Template/Pro forma for Submission

NMHS-FINAL TECHNICAL REPORT (FTR)

Demand-Driven Action Research Project Grant

NMHS Reference No.:	**NMHS/2015-16/SG03/03**

Date of Submission:	2	8	0	0	2	0	1	9
	d	**d**	**m**	**m**	**y**	**y**	**y**	**y**

PROJECT TITLE (IN CAPITAL)

IDENTIFICATION, ASSESSMENT AND ENHANCEMENT OF SOIL CARBON AND NITROGEN SEQUESTRATION POTENTIAL OF DIFFERENT ECOSYSTEMS IN THE CENTRAL HIMALAYAN THROUGH A COMMUNITY PARTICIPATORY APPROACH

Project Duration: *from* (April 2016) *to* (March 2019).

***Submitted to*:**
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GENERAL INSTRUCTIONS:

1. The Final Technical Report (FTR) has to commence from the date of start of the Project (as per the Sanction Order issued at the start of the project) till its completion. Each detail has to comply with the NMHS Sanction Order.
2. The FTR should be neatly typed (in Arial with font size 11 with 1.5 spacing between the lines) with all details as per the enclosed format for direct reproduction by photo-offset process. Colored Photographs (4-5 good action photographs), tables and graphs should be accommodated within the report or should be annexed with captions. Sketches and diagrammatic illustrations may also be given giving step-by-step details about the methodology followed in technology development/modulation, transfer and training. Any correction or rewriting should be avoided. Please give information under each head in serial order.
3. Training/ Capacity Building Manuals (with details contents of training programme technical details and techniques involved) or any such display material related to project activities along with slides, charts, photographs should be brought at the venue of the Annual Monitoring & Evaluation (M&E) Workshop and sent at the NMHS-PMU, GBPNIHESD HQs, Kosi-Katarmal, Almora 263643, Uttarakhand. In all Knowledge Products, the Grant/ Fund support of the NMHS should be duly acknowledged.
4. The FTR Format is in sync with many other essential requirements and norms desired by the Govt. of India time to time, so each section of the NMHS-FTR needs to duly filled by the proponent and verified by the Head of the Lead Implementing Organization/ Institution/ University.
5. Five (5) bound hard copies of the Project Final Technical Report (FTR) and a soft copy should be submitted to the **Nodal Officer, NMHS-PMU, GBPNIHESD HQs, Kosi-Katarmal, Almora, Uttarakhand**.

The FTR is to be submitted into following two parts:

Part A – Project Summary Report

Part B – Project Detailed Report

Following Financial and other necessary documents/certificates need to be submitted along with Final Technical Report (FTR):

Annexure I	**Consolidated and Audited Utilization Certificate (UC) & Statement of Expenditure (SE)**, including interest earned for the last Fiscal year including the duly filled GFR-19A (with year-wise break-up)
Annexure II	**Consolidated Interest Earned Certificate**
Annexure III	**Consolidated Assets Certificate** showing the cost of the equipment in Foreign and Indian currency, Date of Purchase, etc. (with break-up as per the NMHS Sanction Order and year wise).
Annexure IV	**List of all the equipment, assets and peripherals** purchased through the NMHS grant with current status of use including location of deployment.
Annexure V	**Consolidated Manpower Certificate** and **Direct Benefit Transfer (DBT) Details** showing the education background, i.e. NET/GATE etc. qualified or not, Date of joining and leaving, Salary paid per month and per annum (with break up as per the Sanction Order and year-wise).
Annexure VII	**Refund of any unspent balance as Demand Draft in favor of DDO, GBPNIHESD** payable at GBPNIHESD, Kosi-Katarmal, Almora, Uttarakhand.
Annexure VIII	**Details of Technology Transfer and Intellectual Property Rights developed.**

NMHS-Final Technical Report (FTR) *template*

Demand-Driven Action Research Project

DSL: Date of Sanction Letter

3	1	0	3	**2**	**0**	**1**	**6**
d	d	m	m	y	y	y	y

DPC: Date of Project Completion

2	8	0	8	**2**	**0**	**1**	**9**
d	d	m	m	y	y	y	y

Part A: Project Summary Report

1. Project Description

i.	Project Reference No.	NMHS/2015-16/SG-03/03					
ii.	Type of Project	**Small Grant**	×	Medium Grant		Large Grant	
iii.	Project Title	**Identification, assessment and enhancement of soil carbon and nitrogen sequestration potential of different ecosystems in the central Himalayan through a community participatory approach**					
iv.	State under which Project is Sanctioned	**Uttarakhand**					
v.	Project Sites (IHR States covered) (Maps to be attached)	Uttarakhand					
vi.	Scale of Project Operation	Local	×	Regional		Pan-Himalayan	
vii.	Total Budget/ Outlay of the Project	0.3346 (in Cr)					
viii.	Lead Agency	ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora-263601, Uttarakhand					
	Principal Investigator (PI)	Dr. Vijay Singh Meena Scientist- Soil Science ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora-263601, Uttarakhand					

	Co-Principal Investigator (Co-PI)	**Dr. Brij Mohan Pandey** Pr. Scientist-Agronomy ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora-263601, Uttarakhand **Dr. Anirban Mukherjee** Scientist-Agricultural Extension ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora-263601, Uttarakhand **Dr. RP Yadav** Scientist-Agroforestry ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora-263601, Uttarakhand **Dr. Tilak Mondal** Scientist-Agricultural Chemistry ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora-263601, Uttarakhand **Dr. Nawal Kishore Singh** Subject Matter Specialist Krishi Vigyan Kendra, ICAR-VPKAS, Sinduri-Baskhola, Kafligair-263628, Bageshwar, Uttarakhand **Dr. Harish Chandra Joshi** Subject Matter Specialist Krishi Vigyan Kendra, ICAR-VPKAS, Sinduri-Baskhola, Kafligair-263628, Bageshwar, Uttarakhand **Dr. Pankaj Nautiyal** Subject Matter Specialist Krishi Vigyan Kendra, ICAR-VPKAS, Chinyalisaur-249196, Uttarkashi, Uttarakhand **Dr. Gaurav Papna** Subject Matter Specialist Krishi Vigyan Kendra, ICAR-VPKAS, Chinyalisaur-249196, Uttarkashi, Uttarakhand
ix.	Project Implementing Partners	1. Krishi Vigyan Kendra, ICAR-VPKAS, Sinduri-Baskhola, Kafligair-263628, Bageshwar, Uttarakhand 2. Krishi Vigyan Kendra, ICAR-VPKAS, Chinyalisaur-249196, Uttarkashi, Uttarakhand
	Key Persons / Point of Contacts with Contact Details, Ph. No, E-mail	**Dr. Vijay Singh Meena** Scientist- Soil Science ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora-263601, Uttarakhand E-mail- : vijay.meena@icar.gov.in vijayssac.bhu@gmail.com Tel. +91-9410971469/7535021723

2. Project Outcome

2.1. Abstract (not more than 500 words) [it should include background of the study, aim, objectives, methodology, approach, results, conclusion and recommendations).

Background-:

The land holding in the hill area is smaller (700-900 m^2) than the national average (1370 m^2). Transmigration and environmental degradation due to climate change, GHGs, soil erosion are other cardinal issues that confront the IHR and its agriculture. The converting forest land and grassland to arable land is known to decrease the content of SOC and STN, whereas converting land under annual crops into perennial grasslands has the potential to increase C and N sequestration, an assumption proposed to be investigated in this study. However, extensive study on carbon management index (CMI) and soil CN sequestration, especially N sequestration under the Himalayan condition is lacking.

Objectives/ Aim*-:*

1. To assess the soil organic carbon (SOC) and soil total nitrogen (STN) under different land use, land cover and cropping system (forest to agricultural ecosystem) in lower, middle and higher Himalayas of Uttarakhand state.
2. To estimate C and N sequestration potential under selected pilot sites in community and measure the socioeconomic and environmental benefits of improved land management practices.
3. To provide capacity building and training on the optimal land use and land management options to promote environmental awareness, to sequester C and N, enhance land productivity to combat land degradation in Indian Himalayas.
4. To provide information and policy options for the use of carbon (C) and nitrogen (N) sinks in transferring C and N from the atmosphere to soil system.

Methodologies-*:*

Identification on the basis of land use, cover and cropping system for all three topographical position and scaling up of suitable land use and land cover, and IMPs as well as BMPs for conserving soil, agro-ecosystem focusing on enhancement of the soil CN sequestration to attract and ever green bonus towards the farming/ local community.

- Collection of data on crop/plant growth parameters and yield attributes of field experiment in selected sites has been conducted.
- Pre and post implementation observation/ data in site specific technology demonstrated on community based select farm or sites has been analyzed.
- Demonstration of different pilot studies under taken in farmers field has been evaluated and compared with the pre-intervention data for fertility status (pH, EC, OC, NPK).

Approach*:* Scientific and community participatory approach

Results-: Land use changes, forest, grass, cultivated and barren land confirmed distinct effects on WBC, LOC, TC, TN and CMI. Averaged across the soil depth WBC, TC and TN concentrations were generally highest under forest land, followed by grass land, cultivated land, and least in barren land. NLC, LC, LI and CPI concentrations also followed similar trends as WBC, TC and TN. Overall, TC and TN concentrations decreased markedly with increase in soil depth under FL, GL, CL and BL, while in case of LOC in the barren land almost exhibited the same in the 0–30 cm depth.

Conclusion-: The LUS management is necessary for increasing soil carbon and nitrogen stocks, and the research on the carbon and nitrogen storage of different LUS is required for making future policies and strategies on land use planning and management.

Recommendations-: The high carbon and nitrogen losses upon deforestation of natural forest and

2.2. Objective-wise Major Achievements

S. No.	Objectives	Major achievements (in bullets points)
1	To assess the soil organic carbon (SOC) and soil total nitrogen (STN) under different land use, land cover and cropping system (forest to agricultural ecosystem) in lower, middle and higher Himalayas of Uttarakhand state.	• Forest land showed significantly higher carbon and nitrogen stocks • Total carbon and nitrogen stocks will increase in depth as compared to surface soils • Soil organic carbon stocks losses significant higher in cultivated land
2	To estimate C and N sequestration potential under selected pilot sites in community and measure the socioeconomic and environmental benefits of improved land management practices.	• The TC and TN were increase in the grass and forest land as compared to barren and cultivated land. • The TC concentration was highly correlated with TN (R2 = 0.88, p < 0.01) and soil N-sequestration (R2 = 0.93, p < 0.01) concentrations. • Carbon storage and NSP relationship (p < 0.01) was NSP = 0.0916x + 0.7088 (R2 = 0.93). • Overall results indicated that LUS and C-storage were associated with N-storage and CMI.
3	To provide capacity building and training on the optimal land use and land management options to promote environmental awareness, to sequester C and N, enhance land productivity to combat land degradation in Indian Himalayas.	• Three farmers training programme were conducted on soil health management • Nine awareness programme were conducted on fertilizer management, crop management, vegetable cultivation and organic farming • Crop demonstration at farmers field has been conducted
4	To provide information and policy options for the use of carbon (C) and nitrogen (N) sinks in transferring C and N from the atmosphere to soil system.	• Details on policy has been published as research articles • Best nutrient management practices for lower, middle and higher hill has been identified

2.3. Outputs in terms of Quantifiable Deliverables*

S. No.	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations made, if any, and Reason thereof:
1	Data base and digital maps on soil cover, soil	Data base and digital maps on	Data has been generated for	NIL

	quality and cropping system in different transects of Uttarakhand.	the selected soil parameter (Nos).	twelve soil health parameters	
2	Development of pilot field sites for long term monitoring and data collection on soil quality and demonstration of land management practices.	No. of long-term monitoring systems established Nos/ Area in ha).	Five two year experiment has been conduction at all three experimental sites	Due to three year project two year experiment has been conducted
3	Knowledge products like papers, training manuals on c & N sequestration potential.	Models and knowledge products developed and published out of the projects (Nos).	Published 04 Communicated 03	3-4 article will be communicate
4	Training of 150 master trainers on land management.	Communities/ households engaged in Trainings/ Awareness Camps/ Workshops (Nos.).	280 farmers/extension workers/self-help group members Nine awareness programme The farmers training has not been conducted due to the non-availability of fund	Third year fund was not received
5	Policy guidelines on use of carbon and nitrogen sinks in transferring C and N from atmosphere.	Master trainers/ Women participation in science outreach programmes (Nos.).	Three training programmers on soil health management and improved crop management practices	04 paper has been published, 3-4 under process

(*) As stated in the Sanction Letter issued by the NMHS-PMU.

2.4. Strategic Steps with respect to Outcomes (in bullets)

S. No.	Particulars	Number/ Brief Details	Remarks/ Enclosures

S. No.	Particulars	Number/ Brief Details	Remarks/ Enclosures
1.	New Methodology developed	Soil carbon and nitrogen sequestration (Mg ha^{-1} in a single land use system was calculated as follows: : C storage (Mg C ha^{-1}) = [SOC (%) × BD (Mg m^{-3}) × d (m) × 10^{4} m^{2} ha^{-1}]/ 100 where C storage at 0-0.45 m depth (d) (Mg C ha^{-1}), TOC concentration (%) and BD is the bulk density of 0-0.45 m (Mg m^{-3}). Likewise, total soil nitrogen (TSN) content and sequestration (Mg N ha^{-1}) determined.	NIL
2.	New Models/ Process/ Strategy developed	-	
3.	New Species identified	-	
4.	New Database established	-	
5.	New Patent, if any	-	
	I. Filed (Indian/ International)		
	II. Granted (Indian/ International)		
	III. Technology Transfer(if any)		
6.	Others (if any)	-	

3. Technological Intervention

S. No.	Type of Intervention	Brief Narration on the interventions	Unit Details (No. of villagers benefited / Area Developed)
1.	Development and deployment of indigenous technology	• Different crop production technologies has been demonstration	• Balta cluster, Hawalbagh, Almora • Shama cluster, Kapkot block, Bageshwar • Badethi cluster, Chinyalisaur, block, Uttarkashi
2.	Diffusion of High-end Technology in the region		
3.	Induction of New Technology in the region		
4.	Publication of Technological / Process Manuals		
	Others (if any)	• Research/review articles	04 02 (Under process)

4. New Data Generated over the Baseline Data

S. No.	New Data Details	Status of Existing Baseline	Additionality and Utilisation New data
1	Fertility status for macro and micro nutrients	No	It will be useful to make strategies for sustainable food production
2	Soil Health Card	No	Distributed to the farmers
3	Crop management practices	No	It has been developed for all the experimental sites
4	Best nutrient management practices	-	It has been developed for all the experimental sites

5. Demonstrative Skill Development and Capacity Building/ Manpower Trained

S. No.	Beneficiary Groups [Capacity Building]	Particpants/trained
1	No. of Beneficiaries with income generation:	273
2	No. of stakeholders trained, particularly women:	35
3	No. of capacity building Workshops/ trainings:	02
4	No. of Awareness & outreach programmes:	08
5	No. of Research/ Manpower developed:	06

6. Linkages with Regional & National Priorities (SDGs, INDC, etc)/ Collaborations

S. No.	Linkages /collaborations	Details	No. of Publications/ Events Held	Beneficiaries
1.	Sustainable Development Goal (SDG)	-	-	-
2.	Climate Change/INDC targets	-	-	-
3.	International Commitments	-		-
4.	Bilateral engagements	-	-	-
5.	National Policies	-	-	-
6.	Others collaborations	-	-	-

7. Project Stakeholders/ Beneficiaries and Impacts

S. No.	Stakeholders	Support Activities	Impacts
1.	Gram Panchayats	1. Lower hills (Badethi cluster, Chinyalisaur, block, Uttarkashi) 2. Mid hills (Balta cluster, Hawalbagh block, Almora) 3. Higher hills (Shama	• Crop demonstration • Soil Health Card • Best Nutrient management practise

		cluster, Kapkot block, Bageshwar)	
2.	Govt Departments (Agriculture/ Forest)	Agriculture	• Best crop production technology has been identified
3.	Villagers	Badethi, Balta and Shama cluster	
4.	SC Community		
5.	ST Community		
6.	Women Group		
	Others (if any)		

8. Financial Summary (Cumulative) (Attached)

S. No.	Financial Position/Budget Head	Funds Received	Expenditure/ Utilized	% of Total cost
I.	Salaries/Manpower cost			
II.	Travel			
III.	Expendables &Consumables			
IV.	Contingencies			
V.	Activities & Other Project cost			
VI.	Institutional Charges			
VII.	Equipments			
	Total			
	Interest earned			
	Grand Total			

* Please attach the consolidated and audited Utilization Certificate (UC) and Year wise Statement of Expenditure (SE) separately, *ref*. **Annexure I.**

9. Major Equipment/ Peripherals Procured under the Project (if any)**

S. No.	Name of Equipments	Cost (INR)	Utilisation of the Equipment after project
1.	GPS	~ 25000	• It may be used for surveying purpose

Details should be provided in details **(*ref* Annexure III &IV).

10. Quantification of Overall Project Progress

S. No.	Parameters	Total (Numeric)	Remarks/ Attachments/ Soft copies of documents
1.	IHR States Covered	*01*	*Three district (Almora, Bageshwar and Uttarkashi)*
2.	Project Site/ Field Stations Developed	*03*	*Lower hills (Badethi cluster, Chinyalisaur, block, Uttarkashi). For mid hills (Balta cluster, Hawalbagh, Almora) and for higher hills (Shama cluster, Kapkot block, Bageshwar district)*

3.	New Methods/ Modeling Developed	-	-
4.	No. of Trainings arranged	*03 & 09*	*Three training and nine awareness programee*
5.	No of beneficiaries attended trainings	*300*	*From all three sites*
6.	Scientific Manpower Developed (Phd/M.Sc./JRF/SRF/ RA):	-	-
7.	SC stakeholders benefited	-	-
8.	ST stakeholders benefited	-	-
9.	Women Empowered	*50*	*From all three site*
10.	No of Workshops Arranged along with level of participation	*02*	*Soil testing*
11.	On field Demonstration Models initiated	.... (attach maps about location & photos)	*Attached*
12.	Livelihood Options promoted	-	-
13.	Technical/ Training Manuals prepared	-	-
14.	Processing Units established	.... (attach photos)	
15.	No of Species Collected	-	-
16.	New Species identified	-	-
17.	New Database generated (Types):	*Soil fertility*	*Twelve parameters of soils*
	Others (if any)		

11. Knowledge Products and Publications:

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
1.	Journal Research Articles/ Special Issue:	02	02	7.742	Attached
2.	Book Chapter(s)/ Books:		02		
3.	Technical Reports				
4.	Training Manual (Skill Development/ Capacity Building)				
5.	Papers presented in Conferences/Seminars		01		
6.	Policy Drafts/Papers				
7.	Others: Communicated/under process	01	02	~ 8.0	Under Process

* Please append the list of KPs/ publications (with impact factor and further details) with due Acknowledgement to NMHS.

12. Recommendation on Utility of Project Findings, Replicability and Exit Strategy

Particulars	Recommendations
Utility of the Project Findings	• On the basis of identified best nutrient management practices (BNMP) crop planning will be planned. Through BNMP carbon and nitrogen sequestration will be enhanced in long-run.
Replicability of Project	• Yes it may be replicated in other IHR states
Exit Strategy	• Land uses forest, grass, cultivated and barren land confirmed distinct effects on WBC, LOC, TC, TN and CMI. • Averaged across the soil depth WBC, TC and TN concentrations were generally highest under forest land, followed by grass land, cultivated land, and least in barren land. NLC, LC, LI and CPI concentrations also followed similar trends as WBC, TC and TN. • Overall, TC and TN concentrations decreased markedly with increase in soil depth under FL, GL, CL and BL. • The LUS management is necessary for increasing soil carbon and nitrogen stocks, and the research on the carbon and nitrogen storage of different LUS is required for making future policies and strategies on land use planning and management. The high carbon and nitrogen losses upon deforestation of natural forest and potential for carbon and nitrogen storage upon cultivated and grass land abandonment stress the importance of carefully assessing ongoing and future land use system changes. Hence, conservation and restoration of natural ecosystems in addition to incorporation of tree components on cultivated, barren and grass land system will enhance soil quality and sustainability.

(**PROJECT PROPONENT/ COORDINATOR**)

(VIJAY SINGH MEENA)

(**HEAD OF THE INSTITUTION**)

(Signed and Stamped)

Place: Almora………………..
Date: 28.08.2019

PART B: PROJECT DETAILED REPORT

The Detailed report should include an Executive Summary and it should have separate chapters on (i) Introduction (ii) Methodologies, Strategy and Approach (iii) Key Findings and Results (iv) Overall Achievements (v) Project's Impacts in IHR (vi) Exit Strategy and Sustainability (vii) References and (viii) Acknowledgement (It should have a mention of financial grant from the NMHS, MoEF&CC)

Further, description of Technical Activities, List of Trainings/ Workshops/ Seminars with details of trained resources, list of New Products developed under the project, Manual of Standard Operating Procedures (SOPs) developed, Technology developed/Transferred etc should be enclosed as Appendix.

1 EXECUTIVE SUMMARY

The Executive Summary of the project should not be more than 3–5 pages, covering all essential features in precise and concise manner as stated in Part A (Project Summary Report) and Part B (Comprehensive Report).

The land holding in the hill area is smaller (700-900 m^2) than the national average (1370 m^2). Transmigration and environmental degradation due to climate change, GHGs, soil erosion are other cardinal issues that confront the IHR and its agriculture. The topographical situation and soil erosion is mainly responsible for low productivity as the majority of the nutrients are washed along with the soils. Also, the soil C and N moves out of the local C and N cycle further depleting soil fertility. Sustaining soil organic matter (SOM) and STN are, therefore, extremely important for maintaining soil quality in the IHR. Concerns about increasing levels of CO_2 in the atmosphere have resulted in greater public awareness and scientific attention towards the global carbon (C) and nitrogen (N) cycles. The soil organic carbon (SOC) and soil total nitrogen (STN) are key elements of sustainable development of agricultural ecosystem. The SOC and STN affects soil fertility and ecological sustainability, and SOC storage can also mitigate the increasing atmospheric CO_2 concentrations on a decadal timescales or longer. The converting forest land and grassland to arable land is known to decrease the content of SOC and STN, whereas converting land under annual crops into perennial grasslands has the potential to increase C and N sequestration, an assumption proposed to be investigated in this study. However, extensive study on carbon management index (CMI) and soil CN sequestration, especially N sequestration under the Himalayan condition is lacking.

Three experimental sites have been selected based on the geographical context; climate, altitude, ecological and principal farm produce. Hence, the objectives of this study were (i) To assess the SOC and STN under lower, middle and higher ecosystem of central Himalayas; (ii) To estimate CN sequestration potential and measure socioeconomic and environmental benefits of BMPs; (iii) To provide awareness, capacity building and training on land use and land management options (iv) To provide information and policy options for the use of carbon (C) and nitrogen (N) sinks in transferring in soil system.

The CN sequestration potential of different land use, land cover and cropping system at different selected sites measured by the following the standard procedure. Collection of data on crop growth parameters and yield attributes of field experiment in selected sites has been recorded. Pre and post implementation observation in site specific technology demonstrated on community based select farm or sites collected and analyzed. The socioeconomic and environmental benefits of improved land management practices have been measured by applying before after as well as with and without design. Pre tested structured interview schedule and questionnaire have been prepared for the purpose. Case studies has been conducted for capture the qualitative impacts. High quality training tools utilized for capacity building.

Yield gap estimation, BMPs, FIE, soil degradation, SOC pools, RMPs, IMPs has been identified. Economic surplus approach executed to have economic impact.

2 INTRODUCTION

2.1 Rationale of the project: situation analysis, main problem(s) to be considered

Concerns about increasing levels of CO_2 in the atmosphere have resulted in greater public awareness and scientific attention towards the global carbon (C) and nitrogen (N) cycles. A considerable part of the current atmospheric C and N pool comes from the terrestrial ecosystem of which soil is a major component (Bhattacharyya et al., 2013; Liu et al., 2014). The SOC and STN are key elements of sustainability of agricultural ecosystem. The converting forest land and grassland to arable land is known to decrease the content of SOC and STN, whereas converting land under annual crops into perennial grasslands has the potential to increase C and N sequestration, an assumption proposed to be investigated in this study.

The SOC and STN affects soil fertility and ecological sustainability, and SOC storage can also mitigate the increasing atmospheric CO_2 concentrations on a decadal timescales or longer. The changes in temperature and precipitation associated with climate change can influence soil processes leading to feedback mechanisms that help control atmospheric CO_2 concentrations. SOC and STN storage in high tropical and subtropical mountain regions is poorly quantified. The assessment of SOC and STN storage in soils were examined across the IHR. The accumulation and turnover of SOC and STN is a major factor in soil fertility and ecosystem functioning and determines whether soils act as sinks or sources of C and N in the global C and N cycles (Lal, 2014).

Recent estimates indicates that in North-Western Himalayas (NWH), on an average, 17% of the area falls in very severe category with erosion rates > 40 t ha^{-1} yr^{-1}, while ~ 25% area has erosion rate of more than 10 t ha^{-1} yr^{-1}. Within the NWH region, Uttarakhand has highest area (21.19%) under water erosion followed by Himachal Pradesh (17.76%) and least in Jammu and Kashmir (9.14%) (Annual report IISWC, 2014). Overall ~ 23% area in the Himalayan states has potential erosion rates, it calls for serious efforts to employ appropriate soil and water conservation measures to check land degradation problems. The area under forest in Uttarakhand is 3.4 Mha, which constitutes 61.45% of its total land available for utilization. The major forest types occurring in the state are tropical moist deciduous, tropical dry deciduous, sub-tropical pine, Himalayan moist temperate, sub-alpine and alpine forests (UK forest statistics, 2012-13). These forests act as a carbon and nitrogen source. However, there is inadequate effort as well as awareness on conservation and efficient utilization of CN resources. Several studies have been conducted on CN sequestration in India, the organic source treatment significantly (23 to 69%) higher CN sequestration as compared to control or mineral fertilizers treatments (Ghosh et al., 2012; Moharana et al., 2012; Mandal et al., 2013; Lal, 2014). The research work on carbon management index (CMI) has also been done for the Indo-Gangetic Plains (IGP) and foot hills of Himalayas, the results established that vegetative barriers under minimum tillage (MT) was the best management practice (BMPs) for decreasing runoff and soil loss and increasing system productivity on a 2% slope in the region and organic manure were recorded higher CMI as compared to rest of the treatments (Ghosh et al., 2012; Ghosh et al., 2016). However, extensive study on CMI or soil CN sequestration, especially N sequestration under the Himalayan condition is lacking. So far, training to community has laid emphasis on technologies for increasing agricultural productivity or value addition. The specific training on CN sequestration in different ecosystem where community can act as a catalyst in conserving natural resources can play a crucial role in improving sustainable ecological health of the IHR.

2.2 Context: geographical context; climate, altitude, main ecological and socio- economic

The IHR are particularly vulnerable to climate change and have shown 'above average warming' in the 20th Century. The SOC and STN are the essence of all terrestrial life, and are critical to human well-being and nature conservancy. Through its impact on soil quality and several key pedospheric processes, it is the source of numerous ecosystem goods and services. In recent times, the state has shown rapid economic growth (~ 3% at the time of formation of the state to ~8% at present) adding worries to the Himalayan environment. We are planning to study in Uttarakhand. The Uttarakhand is one of the hilly states in the Indian Himalaya. It lies in the northern part of India between the latitudes 28°43′ N and 31°27′ N and longitudes 77°34′ E and 81°02′ E, covering an area of 53,483 km2. The elevation ranges from 210 to 7817 m. The Uttarakhand has also been the fulcrum for environmental activism such as, for example, the Chipko movement indicating possibility of widespread acceptance of corrective measures for ecological balancing especially carbon and nitrogen sequestration.

2.3 Description of project area: Include map and coordinates of project areas characteristics; policy context: relationship to national policies; community context

Three experimental sites has been selected in Uttarakhand and based on the geographical context; climate, altitude, ecological and principal farm produce and livestock. The agricultural soils are among the planet's largest reservoirs of carbon and hold potential for expanded soil carbon and nitrogen sequestration, and thus provide a prospective way of mitigating the increasing atmospheric concentration of CO_2.

The selection on the base of topographic (altitude lower, middle, higher), land use (Dense forest, mixed forest, horticultural, agri-horti, agriculture land etc.), land cover (grass land, shrub land etc.) and cropping system (cereals, pulses, vegetables etc.). Sustainable governance of soil resource is crucial to counteract the loss of productive soils, a corner-stone of the carbon-food-energy nexus. The nexus perspective on soil governance emphasizes the interrelationship within soil system interrelationships between soil-plant systems. It directs attention to (i) the internal dynamics of the resource system soil, (ii) the influence of the governance system on human decisions regarding the resource system soil, (iii) and how this influences other resource systems of carbon and nitrogen cycle and how it is being influenced by social and economic processes at other tiers. Cognizant of agriculture role in the economy, the 11th five-year plan, recognizes the importance of proper soil management in agriculture. Soil degradation through excessive and miscalculated fertilizer use because of emphasis on increased output has led to nearly 2/3rd of India's farmlands to be classified as either degraded or sick. In attempts to increase knowledge on soils and soil management, the Government of India has initiated distribution of soil health card (SHCs) scheme for better soil management although; soil governance part in policy is missing. It can only be accomplished through research based community mobilization.

3 Project descriptions

3.1 Project's framework: please provide a frame work of the project, which should reflect the following:

- **Goal (long term vision) towards which the project will contribute;**

The long term vision of the project is development of model(s) of improved land use, land cover and cropping systems along with BMPs, RMPs and IMPs for minimizing land degradation which will provide a win-win effect in terms of socioeconomic and environmental benefits, greater agro-biodiversity, improved conservation and sustainable environmental management and increased CN sequestration in soil systems. To improve the soil C and N stocks through adoption of RMPs.

Objective(s) of the Project;

1. To assess the soil organic carbon (SOC) and soil total nitrogen (STN) under different land use, land cover and cropping system (forest to agricultural ecosystem) in lower, middle and higher Himalayas of Uttarakhand state.
2. To estimate C and N sequestration potential under selected pilot sites in community and measure the socioeconomic and environmental benefits of improved land management practices.
3. To provide capacity building and training on the optimal land use and land management options to promote environmental awareness, to sequester C and N, enhance land productivity to combat land degradation in Indian Himalayas.
4. To provide information and policy options for the use of carbon (C) and nitrogen (N) sinks in transferring C and N from the atmosphere to soil system.

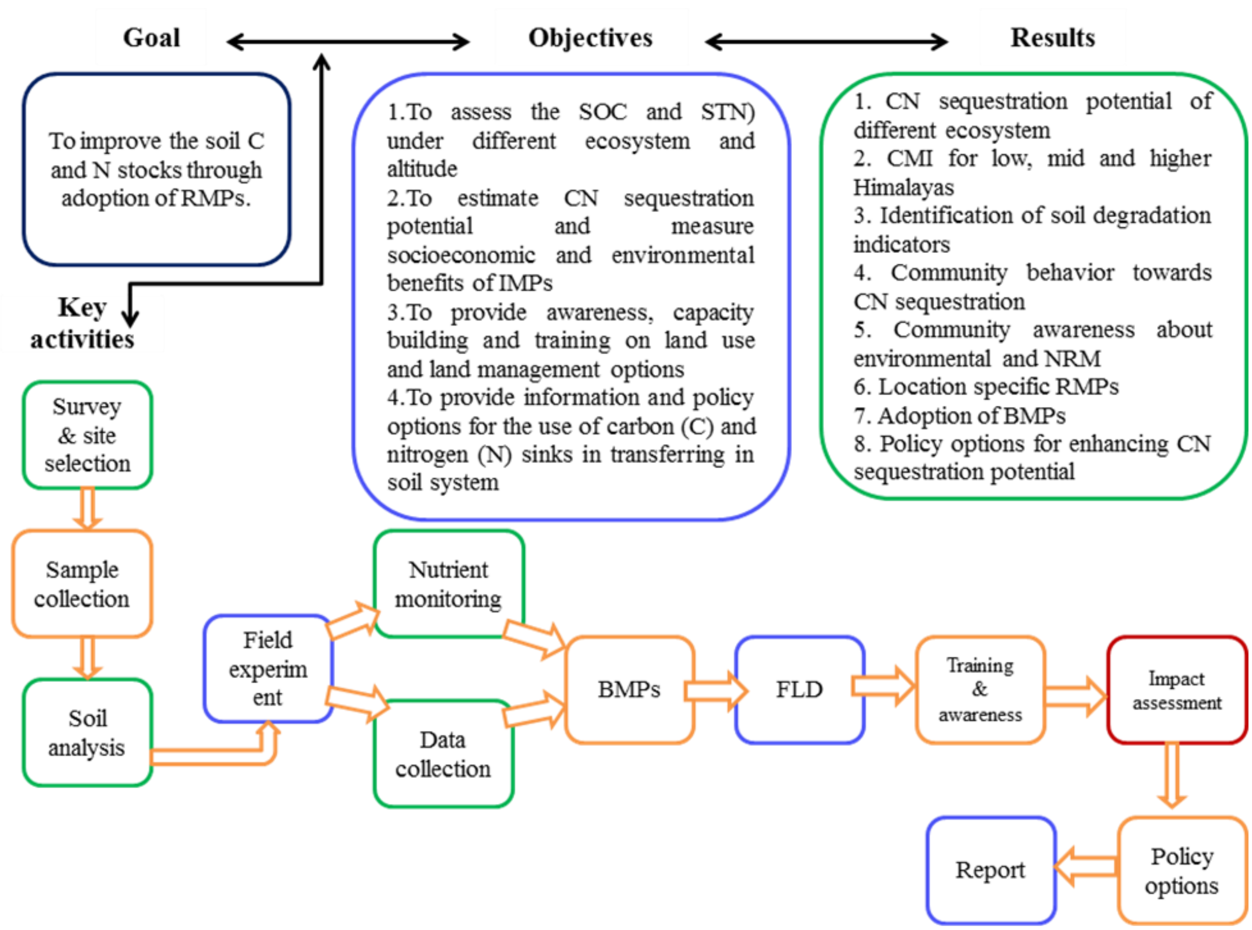

Fig. The project framework of proposed project

3 METHODOLOGIES, STARTEGY AND APPROACH

Identification on the basis of land use, cover and cropping system for all three topographical position and scaling up of suitable land use and land cover, and IMPs as well as BMPs for conserving soil, agro-ecosystem focusing on enhancement of the soil CN sequestration to attract and ever green bonus towards the farming/ local community. The CN sequestration potential of different land use and land cover at different selected sites has been measured by the following the standard procedure. Data analysis, development of index, and interpretations

- Collection of data on crop/plant growth parameters and yield attributes of field experiment in selected sites.
- Pre and post implementation observation/ data in site specific technology demonstrated on community based select farm or sites data analyzed.
- Demonstration of different pilot studies under taken in farmers field has been evaluated and compared with the pre-intervention data for fertility status (pH, EC, OC, NPK).

Community based field experiment treatments details

- Control (as usually community practices)
- Farm Yard manure (FYM) 100%
- Vermicompost 100%
- Biochar 100%

- 50% FYM + 50% Vermicompost
- 50% Biochar + 50% Vermicompost
- 50% Biochar + 50% FYM
- Integrated nutrient management (INM) along with (mineral fertilization – NPK & organics)

The socioeconomic and environmental benefit of improved land management practices has been measured by applying before after as well as with and without analysis. For capacity building and training both participatory field training and in-house training of local community and stockholders had been conducted by using high quality training tools. To promote environmental awareness; CN sequestration, improved crop, soil and environmental management practices participatory community based awareness camps has been conducted.

4 KEY FINDINGS AND RESULTS

- Soil bulk densities under different land use systems (LUS) ranged from 1.30 Mg m^{-3} in forest land to 1.33 Mg m^{-3} in barren land. Difference in soil bulk densities with soil depth was significant ($p < 0.05$). The highest (1.35 Mg m^{-3}) soil bulk densities in 30-45 cm soil layer as compared to 0-15 cm soil layer (1.30 Mg m^{-3}).
- The WBC decrease in CL and BL was accompanied by mean increase in soil bulk density of 21% compared with FL. The WBC and LOC concentrations from barren land, cultivated land, grass land and forest land significantly varied among the LUS and soil depth form 0-15, 15-30 and 30-45 cm soil depth.
- The LOC concentration of FL was generally greater than those of GL and CL of the ecosystem. There were no significant differences in LOC concentrations among 0-45 and 30-45 cm soil depth. There were no significant differences in LOC concentrations among 15-30, 30-45 and 0-45 cm under barren and cultivated LUS. Averaged across the depth, the LOC concentrations of the 0-15, 15-30, 30-45 and 0-45 cm depth were 2.43, 2.22, 1.95 and 2.20 g C kg^{-1} ($p < 0.05$), while in GL labile carbon concentrations 2.38, 2.19 and 1.87 g C kg^{-1} for 0-15, 15-30 and 30-45 cm soil depth, respectively.
- Significantly highest soil C-sequestration (~ 161 Mg ha^{-1}) was observed under the forest land followed by grass land (~ 134 Mg ha^{-1}), cultivated land (~ 92 Mg ha^{-1}) and significantly lowest was observed under the barren land (~ 92 Mg ha^{-1}) in the 0-45 cm soil depth.
- Soil N-sequestration significantly varied from 10.58 to 13.82 Mg ha^{-1} under forest to barren land use systems. Results showed that in the 0-45 cm soil depth, the N-sequestration rate significantly higher (13.82 Mg ha^{-1}) under forest land, at par with grass land (13.66 Mg ha^{-1}) followed by cultivated and barren land with 11.52 and 10.58 Mg ha^{-1}, respectively. At 0-45 cm depth showed its significantly superiority with 12.39 Mg ha^{-1} followed by 0-15 cm (4.41 Mg ha^{-1}), 15-30 cm (4.15 Mg ha^{-1}), however, significantly lowest soil N-sequestration 13.83 Mg ha^{-1} in the 30-45 cm soil depth.
- Averaged across the depth, the CMI of the 0-45 cm depth were 49.80, 49.62, 56.90 and 58.94% ($p < 0.05$) for forest, grass, cultivated and barren land, respectively. While, the CMI value were 49.63, 55.12 and 56.70% for 0-15, 15-30 and 30-45 cm soil depth, respectively.

5 OVERALL ACHIEVEMENTS

The LUS management is necessary for increasing soil carbon and nitrogen stocks, and the research on the carbon and nitrogen storage of different LUS is required for making future policies and strategies on land use planning and management. The high carbon and nitrogen losses upon deforestation of natural forest and potential for carbon and nitrogen storage upon cultivated and grass land abandonment stress the importance of carefully assessing ongoing and future land use system changes. Hence, conservation and restoration of natural ecosystems in addition to incorporation of tree components on cultivated, barren and grass land system will enhance soil quality and sustainability.

6 PROJECT'S IMPACTS IN IHR

The CN sequestration potential of different land use, land cover and cropping system at different selected sites has been measured by the following the standard procedure. Collection of data on crop growth parameters and yield attributes of field experiment in selected sites has been recorded. The socioeconomic and environmental benefits of improved land management practices have been measured by applying before after. High quality training tools has been utilized for capacity building.

7 EXIT STRATEGY AND SUSTAINABILITY

Land use system had minimum effect on non-labile carbon (NLC), lability of carbon (LC), lability index (LI) and carbon pool index (CPI) of the ecosystem. Moreover, TC and TN were increase in the grass and forest land as compared to barren and cultivated land. The TC concentration was highly correlated with TN (R^2 = 0.88, $p < 0.01$) and soil N-sequestration (R^2 = 0.93, $p < 0.01$) concentrations. However, carbon storage and NSP relationship ($p < 0.01$) was NSP = 0.0916x + 0.7088 (R^2 = 0.93). Overall results indicated that LUS and C-storage were associated with N-storage and CMI. These results suggest restoration of degraded barren and cultivated land to grass and forest land and decrease in intensity of land use could increase carbon and nitrogen storage in the study area as well as other similar mountainous regions of Indian mid-Himalayas.

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APPENDICES

Appendix 1 – Details of Technical Activities
Appendix 2 – Copies of Publications duly Acknowledging the Grant/ Fund Support of NMHS
Appendix 3 – List of Trainings/ Workshops/ Seminars with details of trained resources and dissemination material and Proceedings
Appendix 4 – List of New Products (utilizing the local produce like NTFPs, wild edibles, bamboo, etc.)
Appendix 5 – Copies of the Manual of Standard Operating Procedures (SOPs) developed
Appendix 6 – Details of Technology Developed/ Patents filled
Appendix 7 – Any other (specify)

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