A FRAMEWORK FOR QUANTIFYING THE CLIMATE CO-BENEFITS OF MGNREGS WORKS

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Center for Study of Science, Technology and Policy

March 2023

Designed and Edited by CSTEP

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Executive Summary

Usharmukti, a massive river rejuvenation programme launched by the Government of West Bengal, is implemented primarily through the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), in collaboration with grassroot civil society organisations (CSOs) and donor agencies. As one of the largest community-driven water security programmes in the country, *Usharmukti* has contributed to the conservation of natural resources 1) by bringing almost 30,000 ha of fallow lands under plantation with over 1.5 crore new trees between December 2019 and March 2021; and 2) by creating 138 billion litres of water potential through the treatment of 93,330 ha with water conservation and water harvesting structures during the same period. Besides a far-reaching welfare effect, these outcomes carry significant adaptation and mitigation co-benefits. The lead CSOs for *Usharmukti*—Professional Assistance for Development Action (PRADAN) and Hindustan Unilever Foundation (HUF)—recognised the need to quantify these benefits, and, in collaboration with the Center for Study of Science, Technology and Policy (CSTEP), ventured to do that and more.

MGNREGS is a poverty alleviation programme implemented pan India. As an employment guarantee scheme, it successfully captures information on the number of jobs and assets created. However, assessment of the multiple climate co-benefits arising from these assets has been a blind spot. While there have been many studies that attest to the climate co-benefits of MGNREGS works, they have been limited in their geographical scope, resulting in constrained reporting of the accrued benefits.

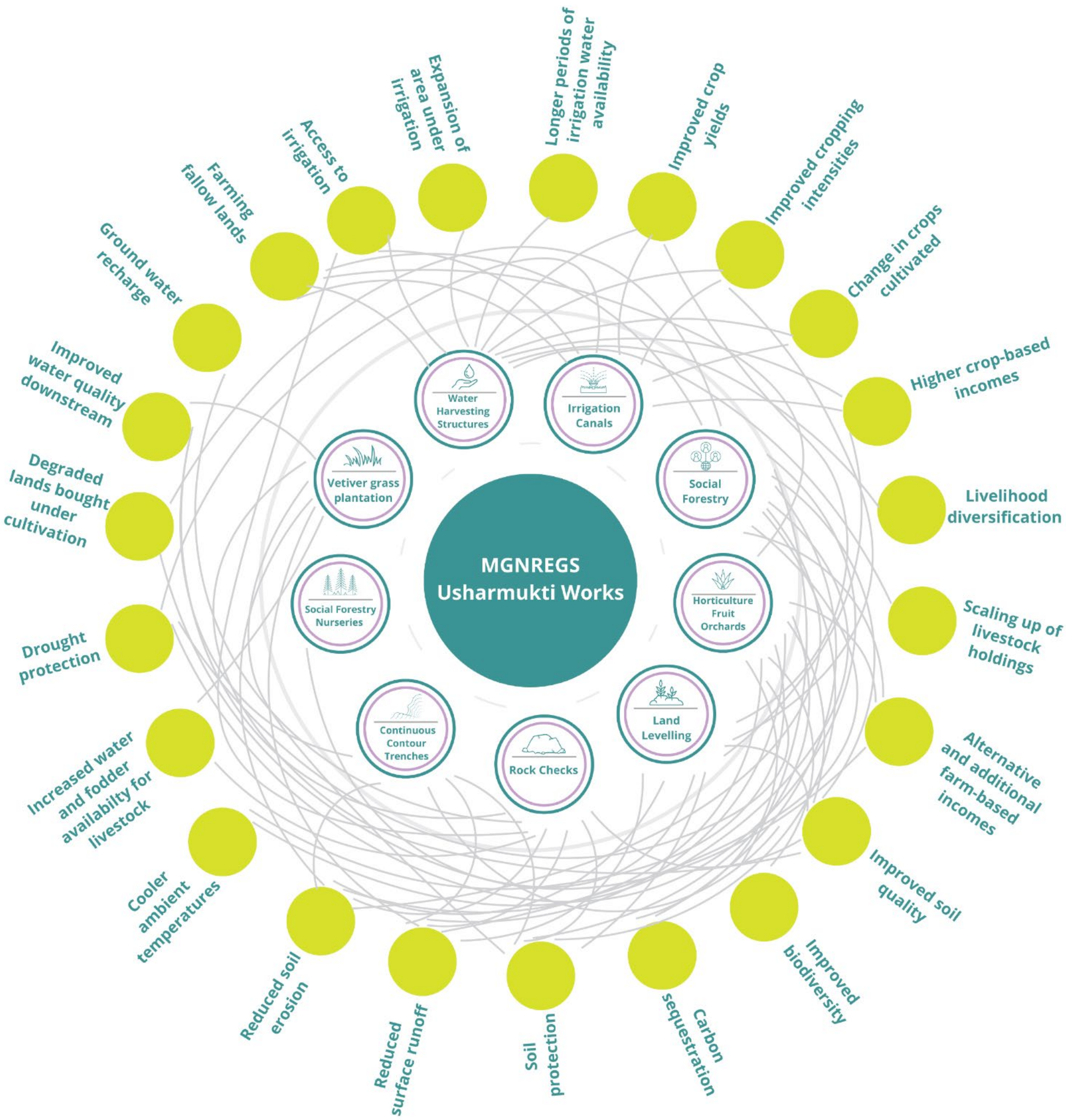
This report details the subnational efforts of CSTEP, PRADAN, and HUF to quantify the climate adaptation and mitigation co-benefits of the *Usharmukti* programme, and develop a monitoring and evaluation framework for quantifying and reporting the climate co-benefits of MGNREGS works.

In collaboration with PRADAN and Awadh Research Foundation (ARF), CSTEP engaged with stakeholders in four districts of West Bengal—Jhargram, Bankura, Purulia, and Paschim Bardhaman—sampling 541 land- and water-based works under the *Usharmukti* programme. The works were assessed for their potential to deliver climate resilience, adaptation, and mitigation co-benefits. ARF, under the guidance and training provided by CSTEP, undertook a combination of primary surveys and focussed group discussions to quantify adaptation and resilience co-benefits, and field measurements of tree biomass and soil organic carbon to quantify mitigation benefits arising from plantation works. The findings from this assessment are reported for a total population of 228,431 *Usharmukti* beneficiary households in the four sampled districts.

For water-based assets, our research predominantly looked at farm ponds and irrigation canals. The construction of ponds through the programme has enabled 48,750 former rainfed farmers to irrigate their lands, and irrigation canals have brought 41.33 ha of barren land under cultivation (only within the sampled watersheds). For those who already had a source of irrigation prior to the programme, the presence of a farm pond increased the area under irrigation and provided access to water for an additional one and a half months. This has resulted in increased crop yields and farm incomes, offering a buffer against climate hazards such as droughts, and enhancing the adaptive capacities of farmers. In addition to aiding irrigation, water harvesting structures serve as fish ponds and increase the availability of water for livestock. Average additional earnings from livestock and fisheries are ₹ 14,321 and ₹ 22,963 per annum per beneficiary, respectively. Income diversification is known to increase the coping capacities of farmers with respect to climate hazards.

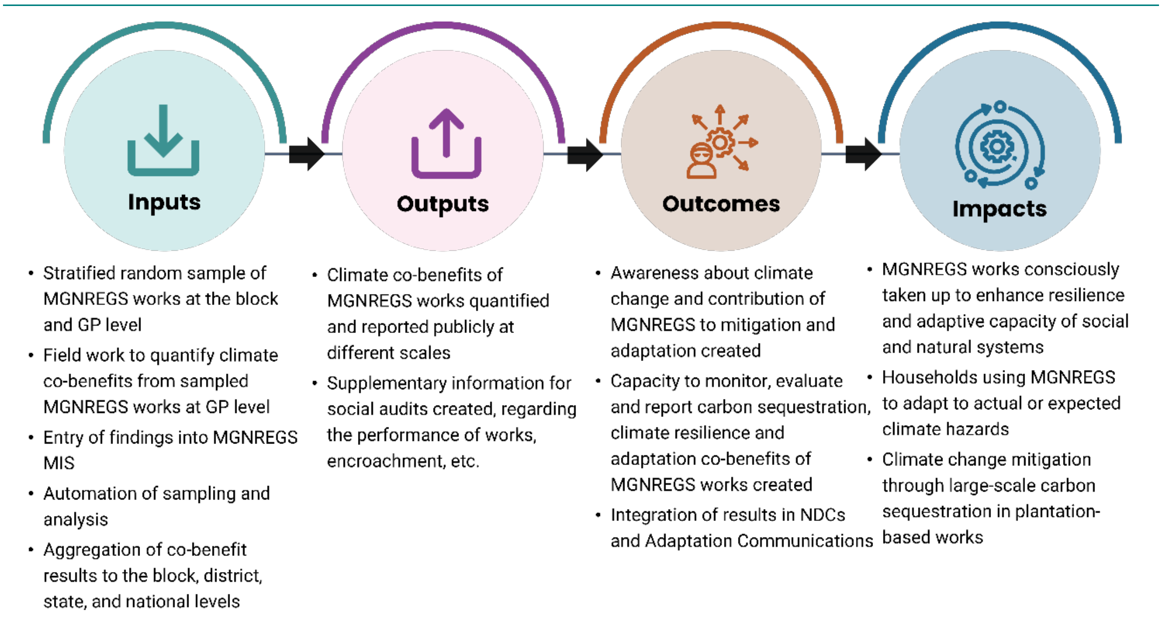
Social forestry and horticulture were the predominant land-based assets that were surveyed as part of this project. Since a random sampling methodology was followed for the study, many of the plantations sampled were younger than four years, and hence did not yield fruits or timber. Yet, most beneficiary households reported a cooler ambient temperature and improved soil quality due to their plantation works. For tree species that were large enough to be measured, our analysis shows that a total of 3,668 tonnes of carbon has been sequestered in tree biomass, and a further 5,707 tonnes of carbon has been sequestered by the soil in plantations, resulting in a total sequestration of 9,367 tonnes of carbon across all the plantation works within the sampled districts under the *Usharmukti* programme.

A summary of the various climate co-benefits from sampled *Usharmukti*/MGNREGS works is presented below:



Being a large-scale programme spanning diverse agro-climatic and socio-economic conditions, it is challenging to design and implement *Usharmukti*/MGNREGS. Considering this, our report provides recommendations for preparing a programme design that can maximise the climate co-benefits of the programme. These include ensuring timely distribution of tree saplings and plant-life-saving irrigation to lower tree mortality, capacity building and technical assistance by horticulture and forest departments for species selection and orchard management, modifying the dimensions and density of water harvesting structures factoring in the opinion of beneficiaries, etc.

More importantly, our study—through the rapid assessment of the climate co-benefits from the *Usharmukti* programme—puts forth a framework that can guide a state to quantify the adaptation, resilience, and mitigation co-benefits arising from MGNREGS assets, thus highlighting at a national level, the scheme's potential to enhance rural resilience and accelerate India's progress towards achieving its climate goals. The framework is depicted below:



While we faced several challenges in conducting the rapid assessment (like having to work with a small sample size due to resource and time constraints, and restricted access to certain areas due to the prevailing local circumstances), we gained deep insights from the study, which inform our climate co-benefits monitoring and quantification framework.

Additionally, the key learnings from our study can help in the efficient implementation of our framework at the state and national level. As such, they have been included in this report. Some of them are:

- A random stratified sampling technique can be applied effectively.
- *Gram Panchayat* will need to be the unit of assessment, as opposed to a watershed (as adopted in this study).
- Irrespective of public or private works, resilience and adaptation co-benefits need to be quantified at a household level.
- Only plantations over 5 years should be included to quantify mitigation co-benefits.
- Income-based indicators and their contribution in aiding adaptation will need to be explicitly defined and quantified after hazard occurrence.

Our framework has been designed in recognition of the crucial need to monitor and report the significant climate co-benefits from this national programme, especially in light of India's Nationally Determined Contributions, the Sustainable Development Goals, and the reporting requirements for Adaptation Communications to the United Nations Framework Convention on Climate Change (UNFCCC) from 2024.

While the framework can help in ensuring that the climate-positive outcomes of the programme do not go unrecorded, much needs to be done to simplify the entire process of undertaking rapid assessments to quantify the climate co-benefits from MGNREGS at scale. With this in view, our report also provides a way forward, outlining how it can be done.

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1. Introduction

The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is an Indian labour law and social security measure aimed at guaranteeing the "right to work" to every rural household whose adult members volunteer to do unskilled manual work (NREGA, 2005). It came into force in 2006 and is implemented by the Ministry of Rural Development, Government of India, with the following objectives:

- Create productive and durable assets.
- Strengthen the livelihood resource base of the rural poor.
- Ensure social inclusion proactively.
- Bolster local institutions while provisioning wage labour.

MGNREGA is ranked as the world's largest public works programme (World Bank, 2015). State governments incorporate all features of the Act into a scheme—the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS)—and implement it to guarantee 100 days of wage labour per year to registered households that demand work. According to the MGNREGA management information system (MIS), the average annual investment in MGNREGS is almost USD 7 billion, supporting over 60 million rural households. Of the total expenditure, about 60% is spent on natural resource management works or asset creation. There are about 260 activities termed as 'works' that are implemented under MGNREGS. These can be broadly classified as natural resource management (NRM) works and rural development works (non-NRM). The works under NRM are further categorised on the basis of their ability to improve irrigation, drainage, soil health, groundwater recharge, soil and water conservation, and area under plantations, and generally contribute positively to the agriculture and allied sectors. Non-NRM works are focussed on improving and protecting rural habitations through investments in essential infrastructure.

Several studies have highlighted the potential of MGNREGS to improve the lives and livelihoods of the poor and marginalised, and also lower their vulnerability (IEG, 2018; NITI Aayog, 2021; PIB, 2022; UNDP, 2015). These studies report an increase in household incomes through wage labour, creation of competitive wage rates in local labour markets, and increased ownership of productive assets such as farm ponds and wells—leading to enhanced incomes from agriculture, livelihood and income diversification, reduced migration, and so forth. Likewise, Ravindranath and Murthy (2021) report that tree-planting activities under MGNREGS could sequester carbon equivalent to 249 MtCO_2 by 2030.

MGNREGS has a dedicated MIS that maintains records of the jobs and assets created at a *Gram Panchayat* level for a period of 9 years (currently from 2014-15 to 2022-23). Since the works implemented under MGNREGS are aimed at creating productive assets and strengthening the livelihood resource base, there are several climate co-benefits that accrue—which are not periodically monitored, quantified, and reported.

India has been reeling under intense heatwaves, droughts and extreme rain-triggered floods and landslides. A lot has been said about how climate change is increasing the frequency, magnitude, and unpredictability of extreme climate events, making a case for strengthening the resilience of natural and socio-economic systems. It is also becoming increasingly clear that while dedicated adaptation programmes are needed, mainstreaming adaptation in developmental programmes is crucial. However, in a programme like MGNREGS, where several adaptation co-benefits do accrue (as the scheme implements several land- and water-based works), they go unmonitored or/and unreported.

Given the scale of implementation of MGNREGS and the multiple climate co-benefits that arise, a monitoring and reporting framework is needed to holistically assess these climate co-benefits. Such a framework will help track the environmental benefits of MGNREGS that translate into supplementary income generation for beneficiary households. Increased incomes help beneficiary households to cope better with the impacts of climate change in the near term, and enhanced resilience of the natural resource base facilitates adaptation in the medium to long term. Carbon sequestration through tree planting can also be tracked to report on the mitigation benefits of the scheme. Using the framework to quantify the benefits beyond jobs and asset creation will enable India to report on its efforts to achieve the Sustainable Development Goals (SDGs) and the Nationally Determined Contributions (NDCs), in addition to preparing the Adaptation Communication to the United Nations Framework Convention on Climate Change (UNFCCC) in the coming years.

1.1. Study Area

Usharmukti (or "salvation from barrenness") is a West Bengal state project aimed at treating micro-watersheds to rejuvenate the seven large rivers that originate from the western half of the state and flow through it. Assets created and works implemented under the project are financed through MGNREGS. These conservation works are aimed at benefitting farmers that operate within treated watersheds, rendering their land *ushar mukt* (drought free).

The project works through the confluence of the state government, civil society organisations or CSOs (with HUF and PRADAN as the lead CSOs), and the Bharat Rural Livelihoods Mission (BRLF). The CSOs work with farmers on the ground to develop watershed activities that would benefit them individually while contributing to the overall goals of *Usharmukti*. These works are discussed and finalised by stakeholders and included within the MGNREGS budget of the *Gram Panchayat* (Kulkarni, 2020). *Usharmukti* is one of the largest community-driven water security programmes in the country. Since its inception in 2017, *Usharmukti* has benefitted 187,199 households and has resulted in:

- Almost 30,000 ha being brought under plantation with over 15 million trees.
- Construction of water conservation and harvesting structures across 93,000 ha has created 138 billion litres of water potential between December 2019 and March 2021.
- Generation of over 53 million days of employment under MGNREGS, benefitting 120,000 individual job-card holders and their families.

Usharmukti is implemented across six south-western districts of West Bengal state, namely Bankura, Birbhum, Jhargram, Paschim Bardhaman, Paschim Medinipur, and Purulia (Figure 1). These districts are undulating and are characterised by red and laterite soils. They receive an average annual rainfall ranging between 1100mm and 1400mm, with an average maximum temperature of 43.8°C and a minimum temperature of 8.7°C. The socio-economic data for these districts (Department of Planning & Statistics, 2014) reveal the following:

- The population is predominantly rural, except in Paschim Bardhaman, which is an urban mining/industrial district.
- Literacy rates range from 64% in Purulia to 79% in Paschim Medinipur with very low

employment rates (only about 40% of the population is employed).

- Agriculture is the main source of income, with paddy being the primary crop cultivated during the kharif (June to September) season.
- The districts have good irrigation coverage (ranging from 54% in Purulia to 88% in Birbhum), except for Jhargram which has less than 5% of area under irrigation. This has resulted in an average cropping intensity of 160% for the region.
- Forest cover in the districts ranges from 3.5% in Birbhum to 29.4% in Jhargram.

These districts have been historically exposed to searing temperatures and droughts. Parts of these districts are also flood prone. However, in the recent past, droughts have led to severe water stress, justifying the need for the implementation of *Usharmukti* (Ghosh, 2019). Out of the six project districts, in this study, works undertaken in the project-activity-intensive blocks (PAIBs) of four of the six districts were sampled (Figure 1). These include Bankura, Jhargram, Paschim Bardhaman, and Purulia (henceforth referred to as study districts).

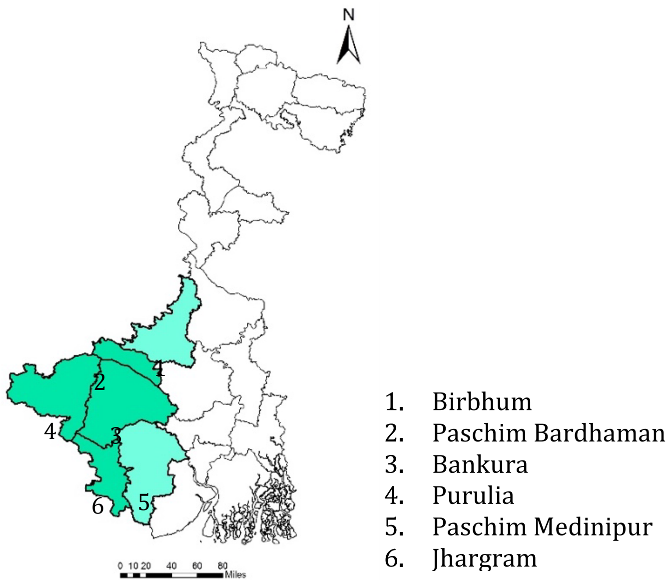

Figure 1: Study area - Usharmikti project districts

CSTEP, in collaboration with Professional Assistance for Development Action (PRADAN) and Awadh Research Foundation (ARF), engaged with stakeholders and collected socioeconomic and biophysical data to assess the impacts of land- and water-based activities implemented under *Usharmukti* with a larger objective that is detailed in Section 1.2.

1.2. Project Objective

The objective of the study was to develop a framework to quantify the climate resilience, adaptation, and carbon sequestration co-benefits of MGNREGS works. The framework is aimed at mainstreaming the quantification and reporting of resilience, adaptation and mitigation co-benefits accruing from MGNREGS at the national level. Given the scale of the programme and the varied socio-physical conditions across the country, a sampling strategy was conceived. Framework development has been possible through the testing of a conceptual framework to quantify the climate co-benefits from *Usharmukti* works—implemented through MGNREGS in West Bengal. The framework is targeted for use by government departments, practitioners, and policymakers.

2. Methodology

A combination of ecological field methods, household surveys, and focussed group discussions (FGDs) was adopted for this study. This section presents the sampling method employed to undertake a rapid assessment of the climate co-benefits from *Usharmukt*i works, implemented through MGNREGS. Also presented are the methods used to quantify the climate co-benefits of sampled works.

2.1. Sampling Method

Although a census survey is most desirable, covering the 223,852 interventions across 183,584 ha of the project area was not feasible. Therefore, a stratified random sampling method was adopted for the study to identify works within PAIBs. The rationale for selection of PAIBs was high work density (i.e., higher number of works were implemented within these blocks as compared to other parts of the *Usharmukti* project districts). The delineated watersheds within the PAIBs have been comprehensively treated with soil and water conservation and harvesting works under *Usharmukti,* following the principles of watershed development. These works have cascading and compounding impacts on the soil and water resources within the watersheds.

Thompson (2012) describes stratified random sampling as the process of dividing a population into sections (strata) on the basis of a common characteristic. Once this division was made, samples were chosen randomly from each of the strata that constituted the sample pool. This method of sampling has been adopted by other studies assessing MGNREGA. For example, Oberst (2015) recommended stratified random sampling to conduct performance audits for MGNREGS at a national level, while Dandekar et al. (2010) used it to conduct an impact assessment of MGNREGS assets in Sikkim, India.

Works are decided by the stakeholders for inclusion in the MGNREGS budget at the scale of Gram Panchayat (GP), which is the smallest administrative unit in the MGNREGS and *Usharmukti* implementation design. About 15% of GPs within PAIBs were randomly selected for the study. Within these GPs, a further 20% of watersheds were randomly selected. However, in some of the sampled watersheds, the number of works implemented through *Usharmukti* were very few. Therefore, an additional filter was applied to eliminate those watersheds that had less than 20 works implemented at the time of the study. A total of 13 watersheds were selected through this process, and all works within these watersheds (totalling 541 works) were assessed for climate co-benefits. The sampling process is illustrated in Figure 2.

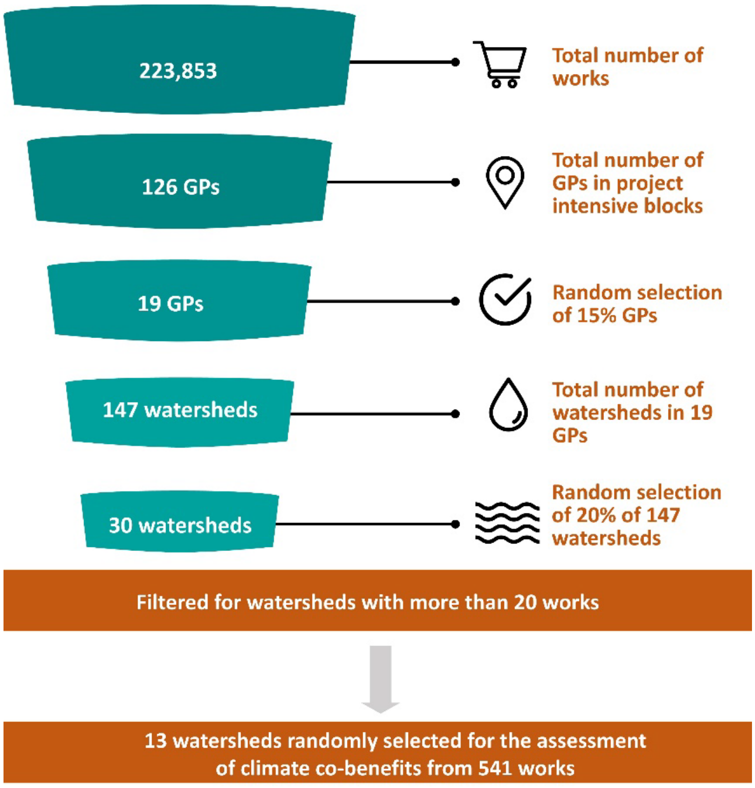

Figure 2: Sampling procedure for selection of watersheds for estimating the climate co-benefits in project-intensive blocks of Usharmukti project

Source: CSTEP

Table 1 lists the 13 watersheds selected to undertake the rapid assessment of climate co-benefits from *Usharmukti* works.

Table 1: Sampled watersheds selected for rapid assessment

District	Block	Gram Panchayat	Watershed
Bankura	Ranibundh	Barikul	BANRAI008
			BANRAN049
			BANRAN048
Jhargram	Nayagram	Baligeria	JHANAY038
		Chandabilla	JHANAY008
		Nayagram	JHANAY045
			JHANAY029
	Binpur-I	Dahijuri	JHABI1038
			JHABI1052
Paschim Bardhaman	Kanksa	Amlajora	WBMKAN024
		Gopalpur	WBMKAN015
Purulia	Jhalda-II	Tatuara	PURJH2015
	Bagmundi	Sindri	PURBAG051

2.2. Categorisation of Works with Potential to Deliver Climate Co-Benefits

The *Usharmukti* project has implemented several works, but not all works deliver climate co-benefits. Therefore, for the sampled watersheds, works implemented under the project were reviewed for their potential to deliver climate co-benefits. Climate co-benefits in this study encompass climate resilience, adaptation, and mitigation. The definitions (IPCC, 2022) of these terms and a few examples are given below:

Resilience is the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions.

For example, if continuous contour trenches are created/provided on a degrading hill, they can conserve and protect the topsoil (by reducing soil erosion) and facilitate groundwater recharge—improving the water quality and quantity downstream, and improving soil moisture retention, thereby facilitating vegetation growth.

All of these benefits increase the ability of the hill side and the dependent natural resources (water and vegetation) to cope with adverse impacts of droughts, as the basic structure of the system has not only been preserved but restored and improved. In short, their resilience has increased.

Adaptation refers to the process of adjustment in human systems in response to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects can happen spontaneously, or human intervention may facilitate this adjustment to expected climate.

The simplest example of adaptation is a shift in cropping patterns. Consider a farmer who is growing paddy (a water-intensive crop) using groundwater as the source of irrigation. With each passing crop cycle, the groundwater table declines. Further, due to changing rainfall patterns (as a result of climate change) the aquifers do not recharge adequately. In such a case, a farmer shifting away from paddy to a drought-resistant and less water-intensive crop (such as millets) would be an example of adaptive mechanism taken up in response to shortage of water. The outcome of adaptation here would be a stable crop yield even in the event of a drought.

Mitigation is any human intervention that reduces the sources or enhances the sinks of greenhouse gases (GHGs). This study focusses on mitigation through the enhancement of sinks of greenhouse gases. A sink reduces atmospheric GHGs by storing (sequestering) carbon in another form. The biggest sinks are the oceans, vegetation (forests or trees), and soils.

Here, we look at the capacity of the trees and soils to remove carbon dioxide from the atmosphere and store it as carbon in biomass and soil, which is a result of horticulture and social forestry plantations under *Usharmukti*.

Table 2 provides a list of the different types of works implemented in the 13 sampled watersheds along with a brief description of each work and the climate co-benefits they potentially could deliver. A total of nine different types of works were implemented in the sampled watersheds and all of them have the potential to generate either climate resilience, adaptation and/or mitigation co-benefits (Esteves et al., 2013). Table 2 also provides the number of works that were included for rapid assessment of climate co-benefits.

Table 2: Works implemented in sampled watersheds, potential climate co-benefits, and the number of works sampled

SN	Type of works	Description of works	Climate co-benefits	Number of works
1	Water harvesting structures (WHS)	Water harvesting structures created under the project include both private and community-based, decentralised irrigation structures. The most common WHS created were farm ponds on individual farmer lands. This was followed by the excavation of *happas* or small tanks, and desilting and renovation or strengthening of bunds of existing surface-water harvesting structures.	Resilience and adaptation	239
2	Irrigation canals	Activities include construction of irrigation canals for expansion of irrigation as well as strengthening of embankments of existing canals. Soil from the excavation of new irrigation channels or desilting of existing ones was used to level lands, providing the dual benefit of improving access to irrigation and improving land productivity.	Resilience and adaptation	43
3	Social forestry with soil and moisture conservation	Upland areas (100 ha in the sample watersheds) were taken up for plantation activities. A variety of forest-tree species that provide non-timber forest products (NTFPs) were planted. Tree species planted include *Terminalia arjuna*, *Acacia auriculiformis* (Sonajhuri), *Tectona grandis* (Segun), etc. Soil and moisture conservation works were carried out in these plantations to enhance survival rates and maximise productivity.	Resilience, adaptation and mitigation	155

4	Horticulture with soil and moisture conservation	A large number of upland farms (45 ha in the sample watersheds) were converted into mono- and mixed-horticulture fruit-tree orchards with the cultivation of mango, dragon fruit, cashew, etc.	Resilience, adaptation and mitigation	87
5	Land levelling	Land-levelling activities were carried out on individual farmer lands (including fallow lands) and common lands (wastelands) to make them better suited for crop cultivation and forestry plantations.	Resilience	5
6	Rock check/Gabion structures	Rock checks or gabion structures were constructed to reduce runoff, conserve soil, and enhance groundwater recharge.	Resilience	1
7	Continuous contour trenches (CCT)	Continuous contour trenches were constructed to protect lands from soil erosion, improve soil moisture retention, reduce runoff, increase groundwater recharge, and improve water quality of surface-water bodies.	Resilience	4
8	Social forestry nurseries	Three self-help groups comprising14 beneficiary households were provided with social forestry tree saplings to set up a nursery as an income generation activity within the sample watersheds.	Adaptation	3
9	Vetiver grass plantation	Vetiver grasses were planted on the embankments of rivers to check soil erosion. These grass plantations may also be harvested for fodder.	Resilience and adaptation	4
Total				**541**

2.3. Methods for Quantification of Climate Co-Benefits

Indicators were identified to quantify the potential climate co-benefits of each work; these were then quantified either through primary surveys or field measurements. All indicators were measured in terms of change (pre- and post-*Usharmukti* project implementation), in order to attribute this change to the project. For field measurements, control plots were identified—these are plots with no project intervention. The methods used for quantification are detailed below:

a) **Primary surveys** for quantifying climate resilience and adaptation co-benefits of all works implemented under *Usharmukti*.
b) **Field measurements** for estimating tree biomass and soil organic carbon and ultimately the mitigation potential of *Usharmukti* plantation works.

A substantial database exists as the project is implemented through MGNREGS, which enabled the selection of sample watersheds and works. Additionally, PRADAN provisioned a dataset pertaining to *Usharmukti* work implementation in PAIBs, which included all details of the sample works. This was used to create a beneficiary list with corresponding work names and work codes, which was then used to identify plots and beneficiary households for measurements and surveys.

Project partner PRADAN informed project beneficiary households about the rapid assessment exercise, and project field-partner ARF, along with two local field assistants, undertook field measurements and primary surveys.

2.3.1. Primary surveys

Primary surveys were conducted to quantify (either qualitatively or quantitatively) the identified indicators to represent climate resilience and adaptation co-benefits of all works implemented in the sampled watersheds. Structured questionnaires were used to conduct surveys of individual beneficiary households. **Household surveys were conducted for two major works—water harvesting structures and horticulture—**as they were mostly implemented on privately-owned lands (Figure 3).

Figure 3: ARF field team conducting household surveys

Participatory rural appraisals (PRAs) were conducted to engage with beneficiary households of public works and/or works that had more than one beneficiary. Thus, the PRAs were conducted for beneficiary households of social forestry and grass plantations, continuous contour trenches, rock checks, social forestry nursery, and irrigation canal construction—works that were implemented on public lands for benefitting a larger number of people (Figure 4). PRA formats were prepared considering the features of work implementation in each of the sampled watersheds. In all, 13 PRAs were conducted.


Figure 4: ARF field team conducting PRAs

2.3.2. Field measurements

Field measurements were conducted for two main works—social forestry and horticulture tree plantations. A standard plot method, normally adopted in ecological studies was used for estimating aboveground biomass. The Intergovernmental Panel on Climate Change (IPCC) default method was adopted for estimating belowground (root) biomass, based on aboveground biomass data. Soil organic carbon was estimated by taking soil samples from plots impacted by works and using laboratory analysis to measure carbon content. Control plots were used to estimate the net impact of works on carbon stocks.

Field measurements include the measurement of tree height and girth, and soil sample collection. These were then converted into carbon stock and the carbon sequestration potential of plantation works taken up under *Usharmukti*. Young and growing plantations, be it forestry or horticulture, capture carbon from the atmosphere and store it. Not only is carbon stored in trees of plantations, but a significant amount is stored in soils as soil organic carbon as well. Although there are five carbon pools in a plantation—aboveground biomass, belowground biomass, deadwood, litter, and soil organic carbon—only aboveground biomass was quantified through measurements, while belowground biomass was derived, and soil organic carbon was estimated. This is because in plantations, very little or no deadwood and litter is expected.

Biomass estimation

The carbon stock in aboveground tree biomass was estimated from the measurements done on sample plots. ARF field team, along with local field assistants, visited the identified sample plots, and laid quadrants of 30 X 30 m (900 sq. m). In each of the locations, three identical quadrants were laid, which is typically done in forest carbon inventories.

A reel of sturdy rope along with measuring tapes (20m) was procured for laying the quadrants. All trees inside a quadrant were measured. Figure 5 provides guidance for inclusion or exclusion of trees within a quadrant, depending on their position relative to the quadrant border.

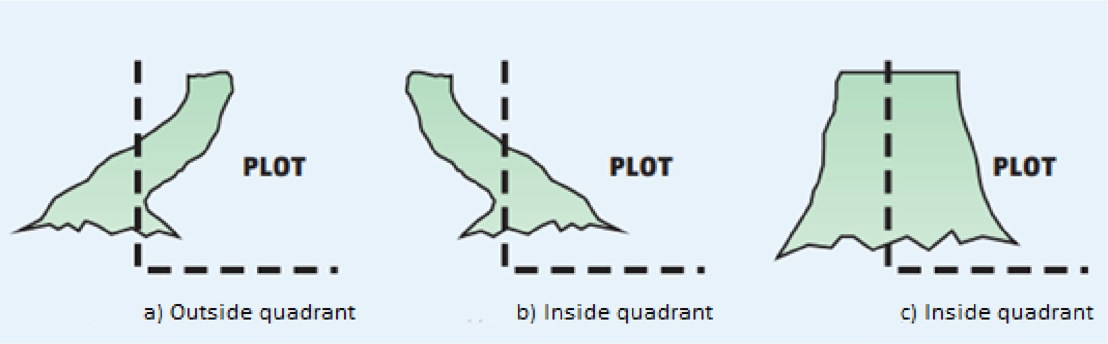

Figure 5: Determining the position of a borderline tree (inside or outside quadrant, for selection)

Source: (UNFCCC, 2015)

Girth at breast height (GBH), which is most commonly used in forest inventories, is defined as the overbark tree stem girth measured at a pre-determined height of 1.3 m above the ground level. In this study, only trees having a girth above 10 cm at breast height (GBH), which is 1.3m above the ground, were measured using a metric tape (Figure 6).

Figure 6: Girth measurement

The estimation of tree biomass requires tree height as an input variable. Tree height was visually estimated by the field team. For all trees or saplings with girth less than 10 cm, only the name of the tree and the number of such trees were recorded.

In addition to project plots, a control plot was laid adjacent to the plantation. A single quadrant of 900sqm was laid and any trees within the quadrant were measured in the control plot. This was done to compare the difference in carbon stock with and without project implementation.

Figure 7 shows field teams from ARF conducting tree measurements for aboveground biomass estimation.

Figure 7: Photographs from the field – ARF staff conducting aboveground biomass estimation

Soil carbon estimation

Soil samples were collected from within the replicate quadrants laid in each sample plantation plot to measure trees. These samples were collected at a depth of 30cm. They were then mixed thoroughly, and a single composite soil sample (approximately 250g) was bagged and tagged for each sample plot. Materials needed to collect soil samples include a measuring tape or scale (30cm), digging implements, a plastic sheet on which soil samples can be mixed, zip-lock bags, and labels. Care was taken to not collect samples near vegetation, water, or other disturbances such as ant hills, etc. Soil samples were then sent to a local soil-testing laboratory for soil organic carbon (SOC) estimation.

Figure 8 shows the ARF field team collecting soil samples from plantation plots.

SOC values estimated and provided by the laboratory were as percentage organic carbon (OC%) for each sample. This was converted to carbon stock in soils (tC/ha), using the following formula:

$$Soil\ organic\ carbon\ \left(\frac{tC}{ha}\right) = organic\ carbon\ (\%) \times soil\ bulk\ density \times depth\ at\ which\ soil\ sample\ was\ collected \times conversion\ factor\ of\ ha\ to\ m^2$$

Which translates to:

$$\frac{tSOC}{ha} = OC\% \ \times 1.6\frac{t}{m^3} \times 0.3m \times 10{,}000m^2$$

Soil organic carbon in plantations was also compared to non-plantation control plots to attribute the change in SOC to the planting of trees under *Usharmukti*.

Figure 8: Photographs of the field teams collecting soil samples

Total carbon stock estimation

The ARF field team collated the field tree measurement data into Microsoft Excel and shared it with CSTEP for analysis. Tree-species-specific allometric equations compiled from literature were used for aboveground biomass (AGB) estimation (Table 3). GBH values are converted to diameter at breast height (DBH) by dividing by π = 3.14. The AGB values are in kg units. For sonajhuri, two equations were used, based on the size of the tree. For trees with DBH less than 10 cm, equation 1a was used, and for trees with DBH over 10 cm, equation 1b was used. In the sampled plots, species such as guava (*Psidium guajava*) and arjun (*Terminalia arjuna*) were recorded, but the trees were too small to measure and include in carbon stock estimation. Belowground biomass (BGB) was estimated by considering an IPCC default proportion of 24% (of AGB).

Table 3: Tree-species-specific allometric equations for aboveground biomass estimation

SN	Local Name	Scientific Name	Allometric Equation
1a	Sonajhuri	*Acacia auriculiformis (DBH <10 cm)*	$(0.108 \times DBH^2) + (0.4211 \times \text{DBH}) - 0.2382$
1b		*Acacia auriculiformis (DBH >10 cm)*	$-67.6663 \times DBH^2 + 113.1102 \times DBH_1 + 4.3385$
2	Segun	*Tectona grandis*	$0.048 \times DBH^2 + 0.812 \times \text{DBH} - 0.351$
3	Cashew	*Anacardium occidentale*	$EXP(-1.996 + 2.32 \times \ln(DBH))$
4	Mango	*Mangifera indica*	$EXP(-2.289 + 2.649 \times \ln DBH - 0.021 \times (\ln DBH)^2)$

Sources: (Collas et al., 2003; Daouda et al., 2017; FSI, 2012)

The total biomass of a tree = AGB + BGB. This was then converted into carbon stock using the IPCC default conversion factor that assumes 45% of biomass to be carbon.

The carbon stock in the trees of each quadrant was then converted into carbon stock per hectare (tC/ha). Considering the age of the plantations, the carbon sequestration rate was estimated as tC/ha/year for each district. This increment value could be used to project the sequestration potential of plantations under the project.

The carbon sequestered by trees and soil was then aggregated to obtain the total carbon stock in plantations (tC/ha).

2.4. Generalisation of Sampled Data to the Project Area

Results from the rapid assessment conducted for a randomly sampled number of works within PAIBs were generalised to the total number of such works implemented within districts from which the sample was selected, i.e., Bankura, Jhargram, Paschim Bardhaman and Purulia. For example, results from 84 horticulture works (three beneficiary households of this work could not be located to undertake the survey) was generalised to 8,199 horticulture work beneficiary households from within the four districts. Table 4 provides the sampled number of works, the number of works actually surveyed, and the total number of the same type of work that were implemented within the four study districts for which results have been generalised.

Table 4: Number of sampled works and total number of works within study districts

SN	Work	Sample number	Surveyed	Total number
1	Water harvesting structures (WHS)	239	217*	18,947
2	Social forestry	155	155	14,410
3	Horticulture	87	84*	8,199
4	Irrigation canals	43	43	6,639
5	Land levelling	5	5	567
6	Continuous contour trenches (CCT)	4	4	986
7	Vetiver grass plantation	4	4	40
8	Social forestry nurseries	3	3	1,208
9	Rock check/Gabion structures	1	1	237

**Of the sampled works 22 WHS and 3 horticulture works were not surveyed as they were not accessible due to prevailing local conditions, at the time of study.*

3. Results

The results of the rapid assessment of climate co-benefits of the identified works in the sampled watersheds are presented in this section and the specific climate co-benefits (such as climate resilience, and adaptation or mitigation co-benefits) that have been realised or are potentially realisable are also discussed.

3.1. Climate Resilience and Adaptation Co-Benefits

As seen in Table 2 provides a list of the different types of works implemented in the 13 sampled watersheds along with a brief description of each work and the climate co-benefits they potentially could deliver. A total of nine different types of works were implemented in the sampled watersheds and all of them have the potential to generate either climate resilience, adaptation and/or mitigation co-benefits (Esteves et al., 2013). Table 2 also provides the number of works that were included for rapid assessment of climate co-benefits.

Table 2, eight of the nine sample works help build resilience of the natural resource base and six out of the nine sample works have the potential to assist beneficiary households in adjusting or adapting to actual or expected climate hazards, particularly drought. The sub-sections below provide insights into the potential of these works to deliver climate co-benefits. The findings from this assessment are reported for a total population of 228,431 *Usharmukti* beneficiary households in the four sampled districts.

3.1.1. Horticulture

Horticulture was promoted as mono and mixed plantations in the four study districts, benefitting a total of 25,125 households (Figure 9). As seen in Figure 10, all districts have 4-year-old plantations. However, our sampling design was random and therefore in Jhargram and Paschim Bardhaman, although 4-year-old plantations exist, they were not part of the sample. Further, in every sample district, all the works identified through random sampling were assessed.

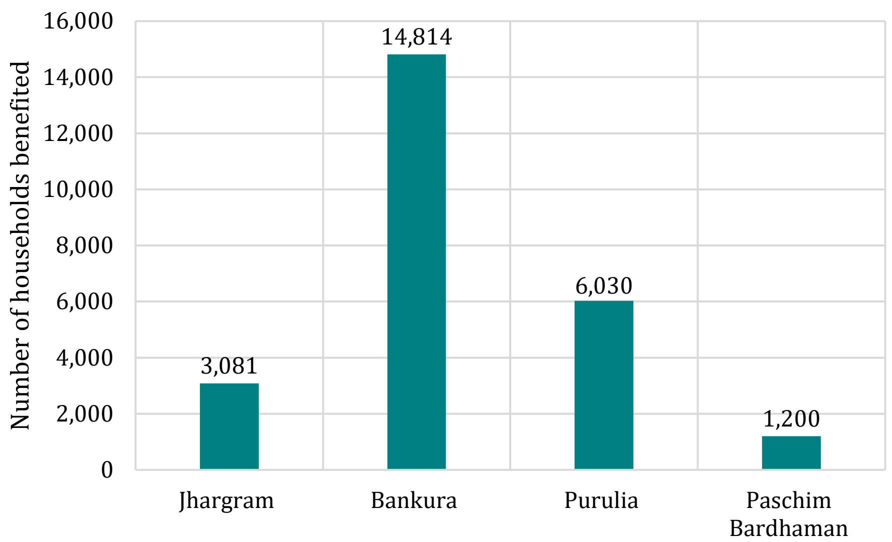

Figure 9: Households benefitted by horticulture plantation works under Usharmukti

Plantation works have been undertaken since 2018. Within the sampled horticulture plantations, the bulk of sampled plantations were 2 to 3 years old. Among the four districts, Purulia had the highest number of 4-year-old plantations (Figure 10).

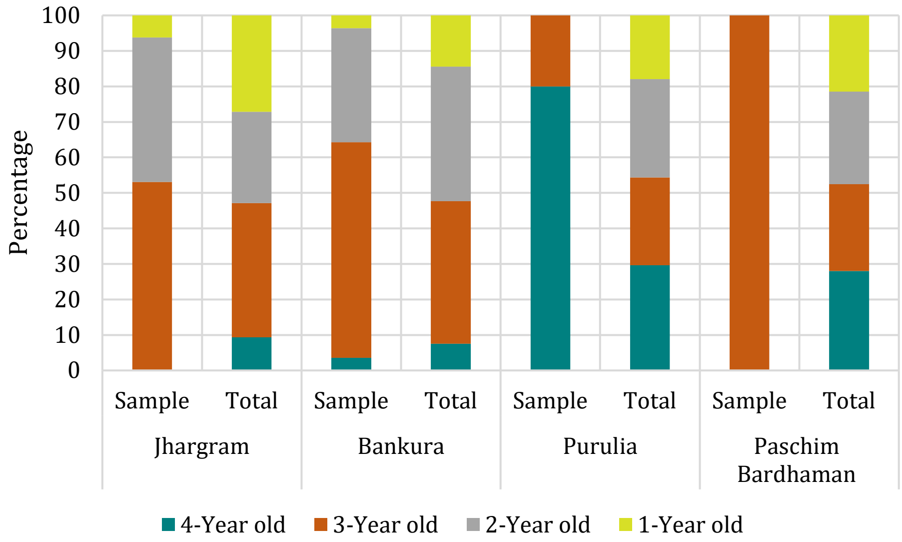

Figure 10: Age-wise distribution of plantations within sampled watersheds and project districts

It can be seen from Figure 11 that monoculture plantations dominate. These include plantations of cashew, mango, and guava. Only in Purulia, a significant percentage of area is under mixed plantations.

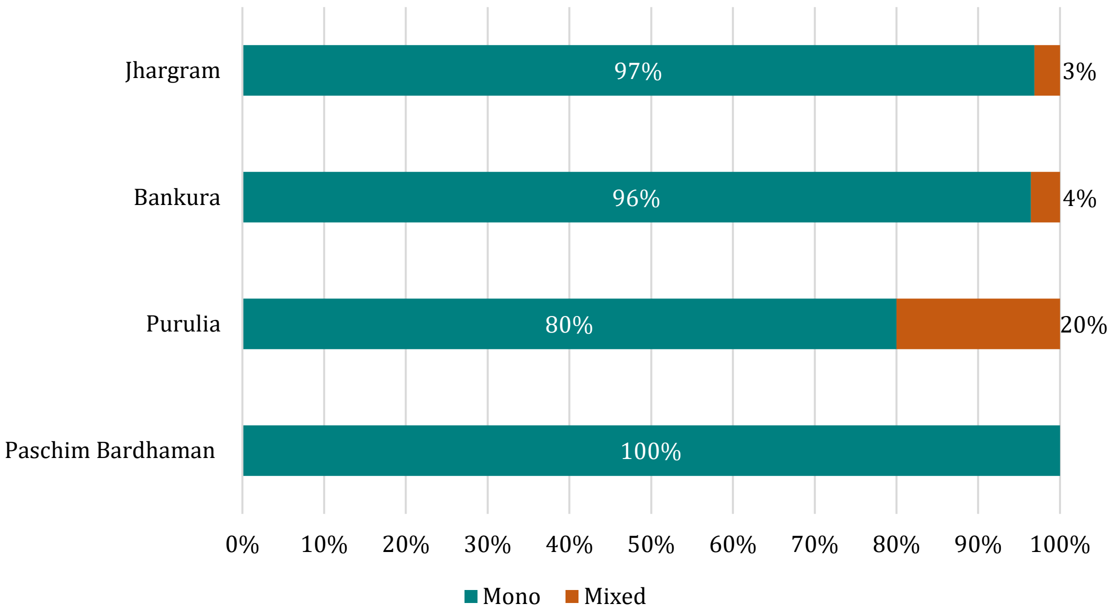

Figure 11: Distribution of mono and mixed plantations within sampled watersheds

Land holding and utilisation pattern

The beneficiary households of sampled horticulture works are marginal farmers (owning up to 1 ha of land, Figure 12). They have dedicated 26% to 76% of the total land holding to horticulture plantations.

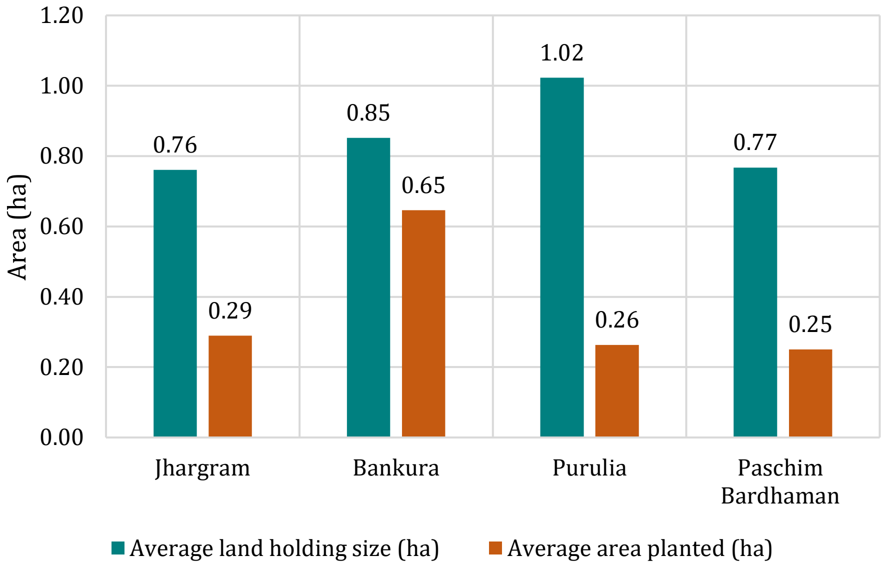

Figure 12: Land-holding size of beneficiary households in sample watersheds and the area planted with horticulture trees

Prior to *Usharmukti,* of the 84 horticulture beneficiary households, about 43% cultivated crops, while the remaining 57% left their land fallow. Figure 13 illustrates the state of horticulture beneficiary households' pre-and post-*Usharmukti* implementation.

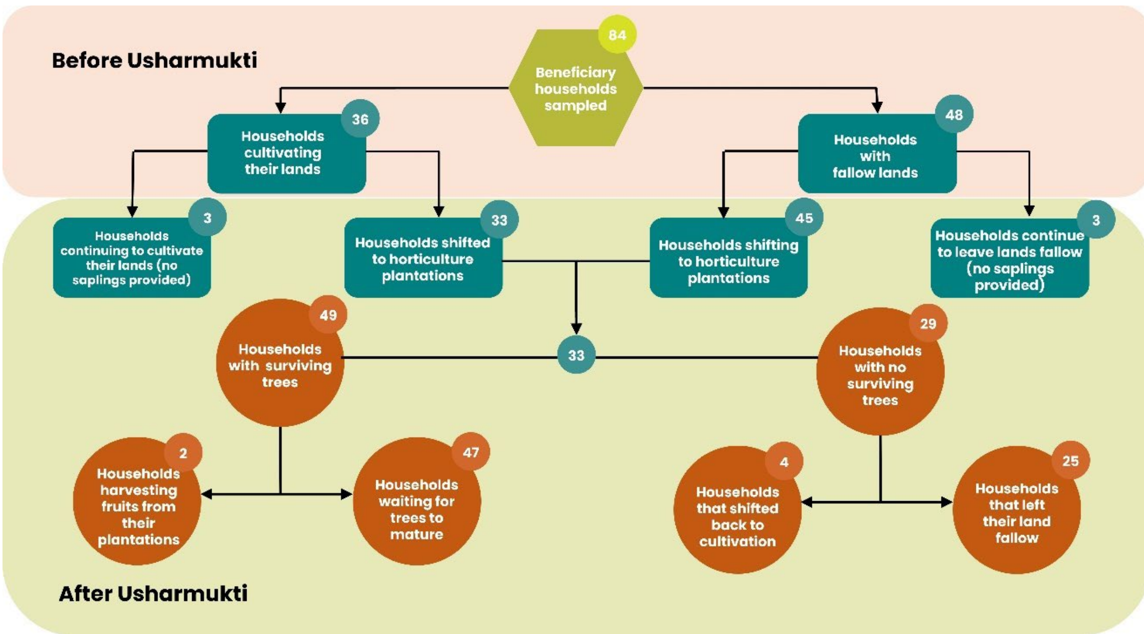

Figure 13: Illustration of the situation pre and post Usharmukti for horticulture beneficiary households

Crops cultivated prior to *Usharmukti* include paddy, maize, brinjal, pulses (*Arhar*), chilli, brinjal, okra, and cabbage. It was principally rainfed, and only 6% of the households had irrigation facility.

Post project, the area under irrigation increased to 10% and the species promoted included cashew, mango, and guava. To some beneficiary households, saplings of sonajhuri and segun were provided due to the unavailability of fruit tree saplings. Further, under the project, 32% of horticulture works were treated with soil and moisture conservation activities to aid establishment of saplings under rainfed conditions.

Survival rates and tree replacement

It is interesting to note that almost all the beneficiaries (99%) had no prior experience of managing horticulture plantations. Furthermore, only about 2.5% of households were trained on raising horticulture saplings. Yet, the recorded survival rate of the horticulture plantations in the study districts was in the range of 21% to 61%—an average of 43.3% (Figure 14).

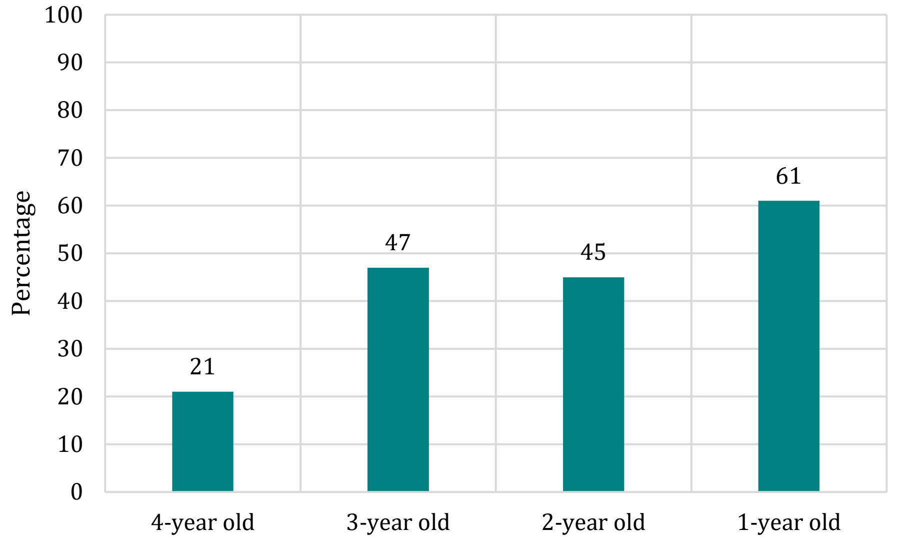

Figure 14: Survival rates of plantations of different ages

Mortality in horticulture plantations is attributed to a number of reasons (Figure 15). One of the primary reasons for tree mortality as expressed by the beneficiary households during the survey was inadequate or no rainfall. Other reasons for failure include disturbance by animals such as elephants, goats, and cattle.

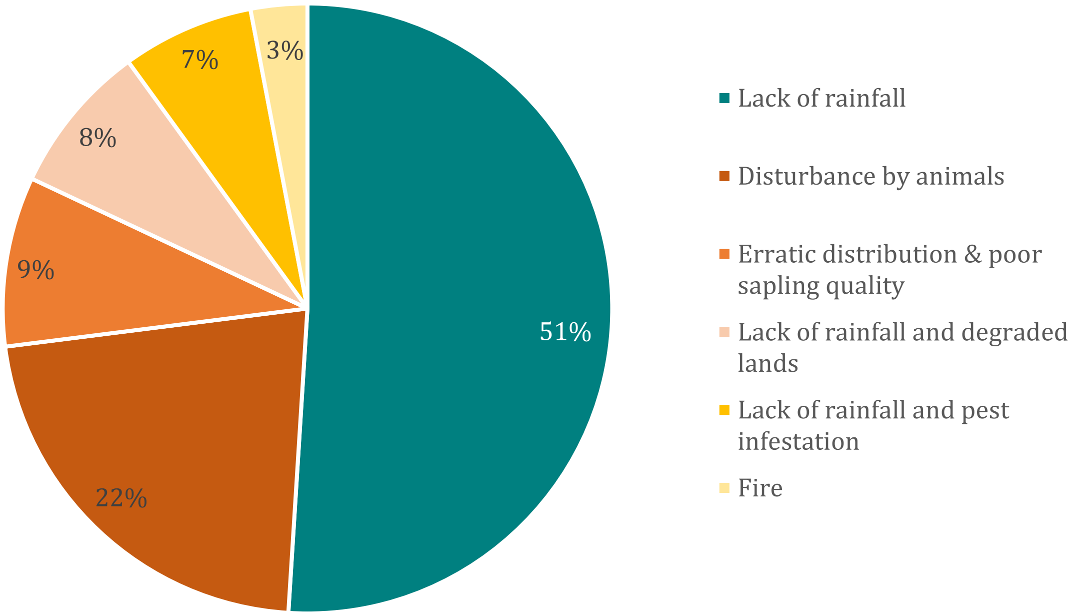

Figure 15: Perceived reasons for tree mortality

Of the 34.5% beneficiary households that recorded mortality, about 14% reverted to cultivating field crops as they had no capacity to replace trees. Only 5.1% of households reported to have replaced trees themselves. About 2.5% of the beneficiary households sought help from the *Gram Panchayat*, while the majority, 92.3% have been unable to replace trees at all.

The survey clearly indicates certain institutional barriers including non-distribution of seedlings by contractors, absence of life-supporting irrigation to the saplings, and discrepancies in record-keeping.

A horticulture plantation, like any other plantation, is highly vulnerable to weather extremities in the first three years while it is in the sapling stage. A reliable/regular source of irrigation, and support for replacing saplings within the first three years would ensure better survival in horticulture orchards.

Resilience co-benefits from horticulture plantations

Among the beneficiary households that raised horticulture plantations under the *Usharmukti* project, 67% report an improvement in soil quality, and also that they experience cooler ambient temperatures. Estimates of soil organic carbon in samples collected from these plantations support the claim. The results indicate higher soil organic carbon content in the treatment plots compared to control plots. On an average, the SOC content in treatment plots is 0.352 tC/ha, compared to 0.314 tC/ha in control plots. This is an increment of about 0.373 tC/ha in soil.

Various studies suggest that increase in SOC content in the soil can be directly linked to improved functioning of soil ecosystem, stabilisation of soil structure, retention and release of plant nutrients, and enhancement of water-holding capacity, thus making it a key indicator not only for agricultural productivity and carbon sequestration, but also resilience (Lefèvre et al., 2017). Some of the beneficiary households also reported improvement in biodiversity, particularly more local fauna such as parrots, woodpeckers, and nightingales in and around the horticulture plantations.

Adaptation co-benefits from horticulture plantations

Fruit yield from horticulture plantations is a potential source of income for the beneficiary households. This is an adaptation co-benefit as in an event of crop failure, income from horticulture plantations helps households to tide over adverse impacts. This benefit is yet to be realised in the sample plantations, as the plantations are young (4 or less than 4 years old) and yet to yield fruits, or timber (in case of beneficiaries who were distributed sonajhuri and segun—the timber-yielding species). During the survey, beneficiaries shared that they are aware of the time needed for trees yields—5 years for fruit yield and 8 years for timber yield. They further expressed that they were not incurring any loss, as these lands were left fallow in any case.

Only in Purulia, 10% of survey respondents stated that their mango plantations have started yielding fruits and the average yield per tree was 5 kg/year. Given that the plantations are young and the yields low, all the fruits are used for subsistence. Additionally, about 5% of survey respondents in Purulia reported collecting dry leaves and branches from plantations to use as fuelwood.

3.1.2. Water harvesting structures

Water harvesting structures (WHS) have been constructed under the project on both private and community lands. A total of 217 beneficiary households were surveyed to assess the benefits from these works. The most common WHS are farm ponds (209 works), constructed on individual farmer lands, and h*appas* or small tanks (8 works), constructed on public lands.

WHS were promoted to help farmers bring fallow lands under cultivation and to provide irrigation to rainfed farms. A total of 109,060 households have benefitted from the construction of WHS (Figure 16).

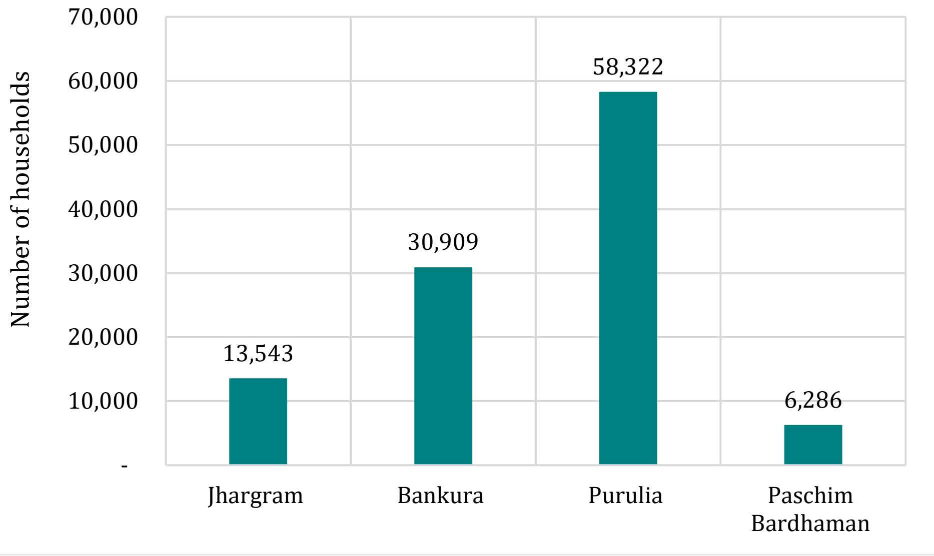

Figure 16: Number of households benefitted by WHS in study districts

Land holding and utilisation pattern

The average landholding size of households that have constructed WHS under the project is 0.61 ha across the sampled watersheds. Of the 217 households that have taken up WHS activity, 84.8% were cultivating their lands prior to the implementation of the project, and the remaining (15.2%) had left their lands fallow (for about 32 years on an average). Among the farmers that cultivated their lands prior to *Usharmukti* (184 households), 63.58 % practiced rainfed agriculture, and 36.4% adopted different methods of irrigation (Figure 17).

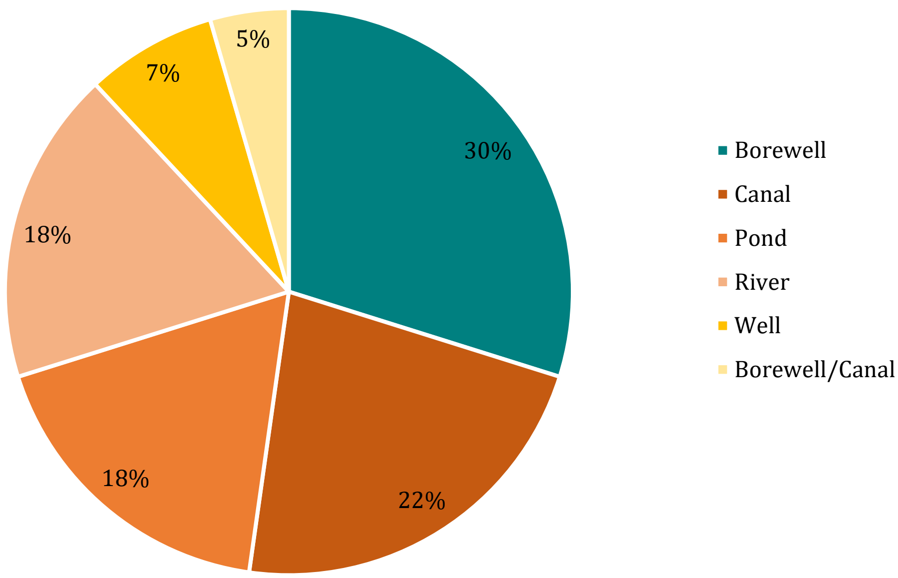

Figure 17: Methods of irrigation prior to Usharmukti

Climate resilience and adaptation co-benefits from WHS

WHS works under *Usharmukti* have brought lands previously left fallow (for over 30 years) under cultivation. This additional source of income or food has the potential to help households cope with the impacts of drought. It has also been reported that the WHS assets constructed under *Usharmukti* have recharged groundwater and consequently increased the overall availability of water. This has resulted in an increase in the area under irrigation. Since irrigation is known to buffer against climate-change-related impacts (such as delayed or untimely rainfall, and in extreme cases, droughts), an increased area under irrigation has the potential to boost farm income by providing farmers an option to change crop varieties and adopt farming techniques to enhance productivity.

The resilience and adaptation co-benefits of WHS are realised in multiple ways. These include:

- Improved irrigation
- Groundwater recharge
- Livelihood and income diversification

Improved irrigation

The primary purpose of a WHS is to provide water for irrigation. Therefore, WHS construction has led to an increase in the area under irrigation (in the case of areas that were earlier rainfed), expansion of area under irrigation (in the case of already irrigated areas), and longer periods of water availability for irrigation. Figure 18 illustrates the situation pre- and post-*Usharmukti* implementation for WHS beneficiary households.

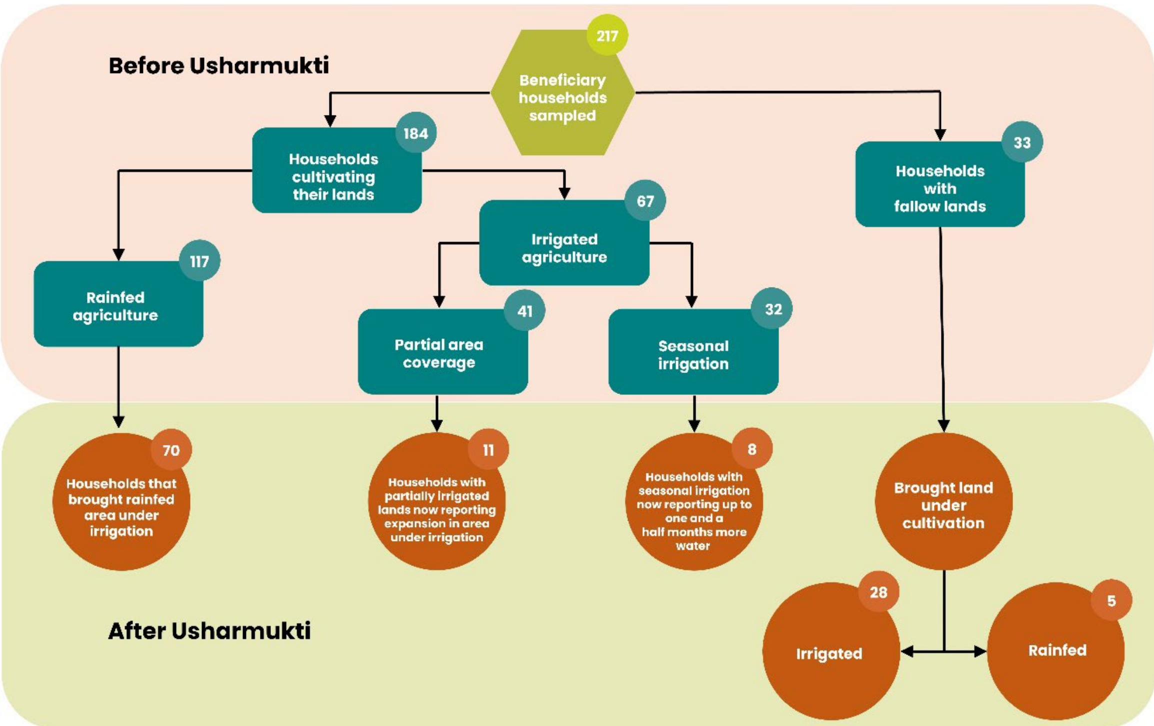

Figure 18: Illustration of the situation pre and post Usharmukti for WHS beneficiary households

Construction of a WHS has enabled 59.8% of rainfed farmers to bring lands under irrigation (Figure 19).

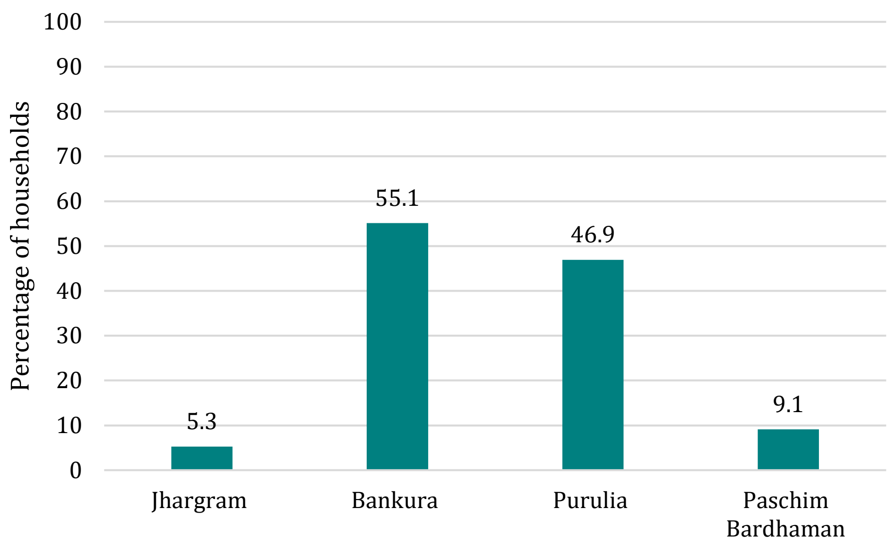

Figure 19: Percentage of rainfed farmers with irrigation post Usharmukti

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If the same level of implementation (as present in the sample area) is assumed across the entire district, about 35,180 rainfed farmers can irrigate approximately 22,095 ha of land—thereby enabling adaptation to dry spells or droughts.

Post *Usharmukti* implementation, 38.81% of the households irrigated the full extent of their lands. The remaining 61.19% could only partially irrigate their lands. Of the farmers that partially irrigated their fields, about 26.83% in three study districts expanded the area under irrigation (Figure 20).

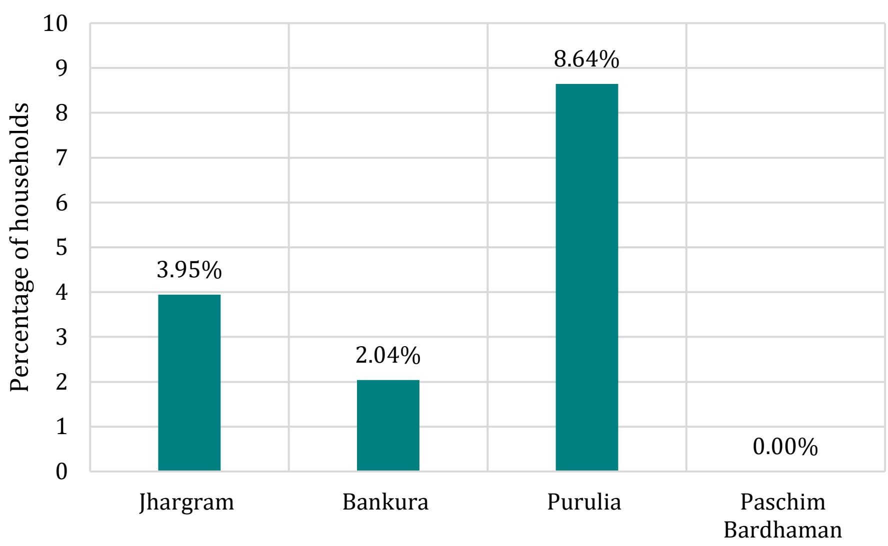

Figure 20: Percentage of households reporting an increase in area under irrigation across sampled districts

If the same level of implementation is assumed across all the three study districts, construction of Usharmukti water harvesting structures can enable 5,528 farmers to increase the area under irrigation, from 14,393 ha to 27,137 ha, thereby protecting a larger portion of the cropped area from climate variability and extremes.

Another significant finding from this rapid assessment was the perceived increase in the duration of water availability among farmers with irrigation sources, because of WHS. Of the 67 households with irrigation sources, 47.8% had seasonal irrigation sources. Of these, 25% reported an increase in availability of water post *Usharmukti* (Figure 21).

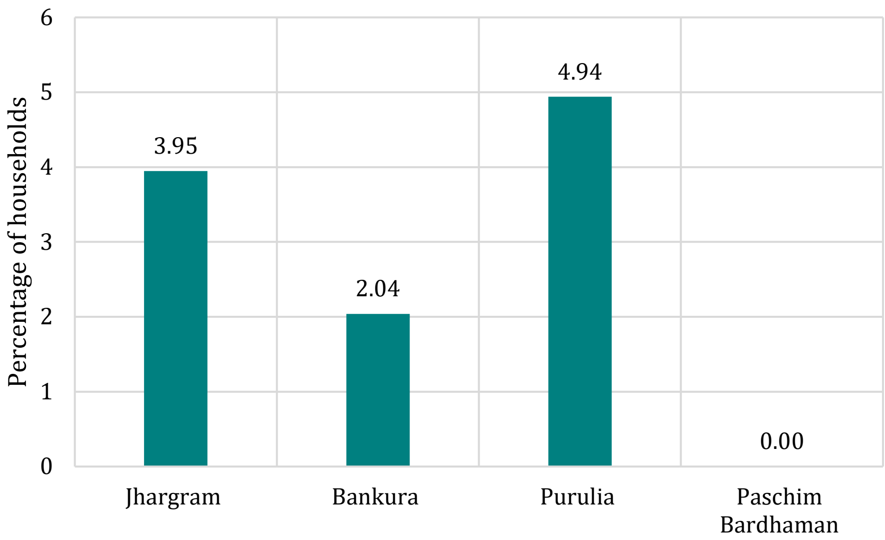

Figure 21: Percentage of households with seasonal irrigation report an increase in water availability

In three of the study districts, 4,021 farmers with seasonal irrigation can now use their irrigation sources for up to a month and a half more than they did before Usharmukti.

Groundwater recharge

The presence of a water harvesting structure does not automatically imply that beneficiary households use water directly from it for irrigation. Depending on the geological profile of the area, WHS can act as a source to recharge aquifers. In such cases, WHS may be used exclusively as a recharge structure or as both—surface irrigation and groundwater recharge structure—as seen in the study area. Further, some beneficiary households use the WHS exclusively for fisheries.

Of the 217 households with WHS, 76.03% (165 households) irrigated their lands post *Usharmukti.*

In Jhargram and Bankura districts, 44.3% of households reported that water from WHS is used indirectly for irrigation, i.e., from groundwater sources such as borewells and wells (Figure 22), indicating recharge.

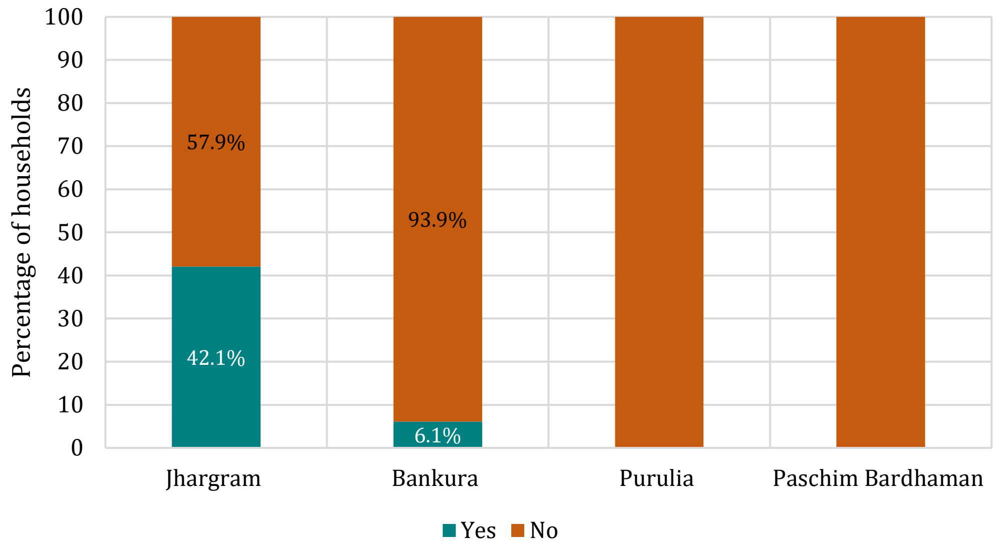

Figure 22: Percentage of households using WHS as a groundwater recharge structure

Assuming the same level of implementation as in the sample, in Jhargram and Bankura districts, 12,447 farmers can use WHS for groundwater recharge.

It is to be noted that the irrigation and groundwater recharge potential of WHS is severely compromised due to their inability to store significant quantity of water post monsoon. Beneficiary households are of the opinion that the depth of the WHS structures (farm ponds and *happas)* is inadequate to provide irrigation for rabi crops.

Livelihood and income diversification – Agriculture

WHS are constructed to provision water for irrigation, and subsequently improve farm outcomes. This section presents the ability of WHS to increase crop productivity, bring about changes in cropping patterns, and increase cropping intensity, and, by extension, increase farm incomes. It is important to note that these are indications of trends and not absolute values.

Paddy is the main crop cultivated in the study area. Of the 165 WHS beneficiary households that irrigate their lands because of WHS, 71.95% reported an increase in productivity of paddy (Figure 23) by 14.6%.

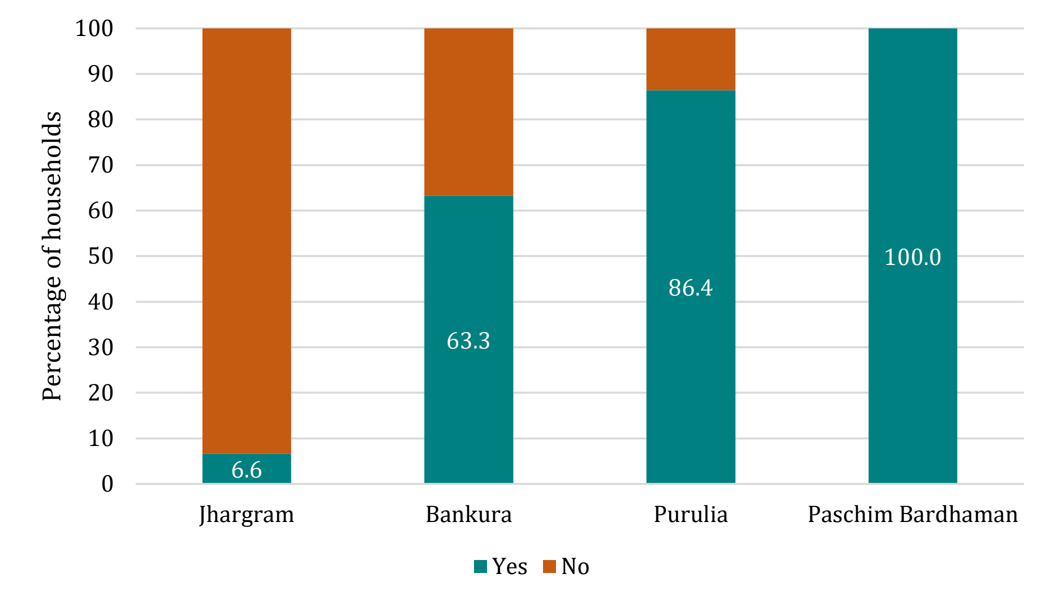

Figure 23: Percentage of households that report an increase in productivity of crops due to WHS

In the project study districts, the productivity of paddy for 59,304 farmers has increased from 2844 kg/ha to 3258 kg/ha.

Productivity gains as a result of WHS construction and water provisioning were also reported by respondents in a study conducted by the Institute of Economic Growth (IEG) in 2018. According to the study, the productivity of rice increased by 12% because of natural resource management (NRM) assets created under MGNREGS, which was acknowledged as a considerable productivity gain for small and marginal farmers.

Across the four study districts, WHS construction has increased farm incomes by 4.05% for 57,279 farmers by improving crop productivity.

Increase in crop productivity has implications on income. Of the 165 households, 65.9% reported a higher income due to increased crop productivity (Figure 24). It is estimated that a one percent increase in cereals productivity leads to an increase in income by 0.27 percent (IEG, 2018).

Of the 165 households reporting an increase in income, about 4.3% reported higher incomes due to a change in crop. The change in crop was mostly a shift from pulses to paddy. About 2.8% reported higher incomes due to higher cropping intensities.

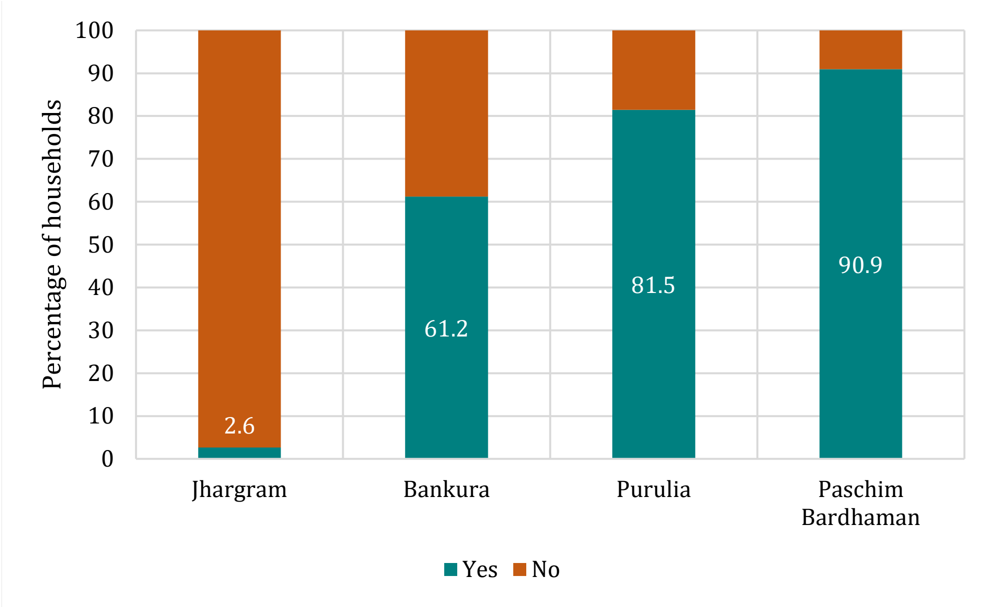

Figure 24: Percentage of households that report an increase in income due to improved productivity of crops

Overall, incomes have increased for 3,015 households due to increased cropping intensity, and for 3,518 households due to a change in crop type.

Livelihood and income diversification – Animal husbandry

Out of the 217 households owning WHS, 44.7% use it as a source of drinking water for livestock (Figure 25). WHS has yielded substantial benefits for animal husbandry in the project study districts.

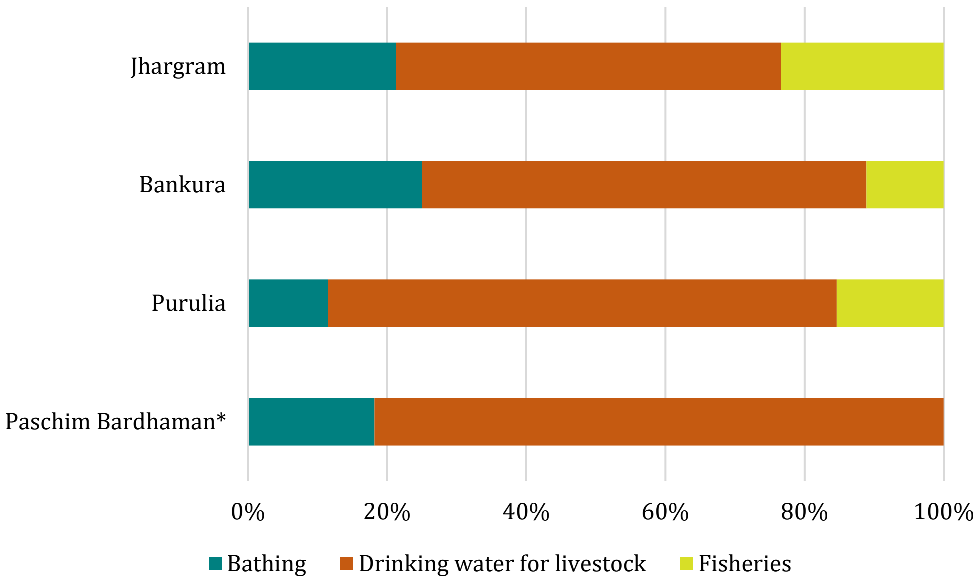

Figure 25: Alternative uses of WHS (apart from irrigation)
**In Paschim Bardhaman, all surveyed households also use their WHS for fisheries*

The beneficiary households of WHS works have taken up new livelihood activities, and one such activity involves rearing livestock (goats, sheep, and cattle). Of the 217 WHS beneficiary households, 63 did not own livestock prior to *Usharmukti*. However, after WHS construction under the project, 6.35% have purchased livestock (although attributing this benefit solely to WHS might not be possible). However, a study by the Institute of Economic Growth (2018)—which is a compilation of studies on the impacts of MGNREGS on natural resources and rural economies—corroborates this finding.

6,924 WHS beneficiary households across the four study districts have purchased livestock—giving them an additional and alternative livelihood option—made possible by increased availability and access to water for livestock.

This increase in livestock holding across the study districts is mostly among WHS beneficiary households who owned livestock prior to *Usharmukti,* i.e., 154 out of the 217 households. Some of the WHS beneficiary households (50.65%) scaled up this alternate livelihood option due to an increase in the availability and access to water for livestock.

A 24.05% increase in the number of livestock (Figure 26) post-*Usharmukti* implementation is reported. The methodology to compute this increase is provided in Appendix 9.4.

In Jhargram, a reduction in the number of cattle owned was reported, but the number of goats and sheep increased in all four study districts.

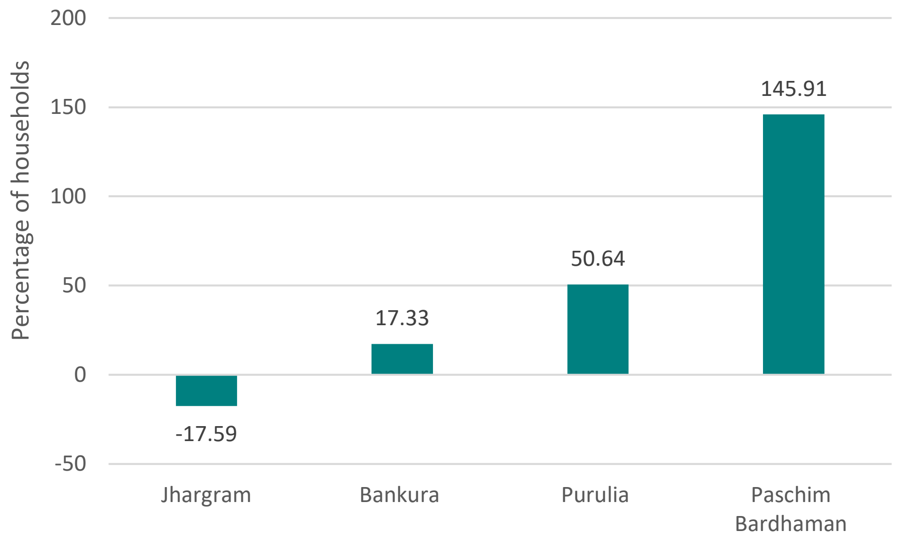

Figure 26: Percentage increase in livestock (cattle and goats/sheep) across all study districts

39,201 WHS beneficiary households across the four study districts have scaled up livestock rearing—an increase from 1.202 to 1.241 livestock units (with a reduction in cattle and an increase in goats and sheep)—to bolster incomes.

Out of the 95 households selling goats prior to the project, 71.6% reported that the income from goat sales increased by 41.13% post project implementation, due to the combined effect of households owning more goats and an increase in price of goats (Figure 27). The average income generated from goat sales per household was reported to be approximately ₹14,321/year.

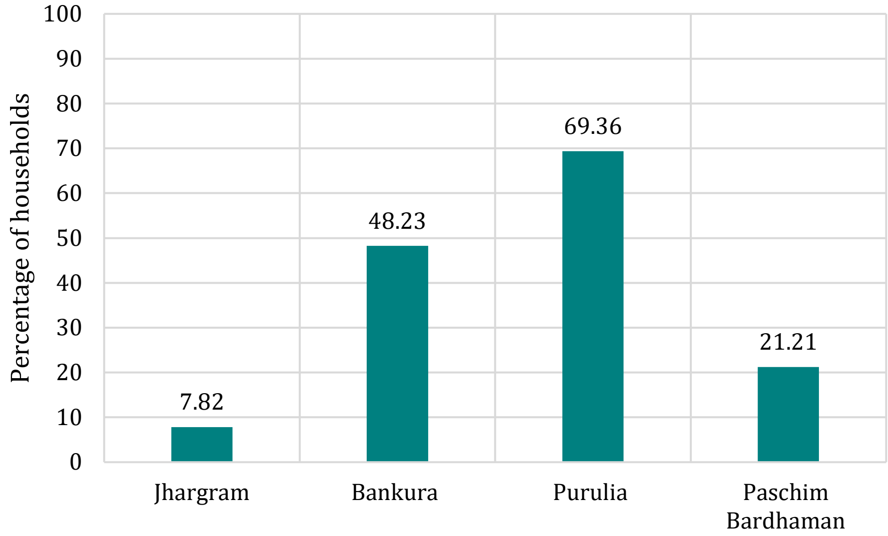

Figure 27: Percentage increase in income from goat sales in sampled districts

49,253 farmers in the study districts have benefitted from the sale of goats, now earning between ₹3,000 – ₹1,60,000 per year.

Livelihood and income diversification – Fisheries

None of the households reported fisheries as a means of livelihood prior to *Usharmukti.* The construction of WHS under *Usharmukti* has created an opportunity for farmers to diversify their incomes by taking up a new and additional livelihood in the form of fisheries.

The construction of farm ponds and *happas* have led to 43.7% households taking up fisheries as a new and supplemental livelihood option (Figure 28).

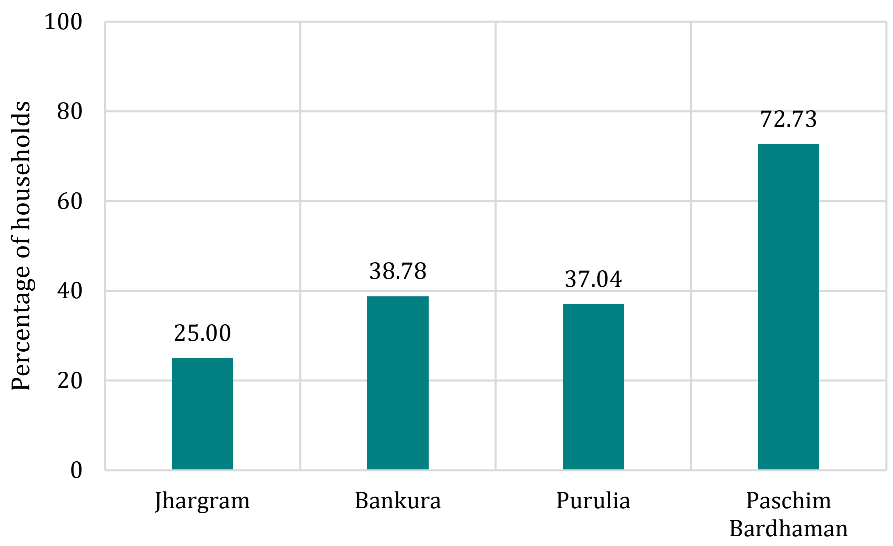

Figure 28: Percentage of households that have taken up fisheries as a new supplemental livelihood across study districts

Of the 217 households sampled, 95 reported an increase in income from the sale of fish alone—an average income of ₹22,963/household/year (Figure 29).

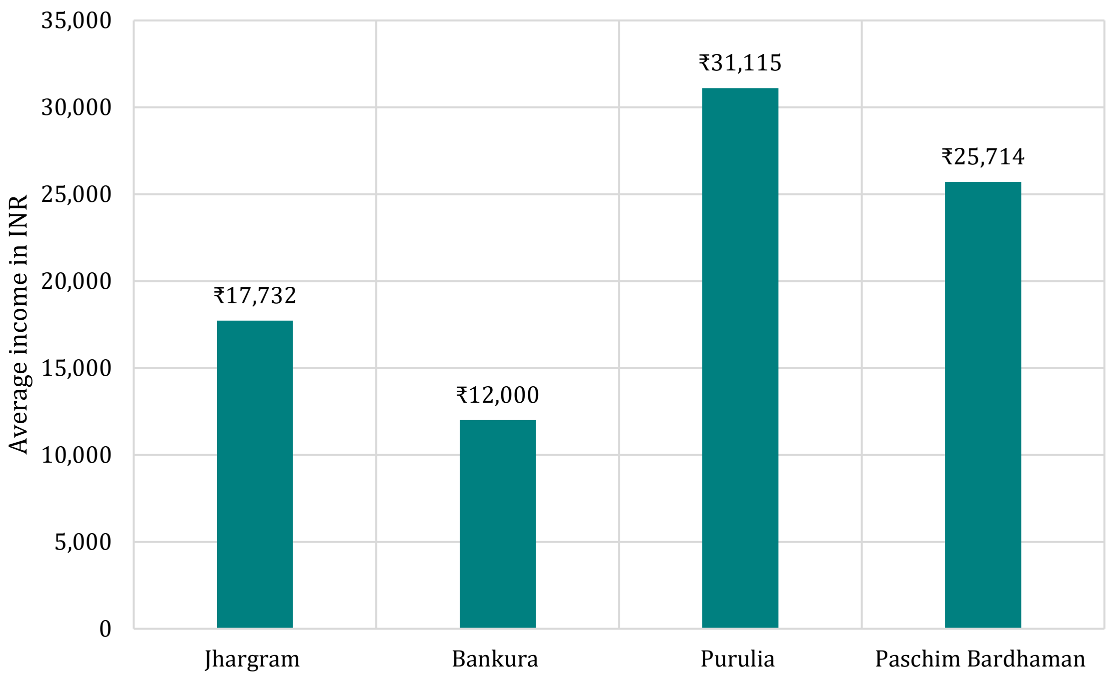

Figure 29: Average income from fisheries across study districts

35,683 households in the four study districts now earn between ₹1,000 and ₹96,000 per year from the sale of fish cultured in their WHS.

A majority of beneficiary households that used WHS for fisheries reported that the ponds were not deep enough and functioned as WHS only during the rainy season, restricting fisheries to the monsoon season. If the ponds are built to function post monsoon, higher incomes from fisheries can be envisioned. Options such as building clusters of multiple WHS, as opposed to isolated and dispersed ones to ensure water is retained for longer periods, may be explored under the project.

3.1.3. Social forestry

Social forestry was promoted under *Usharmukti* by planting trees on public lands to provision timber and non-timber forest produce (NTFP). Sonajhuri was the dominant species planted, along with segun and arjun. In some cases, forest tree saplings were not available, so the horticulture tree species of mango, cashew, and guava were planted. Resilience and adaptation co-benefits from this work were assessed using PRAs.

On an average, 8.5 ha of public land was planted under social forestry works, for the benefit of 42,625 households. A total of 1,34,929 trees were planted in the four study districts (Figure 30).

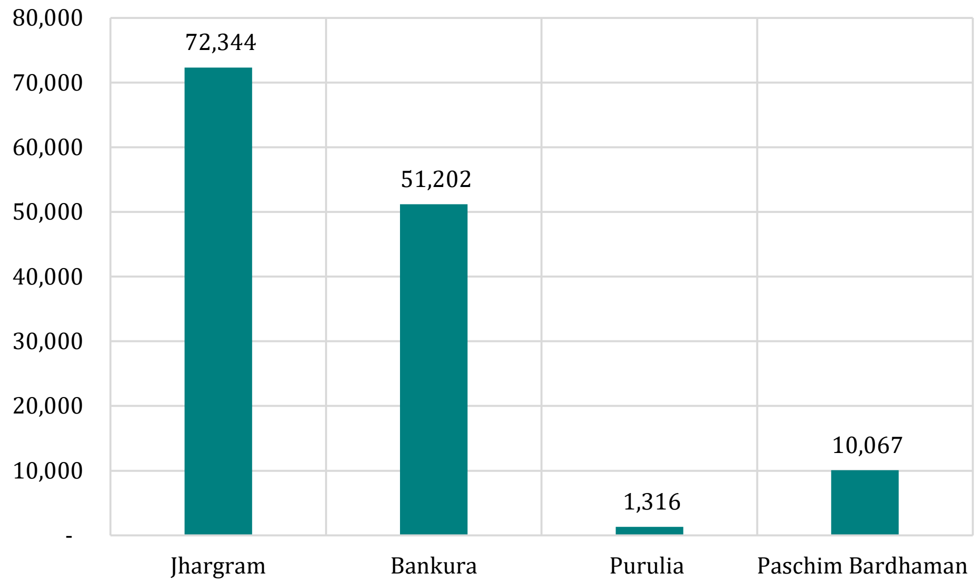

Figure 30: Total number of trees planted across study districts

Survival rate and reasons for mortality

During PRA, the respondents indicated the average survival rate of social forestry plantations to be between 19.87% and 77.45%, i.e., 70.6% on an average (Figure 31). However, for the sampled watersheds of Purulia district, none of the trees planted under social forestry works were reported (during the PRA) to have survived. The same was verified by the field team during field studies.

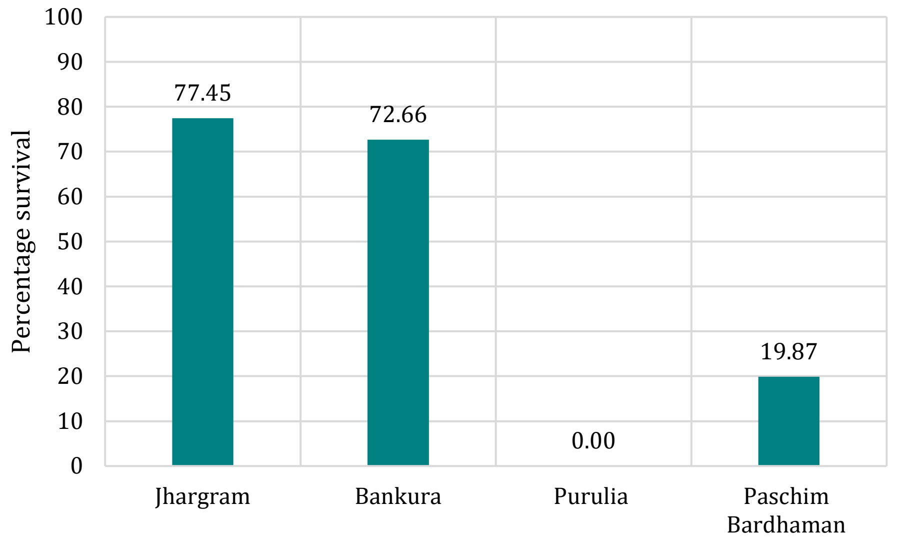

Figure 31: Survival rates of social forestry plantations

Respondents from 7 of the 13 PRAs were of the opinion that the construction of a WHS (30 m x 40 m) could potentially improve the chances of tree survival, as compared to plantations without the WHS.

The primary reasons reported by PRA respondents for zero survival rate in Purulia were lack of rainfall, damage to samplings by goats and other animals, and poor site selection for project implementation. In the other districts, respondents indicated a combination of reasons for tree mortality. These include untimely distribution of saplings (they were distributed post monsoon), leading to mortality due of inadequate water supply; forest fires; apathy of beneficiary households; and damage to saplings by pests and animals.

Tree replacement

With regard to tree replacement, some respondents expressed their willingness to replant themselves after harvesting timber, while the others were willing to replant only if saplings were provided through *Usharmukti* or a similar programme.

Resilience outcomes from social forestry plantations

Resilience outcomes of the social forestry plantations raised under *Usharmukti* include improvements in water availability, local climate, soil fertility, and biodiversity.

Improved water resources

Respondents from 6 out of the 13 watersheds reported that social forestry plantations have increased the availability of water in WHS by two to three months. As a result of higher aquifer recharge, water from borewells and wells is available in higher quantities not only in the vicinity but also downstream. For five watersheds, respondents also reported improved surface-water quality in surface-water harvesting structures downstream.

Improved ecosystem services

Respondents in nine watersheds reported experiencing cooler weather as a result of forest plantations. Similarly, respondents in five watersheds reported an increase in local fauna sightings. These include birds like the Indian golden oriole, woodpecker, openbill stork

(Shamuk khol) and nightingales, and wild animals such as the giant forest hog. Plantations have also been perceived to improve soil quality in 9 out of 13 watersheds.

Adaptation outcomes of social forestry plantations

Since all the social forestry plantation works are 4 years or less than 4 years old, they are yet to yield timber and NTFPs, and thus generate no income currently. However, during the PRA in Jhargram and Bankura districts, some of the respondents reported that they collect NTFP such as tendu leaves, soap nuts, fodder, and fuelwood from natural forests. NTFPs, particularly tendu leaves and soap nuts, are sold in the local market individually as well as collectively, generating an additional income of up to ₹10,000 per household, per year. Beneficiary households are thus aware that NTFPs are a source of income. They are also aware that a minimum of 8 years is needed before timber trees can be harvested.

Like in the case of horticulture works, estimating adaptation outcomes of social forestry works is possible only after the plantations mature (after at least 5 years).

3.1.4. Irrigation canals

Irrigation canals are engineered structures built to transport water from a reservoir or well to a farmer's field for the purpose of irrigation.

An average of 124 farmers in three study districts benefitted from irrigation canals. No canals were constructed in sampled watersheds of Purulia. Irrigation canals helped bring 15 to 95 ha (an average of about 55 ha, as shown in Figure 32) of barren lands within the sampled watersheds.

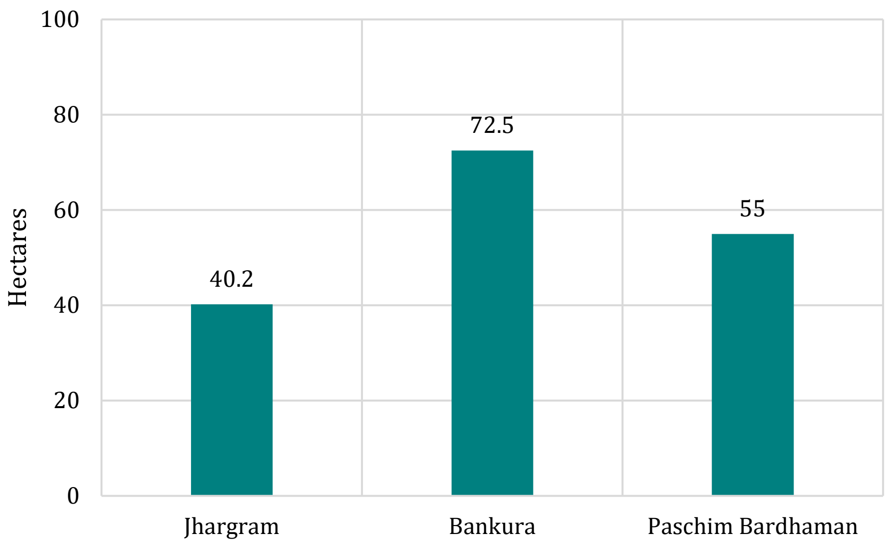

Figure 32: Average area irrigated by irrigation canals

PRA respondents for 7 of the 10 watersheds reported that prior to *Usharmukti,* portions of their lands were irrigated using a combination of irrigation methods—farm ponds, borewells, and *happas.* These respondents reported that between 20% and 100% of their land parcels were left fallow for an average of 42 years prior to canal construction under *Usharmukti*. Post project implementation, in 8 of the 10 watersheds, canals are reported to have helped improve the productivity of crops, as reflected by a 23% increase in the yield of paddy. Furthermore, respondents of one watershed in Jhargram reported introduction of paddy as a crop during the kharif season after the construction of irrigation canal under *Usharmukti*. Similarly, a horticulture crop—watermelon—was introduced during the rabi season by a few farmers of one watershed in Bankura district. These crop system changes have resulted in a majority of watersheds (8 out of 10 watersheds) reporting a12% to 40% increase in income.

Irrigation canals provide assured supply of water to farmlands and protect a farmer from the vagaries of rainfall. This ensures that year-to-year fluctuations in yield and farm income are reduced, which otherwise cause farmers to migrate to nearby towns and cities in search of work for stable income. To that end, respondents in 6 out of 10 watersheds reported that irrigation canals have provided drought protection to crops. Improved productivity, which is a result of drought protection, has reduced migration in four watersheds.

3.1.5. Other works

Works such as desilting of canals, rock checks, continuous contour trenches, and vetiver plantations were carried out sparsely within the sampled watersheds. Among these works, respondents reported benefits from the desilting of canals and the strengthening of tank embankments, which has increased water availability for irrigation, while continuous contour trenches have benefitted sparse areas in Jhargram and Bankura districts. Although records indicate the land-levelling work to have been carried out in certain beneficiary plots, in the selected locations, no such works were seen. Instead, desilting of existing canals was observed to have been done. There have been no perceived benefits from the other works.

3.2. Mitigation Co-Benefits

A total of 239 plantation works (155 social forestry and 84 horticulture works) in 13 watersheds were sampled, and field measurements for biomass estimation and soil sample collection was done. Plantation works implemented next to each other were grouped and a total of 182 quadrants of 30 X 30 m (Table 5) were laid out. In Purulia and Paschim Bardhaman districts, very young plantation works were not measured.

Table 5: Number of social forestry and horticulture works implemented in each sampled watershed, and number of quadrants laid out to measure carbon stock

District	Watershed	Social Forestry	Horticulture	Quadrants
Bankura	BANRAI008	16	18	16
	BANRAN048	17	4	22
	BANRAN049	17	6	18
Jhargram	JHABI1038	11	0	9
	JHABI1052	7	0	5
	JHANAY008	14	8	11
	JHANAY029	11	11	20
	JHANAY038	13	0	6
	JHANAY045	37	13	40
Purulia	PURBAG051	4	23	24

	PURJH2015	1	0	1
Paschim Bardhaman	WBMKAN015	1	1	2
	WBMKAN024	6	3	8

3.2.1. Carbon sequestered in biomass

Four tree species were found to be large enough to measure for aboveground biomass. These included sonajhuri, segun, cashew, and mango. In terms of distribution, the most common tree was sonajhuri (83.6%), followed by cashew (6.9%), mango (6.1%), and segun (3.4%).

The sequestration rate of plantations is highly dependent on the species, age, and density of the plantation. Older plantations sequester more carbon as these trees have more girth and height, while some tree species grow faster and are able to store more carbon as compared to others. It is important to note that the carbon sequestration rate is not exponential but plateaus after trees reach a certain age.

Plantations under *Usharmukti* were found to sequester carbon in tree biomass at an average rate of 0.094 tC/ha/year (Figure 33).

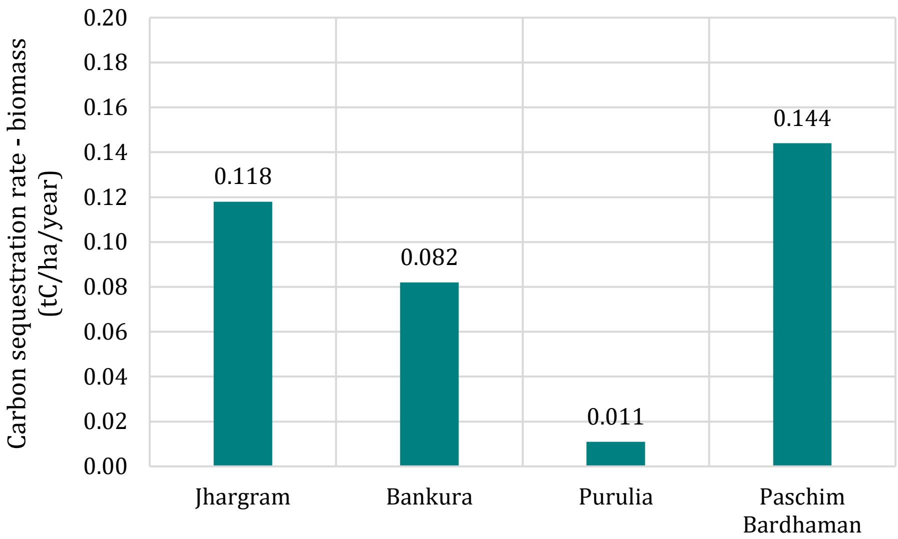

Figure 33: Average carbon sequestration rates of plantations (biomass) across the four study districts

According to Ravindranath and Murthy (2021), the carbon sequestration rate in biomass due to drought-proofing works (essentially tree planting) under MGNREGS ranged between 0.85 and 2.20 tC/ha/year. This is much higher than the carbon sequestration rate of study districts under *Usharmukti*, primarily because Ravindranath and Murthy considered plantation works from 2006-07 up to 2017–18, whereas the current *Usharmukti* study included very young plantations, planted between 2018-19 up to 2020-21.

An average increment in tC/ha/year was estimated for each district and plantation age class (see Appendix 9.3, Table 8) spanning an area of 22,294 ha, which was used to show that plantations under *Usharmukti* have sequestered 3,668 tonnes of carbon, in biomass alone (Figure 34).

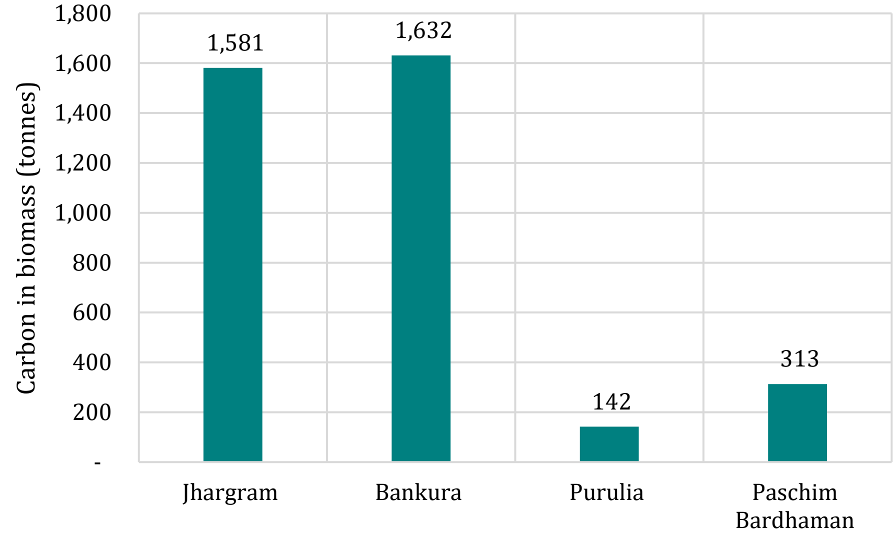

Figure 34: Carbon sequestered in tree biomass (MtC)

3.2.2. Carbon sequestered in soil

The percentage of organic carbon in soil samples ranged from 0.001% to 0.018%. This was then converted to soil organic carbon following the method described in Section 0.

Carbon was sequestered in the soil of plantations raised under *Usharmukti* at the rate of 0.142 tC/ha/year (Figure 35). Overall, it was found that almost 22% more carbon was sequestered in *Usharmukti* plantation plots as compared to control plots.

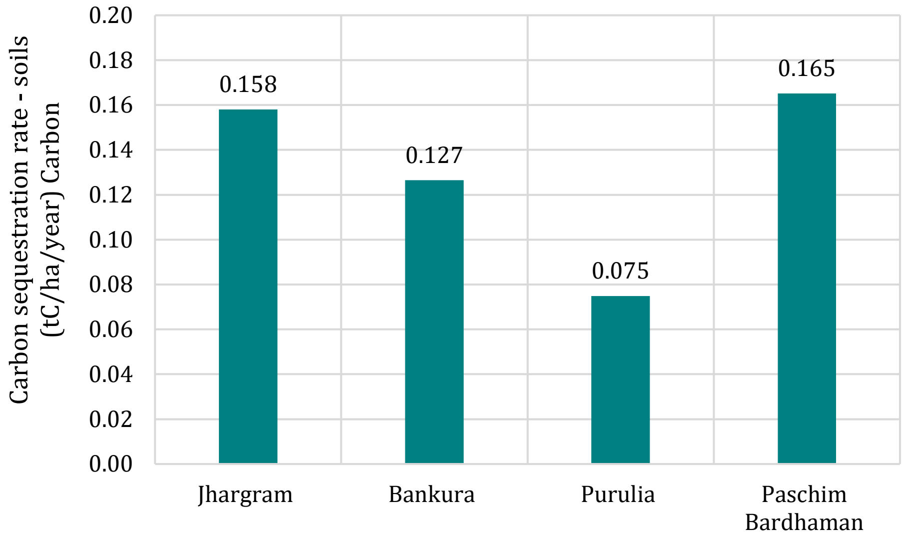

Figure 35: Average soil organic carbon sequestration rate in *Usharmukti* plantation works

SOC is dependent on the age and density of plantations. It also depends on site characteristics (slope, aspect, etc.), intrinsic soil properties (e.g., soil bulk density, texture, etc.), and the management of plantations. The findings from this study are in line with Ravindranath and Murthy (2021), who report a soil carbon sequestration rate of 0.12 to 2.61 tC/ha/year.

Similar to the process followed for calculating total carbon in biomass, the SOC in tC/ha/yr of differently aged plantations in different districts was multiplied with the area under those plantations to arrive at the total carbon sequestered in soils. This amounts to 5,708 tonnes of carbon sequestered by soil in plantations spanning 22,294 ha under *Usharmukti* (Figure 36).

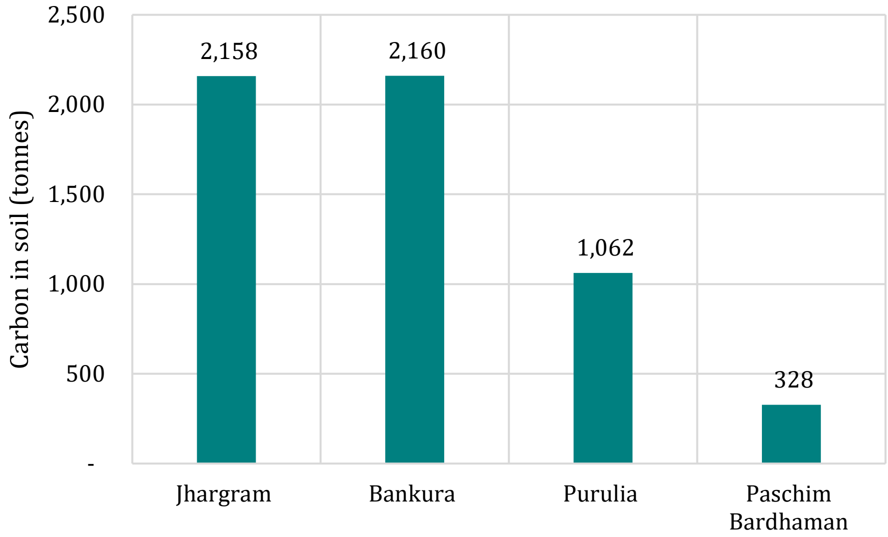

Figure 36: Carbon sequestered by soil of plantation works under Usharmukti

3.2.3. Total carbon sequestered in plantations under *Usharmukti*

By aggregating the carbon in biomass and soil, we arrive at the total carbon sequestered by a plantation. On considering all the plantation works implemented under *Usharmukti*, it is found that 9,376 tonnes of carbon was sequestered in the one-year-old to four-year-old plantations of *Usharmukti* (Figure 37).

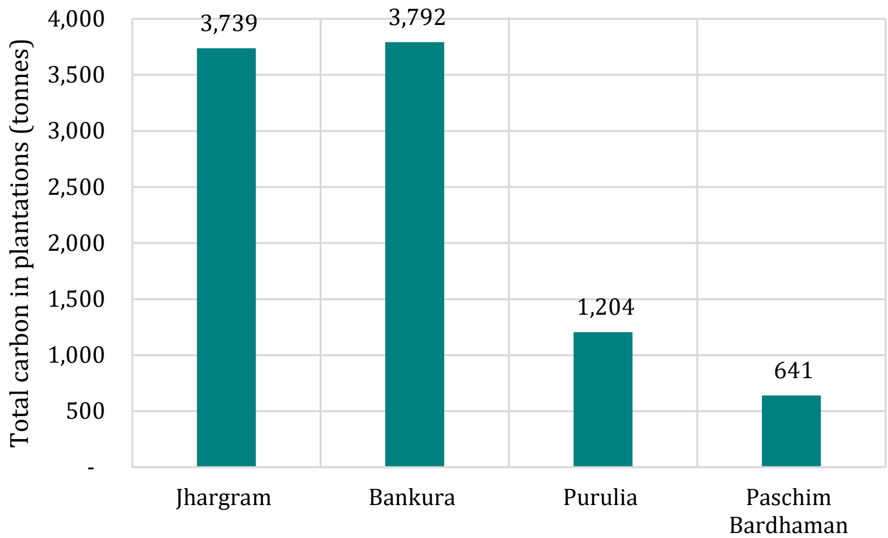

Figure 37: Total carbon sequestered by plantations under Usharmukti

A detailed breakup of this carbon inventory is provided in Appendix 9.3 (Table 8). The plantations under *Usharmukti* indicate immense potential to sequester carbon. Efforts need to be made to maintain or even increase the survival rate of plantations.

4. Summary and Conclusions

It can be inferred from the rapid assessment—a combination of field ecological studies, primary surveys, and PRA—that *Usharmukti* works have led to significant climate co-benefits for the beneficiaries, and for non-beneficiaries as well in some instances. These encompass resilience, adaptation, and mitigation co-benefits arising from a) horticulture and social forestry plantations, b) construction of water harvesting structures, and c) some other works.

Resilience and Adaptation Co-Benefits

Horticulture and social forestry plantations

Horticulture and social forestry plantations have led to improvements in soil organic carbon content that enhances the water-holding capacity of soils. This, in turn, is linked to retention and release of nutrients and improved agricultural productivity.

Further, once established, horticulture plantations are likely to be more resilient to climate variations than field crops, as perennial tree crops are sturdier and can cope better with variations in rainfall and temperature. They thus provide more stable farm incomes. The additional and more stable income generated from horticulture plantations could yield potential adaptation benefits by helping the beneficiaries to tide over the adverse impacts of climate change, particularly of droughts.

While benefits from a few watersheds (from horticulture plantations) have been realised, much is yet to be realised from the remaining watersheds where the plantations are still young. The same is true for social forestry plantations. However, beneficiaries are aware of the gestation period for realising benefits from horticulture (at least 5 years) and social forestry (at least 8 years) plantations.

Water harvesting structures

Increase in water availability increases the resilience of farming systems and farmers to climate change impacts. WHS works have been found to have significant implications for livelihoods. Similar trends were reported in a study conducted by the Institute of Economic Growth in 2018. The overall resilience and adaptation outcomes of WHS include:

- Increased ability of farmers to protect their crops from drought.
    - 66 of the 217 respondents reported to have experienced crop loss at least once in the past 5 years, and 25 reported that WHS helped in providing crop-life-saving irrigation, thereby averting crop failure. Interestingly, 75 of the 217 (about 35%) respondents expressed that WHS had the capacity to protect their lands from droughts but could not quantify the same.
- Diversified and higher incomes (owing to increased crop productivity) that potentially increase the capacities of farmers to cope with crop loss during droughts.
    - Farmers have taken up new and additional livelihood activities such as livestock rearing and fisheries, and some have scaled up alternative livelihood options such as livestock rearing. The additional income generated from these activities can help farmers cope better with the impact of droughts.

Other works

Among the other works implemented under *Usharmukti,* desilting of canals, and strengthening of tank embankments with silt removed has improved the water availability for irrigation. This, in turn, has helped farmers to drought-proof crops by strengthening their ability to provide crop-life-saving irrigation. As a result, farm incomes, particularly during the kharif season, have stabilised or increased, which has reduced migration.

Mitigation Co-Benefits

Horticulture and social forestry plantations raised under the programme, which provide timber and non-timber benefits, are also natural carbon sinks. While the plantations sampled for the study are still young (1-4 years), there is clear indication of the carbon sequestration potential of both horticulture and social forestry plantations. If protected and managed well, these plantations can provide significant carbon sequestration or mitigation benefits.

Moreover, the carbon sequestration benefits of the programme can be enhanced through effective implementation of land- and water-related natural resource management activities aimed at water conservation, irrigation, and enhancement of soil fertility. This would lead to an increase in the biomass production by crops and trees, and ultimately to increased carbon stocks in biomass and soil.

Programme Design, Barriers to Implementation, and Implications for Climate Co-Benefits

The current study is in line with other studies (IEG, 2018; NITI Aayog, 2021; PIB, 2022; Ravindranath & Murthy, 2021; UNDP, 2015) establishing that NRM and other rural development activities implemented under *Usharmukti* or MGNREGS can make significant contributions to climate change adaptation and mitigation. They also can potentially contribute to meeting the climate goals and targets of the Government of India.

However, there **are certain barriers and challenges in programme implementation** that became evident during the field studies—with implications for climate co-benefits.

Horticulture and social forestry

- In the study districts, some beneficiaries reported that distribution of saplings happens during the post-monsoon season. With limited or no access to water, the establishment of saplings is hampered, often causing mortality. This is because saplings are particularly vulnerable to weather extremities during the first three years of growth.
- From an institutional viewpoint, discrepancies in record-keeping have been indicated as a shortfall of the programme by some beneficiary households. This would include a case where records list certain individuals as beneficiaries of horticulture saplings, while in reality they have received none.

Water harvesting structures

- Most households that are beneficiaries of WHS feel that that the depth of the pond is inadequate to store water post monsoon. As a result, they are unable to irrigate their land. Further, with ponds drying up post monsoon (because of design/dimension limitations), fisheries—taken up as an alternate livelihood activity—also suffered.

4.1. Limitations of the study

Usharmukti is a large programme that is implemented in six districts, covering 1,816 watersheds and 5,832 villages (up to March 2022), and spanning different physiographic, agro-climatic, and socioeconomic conditions. As such, conducting a rapid assessment for it was challenging. The main limitations include:

- Small sample size, owing to limitations of resources and time.
- Spatial variability in biomass and soil carbon sequestration rates that may not have been captured by the current sample.
- Restricted access to certain areas during the study period due to local circumstances.

However, it is important to state here that this assessment was a means to:

- provide proof of concept for the climate co-benefits that accrue from works implemented under the *Usharmukti* programme; and
- test and evolve a framework for estimating the adaptation and mitigation co-benefits from MGNREGS at a state and/or national level.

In the context of inventorying carbon from a plantation, it is advisable to undertake measurements in older plantations. Since we followed a random sampling methodology, many plantations with saplings younger than 4 years of age were included in the study sample and these are yet to yield timber, fruit, or carbon sequestration benefits. In the case of assessing benefits from works such as continuous contour trenches, the study design missed on identifying beneficiary households of these assets created on forest lands. Ideally, the PRA design should have ensured representation of households residing in the vicinity.

5. Recommendations to maximise the climate co-benefits from *Usharmukti*

While there are challenges to implementing a large-scale programme like *Usharmukti*/MGNREGS across diverse agro-climatic and socio-economic conditions, preparing a clear programme design and a strong implementation plan on the following lines can maximise the climate co-benefits of the programme.

1. ***Careful consideration of the time lag in climate co-benefits being realised in the short term vs. its contribution to resilience building and adaptation.***
    - Water-resource-based works such as WHS, irrigation canals, etc. impact the soil and water over short periods of time, which translates to improved resilience co-benefits that can be realised. However, quantifying the extent to which these have changed the ability of farmers to adapt to climate hazards or, in other words, made them resilient, can only be measured after a hazard has occurred.
    - In the case of plantations raised, climate co-benefits accrue after a certain time period. As such, the sampling protocol must account for this delay.
        - For quantifying resilience and adaptation co-benefits, mature plantation works that have started yielding incomes may be considered.
        - For quantifying mitigation co-benefits, plantations at least 5 years or older may be considered.
2. ***Evidence generation on climate co-benefits of other works (CCT, vetiver plantations, etc.).***
    - The other works in the sampled watersheds were sparsely implemented and no benefits were reported. However, studies conducted on the impacts of natural resource management on rural economies have clearly shown positive impacts. Thus, there is a need for designing a study that can generate evidence on the climate co-benefits of these works, if any.
3. ***Design modifications to cater to local needs.***
    - Although MGNREGS follows certain design specifications (as seen in the case of WHS implemented under *Usharmukti*), there is a need to take into consideration the local rainfall pattern while deciding on the dimensions of the structure to enable storage of water for extended periods of time, say more than 4 monsoon months. The structures could also be built as clusters of multiple WHS, as opposed to isolated and dispersed ones. This would increase the overall water holding capacity of the structures. Such design modifications can help realise better adaptation and resilience benefits.
4. ***Timely sapling distribution and plant-life-saving irrigation.***
    - Plantations raised under MGNREGS suffered mortality largely due to inadequate or no access to water, as reported in this study. It is therefore important to plan and implement soil moisture conservation works and provide life-saving irrigation for young samplings at the programme design stage itself to decrease

tree mortality. Additionally, distribution of seedlings prior to the monsoon season can increase the chance of survival, while reducing irrigation needs.

5. ***Capacity building and technical assistance for enhancing survival and increased climate co-benefits of plantations.***
    - MGNREGS work implementation is taken up in collaboration with horticulture and forest departments in many states. These departments can be approached to provide technical assistance to beneficiaries in the form of tree species selection and orchard management trainings to lower tree mortality rates.

In addition to these, there is a strong felt need for a mechanism that can comprehensively monitor, record, and quantify the climate co-benefits of MGNREGS works at the national level. Our study findings, analysis, and insights paved the way for a framework that can enable the determination of these climate co-benefits.

6. Framework for Quantifying the Climate Co-Benefits of MGNREGS

MGNREGS is a large programme aimed at poverty alleviation. A vast majority of the works implemented under MGNREGS are “green” in nature, given the focus on regeneration and conservation of natural resources and ecosystems, with special emphasis on land (farmlands, forests, pastures, and wastelands) and water resources. The effect of this, in terms of economic benefits, is improved crop productivity and production, besides job creation. Additionally, flood-management works and vegetation belts created under the programme (particularly in the coastal areas) reduce the potential damage from extreme weather events. There is also evidence to show that MGNREGS works have led to regeneration of degraded soil and land (farmlands, forests, and pastures), and water resources. The “green” outcomes thus include lower soil erosion, improved soil fertility, increased biodiversity, augmentation of surface- and ground-water resources for irrigation and domestic use, and increase in carbon sequestration. A number of such outcomes have been highlighted by studies in the states of Karnataka, Madhya Pradesh, Andhra Pradesh, Rajasthan, Kerala, and Maharashtra (UNDP, 2015), and also by this study in West Bengal. There is also evidence that MGNREGS can have global green impacts, as activities such as soil conservation, fodder development, afforestation, and drought-proofing help sequester carbon.

This design of the programme that incorporates land- and water-based asset creation, rejuvenation, and conservation, thus lends itself to delivering climate co-benefits—both adaptation and mitigation—while also building the resilience of the resources and the beneficiaries dependent on them.

Currently, only data on job creation and number of beneficiaries of the programme is recorded. However, given that the climate co-benefits from the programme are significant, it is crucial to monitor and report them as well, especially in light of India’s NDC goals and targets, its climate goals, and the reporting requirements for the Adaptation Communications to the UNFCCC from 2024. This calls for a framework to quantify and report these climate co-benefits.

The following **key learnings** from the current study feed into the monitoring and quantification framework that we have built and can be applied while implementing the framework nation-wide.

- The scale of the programme calls for a sampling framework to quantify the climate co-benefits of MGNREGS. The current study finds that a random stratified sampling technique can be applied effectively.
- The unit of sampling could be a *Gram Panchayat* (instead of a watershed which is considered in this study), to account for diversity and variability in works undertaken and their impacts.
- Sampling-plantation-based works that are too young yield no results. Therefore, only plantations over 5 years should be included in the sampling framework to quantify carbon sequestration or mitigation co-benefits.
- Although the resilience built in resources and people reflected through increased income, and expansion of livelihood and income sources (a proxy), measuring adaptation would

be possible only in the event of a climate hazard (Did it help people cope better? Did it climate-proof the asset?), as compared to pre-MGNREGS conditions. Under such circumstances, income-based indicators and their contribution in aiding adaptation will need to be explicitly defined and quantified.

Based on the insights and learnings from the study, we present here a framework for quantifying the adaptation and mitigation co-benefits of MGNREGS (Figure 38). The framework outlines broadly the inputs and steps required to achieve climate-positive outcomes and impacts brought about by MGNREGS.

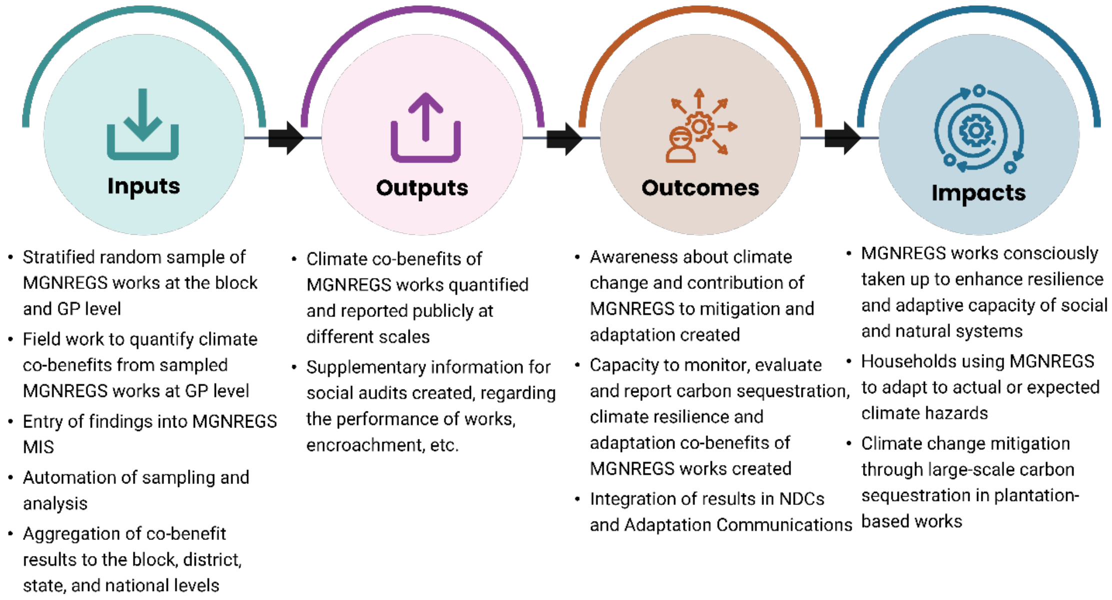

Figure 38: Framework for quantifying climate co-benefits from MGNREGS works

7. Way Forward

There is sufficient evidence to say that MGNREGS has yielded positive climate co-benefits for many Indian states and carries a significant potential for global green impacts. Our study, besides strengthening the evidence base for these climate co-benefits, puts forth a mechanism to quantify, monitor and record these climate co-benefits (in the form of a framework).

While this will be helpful in ensuring that the considerable climate-positive outcomes of MGNREGS are captured, a lot of work is needed to simplify the entire process of undertaking rapid assessments to quantify the climate co-benefits from MGNREGS at scale. The way forward should, therefore, include the following:

- Conducting a detailed mapping of institutions and stakeholders that can undertake such assessments for the states.
- Automation of the sampling process to ease the burden on the state and the institutions undertaking the assessment.
- Mapping the 260+ MGNREGS works to potential SDG and NDC indicators and developing new indicators in line with the existing ones.
- Preparing a methods manual that incorporates guidance for institutions that undertake rapid assessments at scale, covering the subset of 260+ works that have the potential to deliver climate co-benefits.
- Development of optical-mark-recognition- or OMR-based survey formats to ease the data collection and entry process.
- Automation of the data analysis to present and integrate results directly into NREGA-Soft. Data from this platform can be easily aggregated at the national level to report on SDGs, NDCs, and UNFCCC Adaptation Communications.

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9. Appendix

9.1. Data Representing Adaptation and Resilience Co-Benefits from Horticulture Plantations at Different Scales

The complete list of indicators identified for assessing the adaptation and resilience co-benefits accruing from horticulture plantations is provided in Table 6. There are three columns under each district: Column A – Analysed values using data from the sample; Column B – Data from the sample generalised to PAIBs; Column C - Data from the sample generalised to study districts.

Table 6: Indicators identified, quantified, and generalised to assess the adaptation and resilience co-benefits from horticulture plantations under Usharmukti

Indicators	Jhargram			Bankura			Purulia			Paschim Bardhaman		
	A	B	C	A	B	C	A	B	C	A	B	C
Number of mixed horticulture plantations	3.13%	77	96	3.6%	134	529	20%	341	1,206	0%	-	-
Number of mono-horticulture plantations	96.9%	2,370	2,985	96.4%	3,609	14,285	80%	1,366	4,824	100%	302	1,200
Number of households with fallow lands prior to project	100%	2,447	3,081	39.3%	1,471	5,820	10%	171	603	75%	227	900
Number of households that cultivated their lands prior to project	0%	-	-	60.7%	2,272	8,994	90%	1,536	5,427	25%	76	300
Number of households that relied on rainfed agriculture prior to project	100%	2,447	3,081	92.9%	3,476	13,756	85%	1,451	5,126	100%	302	1,200
Number of horticulture works treated with soil and moisture conservation activities	78.1%	1,912	2,407	0%	-	-	10%	171	603	0%	-	-

Indicators	Jhargram			Bankura			Purulia			Paschim Bardhaman		
	A	B	C	A	B	C	A	B	C	A	B	C
Number of households with no prior experience in horticulture	96.9%	2,370	2,985	100%	3,743	14,814	100%	1,707	6,030	100%	302	1,200
Number of households that were given training on raising horticulture trees by the Gram Panchayat	0%	-	-	3.6%	134	529	5%	85	302	0%	-	-
Number of households that have used fertilisers and pesticides as inputs for horticulture cultivation	65.6%	1,606	2,022	50%	1,872	7,407	80%	1,366	4,824	0%	-	-
Number of households reporting a positive change in soil quality due to plantations	78.1%	1,912	2,407	0%	-	-	25%	427	1,507	0%	-	-
Number of households reporting cooler ambient temperatures due to plantations	78.1%	1,912	2,407	0%	-	-	35%	598	2,112	25%	76	300
Number of households with no surviving trees	12.3%	301	379	57.1%	2,139	8,465	40%	683	2,412	25%	76	300
Number of households that could replace trees themselves	9.4%	230	289	0%	-	-	5%	85	302	0%	-	-
Number of households that have sought help from the *Gram Panchayat* to replace trees	6.3%	153	193	0%	-	-	0%	-	-	0%	-	-
Number of households that have chosen not to replace their dead trees	84.4%	2,065	2,600	100%	3,743	14,814	95%	1,622	5,729	100%	302	1,200
Number of households that have reverted to cultivating field crops after their trees died	0%	-	-	3.6%	5	19	15%	51	181	0%	-	-

9.2. Data Representing Adaptation and Resilience Co-Benefits from WHS at Different Scales

The complete list of indicators identified for assessing the adaptation and resilience co-benefits accruing from water harvesting structures is provided in Table 7. There are three columns under each district: Column A – Analysed values using data from the sample; Column B – Data from the sample generalised to PAIBs; Column C - Data from the sample generalised to study districts.

Table 7: Indicators identified, quantified, and generalised to assess the adaptation and resilience co-benefits from WHS under Usharmukti

Indicators	Jhargram			Bankura			Purulia			Paschim Bardhaman		
	A	B	C	A	B	C	A	B	C	A	B	C
Landholding size (ha)	0.54	2,230	7,313	0.58	2,261	17,927	0.66	6,366	38,493	0.76	968	4,777
Number of households cultivating their lands prior to project	96.1%	3,966	13,008	91.8%	3,580	28,386	79.0%	7,622	46,082	18.2%	231	1,143
Number of households that did not cultivate their lands prior to project	3.9%	163	535	8.2%	318	2,522	20.9%	2,025	12,242	81.8%	1,042	5,143
Number of rainfed farmers that now irrigate (after construction of a WHS)	5.3%	217	713	55.1%	2,148	17,032	46.9%	4,525	27,361	9.09%	116	571
Number of households that have reported increased area under irrigation post WHS	3.9%	163	535	2.0%	79.5	630.5	8.7%	833.4	5,039	0%	-	-
Number of households with seasonal irrigation that have reported increased availability of water post WHS	3.9%	163	535	2.0%	79.5	630.5	4.9%	476.5	2,881	0%	-	-

Indicators	Jhargram			Bankura			Purulia			Paschim Bardhaman		
	A	B	C	A	B	C	A	B	C	A	B	C
Number of households that use water indirectly from the WHS for irrigation, i.e., from groundwater sources	42.1%	1,739	5,703	6.12%	238.6	1,892	0%	-	-	0%	-	-
Number of households that have reported an increase in the productivity of crops due to the construction of a WHS	6.6%	271.3	889.8	63.3%	2,466	19,553	86.4%	8,336	50,402	100%	1,274	6,286
Number of households that have reported an increase in income due to higher crop productivity	2.6%	108.6	356.2	61.2%	2,386	18,922	81.5%	7,860	47,521	90.9%	1,158	5,715
Number of households that have reported an increase in income due to a change in crop after the construction of a WHS	2.6%	108.6	356.2	6.1%	238.6	1,892	2.5%	238.3	1,441	0%	-	-
Number of households that have reported an increase in income due to higher cropping intensity after the construction of a WHS	4.7%	192	629.8	8.3%	324.7	2,575	0%	-	-	9.1%	115.8	571.4
Number of households that own livestock (cattle + goats) after WHS	15.8%	651.6	2,137	65.3%	2,546	20,187	71.6%	6,907	41,759	90.9%	1,158	5,715

Indicators	Jhargram			Bankura			Purulia			Paschim Bardhaman		
	A	B	C	A	B	C	A	B	C	A	B	C
Number of households that have reported an increase in income from goat sales after constructing a WHS	14.6%	600.8	1,971	52.0%	2,028	16,082	74.3%	7,171	43,357	21.2%	270.2	1,333
Average income from goat sales after the construction of a WHS (₹)	21,529	-	-	11,687	-	-	15,143	-	-	6,667	-	-
Number of households that have taken up fisheries as a new livelihood after WHS	25%	1,032	3,386	38.8%	1,512	11,987	37.0%	3,573	21,602	72.7%	926.6	4,572
Average income from fisheries (₹)	17,732	-	-	12,000	-	-	31,115	-	-	25,714	-	-
Number of households that have confirmed that recharge from WHS is enough to protect their crops from drought	21.1%	869.2	2,851	32.7%	1,273	10,092	43.2%	4,167	25,195	63.6%	810.3	3,998
Number of households that have reported increase in water availability in a neighbouring field due to their own WHS	14.5%	597.5	1,960	38.8%	1,511	11983	56.8%	5,478	33,121	81.8%	1,042	5,143

9.3. Data Used for Calculating Carbon Stock in Plantations Under *Usharmukti*

The variables that were used to estimate the carbon stock in differently aged plantations is presented in Table 8.

Table 8: Data used to calculate the carbon stock in plantations under Usharmukti

District	Age of plantation	Area under plantation (ha)	Average carbon sequestration rate in biomass (tC/ha/yr)	Average SOC (tC/ha/yr)	Total carbon sequestered in biomass (tC)	Total carbon sequestered in soil (tC)	Total carbon (tC)
A	B	C	D	E	$F = (B \times C \times D)$	$G = (B \times C \times E)$	H= F+G
Jhargram	4	784.270	0.182	0.110	570.949	343.542	914.491
	3	1587.690	0.174	0.144	828.774	685.739	1514.513
	2	1590.700	0.057	0.188	181.340	597.721	779.061
	1	1345.550	0.000	0.394	0.000	530.685	530.685
Bankura	4	832.310	0.063	0.078	208.842	259.015	467.857
	3	2365.960	0.186	0.105	1323.304	746.697	2070.001
	2	3147.020	0.016	0.127	99.849	801.231	901.080
	1	1369.970	0.000	0.258	0.000	352.904	352.904
Purulia	4	1815.790	0.020	0.067	141.995	488.084	630.079

	3	2257.760	0.000	0.085	0.000	574.374	574.374
	2	3188.320	0.000	0.000	0.000	0.000	0.000
	1	1963.520	0.000	0.000	0.000	0.000	0.000
Paschim Bardhaman	4	250.890	0.295	0.104	295.649	104.671	400.320
	3	110.240	0.052	0.182	17.131	60.191	77.322
	2	264.460	0.000	0.308	0.000	162.907	162.907
	1	99.460	0.000	0.000	0.000	0.000	0.000
Total					**3667.833**	**5707.763**	**9375.596**

9.4. Methodology for Calculating Change in Livestock Units

Livestock under the project included goat and cattle, and data related to livestock was collected separately for goat and cattle. They were then aggregated to represent a 'livestock unit'. The livestock unit is a reference unit which facilitates the aggregation of livestock from various species and age as per convention, via the use of specific coefficients. Crossbred cows and buffalos have a co-efficient of 1 as they are among the larger livestock class and relative to their sizes, coefficients are developed for other types of livestock. Here, the number of cattle reported (local cows) was multiplied by a coefficient of 0.94 and the number of goats reported was multiplied by a coefficient of 0.06. The increase in total livestock was computed in this way.

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