ESTIMATION OF CARBON SEQUESTRATION UNDER MGNREGA: ACHIEVEMENT AND POTENTIAL IN INDIA

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Executive Summary

1. The Paris Agreement and the "Katowice Climate Package" highlight the need for estimation and reporting of 'mitigation co-benefits of adaptation' actions. Article 4 and Article 7 of the Paris Agreement and the Rulebook provide clear guidance for reporting the mitigation co-benefits of adaptation actions. India's Nationally Determined Contribution (NDC) has a large carbon sequestration target of 2.5 to 3 billion tonnes of CO_2 by 2030 through increased forest and tree cover.

2. MGNREGA was launched in 2006 by the Government of India. It is one of the world's largest social security programmes with an investment of Rs. 48,000 crores = US$ 7 billion during 2017-18. The bulk of the MGNREGA works (activities) are focused on natural resources such as land, water and trees. Thus, it is important to assess the carbon sequestration potential, as a co-benefit, from MGNREGA. The present study aims to assess carbon sequestration achieved by the programme in 2017-18, and its future potential upto 2030, to deliver climate change mitigation co-benefits and meet the carbon sink target of NDC of India. The broad approach and methodology for estimating the carbon sink is presented briefly later in the Executive Summary.

3. **Carbon Sequestration Potential of MGNREGA: The total mean carbon (biomass and soil organic carbon) sequestered at the national level, considering all the Agro-Ecological Regions and Natural Resource Management (NRM) works, for the year 2017-18 (for cumulative number of works implemented) is estimated to be 62 $MtCO_2$.**

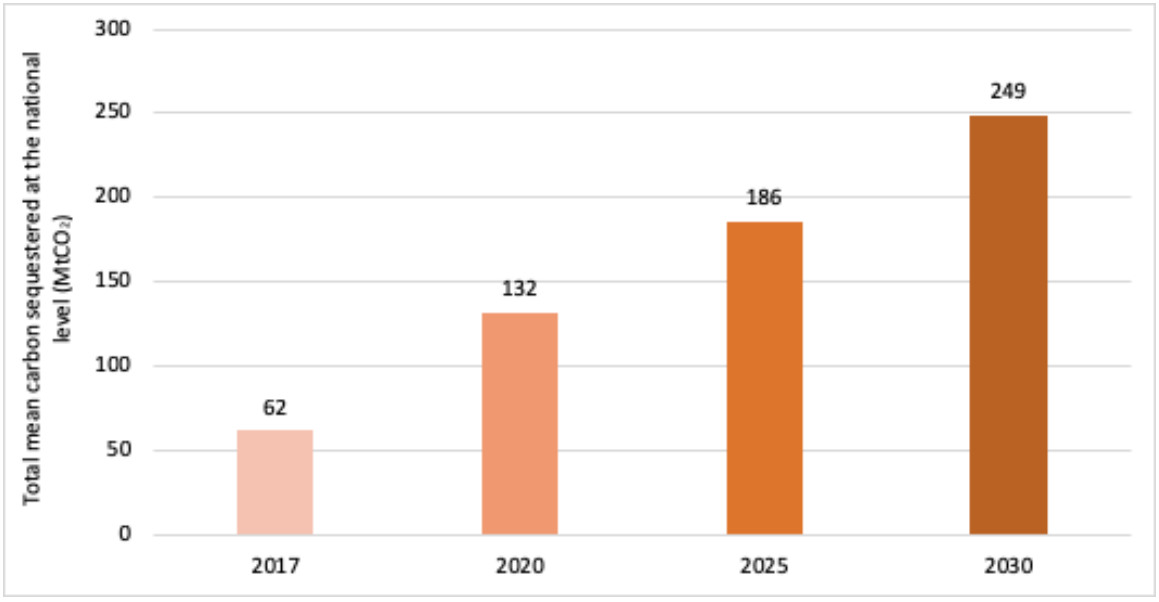

Figure E1: Mean carbon sequestration ($MtCO_2$) trends and projections between 2017-18 and 2030 for the MGNREGA programme in India

   - Among the NRM works, 'Drought Proofing' provides about 40% of the total carbon sequestration, considering all NRM works at the national level.

- Carbon sequestration projected for the period 2020 to 2030 shows a continuous increase, due to an increase in cumulative NRM works implemented.
  - During 2017-18, the total mean carbon sequestered is estimated to be about 62 $MtCO_2$ (estimated likely range 47 to 181 $MtCO_2$)**.**
  - The annual mean carbon sequestration is projected to increase to about 132 $MtCO_2$ by 2020, 186 $MtCO_2$ by 2025 and 249 $MtCO_2$ (estimated likely range 150 to 540 $MtCO_2$) by 2030 (Figure E1).

4. **Carbon Sequestration Potential of MGNREGA in the Context of NDC:** India has set a NDC target of 2.5 to 3 billion tonnes of CO_2 sink creation through increase in forest and tree cover, by 2030. 'Drought proofing' is the NRM activity that largely includes tree planting, horticulture and afforestation, which could contribute to achieving the NDC target of increasing forest and tree cover and carbon sink creation. The mean carbon sequestration achieved in 2017-18 for drought proofing activity is estimated to be 25 $MtCO_2$ (tree biomass and soil carbon) and this is projected to increase to 85 $MtCO_2$ annually, by 2030. Carbon sequestration co-benefit of MGNREGA works also contributes to achieving the Sustainable Development Goals (SDGs).

5. **Implication of Climate Change on Carbon Sequestration Potential and the Need for Resilience:** According to IPCC AR5 (Smith et al., 2014), most categories of adaptation options for climate change in land use sectors have positive impacts on mitigation. Further, mitigation choices taken in a particular land-use sector have the potential to enhance resilience to climate variability and climate change. However, climate change itself could adversely impact the carbon sequestration potential of land-based mitigation and adaptation options. Thus, there is a need for programmes such as the ICRG (Infrastructure for Climate Resilient Growth), supported by DFID, which aim to enhance the resilience of assets created under MGNREGA, to enable sustained delivery of environmental benefits, including carbon sequestration co-benefits.

6. **"*Paris Agreement* and *Katowice Climate Package*" - Implications for Mitigation Benefits of Adaptation Actions:** Implementation of the *Paris Agreement* and reporting requirements, according to *Katowice Climate Package* under Article 7 and Article 4 require estimation and reporting of "Carbon sequestration mitigation co-benefits of adaptation actions".

7. MGNREGA is a very large well-established programme that was initiated in 2006, and promotes adaptation or resilience, with an annual budget of US$6 to US$8 billion. Such a large programme with focus on NRM requires periodic and scientifically robust studies to provide reliable estimates of carbon sequestration as a co-benefit. The present study provides only a preliminary estimate based on a rapid study with limited sampling, which makes a strong case for a large national study to periodically estimate carbon sequestration as a co-benefit of MGNREGA.

8. The Government of India could leverage MGNREGA for meeting the targets of Paris Agreement, NDC and SDGs, and for reporting under United Nations Framework Convention.

Further, rural development programmes such as MGNREGA and watershed also provide soil carbon sequestration mitigation co-benefits. Thus, India could benefit by including soil organic carbon sequestration as an activity for achieving the carbon sink target, in its future NDC submission.

Methodology: *MGNREGA includes a large number of works or activities, mainly linked to land and water resources, implemented in 691 districts and hundreds of thousands of villages in diverse agro-climatic, physiographic and socio-economic conditions. The present study is a rapid and preliminary assessment of the carbon sequestration potential of the programme. The methodology involved the following steps:*

i) *Stratify India into Agro-Ecological Regions (AERs), select representative sample districts and blocks from the AERs, select sample villages from the sample blocks, select all the MGNREGA-NRM works implemented in the sample villages and measure biomass carbon and soil carbon stocks using standard methods.*
ii) *Estimate the cumulative NRM activities (works) implemented upto 2017-18 in each AER.*
iii) *Estimate the average area under each NRM work subjected to carbon sequestration impact at AER level, based on village level estimates for each AER.*
iv) *Estimate the average carbon sequestration rate per ha per year for each NRM work at AER level, based on village level estimates.*
v) *Estimate the carbon sequestration potential at the national level: Based on the cumulative number of works implemented by 2017 in each AER; average area impacted by the individual NRM works in each AER; average carbon sequestration rate per NRM work (tC/ha/year) in each AER; finally, aggregation of carbon sequestration estimates of all the AERs.*
vi) *Projection of the carbon sequestration by 2030 at the national level is based on the projection of the number of NRM works implemented, average carbon sequestration rates for each work and average area impacted by individual NRM works at the AER level; finally, aggregation of carbon sequestration estimates of all AERs for 2030.*

ESTIMATION OF CARBON SEQUESTRATION UNDER MGNREGA: ACHIEVEMENT AND POTENTIAL IN INDIA

1. Introduction and Background

The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) aims to enhance the livelihood security of people in rural areas of India by guaranteeing 100 days of wage-employment in a financial year to a rural household, whose adult members volunteer to work. The Act also seeks to create durable assets to augment land and water resources, improve rural connectivity and strengthen the livelihood resource base of the rural poor. The Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) works or activities are largely focused on improving land and water resources. The 'works' include: water harvesting and conservation, soil conservation and protection, irrigation provisioning and improvement, renovation of traditional water bodies, land development and drought proofing. The activities implemented under MGNREGA are termed "Works". These Natural Resource Management (NRM) related works have the potential to generate environmental benefits such as ground water recharge, soil, water and biodiversity conservation, sustaining food production, halting land degradation and building resilience to current climate risks such as moisture stress, delayed rainfall, droughts and floods (Tiwari et al., 2011; Esteves et al., 2013, MoRD, 2012).

Apart from reducing vulnerability to climate variability and change (Esteves et al., 2013), MGNREGA-NRM activities have the potential to sequester carbon in soil and biomass under different activities such as: land development, soil and water conservation, enhanced irrigation and water availability activities leading to increased tree growth, crop biomass production and soil carbon enhancement. Limited evidence is available on the actual or potential impact of MGNREGA on carbon sequestration for the mitigation of climate change.

Given the scale of the MGNREGA programme, with an average annual investment of US$ 7 billion (average of the recent 5-years), with a focus on natural resources, robust assessments of the environmental impacts including climate change mitigation co-benefits, are needed. The present study aims to assess the carbon sequestration co-benefit of MGNREGA and its future potential to deliver climate change mitigation co-benefits. This study has therefore been carried out in the context of evaluating MGNREGA's potential to meet one of the primary targets of India's Nationally Determined Contribution (NDC) - of sequestering 2.5 to 3 billion tonnes of CO_2 by 2030 through increasing forest and tree cover. Some MGNREGA activities and in some locations could lead to a decline in carbon stocks, especially Soil Organic Carbon (SOC). Thus, in this report, overall aggregate carbon sequestration or stock change resulting from implementation of MGNREGA works is estimated.

MGNREGA programme includes broadly four categories of works that encompass both NRM and non-NRM works. NRM works largely dominate the MGNREGA work implementation in India. NRM activities or works account for about 55% of expenditure in 2014 to about 60% during 2018 *(http://mnregaweb4.nic.in/netnrega/all_lvl_details_dashboard_new.aspx).* This study is focused only on NRM works which have implications for biomass and soil carbon stocks.

1.1. MGNREGA Works: Implications for the Environment, Climate Risk Vulnerability Reduction and Carbon Sequestration

MGNREGA works are largely related to natural resources such as cropland, grazing land, forests and water resources. Majority of the MGNREGA works are related to land, water conservation and management. According to studies by Indian Institute of Science, MGNREGA has demonstrated the potential to deliver multiple environmental benefits, which can contribute to reducing vulnerability to climate risks and building resilience to long term climate change (Esteves et al., 2013), even though the core mandate of MGNREGA is to provide 100 days of guaranteed employment to every family. The MGNREGA programme is being implemented all over rural India. There are several categories of works or activities implemented under MGNREGA. Table 1.1 lists only those activities relevant to carbon sequestration estimation.

Table 1.1: Works or activities under MGNREGA which have the potential to impact carbon stocks

Category –A Works -Public works relating to natural resources management	Category B Works - Individual assets for vulnerable sections
i) Watershed management works such as contour trenches, terracing, contour bunds, boulder checks, gabion structures and springshed development resulting in a comprehensive treatment of a watershed	i) Improving productivity of lands of households specified in Paragraph 5 through land development and by providing suitable infrastructure for irrigation including dug wells, farm ponds and other water harvesting structures
ii) Water conservation and water harvesting structures to augment and improve groundwater like underground dykes, earthen dams, stop dams, check dams with special focus on recharging groundwater including sources of drinking water	ii) Improving livelihoods through horticulture, sericulture, plantation, and farm forestry
iii) Micro and minor irrigation works and creation, renovation and maintenance of irrigation canals and drains	iii) Development of fallow or wastelands of households defined in Paragraph 5 to bring it under cultivation
iv) Renovation of traditional water bodies including desilting of irrigation tanks and other water bodies	iv) Unskilled wage component in construction of houses sanctioned under the Indira AwaasYojana or such other State or Central Government Scheme
v) Afforestation, tree plantation and horticulture in common and forest lands, road margins, canal bunds, tank foreshores and coastal belts duly providing right to usufruct to the households covered in Paragraph 5 of Schedule I	v) Creating infrastructure for promotion of livestock such as, shelters for poultry goats, piggery, cattle and fodder troughs for cattle; and 9 CRISP Modules
	vi) Creating infrastructure for promotion of fisheries such as, fish drying yards, storage facilities, and promotion of fisheries in seasonal water bodies on public land
vi) Land development works in common land	

1.2. MGNREGA Works and Environmental Benefits

There are multiple environmental benefits that result from implementation of land and water-based NRM activities under MGNREGA (Table 1.2).

Table 1.2: Environmental benefits of NRM works implemented under MGNREGA (Tiwari et al., 2011)

Natural resources impacted	MGNREGA works	Potential Environmental benefits
Water	- Water conservation and harvesting - Irrigation provisioning and improvement - Renovation of traditional water bodies - Flood control	- Ground water recharge, soil moisture retention and protection (erosion control), provisioning of water for irrigation, improved drinking water availability and soil quality (nutrient cycling) - Enhance resilience through reduced crop yield variability, provides irrigation to rainfed crops, enhance soil fertility and water holding capacity - Carbon sequestration indirectly
Land	- Land development such as, land levelling, conservation bench terracing, contour and graded bunding - Field bunding - Pasture development - Silt application - Drought proofing - Flood control	- Reclamation of degraded land for agriculture, improve soil organic matter, improve soil moisture retention and protection (erosion control) in cultivated fields, in turn improving crop productivity and reducing crop yield variability leading to enhance resilience. - ***Enhanced SOC and biomass carbon leading to carbon sequestration***
Crop production systems	- Water conservation and harvesting - Irrigation provisioning and improvement - Renovation of traditional water bodies - Flood control - Land development	- Increasing the availability of water for irrigation, reclaiming degraded lands for agriculture, improving soil moisture retention, protection (erosion control) and improving soil quality on cultivated lands, flood control for crop protection, etc. - All these directly impact area under irrigation, crop productivity, cropping patterns and reduce crop yield variability and incomes leading to resilience. - Carbon sequestration indirectly
Forests	- Drought proofing works such as, afforestation/tree plantation, boundary and block plantation - Agroforestry - Mixed plantation of trees having minor forest product and medicinal value, pasture development/silvipasture, etc.	- Conservation and regeneration of biomass and carbon stock improves soil moisture retention and protection, aids flood control - Improves soil quality, regulates local climate and provides an alternate source of income for those households, dependent on minor forest products, fodder and fuelwood, contributing to resilience. - ***Carbon sequestration through enhanced biomass and soil carbon in trees (orchards, trees and forms and afforestation)***

1.3. Implications of MGNREGA-NRM Works for Reducing Vulnerability to Climate Risks

MGNREGA-NRM works related to water and land development have been shown, by the four states study (Esteves et al., 2013), to have contributed to generation of environmental benefits and natural resource conservation - ground water recharge, increased water availability for irrigation, increased soil fertility, reduction in soil erosion, and improved tree cover. These environmental benefits derived from MGNREGA works have contributed to reducing agricultural and livelihood vulnerability in the post-MGNREGA activity implementation period, compared to the pre-MGNREGA period and further have the potential to not only build resilience to cope with current climate risks but also long-term resilience to projected climate change. Further, this study showed that due to the generation of environmental benefits and conservation of natural resources as a result of implementation of MGNREGA works, the adaptive capacities of beneficiary households increased, reducing their vulnerability to climate risks.

1.4. Potential Impacts of MGNREGA on Carbon Sequestration

Land use sectors such as cropland, grassland and forestland result in about 25% of the global CO_2 emissions, contributing to climate change (IPCC, 2014). Thus, there is a need to explore the potential to reduce CO_2 emissions and enhance carbon sinks from the land use sector. Further, India's agricultural soils, especially under dryland or rainfed conditions, are subjected to land degradation and characterized by low soil organic matter / carbon densities. Enhancing soil organic carbon content leads to increased soil fertility, crop productivity and carbon sequestration. Similarly, enhancing tree biomass and soil organic carbon stocks by tree planting under MGNREGA leads to carbon sequestration. Thus, even though carbon sequestration is not the goal of MGNREGA, it is an important co-benefit of the programme.

The four states study by Indian Institute of Science (Esteves et al., 2013) showed that several MGNREGA works such as application of silt to croplands and provision of irrigation lead to increased levels of soil organic carbon, raising tree plantations and fruit orchards lead to carbon sequestration in biomass and soil, potentially contributing to mitigation of climate change. In the 40 study-villages (Esteves et al., 2013), it was found that in 72% of the 899 MGNREGA beneficiary sample plots, covering all categories of MGNREGA works, enhanced soil organic carbon contents were recorded as compared to control plots. Similarly, in 31 of the 40 villages, where afforestation or tree planting works were undertaken, and horticultural plantations were raised under MGNREGA, carbon was sequestered in biomass and soil. Fruit trees and afforested areas when grown to maturity will provide persistent economic benefits in the form of fruits, seeds and leaves in drought years, supplementing the household income. Thus, enhancing soil carbon synergistically provides resilience and mitigation benefits, in addition to reducing vulnerability to climate related risks.

1.5. Paris Agreement, Nationally Determined Contribution and Sustainable Development Goals

The Paris Agreement has clearly recognised the importance of addressing climate change. The world's leaders agreed to make efforts to hold mean global warming to between 1.5 to 2^0C, through aggressive mitigation actions and by promoting climate resilience and adaptation to adverse impacts of climate change.

The Government of India submitted its NDC (Nationally Determined Contributions) and has also signed the Paris Agreement. Government of India in its NDC has committed to sequester 2.5 to 3 billion tonnes of carbon dioxide through afforestation and reforestation, apart from actions to reduce vulnerability to climate risks and enhance investment in resilience and promote adaptation. India has to submit periodic reports on the progress of climate change mitigation and adaptation (resilience) actions.

Government of India also has signed-up to the UN Sustainable Development Goals (SDGs) which Adopted by all United Nations Member States in 2015. The Government of India must submit the progress on the SDG indicators. MGNREGA has been shown to provide both climate change mitigation and adaptation benefits, synergistically with rural development benefits. Further, MGNREGA is a core programme to deliver targets under SDGs, such as SDG 1 - No poverty, SDG 10 - Reduced inequalities, SDG 13 - Climate action, and SDG 15 - Life on land(Faridi, Bhamra and Arora, 2017). Thus, state governments and Government of India could leverage MGNREGA for meeting the targets of Paris Agreement, NDC and SDGs and for reporting under United Nations Framework Convention on Climate Change and SDGs.

1.6. Objectives

MGNREGA works are largely related to natural resource management and the limited evidence available has shown that these works have the potential to deliver multiple environmental benefits, reduce vulnerability to climate risks and sequester carbon in trees and soil. In this context, this study aims to quantify the carbon sequestration co-benefits of MGNREGA works in India by adopting an AER (Agro Ecological Regions) stratification methodology. Specific objectives of this study include:

1. Identification of the MGNREGA-NRM works that lead to carbon sequestration or stock change and estimation of the area and extent of works implemented, according to AERs.
2. Assessment of the actual carbon sequestration rates per ha per year, for different NRM works through field studies in sample villages, blocks, districts and AERs.
3. Estimation of cumulative carbon sequestration or stock change achieved by the MGNREGA works implemented at the national level for the year 2017.
4. Projection of carbon sequestration potential of MGNREGA programme at the national level for the periods – 2020, 2025 and 2030.
5. Assessment of the potential of MGNREGA programme to contribute to mitigation of climate change and, in particular in meeting the NDC target of 2.5-3 $GtCO_2$ sequestration by 2030.

2. Methodology

MGNREGA is a very large programme implemented across all states and districts of India in hundreds of thousands of villages. In this section, the approaches and methods adopted for estimating the carbon sequestration co-benefit from MGNREGA is presented (details are given in Annexure B).

2.1. Broad Approach to Estimation of Carbon Sequestration or Stock Change

The broad approach and steps are presented in Figure 2.1, especially the sampling approach and carbon sequestration or stock change estimation procedures.

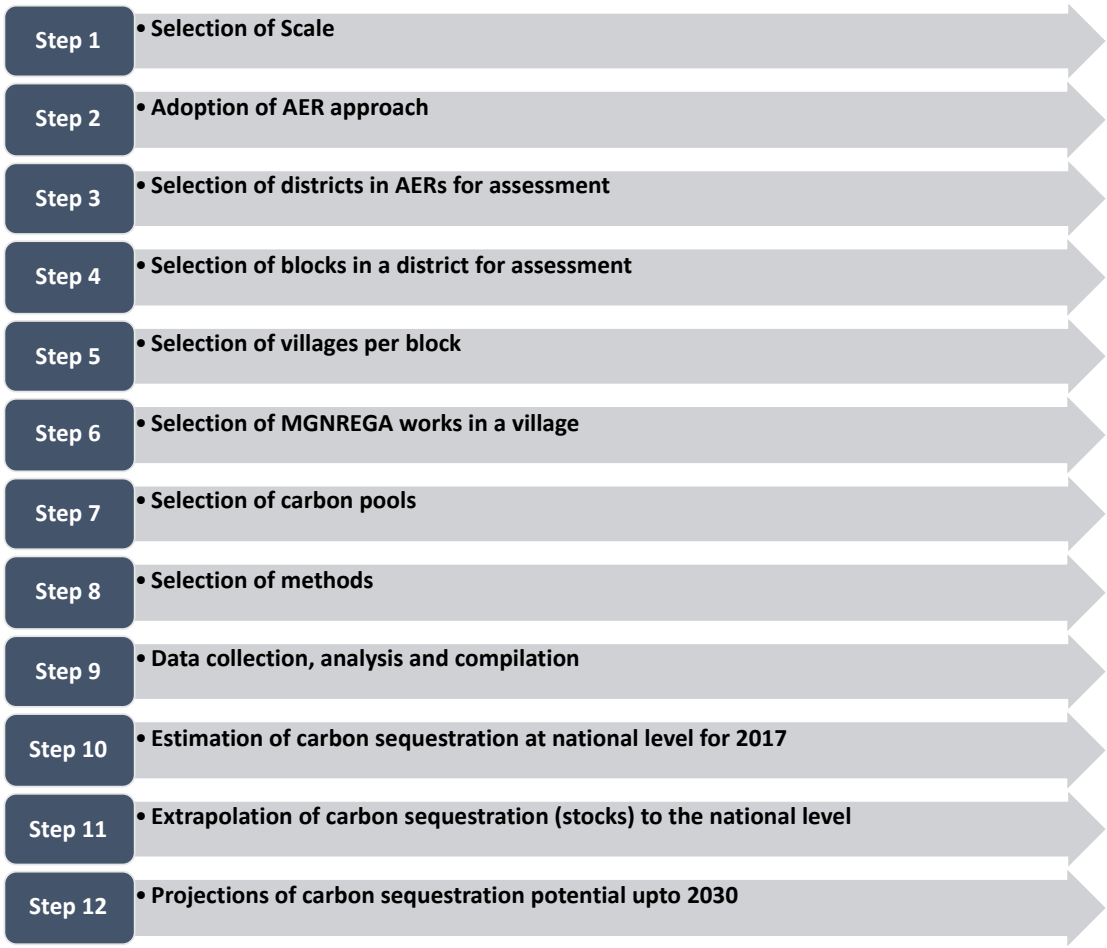

Figure 2.1: Broad steps and approach to estimation of carbon sequestration under MGNREGA

2.2. Sampling Procedure and Methods for Estimating Biomass and Soil Carbon Stocks

Sampling procedure, methods for estimating biomass and soil organic carbon stocks and the calculation methods for obtaining carbon sequestration or stock change on a per hectare basis is given in Table 2.1. A standard plot method, normally adopted in ecological studies is used for estimating above ground biomass. IPCC default method is adopted for estimating below ground (root) biomass, based on above ground biomass data. SOC is estimated by taking soil samples from plots impacted by MGNREGA-NRM activities and using laboratory analysis to measure carbon content. Control plots are used to estimate the net impact of MGNREGA-NRM works on carbon stocks.

Table 2.1: Approach and methods of sampling for biomass and soil carbon estimation

Approach / Steps	Details
Step-1: Selection of scale	National level as MGNREGA is implemented in all the states of India and assessing the potential impact of MGNREGA on India's NDC climate mitigation target requires a national level impact assessment.
Step-2: Adoption of AER approach	AER (Agro Ecological Region) approach is adopted to stratify India. This stratification is adopted by agricultural universities, agriculture departments and other development programmes. In this study, 18 AERs excluding AER 1

	(Western Himalayas, Ladakh Plateau and north Kashmir), and AER 20 (A&N and Lakshadweep islands) have been selected. *Map is provided in Annexure A1 and districts falling in different AERs is presented in Annexure A2.*
Step 3: Selection of districts in AERs for assessment	-The districts belonging to each AER were listed using the AER Map. -Geographic area of all the districts for a given AER was aggregated -Based on resources and time available, 32 districts were selected, accounting for about 5% of 691 total districts where MGNREGA is implemented. -The number of districts selected for each AER is proportional to the percentage share of the total area of all the AERs. -Mean works implemented in each district was obtained from MGNREGA database and aggregated to obtain the total works area by AER. -Selection of districts in each AER is based on the mean number of works implemented. Districts closest to the mean number of works implemented were selected in each AER.
Step 4: Selection of blocks in a district for assessment	All blocks in the identified districts were selected and the same procedure detailed in Step 3 adopted. - Estimate the number of works implemented in each block during 2013-14 (see Step 6) - Estimate mean number of works implemented for all the blocks in a district - Arrange the blocks in ascending order based on number of works - Select two blocks closest to mean number of works implemented for each selected sample district
Step 5: Selection of villages per block	The final unit of sampling for MGNREGA works for estimating carbon sequestration potential is a village. Three villages were selected per block based on the population of the villages (small, medium and large) *Refer to Annexure B1 for districts and number of villages sampled per AER*
Step-6: Selection of MGNREGA works in a village	- Through Participatory Rural Appraisal, all the MGNREGA-NRM works implemented in the village till 2013-14 were identified and located. - Only those MGNREGA-NRM works carried out prior to 2014-15, i.e. upto 2013-14are included in the study, since it is possible to measure the biomass and soil carbon impact, only after a minimum of 3-years after the implementation of the work.
Step-7: Selection of carbon pools	Under MGNREGA, two major carbon pools are likely to be impacted - biomass and/or soil carbon, depending on the type of intervention. *Refer to Annexure B2 for details*
Step 8: Selection of methods	- Carbon sequestration from implementation of MGNREGA works is estimated by taking samples in two types of plots: a) Assessment in MGNREGA-NRM work implemented plots – for estimating biomass and/or soil carbon pools b) Control plots - for comparison and assessment of change or impact of MGNREGA-NRM works – in plots/locations where neither tree-planting based or non-tree-planting based MGNREGA-works have been implemented. - Difference in carbon stocks of MGNREGA impacted plots and Control plots is used to estimate the carbon sequestration or stock change. Calculation of the annual rate of sequestration per ha per year is based on the number of years post-implementation of the work)
Step 9: Stratification of MGNREGA works	MGNREGA works are grouped into two categories for measurement of biomass and soil carbon stock changes

	a)*MGNREGA activities involving tree planting*: both tree biomass and soil carbon pools are measured. It is comprised of largely drought proofing works. *b) MGNREGA activities involving no tree planting*: only SOC is measured, since no tree planting is done for biomass measurement. Includes all land and water related works, excluding drought proofing works.
Step 10: Measurement method for biomass of trees	***Aboveground biomass (AGB):*** Aboveground biomass consists of trees and shrubs. Standard plot method (World Bank Toolkit (2012); Ravindranath and Ostwald, 2008) is adopted and diameter of the trees (DBH) and height of all the trees in the sample plots are measured. - Each MGNREGA-NRM work and the area impacted is identified and located in the field (for example – if check dam is constructed, the area impacted by increased water availability for irrigation from water stored in the check dam or increased ground water level is estimated or obtained through surveys) - 3 to 5 plots of size (25 x 25 meters) are marked randomly in the field - Tree DBH and height are measured. **Calculation of biomass using field data and equations** - Parameters such as DBH and height recorded in the field are used in allometric equations for estimating the above ground biomass of each tree. Allometric equations are available for many tree species. If not available for any species, generic biomass equations available for the region are used. - Below ground biomass is estimated using the standard default values recommended by IPCC (default value for below ground biomass = AGB X 0.26) - Finally, total biomass stock (above ground + below ground) is estimated as tonnes of dry biomass per ha for the selected work (say, drought proofing involving planting trees) - Total biomass is separately estimated for plots with trees planted under Drought Proofing activity under MGNREGA and the Control plots (without tree planting). The control plot biomass stock is zero in most cases. Net biomass stock change = (Biomass stock in drought proofing work plots – Biomass stock in control plots)
Step 11: Measurement method for SOC	SOC is estimated in locations where MGNREGA-NRM works are implemented (tree and non-tree based works), based on plot selection and soil sample collection for laboratory estimation (World Bank Toolkit, 2012; Ravindranath and Ostwald, 2008) - Select 3/5 plots for each work/farm (if large area or farm size, select 5 plots, if small or medium size farm – select 3 plots) - In each plot, obtain samples of soil from three points in the plot (2 corners and one middle) - Collect samples from two depths: 0-15 cm and 15-30 cm - SOC is estimated by adopting the most widely used and cost-effective method: Wet digestion or titrimetric determination (the Walkley and Black) method - SOC is calculated in terms of tC per ha using the following two equations using data on SOC concentration (as a percentage) obtained in the laboratory analysis and bulk density for the two depths:

	SOC (tons/ha) = [Soil mass in 0–30 cm layer × SOC concentration (%)] / 100 Soil mass (tons/ha) = [area (10,000 m^2/ha) × depth (0.3 m) × bulk density (t/m^3)]
Step 12: Estimation of biomass and SOC per ha for each MGNREGA-NRM work	Based on the above methods biomass and soil carbon sequestration or stock change is estimated for each work (such as check dam impacted plots or tree planted plots) as tC/ha/year. Rate per year is estimated based on the number of years the land is impacted, post implementation upto 2017.

2.3. Data Analysis and Estimation of Carbon Sequestration or Stock Change at National Level (based on data from sample villages)

Estimation of carbon sequestration at the national level, based on data from village level sample studies is a challenge for a large programme such as MGNREGA, especially due to limitation of time and resources. The biggest challenge is the absence of data on area impacted by implementation of a MGNREGA-NRM work (such as tree planting or land development or minor irrigation).Area impacted by MGNREGA-NRM works is the starting point for estimating the carbon sequestration co-benefit. No study has attempted to estimate the area impacted by the works implemented so far. The approach and method adopted in this study is to estimate the area impacted by each of the MGNREGA-NRM works and extrapolate the village level estimates of biomass and SOC for each work to the district, AER and national levels as presented in Table 2.2.

Table 2.2: Approach and methods for estimating carbon sequestration or stock change from village level data to national level

Steps	Details
Step-1: Estimation of area subjected to impact of implementation of MGNREGA-NRM work (e.g., minor irrigation or land development or drought proofing work in a village)	Estimation of area subjected to implementation of MGNREGA work in each sample village involved field visit to the work sites in sample villages and PRA - Obtain the list of all the works implemented in the sample village through PRA or from Village Panchayat office. Get preliminary idea about the location of the works in the village and area potentially impacted by each work. - Visit the field and verify or measure or survey the area impacted by the sample works through discussion with the beneficiary. - Obtain the area impacted by each work (minor irrigation, land development, drought proofing, etc.
Step-2: Estimation of average area and total area impacted by each work at AER level (average ha per minor irrigation or land development or drought proofing work in the AER)	Based on the works implemented and area for each work in the sample villages in a district – average area for each work is estimated: – For example, estimate the total number of minor irrigation or land development or drought proofing works implemented in all the districts of an AER from MGNREGA database -Use the estimate of the area impacted by each work, obtained through field studies as described in Step-1, say for minor irrigation or land development or drought

	proofing work in sample villages and estimate the average area impacted by each work. -Based on total minor irrigation or land development or drought proofing, etc., works implemented at district level and average area per work estimated at village level for each district – estimate the total area impacted by each work at district and AER level.
Step-3: Estimation of average carbon sequestration or stock change per ha (tC/ha/year) for each work (e.g., Minor irrigation or land development or drought proofing) in sample villages in an AER	Estimation of the average carbon sequestered per ha for each MGNREGA-NRM work at AER level based on field studies in sample villages is presented in Table 3.3. - Carbon sequestration/stock change for each MGNREGA-NRM work is based on per ha carbon sequestration/work and area per work based on field studies - Estimate of carbon sequestration/stock change (tC/ha/yr) for a given work (such as minor irrigation or land development or drought proofing) at AER level is based on estimates obtained from locations in sample villages from sample districts in an AER - carbon sequestration in tC/ha/work/year - An average carbon sequestration value - tC/ha/year for each work at the AER level is obtained based on estimates from all sample villages considering all the districts covered in an AER.
Step-4: Estimation of total carbon sequestration or stock change for each work (e.g., Minor irrigation or land development or drought proofing work) and for all works at the AER level	Estimation of total carbon sequestration for each work and for all works in an AER is based on extrapolation from village to district to AER level: Using carbon sequestration values estimated considering all the sample villages and area impacted per work, the carbon sequestration across all the districts in an AER for all works implemented under MGNREGA for the period 2006-07 to 2017-18 is estimated using the following procedure: ***1. Estimate total number of works implemented/AER*** -Select all the districts in each AER -Download and compile year-wise, district-wise MGNREGA-NRM works implementation data of all the districts in an AER **- *Period:*** 2006-07; 2007-08; 2008-09; 2009-10; 2010-11; 2011-12; 2012-13; 2013-14; 2014-15; 2015-16; 2016-17 and 2017-18 **- *Works:*** All MGNREGA-NRM works completed during a year ***2. Estimate carbon sequestration per work at AER level*** - Select all the districts belonging to a given AER. - Estimate the average area impacted per work at AER level using area data per work obtained from village sample studies

	- Estimate the average carbon sequestration per work as described earlier as tC/work/year – based on per ha carbon sequestration and average area of the work - Carbon sequestration at AER level is obtained by multiplying the average carbon sequestration rate per work in an AER, the average area impacted per work and the cumulative number of works completed in a year at AER level, considering all the districts and aggregating for all the years.
Step-5: Carbon sequestration or stock change at the national level for all AERs	All India level carbon sequestration or stock change is estimated by the following procedure: -Estimate carbon sequestration for each MGNREGA-NRM work at each AER level -Aggregate carbon sequestration for all the works implemented for each AER -Aggregate the total carbon sequestration estimate for all AERs based on estimates at each AER level.
Step-6: Extrapolation of carbon sequestration or stock change upto 2030	Projection of carbon sequestration or stock change from implementation of MGNREGA programme by 2030 is achieved by adopting the following approach: -Estimate the annual carbon sequestration/stock change using the steps provided above upto Step-5. - Estimate the average annual rate of implementation of each MGNREGA-NRM work, based on data from MGNREGA website for the recent past (2014-2018). - Using the annual mean rate of implementation of each MGNREGA-NRM work for the period 2014 to 2018, project the works to be implemented upto 2027, at constant rates. *- It is assumed that in another 10 years, potential for implementing MGNREGA-NRM works will be exhausted. Further, the demand for MGNREGA works may decline over the years. Finally, even if some works are implemented after 2027, they may provide carbon benefit only after 3 to 5 years (beyond 2030), thus may not be relevant to reporting under Paris Agreement or under NDC.* - Estimate the cumulative carbon sequestration or stock change for years by2030, using the MGNREGA-NRM works implemented cumulatively till 2027.

3. Database for Estimation of Carbon Sequestration or Stock Change

Estimation of total carbon sequestration or stock change due to any MGNREGA-NRM activity is based on four variables:

I. Cumulative works implemented upto 2017-18

II. Mean number of works implemented during the five-year period of 2013-14 to 2017-18
III. Projection of works implemented for 2020, 2025 and 2030, based on the mean annual rates of MGNREGA-NRM works implementation over the previous five-year period (2013-14 to 2017-18)
IV. Average area impacted by each NRM activity, derived from sample villages and districts
V. Average carbon sequestration rates (biomass and soil) of different MGNREGA-NRM works in different districts of different AERs.

3.1. Cumulative Number of Works Completed up to 2017-18 from 2006-07

MGNREGA database provides data on number of works implemented annually. Estimation of cumulative number of works implemented say upto2017-18 is necessary to calculate total carbon sequestration during the year 2017-18. The average area per work and carbon sequestration rates per ha for each NRM work is estimated at AER level (Table 3.3). Thus, cumulative number of NRM works leading to carbon sequestration or stock change is estimated by AER level from MGNREGA database. The cumulative number of major MGNREGA-NRM works with potential to contribute to carbon sequestration or stock change is given for each AER in Table 3.1. Number of different NRM works cannot be compared unless area impacted under each NRM work is estimated (Section 3.3).

Table 3.1: Cumulative number of NRM works implemented under MGNREGA upto 2017-18*

	Drought proofing	Micro irrigation	Renovation of traditional water bodies	Land development	Water conservation & harvesting
AER2	161017	98863	108537	192863	624859
AER3	131536	398422	531685	1648235	1782008
AER4	110729	63273	74595	178015	184176
AER5	37633	7761	28164	134287	225048
AER6	42733	385	8150	7774	63529
AER7	22316	1375	5231	1700	45104
AER8	116324	12387	82901	94604	949984
AER9	84572	41802	63424	155573	124085
AER10	141424	14327	45908	295537	195119
AER11	315259	279278	161936	750960	776506
AER12	67674	10918	65204	93005	159063
AER13	141933	151143	398332	172832	240431
AER14	40982	128390	56758	248022	183297
AER15	342557	178844	328889	376559	488847
AER16	258112	91394	161542	219847	216478
AER17	274655	102550	137618	337221	218593
AER18	19294	12525	20354	11479	11718
AER19	56076	21108	34318	160157	152702

* *MGNREGA database provides data on number of works completed from 2006-07 to 2018*

3.2. Projection of Number of MGNREGA-NRM Works for the Period up to 2030

It is assumed that MGNREGA will continue upto 2030. The annual investment in MGNREGA has increased over the past 12 years since its inception. The following approach is adopted for projecting the number works:

- Estimate the average annual rate of implementation of each MGNREGA-NRM work, based on data from MGNREGA database for the recent five-year period of 2014 to 2018. It can be observed that the standard deviation for majority of the works is low (Table 3.2).
- Using the annual mean rate of implementation of each NRM work for the recent period (2014 to 2018), project the number of works implemented upto 2027, at constant rates. Here it is assumed that there will be demand for MGNREGA works and employment at least for the next 10 years and at nearly constant rates, since no other estimates are available or can be assumed.
- It is assumed that in another 10 years, potential for implementing NRM works may be exhausted. Further, the demand for MGNREGA works may decline over the years. Finally, even if some NRM works are implemented after 2027, they may provide carbon benefit only after 3 to 5 years (beyond 2030), thus may not be relevant to reporting upto 2030.
- Projection of MGNREGA-NRM works implemented is made according to AER and used for estimating the carbon sequestration potential.

The annual number of each MGNREGA-NRM work implemented during the period 2013-14 to 2017-2018 is obtained from the MGNREGA database and mean annual number of works implemented for the period 2013-14 to 2017-18 is estimated and given in Table 3.2. Projection of the carbon sequestration potential is based on the cumulative works implemented for the period up to2020, 2025 and 2030, according to AERs.

Table 3.2: Cumulative, annual and mean number of works implemented for the period 2006-07 to 2017-2018

NRM Works	Total number of works upto 2012-13 from 2006-07	Mean number of works during 2006-07 to 2012-13	Works implemented during					Mean number of works during 2013-14 to 2017-18	Standard deviation (Co-efficient of variation in %) of number of works completed during 2013-14 & 2017-18
			2013-14	**2014-15**	**2015-16**	**2016-17**	**2017-18**		
Drought proofing	1002884	7959	275539	236937	304137	258365	286964	272389	25903 (10.5%)
Micro irrigation	709098	5628	129014	119187	279584	164709	213153	181129	66222 (2.7%)
Water conservation & harvesting	4139040	32850	302521	615298	622858	521795	440036	500502	133655 (3.7%)
Renovation of traditional water bodies	1135072	32850	246688	205001	214123	268072	244590	235695	25767 (9.1%)
Land development	1936730	15371	633686	703749	463954	667025	673527	628388	95231 (6.6%)

3.3. Average Area of each MGNREGA-NRM Work in Different AERs

All the NRM activities (Works) under MGNREGA are largely linked to land and water. Even water related activities impact land by providing irrigation water for crop production. Thus the basic data required for estimating carbon sequestration/stock change would be area subjected to each MGNREGA-NRM activity in each village, extrapolated to the national level. Unfortunately, MGNREGA Database does not provide any information on the area impacted by NRM activity. It provides number of works demanded and implemented, investment, expenditure and employment created. Thus estimating the area impacted by NRM activities is needed from the field studies, in order to estimate carbon sequestration. Esteves et al. (2013), have estimated the environmental benefits including carbon sequestration at the per ha level but not the area impacted by NRM activities. Thus in this study, area subjected to different NRM activities in the sample villages is estimated through survey and field measurements and provided in Table 3.3. Since the area impacted for a given NRM activity, say minor irrigation or land development or drought proofing, may vary among AERs, in this study area impacted data is generated and given at AER level. In the majority of the cases, the area impacted by a work is less than two ha. Average area impacted per MGNREA-NRM activity is used for calculating per hectare carbon sequestration or stock change benefit (Table 3.3).

3.4. Carbon Sequestration/Stock Change Rates for MGNREGA-NRM Activities

Carbon sequestration rates (tC/ha/yr) for each NRM-based work are calculated and extrapolated to village, district and AER scales. The impact of MGNREGA activity on carbon stocks in biomass (trees) and soil carbon is estimated through field studies in sample villages across all the AERs(Table 3.3). The methods adopted are given in Section 2 and Annexure B. Biomass sequestration rates are estimated only for those works or activities involving tree planting, such as drought proofing. SOC is estimated for all activities involving tree planting and other activities not involving tree planting such as land development, minor irrigation works, water conservation and water harvesting, etc. The explanation for the negative carbon sequestration is provided as a footnote to Table 3.3.

The carbon sequestration rates varied for a given work/activity across AERs. The carbon sequestration rates for drought proofing ranged from 0.85 to 2.20 tC/ha/yr for biomass carbon and 0.12 to 2.61 tC/ha/yr for SOC. The carbon sequestration rates for land development are estimated to be in the range of 0.1 to 1.97 tC/ha/yr for SOC. Similarly for water conservation and water harvesting (0.19 to 1.90 tC/ha/yr), and minor irrigation works (0.0 to 1.93 tC/ha/yr). The carbon sequestration rates are positive for most of the NRM activities in majority of the AERs. However, negative carbon sequestration rates for SOC, are recorded for some works/activities in some of the AERs (Table 3.3) as

carbon is being released from the soils as a result of the works being implemented.

Table 3.3: 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 (ha)	Carbon** (tC/ha/year)		
			Soil	**Biomass**	**Total**
AER2	Micro irrigation Works	0.90	1.10		1.10
		0.66	-1.46		-1.46
			0.02		0.02
	Land development	2.28	1.05		1.05
			1.97		1.97
	Drought proofing	1.15	2.07	2.20	4.27
AER3	Water conservation and harvesting	7.25	-0.85		-0.85
		0.71	0.88		0.88
	Land development	2.28	1.37		1.37
	Drought proofing	1.15	2.61	1.89	4.50
	Water conservation and harvesting	0.99	-1.05		-1.05
AER4	Minor irrigation works	0.66	0.20		0.20
			0.35		0.35
	Land development	2.28	-0.90		-0.90
	Water conservation and harvesting	0.71	0.73		0.73
		0.99	-0.51		-0.51
		7.25	0.65		0.65
	Drought proofing	0.75	0.70	0.95	1.65
AER5	Water conservation and harvesting	0.71	0.73		0.73
		0.99	0.95		0.95
	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
AER6	Drought proofing	1.15	-0.21	1.13	0.92
	Renovation of traditional water bodies including desilting of tanks	0.90	1.37		1.37
	Land development	2.28	-0.02		-0.02
	Minor irrigation works	0.66	0.33		0.33
			0.36		0.36
	Water conservation and harvesting	7.25	0.33		0.33
AER7	Minor irrigation works	0.66	1.93		1.93
			-0.23		-0.23
	Drought proofing	0.78	1.23	2.2	3.43
	Minor irrigation works				
AER8	Water conservation and harvesting	0.71	-0.13		-0.13
	Land development	2.28	0.10		0.10
	Drought proofing	0.78	0.12	1.16	1.28
		0.66	-0.97		-0.97

AER9	Renovation of traditional water bodies including desilting of tanks	0.90	0.78		1.21
AER10	Minor irrigation works	0.66	-0.61		-0.61
	Drought proofing	1.82	0.83	1.15	1.98
	Water conservation and harvesting	0.71	1.19		1.19
	Land development	2.28	0.28		0.28
AER11	Water conservation and harvesting	0.71	0.44		0.44
		0.99	0.22		0.22
	Land development	2.28	-0.07		-0.07
	Drought proofing	1.95	0.96	0.98	1.94
	Minor irrigation works	0.66	1.27		1.27
AER12	Land development	2.28	0.29		0.29
	Drought proofing	1.15	0.70	1.35	2.05
	Water conservation and harvesting	7.25	0.36		0.36
AER13	Water conservation and harvesting	0.71	1.90		1.90
	Drought proofing	2.30	2.24	1.15	3.39
	Minor irrigation works	0.66	0.70		0.70
AER14	Minor irrigation works	0.66	1.43		1.43
			0.88		0.88
	Land development	2.28	1.15		1.15
	Drought proofing	1.10	-0.68	0.97	0.29
AER15	Water conservation and harvesting	0.71	-1.73		-1.73
	Drought proofing	0.90	0.55	2.1	2.65
	Land development	2.28	-0.01		-0.01
	Minor irrigation works	0.66	-1.08		-1.08
AER16	Water conservation and harvesting	0.71	-0.20		-0.20
	Minor irrigation works	0.66	-1.97		-1.97
			-0.30		-0.30
	Drought proofing	1.19	0.93	1.18	2.11
AER17	Land development	2.28	0.12		0.12
	Drought proofing	1.10	0.14	0.95	1.09
	Minor irrigation works	0.66	-0.38		-0.38
			0.21		0.21
AER18	Renovation of traditional water bodies including desilting of tanks	0.90	0.73		0.73
	Drought proofing	1.37	0.87	1.15	2.02
	Water conservation and harvesting	0.71	0.19		0.19
	Minor irrigation works	0.66	0.40		0.40
AER19	Drought proofing	1.10	1.07	0.85	1.92
	Water conservation and harvesting	0.71	1.72		1.72
	Minor irrigation works	0.66	0.54		0.54
	Land development	2.28	-0.10		-0.10

**The average area impacted for different AERs is estimated based on the work implemented in the sample villages. In some AERs even though a work is implemented, the sample villages did not contain that NRM work. In such cases, the average area value for a given NRM work is obtained from the neighbouring district/AER. For example, land development work is not reported in sample villages of some AERs, even though the works are implemented at the district or AER level.*

***Negative carbon sequestration rates are obtained for a few NRM works in some AERs. The carbon sequestration in soils is dependent on various factors including, NRM work implemented. Its normal to obtain negative carbon sequestration rates,*

especially in agricultural lands due to various factors such as cultivation practices (ploughing and inter-culture operations), application of organic manure, and incorporation of crop residue into soil or removal of the residue from the crop fields.

NRM activities, by reducing soil erosion, improving soil fertility, providing water for crop irrigation lead to increased crop biomass (including root biomass) production, contribute to enhanced SOC. Activities involving tree planting will lead to accumulation of carbon in plant roots and stems through photosynthesis and SOC increment due to root biomass and decomposition of litter.

4. Carbon Sequestration through NRM Activities Implemented under MGNREGA during 2017-18 in India

This main aim of this study is to estimate annual aggregate national level carbon sequestration achieved by MGNREGA programme and its contribution to mitigation of climate change through the development of a sustained and substantial terrestrial carbon sink. Such an assessment has not been carried out so far. In this study, an initial attempt is made to estimate carbon sequestration achieved by MGNREGA-NRM works at the national level, based on village level estimates, aggregated to district level and then to all districts in different AERs and then aggregation of all AERs. Broadly the following approach is adopted:

a) Estimate the cumulative MGNREGA-NRM activities (works) implemented upto 2017-18 in each AER
b) Estimate the average area of each MGNREGA-NRM related work that has an impact on carbon sequestration(based on village and district level estimates for each AER) – Table 3.3
c) Estimate the average carbon sequestration rate per ha per year for each NRM work at AER level (based on village and district level estimates for each AER) – Table 3.3
d) Based on estimates made above under a, b, and c, estimate the total carbon sequestration for each work at AER level:

Total Carbon Sequestration for AER_i = (Cumulative number of works implemented till 2017-18 for NRM-Work-1 for AER_i) * (Average area impacted for the NRM-Work-1 in ha in AER_i) * (Average Carbon Sequestration for the Work-1 in AER_i in tC/ha/year)

All the MGNREGA-NRM activities, which potentially could impact carbon stocks in soil and tree biomass are included for estimating the carbon sequestration or mitigation potential. Carbon sequestration or stock change estimates for each AER and national level aggregate for all AERs combined are given in Table 4.1. Estimates for each of the NRM works is given in AnnexureC1.

It can be observed that carbon sequestration is positive for majority of the works in majority of the AERs. However, there are a few works such as micro-irrigation, for which carbon stock change is negative i.e. for AERs 2, 3, 5, 10, 15, 16 and 17. Similarly, for a few other NRM works in some AERs, carbon stock change is negative. Only AER8 has an overall negative carbon stock change (-0.11 MtC). However, some NRM works such as renovation of traditional water bodies and drought proofing have net positive carbon stock change or sequestration in all AERs. It is always a challenge to estimate SOC sequestration rates and expect a trend due to the large spatial variation and the heterogeneity in crop cultivation practices adopted.

The total carbon (biomass and SOC) sequestered at the national level, in all the AERs and for all the MGNREGA-NRM works, for the year 2017-18 (considering cumulative works implemented) is estimated to be 16.9MtC (61.9 $MtCO_2$).

Table 4.1: Total carbon (MtC and $MtCO_2$)sequestered by MGNREGA-NRM works during 2017-18, based on cumulative number of works implemented during 2006-07 to 2017-18

AERs	Total carbon sequestered by different NRM works in 2017-18 (MtC)						Total sequestration during 2017-18 ($MtCO_2$)
	Land development works	Micro irrigation works	Water conservation and harvesting works	Renovation of traditional water bodies	Drought proofing works	Total of all works	
AER2	1.374	-0.002	0.055	0.080	0.791	2.30	8.43
AER3	3.734	-0.010	-1.808	0.650	0.681	3.25	11.91
AER4	0.210	0.025	0.187	0.050	0.137	0.61	2.23
AER5	-0.139	-0.007	0.061	0.030	0.109	0.05	0.20
AER6	-0.016	0.003	0.510	0.010	0.045	0.55	2.02
AER7	0.002	0.000	0.108	0.000	0.060	0.17	0.62
AER8	-0.002	0.015	-0.296	0.060	0.116	-0.11	-0.39
AER9	0.013	0.056	0.411	0.070	0.059	0.61	2.21
AER10	0.374	-0.021	0.819	0.030	0.510	1.71	6.28
AER11	0.242	0.017	0.073	0.110	1.193	1.63	5.99
AER12	0.206	0.025	0.415	0.040	0.160	0.85	3.10
AER13	-0.010	0.023	0.324	0.280	1.107	1.72	6.32
AER14	0.064	0.249	0.056	0.070	0.013	0.45	1.66
AER15	0.384	-0.063	0.038	0.220	0.817	1.40	5.12
AER16	-0.002	-0.011	-0.027	0.110	0.648	0.72	2.63
AER17	0.046	-0.002	-0.048	0.170	0.328	0.49	1.81
AER18	-0.001	0.005	0.002	0.010	0.053	0.07	0.25
AER19	-0.018	0.010	0.289	0.020	0.119	0.42	1.54
Total	**6.46**	**0.31**	**1.17**	**2.03**	**6.95**	**16.90**	**61.96**

4.1. Biomass and Soil Carbon Sequestration (MtC) by Drought Proofing Works

Drought proofing works were the only category of works to include tree planting through afforestation and horticultural fruit tree planting. Tree biomass and SOC estimates are made separately and presented in Table 4.2. It can be observed that biomass carbon sequestration accounted for 3.84 MtC and SOC for 3.04 MtC. Drought proofing accounted for a little over 40% of total carbon sequestration, considering all NRM works at the national level. Thus, drought proofing involving tree planting is crucial in achieving enhanced carbon sequestration from MGNREGA programme.

Table 4.2: Biomass and SOC Sequestration (MtC) by Drought Proofing Works during 2017-18

	Carbon sequestered in biomass (MtC)	Carbon sequestered in soil (MtC)	Total carbon sequestered in biomass and soil (MtC)	Total carbon sequestered in biomass and soil in $MtCO_2$
AER2	0.407	0.383	0.791	2.90
AER3	0.286	0.395	0.681	2.50
AER4	0.079	0.058	0.137	0.50
AER5	0.071	0.038	0.109	0.40
AER6	0.056	-0.010	0.045	0.17
AER7	0.038	0.021	0.060	0.22
AER8	0.105	0.011	0.116	0.43
AER9	0.000	0.059	0.059	0.22
AER10	0.296	0.214	0.510	1.87
AER11	0.602	0.590	1.193	4.37
AER12	0.105	0.054	0.160	0.59
AER13	0.375	0.732	1.107	4.06
AER14	0.044	-0.031	0.013	0.05
AER15	0.647	0.170	0.817	3.00
AER16	0.362	0.286	0.648	2.38
AER17	0.287	0.041	0.328	1.20
AER18	0.030	0.023	0.053	0.19
AER19	0.052	0.066	0.119	0.44
Total (MtC)	**3.84**	**3.04**	**6.95**	**25.48**

5. Carbon Sequestration or Stock Change Projections from 2017 to 2030 for India

In Section 4, carbon sequestration or stock change is estimated for the MGNREGA-NRM works implemented upto 2017-18. In this section, carbon sequestration is projected upto 2030. The methodology adopted for projection is given in Table 2.2.The projection requires an estimate of the number of NRM works implemented, area to be impacted and carbon sequestration rates to be made over the full time period of the projection.

5.1. Projection of Carbon Sequestration for the Period up to 2030

Table 5.1 presents the carbon sequestration projections for the period 2020 to 2030 according to AERs. The projection of cumulative number of works completed for the period upto - 2020, 2025 and 2030 for the MGNREGA-NRM works is provided in Annexure C2. Carbon sequestration projections for period upto 2030 is estimated using the following broad steps and presented in Table 5.1:

- Estimate the cumulative works implemented to 2020, 2025 and 2030 (Annexure C2)
- Average area for each of the work is taken from Table 3.3, based on field surveys
- Average carbon sequestration rates recorded for the period to 2017 (Table 3.3) are used for projections:

- it is assumed that the rate of change in carbon stocks for different MGNREGA-NRM works will be similar to the values obtained for the period to 2017-18.
- This assumption is made in the absence of dynamic rates of change in carbon stock for multiple NRM works implemented under MGNREGA.

- Projection of carbon sequestration is obtained by multiplying the cumulative number of works implemented upto 2020, 2025 and 2030 by the average area per work and mean carbon sequestration rate (tC/ha/year) for each work.

Table 5.1: Projections of national annual net carbon sequestration by AER in 2017, 2020, 2025 and 2030 ($MtCO_2$)

	National net carbon sequestration by MGNREGA-NRM works during 2017 ($MtCO_2$)	Total carbon sequestration by MGNREGA-NRM works during 2020 ($MtCO_2$)	Total carbon sequestration by MGNREGA-NRM works during 2025 ($MtCO_2$)	Total carbon sequestration by MGNREGA-NRM works during 2030 ($MtCO_2$)
AER2	8.43	15.26	21.98	29.14
AER3	11.91	10.18	15.92	20.13
AER4	2.23	4.96	7.22	9.88
AER5	0.20	9.24	12.03	14.09
AER6	2.02	6.31	8.02	10.18
AER7	0.62	8.50	10.03	11.89
AER8	-0.39	4.87	6.59	8.74
AER9	2.23	4.41	5.75	7.71
AER10	6.28	3.72	5.65	8.00
AER11	5.99	6.33	11.56	17.24
AER12	3.10	10.46	13.42	16.86
AER13	6.32	21.45	26.20	34.68
AER14	1.66	5.51	8.10	10.69
AER15	5.12	3.64	5.55	8.74
AER16	2.63	3.82	5.74	8.60
AER17	1.81	5.30	10.97	16.83
AER18	0.25	3.06	4.45	6.32
AER19	1.54	5.00	6.81	9.28
Total	**61.96**	**132.00**	**186.00**	**249.00**

Carbon sequestration projected for the period 2020 to 2030 shows a continuous increase, due to increase in cumulative NRM works implemented under MGNREGA. During 2017, total carbon sequestered is estimated to be 62 $MtCO_2$(Figure 5.1).The annual carbon sequestration is projected to increase to:

- 2020: 132 $MtCO_2$
- 2025: 186 $MtCO_2$
- 2030: 249 $MtCO_2$

Thus, even though MGNREGA is a livelihood security programme, the carbon sequestration co-benefit is significant.

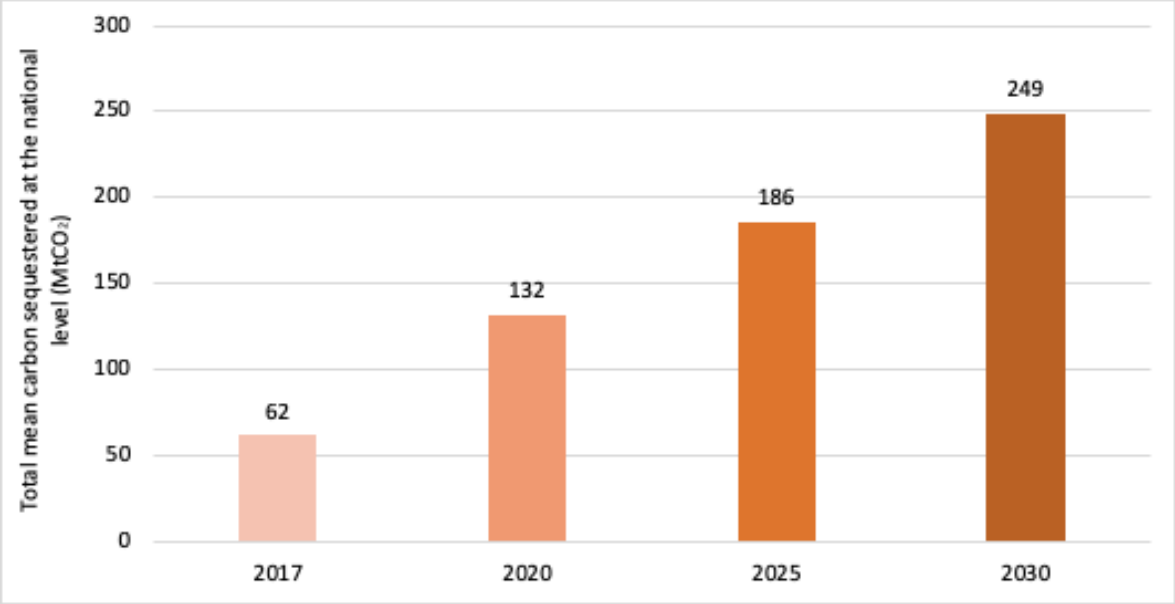

Figure 5.1: Mean CO_2 sequestration trends and projections between 2017-18 and 2030 for the MGNREGA programme in India

5.2. Estimation of Potential Range of Carbon Sequestration

Table 5.1 and Figure 5.1 presented the mean carbon sequestration achieved under MGNREGA programme. Mean carbon sequestration potential is projected based on the averge area under a given MGNREGA-NRM work and average carbon sequesrtation rate for that work in an AER. An attempt is made here to provide a range for the carbon sequestration potential, by considering the range of low and high rates of carbon sequestration per hectare measured during the field surveys for a given NRM work category. The likely ranges of low to high carbon sequestration potentials are provided in Table 5.2.

Table 5.2: Range in carbon sequestration potential of all MGNREGA–NRM works and in drought proofing works

Years	Maximum potential	Mean potential	Minimum potential
C-Sequestration by All NRM Activities ($MtCO_2$)			
2017	181	62	47
2020	301	132	87
2025	474	186	117
2030	540	249	150
C-Sequestration by only Drought Proofing Works ($MtCO_2$)			
2017	104	25	20
2020	96	43	37
2025	147	59	54
2030	197	85	72

The estimates should be viewed with caution, given the large spatial variation across the districts, with respect to average area impacted by a given work, the climatic factors, soil quality, slope, crop cultivation practices, etc.

- Considering all the NRM works, during 2017, the mean carbon sequetration potential is estimated to be 62 $MtCO_2$, while the range is between 47 $MtCO_2$ to 181 $MtCO_2$.
- When only drought proofing works are considered, the carbon sequestration potential during 2017 is in the range of 20 $MtCO_2$ to 104 $MtCO_2$.
- When projections are made for all MGNREGA-NRM works, carbon sequestration is in the range of 150 $MtCO_2$ to 540 $MtCO_2$ by 2030.
- When only drought proofing activity is considered, carbon sequestration could be in the range of 72 $MtCO_2$ to 197 $MtCO_2$ by 2030.

The estimate provides a broad idea of the potential for enhancing the carbon sequestration rates of MGNREGA-NRM works. However, these estimates of maximum carbon sequestration potential should be viewed cautiously since the sample size is inadequate to obtain a range of carbon sequestration rates for each NRM work in each of the AERs.

6. Implications of Carbon Sequestration under MGNREGA for Climate Change Mitigation and Contribution to NDC Target

According to IPCC (Smith et al., 2014), most categories of adaptation options for climate change in land use sectors have positive impacts on mitigation. Further, mitigation choices taken in a particular land-use sector may enhance or reduce resilience to climate variability and change within or across sectors. Smith and Olesen (2010) have identified a number of synergies between mitigation options in agriculture, which also enhance resilience to future climate change, for example, enhancement of soil carbon stocks. On current agricultural land, mitigation and adaptation interaction can be mutually re-enforcing, particularly for improving resilience to increased climate variability under climate change (Griscom et al., 2017; Rosenzweig and Tubiello, 2007). Mitigation practices for soil carbon sequestration will increase the ability of soils to hold soil moisture and reduce erosion. It will also enrich ecosystem biodiversity by establishing more diversified cropping systems, and help cropping systems to cope with droughts and floods, both of which are projected to increase in frequency and severity under a future warmer climate (Rosenzweig and Tubiello, 2007).

In the agriculture sector, cropland adaptation options that also contribute to mitigation are 'soil management practices that reduce fertilizer use and increase crop diversification; promotion of legumes in crop rotations; increasing biodiversity, the availability of quality seeds and integrated crop/livestock systems (FAO, 2008, 2009; Griscom et al, 2017). Agroforestry is an option which provides mitigation-adaptation synergy in the agriculture sector, as trees planted sequester carbon in biomass and soil, and tree products such as fruits, leaves and seeds are a source of income and livelihood to communities, especially during drought years (Verchot et al., 2007).

Thus, in this section, the linkage between adaptation or resilience building measures and practices and carbon sequestration under MGNREGA is presented.

6.1. Climate Change, MGNREGA and Carbon Sequestration

One of the targets of India's NDC is to "create an additional carbon sink of 2.5 to 3.0 billion tonnes of CO_2-equivalent through additional forest and tree cover by 2030" (GoI, 2015). The NDC target includes only lands subjected to enhancing forest and tree cover through tree planting. Thus, only drought proofing activity would qualify for meeting the carbon sink target of the NDC. The carbon

sequestration or stock change estimates made in this study should be considered as preliminary and rapid estimates. Some of the potential implications of CO_2 sequestered by the large MGNREGA programme are as follows:

- The annual mean carbon sequestration from implementation of MGNREGA works is estimated to increase from 62 $MtCO_2$ in 2017-18 to 249 $MtCO_2$ by 2030. The carbon sequestration rate estimated and projected includes all the NRM works, both with tree planting and without tree planting.
- Drought proofing is the NRM activity that includes tree planting. The carbon sequestration rate in 2017 for this activity is estimated to be 25 $MtCO_2$. This is projected to increase to 85 $MtCO_2$ annually, by 2030 (Table 5.2).
- The total CO_2 removal or sequestration estimated for all the land categories in India for 2010, according to the Second Biennial Update Report of India (MoEFCC, 2018) is 301 $MtCO_2$. Compared to this, the carbon sequestration rate in 2017 through MGNREGA is estimated to be 62 $MtCO_2$. By 2030, the contribution could be a mean of 249 $MtCO_2$ or a minimum of 150 $MtCO_2$. This shows that MGNREGA programme can make a significant contribution to climate change mitigation in India in the land use sector.

6.2. Impact of Climate Change on MGNREGA Works and Carbon Sequestration

Climate change could impact land degradation, water availability and demand, crop productivity and tree growth in the long-term. Studies by Esteves et al. (2013) have shown that MGNREGA works provide multiple environmental benefits such as improving soil fertility, water conservation, increased crop productivity and reduction of vulnerability to current climate risks. Section 1.1 highlighted the potential environmental benefits of MGNREGA.

Impact of Climate Change on carbon sequestration has been discussed in the Fifth Assessment Report of the IPCC (2014). It is shown that climate change could potentially have an adverse impact on carbon sequestration potential of land-based mitigation options. Studies have also shown the synergy between adaptation and mitigation in land use sectors and mitigation options (Ravindranath, 2007). For example, drought proofing involving tree planting, particularly fruit yielding species, not only sequesters carbon but also provides alternate source of income especially during drought years. Thus, drought proofing activity under MGNREGA is both a mitigation and adaptation strategy.

6.3. Infrastructure for Climate Resilient Growth, Resilience to Climate Change and Carbon Sequestration

In India, the UK's Department For International Development (DFID) and Ministry of Rural Development (MoRD) launched a programme titled 'Infrastructure for Climate Resilient Growth (ICRG)', aimed at promoting resilience to climate change especially by climate proofing MGNREGA assets. ICRG's programme aims at improving the climate resilience of vulnerable people in India. The intended outcome is improved quality of the physical assets under MGNREGA, which will be resilient to climate change impacts. Sustained carbon sequestration benefits through MGNREGA NRM works, especially the drought proofing works, would require building resilience to the physical assets as well as the biological assets such as planting of orchards and afforestation. The ICRG programme has developed a strategy to mainstream climate change adaptation or resilience into MGNREGA works, so that the environmental benefits, including carbon sequestration benefits are sustained.

7. Potential for Enhancing Carbon Sequestration Benefits from MGNREGA

In the context of the NDC target of 2.5 to 3 billion tonnes of CO_2 sequestration through enhanced forest and tree cover, it is necessary to explore options in all land categories such as forestland, grazing land or community land, wastelands and croplands. The present study has shown the potential for carbon sequestration to be in the range of 150 to 540 $MtCO_2$ by 2030, with a mean value of 249 $MtCO_2$, considering NRM works. The wide range is mainly due to due to varying rates of carbon sequestration measured for the different NRM works within an AER and in particular across the AERs. The carbon sequestration rates for a given activity such as a fruit orchard or afforestation of similar species composition and density could vary even within a district due to factors such as soil quality, slope, genetic seed material, rainfall and cultivation practices. Similarly, the impact of soil and water conservation measures on crop or tree biomass productivity could vary, even for a given NRM work within a village or a Panchayat or a district. Thus, effective implementation of all NRM works under MGNREGA could lead to enhanced soil carbon sequestration and tree biomass carbon sequestration as a co-benefit.

7.1. Options for Enhancing Carbon Sequestration Benefits through MGNREGA

The present study and the previous study in 4-States (Esteves et al., 2013), have shown that on the whole multiple MGNREGA works, in particular drought proofing, have delivered carbon sequestration co-benefits. Potential options for enhancing carbon sequestration benefits are as follows:

- Mainstream resilience to climate change into designing of infrastructure and assets and their implementation under MGNREGA, to ensure sustained carbon sequestration co-benefit.
- Enhance the effectiveness of all land and water related NRM activities, particularly aimed at improving soil fertility, enhancing water conservation and availability, and ultimately increasing biomass production of annuals such as crops, and perennials such as orchards and trees. Increased biomass production will lead to increased soil organic carbon stock and tree biomass stock.
    - A study by Indian Institute of Science in 4-states showed that MGNREGA works such as silt application, check dams, horticulture development, trench cum bund barrow pits, provision of irrigation facility, land development, percolation tanks, pond works, contour development, canal construction, pasture land development and afforestation/plantation development have led to enhanced carbon stocks.
- Incorporate tree planting, especially fruit and fodder yielding trees into NRM works in addition to drought proofing under MGNREGA, with an aim of generating alternate income and livelihood sources from the production and utilisation of timber, fuelwood, fruits, leaves and other products. Carbon sequestration will be a co-benefit.
- The 2016 guidelines on “Mission Water Conservation – Natural Resource Management Framework under MGNREGS within the overall framework of PMKSY” aims at a paradigm shift from Relief Works approach to Integrated Natural Resource Management (INRM) in implementation of MGNREGS.
    - This guideline clearly demonstrates the feasibility and potential for enhacing carbon sequestration as a co-benefit, where planned and systematic development of land and harnessing of rainwater following watershed principles is the central focus of

MGNREGS works, to sustainably enhance farm productivity and incomes of poor people.

- Thus, any effort to improve the efficiency and effectiveness of NRM works implemented under MGNREGA will contribute to not only improving farm productivity and incomes but build resilience to climate risks and also sequester carbon as a co-benefit.

8. Limitations of the Carbon Sequestration Potential Assessment

MGNREGA is a very large programme implemented in nearly 691 districts, covering hundreds of thousands of villages, in diverse agroclimatic**,** physiographic and socio-economic conditions by different state governments with varying institutional capacities.There are several limitations associated with this study and thus carbon sequestration or mitigation potential estimates could only be considered as preliminary estimates and with caution. Some of the limitations include: i) small sample size due to limitations of resources and time; ii) absence of data on area impacted by each MGNREGA work at a village level; iii) large spatial and temporal variability of carbon sequestration rates across different MGNREGA-NRM works even within a district, iv) absence of dynamic carbon sequestration rates for biomass and SOC for multiple NRM works for 2020, 2025 and 2030, v) difficulty in projecting the demand for MGNREGA works**,** and in particular MGNREGA-NRM works upto 2025 or 2030, and vi) non-suitability of existing carbon sequestration projection models to accommodate; a large diversity and numbers of MGNREGA-NRM activities contributing indirectly to soil organic carbon stock change, small scale of area impacted by individual works (often less than one hectare) and large spatial variability of soil carbon sequestration rates across 691 districts of India.

Nevertheless, the estimates are considered by the authors to be adequate to underpin the broad and substantial potential of MGNREGA to provide meaningful and cost-effective carbon s**e**questration co-benefits. Thus, a large, comprehensive and long-term study involving a much larger sampling is urgently required, to assess the carbon sequestration potential of MGNREGA, implemented under diverse conditions.

9. 'Paris Agreement' and 'Katowice Climate Package' Decisions: Implications for Mitigation Estimates of Adaptation Actions

The Paris Agreement and the procedures and guidelines adopted at Katowice Climate Convention, highlight the need for reporting "Mitigation Co-benefits of Adaptation Actions".

- Elements of Adaptation Communication under Article 7 of the Paris Agreement require reporting of "(f) Adaptation actions and/or economic diversification plans, including those that result in mitigation co-benefits" *(https://unfccc.int/node/187572).*
- Reporting under Article 4 requires, "Party with a nationally determined contribution under Article 4 of the Paris Agreement that consists of mitigation co-benefits resulting from its adaptation action and/or economic diversification plans consistent with Article 4, paragraph 7, of the Paris Agreement shall provide the information referred to in annex I as applicable to its nationally determined contribution and as it relates to such mitigation co-benefits" (*FCCC/CP/2018/L.22*).
- "Information to facilitate clarity, transparency and understanding of nationally determined contributions, referred to in decision 1/CP.21, paragraph 28" also requires "Mitigation co-

benefits resulting from Parties' adaptation actions and/or economic diversification plans, including description of specific projects, measures and initiatives of Parties' adaptation actions and/or economic diversification plans" (*FCCC/CP/2018/L.22*) to be reported.

Thus, implementation of Paris Agreement and reporting requirements, according to Katowice Climate Package under Article 7 and Article 4 require estimates of carbon sequestration mitigation as a co-benefit of adaptation actions. Since MGNREGA is a very large programme aimed at adaptation or resilience, with an annual budget of US$6 to US$8 billion, periodic and scientifically robust studies to provide estimates of carbon sequestration are required. The present study provides a very preliminary estimate based on limited sampling, which calls for a large national study to estimate the carbon sequestration as a co-benefit of MGNREGA.

The Government of India could leverage MGNREGA for meeting the targets of Paris Agreement, NDC and SDGs, and for reporting under the United Nations Framework Convention. Further, rural development programmes such as MGNREGA and watershed also provide soil carbon sequestration mitigation co-benefits. Thus, India could benefit by including soil organic carbon sequestration as an activity, in addition to enhancement of forest and tree cover, for achieving the carbon sink target, in its future NDC submission.

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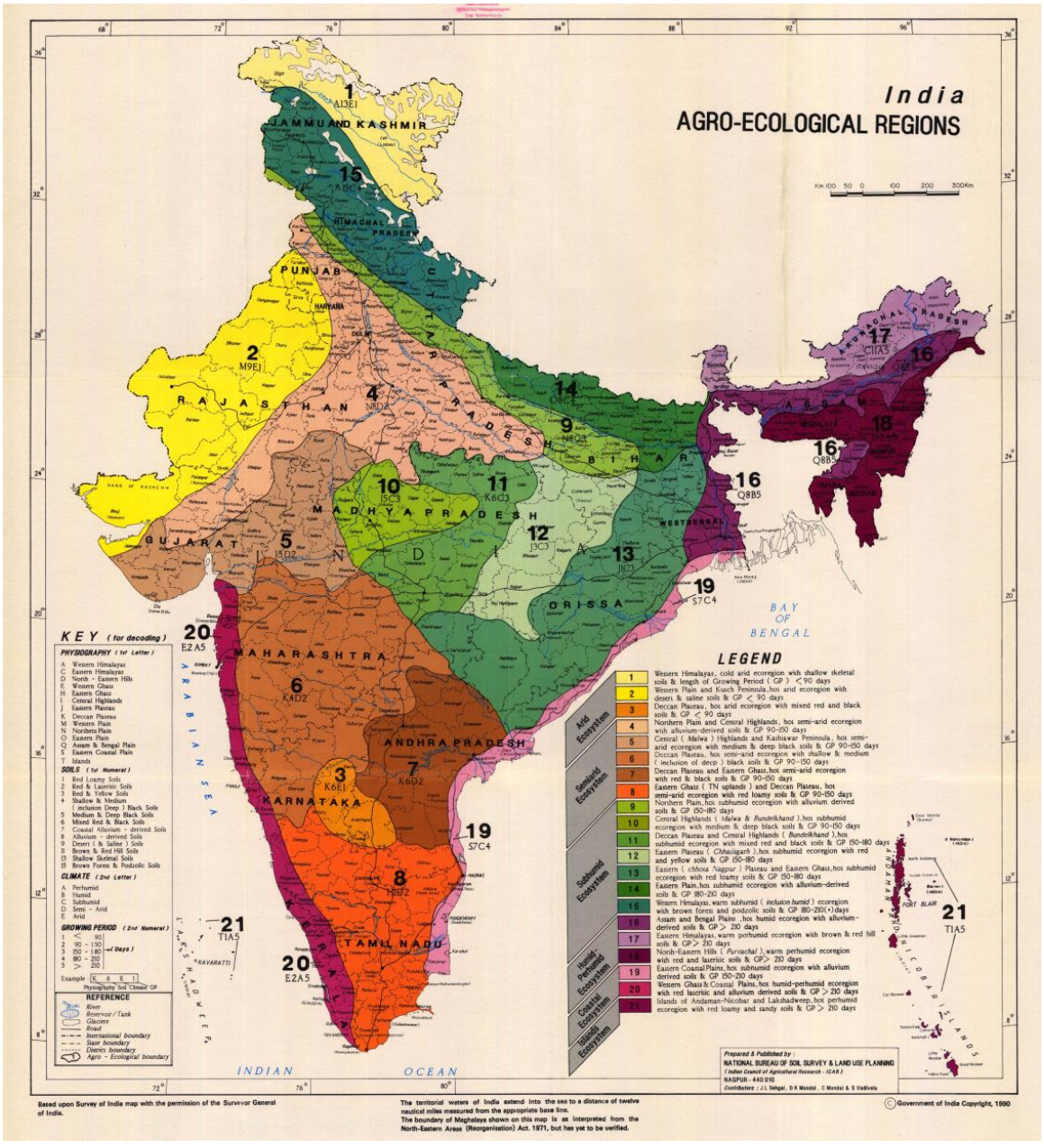
Annexures

Annexure A

Annexure A1: Agro-Ecological Regions of India



Annexure A2: Distribution of districts across AERs

AER	AER regions	State and Districts
1	Cold Arid Ecoregion with Shallow Skelatal Soils	**J&K:** Ladhak (Leh, Gilgit) **HP:** Lahul & Spiti valleys
2	Hot Arid Ecoregion with desert and saline soils	**Rajasthan:** Churu, Jhun- jhunun, Sirohi, Jalore, Bikaner, Jaisalmer, Barmer, Jodhpur (50%) and Ganganagar **Punjab:** Faridkot, Bathinda, Firozpur **Gujarat:** Lakhpat, Banni, Great Rann of Kutch, Bansaskantha (Palanpur), Bhuj including Rapar, Adesar, Anjar, Kandla talukas, Northern part of Jamnagar district **Haryana:** Sirsa, Hissar, Bhiwandi* Mahendragarh (Narnaul)
3	Hot Arid Ecoregion with Red and Black Soil	**Karnataka:** Bellary and Southern Raichur, Bijapur, Northern Chitradurga and Tumkur **Andhra Pradesh:** Anantpur
4	Hot Semi-Arid Ecoregion with Alluvium derived Soils	**Punjab:** Amritsar, Kapurthala, Northern Firozpur and Faridkot, Sangrur, Ludhiana (Western), Patiala (Southern) **U.P:** (W.Part), Ghaziabad, Bulandshahr, Aligarh, Mathura, Etah, Agra, Mainpuri, Moradabad (S.Part), Bandaun, Shajahanpur (S.Part), Lalitpur Fatehgarh, (Farukkabad), Hardoi, Unnao, Etawah, Kanpur, Orai, Jalaun), Rai Bareily, Fatehpur, Bela (Pratapgarh), Jaunpur, Allahabad, Western part of Varanasi, **Rajasthan:** Alwar, Bharatpur, Jaipur, Sawai-Madhopur, Dhaulpur, Ajmer, Tonk, Bhilwara, Udaipur, Dungarpur **Gujarat:** Sabarkantha (Himatnagar) Mehsana, Ahmedabad, Surendranagar, part of Bhuj (Radhanpur) **M.P.:** Bhind, Morena, Gwalior, Datia, Shivpuri
5	Hot Semi-Arid Ecoregion with Medium and Deep Black Soils	**Gujarat:** Northern part of Junagadh, Amreli, Rajkot and Western part of Bhavnagar, Panch Mahal (Godhra), Kheda, Vadodara, Bharuch, Surat (N. Part). Coastal parts of Junagadh, Amrelli and Bhavnagar, **Rajasthan:** Bundi, Chittourgarh, Banswara, Kota, Jhalawar **M.P.:** Ujjain, Ratlam, Jhabua, Indore, Dhar, Dewas, Khandwa (East Nimar), Khargone (West Nimar), Mandsaur **Diu (Daman & Diu)**
6	Hot Semi-Arid Ecoregion with Shallow and Medium (Dominant) Black Soils	**Maharashtra:** Eastern half of Pune, Satara and Sangli, Solapur, Osmanabad, Bid, Ahmadnagar, Dhule, Nasik, Jalgaon (W. Part), Aurangabad, Northern hilly part of Ahmadnagar, Jalna, Parbhani, Nanded, Latur, Jabalpur (E. Part), Buldhana, Akola, Amravati, Yavatmal, Western parts of Pune, Satara and Sangli, Kolhapur (E. Part) **Karnataka:** Belgaum, Dharwar, Eastern part of Uttar Kannad (Karwar), Gadag, Bijapur (N. Part), Raichur and Dharwad (E. Part)
7	Hot Semi-Arid Ecoregion with Red and Black Soils	**A.P.:** Cuddapah, Kurnool, Karimnagar, Rangareddi, Hyderabad, Warangal, Khammam, Mahboobnagar, Nalgonda, Sangareddi, Medak, Western parts (highlands) of Eluru (W. Godavari and Krishna (machillipatnam) Guntur and Ongole (Prakasam) and Nellore (NE parts) **Maharashtra:** Satara and Sangli, Solapur, Osmanabad, Bid, Ahmadnagar
8	Hot Semi-Arid Ecoregion with Red Loamy Soils	**T.N.:** Coimbatore, Anna (Dindigul), Madurai, Kamrajar (Virudunagar), Tirunelveli, Kanyakumari (Non-Coastal), North Arcot (Vellore), Dharamapuri, Salem, Arcot (Cuddalore), Chengalpattu (Kanchipuram), Periyar (Erode), Tiruchhirapalli, Pudukottai and Tuticorin (Non-Coastal plains and Uplands) part) **A.P.:** Chittoor **Karnataka:** Eastern part of Shimoga and Chikmangalur, Hassan, Mysore, Mandya, Bangalore, Chitradurga (S. Part), Kolar, Tumkur

9	Hot Sub-Humid (dry) Ecoregion with Alluvium derived Soils	**Punjab:** Southern part of Gurdaspur, Hoshiarpur, Jalandhar, Rupnagar, Northern part of Ludhiana and Patiala **Union Territory of Chandigarh** **Haryana:** Ambala **U.P.:** Saharanpur, Bijnor, Moradabad (N. Part), Eastern part of Muzaffarnagar, Rampur, Bareily, Pilibhit, Northern part of Shajahanpur, Southern part of Lakhimpur (Kheri), Sitapur, Lucknow, Barabanki, Faizabad, Sultanpur, Azamgarh, Balia, Ghazipur, Eastern part of Varanasi **Bihar:** Bhojpur (Ara), Rohtas (Sasaram), Jahanabad, Patna, Bihar-Sariff (Nalanda), Aurangabad, Gaya, Nawada
10	Hot Sub-Humid (dry) Ecoregion with Red and Black Soils	**M.P.:** Guna, Sagar, Bhopal, Damoh, Vidisha, Rajgarh, Shajapur, Sehore, Raisen, Western parts of Jabalpur, Narsimpur and Hoshangabad, Betul Central Highlands (VindhyanScarpland), Tikamgarh, Chhatarpur, and Bundelkhand, Panna, Satna, Rewa, Sidhi, Shahdol, Chhindwara, Seoni, Mandla, Balaghat, Eastern parts of Jabalpur, Narsimpur and Hoshangabad **Maharashtra:** Bhandara, Wardha, Nagpur
11	Hot Sub-Humid (dry) Ecoregion with Red and Yellow Soils	**U.P.:** Mirzapur **Bihar:** Palamu (Daltonganj), Hazaribag, Gumla, Lohardaga **M.P.:** Ambikapur, Bilaspur, Raigarh, Raipur, Rajnangaon, Durg
12	Hot Sub-Humid (dry) Ecoregion with Red and Lateritic Soils	**Maharashtra:** Chandrapur, Gadchiroli **M.P.:** Bastar (Jagdalpur) **A.P.:** Western highlands of Vishakhapatnam, Vizianagram **Orissa:** Western highlands of Ganjam (Chhatrapur), Puri (Bhubaneswar), Cuttack and Baleshwar (Non-Coastal part), Koraput, Kalahandi (Bhiwanipatna), Phulbani, Bolangir, Sambalpur, Sundergarh, Dhenkanal, Mayurbhanj (Baripada), Kendujhargarh (Kendujhra) **Bihar:** Dumka, Devghar, Giridih, Dhanbad, Ranchi, Singhbum (Chaibasa) **West Bengal:** Western parts of Birbhum, Bankura, Bardhaman and Medinipur (Siuri, Simlapal, Asansol, Jhargram subdivision, respectively), Puruliya
13	Hot Sub-Humid (Moist) Eco region with Alluvium-derived Soils	**U.P.:** Bahraich, Gonda, Gorakhpur and Deoria , Foothills in Kheri and Bahraich, Pilibhit, Gonda, Basti, Gorakhpur **Bihar:** Paschim Champaran (Bettiah) PurabChamparan (Motihari), Gopalganj, Siwan, Sitamari, Muzaffarpur, Chhapra (Saran), Madhubani, Darbhanga, Samastipur, Saharsa, Begusarai, Munger, Khagaria, Sahibganj, Bhagalpur, Katihar, Madhepura, Purnia, Hazipur, Godda
14	Warm Sub-Humid to Humid with Inclusion of per humid Ecoregion with Brown Forest and Podzolic Soils	**J&K:** Tribal Territory, Chilas, Gilgitwazarat, Srinagar (N. Part), Udhampur (N. Part), Baramulla (N. Part) H.P.: Northern parts of Chamba, Kullu, major sourthern part of Lahul and Spiti (Keylong), Kalpa (Kinnaur), Muzaffarabad, Baramulla (S. Part), Punch, Mirpur, Srinagar (S. Part), Anantnag, Riaisi, Jammu, Udhampur (S. Part), Kathua **Punjab:** Northern wedge (Siwalik foothills) of Gurdaspur and Hoshiarpur **H.P.:** Southern part of Chamba, Una (Hamirpur), Solan, Bilaspur, Nahan, Kullu (S. Part), Dharamshala (S. Part) , Dharamsala, Mandi, Shimla, Bilaspur **U.P.:** Dehradun (S. Part), Southern part of Narendranagar (Tehri Garhwal), Gopeshwar (Chamoli), Almora, Pithoragarh, Dehradun (N. Part), Uttar Kashi (S. Part), Tehri Garhwal (N. Part), Pauri Garhwal, Nainital
15	Hot Sub-Humid (Moist) to Humid (inclusion of per	**West Bengal:** West Dinajpur (Balurghat), Maldah, Murshidabad (Behrampur), Krishnanagar, Hoogli, North 24-Parganas, Howrah Calcutta: Eastern parts of Medinipur, Bankura, Bardhaman and

	humid) Eco region with Alluvium-derived Soils	Birbhum, Jalpaiguri (Plain), Koch Bihar **Assam:** Barpeta, Kamrup, Nalbari (S. Part), Darrang (Mangaldoi), Sonipur (Tezpur), Nagaur, Goalpara, Dhubri, Kokrajhar (Plain), Silchar, Karimgunj, Jorhat, Golaghat, Sibsagar, Dibrugarh, Northern plain of Kabir Anglong, Northern Lakhimpur **Tripura:** Northern part of Dharmanagar
16	Warm Sub-Humid Ecoregion with Brown and Red Hill Soils	**West Bengal:** Foothills of Siliguri and Jalpaiguri , Darjiling Udorthents, (subdivision of Darjeeling Dystrochrepts, district) **Assam:** Foothills of Kokrajhar, Udorthents Barpeta, Nalbari and Darrang (Mangaldoi) **Sikkim:** North, South, East and West Sikkim **Arunachal Pradesh:** Bomdila (W. Kameng), Seppa (East Kameng), Lower Subansiri (Zirol, Upper Subansiri (Daporijo), W. Siang (Along), E. Siang (Pasighat), Dibang Valley (Anini), Lohit (Tezu)
17	Warm per humid Ecoregion with Red and Lateritic Soils	**Meghalaya:** W. Garo hills (Tura), E. Garo hills, E. Khasi hill (Shillong), Nongstain, Jowai **Assam:** N. Cachchar (Haflong), Karbi-Anglong (Diphu) **Nagaland:** Kohima, Phek, Zunhebhoto, Eastern part of Wokha Mokakchung, Thensung, Mon. **Arunachal Pradesh:** Tirup (Khonsa) **Manipur:** Senapati (Karong), Ukhrul, Imphal, Churachandpur, Tamenglog, Thoubal (Chandel) **Mizoram:** Aizwal, Lunglie, Lawngtlai **Tripura:** W. Agartala, Dharmanagar (N. Part), Udaipur (S. Part)
18	Hot Sub-Humid to Semi-Arid Ecoregion with Coastal Alluvium-Derived Soils	**T.N.:** Coastal plains of Pudukkottai, Ramnathapuram, Tuticorin, Tirunelveli and Kannyakumari, Madras, Coastal plain of chengalPattu, Cuddalore, Thanjavur, Karaikal and Pondicherry (U.T.) **A.P.:** Coastal plain of W. Godavari, Krishna and Guntur, Prakasham and Nellore, Srikakulam, Coastal plains of E. Godavari (Kakinada) Vishakhapatnam, Vizianagaram **Orissa:** Coastal plain of Ganjam, Puri and Cuttack, Coastal plain of Baleshwar **West Bengal:** Coastal plains of Medinipur (Contai subdivision) and South 24-Parganas (including Sundarban) Sagar Island
19	Hot Humid per humid Ecoregion with Red, Lateritic and Alluvium-Derived Soils	**Gujarat:** Southern part of Surat, Dang, Valsad, Daman (Daman & Diu), and U.T. of Dadra Nagar Haveli **Maharashtra:** Thane, Bombay, Alibagh (Kulaba), Ratnagiri, Sindhudurg, Dang, Hilly parts of Kolhapur Goa: Panaji, Narrow coastal strip of Ratnagiri, Sindhudurg and Union Territory of Goa **Karnataka:** Western parts of Uttar Kannada (Karwar), Shimoga and Dakshin Kannada (Mangalore), Western parts of Chikmagalur and Kadagul (Madikari), Narrow coastal strip of Karwar, Mangalore **Kerala:** Cannanore (Hilly part), Wayanad (Kottapadi), uplands of Kozhikode (Calicut), Highlands of Malappuram, Palghat and Ernakulum, Kottayam, Pattanamtitta, Quilon and Trivandrum, Idukki, Western half of Cannanore, narrow coastal strip of Malappuram, Calicut, Trichur and Ernakulam, Aleppy, Quilon and Trivandrum **T.N.:** Udagamandalam (Nilgiri), Uplands of Trichur
20	Hot Humid per humid Island Ecoregion with Red Loamy and Sandy Soils	Andaman & Nicobar Islands group Lakshadweep group of Islands

Annexure B

Annexure B1: Districts and villages sampled in different AERs of India

AERs	States	Districts	Villages
AER2	Rajasthan	Jaisalmer	Damodara
			Dewa
			Kandi
			Damodara
		Shri Ganganagar	Bachhrara
			Banwali
			Budharwali
			Manewala
			Noor pura
			Udaipur godaran
	Haryana	Hisar	Haryana-sisar
			Hisar
			Khanda kheri
			Mangalijhara
			Mangaliaklan
			Ugalan
		Sirsa	Bhamboor
			Bupp
			Dhanibharo khan
			Madhosinghana
			Nagoki
			Nezadellakhurd
AER3	Andhra Pradesh	Anantapur	Gunjepalle
			Jonnalakothapalle
			Reddipalle
			Roddam
AER4	Uttar Pradesh	Fatehpur	Ajmatpur
			Baruha
			Behata
			Besandi
			Darautalalpur
			Jamlamau
		Jalaun	Ameesa
			Bhadreki
			Birguwa
			Chakjagdevpur
			Garha
			Reniya
		Mainpuri	Ahinkaripur
			Bajhera
			Budharra

			Chhabilepur
			Madhan
			Talibpur
AER5	Rajasthan	Chittorgarh	Adana
			Khaimaliya
			Marvadiya
			Rood
			Soni
			Utarwada
	Madhya Pradesh	Khargone	Aghavan
			Dalka
			Jamaniyabaju
			Khodgaon
			Oonkhurd
			Poi
AER6	Maharashtra	Ahmednagar	Ambi
			Chandebk
			Chinchvihire
			Kendal kh
			Miraj gaon
			Nimbodh-prob
		Nashik	Aliyabad
			Arai
			Aswaliharsha
			Aundane
			Devdongara
			Hatlondhi
		Osmanabad	Baswant wadi
			Bhatambri
			Gandhora
			Hipparga
			Khed
			Nangral
		Sangali	Ankale
			Bajhera
			Dafalapur
			Ghopadi
			Malan gaon
			Nangole
AER7	Telangana	Karimnagar	Andugullapally
			Cheekral
			Lingapur
			Palakurthy
			Peddakalwala
			Potiyala

AER8	Tamilnadu	Kanchipuram	Kalakatoor
			Kilar
			Meyyur
			Silavattam
			Sirunaiperugal
	Karnataka	Chikkamagaluru	Hanthur1
			Hesgal
			Indavara
			Thalihalla
AER9	Bihar	Nawada	Barat
			Gonawa
			Loharpura
			Sahbajpursaray
AER10	Madhya Pradesh	Guna	Ajgara
			Bhumlakhedi
			Gochaamalya
			Godiya
			Moti pura
			Tulshikhedi
		Tikamgarh	Bedpur
			Devi nagar
			Gotet
			Jatera
			Lar khurd
			Raj nagar
AER11	Chhattisgarh	Bilaspur	Bahtarai
			Bhaisbod
			Girari
			Godhi
			Lata
AER12	Odisha	Bolangir	Dhandamunda
			Kaccharpali
			Karunjhar
			Udaipali
		Mayurbhanj	Damodarpur
			Kaladahi
			Kanfuli
			Parasibadi
AER13	Bihar	Purnia	Amour
			Barhari
			Bhawanipur east
			Haripur
AER14	Himachal Pradesh	Bilaspur	Barmana
			Devlaccham
			Harlog

			Malyawar
		Chamba	Baili
			Ligga
			Multhar
			Raan
AER15	West Bengal	Uttar Dinapur	Dalkhola
			Hassan
			Karandighi
			Suhiya
AER16	West Bengal	Siliguru Mahakuma	Katia
			Ketugaurjote
			Roypara
			Uttarpradhan
AER17	Nagaland	Kohima	Chichama
			Merema
			Mima
			Peechama
AER18	Tamilnadu	Cuddalore	Arunmozhidevan
			Ayeepettai
			Chinnakomatti
			Enaanagaram
			Keelamanakudi
			Vakasakkadu
AER19	Karnataka	Uttara Kannada	Alageri
			Mundali
			Muttalli
			Vandige

Annexure B2. Selection of Carbon Pools

Carbon inventory, in principle, involves estimation of changes in stocks of all the carbon pools. However, not all carbon pools are relevant to all land-use categories, or project types, and the general practice is to estimate the changes in the stock of a key pool or a set of key pools. Further, estimation of changes in stocks of all the carbon pools is expensive. The choice of a carbon pool or pools for monitoring or estimation for different land-based programmes and projects depends on the land-use system, goals of the project, activities implemented and the period selected for monitoring. Under MGNREGA, the two carbon pools likely to be impacted largely are biomass and/or soil carbon pools, depending on the type of intervention.

- Biomass is defined as the total quantity of live and inert or dead organic matter, above and below the ground, expressed in tonnes of dry matter per unit area, such as a hectare.
    - Biomass is converted to carbon by multiplying it with a carbon fraction of dry matter. The exact value of the fraction varies within a small range for different species and components of plants, and is usually about 0.5 (IPCC 2006).
- Soil carbon is carbon held in soil as organic matter, humified material and in stable structures such as charcoal.

Table B2.1 presents the major interventions or MGNREGA activities implemented and key carbon pools likely to be impacted.

Table B2.1: Features of MGNREGA works and carbon pools impacted

MGNREGA works involving tree-planting	Biomass carbon estimation	Soil carbon estimation	MGNREGA works with no tree planting	Biomass carbon estimation	Soil carbon estimation
Plantations/orchards and agroforestry (fruit orchards of Mango, Guava, etc., or any other tree plantations of Eucalyptus/ Pongamia or any other species on croplands	Yes	Yes	Check dam	No	Yes
Agroforestry/ planting trees in rows on the boundary of farm or within the farms	Yes	Yes	Percolation tanks / pits	No	Yes
Afforestation on community lands/government lands	Yes	Yes	Farm ponds	No	Yes
Others (If any)	Yes	Yes	Land levelling	No	Yes
			Silt application	No	Yes
			Soil conservation	No	Yes
			Water conservation	No	Yes
			Irrigation	No	Yes

Annexure C

Annexure C1: Carbon sequestration upto 2017-18 according to AERs for NRM-MGNRGEGA works

C.1.1. Carbon Sequestration (MtC) by Land Development Works

	Cumulative number of NRM works implemented during 2006-07 to 2017-18	Total number of land development works implemented in AER during 2006-07 to 2017-18	Average area implemented under land development work in AER (ha)	Average carbon sequestered under land development work (tC/ha/year)	Total carbon sequestered under land development work during 2017 (MtC)
AER2	1300349	192863	6.79	1.05	1.3742
AER3	5138846	1648235	1.15	1.97	3.7341
AER4	1100446	178015	0.86	1.37	0.2097
AER5	705769	134287	1.15	-0.90	-0.1388
AER6	244125	7774	2.28	-0.88	-0.0156
AER7	156617	1700	1.15	1.06	0.0021
AER8	1760251	94604	0.86	-0.02	-0.0016
AER9	792324	155573	0.86	0.10	0.0130
AER10	1542141	295537	1.15	1.10	0.3739
AER11	2483512	750960	1.15	0.28	0.2418
AER12	864012	93005	2.28	0.97	0.2057
AER13	1270803	172832	0.89	-0.07	-0.0100
AER14	965161	248023	0.89	0.29	0.0640
AER15	1888039	376559	0.89	1.15	0.3839
AER16	978742	219847	0.89	-0.01	-0.0020
AER17	1318061	337221	1.10	0.12	0.0456
AER18	188741	11479	0.89	-0.10	-0.0010
AER19	491033	160157	1.10	-0.10	-0.0176
				Total Carbon Sequestered	**6.46 MtC**

C1.2. Carbon sequestration (MtC) by Micro Irrigation Works

	Cumulative number of NRM works implemented during 2006-07 to 2017-18	Total number of micro irrigation works implemented in AER during 2006-07 to 2017-18	Average area implemented under micro irrigation works in AER (ha)	Average carbon sequestered under micro irrigation works (tC/ha/year)	Total carbon sequestered under micro irrigation works during 2017 (MtC)
AER2	1300349	26496	0.66	-0.11	-0.0020
AER3	5138846	128875	0.66	-0.11	-0.0097
AER4	1100446	139122	0.66	0.28	0.0254
AER5	705769	38221	0.66	-0.29	-0.0073
AER6	244125	12328	0.66	0.34	0.0028
AER7	156617	441	0.66	0.85	0.0002
AER8	1760251	66371	0.66	0.34	0.0149
AER9	792324	100665	0.66	0.85	0.0563
AER10	1542141	52521	0.66	-0.61	-0.0211
AER11	2483512	20381	0.66	1.27	0.0171
AER12	864012	53951	0.66	0.70	0.0249
AER13	1270803	50686	0.66	0.70	0.0234
AER14	965161	327070	0.66	1.15	0.2489
AER15	1888039	88124	0.66	-1.08	-0.0628
AER16	978742	11021	0.90	-1.13	-0.0112
AER17	1318061	41634	0.66	-0.09	-0.0024
AER18	188741	20265	0.66	0.40	0.0053
AER19	491033	27635	0.66	0.54	0.0098
				Total Carbon Sequestered	**0.31 MtC**

C1.3. Carbon sequestration (MtC) by Water Conservation and Water Harvesting Works

	Cumulative number of NRM works implemented during 2006-07 to 2017-18	Total number of water conservation and harvesting works implemented in AER during 2006-07 to 2017-18	Average area implemented under water conservation and harvesting works in AER (ha)	Average carbon sequestered under water conservation and harvesting works (tC/ha/year)	Total carbon sequestered under water conservation and harvesting works during 2017 (MtC)
AER2	1300349	624860	0.80	0.11	0.055
AER3	5138846	1782008	2.98	-0.34	-1.808
AER4	1100446	184176	2.98	0.34	0.187
AER5	705769	225048	0.80	0.34	0.061
AER6	244125	63529	7.25	1.11	0.510
AER7	156617	45104	2.87	0.83	0.108
AER8	1760251	949984	0.85	-0.37	-0.296
AER9	792324	124085	2.98	1.11	0.411
AER10	1542141	195119	**3.98**	1.06	0.819
AER11	2483512	776506	0.85	0.11	0.073
AER12	864012	159063	7.25	0.36	0.415
AER13	1270803	240431	0.71	1.90	0.324
AER14	965161	183297	0.85	0.36	0.056
AER15	1888039	488847	0.71	0.11	0.038
AER16	978742	216478	0.62	-0.20	-0.027
AER17	1318061	218593	1.10	-0.20	-0.048
AER18	188741	11718	0.84	0.19	0.002
AER19	491033	152702	1.10	1.72	0.289
				Total Carbon Sequestered	**1.17 MtC**

C1.4. Carbon sequestration (MtC) by Renovation of Traditional Water Bodies

	Cumulative number of NRM works implemented during 2006-07 to 2017-18	Total number of renovation of traditional water bodies implemented in AER during 2006-07 to 2017-18	Average area implemented under renovation of traditional water bodies in AER (ha)	Average carbon sequestered under renovation of traditional water bodies (tC/ha/year)	Total carbon sequestered under renovation of traditional water bodies during 2017 (MtC)
AER2	1300349	108537	0.9	0.78	0.08
AER3	5138846	531685	0.9	1.365	0.65
AER4	1100446	74595	0.9	0.78	0.05
AER5	705769	28164	0.9	1.21	0.03
AER6	244125	8150	0.9	1.365	0.01
AER7	156617	5231	0.9	0.78	0.00
AER8	1760251	82901	0.9	0.78	0.06
AER9	792324	63424	0.9	1.21	0.07
AER10	1542141	45908	0.9	0.78	0.03
AER11	2483512	161936	0.9	0.78	0.11
AER12	864012	65204	0.9	0.73	0.04
AER13	1270803	398332	0.9	0.78	0.28
AER14	965161	56758.47	0.9	1.365	0.07
AER15	1888039	328889	0.9	0.73	0.22
AER16	978742	161542	0.9	0.78	0.11
AER17	1318061	137618	0.9	1.365	0.17
AER18	188741	20354	0.9	0.73	0.01
AER19	491033	34318	0.9	0.78	0.02
				Total Carbon Sequestered	**2.03 MtC**

C1.5. Carbon sequestration (MtC) by Drought Proofing Works

	Cumulative number of NRM works implemented during 2006-07 to 2017-18	Total number of drought proofing works implemented in AER during 2006-07 to 2017-18	Average area implemented under drought proofing works in AER (ha)	Average carbon sequestered by biomass under drought proofing works (tC/ha/year)	Average carbon sequestered by soil under drought proofing works (tC/ha/year)	Total carbon sequestered by biomass and soil under drought proofing works (tC/ha/year)	Total carbon sequestered under drought proofing works during 2017 (MtC)
AER2	1300349	161017	1.15	2.2	2.07	4.27	0.791
AER3	5138846	131536	1.15	1.89	2.61	4.5	0.681
AER4	1100446	110729	0.75	0.95	0.7	1.65	0.137
AER5	705769	37633	1.8	1.05	0.56	1.61	0.109
AER6	244125	42733	1.15	1.13	-0.21	0.92	0.045
AER7	156617	22316	0.78	2.2	1.23	3.43	0.06
AER8	1760251	116324	0.78	1.16	0.12	1.28	0.116
AER9	792324	84572	0.90		0.78	0.78	0.059
AER10	1542141	141424	1.82	1.15	0.83	1.98	0.51
AER11	2483512	315259	1.95	0.98	0.96	1.94	1.193
AER12	864012	67674	1.15	1.35	0.7	2.05	0.16
AER13	1270803	141933	2.3	1.15	2.24	3.39	1.107
AER14	965161	40982	1.1	0.97	-0.68	0.29	0.013
AER15	1888039	342557	0.9	2.1	0.55	2.65	0.817
AER16	978742	258112	1.19	1.18	0.93	2.11	0.648
AER17	1318061	274655	1.1	0.95	0.14	1.09	0.328
AER18	188741	19294	1.37	1.15	0.87	2.02	0.053
AER19	491033	56076	1.1	0.85	1.07	1.92	0.119
						Total Carbon Sequestered	**6.95 MtC**

Annexure C2: Projected number of works to be implemented during 2020, 2025 and 2030 based on mean number of works implemented during 2014-15 to 2017-2018

C2.1. Projected number of drought proofing works to be implemented during 2020, 2025 and 2030 based on mean number of works implemented during 2014-15 to 2017-2018

	Total works upto 2017 (2006-07 to 2017-18 - Cumulative)	Mean number of works implemented during 2013-14 to 2017-18	Total number of works during 2020	Total number of works during 2025	Total number of works during 2030
AER2	161017	9651	180320	228577	276834
AER3	131536	18323	168181	259794	351407
AER4	110729	3616	117962	136044	154126
AER5	37633	38341	114315	306021	497727
AER6	42733	30272	103277	254637	405997
AER7	22316	41374	105065	311937	518809
AER8	116324	3346	123016	139746	156476
AER9	84572	7954	100481	140253	180025
AER10	141424	24657	190739	314025	437311
AER11	315259	8088	331436	371878	412320
AER12	67674	9124	85922	131542	177162
AER13	141933	2257	146447	157733	169019
AER14	40982	7033	55048	90212	125376
AER15	342557	3641	349840	368047	386254
AER16	258112	14081	286274	356678	427082
AER17	274655	8520	291695	334295	376895
AER18	19294	7109	33512	69058	104604
AER19	56076	34999	126074	301069	476064

C2.2. Projected number of micro irrigation works to be implemented during 2020, 2025 and 2030 based on mean number of works implemented during 2014-15 to 2017-2018

	Total works upto 2017 (2006-07 to 2017-18 - Cumulative)	Mean number of works implemented during 2013-14 to 2017-18	Total number of works during 2020	Total number of works during 2025	Total number of works during 2030
AER2	98863	1377	101617	108501	115385
AER3	398422	20600	439621	542619	645617
AER4	63273	17456	98185	185465	272745
AER5	7761	20645	49050	152273	255496
AER6	385	12024	24433	84554	144675
AER7	1375	10333	22040	73703	125366
AER8	12387	957	14301	19085	23869
AER9	41802	2314	46430	57999	69568
AER10	14327	11501	37329	94833	152337
AER11	279278	31811	342901	501958	661015
AER12	10918	7669	26256	64600	102944
AER13	151143	584	152311	155230	158149
AER14	128390	62	128515	128827	129139
AER15	178844	213	179270	180336	181402
AER16	91394	1795	94985	103962	112939
AER17	102550	4192	110934	131895	152856
AER18	12525	314	13153	14724	16295
AER19	21108	37283	95674	282088	468502

C2.3. Projected number of land development works to be implemented during 2020, 2025 and 2030 based on mean number of works implemented during 2014-15 to 2017-2018

	Total works upto 2017 (2006-07 to 2017-18 - Cumulative)	Mean number of works implemented during 2013-14 to 2017-18	Total number of works during 2020	Total number of works during 2025	Total number of works during 2030
AER2	192863	14310	221484	293036	364588
AER3	1648235	23761	1695757	1814562	1933367
AER4	178015	33089	244194	409641	575088
AER5	134287	54283	242854	514271	785688
AER6	7774	31590	70955	228907	386859
AER7	1700	39441	80582	277788	474994
AER8	94604	1236	97075	103253	109431
AER9	155573	16690	188952	272400	355848
AER10	295537	23673	342884	461251	579619
AER11	750960	208701	1168361	2211864	3255367
AER12	93005	19534	132073	229743	327413
AER13	172832	6536	185904	218585	251266
AER14	248023	1388	250799	257740	264681
AER15	376559	263	377084	378397	379710
AER16	219847	13057	245960	311243	376526
AER17	337221	14308	365837	437376	508915
AER18	11479	21215	53910	159987	266064
AER19	160157	105312	370782	897344	1423906

C2.4. Projected number of works - renovation of traditional water bodies to be implemented during 2020, 2025 and 2030 based on mean number of works implemented during 2014-15 to 2017-2018

	Total works upto 2017 (2006-07 to 2017-18 - Cumulative)	Mean number of works implemented during 2013-14 to 2017-18	Total number of works during 2020	Total number of works during 2025	Total number of works during 2030
AER2	108537	5857	120251	149537	178823
AER3	531685	45745	623174	851897	1080620
AER4	74595	5271	85136	111490	137843
AER5	28164	34475	97113	269486	441859
AER6	8150	17279	42708	129104	215500
AER7	5231	8578	22387	65278	108169
AER8	82901	1990	86882	96834	106786
AER9	63424	2673	68770	82136	95502
AER10	45908	9011	63930	108985	154039
AER11	161936	50139	262213	512906	763599
AER12	65204	4608	74419	97457	120495
AER13	398332	2173	402679	413546	424413
AER14	56758	1036	58830	64008	69186
AER15	328889	823	330535	334649	338763
AER16	161542	7130	175802	211451	247100
AER17	137618	4199	146017	167014	188011
AER18	20354	5495	31344	58819	86294
AER19	34318	14684	63687	137109	210531

C2.5. Projected number of water conservation and water harvesting works to be implemented during 2020, 2025 and 2030 based on mean number of works implemented during 2014-15 to 2017-2018

	Total works upto 2017 (2006-07 to 2017-18 - Cumulative)	Mean number of works implemented during 2013-14 to 2017-18	Total number of works during 2020	Total number of works during 2025	Total number of works during 2030
AER2	624860	8736	642331	686009	729687
AER3	1782008	29335	1840677	1987350	2134023
AER4	184176	20001	224178	324182	424186
AER5	225048	46692	318433	551895	785357
AER6	63529	22417	108363	220449	332535
AER7	45104	20122	85348	185959	286570
AER8	949984	1342	952668	959378	966088
AER9	124085	9348	142782	189524	236266
AER10	195119	73176	341471	707352	1073232
AER11	776506	129097	1034700	1680185	2325670
AER12	159063	14110	187283	257833	328383
AER13	240431	23038	286507	401698	516889
AER14	183297	7295	197887	234361	270835
AER15	488847	7389	503625	540569	577513
AER16	216478	17693	251865	340332	428799
AER17	218593	11082	240757	296166	351575
AER18	11718	9833	31384	80548	129712
AER19	152702	49795	252293	501270	750247

Annexure C3: Carbon sequestration by different works during 2020, 2025 and 2030 according to AERs for NRM-MGNRGEGA works

C3.1: Carbon sequestration by NRM Works implemented under MGNREGA by 2020