

Role of MGNREGS of India in building Climate Resilience: Study on Environmental Impact of Plantations work in Karnataka village

Pleasa Serin Abraham¹, Sheetal Bharat², Rajesh B.³

¹*Shiv Nadar University Chennai*

²*Vidyashilp University Bengaluru*

³*Mahindra University Hyderabad*

Abstract—This study presents a compelling case of how social welfare programs can be strategically designed to achieve environmental co-benefits, creating sustainable livelihoods while enhancing natural capital—a model with significant replication potential. It analyses the environmental impact of the plantation work done in the Honnakiranangi village, Karnataka as part of Mahatma Gandhi National Rural Employment Guarantee Scheme which is also considered as one of the world’s largest works-based social protection schemes. The impact is assessed using the ecosystem services approach as the project aimed at the enhancement of natural capital by creating a new ecosystem through afforesting the 21 km boundary of the site of the proposed power plant. “Ecosystem services” show wide variety of benefits the environment brings to human beings of which some have direct and indirect use values. This approach incorporates the valuation of regulatory, provisional, supporting, and cultural services of natural capital. The sustainability indicators show that the MGNREGS plantation work is very positive toward environmental goals.

Biomass addition and carbon stock addition are very crucial from the perspective of sustainable development. The biodiversity enhancement and pollination services will have positive effects on the agricultural land near the site of plantation work. The study found that there has been the generation of 27,94,221 to 38,54,142 kg of biomass from eight species of trees which are aged between four and ten years and will have sequestered 5,126 to 7,072 tonnes of carbon dioxide through their lifetime. This is equivalent to the emissions from about 1,011 to 1,395 typical passenger vehicles per year.

The timber value of some trees is estimated and the value of NTFP (Non-Timber Forestry Products) like honey, fruits are estimated using direct market prices. This ecosystem caters to 4,000 to 5,000 goats per day and this shows an addition to the fodder. The availability of

fuelwood also has increased nearly 15,000 kg of dry wood is collected every day. The value of carbon sequestration has been estimated and the increase in the pollination services through the new ecosystem has been observed. One of the main services under ecological balance control is biodiversity enhancement through increasing the population of the existing species and the addition of species has been observed and recorded. Improvement and conservation of soil by the trench work which is a main part of the MGNREGS plantation work helped in the improvement of the groundwater levels.

Index Terms—MGNREGS, Ecosystem Services, carbon sequestration

I. INTRODUCTION

India’s National Rural Employment Guarantee Act (NREGA, 2005) provided work as a legal entitlement to rural Indian households and employed 28 per cent of them in 2019–2020 (Narayan, 2022). As the largest public works program in the world and biggest social protection program of India, it guarantees households 100 days of work per year to any person above 18 years of age, regardless of caste, gender, or religion, typically in unskilled manual labour on infrastructure projects. Any of a wide variety of works may be offered, depending on the circumstance – works pertaining to roads, ponds, bunds, irrigation, plantation, forestry, compost pit, cattle shed, tree plantation, wall construction, desilting open wells and tanks, among others. The rules laid down further require that the work should be within a radius of 5km from the residence of the applicant. If the work is farther out, it must be within the block, and a travel

allowance must be paid. There are several other rules – pertaining to timely payment, unemployment benefit if work is not provided, worksite facilities, *etc.* – that aim to make the scheme as functional as possible, so that the desired result of reducing economic vulnerability is achieved. The scope of the scheme has expanded significantly in the as the number of types of works provided has increased through convergence schemes, the number of people who have registered for the scheme has increased and the funds allocated to the scheme annually have kept pace of the demand. Some of the perceived expected outcomes from convergence initiatives includes increased social, physical, and natural capital, enhancing economic opportunities and strengthening people’s participation in democratic processes (UNDP, 2014).

NREGS aims to support inclusive and climate-resilient development whose beneficiaries are among the most climate-vulnerable people in India. This conditional payment scheme provides significant addition to natural capital through different activities such as afforestation, drought proofing, flood proofing, and watershed management (IIED, 2018).

II. OBJECTIVE OF AND APPROACH TO THE STUDY

The objective of the paper is to assess the environmental impact of plantation work done in Honnakiranangi village, Kalburgi district, Karnataka through NREGS. This also throws light to global policymakers on how to mainstream natural resource management and climate change mitigation goals into social protection programmes, to address poverty in the context of climate change.

The environmental impact of the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) scheme of plantation works can be measured by the estimation and valuation of the direct, indirect, tangible, intangible, visible and invisible services of the ecosystem created by it. This study has adopted an *ecosystem services* (ES) approach towards the environmental valuation according to the similar guidelines in TEEB (The Economics of Ecosystem and Biodiversity) framework. These estimated values can become a referral point in making informed policy choices, executive actions, business decision and consumer behaviour (Wittmer & Gundimeda, 2012).

Among the many invaluable services of the ecosystem, study has only concentrated on a few ecosystem services for the valuation. This is due to the limitation in the resources, time constraint and lack of technical expertise.

III. LITERATURE REVIEW

In addition to traditional natural resources, such as timber, water, and energy and mineral reserves, natural capital includes natural assets that are not easily valued monetarily, such as species diversity, endangered species, and the ecosystems which perform ecological services like air and water filtration. Natural capital can be considered as the components of nature that can be linked directly or indirectly with human welfare. The ideal concept to be adopted is “ecosystem services” as it has a broad scope and incorporates regulatory, provisional, supporting, and cultural services of natural capital. Thus, in this study, the ecosystem services approach is used to study the impacts of MGNREGS works related to natural resources and production systems. Natural resources include soil, ground–water, surface water, grazing lands, forests, *etc.*, and production systems include crops, livestock, and plantations. The major natural resources in rural India are cropland, water, forests, and grazing land. MGNREGS works with these resources as they contribute to increased agricultural production, further leading to sustainable employment opportunities. They also contribute to the reduction in vulnerability to climate risks as well as sequestration of carbon.

The MGNREGS creates employment through various activities such as water harvesting, drought proofing, afforestation, reforestation, flood protection, plantations, and others that can prevent or reduce the impact of natural disasters on livelihoods (McCord & Paul, 2019). There are also some state-level projects meant to promote environmental benefits such as Chief Minister's Water Conservation Programme in Rajasthan, ‘Neeru Chettu’ Mission for Water Conservation in Andhra Pradesh, and water resource-related activities in Madhya Pradesh (Yadava & Sinha, 2021).

The forest tree species supply fodder, fuelwood, and non-timber forest products, while fruit trees supply fruits, flowers, and nuts, generating additional income and diversifying livelihoods, and contributing to a reduction in vulnerability to climate risks. Empirically

it is proved that higher soil organic carbon content was recorded in 72 percent of the 899 beneficiary sample plots, covering all MGNREGS works, when compared to control plots (IISc, Bangalore & Ministry of Rural Development, Government of India and GIZ, 2013). Women, especially pregnant women, differently-abled people, children, and tribal populations are particularly vulnerable to climate change. Climate change and variability are expected to harm local crop production and other natural ecosystem functions that are critical for the livelihoods of millions of people worldwide. Gender-based study related to climate change under MGNREGA has laid the groundwork for women to 'hang in' (Steinbach, Kaur, Manuel, & Saigal, 2017) by increasing their purchasing power and decision-making power through institutional reform. Since MGNREGS has incorporated climate-responsive mechanisms into its program after the households whose members are active participants in the programme in the states of Bihar, Chhattisgarh, and Odisha are capable to protect their income and other resources from natural calamities despite of increasing climate vulnerability.

One major study has been carried out concerning environmental benefit under MGNREGA in the 30 districts in India which found that soil and water have positively impacted beneficiaries by improving land quality or increasing access to groundwater, drinking water by 93 percent, 86 percent, and 74 percent respectively (IEG, 2018). Furthermore, Andhra Pradesh, Chhattisgarh, and Rajasthan generate additional economic gain ranging from Rupees 4,600 to 17,200 per hectare per year (based on the current exchange rate), as well as some indirect benefits to strengthen environmental services and rural livelihood by NRM (Natural Resource Management) under MGNREGA. Also, this program's significant contributions to surface runoff harvesting, groundwater recharge, soil erosion reduction, and flood control. Irrigation land increased from 4 to 95 ha in study villages, accounting for about 5–10% of total cultivable land (Anantha, et al., 2021).

In the state Karnataka, environmental services under MGNREGA plays an important role because apart from providing employment and income to rural communities the scheme has provided multiple environmental services and reduced vulnerability by improving groundwater recharge, water percolation, increased water storage in tanks, improved soil

fertility, reclamation of degraded lands, and carbon sequestration. Hence, increased crop and livestock production was aided by these services, which had positive consequences. Besides, the findings show that, in addition to providing employment and income to rural communities, the scheme has provided multiple environmental services and reduced vulnerability. Groundwater recharge, water percolation, increased water storage in tanks, increased soil fertility, reclamation of degraded lands, and carbon sequestration are among the environmental services. Under the scheme, about 2,341 ha of Pongamia plantations have been planted in the Chitra Durga district. Pongamia plantations efficiently provide diversification of environmental services, including leaf manure for crop production, fuelwood, biodiesel production, and carbon sequestration at high rates (Tiwari, et al., 2011).

Social forestry works under MGNREGS have been initiated by the government of Bihar for creating job opportunities for old age people, handicapped, widows, and women. The impact of plantation works under social forestry program in Bihar state shows that 8.33 percent increase in 50,000 woods cum fruit-bearing plants per gram panchayat forest cover.

Few scientific studies have been conducted on the actual performance productivity of assets under the MGNREGS scheme. One of the few asset performance studies (Tiwari, et al., 2011) looked at the rapid scientific evaluation of interdisciplinary assets in Karnataka's Chitradurga district to investigate how the MGNREGS affects environmental benefits and climate change vulnerability. In addition to employment generation, the findings of this and other research (Kareemulla, Reddy, Rao, Kumar, & Venkateswarlu, 2009) demonstrate that the MGNREGS offers environmental benefits.

The ecosystem provides several goods and services by different provisions like food, raw material, medical, etc and the other side of the ecosystem provides different services and within these goods and services many studies analyse economic evaluation. Taking into consideration these concepts, literature reviews have been done looking at these aspects.

Hussain et al (2019) found that forest revenue plays an important role in the livelihood of the local community as households get active in collecting forest produce for various subsistence purposes. As a result, forest revenue is the most important component of total

household income, accounting for 39 percent of total household income. Agriculture revenue is the second-largest share after forest income, accounting for 33%, livestock income accounting for 16%, and off-farm income accounting for 12%. According to the estimates, firewood contributes the most to forest income, accounting for 52 percent of total forest income. Forest resources are extremely important for rural livelihoods, yet overexploitation of natural forest resources affects the biodiversity and ecosystem conservation. Forest resources are extremely important for rural livelihoods, yet overexploitation of natural forest resources can have a negative impact on biodiversity and eco-system conservation (Hussain, et al., 2019).

Nagar et al (2021) found that agroforestry provided about two-thirds of the fuelwood and fodder in the study region, with the remaining one-third coming from other sources. As a result, rural households in hilly terrain in agroforestry-dominated communities rely mostly on agroforestry for fuelwood and fodder, rather than other sources. Fodder consumption from agroforestry was predicted to be 7.65, 10.35, and 12.96 kg/ACU¹/day during the rainy season, summer, and winter, respectively, while the comparable fodder consumption from other sources was 11.58, 4.76, and 3.53 kg/ACU/day (Nagar, Rawat, Pandey, Kumar, & Alatalo, 2022).

The study conducted by Bhandari, et al (2021) reveals that the rate of annual soil erosion from forest land is low and showed that the model may be used to assess soil erosion risk in the mid-hill region using annual soil loss rates in a reasonable amount of time and at a cheap cost. In steep to very steep slopes of agriculture and barren land, spatial soil erosion risk was observed to be much higher than in flat areas, while there was little risk in areas covered with trees. Due to the removal of topsoil and the construction of gullies, the cultivated area's total volume output of crops and the productivity of the watershed has decreased. Similarly, the removal of top fertile soil, gully formation in farms, and increased droughtiness during the summer season are the three most significant factors for diminishing agricultural production in the watershed. Soil erosion, on the other hand, has a negative influence on crop output, grazing land or

cropland, and lower fertility (Bhandari, Joshi, Regmi, & Awasthi, 2021).

Groot (2002) revealed multiple value approaches can be applied to each ecological function. There appears to be a link between the major type of function and the chosen valuation methods as well: Regulation Functions were primarily valued using Indirect Market Valuation techniques (particularly Avoided Cost and Replacement Cost), Habitat Functions primarily using Direct Market Pricing (i.e. money donated for conservation purposes), Production Functions primarily using Direct Market Pricing and Factor Income methods, and Information Functions primarily using Contingent Valuation (cultural and spiritual information), Hedonic Pricing (aesthetic information), and Market Pricing (recreation, tourism and science) designed to establish the best valuation approach (De Groot, Wilson, & Boumans, 2002).

Siwar (2016) in the study discovered significant differences in the economic values of carbon stock and carbon dioxide emissions. The uncertainties associated with estimations produced using many currently available methodologies are also noted. Soil quality-based procedures are specific to the agricultural ecosystem and must be adapted to fit the forest ecosystem's unique characteristics. The review has given us the information we need to make educated decisions about the valuation method(s) to use to value soil carbon and sequestration services in the forest ecosystem. The adoption of the market price approach as a practical way for evaluating soil carbon sequestration services in the Malaysian forest sector is recommended after this study (Siwar, Chinade, Ismail, & Isahak, 2016).

A study was done in Pakistan in 2019 in which it was tried to find out how much dependence of rural livelihood on forest resources. In which there were firewood, fodder and fruits/vegetables mean forest resources which were being used as highest amount in that place. The direct market price method was used to get the value of these environmental goods. The result shows that the mean income annually from firewood, fodder, and fruits/vegetable was 106374.2, 1629, and 967.7 PKR, respectively (Hussain, et al., 2019). Another study from Pakistan tried to find the socioeconomic impact of livelihood fuelwood and timber consumption on the sustainability of the forest

¹ ACU-Adult Cattle Units

environment. Fuelwood, charcoal, and fiber have been calculated at direct market price and results show that they are consumed at 8502, 10505.61 and 60121 kg/month respectively (Ullah, Noor, & Abid, 2021). Another study has been done in Ethiopia to evaluate the economic dependence on forest resources, in which DMP have been used and value of the fodder was 603 USD per annum which was third time lesser than today's price of fodder in Pakistan (Mamo, Sjaastad, & Vedeled, 2007).

Some studies have focused on the consumption aspect of the environmental good. Fuelwood and fodder are consumed by the local population in quantities that may vary by season (Bhatt, 2016) (Nagar, Rawat, Pandey, Kumar, & Alatalo, 2022). Lot of environmental goods also have been used to make handicrafts and decorative items which is highly valuable at present days.

We now turn toward the regulating services provided by the ecosystem. One study on India found that the total economic value of carbon lost from 2000 to 2018 was about Rupees 1.42 million (Babbar, et al., 2021). Another study in Spain that focused on erosion prevention shows that Rupees 13.71 per hectare per household per year was the cost of erosion prevention (Almansa, Calatrava, & Martinez-Paz, 2012).

Next, environmental services also include biological control, this is a type of pest control that employs other organisms to control pests such as insects, mites, weeds, and plant diseases. Related to this service, the study was conducted in South Africa which was based on biological control and the purpose of this study was to give a retrospective analysis of the relative herbicide cost savings associated with the use of biological control rather than chemical control. The result shows that the estimated cost of biological control on all four aquatic weeds was approximately USD 7.8 million, whereas the estimated cost of chemical control to achieve the same level of control ranged between USD 150 million and 1 billion.

Planting trees and increasing greenery is an important step in maintaining biodiversity and it helps to battle concerns such as global warming and soil degradation. Plantation and afforestation activities help humans by producing fruits, fodder, fuelwood, and timber as well as provides many ecosystem services which have an economic value under the TEV framework.

To achieve the goal of rural development and protection of environment, many state-level plans

were made with different names such as plantation, afforestation, social forestry etc under the MGNREGS. The plantation works done in Odisha under MGNREGS along with the convergence with central level and state/ district sector schemes level. They followed two important processes followed by the Indian government to make the optimum utilisation of natural resources management. Plantation work under MGNREGS has been initiated by Panchayat Raj Institutions such as avenue/block plantation, Gram Panchayat School, Anganwadi Centre, and plantation in the orchard owned by the Gram Panchayat etc (Nayak et.al 2017).

The state governments tried to bring synergy in the implementation of several rural programs under different departments and ministries to make MGNREGS more effective. Its primary goal is to increase wage employment, and the secondary goal is to strengthen natural resource management by creating assets in areas such as irrigation, water collection, afforestation, soil conservation, plantation, and flood protection. In 2014-15, state of Bihar converged MGNREGS with other line departments where afforestation was converged with Environment and Forest Department, 'Vricch Sanrakshan Yojana'. Orissa is one of the states that implemented several plantations schemes under MGNREGS along with forest department over 881 hectares of Artificial Regeneration (AR) Plantations, 24,586 hectares of Assisted Natural Regeneration (ANR) with Gap Plantations, and 3430 RKM of Avenue Plantations during 2020-21 by planting 72.74 lakh seedlings of various species. During the years 2021-22, there is a proposal to take up 15000 hectares of AR, 35000 hectares of ANR with gap planting, and 5000 RKM of Avenue plantation. Moreover, during 2008-09, work on establishing study on medicinal plants to add on to knowledge about medicinal plant species. To date, 314 species were planted by outline bunds to ensure zero streams. All 314 plant species have been placed in a manicured area as part of a demonstration area. In year 2017-18 of Rs.150.00 lakh has been set aside for the development and preservation of rare medicinal species and bamboo (Odisha State Forest Department, 2022). In Gujarat, MGNREGA undertook fruit plantation, grassland, soil moisture conservation, fodder development, and projects in Shooplaneshwar Wildlife Sanctuary. Moreover, habitat enhancement operations such as plantation, 'van talavadi', and water

hole building were carried out in the non-forest and forest areas of the state through MGNREGA. These types of actions aid in the improvement of habitat and, as a result, the growth in the number of wild animals. Bamboo decongestion, check dams, and fruit species plantation projects are being carried out in Dang district under the MGNREGA for habitat improvement in the Purna and Vasda Protected Areas. Different plantation models are formulated for the work of conservation of soil and moisture with different schemes under several areas like coastal border plantation, mangrove plantation, Plantation. Surat, Narmada, Vyara, Dang, Panchmahal, and Banaskantha completed work of soil moisture conservation and this created livelihood by green jobs (Gujarat Forest Department, 2018).

The initiative of MGNREGS works undertaken will improve natural resource management and address severe poverty issues like soil erosion, drought, and deforestation, thereby promoting long-term development. Some studies reflect that this program is managing the employment, poverty, and environmental issues in Andhra Pradesh. Kareemulla (2009) points that soil and water preservation projects have recorded for more than 80% of all projects in Andhra Pradesh. (Kareemulla, Reddy, Rao, Kumar, & Venkateswarlu, 2009).

Description of Study Area

Honnakiranangi village lies near the district headquarters of Kalaburagi city, 20 minutes further interior from the main highway going south towards Bellary in the Indian state of Karnataka. It is a small village with only towards and a population of just 5,500 according to the 2011 Census of India. This village forms the focus of this study because it was so assigned by the Rural Development and Panchayati Raj Department of the Government of Karnataka. MGNREGS workers planted tree saplings from 2014 onwards along the boundary of the site for the proposed super-critical thermal power plant at Honnakiranangi village. Around 1,600 acres of land was acquired for the proposed thermal power plant which is not functional yet. The perimeter of the plot is 21 km, of which 11 km of the boundary has three to six rows of trees planted from 2012- 2022. These

saplings although faced high failure rates initially have grown and are currently at various stages of growth. Extended soil and moisture conservation work as being undertaken as part of MGNREGS. Along 10 km of the boundary, major trench work is currently going on for soil and moisture conservation.

The plantation works initiated in Honnakiranangi consisted of two main environmental goals. One is to plant trees and establish an ecosystem and another one is to improve soil and moisture conservation to preserve the greenery which has been created. In 2012-13, nearly 8000 tree saplings were planted in the area as an experimental project by Gram Panchayat. In 2014, MGNREGS has adopted it as a part of the addition to the natural capital. The area is categorised as dry based on the annual rainfall (Brown et al 1989)². Honnakiranangi lies in the belt which receives less than 1500mm of rainfall annually. In 2014 the village has started three-row plantation work and it expanded to four-row and later to six rows in the boundary of the prospective Super Critical Thermal Power plant site. The trench work was done to help underground water recharge and to improve the permeability of rain water and thereby retaining moisture of the land. This was done not only to help the mini-forest building on the boundary of the site but also helped the agricultural lands lying on both sides of the site.

IV. METHOD OF STUDY AND DATA COLLECTION

The decision of inclusion of plantation work as a part of MGNREGS has been a decision from decentralised agencies. The 2012 panchayat-level experimentation of planting trees in the site was taken over by MGNREGS. From 2012 onwards nearly 32,451 tree saplings were planted in the site which have been supplied by department of forests. The table 4 shows the list of thirteen species and their scientific names of the tree saplings planted from 2012 -2018.

Table 1: List of tree saplings provided by Forestry Department, Karnataka

Scientific name	Common name
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² Biomass estimation methods for tropical forests with applications to forest inventory data.

Tamarindus indica	Tamarind / Imli
Bambusa Arandinacea	Bamboo
Azadirachta indica	Neem
Pongamia Pinnata	Honge
Cassia Fistula	Kassod / Thailand shower
Mangifera indica	Mango
Acasia nilotica	Babool / Indian gum tree
Ficus Religiosa	Pipal / Bodhi
Bauhinia Purpurea	Orchid / Butterfly tree
Delonix Regia	Gulmohar / Flame tree
Syzygium Cumini	Jamun
Samanea Saman	Rain tree
Gliricidia Sepium	Gliricidia

However, the failure rates of the saplings were high. Officials cite several reasons for these failure rates in the growth of tree saplings. It is found that when the work started in 2012, the moisture content of the soil was very low and the dryness of the land made it uninhabitable for many saplings. Also, many saplings they received were damaged and saplings from plant nurseries survive best in controlled farms and

nurseries with proper care. The people who have been coordinating the works from the initial stage identify that the seeds survived best in the harsh and rough conditions than saplings and the failure rates from seeds were less compared to that of saplings. Table 5 shows the survival rate of the tree sapling planted in six years as part of the MGNREGS project.

Interviews with officials made it clear that they have been no tree census and there is a lack of documentation on the number of trees. The discussions with the officials gave the information that nearly 40,000 trees are planted as saplings and seeds. Proper data is not available on the number of trees grown from seeds sown. Because of this limitation, we have only taken 17,182 trees that belonged to eight different species while extrapolating the results. The trees planted from 2012 to 2018 were taken into the sample and those planted after 2018 are too small for the measurement of the diameter which is crucial in the calculation of the biomass. In the year 2018-2019, the project temporarily stopped planting trees and concentrated on trench work to improve water permeability and moisture retention. From 2019 to 2021 plantation works ensured the planting of trees in the 10 km of the boundary of the site where they did not plant trees before. Increased moisture content in the soil, water quality, and quality seedling have ensured better growth of plants in this phase. The trees planted from 2019-21 are not taken into consideration for the calculation of biomass and sequestration as they are in their initial stages of growth.

Table 2: Survival rates of tree saplings planted from 2012-2018

Year	Number of saplings planted	Species	Survival rates of the saplings
2012-13	8000	Neem, Peepal, Tamarind	0.625
2014-16	8400	Neem, Peepal, Tamarind, Honge, Mango, Kassod, Babool, Gliricidia	0.714
2016-17	7200	Raintree, Neem, Peepal, Honge, Mango, Gulmohar, Jamun	0.75
2017-18	8851	Orchid tree, Gulmohar, Bamboo, Tamarind, Jamun	0.564

Calculation of biomass and Carbon sequestration potential of trees

Planting trees is an important low-cost climate mitigation option as it is also a ‘low-hanging’ fruit considering the carbon credits it can earn through

Reduced Emissions from deforestation and forest degradation (REDD+). The afforestation programs in developing countries, in addition to restoring biodiversity using exotic and indigenous species on lands, are in response to global climate change

mitigation efforts and payment for environmental services mechanisms. The MGNREGS’ interest also lies in raising the socio-economic development and will come under protected plantations which can be used for protection of soil and water, rehabilitation of degraded lands, restoration of biodiversity, enhancing the resilience of ecosystem sustainability, and the carbon sink services provided by the trees. The quantitative valuation of these protective plantations in terms of contribution to the global carbon cycle and carbon sequestration is essential to do the valuation of the addition to natural capital.

One of the main objectives of this section is to estimate the biomass of the trees and calculate their carbon sequestration potential. Allometric equations were used to estimate the carbon stocks in different tree species from their biomass.

According to the Intergovernmental Panel on Climate Change (2006), major carbon sinks of terrestrial ecosystem biomass are above-ground biomass and below-ground biomass (IPCC, 2006). Autotrophs take up carbon dioxide from the atmosphere—a part of which is released back into the atmosphere and the remainder is stored in the plant tissues in the form of above and below-ground biomass. The carbon assimilated by trees is retained for a longer duration with little leakage into the atmosphere. Annual rates of carbon sequestration largely depend on the tree size at maturity, life span, and growth rates, and after the tree falls the biomass either enters the food chain or the soil as soil carbon (Nowak and Crane 2002; Suryavanshi, et al. 2014). To measure the weight of carbon dioxide sequestered in the tree, multiply the weight of carbon in the tree by 3.67 or 44/12 (Sharma, Pradhan, Kumari, & Bhattacharya, 2020).

The sequestration potential is non-linearly related to the growth of each tree. Most sequestration happens in the younger stages of tree growth and varies according to individual species and other factors which affect the

growth conditions, with the sequestration of carbon dioxide per year dropping thereafter. Therefore, the exact carbon dioxide sequestration rates may vary according to the differences in allometric equations, calculation of biomass, and choice of green weight or dry weight for calculation of carbon content in the tree. Nevertheless, the impact of trees is undeniable in mitigating climate change, in addition to the several other functions it can fulfil.

V. MATERIALS AND METHODS

Between 18th and 22nd February 2022, a sampling study has been conducted on the site. A total of 197 trees were sampled from eight species. All the trees were aged four to ten years as they were planted between 2012-2018.

Tree height and Diameter at Breast Height (DBH)

A non-destructive way of biomass estimation was used to measure the tree height and diameter at breast height (DBH) of the individual trees. Individual trees greater than or equal to 19 cm in girth at breast height (1.37m) were measured. The girth was measured using measuring tapes and the height of the tree was estimated using an app named ‘Trees’. Trees app could record the girth and convert it to DBH by dividing it with ‘pi’ and it recorded the height, DBH, latitude, longitude, and azimuth of the individual trees. This data was converted to excel sheets for further analysis. Species-level identification of trees was obtained through visual observation and with the help of people in charge of handling the project. Shrubs and herbs were not recorded. The inventory approach used for the calculation of biomass is to measure the woody biomass of trees larger than a minimum diameter of DBH >5 cm (MacDicken, 1997). The average height, diameter, range of height, and diameter of 197 trees are presented in table 1.

Table 1: Summary Statistics

Common Name	Scientific Name	Trees in sample	Average Diameter at Breast Height or DBH (cm)	Average height of tree (m)	Range of Diameter at Breast Height or DBH (cm)	Range of height (m)
Neem	Azadirachta indica	34	18.74688	6.675	7.6 - 28.6	4-9.9

Kasshod	Cassia fistula	36	18.84	6.35	6.4-44.6	3.2-8.9
Pipul	Ficus Religiosa	36	18.18	6.77	6.9-111.5	3.6-11.7
Honge	Pongamia pinnata	36	14.6	4.98	6.3-25.5	2.4-8.8
Tamarind	Tamarindus indica	12	12.69	6.13	7.9-17.2	4.7-9.3
Gliricidia	Gliricidia Sepium	12	17.4	6.16	6.1-24.2	4.7-8.1
Jamun	Syzygium Cumini	18	11.96	3.74	9.8-13.7	2.3-4.9
Babool	Acacia nilotica	13	14.69	5.63	7.3-30.3	3.2-10.2

Above-Ground and Below-Ground Biomass (AGB and BGB)

Above-ground biomasses were estimated based on field measurements of diameter at breast height of the tree using tree-specific or generic allometric equations (MacDicken 1997; Brahma, et al. 2021; MacDicken 1997; Sharma, et al. 2020; Mohamed, et al. 2018). Three sets of allometric equations used to estimate the AGB of eight species is given in table 2.

Table 2: Allometric Equations used for calculation of biomass

Species	Equation used for calculation of AGB	Source
Kasshod, Pipul, Tamarind, Gliricidia, Jamun, Babul	$AGB = (0.18D^{2.16}) * 1.32$	(Mohamed, Rao, Keerthika, Gupta, & Shukla, 2018)
Neem	$AGB = (0.016D^{4.862})$	(Brahma, et al., 2021)
Honge	$AGB = (34.4703 - 8.0671D + 0.6589D^2)$	(Sharma, Pradhan, Kumari, & Bhattacharya, 2020)

Note: D is the DBH (cm)

Calculation of BGB

Previous studies have estimated BGB from AGB. Below Ground Biomass is approximately 15 % of AGB (Sharma, Pradhan, Kumari, & Bhattacharya, 2020). So, the formula used to find below ground biomass is

$$BGB = AGB \times (15/100)$$

Estimation of Total Biomass – Green weight (Method I)

Total biomass of individual trees will be the sum of their above- and below-ground biomasses, respectively, given by the following equation:

$$Total\ Biomass = AGB + BGB$$

Estimation of Dry Weight of the tree – Method II

An average tree is 72.5% dry matter and 27.5% moisture. The green weight of the tree has to be multiplied by 72.5% in order to get the dry weight (Ecomatcher, 2022) .

$$Dry\ weight = 0.725 \times green\ weight$$

Estimation of Carbon Content

Generally, for any plant species, 50% of its biomass is its carbon content (Sharma, Pradhan, Kumari, & Bhattacharya, 2020), carbon fraction of any dry matter for that case is 0.5.

$$Carbon\ Content = 0.5 \times Total\ Biomass$$

CO2 equivalent is then calculated using the below given equation:

$$CO_2 \text{ (eq.)} = (\text{Carbon content} \times 44/12) \text{ or } (\text{Carbon Content} \times 3.67) \text{ (Sharma et al; 2020)}$$

Table 3: Extrapolation of results to all trees of eight species

Common Name	Scientific name	Species	Number of trees	Green weight (kg)	C content – green (kg)	CO ₂ eq – green (tonnes)
				Dry weight (kg)	C content - dry (kg)	CO ₂ eq – dry (tonnes)
Neem	Azadirachta indica	Native	4,500	12,63,655	6,31,828	2,319
				9,16,150	4,58,075	1681
Kasshod	Cassia fistula	Native	1,358	2,53,812.5	1,26,906	466
				1,84,014	92,007	337
Pipul	Ficus Religiosa	Native	6,011	19,21,266	9,60,633	3,526
				13,92,918	6,96,459	2556
Honge	Pongamia pinnata	Exotic	1,420	1,27,141	63,570	233
				92,177	46,088.5	169
Tamarind	Tamarindus indica	Exotic	1,391	97,146	48,573	178
				70,431	35,215.5	129
Gliricidia	Gliricidia Sepium	Exotic	490	71,847	35,924	132
				52,089	26,044.5	95.5
Jamun	Syzygium Cumini	Native	2,000	1,17,842	58,921	216
				85,435.5	42,717.7	157
Babul	Acacia nilotica	Native	12	1,431	716	3
				1037.7	519	1.9
Total			17,182	38,54,142	19,27,071	7,072
				27,94,221	13,97,125.7	5126.4

Only 17,182 trees were considered while extrapolating the results. The officials claim that the total number is around 40,000 but due to lack of proper documentation we have only considered the trees grown from the saplings. As per the results, the addition to the biomass stock is 27,94,221 kg in dry weight and 38,54,142 kg in green weight. Since most of the species have more years to become mature, in regular conditions the volume of biomass of these trees should grow. Some studies show the application of biomass expansion factor (BEF) to estimate the volume of biomass once the tree matures. However, in this study, we have not extended the estimates to the future growth of trees. Overall, results revealed that individual tree carbon accumulation within species increased from trees

when they grow as part of an ecosystem than they grow in isolation as just shade trees.

The second objective of this section is to identify the ecosystem services provided by the forested area. The approach we used for this was interviews, discussions, records, and visual observations. Most of the products derived from the trees which have a market were accessible free of charge to the residents of the village. However, their value can be calculated by multiplying their market prices and quantities. Table 4 provides an insight into those provisioning services, regulating services, and in terms of ecological balance control. All the monetary values generated are estimated based on direct market prices.

Table 4: Economic Value of the Ecosystem Services from the Plantation works

Ecosystem Services	Category	State indicator	Monetary Value of the service
Provisioning Services	Food Provision	<ul style="list-style-type: none"> Honey: 370 honeycombs harvested in one year --> 555 litres of honey (@1.5 l per comb) 	Rs 1,66,500/year at Rs 300/litre
		<ul style="list-style-type: none"> Jamun Total 36 kg of Jamun from six trees 	Rs 7,200 this year at Rs 200 per kg
	Firewood	<ul style="list-style-type: none"> Dry wood collected around 15,000kg per year 	Rs 50 for 10 kg of firewood in the open market
	Fodder	<ul style="list-style-type: none"> Silvopasture: 4,000-5,000 goats graze in the area daily 	Rs 24,000-Rs 30,000 per day (Goat feed is Rs 6 for 250gm)
	Industrial Material Provision	<p style="text-align: center;">Timber</p> <ul style="list-style-type: none"> Tamarind: Timber price of tamarind wood is around Rs 4.2 per kg and total timber value of the ecosystem would turn up to Rs 4,08,014. (97,146.35 kg x 4.2) Babul: Timber price of Babul is around Rs 8.8 and total timber value would turn up to Rs 12,592.8 (1,431 kg x 8.8) 	
Regulating Services	Carbon Sequestration	The value of stored carbon can be calculated by carbon trading schemes. This value computation varies by source. It is estimated that 5,126 - 7,072 tonnes of carbon-dioxide will have been sequestered by the trees in their lifetime. Assuming a lower bound value of \$2 (Rs 152) for per tonne of carbon sequestered, the amount of carbon sequestered by this afforested area is worth Rs 7,79,152 to Rs 10,79,187.	
	Pollination Promotion	Three hundred and seventy beehives were harvested and it indicates high pollination activity through bees. Growth of neem trees have increased number of birds who feed on neem seeds and they also aid in pollination	
Ecological Balance control	Biodiversity Enhancement	<p>Increased spotting of common like sparrows, pigeons, parrots, crows, hornbills, sunbirds, drongos and arrival of migratory birds provides breeding, feeding and resting habitat</p> <p style="text-align: center;"><i>Addition to species:</i></p> <p>Deer (population 20), peacocks (50-60), rabbits between 200-300, regular spotting of reptiles like snakes and predators like mongoose</p>	
	Soil and Moisture Conservation	Trench work have resulted in underground water recharge and moisture content has increased which resulted in the improved growth of plants	

VI. FINDINGS AND SUGGESTIONS

Natural Capital was not recognized as physical capital and was even considered as easily substitutable with physical capital. The economic valuation of the services has changed the perspective towards investment in environmental and natural resource

management, addition, and loss of natural capital. When we check the many illustrative indicators of the sustainability approach, this MGNREGS plantation work is very positive towards environmental goals as well. A new ecosystem is established by afforesting it with three to six rows on the 21km-boundary of the site of the proposed power plant. The study records

that there has been the generation of 27,94,221 to 38,54,142 kg of biomass from eight species of trees which are aged between four and ten years and will have sequestered 5,126 to 7,072 tonnes of carbon dioxide through their lifetime. This is equivalent to the emissions from about 1,011 to 1,395 typical passenger vehicles per year.

Although the survival rates of trees from saplings were low in the initial phase, the trench work has become instrumental in ensuring the survival of trees and therefore the success of the afforestation project. Along with the moisture conservation through trench work, planting of native seedlings ensured better germination of plants.

Among the provisioning services the harvested Non-Timber Forestry Products from the ecosystem includes honey and Jamun fruit only. Most of the other products like fruits from trees are yet to give yields. This ecosystem caters to 4,000 to 5,000 goats per day and this shows an addition to the fodder. The availability of fuelwood also has increased nearly 15,000 kg of dry wood is collected every day. Timber and Babul are the two timber trees and their timber value is also estimated. The economic valuation of provisioning services was done using the direct market price method.

Two regulating services are considered in the study, the value of carbon sequestration has been estimated and the increase in the pollination services through the new ecosystem has been observed. Carbon sequestration potential was assessed by taking into consideration the value of the biomass of the tree which was calculated using the allometric equations. The type of allometric equation and the carbon concentration values used influenced carbon estimation.

One of the main services under ecological balance control is biodiversity enhancement through increasing the population of the existing species and the addition of species has been observed and recorded. Improvement and conservation of soil by the trench work which is a main part of the MGNREGS plantation work is commendable but without data on historical groundwater levels in the area, this study was unable to quantify the value of the service in improving the availability of water and moisture content of the soil.

Natural resource accounting is a very prominent factor that helps in calculating the value. The plantation

workers will have to conduct a tree census to get the correct number of trees, their species, and their age. The population of trees according to native, exotic, and invasive categorization is also important, and the method of forest inventory must be adopted for this. A better system of records of trees planted and surviving is required to conduct a more thorough study on the environmental impact.

Data was limited to study the effect of the ecosystem on water levels. The data on groundwater level pre and post to trench work would have been helpful to measure the impact of the plantation work on the water availability and quality.

The non-timber forestry products have a market but these trees are in the initial stages of getting yield and not getting marketed properly. The yield of fruits and vegetables must be recorded and it would be better if they can connect their produce from the area to a formal structure like the Agricultural Produce Market Committee.

The biomass addition and carbon stock addition are very crucial from the perspective of sustainable development. The biodiversity enhancement and pollination services will have positive effects on the agricultural land near to the site of plantation work.

Similarly, even though the environmental impact is measured in this project at the level of community, direct and indirect effects are certainly perceived at the level of individual households. The direct environmental benefits to households is the value of the firewood and any fruit that they can gather without having to pay the full market price for it, the fact that the goat can graze, the value of the medicinal leaves that they have free access to, the fact that a higher water table means they will have to dig less to access water to irrigate their fields, among others. The indirect benefits to households would be the value of the cleaner, less polluted air they breathe, the fact that the higher water table will benefit their crops, the reduced temperature fluctuations as a result of more greenery in the neighbourhood, etc.

It is clear from the above few examples that what we refer to as community-level impacts do at some point become very real at the household level and *vice versa*, whether we are talking about economic or environmental impacts. For this reason, the scheme would do best to be more self-aware of the wide range of impacts it can have and push for a more ambitious

scale of application, both within Honnakiranagi village and beyond. And this requires better documentation of all aspects of the plantation scheme.

To conclude it is to be noted that MGNREGS is a multidimensional system which can boost the social, environmental, and economic sustainability in rural areas. Along with the generation of wage employment and creation of sustainable and productive assets it also recognises natural capital and creates a positive impact on rural environment and community level participation in enhancement of ecosystem and its services. The interaction of goals between a conditional payment system like MGNREGS has huge potential as incentive-based mechanisms can encourage and acknowledge those efforts in conserving the ecosystem to maintain and/or improve it. Many MGNREGS sponsored projects along with social protection have helped in building climate resilience and it is time to ensure clarity and transparency on additionality of carbon reductions so that it can get accounted as climate change mitigation option. The ecosystem services of the scheme should try to monetise the value of the services through PES (Payment of Ecosystem Services).

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