MGNREGA for Environmental Service Enhancement and Vulnerability Reduction: Rapid Appraisal in Chitradurga District, Karnataka

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The activities undertaken under the Mahatma Gandhi National Rural Employment Guarantee Act in Chitradurga district, Karnataka, were assessed for their potential to enhance and provide environmental services. Key programmes implemented in 20 villages during 2009 were studied using rapid scientific assessment methods. An indicator approach was adopted to analyse environmental services such as water for irrigation and improvement in soil quality. The status of environmental services before and after implementation of the activities was examined and vulnerability indices were constructed and compared. The activities were found to have reduced the vulnerability of agricultural production, water resources and livelihoods to uncertain rainfall, water scarcity and poor soil fertility.

We thank GTZ India for initiating and supporting the project. In particular, we acknowledge the support provided by Vera Scholtz and Kasturi Basu. We benefited from discussions with the Ministry of Rural Development, Government of India, especially with Rita Sharma and Amita Sharma. We thank Joyashree Roy, K Narayanan, and Sandhya Rao for assisting with methodology and interpretation of the results. We thank the MGNREGA programme officials in Chitradurga district and the Karnataka State Council for Science and Technology team for their cooperation and support. Support provided by the field team (Horurappa, Mohan N A, Prasanna, Saqeebulla, Harsha B V, Harsha Venkatesh, Veera Nagappa, Vijay Kumar, Vinay Shankar) is appreciated. Most of all, we thank the farmers for the time and cooperation they extended during the study.

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1 Introduction

The National Rural Employment Guarantee Act (NREGA), enacted on 25 August 2005 and renamed the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) on 2 October 2009, includes activities under nine different heads to provide employment to village communities and improve their livelihoods. The Act has been implemented in three phases since 2006, providing 4.48 billion days of employment over a period of three years. About Rs 34,600 crore has been spent on wages, indicating the gigantic size of this programme intended to benefit the poor and the huge investment that has been made in it. In addition to directly benefiting the landless and farmers with employment and wages, the wider, short- and long-term environmental dividends it yields are significant. Since the NREGA's implementation all over India, it has been deemed to have huge potential in empowering rural communities – with work and natural capital or livelihood capacity addition. There have been various studies looking into aspects such as its socio-economic impact, its finances, and its administration and implementation (for instance, Shah 2007; Ambasta et al 2008 and Kareemulla et al 2009). Others focus on subjects such as rural poverty alleviation, gender issues, livelihood and food security, and migration, but there has been no major study on the environmental impact of the activities that have been carried out so far.

This study attempts to examine and assess the environmental implications of the activities implemented under the NREGA. We undertook a rapid assessment of the environmental services provided by NREGA activities and their contribution towards reducing the vulnerability of production systems (for example, crop yields) and livelihoods to climate variability (for example, drought). The impact of activities has been analysed through the two lenses of contemporary ecological science – environmental services and climate change.

The activities undertaken under the NREGA mainly focus on improving the availability of resources and conserving them (Table 1, p 40). These activities are known to improve or help in conserving the resource base, but rarely has there been an attempt to quantify them. The old name, NREGA, has been used to refer to the MGNREGA as well in this essay.

The subsequent sections describe the study area, sample villages and criteria for selection, followed by a section on the methods and approaches adopted to assess the implications of the activities for

Table 1: Key Activities under the Major Themes of the NREGA
(Including the activities referred to in the convergence guidelines of 2005)

Water and Soil	Land Development and Drought Proofing
Catchment area treatment (contour trenches and bunds, graded bunds, bench terracing, field bunds)	Land development (conservation bench terracing [CBT], contour and graded bunds, field bunds, pasture development)
Check dam construction Ponds (dugout sunken ponds, ponds with pucca outlet and bathing ghats, irrigation ponds, percolation tanks, lowland aquaculture tanks, farm ponds) Water harvesting (embankment type, farm ponds, roof top, waste water recycling system for irrigation) Groundwater recharge (contour trenching, recharge shafts, low height check dams across streams) Irrigation provisioning and improvement (construction of new canals, renovation of canals, desilting, dug well in tail reach; water course: from outlet of minor with structure-like farm turnouts (outlets), siphon outlets, road crossing, tail crossing; field channel: from outlet of water course to individual fields; sprinkler/drip irrigation, low energy water application) Renovation of traditional water bodies (desilting, renovation)	Drought proofing – Afforestation (afforestation/tree plantation, boundary plantation, agro forestry, block plantation, agro horticulture, root stock regeneration, fencing, monitoring and evaluation, training, awareness raising; aided natural regeneration, artificial regeneration, bamboo plantation, cane plantation, mixed plantation of trees having minor forest product and medicinal value, regeneration of perennial herbs and shrubs of medicine value, pasture development/ silvopasture) Flood control (diversion channel, peripheral bunds, surface drainage: with respect to topography, soil crop and outlet, field drains with culverts and drop; sub-surface drainage: to lower the groundwater level with sufficient depth of soil strata; renovation of drainage)

environmental services and vulnerability reduction. Another section on the results describes the findings on these two aspects.

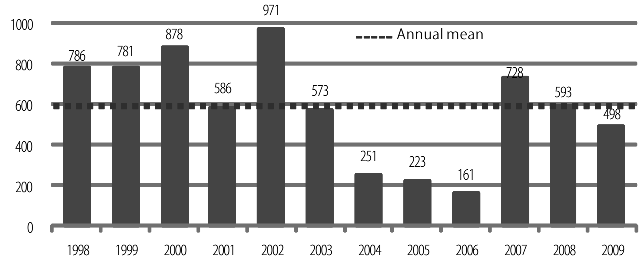
2 Study Area: Chitradurga

Chitradurga district is located in the east central part of Karnataka and has an area of 8,388 square kilometres with a population of 1.8 million, according to the 2001 Census. The district has six taluks, 185 gram panchayats and 1,059 villages. Chitradurga experiences a hot, seasonally dry, tropical savannah climate, typical of most regions in southern Karnataka. It receives low to moderate rainfall and is one of the drought-prone districts in the state. The normal annual rainfall in the district, based on a 30-year average, is 574 mm. The average temperature during the summer months may go up to 32° Celsius and the minimum average temperature during the winter months may fall to 12° C.

A major part of the district lies in the Krishna basin and is drained by the Vedavathi river. A reservoir has built across the Vedavathi near Vanivilaspura in Hiriyur taluk and a canal network provides irrigation facilities to the farmers in the taluk as well as those in a few nearby villages. The other rivers in the taluk are the Janagahalli, Chikhagari, Swamamukhi, Garain and Nayakanahallihalla. In addition, there are 291 tanks in the district, which provide irrigation facilities to small stretches of lands. Agriculture in the district is rainfed and mainly dependent on timely and adequate rainfall. Dryland crops constitute the bulk of the agricultural produce and inadequate rainfall frequently results in crop losses. Figure 1 shows the trends in mean annual rainfall over the past decade.

Chitradurga was covered in the first phase of the NREGA (during 2006) and recorded the highest

Figure 1: Trends in Annual Rainfall in Chitradurga District (1998-2009)
(Annual Rainfall in mm)



number of activities implemented in Karnataka state (10,282 activities), followed by Belgaum, Bellary and Gulbarga districts. The activities were focused mainly on water conservation and being a semi-arid district (moisture indices of less than minus 60%), it was a natural choice for assessing their implications. The highest number of activities was implemented in the first year in Challakere taluk of Chitradurga district. During 2008, they were extended to all six taluks and Chitradurga, Holalkere, Challakere and Hiriyur topped the list. About 2,775 activities had been completed till recently, spending Rs 40 crore. About 49,145 households were employed, generating 2.35 million days of work and 43% to 45% of the beneficiaries were women.

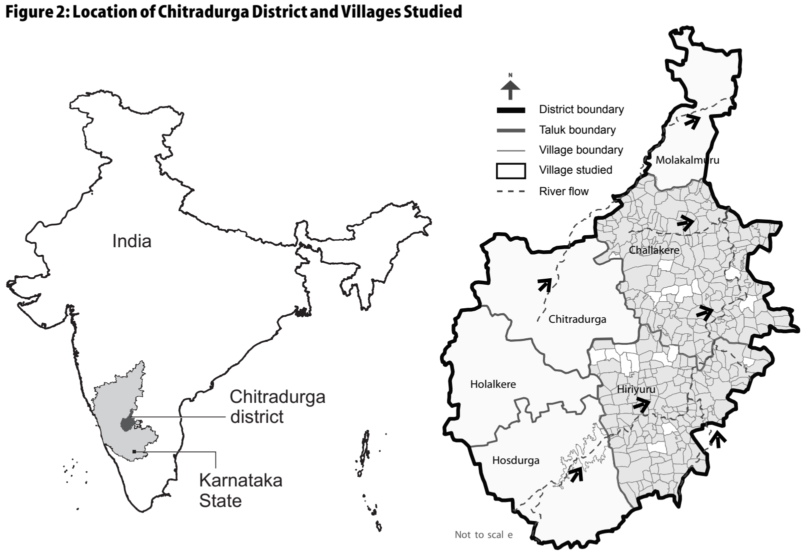
2.1 Sample Village Selection

In Chitradurga district, NREGA activities were implemented in different villages in different years, beginning from 2006. The implementation of the activities did not follow any pattern because it was mainly administrative planning and people's participation that determined it. This makes it difficult to stratify the process. Since the main objective was to measure environmental services provided by NREGA activities, the approach adopted was to select villages where the dominant activities were implemented in a large number in earlier years. The locations of the villages studied are shown in Figure 2.

3 Rapid Assessment: Approach and Methods

The impact and environmental services of the activities were assessed by comparing the pre- and post-NREGA status of natural

Figure 2: Location of Chitradurga District and Villages Studied



resources (for example, groundwater levels) and production systems (for example, crop yields). The potential environmental services, the indicators used to assess them and the methods adopted are shown in Table 2. Rapid scientific assessment methods were adopted and they included participatory rural appraisal (PRA), key informant surveys (KIS), hydrological measurements for water-related studies, and laboratory analyses for soil studies.

Table 2: Environmental Services, Indicators and Methods Adopted for Monitoring

Environmental Service	Indicators and Measure	Methods
Increased water availability for irrigation	Groundwater level in borewells (metres of water)	PRA and hydrological measurements
	Area irrigated (hectares)	PRA and SD
	Water storage capacity (cubic metres)	Hydrological modelling
Groundwater recharge	Groundwater level in borewells (metres of water)	PRA and hydrological measurements
	Water percolation (cubic metres)	Hydrological modelling
Increased agricultural production and yields	Soil fertility (% of organic carbon and nitrogen-phosphorus-potassium)	Soil sampling and analysis
	Changes in crop yield (percentage)	PRA
	Area cultivated (ha)	PRA and SD
	Green leafy manure (tonnes)	PRA and KIS=based estimation
Carbon sequestration and climate change mitigation	Biomass production (total tonnes of fuel wood)	Biomass estimation
	Carbon sequestration potential (tonnes of carbon)	Tree measurement and soil study

PRA: participatory rural appraisal; KIS: key informant surveys; SD: secondary data.

3.1 Environmental Services

Factors such as low crop and livestock productivity, water shortage for drinking and irrigation and scarcity of fuel wood and grass lead to rural poverty. This can be linked to degradation of natural resources such as soil, water resources, grazing lands and forests. Soil erosion and loss of soil fertility, silting of water bodies and low water percolation rates, excessive groundwater extraction, overgrazing, and over harvesting of forests are all factors that result in low crop and livestock production and water scarcity. The only way to increase and sustain crop and livestock production and water supply (for drinking and irrigation) is through conserving natural resources and enhancing their capacity to provide higher levels of environmental services.

The activities under the NREGA are largely linked to water, soil and land, which are the key natural resources determining agricultural and livestock production. They can have a positive or negative influence on these natural resources, affecting their ability to provide environmental services. Environmental services include recharging groundwater, increasing rain water percolation, conserving water, increasing the area irrigated, reducing soil erosion, increasing soil fertility, conserving biodiversity, reclaiming degraded crop and grazing lands, enhancing the supply of leaf manure, fuel wood and non-wood forest produce, and carbon sequestration. The goal of NREGA activities has to be conserving natural resources and enhancing environmental services to sustain food and livestock production, increasing the supply of fresh water for drinking, and increasing grass and forest product production. The benefits accruing from the activities implemented under the NREGA can be described as "services provided". The Millennium Ecosystem Assessment (MEA 2005) considers humans an integral component of the natural ecosystem unlike classical approaches, which differentiate humans as non-natural. The approach also addresses the sustainability of resources and livelihoods by considering human well-being a parallel theme to the functioning of the natural ecosystem.

The impact of NREGA activities may be manifested immediately or over the long term. Some of the effects can be directly measured, as with a quantifiable increase in the area irrigated, the storage capacity of a water body, the area afforested, the production of food, fodder or grass and other parameters linked to the functioning of the ecosystems. However, the linkages between various resources and processes in village ecosystems are highly complex and changes or interventions are likely to have broader and wider implications, some in the long term.

Identifying the potential environmental services that result from NREGA activities is crucial to understanding and quantifying their impact. As the MEA (2005) points out, the linkages and the trade-offs of interventions or changes in an ecosystem are very complex. In this study, for the first level, we identify the key environmental services of NREGA activities. The definition of "services" in this context has been expanded to incorporate measurable physical, biological and socio-economic indicators, including livelihood indicators. Global concerns related to food security, water security, adaptation to climate change and variability, and sustainable livelihoods have been given adequate importance. Indicators have been developed for assessing and quantifying the effect NREGA activities have on delivering these services. Services having direct implications within the ecological boundary of the activity and related components of the system are considered local. Village or micro-watershed boundaries have been considered local. Global services include those that have implications beyond regional boundaries (for example, climate change mitigation through carbon sequestration). These services are classified as provisional and regulatory (Table 3).

In this study, an indicator refers to a measurable parameter representing the extent or quantum of any resource, dependency or

Table 3: NREGA Activities and Key Environmental Services: Local and Global

NREGA Activities	Local Environmental Services	Regional and Global Environmental Services
Water conservation and harvesting	Groundwater recharge, soil moisture retention and protection (erosion control), flood control (reduced risk), providing irrigation and drinking water and soil quality (nutrient cycling)	Water conservation
Irrigation provisioning and improvement	Providing irrigation, improved agriculture and livelihoods, increased crop production	–
Renovation of traditional water bodies	Improved storage capacity, irrigation availability, groundwater recharge, soil quality (nutrient cycling), biomass production and crop production	Water conservation
Land development	Land reclaimed for agriculture, improved irrigation availability, hence agriculture and livelihood improvement	–
Drought proofing	Soil moisture retention, protection (erosion control) and soil quality (nutrient cycling), flood control (reduced risk), biomass production (fuel wood) and local climate regulation	Water conservation, carbon sequestration, biodiversity conservation
Flood control	Groundwater recharge, soil moisture retention and protection (erosion control) and flood control (reduced risk)	Water conservation

sufficiency/deficiency, which may vary due to the impact of NREGA activities over time. These indicators range from direct generic indicators such as water quantity, groundwater level and soil carbon to socio-economic aspects such as employment availability, income, access to resources and their availability. These indicators were selected and developed to represent local situations. Indicators for poverty, environmental impact, socio-economic status, food security, fuel security, climate vulnerability and other aspects have also been included to provide a wider scope and to test their performance and relevance to the respective themes.

Each activity is associated with several interlinked components of a village ecosystem, and therefore services. An integrated approach of aggregating the services keeping in mind the interlinkages is essential. An indicator-based approach was adopted to identify key indicator parameters measurable either from secondary data, direct measurement or proxies. The set of indicators included primary indicators (those that reflect immediate and directly measurable implications such as changes in water holding capacity, the groundwater level and the area irrigated) and secondary indicators (usually representing the implications of primary indicators on the processes and outputs in the ecosystems such as variations in yield, biomass production, nutrient cycling, soil moisture retention and biodiversity conservation).

Indicators that reflect the implications of NREGA activities on natural resources, the environment and livelihoods of the communities were identified by looking at them through two lenses – sectorwise and activity-wise. Further, based on the properties of the parameters being measured, the indicators can be classified into physical, biological and ecological. These indicators are region and objective specific and they have to be redefined to suit regional details and the purpose of monitoring. Factors such as efficiency of the methods, reliability, replicability, convenience, expertise required and costs were considered during selection of the indicators. They were quantified adopting a two-tier approach of simple as well as advanced methods and tools, as detailed in Table 4.

Table 4: Methods Adopted for Quantification of Indicators for Environmental Services

Indicator Parameter	Tier 1: Direct Measurement Simple Field Measurements and Socio-economic Surveys	Tier 2: Advanced Methods and Tools Simulation Studies, Decision Support Systems and Others
Area irrigated	Reconnaissance survey: field observations and measurement and secondary data	–
Biomass production in plantations	Reconnaissance survey: field observations and measurement	Biomass estimation – volume equations
Crop production and yields	FGD and KIS	–
Groundwater level	Hydrological measurements; FGD and KIS; secondary data	Hydrological modelling
Water availability	FGD and KIS	Hydrological modelling
Water storage capacity of the water bodies	FGD and KIS	Hydrological modelling
Reduced loss of water through run off	–	Hydrological modelling
Soil organic carbon (SOC), NPK and other physical and chemical parameters	–	Soil sampling and physical-chemical analysis
Soil moisture – water holding capacity (WHC)	–	Soil sampling and physical analysis; Hydrological modelling
Income during summer	FGD and KIS; secondary records	–

FGD: focus group discussions; KIS: key informant surveys.

3.2 Vulnerability Assessment

The effects of NREGA activities on the vulnerability of agricultural production systems and livelihoods were assessed using three indices – those of water, agricultural and livelihood vulnerability. A vulnerability assessment may be virtually indistinguishable from a sustainability assessment (Brenkert and Elizabeth 2005). A vulnerability assessment shifts the focus from relatively more physical and quantifiable effects to meaningful consequences for human societies. The focus also shifts from a physical/economic representation of climate changes, emission activities, effects on crop yields and water availability to a more qualitative representation of human attributes and institutions (Challinor et al 2006). This study provides a numerical framework rather than a descriptive assessment to understand multidimensional systems (such as village ecosystems) and the effect resource management has on improving sustainability of resources and livelihoods. The steps adopted include the following.

Selection of Indicators: Indicators were selected to reflect the environmental services that contribute to reducing vulnerability.

Methods for Quantification of Indicators: Field measurements, focus group discussions, key informant surveys, analyses of stakeholders' perceptions, hydrological modelling and soil chemical analyses.

Baseline Assumptions: The pre-NREGA scenario was developed on the basis of secondary data, focus group discussions and field observations.

Development of Vulnerability Indices: Environmental service indicators were measured/estimated and interpreted for their impact on vulnerability of the system and as effects of NREGA activities. Indicator status before and after implementation of NREGA activities was compared.

Normalisation: Indicators were normalised to assess the aggregated impact of different NREGA activities on vulnerability. Normalisation renders the value dimensionless and enables aggregation. The approaches considered for normalisation specific to indicators include (a) maximum value based; the maximum value a parameter can have; (b) endowment based; for parameters that depend on the actual potential of a resource; (c) increment based; for some parameters the base number is technically irrelevant and only the incremental service is reflected by the indicators; and (d) minimum value assumption; the minimum value a parameter can have.

Weighting and Aggregation: The relevance of each indicator in an index affects the final index as well as the interpretation and trends the analysis conveys. To account for the differential significance of indicators, weights were assigned based on a multi-stakeholder perception analysis. Farmers and district administrators at various levels were interviewed to arrive at the final weights. A linear aggregation method was adopted to aggregate the weighted indicator variables.

$$\text{Index (I)} = \sum_{i=1}^{n} w_i \times \frac{i}{i_{base}} \qquad \text{Equation 1}$$

where an index (I) is a linear aggregation of n number of indicators (i) represented as a ratio to the respective baseline (i_{base}) value and with weightage of w_i. The current or post-NREGA implementation value is represented by i and i_{base} represents the pre-implementation value.

3.3 Baseline Value Determination

There are different approaches and methods to represent or aggregate indicators. The key indicators identified for an index are most often measured in different units, using different methods. So it is difficult to directly aggregate the indicators. Normalisation of both the units and the scores is necessary before aggregation. Further, representing the optimum or baseline value for the parameter is complex. The baseline assumptions for the various indicators considered are presented in Table 5. The following considerations played a part in choosing the approach.

Boundary: The village, the production system boundary, was taken as the unit, including croplands, water sources, wasteland, forests and communities. It is not possible to precisely mark the boundary of the effects of an intervention, but it is necessary to have a boundary to identify the scale of work and the levels of impact.

Regional Variability: Regional variability in the scale of activity, physical barriers or variability in natural resource base, which may determine the impact of an NREGA activity and the other factors that need to be considered. Villages with tanks, with potential land for afforestation, and the extent of land suitable for plantation are some examples of parameters that determine the feasibility of implementing a particular activity.

Extent of Work and Endowment: The potential for implementing an activity varies from village to village and determines its potential in reducing vulnerability. Examples would be the potential area available for afforestation or the size of a tank. Or, there could be technical limitations to implementing soil conservation measures in some places.

3.4 Impact Measurability

The projects implemented in Chitradurga district include those that provide benefits in the short term as well as in the long run. Further, some of the effects will be visible only over a period of time. For example, desilting will have an immediate effect on the groundwater level in the downstream area. Similarly, application of silt to croplands will generate an immediate benefit in the form of improved

Table 5: Indicators Used for Vulnerability Assessment: Rationale Assumptions and Normalisation Approaches

Indicator Measure (Unit)	Rationale	Assumptions and Limitations	Normalisation Approach
Groundwater level [DIR] Change in-depth of downstream borewells (metres below ground)	Improved water storage capacity enhances water storage time in tanks leading to improved percolation and water availability for agriculture	(1) Subjectivity of the recall method (2) Measurements conducted were single time point measurements (3) Rainfall variability between the two time points compared have been assumed to be least (4) Relevant to borewells since open wells were largely unused	Initial year depth was taken as the baseline
Area irrigated [INV] Area or extent of agricultural area irrigated, including groundwater irrigation (hectares)	Increased storage capacity of the tank and groundwater recharge implies increased water availability for agriculture	All the tanks in the villages studied were not directly utilised for irrigation and were mainly meant to hold water for recharge. Hence proxies used are (a) increased irrigated area by borewells, and (b) number of days water is available from borewells	Total potential irrigable land in the village
Irrigation availability [INV] Number of days water available for crop (days)	Improved irrigation sources lead to additional number of days irrigation availability	(1) Days in relation to total number of days in a year (365) (2) Subjective and can be misleading if the years compared differ in rainfall	Maximum number of days irrigation available
Tank storage capacity [INV] Volume of silt removed can be taken as proxy for additional storage capacity (cubic metres)	Increased storage capacity of the tank implies more water stored in tank and hence more recharge	(1) Total capacity of the tank, capacity improved and proportion of additional capacity to the total is a crucial consideration reflecting the scale of desilting implying higher storage capacity (2) Measure of additionality for the time period being considered	Total potential storage capacity of the tank, less the additionality
Additional income [INV] Total days of work provided multiplied by the wages (Rs)	Income in terms of total wages paid	A comparison of worst-case and best-case situation. Assumes maximum work can be provided each year.	Income from labour during summer (without NREGA)
Summer work availability [INV] Total days work provided under NREGA and labour availability during summer in the past (days)	Work availability in terms of man days of work provided	Best of three-year performance taken. An estimate of the maximum potential man days. Base number of days work available (especially summer) was taken as least potential	Expressed in terms of total work available in the absence of NREGA during summer
Soil organic matter [INV] Increase in SOM of cropland soils with silt application (percentage)	Application of tank silt to cropland soils improves soil fertility and crop production	Improved soil organic matter improves nutrient uptake and increases crop productivity	Control plot values taken as the baseline
Financial investment [INV] Capital flows before and with NREGA at the village level (dimensionless - ratio)	Ratio of the financial flow at the village level with and without NREGA	Base implementation has been taken as Rs 50,000 for minimum or without NRGEA investment potential	As ratio to the base or minimum investment

(Indicators with [DIR] and [INV] represent direct and indirect relationship of the indicators with vulnerability).

soil fertility and increased crop productivity. However, structures such as percolation tanks and check dams will provide benefits only in the long term through reducing soil erosion and recharging groundwater. Likewise, afforestation programmes involving trees of genuses such as *Pongamia* will provide oil seeds only after 8 to 10 years.

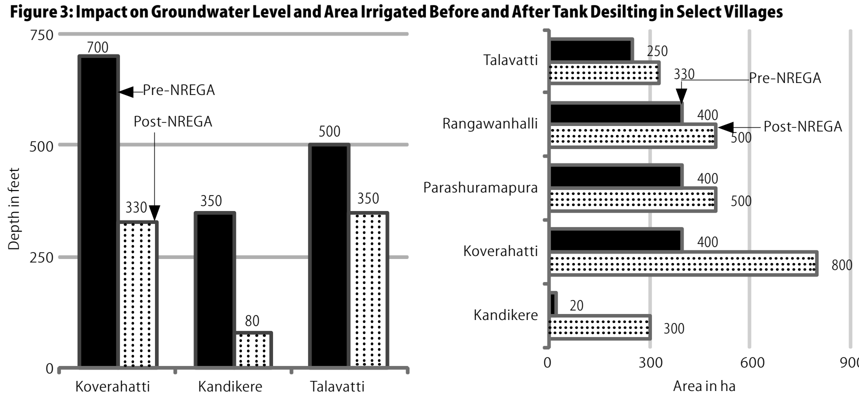
4 Results Part I: Environmental Services

This section provides an assessment of NREGA activities in enhancing and providing environmental services. The implications of resource management were assessed through a rapid scientific appraisal method. The implications and the drivers are discussed below in each class of activity.

4.1 Renovation of Traditional Water Bodies: Desilting Tanks

Desilting has provided several sustained environmental services, including a rise in the groundwater level, an increase in irrigated area and better soil fertility, thereby increasing food production, and contributing to water and food security in the villages of drought-prone Chitradurga district. Loss of vegetation cover, over grazing and inappropriate cultivation practices in water catchment areas have led to silting of water bodies such as tanks and dams, resulting in a loss of water storage capacity and reduction of groundwater recharge. Desilting involves removing silt from the water body using human labour. Farmers are encouraged to collect the silt and apply it to crop fields to improve soil fertility. The tanks in the district are largely used as percolation tanks.

Figure 3: Impact on Groundwater Level and Area Irrigated Before and After Tank Desilting in Select Villages



In Chitradurga, about 62% of the total cultivable land is dryland. Only about 9% of cropland (63,631 ha) is irrigated. Further, 79% of the irrigated land is dependent on tube wells, 9% each on tanks and canals and 3% on open wells. There are 291 small and large tanks in Chitradurga district with 53 and 72 in Hiriyur and Challakere taluks, respectively. About 9,26,890 cubic metres of silt was removed from the tanks in the district, most of them during 2007 and 2008 under the NREGA. Among the 20 sample villages, this activity was studied in Table 6 where it was done on a significant scale.

Environmental services from desilting were assessed in six villages where it was done in a big way. Among the six, there was a significant improvement in groundwater levels in three villages, which could be measured by the level of water in their borewells.

4.1.1 Impact on Groundwater Level and Area Irrigated

Post-NREGA groundwater levels were partially measured and partially collected from key informant surveys or focus group discussions. Past values were obtained from focus group discussions. Koverahatti, Khandikere and Talavatti recorded a significant improvement in groundwater levels. Koverahatti recorded a rise of 113 metre (a 77% rise). Khandikere and Talavatti recorded an 82 metre and 46 metre rise (53% and 30%), respectively. Khandikere has witnessed groundwater recharge in all its downstream borewells and

Table 6: Villages Studied and Extent of Desilting under the NREGA

Village	Desilted Tank	Year	Silt Removed (m^3)
Khandikere	Khandikere tank	2009	40,500
Gowdanahalli	Sannakere	2008	5,063
Gudnuranahalli	Hosakere, Halekere	2007	60,750
Talavatti	Talavatti tank	2008	1,800
Budnahatti Kere	Budnahatti Kere	2006	675
Upparahatti	Upparahatti Kere	2007	7,594
Dodderi	Kunte Kere	2006	6,143

in Talavatti, the impact has been observed in downstream villages such as Basappanamalige and Bandlurahatti (Figure 3).

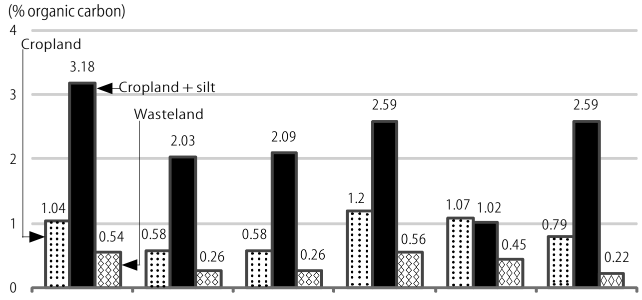
The area irrigated in a village is determined by the availability of groundwater for irrigation. Khandikere, Gudnuranahalli, Gowdanahalli and Talavatti also have surface water irrigation through tanks. Six villages showed a significant improvement in area irrigated by borewells (Figure 3). Dodderi and Khandikere recorded a more than 90% increase in irrigated area. Koverahatti recorded a doubling from 400 ha irrigated before desilting to 800 ha irrigated after desilting. Parashuramapura, Rangavanahalli and Talavatti recorded increases more than 20%.

That effects were not significant or observable in other villages was either because desilting was carried out at a much lower level in them or because desilting had only been carried out too recently to show tangible results. Further, in some places, it could take a longer interval for the effect to manifest.

4.1.2 Impact on Soil Quality

Silt removed from water bodies was applied to crop fields in all the villages where desilting was carried out. The effect of tank silt on cropland soil quality was assessed by sampling the soil from croplands, with and without silt. Wasteland sample values were taken as the baseline. Silt applied cropland soils recorded a two to threefold

Figure 4: Changes in Soil Organic Carbon with Silt Application
(% organic carbon)



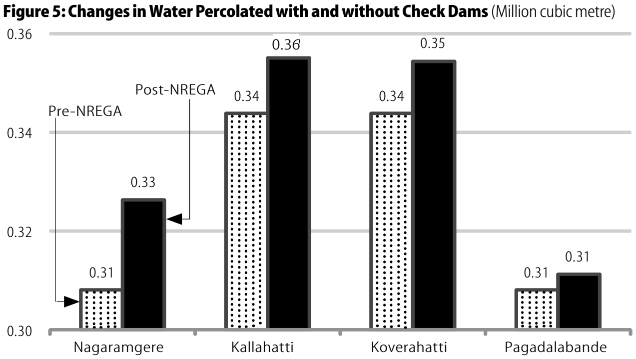
increase in organic carbon content. Organic carbon is also indicative of nitrogen in soil (Figure 4, p 44). The increase reflected the potential of silt to enhance soil fertility. In Parashuramapura, no change in soil organic carbon was reported and the reason for this is not clear.

4.1.3 Impact on Water Percolation

The study revealed that the construction of percolation tanks and check dams under the NREGA in Chitradurga district enhanced environmental services through recharging shallow aquifers, increasing the water available for agriculture, and locally reducing soil erosion by trapping soil in check dams. The direct and major benefits of these structures will be arresting run-off rates and improving percolation. Reduced run-off was determined by field measurements for dimension, catchment area and other particulars and a conservative estimate was derived based on the precipitation pattern during 2006-09.

The percolation potential of the villages studied improved by 1,000-28,000 cubic metres a year (Figure 5). In Koverahatti, the construction of percolation tanks improved recharge by 24% in the watershed considered and two check dams increased it by about 1% to 2%. Nagaramgere showed up to a 6% increase in recharge of the region. The Kallahatti check dam and one of the Koverahatti check dams showed a 3% increase in recharge. The potential of check dams to percolate water depends on size, watershed structure and quantum of rainfall.

Figure 5: Changes in Water Percolated with and without Check Dams (Million cubic metre)



Although recharge will have a positive impact on the groundwater, it will be difficult to attribute the changes to the scale of the activities implemented. But in the long term, water percolation will continue and have significant and observable effects on the groundwater.

4.2 Drought Proofing: Tree Planting/Afforestation

Drought proofing involved planting trees on crop and tank bunds and wastelands. Three villages with three-year-old plantations of *honge* or *karanj* (*Pongamia pinnata*) were studied (Table 7). The potential environmental services are leaf manure, oil seeds and fuel wood, and carbon sequestration.

Table 7: Particulars of the Species Planted in Sample Villages

Village	Year of Planting	Area Planted (ha)*	Species	Number of Trees Planted	Density (trees/ha)
Parashuramapura	2006 and	32	*Pongamia pinnata*	10,000	313
	2007		*Jatropha curcas*	12,000	375
Budnahatti	2007	40	*Pongamia pinnata*	10,000	250
			Azadirachta indica	30	1
Pagadalabande	2006	12	*Pongamia pinnata*	2,500	208

* Including crop bunds, embankments and block plantations.

At the district level, about 2,044 activities were completed during 2006-09, which included planting trees over an area of 2,341 ha on cropland bunds, tank bunds and as block plantations. Since most of the plantations established under the NREGA are less than three years old, the following environmental services and indicators were assessed using literature-based growth rates. *Pongamia* is the dominant genus planted in Chitradurga.

4.2.1 Implication for Biomass Production

Biomass or wood production and carbon sequestration potential was projected using a potential growth rate of 3 tonnes per hectare a year. One-third of the annual biomass growth is taken as potential extractable biomass for fuel wood and 1 t/ha as extractable dry leaf biomass for manure. Carbon sequestration potential is estimated by considering above ground biomass accumulation over 30 years, along with below ground biomass, as a proportion of above ground biomass (about 28%). Biomass estimates are converted to carbon using a carbon fraction factor of 0.5.

4.2.2 Carbon Sequestration

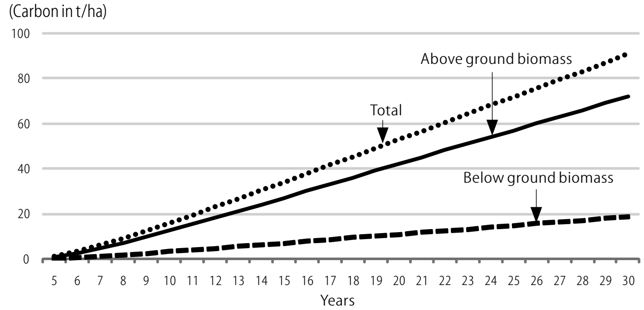
Cumulative carbon sequestration after 30 years (Figure 6) is projected to be 93 tonnes of carbon (tC) per hectare (74 tC/h above ground and 19 tC/ha below ground). The total potential of the plantations in Pagadalabande, Budnahatti and Pagadalabande to sequester carbon over 30 years is projected to be 2,964, 3,659 and 1,089 tC, respectively.

4.2.3 Green Leaf Manure and Biodiesel Production Potential

The application of *Pongamia* leaves to paddy fields has been a traditional nutrient substitution practice. A 10-year-old tree can potentially yield on average about 20 head loads (of 5 kg) of green leaves. Dry leaf biomass production potential of about 1 t/ha (or 5 t/ha fresh biomass) is used for estimating leaf manure production. A survey-based estimation of green leafy manure application rates revealed that one acre of paddy land requires about 62 head loads of green leaves. One hectare of *Pongamia* plantation with about 300 trees has the potential to provide 2,604 head loads of green leaves annually, which can potentially supply leaf manure for about 40 ha.

Pongamia pinnata trees, apart from providing leaf manure, also produce oil-bearing seeds. *Pongamia* plantations are raised to produce biodiesel (Table 8, p 46). A conservative estimate of 1 t of biodiesel could be obtained after the 10th year. In Chitradurga

Figure 6: Projected Cumulative Total Carbon Stocks for *Pongamia Pinnata* Including Above Ground (AGB) and Below Ground Biomass (BGB)
(Carbon in t/ha)



(Estimates for one-hectare block plantation raised under the NREGA with a density of 300 trees in Parashurampura).

district, about 2,341 ha of *Pongamia* plantations have been raised under the NREGA. *Pongamia* plantations have the potential to provide multiple environmental services – leaf manure for crop production, fuel wood, biodiesel production and carbon sequestration at the potential rates shown in Table 8.

Table 8: Projections of Potential Fuel Wood, Leaf Manure, Biodiesel Production and Carbon Sequestration in *Pongamia* Plantations in Three Villages

Village	Parashuramapura	Budnahatti	Pagadalabande
Area planted (ha)	32	40	12
Carbon sequestration (tC/ha/y)	3.7	3.66	3.63
Fuel wood potential (t/ha/y)	2	1.9	1.9
Dry leaf biomass potential (t/ha/y)	1.3	1.6	0.5
Biodiesel potential (t/ha/y)	1.22	1.29	0.46

4.3 Land Development

Three of the sample villages, Chikkasiddavanahalli, Dharmapura and Koverahatti, where land development activities were implemented were studied. The NREGA activities involved land levelling, building bunds and terracing, which were carried out on fallow or marginal croplands of scheduled caste and scheduled tribe farmers. These lands, which had not been cropped earlier due to their slope or degraded nature, are being cultivated after the land development activities.

Individual farmers levelled their fallow or wastelands that were earlier not suited to profitable crop cultivation. There has been a significant improvement in the income of individual farmers. The income from crops cultivated increased from zero to up to Rs 1 lakh/acre/year. Thus land levelling and reclamation activities have not only helped land development but also provided large financial benefits to individual farmers.

We next examine the NREGA programmes related to water, agriculture and livelihood through relevant indices for their potential to reduce vulnerability to climate variability. Production systems such as food and fresh water supply are subject to climate variability and probably in the future to climate change. Vulnerability to climate variability could contribute to uncertain food production, fresh water supply and livelihoods. NREGA activities have the potential to reduce vulnerability by conserving natural resources and providing sustained environmental services such as groundwater recharge, reduced soil erosion, soil fertility enhancement and water conservation. By thus enhancing the resource base, the resilience and, ultimately, adaptive capacity of the systems is also increased.

5 Results Part II: Vulnerability Reduction

NREGA activities have shown enormous potential to reduce vulnerability of the production system to climate variability. Water-related activities are most critical to reducing vulnerability and a long-term monitoring of such interventions can provide further insights. The findings of a vulnerability assessment based on the three indices are presented below. It should be noted that these numbers should be interpreted with caution as ecological-sociocultural systems and human-natural resource interactions are highly complex and may not be adequately represented by small numbers.

Impact on Water Vulnerability: Khandikere and Koverahatti villages demonstrated a significant reduction in water vulnerability. This was due to check dam construction and desilting of tanks in the villages under the NREGA. Dharmapura showed a lower level of reduction in vulnerability, which may have been due to the extent of activity there being small compared to the potential scale required to enhance the resource base and reduce vulnerability. Gowdanahalli showed no change because the activities were implemented only during the last three years, that too on an insignificant scale.

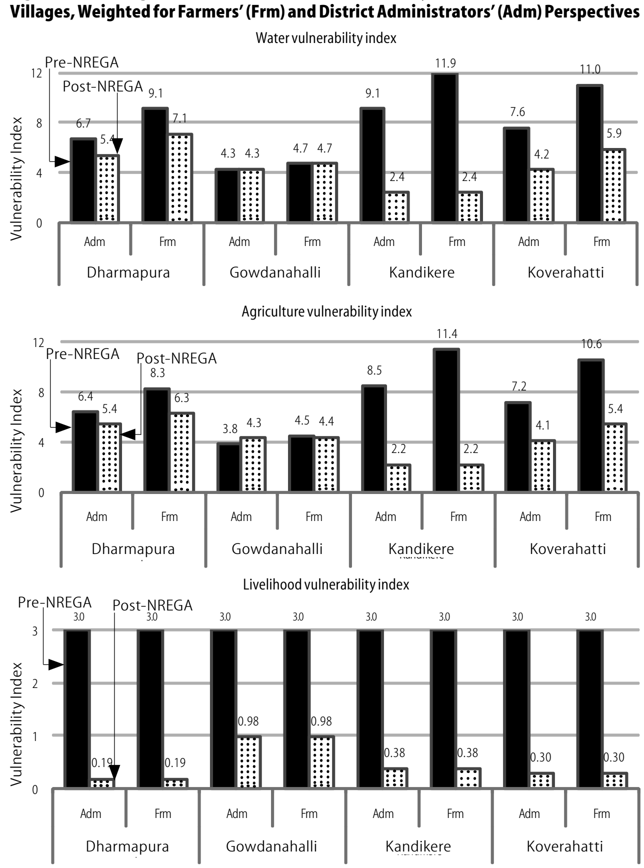
Impact on Agriculture Vulnerability: Khandikere and Koverahatti villages showed a significant reduction in vulnerability. This was reflected in improved water resources, an increase in area irrigated and a nutrient addition to cropland. Dharmapura recorded a marginal reduction because the activities implemented were not on a significant scale. Gowdanahalli recorded only a marginal change in vulnerability for the same reason. Further, the great increase in the number of borewells and the dependency on them has contributed to the observed trend.

Impact on Livelihood Vulnerability: A significant reduction in livelihood vulnerability was observed in all the villages because the NREGA activities created employment and provided additional income (Figure 7).

5.1 Implications for Overall Vulnerability

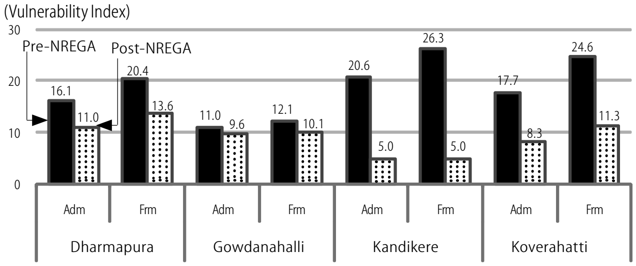
No village showed any negative impact on vulnerability due to NREGA activities. Khandikere and Koverahatti villages recorded

Figure 7: Water, Agriculture and Livelihood Vulnerability Indices for Selected Villages, Weighted for Farmers' (Frm) and District Administrators' (Adm) Perspectives



(Stratified sample surveys for farmers' perspectives and a separate survey for those of district-level administrators was conducted to arrive at the weights).

Figure 8: Aggregated Vulnerability Indices, Weighted for Farmers' (Frm) and Administrators' (Adm) Perspectives



significant reductions in water and agricultural vulnerability, leading to a reduction in overall vulnerability. Dharmapura recorded lower levels of vulnerability reduction due to the smaller scale of activities implemented in it. Gowdanahalli showed only a marginal reduction for the same reason and other local factors.

NREGA activities such as water conservation, water harvesting and desilting of tanks led to improved water storage, percolation and groundwater recharge. This resulted in more water being available for irrigation and an improvement in soil fertility, which contributed to an increase in crop yields. Water-related factors contributed the most to the reduction of vulnerability index. So water conservation activities are very critical to reducing the vulnerability of production systems and livelihoods (Figure 8). *Pongamia* plantations that have come up as a part of drought-proofing activities have the potential to produce leaf manure, fuel wood and oil seeds for reducing vulnerability, in addition to sequestering carbon within them and in the soil.

6 Conclusions

This multidisciplinary rapid scientific appraisal in Chitradurga district of Karnataka was undertaken to understand the benefits of the NREGA in enhancing environmental services and reducing vulnerability to climate variability. The findings clearly indicate that the NREGA has provided multiple environmental services and reduced vulnerability, apart from providing employment and income to rural communities. The environmental services include groundwater recharge, water percolation, more water storage in tanks, increased soil fertility, reclamation of degraded lands and carbon sequestration. These services contributed to, and had positive implications for, increased crop and livestock production.

The NREGA activities were found to reduce the vulnerability of agricultural production, water resources and livelihoods to uncertain and low rainfall, water scarcity and poor soil fertility. The implications measured in this study are only for about one to three years of NREGA activities. A longer period of five to 10 years is needed to understand the full extent of environmental services and the potential for vulnerability reduction, given the gestation period in ecological, hydrological and soil processes (for example, groundwater recharge, soil fertility improvement and tree biomass growth).

There is huge potential for using the NREGA programme as an approach to reducing the vulnerability of production systems and livelihoods in the short and long term, especially against the background of increasing climate variability and climate change. Most activities that reduce vulnerability to current stresses such as moisture stress or low soil fertility also have the potential to reduce vulnerability to the long-term effects of climate change.

Trade-offs and cross-boundary implications of the activities were observed during the study. For example, watershed activities upstream have the local effect of affecting water availability downstream. Tree plantations, on the other hand, not only provide local benefits such as fodder and green manure, but also regulate local climate and sequester carbon, contributing to mitigating global climate change. The study highlights considerations such as the scale of impact, trade-offs and implications beyond administrative boundaries. Mechanisms such as payment for environmental services need to be explored and analysed in the context of rewarding the poor for contributing benefits which cross boundaries. More studies, especially field-based measurements and a monitoring of effects to understand and identify activities that improve soil, water, grass and forest resources, are required.

The NREGA has some built-in limitations (focus on employment; activities not implemented according to a plan, spatially or time-wise; disconnected and scattered implementation of activities, to name a few), but its many activities still have the potential to provide environmental services, and conserve and enhance natural resources (soil, water, grass and forest resources). There is the need to identify fail-safe activities that improve soil, water, grass and forest resources even without micro-plans or watershed plans. A thorough analysis of investment in different types of NREGA activities, especially in the long term, is also required.

Investment in NREGA activities, given their scale and importance, should focus on a sustained flow of benefits such as employment, income, water supply, and food and grass production. The economic return, though not calculated in this study, is likely to be very high due to the NREGA's potential to deliver sustained multiple benefits over long periods of time. Its activities bring benefits at the private or individual level (land levelling and development) as well as the community level (irrigation tank desilting and grazing land development). Investment could be focused more on activities providing benefits at the community level so that the poor derive maximum benefits. Ultimately, the enhancement of environmental services will lead to long term and sustained employment and incomes for rural communities, the main goal of the NREGA.

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