Working Paper

DEFORESTATION, DESERTIFICATION AND LAND DEGRADATION

IS IT TIME FOR A UNIFIED LAND-BASED CARBON SINK MECHANISM?

Chandra Bhushan and Tarun Gopalakrishnan

INTRODUCTION

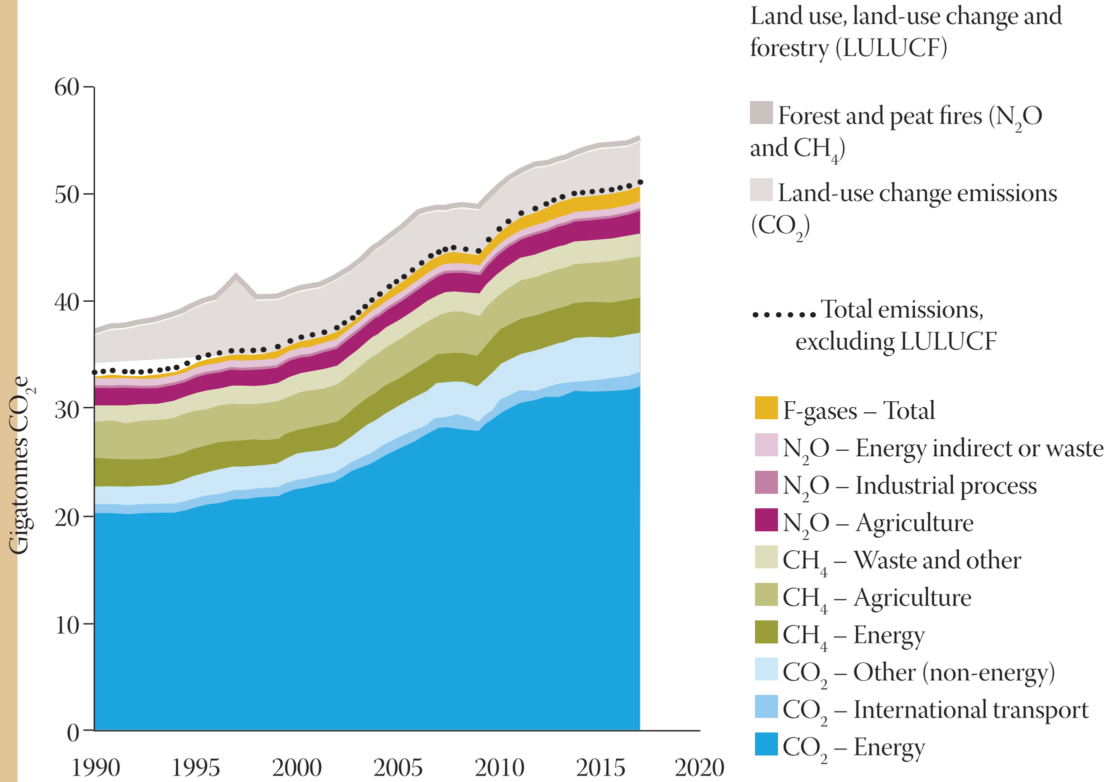
Desertification, deforestation and climate: Nature of the problem

The land, land-use change and forestry (LULUCF) sector is a key driver of climate change. In 2017, it accounted for around 5 billion tonnes of carbon dioxide-equivalent (CO_2e) in emissions. All other sectors contributed about 50 billion tonnes of CO_2e emissions in the same year.[1] Clearly, LULUCF represents a significant chunk of total emissions.

Forests are a key component of the global carbon cycle. They sequester carbon in regrowth forests, thereby reducing atmospheric carbon; and emit it when deforestation and degradation happens, thus increasing atmospheric carbon. The balance of this cycle is threatened by a global trend towards deforestation, which is particularly pronounced in the tropics.

Deforestation and forest degradation account for approximately 17 per cent of carbon emissions, more than the entire global transportation sector and second only to the energy sector.[2] Tropical forests are spread over about 15 per cent of the world's land surface and contain about 25 per cent of the terrestrial biosphere carbon.[3] Between 1990 and 2015, the world lost 129 million hectares of tropical forest—nearly 6.5 million hectares annually.[4] Between 2015 and 2017, annual gross carbon dioxide emissions from tree cover loss in tropical countries averaged 4.8 billion tonnes per year. That is significantly worse than the already poor performance over the previous decade—between 2001 and 2014, the same figure averaged 2.9 billion tonnes per year.[5]

Graph 1: Global green house gas emissions, per type of gas and source, including LULUCF



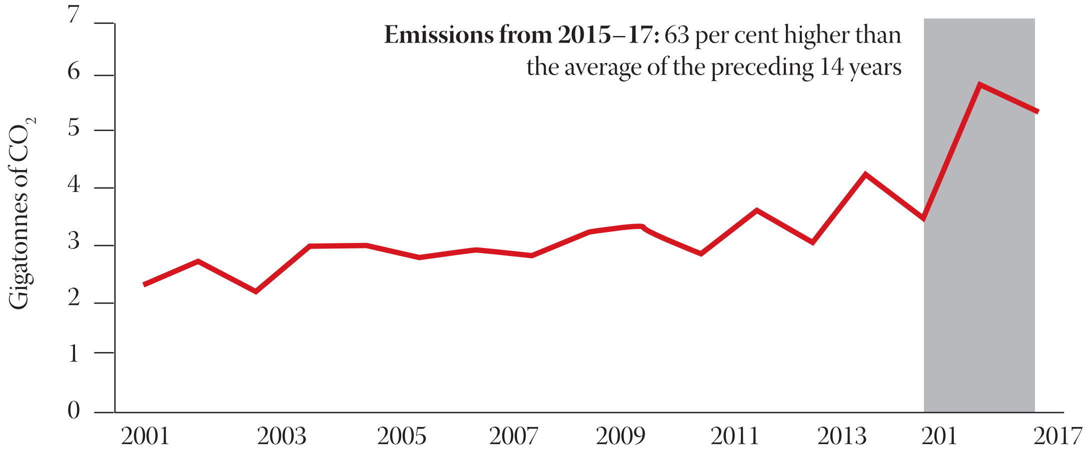
Source: Oliver and Peters, 2018

At this rate, we will lose another 289 million hectares of forest by the year 2040, resulting in 169 billion additional tonnes of carbon dioxide emissions, unless concerted efforts are made to reduce deforestation.[6]

Carbon is also sequestered by the soil, which soaks up carbon from dead plant matter. Plants absorb CO_2 from the atmosphere through photosynthesis, and pass a part of this carbon to the ground when dead roots and leaves decompose. One estimate indicates that around 133 billion tonnes of soil carbon has been lost since the dawn of agriculture.[7] A significant portion of this loss is due to unsustainable land practices which degrade the quality of soil.

An area of around 2 billion hectares of land has been degraded globally; approximately 12 million additional hectares of land are degraded every year.[8] The Intergovernmental Panel on Climate Change (IPCC) found that 6.1 per cent global land area experienced very high soil erosion rates (exceeding 10 tonnes per hectare per year) in 2012, with Africa, Asia and South America the worst affected. It also highlighted the critical need for improved estimation and mapping of areas undergoing desertification.[9]

Graph 2: CO_2 emissions from tropical tree cover loss



Source: David Gibbs et al., 2018

While the discussion around climate and land tends to focus on afforestation and agriculture, drylands are a somewhat overlooked part of the challenge. Drylands cover about 40 per cent of the Earth's land surface (excluding Antarctica and Greenland) and are home to more than two billion people. They are susceptible to desertification, land degradation and drought. Their populations, agriculture and ecosystems are very vulnerable to climate change and variability.[10]

The IPCC indicates that arid ecosystems store between 240 to 470 billion tonnes of carbon and could be an important global carbon sink, depending on soil-water availability.[11] Globally, plant biomass per unit area of drylands is only about 6 kilograms per square meter, which is low compared to 10–18 kilograms in many terrestrial ecosystems. However, drylands cover a large surface area of the globe and total dryland soil organic carbon reserves comprise 27 per cent of the global soil organic carbon reserves.[12]

Carbon sequestered in these soils is being lost, but at an uncertain rate. One estimate indicates 18 to 28 billion tonnes of sequestered carbon historically lost to desertification and degradation in dryland areas (0.2 to 0.3 billion tonnes of carbon, or 0.7 to 1.1 tonnes of CO_2e per year). It also indicates that about two-thirds of this total could be re-sequestered with the appropriate land use policies.[13] In addition, the degraded state of many dryland soils means that their potential to sequester carbon may be very high. This is of particular interest to India—South Asia has one of the highest percentages of carbon stocks held in drylands.[14]

India currently suffers from a land degradation problem cutting across soil types. Around 30 per cent of the country's geographical area (approximately 96 out of 278 million hectares) is either degraded or facing desertification. Twenty-six of 29 Indian

Table 1: Comparison of total and drylands carbon stocks in regions of the world

Map number	Region	Total carbon stock per region (Gt)	Carbon stock in drylands (Gt)	Share of regional carbon stock held in drylands (percentage)
1	North America	388	121	31
2	Greenland	5	0	0
3	Central America and Caribbean	16	1	7
4	South America	341	115	34
5	Europe	100	18	18
6	North Eurasia	404	96	24
7	Africa	356	211	59
8	Middle East	44	41	94
9	South Asia	54	26	49
10	East Asia	124	41	33
11	South East Asia	132	3	2
12	Australia and New Zealand	85	68	80
13	Pacific	3	0	0
Total		2,053	743	36

Source: Kate Trumper et al., 2008, Carbon in Drylands: Desertification, Climate Change and Carbon Finance

states have reported an increasing rate of desertification in the past decade.[15] In China, it is estimated that around 855.45 million tonnes of carbon are stored in the 0–50 cm depth across different types of desertified land. The total net emission from desertified land in China in the past four decades is approximately 333 million tonnes of CO_2e.[16]

Forestry and desertification are a critical part of keeping the planet under 1.5°C of warming since the industrial era. IPCC's report on the subject highlighted the indispensability of carbon removal as part of all 1.5°C-consistent pathways. While some have interpreted this as a call for carbon-removal technology, the IPCC is clear about the significantly better carbon sequestration potential of land-use policy.[17]

By 2030, it projects that better land use approaches could sequester up to 5 billion tonnes of CO_2e each year, which is better than the potential 1 billion tonnes offered by bio-energy carbon capture and storage (BECCS) technology. By 2050, land use could sequester up to 11 billion tonnes per year, compared to eight billion tonnes by BECCS.[18] Besides, while bio-energy proposals demand significant amounts of land, threatening adverse effects for climate adaptation, desertification, land degradation and food security, better land-use policies have generally high co-benefit potential on the same fronts.[19]

The limitations of current global mechanisms

International funding to address these priorities has been scarce. Reducing emissions from deforestation and forest degradation (REDD+) is a mechanism developed by Parties to the United Nations Framework Convention on Climate Change (UNFCCC). It offers results-based payments for developing countries to reduce emissions from forested lands and invest in low-carbon pathways to sustainable development.

The mechanism has not raised enough finance—global aggregate pledges and investments for REDD+ totalled more than US $9.8 billion from 2006–14. This compares unfavourably with the estimates of finance required to avoid deforestation, which range from US $5 billion to US $28 billion each year.[20] Worse, REDD+ payments are made after the carbon benefits are verified, which means that countries have to invest upfront in these programmes with uncertain returns.

For communities, REDD+ funded projects also involve large upfront opportunity costs that are not taken into account. In India, the minimum carbon price needed to transition away from fuel-wood is US $22.6 per tonne of CO_2e. Voluntary markets offer only US $4.5 per tonne, and REDD+ projects in developing countries struggled to find buyers even at that price.[21]

REDD+ incentivizes GHG emissions reduction in forests, but not other types of benefits that forests provide. This failure to emphasize co-benefits results in unsustainable projects that 'often disrupt local peoples' livelihoods and strategies, institutions and socio-cultural systems', including through 'unequal benefit-sharing, food insecurity, introduction of new powerful stakeholders, illegal land acquisition, unfair free prior and informed consent, and the introduction of monoculture plantations.'[22] The first set of REDD+ guidelines, adopted in Warsaw in 2013, are not rigorous in their approach to safeguards, preferring to defer to what governments are reporting, and leaving communities unprotected.

By allowing tradable credits to be generated for the forestry sector, REDD+ has the potential to generate 'cheap' low-integrity mitigation, which allows developed countries to avoid the fundamental transformation required in their economies.[23] As a 'voluntary' mechanism, it also encourages avoidance of developed countries' responsibility to provide finance.

At Cancun in 2010, it was decided that REDD+ finance could come from a variety of sources, public and private, bilateral and multilateral, including alternative sources. This has resulted in a proliferation of donor and funding agencies, all applying their own sets of safeguards and standards with limited coordination.

The criticism regarding low-integrity credit generation was also leveled at the Clean Development Mechanism (CDM)—a market mechanism preceding REDD+—which was set up under the Kyoto Protocol. While land use proposals were initially excluded from it, a limited subset of forestry proposals (afforestation/reforestation or 'A/R') were later included in the CDM.

Their inclusion resulted in the creation of some of the cheapest certified emissions reductions (CERs) available, estimated to require an investment of around US $10 per tonne of CO_2e—significantly cheaper than sectors such as wind (closer to US $per tonne) and solar (US $per tonne).[24]

This was despite the imposition of a cap on the use of CDM forestry sink projects by developed countries to fulfill their emissions reduction commitments. This was also despite the exclusion of the 'avoided deforestation' sector which, based on evidence from voluntary markets, has the potential to generate even cheaper offsets (estimated at US $5.2 per tonne of CO_2e versus US $ 7.7 per tonne of CO_2e for the A/R sector).[25]

Other international institutions have also made contributions to land-based sink enhancement. The Global Environment Facility (GEF) approved US $179 million in new finances 2019 to support projects focused on biodiversity conservation, trans-boundary water resources management, sustainable land management, highly hazardous pesticide remediation, and climate change adaptation. US $44 million will flow through the Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF) to climate adaptation projects focused on agriculture.[26]

The Land Degradation Neutrality (LDN) Fund, set up under the UN Convention on Combating Desertification (UNCCD), is well on its way to an initial capitalization target of US $300 million. This has come from voluntary pledges by a variety of contributors, including the European Investment Bank; Agence Française de Développement, Fondaction, a retirement savings plan by workers in Quebec; Fondation de France; and BNP Paribas Cardif. The LDN Fund is also looking to leverage its stake in an impact investing firm to direct €1 billion toward its aims by 2022.[27] These figures must be set in the context of the challenge, however, addressing the land degradation problem will require US $450 billion each year.[28]

The emerging picture is of a shortage in finance to address the scope of the sink enhancement challenge. This is true particularly of traditional fund-based mechanisms. On the flip side, innovative instruments that boast of strong potential to raise funds (such as markets or results-based payments) end up sidelining communities, worsening existing inequities, and failing to deliver sustainable carbon sequestration benefits.

There is a continuing separation of international action on desertification, agriculture and forests. The UNFCCC (through REDD+ covers forests) the FAO and GEF collaborate on agriculture, while the UNCCD has just started to raise significant money targeting deserts. There are narrow areas of technical overlap, such as on agro-forestry and dryland agriculture, or the emerging technical understanding of forests-in-deserts.[29] However, a policy (and financial) approach which addresses these sectors as an integrated land-based carbon sink is missing.

Land-based sink targets in Nationally Determined Contributions

Despite the shortage in finance, countries are moving forward with afforestation and sustainable land management initiatives at the national level. Evidence of this is found in their first Nationally Determined Contributions (NDCs) to the UNFCCC.

Agriculture and LULUCF are among the most frequently included sectors in countries' mitigation contributions (targets and actions), finding mention in 89 per cent of NDCs (92 per cent if bio-energy is included). LULUCF has been made part of mitigation contributions by 157 countries, including 80 per cent of developing countries, 75 per cent of countries whose economies are in transition and 98 per cent of developed countries. Countries that include agriculture collectively account for 92 per cent of global agricultural GHG emissions.[30]

This promising trend is somewhat offset by the fact that countries rarely include quantified sector-specific targets for agriculture and LULUCF. However, forestry is the second most-referenced sector for non-GHG targets (i.e., targets that are not described in tonnes of greenhouse gas).[31]

Several countries include specific policies and measures when outlining how to achieve their intended mitigation contributions. For agriculture and LULUCF, these focus on cropland, livestock and grazing land management; and forest management and restoration, A/R, and reducing deforestation.[32]

The full implementation of announced NDCs is estimated to turn the LULUCF sector globally from a net source (emitting between 0.2 and 2.4 billion tonnes of CO_2e per year) during 1990–2010, to a net sink (that could sequester between 0.6 and 1.6 billion tonnes per year) by 2030.[33] This is significant, but does not yet match the 5 billion tonne target required to stay under the 1.5°C threshold as indicated by the IPCC.

The specifics of countries' commitments indicate the significant uncertainties that remain regarding the sequestration potential of land-based sinks. Canada states that it will use a 'production approach' to account for harvested wood products, but does not clarify what this means. The European Union commits to integrate LULUCF into its 2030 greenhouse gas mitigation framework, but only when 'technical conditions allow'.[34]

Sustainable land management approaches

Land development policies have a long history, but the shift toward sustainable land management (SLM) is a relatively recent one. A definition developed at the 1992 Earth Summit identifies SLM as 'the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions.'[35]

Broadly speaking, the common principles of SLM are:

(1) Understanding the ecology of land use management

(2) Maintaining or enhancing productivity

(3) Maintaining soil quality

(4) Increasing diversity for higher stability and resilience

(5) Providing economic and ecosystem service benefits for communities

(6) Social acceptability[36]

Examples of policy approaches that embody these principles include agro-forestry, precision agricultural systems and conservation agriculture. In addition, SLM principles can be mainstreamed into long-standing land development initiatives such as watershed development.

India's new agro-forestry policy seeks to direct US $40 million towards the strategy, aiming to significantly add to the 13.5 million hectares of land already under agro-forestry (which generates 450 employment-days per hectare each year).[37] The soil health card scheme, introduced in 2015, consists of three steps: Collecting a soil sample, testing the sample and distributing cards bearing soil health indicators to farmers. Thus far, it has spent around Rs 406 crore to print around 171 million soil health cards.

In Kenya, the government aims to convert 20 per cent of its rain-fed agricultural croplands away from full tillage. Out of the country's 9.5 million hectares of rain-fed agricultural cropland, about 25 per cent is fully tilled. Kenya aims to convert 475,000 hectares to conservation tillage over ten years. In addition, the practice of using fire to manage rangelands and crop resides is common, with over 430,000 hectares of rangeland and 2.3 million hectares of crop reside burned each year. This results in approximately 1.2 million tonnes of CO_2e emitted per year—Kenya aims to eliminate 60 per cent of this within 10 years.[38]

CARBON BENEFITS OF LAND IMPROVEMENT INITIATIVES IN INDIA: SOME CASE STUDIES

The success of these sustainable land management approaches is highly context-specific. The range of techniques employed could have co-benefits for (or adverse impacts on) the global climate. Systematic evaluation of the climate impacts of land and water development schemes is still nascent.

Such evaluation is important for two reasons. Firstly, if such programmes have climate benefits, they are benefitting a global commons. They should be supported by climate finance from across the world, particularly from developed countries. Secondly, where some techniques of land restoration generate better climate benefits than others, climate finance needs to support the right techniques, and create disincentives for those with adverse climate impacts.

To that end, we review land improvement programmes in two districts of India. The land in both these districts was (and, to an extent, is) severely degraded. Both districts have been targeted by schemes of the Indian government intended to improve water access and soil productivity. Both are considered to be 'successful' interventions with positive socio-economic results. Neither district (or programme) has been systematically evaluated for economic benefits from soil-based carbon sequestration.

Watershed development in Jhabua

Introduction to area and policy

Jhabua is a predominantly rural district in Madhya Pradesh, home to a significant indigenous tribal population. It is located in a semi-arid region historically vulnerable to drought. Starting in 1994, it was one of the districts targeted for action under the Central government's expanded Drought Prone Areas Programme.

It has since also been targeted under the Integrated Wasteland Development Programme and the Rajiv Gandhi Mission for Watershed Management. All these initiatives have now been harmonized by the Central government's Ministry of Rural Development under the framework of the National Watershed Development Programme (NWDP). The NWDP takes a more holistic 'watershed' approach where earlier initiatives were focused on administrative units.

Starting in 2007, watershed development has been linked with the Mahatma Gandhi National Rural Employment Guarantee (MGNREGA) scheme (an employment generation policy later formalized as an Act of Parliament). In 2017, 35,000 labourers were employed in watershed development projects, including to build hundreds of ponds.

Socio-economic impact

Reports from Madhya Pradesh are mixed—one review by Central government's Centre for Rural Studies found that '[i]n Madhya Pradesh, the quality of water harvesting structures in majority of watersheds (92 per cent) was found to be either satisfactory or good. About 5.3 per cent of watersheds are found to be very good. However, maintenance is poor during post implementation. The management of activities after implementation is found to be weak in many watersheds.'[39]

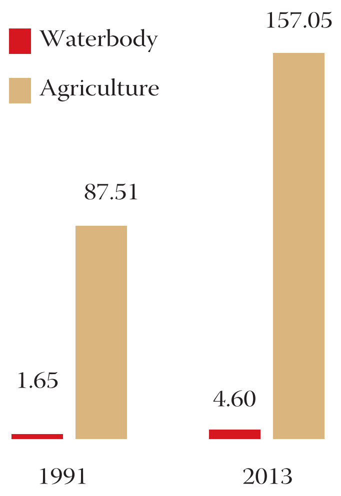
This was echoed by a report submitted to the National Institute for Rural Development which showed that 'most projects have performed in the average [category] and only around 30 per cent projects could be termed "poor"', but also highlighted the unsatisfactory performance in terms of social and participatory aspects, institutional arrangements at the local level, management of non-private resources, enhancement of diversified production and maintenance of assets.[40]

Jhabua was regularly referenced positively in the report, especially in terms of social impact. Jhabua reported among the better scores for improvements in labour opportunities, and among the best scores for improvements in household-level social indicators as well as creation and management of common property resources. This is allied to good scores across the more ecologically-focused indicators such as (reduction in) soil erosion and (increase in) cropping intensity.

This is not surprising—since at least 1998, when Centre for Science and Environment (CSE) first visited the district, it has been clear that Jhabua is one of the highlights of drought-resilience development in the country. This is in part because of the government's policy interventions, but equally because of 'three key ingredients that are missing in most government programmes: Political will, competent and committed bureaucratic support, and people's participation.'[41]

Nearly two decades later, Jhabua's status as a model district endures, despite other formerly model districts (such as Sukhomajiri in Haryana) failing to sustain their initial potential. In the year 2015-16, when the region was hit by a rainfall deficit of nearly 50 per cent and 42 of Madhya Pradesh's 51 districts (including Jhabua) were declared drought-hit, Jhabua's groundwater development tided it over a potential crisis.[42]

Graph 3: Areal change, water bodies and irrigated agriculture land in the study area*



** Based on IRS LISS II (1991) and IRS LISS III (2013) images*

Source: Arunima Dasgupta et al., 2015, Case Study, Jhabua, Madhya Pradesh

Watershed Development Programmes

The Department of Land Resources under the Ministry of Rural Development is administering three area-based watershed programmes for development of wastelands or degraded lands, namely Drought Prone Areas Programmes (DPAP), Desert Development Programme (DDP) and Integrated Wastelands Development Programme (IWDP) to check diminishing productivity of wasteland and loss of natural resources.

The DPAP was launched in 1973–74 to tackle the special problems faced by areas that are constantly afflicted by drought conditions. Presently, 972 blocks of 195 districts in 16 states are covered under the programme. DDP was launched in 1977–78 to mitigate the adverse effects of desertification. Presently, 235 blocks of 40 districts in seven states are covered under the programme. IWDP has been under implementation since 1989–90. The projects under the IWDP are generally sanctioned in areas that are not covered under DDP or DPAP.

Since 1 April 1995, these three programmes are being implemented on the basis of the Common Guidelines for Watershed Development.

Table 2: Details of projects sanctioned and funds released from 1995–96 to 2007–08

Name of scheme	Number of project sanctioned	Area covered (in lakh hectare)	Funds released by the Central government (in Rs crores)
DPAP	27,439	130.20	2,838
DDP	15,746	78.73	2,103
IWDP	1,877	107.0	2,798
Grand Total	45,062	322.93	7,739

Projects under DPAP and DDP are sanctioned for 500 hectares each while IWDP projects cover an area of 5,000–6,000 hectares each. Cost norms for all three schemes have been revised to Rs 6,000 per hectare. Under DPAP and DDP, the cost is shared between the Centre and the states in a ratio of 75:25. In case of IWDP, cost sharing between the Central and state governments is in the ratio of 11:1.

Funds are released in seven installments, six installments at the rate of 15 per cent and the last installment at the rate of 10 per cent. The first installment is released along with the initial sanction-order and subsequent installments on receipt of utilization for 50 per cent of the available funds as well as the following documents:

- Quarterly progress reports
- Utilization certificates
- Audited statement of accounts for the previous years
- Evidence of satisfactory completion of institutional arrangements

The track record of these initiatives has been mixed. A 2007 evaluation of watershed management in Gujarat found that 'the performance under these schemes has so far been not satisfactory', attributing it to: a) Lack of convergence of other rural and agriculture development programmes at the ground level
b) Isolated and disjointed manner of implementation
c) Failure of proper management due to lack of inter-departmental coordination
d) Projects under these programmes becoming too large to handle over the years
e) Large-scale malpractices

It noted, however, that projects under the supervision of NGOs and local community-based organizations showed some positive results in reducing the impact of drought in the state and particularly highlighted the work done by the Kutch Mahila Vikash Sangathan during 2003–04.

Sources: Government of India, National Watershed Development Programme, Anil Kumar Roy and Indira Hirway, 2007, Multiple Impacts of Droughts and Assessment of Drought Policy in Major Drought Prone States in India

A *Down To Earth* report in 2017 described the district thus:

'The villages, scattered along the hill slopes and nestled in the valleys, resemble an oasis in the barren landscape of southwestern Madhya Pradesh. Contour trenches, up to three-metre deep, crisscross the slope of almost every hill in sight, while check dams dot the streams and the Nugami, the only river flowing through the district. The once denuded hill tops and slopes remain covered by mixed-species plantations. All the 818 villages in the district have ponds and dugwells that yield water round the year.'[43]

Carbon sequestration estimate

Less appreciated are the climate or non-local positive externalities generated by this watershed success story. A 2015 case study used geo-spatial technology to assess the impact of these programmes in Jhabua (and the neighbouring district of Dhar), found significant increases in the area taken up by irrigated agriculture and by water bodies.[44]

The study noted that between 1991 and 2013, the number of water bodies increased from about 103 to 270 and the average area of a water body increased from about 1.65 to 4.6 sq km. That makes for a total of 493 sq km (49,300 hectares) of additional area under water bodies in those 22 years, or 22.4 sq km (2,240 hectares) of water body added each year, on average. In the same time period, the area under irrigated agriculture increased from about 87.5 sq km to about 157 sq km. That amounts to about 0.08 sq km (or eight hectares) of land brought under irrigated agriculture each year.

Water conservation (through creating new water bodies and expanding existing ones) in such regions has positive carbon sequestration potential. A 2018 study estimated carbon sequestration potentials for various land and water development activities carried out under the National Rural Employment Guarantee Scheme (now Act).[45] To do so, it divided the country into Agro-Ecological Regions (AERs). Jhabua falls in AER5, the 'Hot Semi-Arid Eco-region with Medium and Deep Black Soils'. The carbon sequestration potential of land and water development activities in AER5 is captured in *Table 3: Average area impacted by MGNREGA–NRM works in different AERs and average biomass and soil carbon sequestration rates (tC/ha/yr) for each work.*

The potential of sequestration from water conservation and harvesting is estimated at 1.64 tonnes of carbon per hectare per year. Combining that with the 2,240 hectares of land brought under water bodies (i.e., water conservation activities) each year between 1991 and 2013, the cumulative amount of carbon sequestered amounts to 7.4 million tonnes (or approximately 27 million tonnes of CO_2e).

The cost of all projects under the Watershed Development Programme between 2001 and 2011 were standardized at Rs 6,000 per hectare. Adjusting for rupee inflation since 1991, the cost of developing an additional 49,300 hectares of water bodies is approximately

The Indira Gandhi Canal System

The Indira Gandhi Canal is aimed at reclaiming the Thar Desert and checking desertification of fertile areas, especially in Western Rajasthan. The Indira Gandhi Nahar Pariyojana (IGNP) was sanctioned in 1957, after the negotiation of a water-sharing treaty between India and Pakistan, under which Rajasthan was allotted 8 million-acre feet (MAF) of Ravi–Beas basin water. The allotment later rose to 8.6 MAF.

The canal system starts at the Harika barrage in Punjab at the confluence of the Sude and Beas rivers in the foothills of the Himalayas. The main canal, which traverses the districts of Ganganagar, Bikaner and Jaisalmer, has a total length of 445 km with 204 km of feeder canal (the Rajasthan feeder canal). Despite traversing 150 km of Punjab and 19 km of Haryana, the feeder canal does not irrigate any land until the Masitawali Head in northern Rajasthan, where it releases about 523.93 cusecs of water to the main canal. The main canal is 40.8 metres wide at the bottom and 6.4 metres deep. The discharge at the head of the main canal is 18,500 cusecs. The first water from the canal was released on 11 October 1961.

The IGNP canal system is divided into two stages: Stage I covers northeastern areas (from Harika barrage to Pungal in Bikaner); Stage II covers southwestern areas (from Pungal to Mohangarh in Jaisalmer). The total cultivable command area for the completed project is estimated at 1.48 million hectares. The total expenditure on completion is estimated at about Rs 2,900 crore.

Table 3: Average area impacted by MGNREGA–NRM works in different AERs and average biomass and soil carbon sequestration rates (tC/ha/yr) for each work

AERs	MGNREGA works	Average area per work (hectare)	Carbon (tC/ha/year)		
			Soil	Biomass	Total
AER5	Land development	2.28	1.06		1.06
			-0.88		-0.88
	Drought proofing	1.80	0.56	1.05	1.61
	Minor irrigation works	0.66	-0.66		-0.66
			0.08		0.08
	Water conservation and harvesting	0.71	1.64		1.64

Source: N.H. Ravindranath and Indu K. Murthy, 2018, Estimation Of Carbon Sequestration Under MGNREGA : Achievement And Potential in India

Rs 82 crore (over 22 years)—i.e., Rs 30 per tonne of CO_2e. In comparison, the price of carbon offsets transacted on voluntary carbon markets in January–March 2018 was US $2.4 per tonne of CO_2e (or Rs 172 at present exchange rates).[46]

If we take that price as an indicator of the economic value of carbon sequestration, land use modification in Jhabua has generated around Rs 464 crore of present value. If we take the social cost of carbon for India (US $86 per tonne of carbon dioxide, or approximately Rs 6,170 at present exchange rates)[47], the same land-use modifications have generated approximately Rs 16,659 crore of present value.

Shelter-belts in Jaisalmer

Introduction to area and policy

Jaisalmer is the largest district of Rajasthan, covering an area of 38,401 sq km. Located in the extremely hot arid part of India, it falls within the 'arid western plain' agro-climatic zone of the country. The district is also part of the Thar Desert, and features a dominant sandy terrain and climatically very low rainfall. There is an absence of any substantial vegetation cover and agricultural activities, coupled with high wind velocity, making the region prone to wind erosion and deposition form of degradation.

The district has been a focus of a long-running capital-intensive government project to expand the irrigated area in Rajasthan. The key feature of this project is the creation of the IGNP canal system. As part of a broader strategy to combat land degradation in the region, IGNP expenditures have extended to projects to improve soil quality and integrity. One of these initiatives is the planting of trees (known as 'shelter-belts') in areas highly sensitive to soil erosion, including the area around the developing canal system.

Socio-economic impact

The benefits of shelter-belts for agriculture are well known. They reduce wind velocities and consequently evapo-transpiration, preventing wind erosion. They correlate with higher yields, and provide shelter to livestock. They can change soil profile over time, adding to the leaf litter and increasing the level of humus. Around the canal area, shelter-belts have arguably contributed to increase in sown area as much as the canal itself—without the soil stability they provide, an increase in irrigated water supply would have converted the desert into quicksand.[48]

A 2016 study in Jaisalmer compared households near shelter-belts with those without; it found that input costs are less for both crops grown in the intervention areas. For the crop *guar*, shelter-belt farmers saved more than Rs 700 per hectare; among those growing *chana*, farmers with shelter-belts saved Rs 2,000, on average. Revenues and profits were also significantly (10 to 30 per cent) higher for both crops.[49]

An earlier study found similar effects on productivity and revenue for farmers, across *rabi* and *kharif* seasons. It found significant benefits in terms of extreme weather resilience—average losses in crop productivity from cold-waves was 17 per cent in shelter-belted areas (compared to 30 per cent on other farms). During heat-waves, shelter-belts reduced productivity losses over 30 per cent to about 12–16 per cent in summer and kharif seasons.[50]

In addition, shelter-belts provided significant additional income from tree produce—fuel wood, timber and fruits. The Forest Department, Jaisalmer estimated that 1,270

Table 4: The additional income generated from 15–20 years old shelter-belt plantations

Particular	Annual additional income (Rupees per farm of five hectare)	
	Dense	Partial
Fuel	30,000	18,000
Timer and fruits	7,500	7,000
Total	37,500	25,000

Source: R.S. Mertia et al., 2006, Impact of Shelterbelts in Arid Region of Western Rajasthan

quintals of fuel wood and 48.5 cubic metres of timber were produced in five forest ranges of the district during the year 2004. Additional income generated from older plants, in particular, was considerable.[51]

Finally, the afforestation work created employment opportunities for men and women, skilled and unskilled. Between 1990 to 2002, a total of 2.4 million person-days of employment were generated in Jaisalmer for execution of various plantation programmes along canals, roads, sand dunes, etc. The intervention also indirectly generated an increase in on-farm employment of between 107 per cent and 115 per cent per farm.[52]

Carbon sequestration estimate

These well known erosion-limiting attributes of shelter-belts imply the possibility of climate benefits, but no systematic assessment of their carbon sequestration impact has been undertaken.

A study of wind erosion in Jaisalmer approximated accumulated soil carbon loss from wind erosion at 45.9 kg (or 168 kg of CO_2e) per hectare per year.[53] Shelter-belt plantation along the IGNP canal in Jaisalmer covered an area of approximately 70,300 hectares.

This was achieved between 1990 to 2002, which amounts to 5858 hectares brought under plantation each year over a period of 12 years. The cumulative avoided CO_2e emissions from soil erosion over those 12 years is, therefore, around 359 million kg (35,900 tonnes).

Further, the carbon sequestered in shrub or tree biomass in Jaisalmer is estimated at between 0.6 and five tonnes per hectare.[54] At the point when the shelter-belts in Jaisalmer are fully mature, therefore, the total shrub or tree carbon sequestered will range between 154,800 to 1,290,000 tonnes of CO_2e.

The investment for afforestation around the canal totalled around Rs 170 crore in these 12 years, which amounts to Rs 655 crore when adjusted for inflation.[55] Based on the price of carbon offsets transacted on voluntary carbon markets in January–March 2018 (US $2.4 or Rs 172 at current exchange rates), land-use modification in Jaisalmer has generated between Rs 3–23 crore of present value.[56] If we take the social cost of carbon for India (US

$86 per tonne of carbon dioxide or, approximately, Rs 6,170 at current exchange rates)[57], the same land-use modifications have generated approximately Rs 118–818 crore of present (inflation-adjusted) value.

Takeaways from the cases

The picture presented here is of land improvement programmes in two districts with enormous carbon sequestration potential. This is over and above their well-documented direct socio-economic benefits. The takeaways from these cases are:

Need for systematic soil carbon monitoring

The estimate presented in the previous section are only the tip of the iceberg. In Jhabua, watershed development was not limited to creating water bodies, it included funding for updated agricultural techniques such as bunding, etc. In Jaisalmer, shelter-belts were not uniform—they were planted as part of farm and agricultural forestry, to stabilize dunes, lining road-sides, and as part of pasture development, among others—which will each have unique carbon sequestration effects that are not being regularly assessed.

Moreover, this estimate does not rely on actual measurements of soil carbon or avoided soil carbon loss. It relies on projections of per unit carbon sequestration potential of certain activities, if perfectly implemented. Although these programmes are generally considered to have achieved their land improvement targets in these districts, actual measurements of soil carbon before and after the intervention are desperately needed.

Replicate specific successes, avoid subsidizing failure

Most significantly, these estimates focus on activities that are generally known to have positive climate effects. Significant parts of these government programmes that have adverse effects—the Indira Gandhi canal, for example, has been criticized for destroying pre-existing common property resources,[58] and local bio-diversity.[59] The watershed programme has developed a reputation for being a top-down capital-intensive imposition;[60] in addition, projects are often left incomplete, worsening water availability, and huge sums are lost to corruption.[61]

It is important for any solution to emphasize the successful elements of these examples, and push for their replication elsewhere. The intervention in Jhabua has succeeded because of the participation of the local community, that has been made possible by the high density of NGOs and civil society organizations engaged on the ground. This represents a financial and capacity commitment which other districts have not seen. Supporting a top-down watershed development programme without investing in local participation would be a waste of climate finance.

The shelter-belt solution has worked in Jaisalmer, but the political will to implement it

Table 5: Sequestration of land improvement programmes in Jhabua and Jaisalmer

Area	Intervention	Investment per unit area	Carbon sequestration co-benefits	
			Low end (based on 2018 price of carbon in voluntary markets)	High end (based on social cost of carbon in India)
Jhabua (Madhya Pradesh)	Creation of water bodies under watershed development programme	Rs 16,600 per hectare	Rs 94,100 per hectare	Rs 33.8 lakh per hectare
Jaisalmer (Rajasthan)	Creation of shelter-belt alongside canal	Rs 93,000 per hectare	Rs 430–3,300 per hectare	Rs 17,000–1.2 lakh per hectare

Source: CSE analysis

at scale through the rest of the state is uncertain.[62] Even if approved, it will be a technically complex project which will need better financial and technical support to avoid the pitfalls that plagued the Green Wall endeavour in China.[63] Meanwhile, the Eastern Rajasthan Canal Project is gathering political momentum[64]. It remains to be seen whether water erosion, water-logging and soil alkalization that plagued the IGNP can be avoided under this project.[65] It is also unclear whether a shelter-belt approach will be part of this canal project. Without clarifications regarding these elements, climate benefits of such an initiative remain uncertain.

THE PROPOSAL: A NON-MARKET MECHANISM FOR DESERTIFICATION AND CLIMATE

The initiaves at Jabua and Jaisalmer have the potential to be replicated elsewhere to generate strong climate and socio-economic co-benefits, but only if they find the right kind of support. This means guaranteeing long-term consistent funding matching the technical challenge, while yielding political ownership to local communities. There are two models of funding currently, neither of which are capable of meet these needs.

The first is grant funding or international 'aid' for socio-economic development, with some tagging of activities as 'climate-friendly'. This international aid is inherently political and not a sustainable basis for long-term planning. In addition, the climate focus of such aid is often questionable, with activities tagged as climate-friendly even in the absence of any quantifiable deliverables on this front. These problems (and their solutions) are related—if tangible climate benefits are delivered, such finance is no longer aid, it is payment for ecosystem services. Revenues can serve as a basis for planning where charity cannot.

The second model is creating a 'market' for climate benefits—trading of standardized tradable instruments representing mitigated or avoided emissions. This model runs into enough trouble in 'easy' sectors (such as energy). In the case of carbon sinks, such as forests and land-use change, accounting methodologies are extremely unreliable and unsuited to standardization. A coal power plant in India can be compared like-for-like to one in Australia; this is not so for two units of land, even across districts of Rajasthan.

In addition, voluntary carbon markets operating in the forestry sector are not able to guarantee revenue for investments in forestry, until after they are completed.[66] Even when finance from carbon markets comes through, it is not sufficient to cover the opportunity cost of not using the land in other ways. If a market for sinks is pushed through, there will be supply of and demand for land carbon sequestration projects, but it will likely involve disenfranchising communities and cutting them out of the benefits. This is even less sustainable than the 'aid' model.

What is needed is a specialized mechanism for sinks. It must cut across the UNFCCC and the UNCCD, and unify forests, land and agriculture under a common approach to raising finance. This mechanism should take a non-market approach and should be separate from the new market mechanisms under Article 6 of the Paris Agreement (as CSE has outlined in previous assessments).[67]

This sink mechanism should operate on the following principles:

National investment to catalyze international payments

The bulk of investment in carbon sink enhancement projects should be met from domestic sources. This should be supplemented by support from international funds, with a balance between upfront investment and results-based payments.

A sequestration-plus-livelihoods approach to mitigation

A balance must be struck between carbon sequestration, and ecological and social co-benefits, such as promoting better land use, forest management, and agricultural practices, and improving communities' livelihoods. This can be taken further by creating locally held carbon rights, as well as stronger benefit-sharing protocols.

Transformative impact for sustainable land management

Rather than taking an offset approach, the mechanism must aim to fundamentally change land management practices across the board. Standard land management practices should be established as an eligibility requirement for projects or communities that seek payment for the sequestered carbon. The mechanism should work with local land experts around the globe to develop tailored methodologies for carbon accounting.

ENDNOTES

1 Jos GJ Olivier and Jeroen AHW Peters, 2018, *Trends in Global CO_2 and Total Greenhouse Gas Emissions*, accessed at https://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2018-trends-in-global-co2-and-total-greenhouse-gas-emissons-2018-report_3125.pdf.

2 UN-REDD, *About REDD+*, accessed at https://www.unredd.net/about/what-is-redd-plus.html.

3 L Poorter et al., 2015, *Diversity enhances carbon storage in tropical forests*, accessed at https://pdfs.semanticscholar.org/ecde/9b97575a261b66f1b186f80b280bf7ef1576.pdf.

4 Rodney J Keenan et al., 2015, *Dynamics of global forest area: Results from the FAO Global Forest Resources Assessment 2015*, accessed at http://www.indiaenvironmentportal.org.in/files/file/Global%20Forest%20Resources%20Assessment%202015.pdf.

5 David Gibbs et al., 2018, *By the Numbers: The Value of Tropical Forests in the Climate Change Equation*, accessed at https://www.wri.org/blog/2018/10/numbers-value-tropical-forests-climate-change-equation.

6 Frances Seymour and Jonah Busch, 2016, *Why Forests? Why Now? The Science, Economics, and Politics of Tropical Forests and Climate Change*, accessed at https://www.cgdev.org/sites/default/files/Seymour-Busch-why-forests-why-now-full-book.PDF.

7 Daisy Dunne, 2017, *World's soils have lost 133bn tonnes of carbon since the dawn of agriculture*, accessed at https://www.carbonbrief.org/worlds-soils-have-lost-133bn-tonnes-of-carbon-since-the-dawn-of-agriculture.

8 Justus Wanzala, 2016, *Funding Lags to Combat Land Degradation*, accessed at http://sdg.iisd.org/news/investors-announce-ldn-fund-commitments/.

9 Inter-governmental Panel on Climate Change, 2019, *Climate Change and Land: A Summary for Policy-makers*, accessed at https://www.ipcc.ch/site/assets/uploads/2019/08/4.-SPM_Approved_Microsite_FINAL.pdf.

10 Kate Trumper et al., 2008, *Carbon in Drylands: Desertification, Climate Change and Carbon Finance*, accessed at https://pdfs.semanticscholar.org/cb95/9da9184a9f4cd60ec6b2b46ccbeca35a927c.pdf.

11 Inter-governmental Panel on Climate Change, 2019, *Climate Change and Land: A Summary for Policy-makers*, accessed at https://www.ipcc.ch/site/assets/uploads/2019/08/4.-SPM_Approved_Microsite_FINAL.pdf.

12 Kate Trumper et al., 2008, *Carbon in Drylands: Desertification, Climate Change and Carbon Finance*, accessed at https://pdfs.semanticscholar.org/cb95/9da9184a9f4cd60ec6b2b46ccbeca35a927c.pdf.

13 R Lal, 2001, *Potential of Desertification Control to Sequester Carbon and Mitigate the Greenhouse Effect*, accessed at https://pdfs.semanticscholar.org/79b5/d2d0e090285c0d-

224de59ef8fb99fcb4eaad.pdf.

14 Kate Trumper et al., 2008, *Carbon in Drylands: Desertification, Climate Change and Carbon Finance*, accessed at https://pdfs.semanticscholar.org/cb95/9da9184a9f4cd60ec6b-2b46ccbeca35a927c.pdf.

15 Down To Earth, 2017, *Desertification has increased in 90 per cent of states in India*, accessed at https://www.downtoearth.org.in/news/agriculture/desertification-has-increased-in-90-per-cent-of-the-indian-states-58057

16 Haotian Yang et al., 2014, *Carbon sequestration capacity of shifting sand dune after establishing new vegetation in the Tengger Desert, northern China*, accessed at https://iopscience.iop.org/article/10.1088/1757-899X/394/5/052028/pdf.

17 Inter-governmental Panel on Climate Change, 2018, *Global Warming of 1.5°C; A Summary for Policy-makers*, accessed at https://www.ipcc.ch/sr15/chapter/spm/.

18 Ibid.

19 Inter-governmental Panel on Climate Change, 2019, *Climate Change and Land: A Summary for Policy-makers*, accessed at https://www.ipcc.ch/site/assets/uploads/2019/08/4.-SPM_Approved_Microsite_FINAL.pdf.

20 Shruti Agarwal et al., 2018, *Rethinking REDD+: A CSE assessment,* accessed at https://www.cseindia.org/rethinking-redd--9198; Chandra Bhushan et al., 2010, *New Market Mechanism under the Paris Agreement*, accessed at https://www.cseindia.org/new-market-mechanism-under-the-paris-agreement-8973

21 Ibid.

22 Mucahid Mustafa Bayrak and Lawal Mohammed Marafa, 2016, *Ten Years of REDD+: A Critical Review of the Impact of REDD+ on Forest-Dependent Communities*, accessed at https://www.mdpi.com/2071-1050/8/7/620/pdf.

23 Carbon Market Watch, 2013, *REDD*, accessed at https://carbonmarketwatch.org/2013/04/09/redd/.

24 Michael Gillenwater, 2011, *The Clean Development Mechanism: A Review of the First International Offset Program*, accessed at http://www.indiaenvironmentportal.org.in/files/clean-development-mechanism-review-of-first-international-offset-program.pdf.

25 Kelley Hamrick, 2015, *State of the Voluntary Carbon Markets (Presentation),* accessed at https://www.forest-trends.org/wp-content/uploads/2015/06/SOVCM-Webinar-Presentation-June-25-2015.pdf.

26 Global Environment Facility, 2019, *New funding boosts efforts to combat deforestation, desertification, climate change and strengthen food systems*, accessed at https://www.thegef.org/news/new-funding-boosts-efforts-combat-deforestation-desertification-climate-change-and-strengthen

27 Wangu Mwangi, 2018, *Investors Announce LDN Fund Commitments*, accessed at http://

sdg.iisd.org/news/investors-announce-ldn-fund-commitments/.

28 Justus Wanzala, 2016, *Funding Lags to Combat Land Degradation*, accessed at http://www.ipsnews.net/2016/10/funding-lags-to-combat-land-degradation/.

29 Fred Stolle and John-Rob Poole, 2017, *We Discovered 1.8 Million Square Miles of Forest in the Desert*, accessed at https://www.wri.org/blog/2017/05/we-discovered-18-million-square-miles-forest-desert.

30 Food and Agriculture Organisation, 2016, *The agriculture sectors in the Intended Nationally Determined Contributions*, accessed at http://www.fao.org/3/a-i5687e.pdf.

31 Ibid.

32 Ibid.

33 Giacomo Grassi et al., 2017, *The key role of forests in meeting climate targets requires science for credible mitigation*, accessed at https://www.researchgate.net/publication/314192936_The_key_role_of_forests_in_meeting_climate_targets_requires_science_for_credible_mitigation.

34 Shruti Agarwal et al., 2018, *Rethinking REDD+: A CSE assessment,* accessed at https://www.cseindia.org/rethinking-redd--9198; Chandra Bhushan et al., 2010, *New Market Mechanism under the Paris Agreement*, accessed at https://www.cseindia.org/new-market-mechanism-under-the-paris-agreement-8973

35 Peter Motavalli, 2013, *Global achievements in sustainable land management*, accessed at https://www.sciencedirect.com/science/article/pii/S2095633915300447.

36 Ibid.

37 World Agroforestry, 2014, *India leads the way with agroforestry policy*, accessed at http://www.worldagroforestry.org/news/india-leads-way-agroforestry-policy.

38 Seton Stiebert et al., 2012, *Kenya's Climate Change Action Plan: Mitigation. Chapter 3: Agriculture* , accessed at http://www.kccap.info/phocadownload/final/SC4/Chapter%203%20SC4_%20agriculture_FINAL.pdf.

39 Prem Singh et al., *Impact and Effectiveness of Watershed Development Programmes in India*, accessed at https://www.cse.iitb.ac.in/~karjat/waterdocs/Impact%20and%20Effectiveness%20of%20WDP%20by%20LBSNAA.pdf

40 Watershed Development Research Team, *Impact Assessment of Watershed Development Projects (Selected districts of Madhya Pradesh)*, accessed at https://www.soppecom.org/pdf/Impact%20assessment%20of%20watershed%20development%20projects-%20MP.pdf.

41 Rashmi Verma, 2017, *This tribal district has become 'immune to drought' with people's participation* , accessed at https://www.downtoearth.org.in/news/water/immune-to-drought-57892.

42 Ibid.

43 Ibid.

44 Arunima Dasgupta et al., 2015, *Monitoring implementation of desertification combating plan using geomatics – a Case Study, districts Dharand Jhabua, Madhya Pradesh*, accessed at https://www.ias.ac.in/article/fulltext/jess/124/01/0087-0099.

45 NH Ravindranath and Indu K Murthy, 2018, *Estimation Of Carbon Sequestration Under MGNREGA : Achievement And Potential in India*, accessed at https://assets.publishing.service.gov.uk/media/5cefa31b40f0b650d8050688/NREGA_Carbon_Sequestration_Report.pdf.

46 Kelley Hamrick and Melissa Gallant, 2018, *Voluntary Carbon Markets Insights:2018 Outlook and First-Quarter Trends*, accessed at https://www.forest-trends.org/wp-content/uploads/2018/08/Q12018VoluntaryCarbon.pdf.

47 Down To Earth, *Social Cost of* CO_2, accessed at https://www.downtoearth.org.in/dte-infographics/social_cost_corbon/index.html.

48 The Energy and Resources Institute, 2016, *Economics of Desertification, Land Degradation and Drought in India Vol II: Six micro-economic case studies of degradation*, accessed at https://www.teriin.org/sites/default/files/2018-04/Vol%20II%20-%20Six%20micro-economic%20case%20studies%20of%20degradation_0.pdf.

49 Ibid.

50 RS Mertia et al., 2006, *Impact of Shelterbelts in Arid Region of Western Rajasthan*, accessed at http://www.cazri.res.in/publications/KrishiKosh/108-(IMPACT.pdf.

51 Ibid.

52 Ibid.

53 Priyabrata Santra, 2013, *Loss of Soil Carbon and Nitrogen through Wind Erosion in the Indian Thar Desert*, accessed at https://pdfs.semanticscholar.org/b2b3/dbdd9eae008f63f38a3b97633e6c388af32a.pdf.

54 Ritu Sharma et al., 2017, *Spatial variations in floristic diversity and carbon storage in arid zone forests of western Rajasthan, India*, accessed at https://pdfs.semanticscholar.org/3f20/bedc14b13f2a5bc0e80a113369dc58e6c4ae.pdf.

55 Japan International Cooperation Agency, 2003, *Afforestation and Pasture Development Project Along Indira Gandhi Canal Area*, accessed at https://www.jica.go.jp/english/our_work/evaluation/oda_loan/post/2004/pdf/2-41_full.pdf.

56 Kelley Hamrick and Melissa Gallant, 2018, *Voluntary Carbon Markets Insights:2018 Outlook and First-Quarter Trends*, accessed at https://www.forest-trends.org/wp-content/uploads/2018/08/Q12018VoluntaryCarbon.pdf.

57 Down To Earth, *Social Cost of* CO_2, accessed at https://www.downtoearth.org.in/dte-infographics/social_cost_corbon/index.html.

58 Hanwant Singh Rathore, 2013, *Camel Yatra*, accessed at http://www.lpps.org/wp-content/uploads/2013/07/downtoearth.pdf.

59 Nitin Sreedhar, 2018, *The Great Indian Bustard's last sigh*, accessed at https://www.live-mint.com/Leisure/aE08dRPnA2iRRIOiVD7rAO/The-Great-Indian-Bustards-last-sigh.html

60 Down To Earth, , *Sukhomajri at the crossroads*, accessed at https://www.downtoearth.org.in/indepth/sukhomajri-at-the-crossroads-22807.

61 Aparna Pallavi and Akshay Deshmane, 2013, *Maharashtra's Rs 60,000 crore watershed failure*, accessed at https://www.rediff.com/news/slide-show/slide-show-1-maharashtra-reels-under-rs-60000-cr-watershed-failure/20130321.htm.

62 Rachna Singh, 2012, *Mega shelter belts proposed in western Raj to contain climate change*, accessed at https://timesofindia.indiatimes.com/city/jaipur/Mega-shelter-belts-proposed-in-western-Raj-to-contain-climate-change/articleshow/16985812.cms

63 Fred Pearce, 2019, *Why Green Pledges Will Not Create the Natural Forests We Need*, accessed at https://e360.yale.edu/features/why-green-pledges-will-not-create-the-natural-forests-we-need.

64 Aditya Sharma, 2019, *Rajasthan's Canal Project is the Test Centre Must Pass to Show its Commitment Towards Water Crisis*, accessed at https://www.news18.com/news/india/rajasthans-canal-project-is-the-test-centre-must-pass-to-show-its-commitment-on-water-crisis-2193891.html.

65 VP Tewari et al., 1997, *Problem of soil salinity and water logging in Indira Gandhi Canal area of Rajasthan State*, accessed at https://www.researchgate.net/publication/228117084_Problem_of_soil_salinity_and_water_logging_in_Indira_Gandhi_Canal_area_of_Rajasthan_State.

66 Shruti Agarwal et al., 2018, *Rethinking REDD+: A CSE assessment,* accessed at https://www.cseindia.org/rethinking-redd--9198

67 Shruti Agarwal et al., 2018, *Rethinking REDD+: A CSE assessment,* accessed at https://www.cseindia.org/rethinking-redd--9198; Chandra Bhushan et al., 2010, *New Market Mechanism under the Paris Agreement*, accessed at https://www.cseindia.org/new-market-mechanism-under-the-paris-agreement-8973

Centre for Science and Environment is a public-interest research and advocacy organization, which promotes environmentally sound and equitable development strategies. The Centre's work since its establishment in 1980 has led it to believe and argue, both nationally and internationally, that participation, equity and community-based natural resource management systems alone will lead the nations of the world towards durable peace and development.

As a public-interest organization, the Centre supports and organizes information flow in a way that the better organized sections of the world get to hear the problems and perspectives of the less organized. Environmental issues are seen in an anthropocentric perspective that seeks to bring about changes in the behaviour of human societies through appropriate governance systems, human–nature interactions and the use of science and technology.

Though the public awareness programmes of the Centre have been its key strength and focus of work, it has endeavoured to move into associated areas of work like policy research and advocacy. Learning from the people and from the innovations of the committed has helped the Centre spread the message regarding environment without its normal association with doom and gloom. Rather, the effort of the Centre is to constantly search for people-based solutions and create a climate of hope.

The Centre has always been, and will continue to be, editorially independent of interest groups, governments, political parties, international agencies and funding sources. It never accepts funding to push a donor's viewpoint. All its outputs are available for public dissemination.

Centre for Science and Environment
41, Tughlakabad Institutional Area New Delhi 110 062
Phone: 91-11-40616000
Fax: 91-11-29955879
E-mail: cse@cseindia.org
Website: www.cseindia.org