cop/cop-13/hls/Cancun%20Declaration-EN.pdf>

²⁷ The current published version of the Evaluation Framework can be found here: <http://www.teebweb.org/agriculture-and-food/#framework>. The Framework that is to be published in the upcoming TEEBAgriFood ‘Foundations’ report is an evolution of this previous version but retains the same core components. The ‘Foundations’ report is due to be published in Q1 2018 and thus the Framework will be finalized before the current EC Partnership Instrument project is contracted.

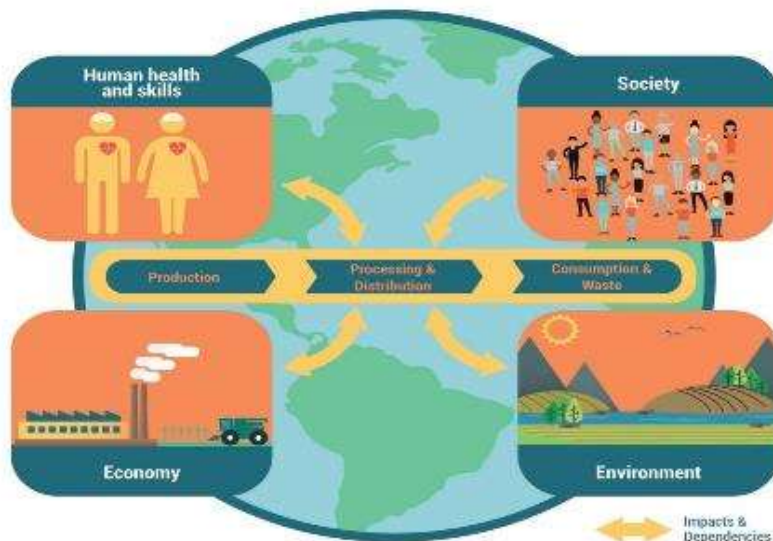
²⁸ For more details, see Chapter 3 in the TEEBAgriFood Interim Report: <http://www.teebweb.org/publication/teebagfood-interim-report/>

Figure 6: The visible and invisible flows of agricultural production



The schematic in Figure 6 above refers to the impacts and dependencies that occur within the farm-gate, but the Evaluation Framework looks at inter-linkages across the value chain, and trade-offs across capital stocks in the eco-agri-food systems complex. This is illustrated in the schematic below (Figure 7).

Figure 7: The eco-agri-food systems complex



9. The project builds on the momentum of the international TEEB initiative²⁹, TEEB country studies³⁰, TEEB for Agriculture and Food³¹ and on national interest.

²⁹ <http://www.teebweb.org/>

³⁰ <http://www.teebweb.org/areas-of-work/country-studies-home/>

³¹ <http://www.teebweb.org/agriculture-and-food/>

10. It also builds on the on-going UN Environment/TEEB initiatives in India³². India launched a national TEEB study in February 2011³³ and a scoping report was jointly released by Ministry of Environment and Forests, Government of India, and GIZ in 2012³⁴. The report presents an overview of status and trends, and a synthesis of valuation data on ecosystem services delivered by forests, inland wetlands, and coastal and marine ecosystems. The TEEB India Interim report was released in 2014³⁵. The project will take the outcomes of this report into consideration.
11. TEEB will work closely with:
- The Natural Capital Protocol, and links will be made to ensure representation from those firms which have already committed to Protocol on the project meetings.
 - The Partnership Instrument project "Natural Capital Accounting and Valuation of Ecosystem Services" (AAP 2015) involving UNDESA, UNEP-TEEB and the Secretariat of the Convention on Biological Diversity (sCBD) which aims to apply macro accounting in five countries including India.
 - BIOFIN³⁶ is a global partnership developed to improve biodiversity management through sound financing and economic thinking. BIOFIN works directly with Finance and Environmental ministries in 30 countries helping them to understand how to use finance solutions to maintain ecosystems and the services they provide, and India is part of this partnership.

Beyond these specific country links, there are complementarities between this project and initiatives providing guidance and opportunities in this space including FAO-OECD Guidelines on Responsible Supply Chains; the BioTrade initiative managed by UNCTAD³⁷; the Intergovernmental Science- Policy Platform on Biodiversity and Ecosystem Services (IPBES)³⁸; ESMERALDA³⁹ (Enhancing Ecosystem Services Mapping For Policy And Decision Making); FAO assessment/Platform on mainstreaming biodiversity in agricultural sectors⁴⁰ and DG Research and Innovation initiatives such as FOOD 2030⁴¹.

³² <http://www.teebweb.org/countryprofile/india/>

³³ <http://www.moef.nic.in/downloads/public-information/2011-02-23%20Press%20Brief%20-%20TEEB%20India.pdf>

³⁴ http://www.academia.edu/2366448/TEEB-India_Initial_Assessment_and_Scoping_Report

³⁵ <https://www.giz.de/en/downloads/giz2015-en-ecosystems-biodiversity-interim-report-india.pdf>

³⁶ Can be found: <http://www.biodiversityfinance.net>. Assessed Nov 2017

³⁷ www.biotrade.org

³⁸ <http://www.ipbes.net/>

³⁹ <http://www.esmeralda-project.eu/>

⁴⁰ <http://www.fao.org/biodiversity/en/>

⁴¹ <http://ec.europa.eu/research/conferences/2016/food2030/index.cfm>

2 Overview of national policies in agriculture and biodiversity

The Indian economy is built on the concept of planning, carried out via “Five-Year Plans”, which are primarily centralized and integrated national economic programs. Thus, missions and schemes are formulated in line with the plans. The first plan was from 1951 to 1956 and the most recent one, **the Twelfth Plan, 2012 to 2017 emphasized sustainable management of natural resources and agriculture.**

2.1 The Twelfth Five-Year Plan

Developed by the Planning Commission, **the goal of the Twelfth Five-Year Plan (2012-2017)** was to achieve **“faster, sustainable and more inclusive growth.”** Regarding sustainable management of natural resources and agriculture, the following are envisaged.

Sustainable management of natural resources

- (1) Maintenance and management of surface water and ground water bodies;
- (2) Reforms in major and medium irrigation;
- (3) Water requirements of industry and urban centres;
- (4) Improving forest cover;
- (5) Preserving biodiversity, marine environment and wildlife.

Agriculture

- (1) improving the availability and diversification of food toward food sovereignty;
- (2) increasing the value added and competitiveness enhancing agricultural food products;
- (3) developing raw material availabilities for bioindustry and bioenergy;
- (4) improving the income and welfare of farmers and
- (5) improving the performance quality of agricultural government apparatus trustworthily and professionally.

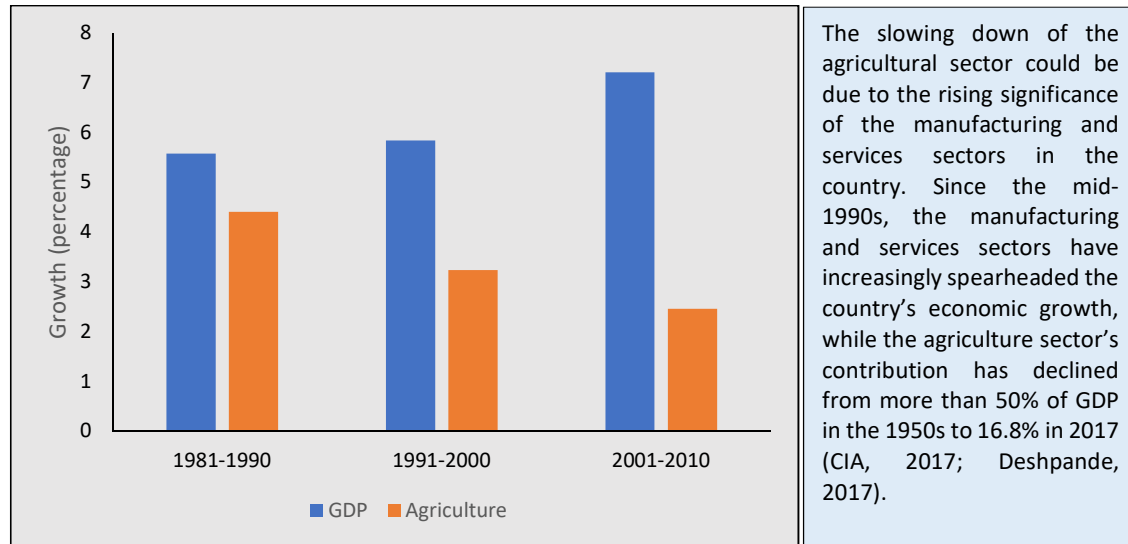
2.2 The evolution of agricultural policy

Soon after independence, India pursued a policy of food self-sufficiency particularly in the two staple foods, rice and wheat. The ‘Green Revolution’ strategy was adopted in the mid-1960s. This heightened the use of modern technology, high yielding crop varieties, chemical fertilizers, irrigation facilities, and improved farm implements and crop protection measures (Sing, 2000). Expansion of cultivated area, land reform, community development, and restructuring rural credit institutions were strongly encouraged. Trade was severely controlled via both quota restrictions and high tariff rates (Gilmour, 2008). By the 1980s, India was largely self-sufficient in food grain production (Acharya, 2009).

In the early 1990s, India instituted economic liberalization measures, which included industrial deregulation, privatization of state-owned enterprises, and reduced controls on foreign trade and investment. However, the agricultural sector was largely left untouched, save for the removal of the export controls. These reforms helped to accelerate the country's growth and improved agricultural

terms of trade. Despite the reforms that apparently favoured agriculture, growth of the sector has essentially slackened since the mid-1990s as shown in Figure 8.

Figure 8: India's average annual growth rate of GDP and agriculture (at constant prices)



Source: Statistics Times (2018)

Some of the current policies related to agriculture are outlined below.

1. The National Agricultural Policy (NAP) 2000

In 2000, the Government of India published a comprehensive agricultural policy statement — the National Agricultural Policy (NAP) that sets out clear objectives and measures for all the important sub-sectors of agriculture. **Until 2020, this policy aims to attain an agricultural growth rate of more than 4% per annum through the efficient use of natural resources** and a combination of other measures. The main elements of the policy include:

- **Efficient use of natural resources, while conserving soil, water and biodiversity**
- Growth with equity, i.e. growth which is widespread across regions and farmers
- Growth that is demand-driven and caters to the domestic markets and maximizes benefits from exports of agricultural products in the face of challenges arising from economic liberalization and globalization.
- **Growth that is sustainable technologically, environmentally and economically.**

The policy also seeks to utilize large areas of wasteland for agriculture and afforestation. It also calls for special efforts to raise crop productivity to meet the growing domestic demand for food and agricultural products. The major focus is on horticulture, floriculture, roots and tubers, plantation crops, aromatic and medicinal plants and bee-keeping. It also emphasizes raising the production of animal and fish products (V. P. S. Arora, 2013).

Despite, the NAP being in place, the annual growth rate achieved during the Tenth Five Year Plan (2002–03 to 2006–07) averaged around 2.3 per cent. The decline in agricultural growth coupled with

declining profitability in the agriculture necessitated a need for a major reorientation in policy. In response the National Policy for Farmers was approved by the Government in 2007 (Government of India, 2007).

2. National Policy for Farmers (NPF) 2007

One of the main objectives of NPF is to improve agricultural productivity with the aim of improving net income of farmers. **It emphasizes increased productivity, profitability, institutional support, and improvement of land, water and support services.**

The major goals of the National Policy for Farmers are:

- (i) To improve economic viability of farming by substantially increasing the net income of farmers and to ensure that agricultural progress is measured by advances made in this income.
- (ii) **To protect and improve land, water, bio-diversity and genetic resources essential for sustained increase in the productivity, profitability and stability of major farming systems by creating an economic stake in conservation.**
- (iii) To develop support services including provision for seeds, irrigation, power, machinery and implements, fertilizers and credit at affordable prices in adequate quantity for farmers.
- (iv) **To strengthen the bio-security of crops, farm animals, fish and forest trees** for safeguarding the livelihood and income security of farmer families and the health and trade security of the nation.
- (v) To provide appropriate price and trade policy mechanisms to enhance farmers' income.
- (vi) To provide for suitable risk management measures for adequate and timely compensation to farmers.
- (vii) To complete the unfinished agenda in land reforms and to initiate comprehensive asset and aquarian reforms.
- (viii) To mainstream the human and gender dimension in all farm policies and programmes.
- (ix) To pay explicit attention to sustainable rural livelihoods.
- (x) To foster community-centred food, water and energy security systems in rural India and to ensure nutrition security at the level of every child, woman and man.
- (xi) To introduce measures which can help attract and retain youths in farming and processing of farm products for higher value addition by making it intellectually stimulating and economically rewarding.
- (xii) To make India a global outsourcing hub in the production and supply of the inputs needed for sustainable agriculture products and processes developed through biotechnology and Information and Communication Technology (ICT).
- (xiii) To restructure the agricultural curriculum and pedagogic methodologies for enabling every farm and home science graduate to become an entrepreneur and to make agricultural education gender sensitive
- (xiv) To develop and introduce a social security system for farmers.
- (xv) To provide appropriate opportunities in adequate measure for non-farm employment for the farm households.

Source: Government of India (2007, pp. 3-4)

3. National Agroforestry Policy 2014

On 6 February 2014, the Government approved the National Agroforestry Policy, making India one of the first countries to adopt agroforestry policy. It was launched on February 10, the first day of the World Congress on Agroforestry, held in Delhi. Agroforestry is the practice of integrating trees, crops and livestock on the same plot of land. It has the potential to achieve sustainability in agriculture while optimising its productivity and mitigating climate change impact. **It is envisaged that the policy will enable farmers to reap the benefit of agroforestry to meet the country's population demand for food, fodder, firewood and timber; conserving biodiversity and protecting wildlife; and holding and repairing soils, against a backdrop of shrinking land and water resources for agriculture and the threat of climate change** (Government of India, 2014a).

The major policy goals are:

- Setting up a National Agroforestry Mission or an Agroforestry Board to implement the National Policy by bringing coordination, convergence and synergy among various elements of agroforestry scattered in various existing, missions, programmes, schemes and agencies pertaining to agriculture, environment, forestry, and rural development sectors of the Government.
- Improving the productivity; employment, income and livelihood opportunities of rural households, especially of the smallholder farmers through agroforestry.
- Meeting the ever-increasing demand of timber, food, fuel, fodder, fertilizer, fibre, and other agroforestry products; conserving the natural resources and forest; protecting the environment & providing environmental security; and increasing the forest/tree cover, there is a need to increase the availability of these from outside the natural forests.

The basic objectives of the National Agroforestry Policy are to:

- Encourage and expand tree plantation in complementarity and integrated manner with crops and livestock to improve productivity, employment, income and livelihoods of rural households, especially the small holder farmers.
- Protect and stabilize ecosystems, and promote resilient cropping and farming systems to minimize the risk during extreme climatic events.
- Meet the raw material requirements of wood based industries and reduce import of wood and wood products to save foreign exchange.
- Supplement the availability of agroforestry products (AFPs), such as the fuel-wood, fodder, non-timber forest produce and small timber of the rural and tribal populations, thereby reducing the pressure on existing forests.
- Complement achieving the target of increasing forest/tree cover to promote ecological stability, especially in the vulnerable regions.
- Develop capacity and strengthen research in agroforestry and create a massive people's movement for achieving these objectives and to minimize pressure on existing forests.

Government of India (2014a, pp. 5-6).

After enacting the National Food Security Act, 2013, which aims at providing food to more than 80 crore of the country's population, there was a need to increase agricultural production in a sustainable manner. Over 80% of farmers in India are smallholders, owning at most two hectares and 60% of the cultivated area is rainfed. Inadequate irrigation and low biodiversity put stress on these farmers. Therefore, agroforestry is seen as a solution to these challenges. **Agroforestry is also regarded as one alternative to meeting**

the target of increasing forest or tree cover to 33% from the present level of less than 25%, as envisaged in the National Forest Policy, 1988.

Earlier policy initiatives to promote agroforestry include National Forest Policy, National Agriculture Policy of 2000, Planning Commission Task Force on Greening India, 2001, National Bamboo Mission, 2002, National Policy on Farmers, 2007, and Green India Mission, 2010. These policies emphasized the role of agroforestry for efficient nutrient cycling, organic matter addition for sustainable agriculture and for improving vegetation cover. However, agroforestry did not gain widespread recognition as a resource development tool due to various factors including restrictive legal provisions for harvesting and transportation of trees planted on farmlands and use of non-timber produce, near non-existent extension mechanisms, lack of institutional support mechanisms, lack of quality planting materials, inadequate research on agroforestry models suitable across various ecological regions of the country, inadequate marketing infrastructure and price discovery mechanisms and lack of post-harvest processing technologies (Government of India, 2014a).

To achieve some of the policy goals highlighted above, India has developed a range policy instruments; a few are outlined below.

1. Minimum support prices (MSP)

Price interventions in food grain market were introduced in the mid-1960s as a part of India's efforts to make the Green Revolution a reality. Essentially, **the aim was to offer remunerative prices to producers through a system of minimum support prices (MSP) largely via procurement of grain and minimization of short-run and year-to-year price fluctuations.** The process has been mainly conducted through open market operations and distribution of food grains at subsidized prices through public distribution system (PDS).

In each season, the Government announces MSPs for major agricultural commodities and arranges purchase operations through public and cooperative agencies. Central nodal agencies are empowered to intervene in the market by undertaking procurement operations. This is done to ensure that the market prices do not fall below the MSPs fixed by the Government.

One of the major factors in determining MSP of mandated crops is cost of production. Apart from production cost, the Commission takes into account other key factors such as demand and supply, price trend in the domestic and international markets, inter-crop price parity, terms of trade between agricultural and non-agricultural sectors and the likely impact of MSPs on consumers, besides ensuring rational use of natural resources like land and water (Government of India, 2017). Although the policy has been partially responsible for rapidly rising output of some agricultural products, especially wheat and rice, there are some concerns that the MSP may not be beneficial to some target groups including the tens of thousands of poor wood gatherers living in remote villages, each with a small volume of produce for trade (Government of India, 2011).

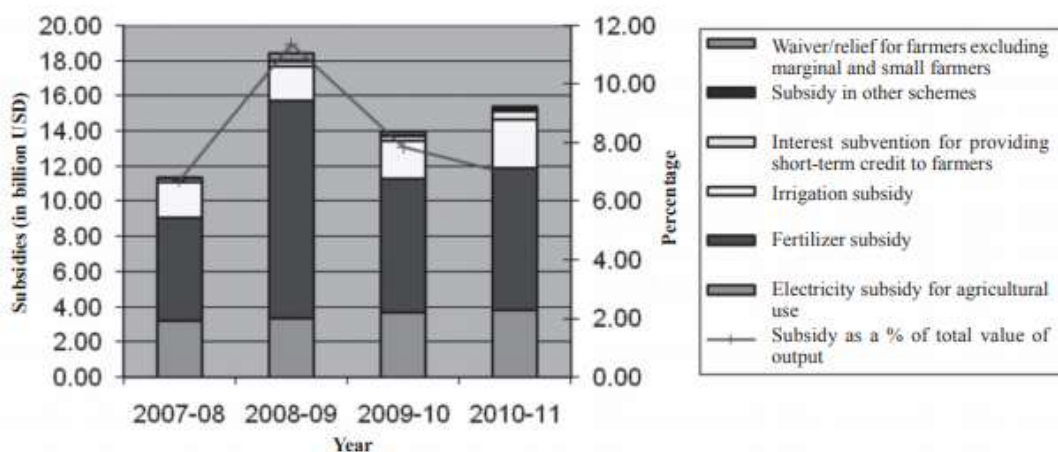
2. Input subsidy to farmers and food subsidy for consumers

According to the Government of India (2015), for sustained agricultural growth and to promote balanced nutrient application, it is imperative that fertilizers are made available to farmers at affordable prices. So, since 1977, chemical fertilizers have been highly subsidized in India and the amount of fertilizer subsidy has grown exponentially from Rs. 60 crore (about US\$68.7 million) in 1977 to Rs. 61,264 crore (about US\$13.4 billion) in 2010 (FAOSTAT, 2018; Government of India, 2011).

By 2012, farmers paid only 58 to 73% of the delivered cost of potassic and phosphatic fertilizers, while the rest was borne by the government as subsidy. Irrigation and electricity are also supplied directly to farmers at prices that are below the production cost.

The cost of agricultural input subsidy as a share of agricultural output almost doubled from 6.0% in 2003-04 to 11.6% in 2009-10, driven mostly by large increase in the subsidies to fertilizer and electricity as shown in Figure 9.

Figure 9: Trend in non-product specific subsidies in India



Source: V. P. S. Arora (2013, p. 149)

Much as there is a consensus in favour of fertilizer subsidy to increase fertiliser use in many parts of the country, **there are some concerns that the overuse of chemical fertilizers in many other areas has resulted in severe degradation of soils, soil nutrient imbalance, environmental pollution, and groundwater depletion**, all of which have caused decreased effectiveness of inputs. It has therefore been suggested that there is a need to rejuvenate soil and restore soil health through addition of soil organic matter in bulk quantities and micro-nutrients (Government of India, 2011).

Regarding food subsidy, the Food Security Bill, 2013, was passed in August 2013. It gives right to the people to receive adequate quantity of food grains at affordable prices. The Bill has special focus on the needs of poorest of the poor, women and children. In case of non-supply of food grains, people will get Food Security Allowance (V. P. S. Arora, 2013). The Food Corporation of India (FCI) purchases food grains from farmers at the MSPs and sells at subsidized prices through the public distribution system (PDS) (Gilmour, 2008). The aim of this subsidy is to cushion low income consumers from food

price shocks. Just like fertilizer subsidy, food subsidy has witnessed a very sharp uptrend since 1991; increasing by 600% between 1990-91 and 2015-16 (Gilmour, 2008; Sharma & Alagh, 2013).

3. Regulated markets

Since independence, India's domestic agricultural markets have operated under a complex regulatory framework. For instance, the Essential Commodities Act of 1955 permits central and state governments to put restrictions on the storage and movement of commodities considered indispensable by governments (Gilmour, 2008). To guarantee food security, remunerative prices to farmers and fair prices to consumers, Indian States are geographically divided into markets; such that in each state Agricultural Produce Market Committees (APMCs) are sanctioned to ensure that farm produce are sold only at regulated markets through registered intermediaries.

4. Agricultural trade policy

Prior to the early 1990s, India's agricultural trade was heavily regulated with high tariffs and quotas. The country embarked on agricultural export policy liberalization in 1994; with reforms including a reduction in products subject to state trading, relaxation of export quotas, and removal of minimum export prices. In 2001, quantitative restrictions on imports of all agricultural products was replaced with import tariffs. However, there is still a wide gap between applied and bound tariff rates. These gaps provide India with the discretionary ability to adjust tariffs to balance competing producer and consumer interests (Gilmour, 2008).

2.3 Policies on biodiversity conservation in India

India is party to a number of international conventions that promote forest and biodiversity conservation. These include: 'Convention on Biological Diversity (CBD), 1992'; 'United Nations Framework Convention on Climate Change (UNFCCC), 1992'; 'United Nations Convention to Combat Desertification (UNCCD), 1994'; 'United Nations Convention on the Laws of the Sea (UNCLOS)', 1982; 'Convention on the Conservation of Migratory Species of Wild Animals, Bonn, 1979'; 'Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), 1973'; 'Convention for the Protection of the World Cultural and Natural Heritage, 1972'; 'Convention on Wetlands of International Importance especially as Waterfowl Habitat, (Ramsar, 1971)'; and 'International Convention for the Regulation of Whaling, 1946' (UNDP, 2008). **India has come up with various national strategies, legislation and administrative instruments to address the obligations under the conventions.** For instance, under the CBD (1992), **the country has implemented its National Biodiversity Action Plan (NBAP) since 2008** (Government of India, 2014b).

2.3.1 National Biodiversity Action Plan (NBAP)

India developed its National Biodiversity Action Plan (NBAP) in 2008. The NBAP is broadly aligned to the global Strategic Plan for Biodiversity 2011 – 2020 adopted under the aegis of the Convention on Biological Diversity (CBD) in 2010 (Government of India, 2014b). It also used its 20 Aichi Biodiversity Targets as a framework. **The plan was updated in 2014 during which time 12 National Biodiversity Targets were included.** More information regarding this plan is illustrated in in Table 4.

Table 4: India's National Biodiversity Action Plan

Reference	Target	Related Strategic Goals/Aichi Targets
National Biodiversity Target 1	By 2020, a significant proportion of the country's population, especially the youth, is aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.	1
National Biodiversity Target 2	By 2020, values of biodiversity are integrated in National and State planning processes, development programmes and poverty alleviation strategies.	2
National Biodiversity Target 3	Strategies for reducing rate of degradation, fragmentation and loss of all-natural habitats are finalized and actions put in place by 2020 for environmental amelioration and human well-being.	5, 15
National Biodiversity Target 4	By 2020, invasive alien species and pathways are identified and strategies to manage them developed so that populations of prioritized invasive alien species are managed.	9
National Biodiversity Target 5	By 2020, measures are adopted for sustainable management of agriculture, forestry and fisheries.	6, 7, 8
National Biodiversity Target 6	Ecologically representative areas on land and in inland waters, as well as coastal and marine zones, especially those of particular importance for species, biodiversity and ecosystem services, are conserved effectively and equitably, on the basis of PA designation and management and other area-based conservation measures and are integrated into the wider landscapes and seascapes, covering over 20% of the geographic area of the country, by 2020.	10, 11, 12
National Biodiversity Target 7	By 2020, genetic diversity of cultivated plants, farm livestock and their wild relatives, including other socioeconomically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.	13
National Biodiversity Target 8	By 2020, ecosystem services, especially those relating to water, human health, livelihoods and wellbeing, are enumerated and measures to safeguard them are identified, taking into account the needs of women and local communities, particularly the poor and vulnerable sections.	14
National Biodiversity Target 9	By 2015, Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization as per the Nagoya Protocol are operational, consistent with national legislation.	16
National Biodiversity Target 10	By 2020, an effective, participatory and updated national biodiversity action plan is made operational at different levels of governance.	3, 4, 17
National Biodiversity Target 11	By 2020, national initiatives using communities' traditional knowledge relating to biodiversity are strengthened, with a view to protecting this knowledge in accordance with national legislations and international obligations.	18
National Biodiversity Target 12	By 2020, opportunities to increase the availability of financial, human and technical resources to facilitate effective implementation of the Strategic Plan for Biodiversity 2011–2020 and the national targets are identified and the Strategy for Resource Mobilization is adopted.	19, 20

Source: <https://www.cbd.int/nbsap/targets/default.shtml>

In line with the Strategic Plan for Biodiversity 2011-2020 and the Aichi Targets, India's NBAP is developed with the aim of addressing the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society and reducing the direct pressures on biodiversity and promoting its sustainable use (Government of India, 2014b).

Despite the effort to promote sustainable agriculture, and conservation of biodiversity and natural resources, challenges remain. The extent of these impacts is highlighted further using case studies outlined below.

3 Case studies on agricultural impacts in India

There is increased concern on the potential environmental effects from expansion of agricultural land. However, there is paucity of studies assessing environmental impacts of agri-food systems across the value chain in India. **A few studies conducted mostly at farm gate point towards significant impacts on biodiversity, climate change and natural resources, leading to losses of carbon from the landscape, threats to rare and endemic species, and water and air pollution.** A total of six case studies are explored here in depth, four highlighting impacts and two assessing potential sustainable solutions in the agri-food sector.

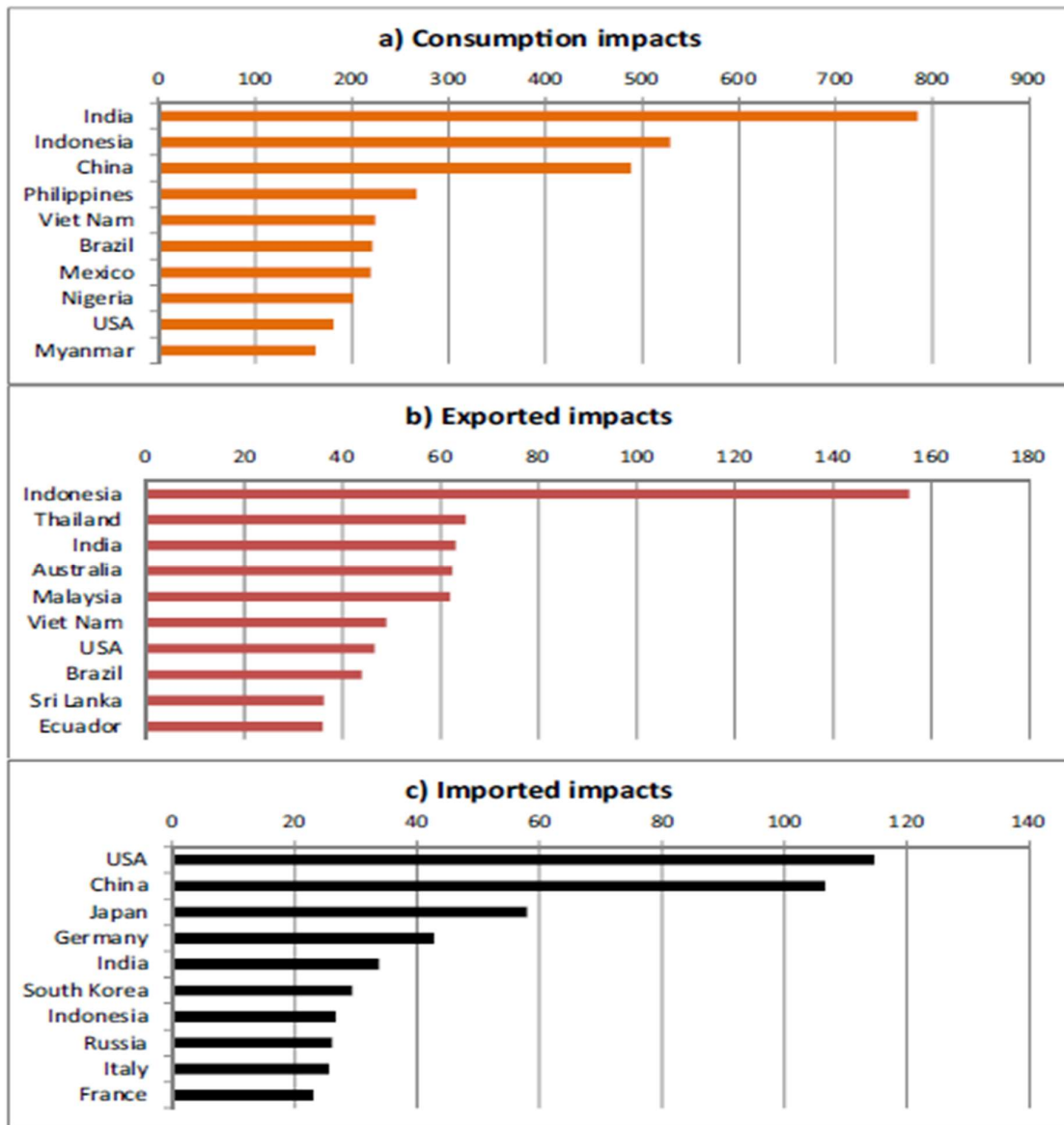
Case study 1: Agricultural land use to meet the demands of a growing population, changing diets, and lifestyles is a key driver of biodiversity loss in India

Biodiversity offers several benefits, including pollination and nutrient cycling, that are key to human health and the economy. Unfortunately, in the past 500 years, over 300 vertebrate species have been obliterated, and many more are under threat of extinction; and agriculture is a key driver of biodiversity loss (European Commission, 2016).

A study by Chaudhary and Kastner (2016) **employed the countryside species area relationship (SAR) model to estimate the mammals, birds, amphibians and reptiles species lost due to agricultural land use in 804 regions globally.** The study combined this measure of species lost with high spatial resolution global maps of crop yields to compute species lost per ton for 170 crops in 184 countries. Then, the study linked the impacts per ton with the bilateral trade data of crop products to calculate the land use biodiversity impacts embodied in international crop trade and consumption. Finally, the impacts per ton were multiplied by each country's volumes of current crop production (in tons) to identify which crop causes high land-use impacts. This process helped to identify the hotspots of biodiversity loss due to global agricultural land use.

The findings showed that **wheat, rice and maize land use contributed to 2,220 species lost (40% of global agricultural land use impacts).** Such results did not come as a surprise because together these three crops occupy 40% of global cropland. Surprisingly, crops such as **sugarcane, palm oil, coconut, cassava, rubber and coffee contributed to 23% of global land use impacts,** which was quite high given that together they only occupy less than 10% of global cropland. Figure 10 shows the top-ranking countries for biodiversity impacts due to consumption, exports and imports.

Figure 10: Top-ranking countries for biodiversity impacts due to consumption, exports and imports (Unit: number of species lost)



Source: Chaudhary and Kastner (2016, p. 198)

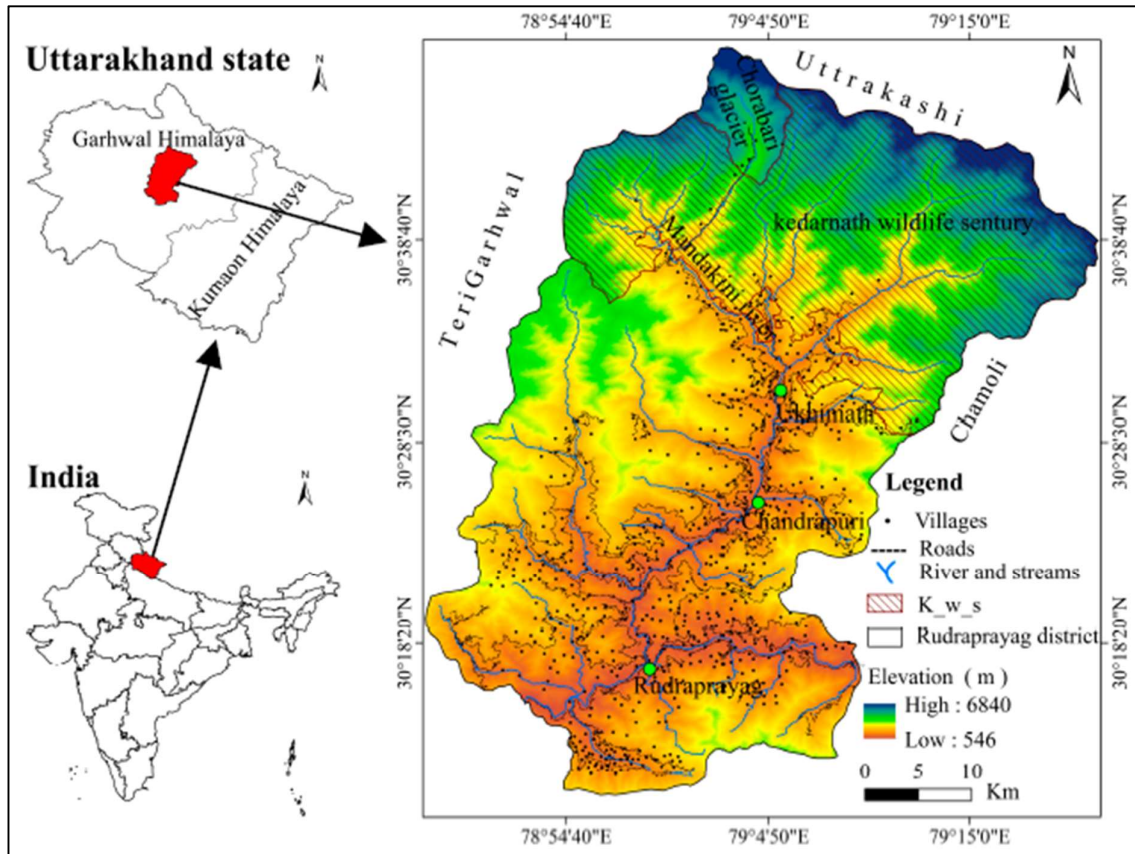
Regarding the **top-ranking countries for biodiversity impacts**, India is ranked **1st on consumption**, **3rd on exports** and **5th on imports**. This highlights the fact that India's footprint on biodiversity is one of the highest in the world.

Case Study 2: Agriculture is among the key drivers to loss of forest cover and forest fragmentation in the Garhwal Himalayan Region of India

Some parts of India have experienced extensive deforestation and forest fragmentation. An example of such regions is the Garhwal Himalaya. Batar et al. (2017) conducted a study to assess the observed regional changes in land cover and forest fragmentation that occurred between 1976 and 2014. Figure

11 shows the study area, the Rudraprayag district, which is an area of the vulnerable zone in the Garhwal Himalaya region of the Uttarakhand state in India.

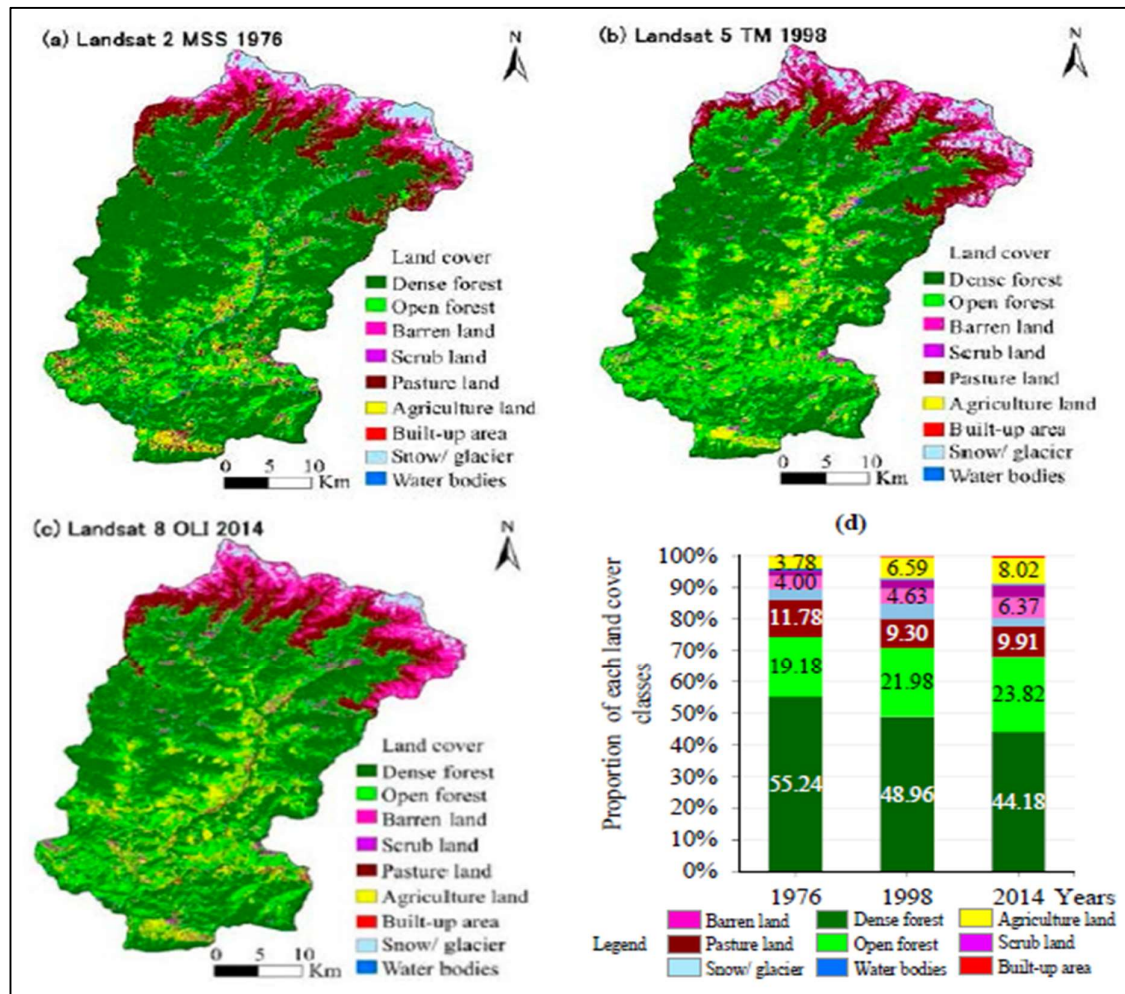
Figure 11: Location and extent of the Rudraprayag district, Uttarakhand, India



Source: Batar et al. (2017, p. 4)

Their findings are as shown Figure 12, which depicts the final output of the supervised classification, comprising three classified maps of the Rudraprayag district, for 1976, 1998, and 2014 and a comparison in terms of the total area for each land cover category.

Figure 12: Land-cover map for the year (a) 1976; (b) 1998; and (c) 2014; and (d) comparison of land use and land cover classes by percentage of the total study area (study area = 936.06 km²)



Source: Batar et al. (2017, p. 7)

From Figure 12 above, it shows that dense forest cover has consistently declined from 55.24% in 1976, to 48.96% in 1998, and finally 44.18% in 2014. **One key driver of such decline in forest land cover is agriculture.** The findings show that **land for agriculture increased from 3.78% in 1976, to 6.59% in 1998, and 8.02% in 2014.**

Case Study 3: Rice – wheat cultivation leads to water depletion in Punjab

Punjab is one of the most agriculturally advanced states in India. The state is not naturally suited for rice cultivation. **The key driver wheat-rice monoculture in Punjab has been the Minimum Support Price (MSP) coupled with central procurement of grains.** The central government procures nearly 95% of the actual produce of wheat and rice at MSP making it an attractive option for farmers – with low risk and high returns. **Given that rainfall pattern hardly supports rice cultivation naturally in Punjab, irrigation is the most common alternative, which, unfortunately has led to ground water exploitation and depletion** (Misra, 2014). There is a strong correlation between wheat – rice production as shown in Figure 13 and water over exploitation as shown in Figure 14.

Figure 13: Crop rotation map of Punjab (1998 – 1999)

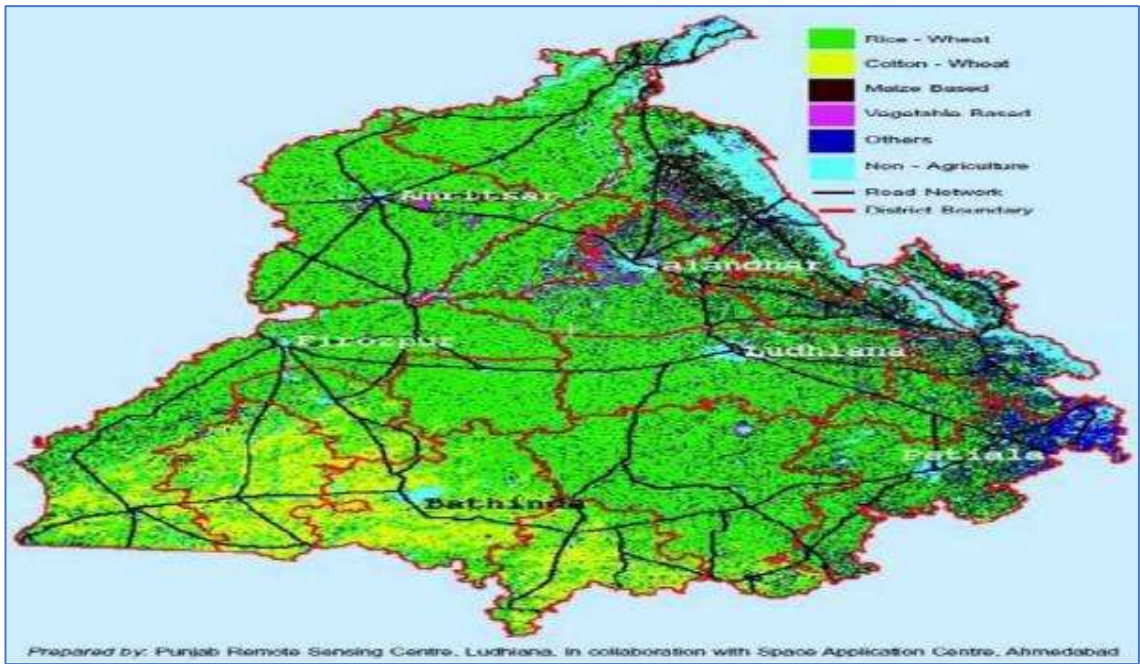
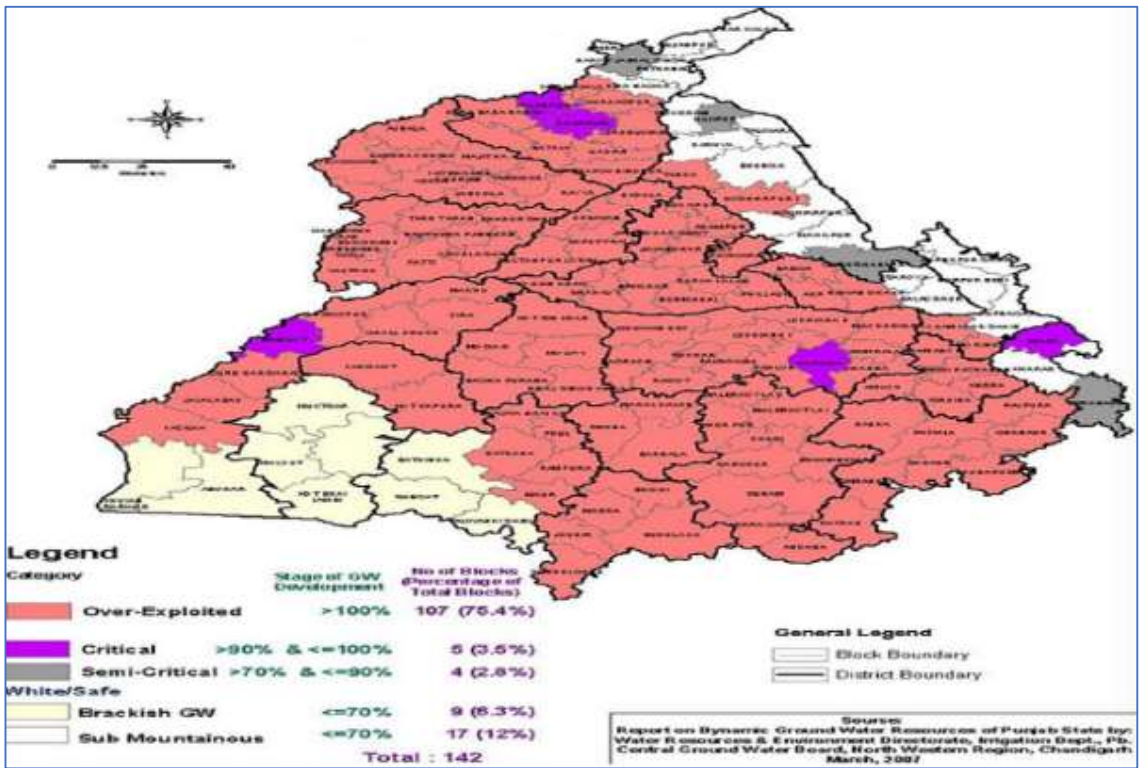


Figure 14: Ground water development (profile) in Punjab (2004)

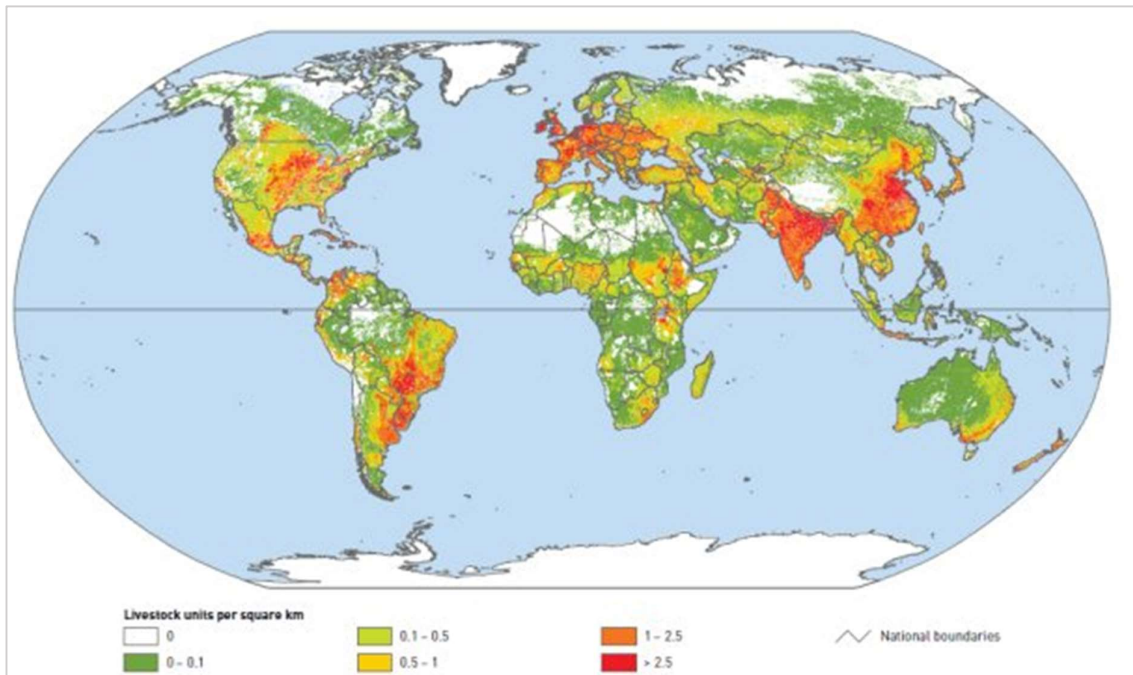


Ground water is over-exploited or critical in about 80% of total blocks of cultivated areas. Further increase in agriculture production is likely to exacerbate these problems, coupled with impacts from other competing sectors and domestic demand from the growing population.

Case Study 4: India's livestock has a significant impact on emissions, land and water.

India is one of the few countries with the largest populations and densities of both people and livestock in the world as shown in Figure 15.

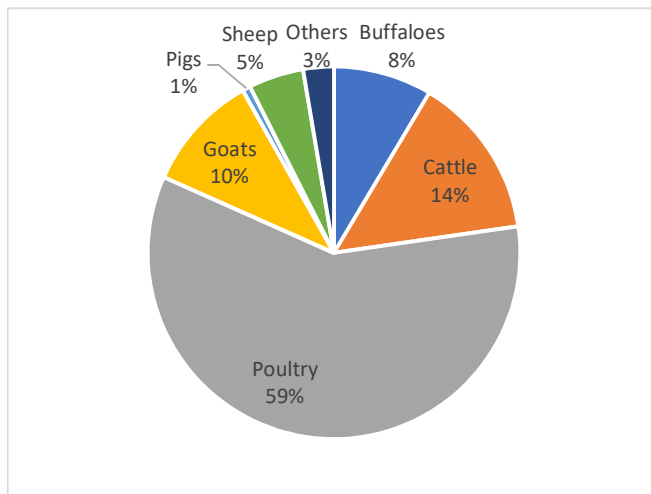
Figure 15: Livestock density country-wise (pigs, poultry, cattle and small ruminants)



Source: FAO (2011)

Between 1980 and 2004, livestock production increased at an annual rate of 4.3%, much faster than the agricultural sector (2.85) as a whole. This livestock production growth was dominated by the dairy and poultry sectors as shown in Figure 16.

Figure 16: Distribution of livestock in India (2016)



Accounting for 59% of the total livestock production in 2016, poultry is the largest and fastest growing segment, seconded by cattle (14%).

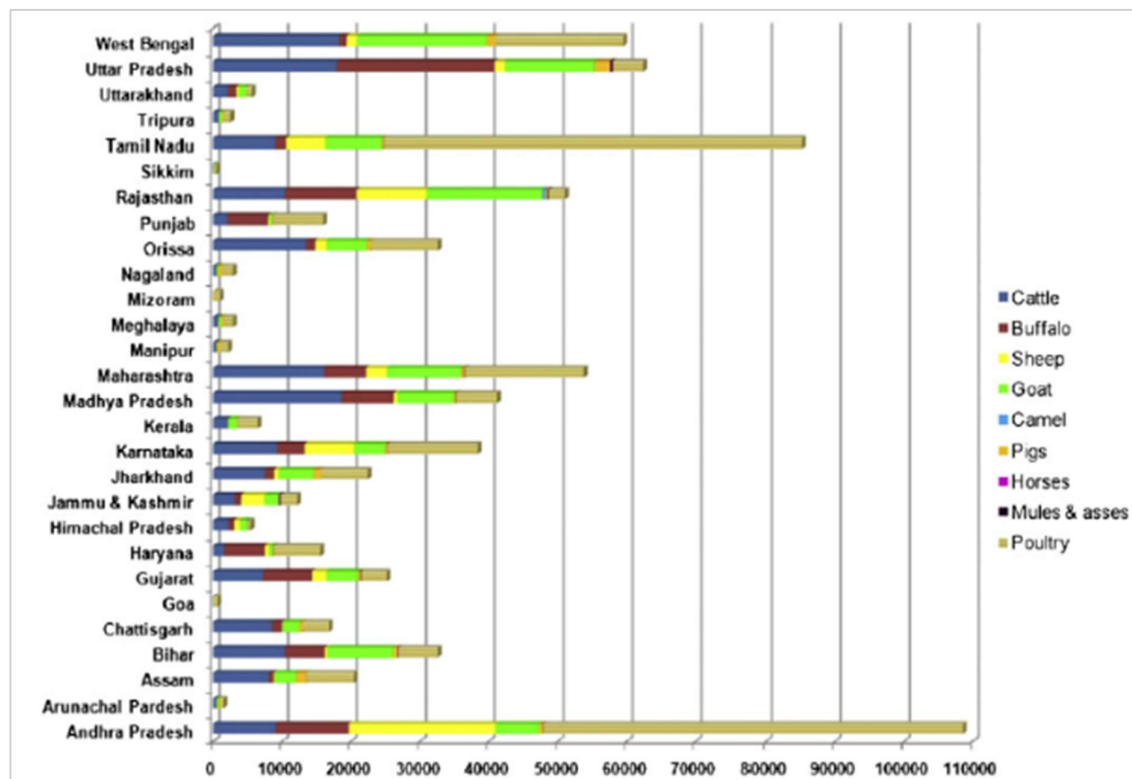
This trend has remained consistent for several decades. For instance, in 2003 poultry accounted for about 34%, which was then the largest followed by cattle at about 25% (Aneja et al., 2012).

While between 2003 and 2016, poultry has almost doubled, cattle production has declined from 25% to 14% of the total livestock.

Data sourced from: FAOSTAT (2018)

Regarding geographical distribution, **poultry production is highly concentrated in Andhra Pradesh and Tamil Nadu. West Bengal, Uttar Pradesh, Maharashtra and Madhya Pradesh** are some of the top producers of cattle as shown in Figure 17.

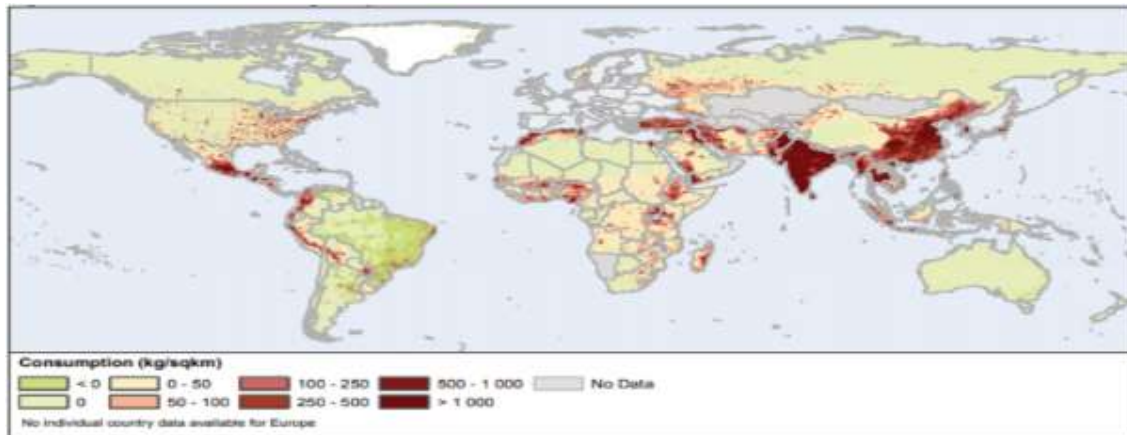
Figure 17: Livestock population (in thousands) in various states of India



Source: Aneja et al. (2012)

The increase in livestock production is partly driven by a rise in domestic demand, accentuated by rising incomes, urbanisation, changing diets, among others. **According to FAO (2011), India is expected to be the key driver of global growth for nearly all animal-based food products over the period 2000 to 2030** as shown in Figure 18 (for poultry meat).

Figure 18: Growth in demand for poultry meat from 2000 to 2030



Source: FAO (2011)

Government policies have also contributed to the growth of livestock in the country. For instance, India's trade liberalisation policy of 1991 propelled fast growth in the livestock sector in country (Intercooperation in India, 2008). In 2013, the Government of India approved **the National Livestock Policy** which is aimed at **"increasing livestock productivity and production in a sustainable manner, while protecting the environment, preserving animal bio-diversity, ensuring bio-security and farmers' livelihood"** (Government of India, 2013).

Currently **India is already grappling with severe emission, land and water challenges**. Further increase in livestock is likely to exacerbate these problems. Unfortunately, **these problems, such as shortage of water and land, water pollution and climate change would in turn harm the livestock industry**. For instance, already, **the livestock sector in India faces shortage of feed and fodder due to decreasing area under fodder cultivation and declining availability of crop residues as fodder** (Government of India, 2013).

Some of the environmental footprint of livestock in India are highlighted below.

1. Greenhouse Gas emissions

- Methane (CH₄), nitrous oxide (N₂O) and carbon dioxide (CO₂) are key greenhouse gases that are associated with livestock.
- **According to Government of India (2010), enteric fermentation in livestock constituted 63.4% of the total GHG emissions (CO₂ eq) from agriculture sector in India.**
- In 2010, enteric methane emission from livestock in India was estimated to constitute nearly 15% of the world total (Patra, 2014).
- **According to MacDonald and Iyer (2012), India's emissions of the greenhouse gas methane from livestock are larger than any other country.**

2. Land and water pollution

- **Animal agriculture is a major source of water pollution in India.** Strains on land are equally enormous. With agricultural land per farmer standing at just 0.3 hectare, an estimated 45% of India's land is degraded from over-grazing and over-production of crops (MacDonald & Iyer, 2012).
- **India's poultry production is a source of a variety of environmental pollutants** such as ammonia, nutrients (specifically nitrogen and phosphorus), pathogens, trace elements, antibiotics, pesticides, hormones and airborne bacteria. For instance, groundwater samples from the caged poultry farms showed nitrates, that should be less than 45 milligrams per litre, to be in the range of 60-171 (Jayasimha, 2018).

Besides assessing environmental footprints, research around potential sustainable solutions to agriculture is emerging, but is still at its infancy. Two case studies are outline below.

Case Study 5: Agroforestry has the potential to improve water productivity and net income of farmers

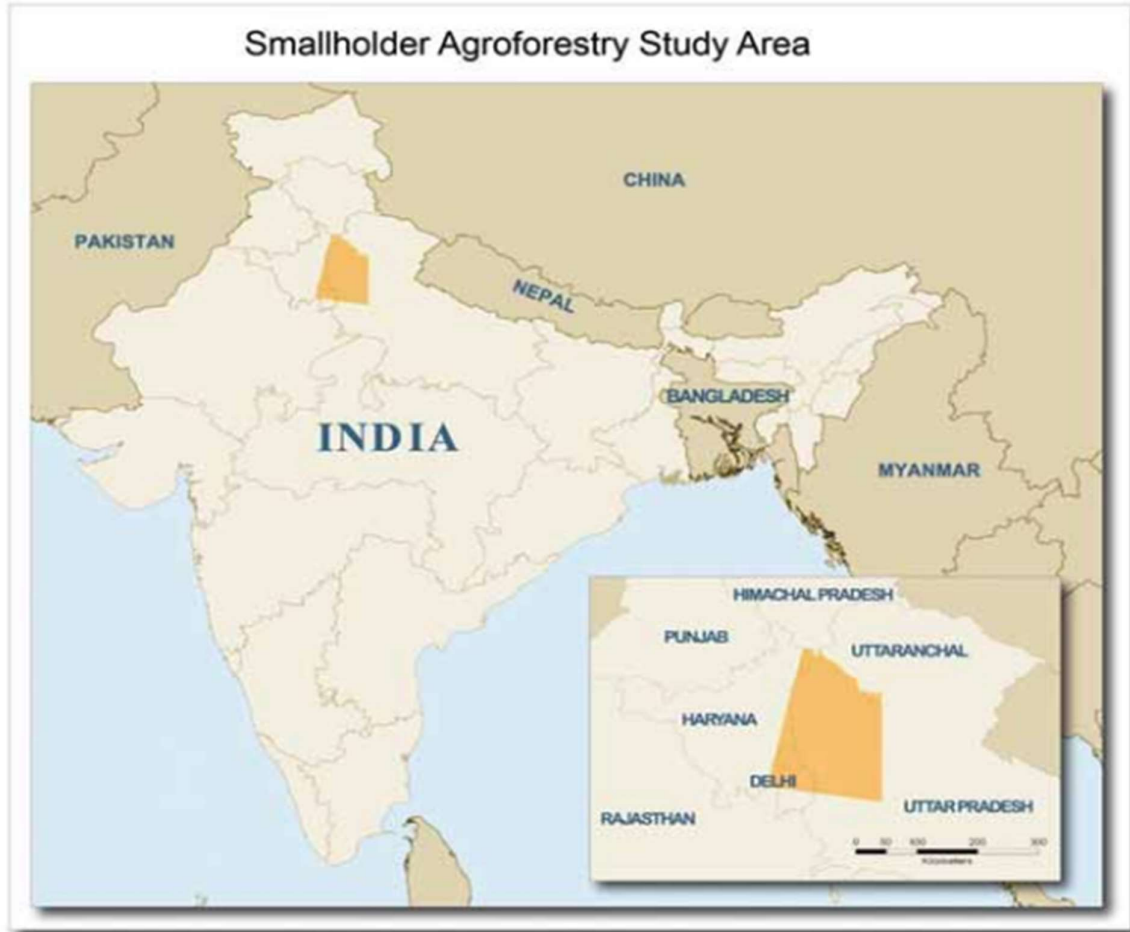
Agroforestry is considered a model of sustainable agricultural practices with several benefits. One benefit of agroforestry is that it helps improve water productivity. It also helps reduce soil erosion as well as meet the growing demand for wood and timber, a socio-economic benefit. Agroforestry is gaining popularity across the states of Punjab, Haryana and Uttar Pradesh. A few examples are highlighted below.

(a) Agroforestry has the potential to improve water productivity in irrigated lands in Northern India

In northern India, from Punjab through Haryana and Uttar Pradesh to West Bengal, poplar based agroforestry was adopted in the 1970s when farmers started planting such trees to supply wood to a local match producing company. These trees are usually planted on irrigated land used for cereal production in a rice/wheat rotation. **This system has received widespread support in India, as evidenced by the adoption of the National Agroforestry Policy in 2014.** For example, Zomer et al. (2007) conducted a study to understand the hydrologic implications of the increased tree cover within the agricultural landscape of northern India, at farm to regional scales. **The study was conducted in**

northern India (Punjab, Haryana and western Uttar Pradesh), as shown in Figure 19, using farmer-survey data, remote sensing, and hydrological modelling of the prevalent cropping systems.

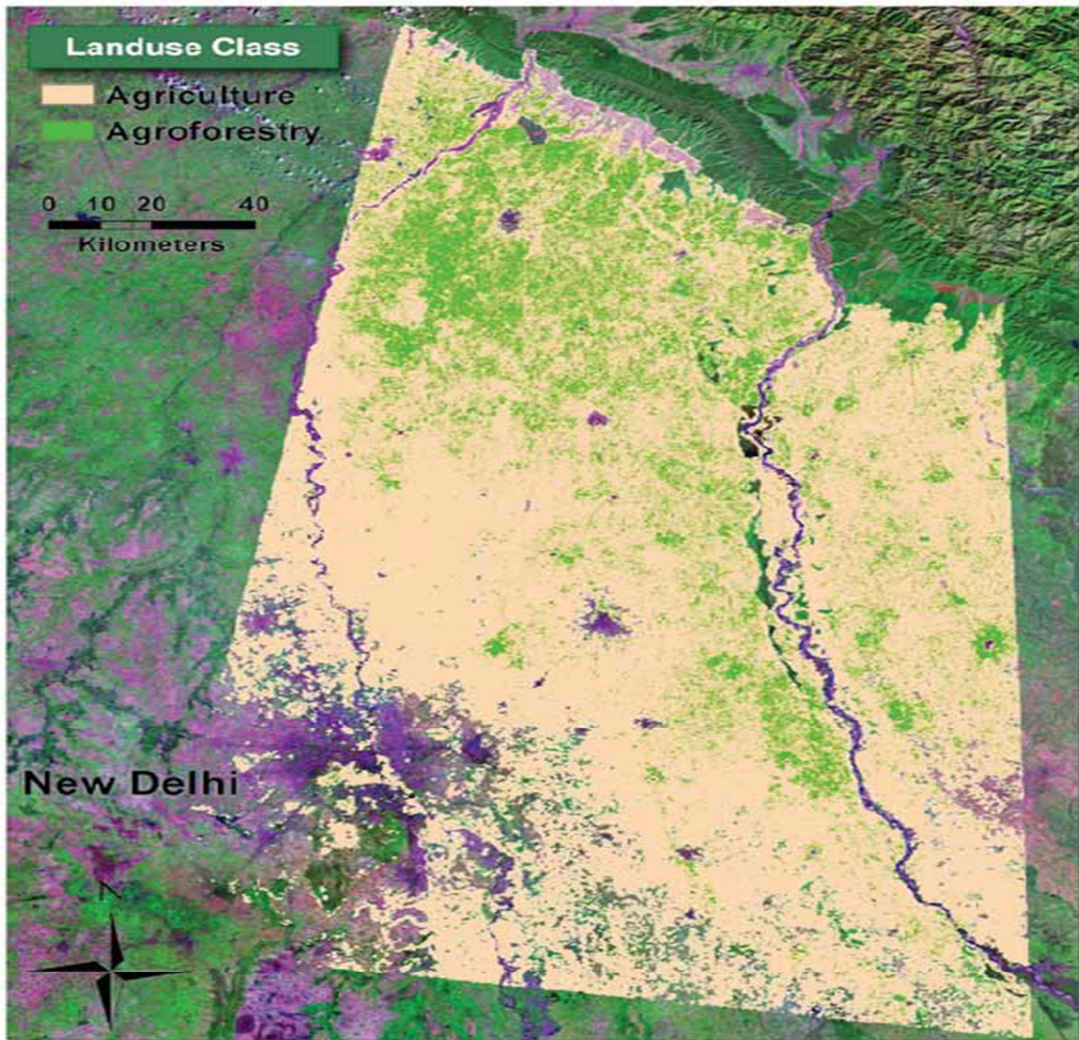
Figure 19: Map showing the location of the study area in northern India. Poplar agroforestry stretches in a belt from the Punjab, through Haryana and western Uttar Pradesh states



Source: Zomer et al. (2007)

Figure 20 shows tree cover within irrigated agricultural land (agroforestry in green and agriculture in light yellow). Areal extent of agroforestry was identified using the Forest Canopy Density (FCD) Mapper algorithm. The map was based on a 75% canopy cover threshold (per pixel), which resulted in **agroforestry being present on 9.8% of all irrigated lands with the study area.**

Figure 20: Tree cover within irrigated agricultural land (agroforestry in green and agriculture in light yellow)



Source: Zomer et al. (2007)

Considering the study area in which agroforestry was present on 9.8% of all irrigated lands, the findings, as shown in Table 5, illustrate that at 10% of agroforestry, annual vapour flow (AET) ranges from 1,614 mm to 1,940 mm with a mean increase in annual vapour flow of 18 mm (1.1%).

Table 5: Annual Vapor Flow (AET) for the entire agricultural landscape at various levels of adoption of the poplar agroforestry system

Annual Vapor Flow				
Agroforestry (% of Irrigated Area)	Mean (mm)	Min (mm)	Max (mm)	Std (mm)
0	1,666	1,613	1,707	15
10	1,684	1,614	1,940	53
15	1,693	1,614	1,941	64
20	1,702	1,614	1,941	70
25	1,710	1,614	1,941	75
50	1,754	1,614	1,942	87
100	1,839	1,780	1,942	17
Annual Vapor Flow Increase (mm)				
Agroforestry (% of Irrigated Area)	Mean (mm)	Min (mm)	Max (mm)	Std (mm)
0	0	0	0	0
10	18	0	245	53
15	28	0	245	64
20	36	0	245	71
25	44	0	245	76
50	88	0	258	87
100	173	130	172	15
Annual Vapor Flow Increase (%)				
Agroforestry (% of Irrigated Area)	Mean (%)	Min (%)	Max (%)	Std (%)
0	0.0	0.0	0.0	0
10	1.1	0.0	14.5	3
15	1.7	0.0	14.5	4
20	2.1	0.0	14.5	4
25	2.6	0.0	14.5	5
50	5.3	0.0	15.6	5
100	10.4	7.7	15.6	1

Source: Zomer et al. (2007)

The study concluded that the **widespread adoption of poplar agroforestry and other tree-based systems in Northern India had created a significant improvement in the water productivity of this intensively irrigated region. The study also highlighted that on-farm trees have the potential to reduce pressure on forests, wildlife habitat and biodiversity.** However, some studies have suggested that agroforestry could lead to competition for water between crops and trees, conditioned on the type of trees (e.g. Eucalyptus in semi-arid areas) and other factors (Misra, 2014).

(b) Economic benefits of agroforestry systems in western Uttar Pradesh, Northern India

A study carried from 2001 to 2003 by Kareemulla et al. (2005) in Yamunanagar in Haryana and Saharanpur district, western Uttar Pradesh, Northern India looked at the economics benefits of

agroforestry. The sampled poplar farmers were grouped into two: 78% practiced bund/boundary system while the practiced agrisilviculture. The tree density in poplar-based bund/boundary system was 146 trees per hectare compared to 481 trees per hectare for the other group. The profitability of poplar-based agroforestry systems is compared in Table 6.

Table 6: Profitability of poplar-based agroforestry systems

System	NPV	Discount rate	Benefit-Cost Ratio (BCR)
Bund/boundary system (8-year rotation)	Rs. 137,000	8	2.8
	Rs. 127,000	10	2.8
	Rs. 118,000	12	2.8
Agrisilviculture (7-year rotation)	Rs. 123,000	8	2.18
	Rs. 111,000	10	2.15
	Rs. 101,000	12	2.12
Conventional crop rotation	-	-	1.34-1.42

Focussing on the BCR, the study concluded that both poplar-based agroforestry systems were more profitable than the conventional crop rotation system. Other studies conducted in other regions of India point to the same conclusion e.g. a study by Prasad et.al (2010) in Southern India.

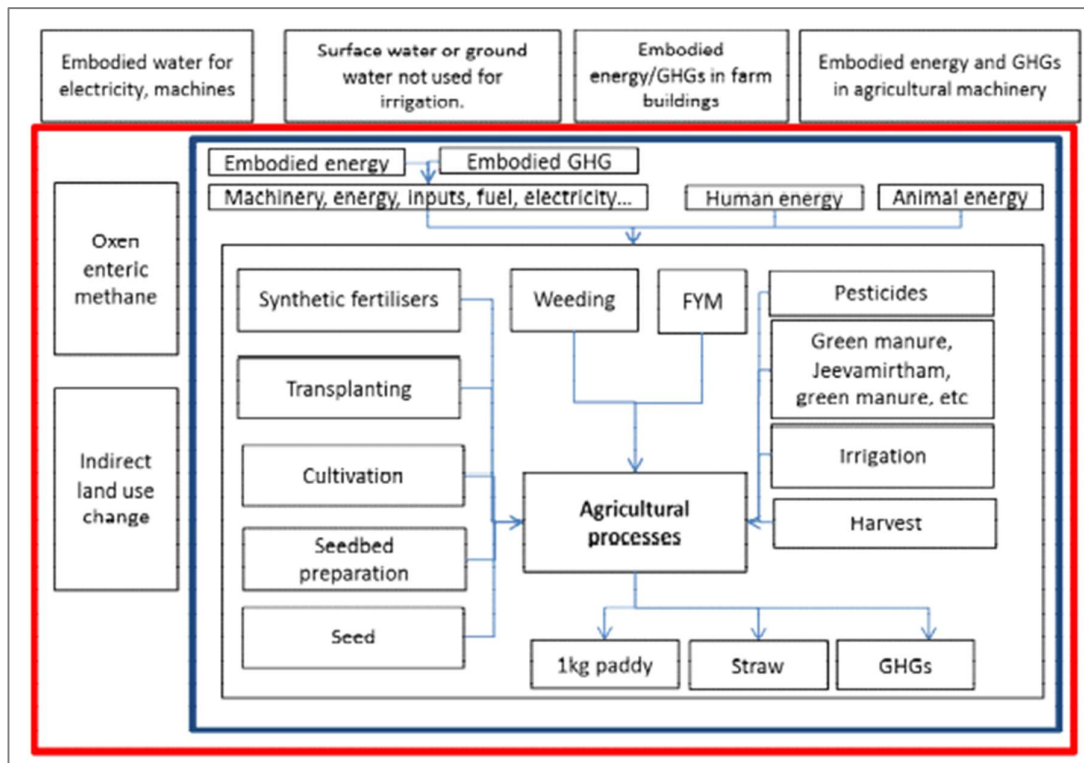
Case Study 6: Assessing environmental footprints under different rice production methods

Globally, rice cultivation covers nearly 157 million hectares, of which about 44.1 million hectares are in India (FAOSTAT, 2018). Environmentally, the crop is very important particularly due to the magnitude of its physical footprint, which is heightened by the practise of irrigation. Irrigated rice accounts for most rice production in the world. About 79 million hectares of irrigated rice produce nearly 75% of the annual global rice, using between 34% and 43% of global irrigated water, or between 24% and 30% of the total freshwater withdrawals (Belluscio, 2009).

To this end, Gathorne–Hardy (2013) employed the Life Cycle Assessment (LCA) approach **to assess the impact of rice production on GHG emissions, energy use and groundwater use in India.** Four different types of rice production were considered: (a) High Yielding Variety (HYV) rice, typically cultivated across India; (b) Organic rice, which is a largely unregulated industry and currently predominantly cultivated for domestic consumption; (c) The System of Rice Intensification (SRI); and (d) Rain-fed rice. **Data collection, from semi-arid regions of South and East India,** was conducted using recall surveys across the four technological systems.

The functional unit used was 1 kilogram of paddy at the farm gate. This included all the processes that go into producing the paddy but not those processes that convert paddy to rice. The system boundaries are as shown in Figure 21.

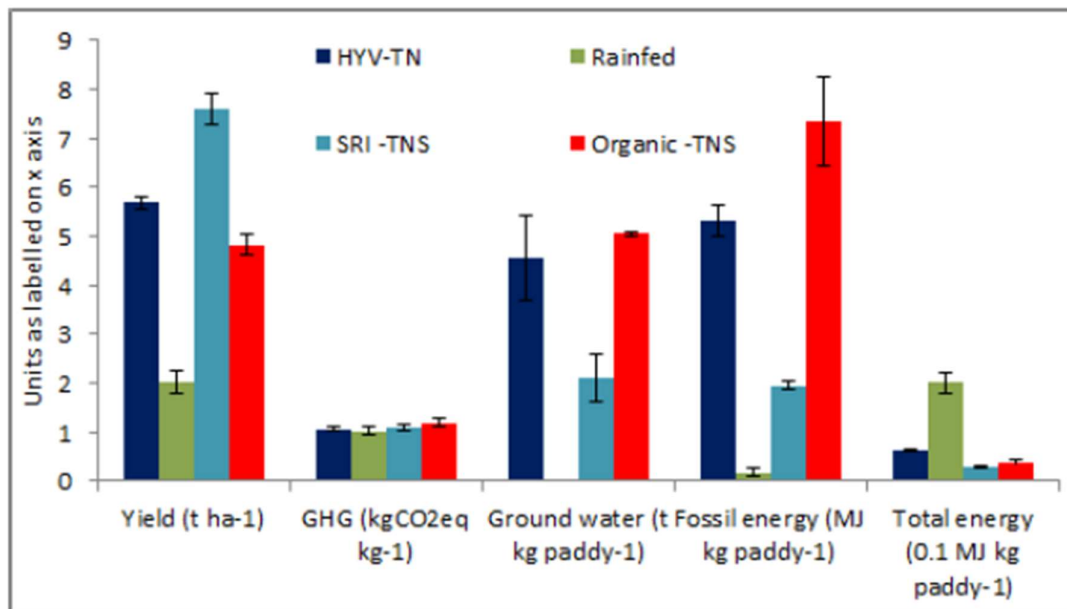
Figure 21: System boundaries for determining the environmental burden of 1 kilogram of paddy



Source: Gathorne-Hardy (2013, p. 43)

All elements within the dark-blue box were included while elements only within the red box were optionally included in the study. Outside the red box, one element, embodied water for electricity and machines, was not included due to lack of data. Results are shown in Figure 22: The key environmental criteria (all displayed per kg of paddy, except yield).

Figure 22: The key environmental criteria (all displayed per kg of paddy, except yield)



Source: Gathorne-Hardy (2013, p. 53)

There are **no major differences in the GHG emissions associated with paddy production** between the different production systems. However, there are major differences between different techniques with organic rice using the highest amount of ground water seconded by HYV and lastly SRI rice. Regarding the use of fossil energy, the same pattern is observed. Organic rice using the highest amount of fossil energy seconded by HYV. **Environmental footprint from the System of Rice Intensification (SRI) was the lowest across all three environmental indicators (GHG emissions, energy use and groundwater use).** The study highlights that adoption of more sustainable rice production systems have the potential to lower environmental footprint in rice production.

The case studies outlined above are not exhaustive, but highlight the current and potential future impacts of the agriculture on the environment and biodiversity. The case studies, further highlight the need to strengthen conservation efforts in the agriculture sector.

4 Conclusion

Over the past three decades, the Indian economy has grown substantially making India the sixth largest economy in the world, in terms of nominal GDP. Though the agricultural sector has declined in relative importance, it remains the mainstay of the economy and among the key driver of Indian economic growth. However, on the one hand India's agriculture sector has a large environmental footprint and a key threat to biodiversity loss and climate change. On the other hand, climate change is also becoming a serious threat to its agriculture sustainability.

Presently, **agriculture in India is facing the critical challenge of feeding an escalating human population (1.25 billion) under increasingly declining soil quality, land and water scarcity and changing climatic conditions.** Although India is undertaking many steps to halt and reverse the

pressures on the environment and biodiversity arising from the agri-food sector, there is a long road ahead to close the gap between aspiration and application. The case studies investigated reveal the potential for complex trade-off between social- economic and environmental objectives in the Indian agri-food systems. Research into this area is still evolving, with an evaluation of possible trade-offs mainly focused at farm level. More comprehensive analysis of potential social- economic and environmental trade-offs is generally constrained by the complexity of the agri-food value chains and data availability.

However, an understanding of these trade-off is crucial for the effective implementation of the Indian Government sustainable agriculture initiatives. **The UN Environment TEEB project on “Promoting biodiversity and sustainability in the agriculture and food sector in India”** complements the Government green growth initiatives by **highlighting several trade-offs made in land-use decisions and mainstreaming the values of biodiversity and ecosystem services values in decision-making.**

References

- Acharya, S. S. (2009). Food security and Indian Agriculture: Policies, production performance and marketing environment. *Agricultural Economics Research Review*, 22(1), 1-19.
- Agri-farming. (2018). Jute cultivation information detailed guide. <http://www.agrifarming.in/jute-cultivation/>.
- Aneja, V. P., Schlesinger, W. H., Erisman, J. W., Behera, S. N., Sharma, M., & Battye, W. (2012). Reactive nitrogen emissions from crop and livestock farming in India. *Atmospheric environment*, 47, 92-103.
- Anil, M. N. V., Kumari, K., & Wate, S. R. (2014). Loss of biodiversity and conservation strategies: An outlook of Indian scenario. *Asian Journal of Conservation Biology*, 3(2), 105 –114.
- Arora, S. (2016). Convention on biological diversity, biological diversity act and related issues. <http://www.moef.gov.in/sites/default/files/Biological%20Diversity.pdf>.
- Arora, V. P. S. (2013). Agricultural policies in India: Retrospect and prospect. *Agricultural Economics Research Review*, 26(2), 135-157.
- Batar, A. K., Watanabe, T., & Kumar, A. (2017). Assessment of land-use/land-cover change and forest fragmentation in the Garhwal Himalayan Region of India. *Environments*, 4(2), 1-16.
- Belluscio, A. (2009). Planting trees can shift water flow, in: Nature (Ed.), Nature. Nature, <http://www.nature.com/news/2009/091107/full/news.2009.1057.html>.
- Central Statistics Office. (2017). Statewise and item-wise estimates of value of output from agriculture and allied sector, http://www.mospi.gov.in/sites/default/files/publication_reports/State-wise_Agri_Allied_Sector_GVO_2011-12_to_2014-15.pdf.
- Chaudhary, A., & Kastner, T. (2016). Land use biodiversity impacts embodied in international food trade. *Global Environmental Change*, 38, 195-204.
- CIA. (2017). The world factbook. Retrieved from <https://www.cia.gov/library/publications/the-world-factbook/geos/id.html>
- Deshpande, T. (2017). State of agriculture in India, <http://www.prsindia.org/uploads/media/Analytical%20Report/State%20of%20Agriculture%20in%20India.pdf>.
- European Commission. (2016). The hidden biodiversity impacts of global crop production and trade. . *Science for Environmental Policy*(461), 1-2.
- FAO. (2011). Mapping supply and demand for animal-source foods to 2030, by T.P. Robinson & F. Pozzi. Animal Production and Health Working Paper. No. 2. Rome. <http://www.fao.org/docrep/014/i2425e/i2425e00.pdf>.
- FAO. (2015). Statistical pocketbook, <http://www.fao.org/3/a-i4691e.pdf>.
- FAOSTAT. (2018). Data, <http://www.fao.org/faostat/en/#data>.
- Gathorne-Hardy, A. (2013). *A life cycle assessment of four rice production systems: High yielding varieties, rain-fed rice, system of rice intensification and organic rice*. Paper presented at the Technology, jobs and a lower carbon future: Methods, substance and ideas for the informal economy (the case of rice in India), New Delhi, India.
- Gilmour, B. W. (2008). India agricultural policy review. *Agriculture and Agri-Food Canada*, 4(3), 1-5.
- Government of India. (2007). National policy for farmers. <http://agricoop.nic.in/sites/default/files/nppf2007%20%281%29.pdf>
- Government of India. (2008). National action plan on climate change. <http://www.moef.nic.in/downloads/home/Pg01-52.pdf>.
- Government of India. (2010). India: Greenhouse gas emissions 2007. http://www.moef.nic.in/downloads/public-information/Report_INCCA.pdf.
- Government of India. (2011). Faster, sustainable and more inclusive growth: An approach to the twelfth five year plan. http://planningcommission.nic.in/plans/planrel/12appdrft/appraoch_12plan.pdf.

- Government of India. (2013). National livestock policy, 2013. <http://www.indiaenvironmentportal.org.in/files/file/NLP%202013%20Final.pdf>.
- Government of India. (2014a). National agroforestry policy. http://www.cafri.res.in/NAF_Policy.pdf.
- Government of India. (2014b). National biodiversity action plan. <https://www.cbd.int/doc/world/in/in-nbsap-v3-en.pdf>
- Government of India. (2015). Fertilizer policy. <http://fert.nic.in/page/fertilizer-policy>.
- Government of India. (2017). Annual report 2016-2017, Department of Agriculture, Cooperation & Farmers Welfare, http://agricoop.nic.in/sites/default/files/Annual_rpt_201617_E.pdf.
- Halder, N. (2016). Paddy field of west bengal, India. <https://www.youtube.com/watch?v=t62LH3VYEEY>.
- IBEF. (2018). Agriculture in India: Information about indian agriculture & its importance, <https://www.ibef.org/industry/agriculture-india.aspx>.
- Indian Agricultural Research Institute. (nd). Agriculture policy: Vision 2020. http://www.planningcommission.nic.in/reports/genrep/bkpap2020/24_bg2020.pdf.
- Intercooperation in India. (2008). Livestock in the changing landscape in India: Its environmental, social and health consequences and responses, Working paper 6. <http://www.intercooperation.org.in/wp-content/themes/IC/images/Livestock%20in%20the%20changing.pdf>.
- Joshi, M., Frame, D., Hawkins, E., Sutton, R., & Lowe, J. (2011). Projections of when temperature change will exceed 2 degrees C above pre-industrial levels. *Nature Climate Change*, 1(407-412).
- Kareemulla, K., Rizvi, R., Kumar, K., Dwivedi, R., & Singh, R. (2005). Poplar agroforestry systems of Western Uttar Pradesh in northern India: A socio-economic analysis. <file:///C:/Users/lenam/Downloads/ForestsTreesLivelihoods2005.pdf>.
- Kumar, U., & Asija, M. J. (2000). Biodiversity conservation. In *Biodiversity: Principles and conservation*. Jodhpur: Agrobiosis (India).
- MacDonald, M., & Iyer, S. (2012). Veg or non-veg? India at the crossroads, Brighter Green. http://www.brightergreen.org/files/india_bg_pp_2011.pdf.
- Ministry of Textiles. (2018). State wise production & raw jute. <http://jutecomm.gov.in/statewise%20P%20&%20R%20jute.htm>
- Misra, A. (2014). Agro-forestry, key for achieving one third area under forests and tree cover: Punjab scenario. http://www.teriuniversity.ac.in/mct/pdf/new/assignment/Amit_Misra_Agroforestry_Punjab.pdf.
- MoEFCC, & GIZ. (2014). The economics of ecosystems and biodiversity TEEB India initiative: Interim report - Working document. 92p. <https://www.giz.de/en/downloads/giz2015-en-ecosystems-biodiversity-interim-report-india.pdf>.
- National Dairy Development Board. (2018). Milk production by states. <http://nddb.coop/information/stats/milkprodstate>.
- Negi, V. S., Pharswan, D., Thakur, S., Dhyan, P. P., & Maikhuri, R. K. (2017). Climate change impact in the Western Himalaya: people's perception and adaptive strategies. *Journal of Mountain Science*, 14(2), 403-416. doi:10.1007/s11629-015-3814-1
- Patra, A. K. (2014). Trends and projected estimates of GHG emissions from Indian livestock in comparisons with GHG emissions from world and developing countries. *Asian-Australasian journal of animal sciences*, 27(4), 592.
- Rahman, S. (2015). Green Revolution in India: Environmental degradation and impact on livestock. *Asian Journal Of Water, Environment And Pollution*, 12(1), 75-80.
- Ramakrishnappa, K. (2003). *Impact of cultivation and gathering of medicinal plants on biodiversity: case studies from India*. Paper presented at the Biodiversity and the ecosystem approach in agriculture, forestry and fisheries. Proceedings, Rome, Italy, 12-13 October 2002.

- Sharma, V. P., & Alagh, M. (2013). Food subsidy in India: Its components, trends, causes and reforms for public policy. *India Journal of Agricultural Economics*, 68(2), 195 - 221.
- Sheth, K. (2018). Top milk producing countries in the world. <https://www.worldatlas.com/articles/top-cows-milk-producing-countries-in-the-world.html>.
- Sing, R. B. (2000). Environmental consequences of agricultural development: A case study from the green revolution state of Haryana, India. *Agriculture, Ecosystems and Environment*, 82, 97-103.
- Singh, K., Hartley, S. E., Hill, J. K., McClean, C. J., & Buker, P. (2017). Mapping regional risks from climate change for rainfed rice cultivation in India. *Agricultural Systems*, 156, 76–84.
- Statista. (2018). Principal rice exporting countries worldwide in 2017/2018, <https://www.statista.com/statistics/255947/top-rice-exporting-countries-worldwide-2011/>.
- Statistics Times. (2018). India. <http://statisticstimes.com/index.php>.
- UNDP. (2008). Biodiversity conservation, land use, land use change and forestry (LULUCF) programmes: Ideas for implementation. file:///C:/Users/lenam/Downloads/biodiversity_conservation_land_use_land_use_change_and_forestry.pdf.
- UNEP. (2016). Loss and damage: The role of ecosystem services. https://uneplive.unep.org/media/docs/assessments/loss_and_damage.pdf.
- USDA. (2018). Grain: World markets and trade, <https://apps.fas.usda.gov/psdonline/circulars/grain-rice.pdf>.
- World Bank. (2011). Environmental management in India. http://web.worldbank.org/archive/website01291/WEB/0__CO-15.HTM.
- Zomer, R. J., Bossio, D. A., Trabucco, A., Yuanjie, L., Gupta, D. C., & Singh, V. P. (2007). *Trees and water: smallholder agroforestry on irrigated lands in Northern India*. Retrieved from <https://ageconsearch.umn.edu/bitstream/53067/2/RR122.pdf>