DEPARTMENT OF GEOGRAPHY
Shivaji College
(University of Delhi)
RING ROAD, RAJA GARDEN,
NEW DELHI-110027
(NAAC "A" Grade)

Ref. No. 29/04/2019

Dated. ....

To
Revathy Vishwanath
Deputy Director I/c (RP)
ICSSR, New Delhi

Sub: Submission of Project Report

Dear Ma'am

This letter is in reference to the subject cited above. Find the attached list of documents for ICSSR, Research Project entitled 'Indigenous Ecological Knowledge of Soil Water and Nutrient Conservation in Sikkim Himalaya' vide File No (F. No.-02/298/2016-17/RP - Dated 29/03/2017) for perusal.

1. Final Project Report- 02 Copies
2. Summary of the Project Report-02 Copies
3. The audited statements of account for all expenditure incurred together with utilization certificate in GFR 19A Form
4. A statement of asset costing over Rs. 100/-
5. Grant-in-Aid Bill (Rs.1,20,000)

Kindly mark it for necessary action

Thanking You.

Regards

29/4/2019

Dr. Prabuddh Kr. Mishra
Project Director

Dr. Prabuddh Kr. Mishra
Assistant Professor
Department of Geography
Shivaji College
University of Delhi, Delhi

Received final Reports
3/4

Udin:- 19519942AAAAAE4128

FORM
GFR 19-A
(See Rule 212 (1))
Form of Utilization Certificate

S No.	Letter No. and Date	Amount (Rs.)
1.	F. No.-02/298/2016-17/RP Dated – 26/05/2017	Rs. 2,40,000/-
2.	F. No.-02/298/2016-17/RP Dated – 26/03/2018	Rs. 2,40,000/-
	Total	**4,80,000/-**

Certified that out of **Rs 4,80,000/-**of grants-in-aid sanctioned during the year 2017-18 in favour of Principal, Shivaji College, under the ICSSR Letter No. F. No.-02/298/2016-17/RP and Rs. **Nil** on account of unspent balance of the previous year, a sum of **Rs. 6,00,063/-** has been utilized for the purpose for which it was sanctioned and that the balance of Rs. **Nil** remaining unutilized at the end of the year has been surrendered to the ICSSR (vide No.-----Dated -------) will be adjusted towards the grants-in-aid payable during the next Year---------.

2. Certified that I have satisfied myself that the conditions on which the grants-in aid was sanctioned have been duly fulfilled/ are being fulfilled and that I have exercised the following checks to see that the money was actually utilized for the purpose for which it was sanctioned.

Kinds of checks exercised:

1. Audited statement of Account
2. Vouchers and Bills
3. Sanction Letter

Principal
(Dr. Shashi Nijhawan)
शिवाजी महाविद्यालय / Shivaji College
(दिल्ली विश्वविद्यालय) / (University of Delhi)
राजा गार्डन, नई दिल्ली-110027
Raja Garden, New Delhi-110027

GUPTA ANKIT & CO. CHARTERED ACCOUNTANTS DELHI FRN:022928N

CA Deepika Gupta
Partner
M. No. 519942

Certified by the C.A.
(Signature with Rubber Stamp)

29/04/2019
Project Director
(Dr. Prabuddh Kumar Mishra)

Dr. Prabuddh Kr. Mishra
Assistant Professor
Department of Geography
Shivaji College
University of Delhi, Delhi

Project Summary

Indigenous Ecological Knowledge of Soil, Water and Nutrient Conservation Practices in Sikkim Himalaya

Submitted to

Indian Council of Social Science Research
JNU Institutional Area
Aruna Asaf Ali Marg
New Delhi-110067

Submitted by

Dr. Prabuddh Kumar Mishra
Assistant Professor

Department of Geography
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April 2019

Summary

The ecological problems including degradation of fragile ecosystems of the Himalayan region are quite conspicuous. The carrying capacity of the various ecosystems differs in time and space, and the mountains being one of the fragile ecosystems are affected by many drivers of change. Among these land degradation, climate change, biodiversity loss and loss of indigenous knowledge systems are the most noticeable. In response, resource-conserving practices of local communities drawn from their indigenous ecological knowledge systems have been described from many parts of the world and for many different cultures and environments. Human societies across the globe have developed precious experiential wisdom and explanations relating to the environments they live in and the past few decades have witnessed the importance of understanding the linkages between social and ecological systems for managing the use of natural resources. In this context, the present study tries to identify, document and validate the role of farmer's indigenous knowledge of soil, water and nutrient conservation practices and management in Sikkim Himalaya.

Watersheds are considered as a unit for natural resource management and development in hilly areas. Using watershed as a unit, the present research focuses on the *Indigenous Ecological Knowledge of Soil, Water and Nutrient Conservation Practices* in Rani Khola watershed of Sikkim Himalaya, India. The study watershed is located between 27°13'9 N to 27°23'51 N and 88°29'31 E to 88°43'18 E with an area of about 254 km^2 and located in the East District of Sikkim State. The study was undertaken with the following main objectives: (i) Resource inventory analysis of the watershed; (ii) to identify and document soil and water conservation practices in the watershed; (iii)To quantify and assess the environmental and economic cost of overland flow, soil loss, and nutrient loss from different land use practices; (iv) To study farmers' knowledge and perception of soil erosion and identification of erosion indicators and conservation measure; (v) To develop an intervention strategy for sustainable rural development based on soil and water conservation.

Primary data for the study were collected during the year 2017-18 based on a household survey of 300 farmers, focus group discussions, key informant interviews, and field observation and experimental erosion plots form different land use systems. Secondary data was gathered through published literature including research papers, reference books, reports, articles, Sikkim government statistical abstracts, census data, internet sources, and

satellite images. The data includes information on water resources, land-use types, land holdings, farming systems, crop production factors, and livestock population and production.

Chapter 2 entitled as Geographical profile of the study area and focus on the various physical and cultural characteristics of the watershed. Elevation ranges from 311 m to 4112 above mean sea level. The watershed is named after Rani Khola, also known as *Rongni chu* in the local dialect is the major river that drains to river Teesta. Rani Khola watershed is one of the very prominent watersheds of Teesta basin, and it is characterised by a variety of landforms. The river receives water from many tributaries on either side of its course. The primary sources of water in the watershed are springs, streams *(Dhara)* and small rivers *(Khola)* through the surface and sub-surface water flows originating mostly from the unconfined aquifers. Geology of the watershed is characterized by Gorubathan formation, Chungthang formation, Lingtse Granite Gneiss rock formations. More than 50% of the area is made up of the rocks belonging to Gorubathan Formation and concentrated in the central and western part of the watershed (GSI 2006). Vegetation in this watershed consists of the subtropical broad-leaved evergreen type, mixed coniferous forest, cool broad-leaved forest (Rumtek, Rorathang), lauraceous forest (Pakyong, Gangtok), buk oak forests, sub-alpine, alpine scrub and alpine pasture. *Fambong Lho Wildlife Sanctuary* and *Kyongnosla Alpine Sanctuary* are the famous sanctuaries of Sikkim Himalaya both of them partially lies in the watershed. Reserved forests such as Martam Reserved Forest; Bhusuk Reserved Forest and Assam Reserved Forest enrich the floral diversity of the area. Climatically, the watershed enjoys sub-tropical to alpine climatic conditions. The average temperature of the watershed ranges from an average maximum of 22° C during summer and 4° C during the winter season. Agriculture is the main source of livelihood in the rural areas of the watershed and represents most of the human habitation zones that exist in the Sikkim Himalaya. The watershed consists of 44 villages and has a total population of 1,61,394 with an average density of 635 person/km^2 and most of the area is rural. The population comprises mainly of Nepali, Bhutia and Lepchas and major languages are Nepali, Bhutia and Lepcha. Majority of the population speaks Nepali. The inhabitants of the watershed are predominantly Hindus, Buddhists and Christians.

The geographic profile of the study area outlined as per the requirement of the study. Various thematic maps of the watershed such as drainage, slope, aspect and contour lines map were prepared from satellite data and some maps were digitized using existing old maps of Soil and geology. These maps are required for detailed study and a better understanding of the various geographical characteristics of the watershed. Major reference utilized to prepare the chapter include available reports on the various thematic areas of the watershed such as: Census Data, 2011, Geological Map of Sikkim, Toposheet by Survey of India, Report published by Centre for Inter-Disciplinary Studies of Mountain & Hill Environment, University of Delhi (CISMHE), project reports from Forest Department, Government of Sikkim etc. The watershed presents a diverse biophysical and socioeconomic characteristic. The detailed resource inventory analysis of the Rani Khola watershed is performed in the next chapter.

Chapter 3 provides a detailed inventory of resource base of the watershed such as land, water, agriculture including forest resources has been outlined to understand the complexities and determining the quality and quantity of available resources for planning and development. Data provides a systematic and detailed analysis of environmental quality and natural resource base of the watershed. In the present chapter information about land-use/cover pattern, agriculture, agroforestry, floriculture, animal husbandry and forestry has been outlined and assessed. The spatiotemporal changes in LULC pattern of the watershed were assessed using Landsat-5 TM and sentinel-2 data from 1988 to 2017. The result of this study reveals that the major land use in the watershed is forestry. Due to massive afforestation programme, declaration of Sikkim as an organic state in 2005, stringent law enforcement in the forestry sector and sustainable agroforestry systems the area under dense forest has increased by 16.4 % (41.76 km^2) between 1988 to 2017. Open forest showed an increasing trend during 1988-1996 whereas decreasing trend has been observed during 1996-2017, this may be associated with the conversion of open forest into the dense forest area. The other dominant land use is agriculture which was recorded as 17.63% (2017) as against 12.75% in 2008 due to traditional agroforestry practices, horticulture, floriculture and animal husbandry which are widely practised by the. During the study period (1988–2017), barren land has been decreased significantly due to conversion in agriculture, vegetation and built-up land. The major changes in the built-up area were noted along the periphery of Gangtok is the capital city due to urban sprawl and expansion of the town area during the last two decades.

Agriculture is one of the major land use and covers 17.63% of the total land in the watershed and major source of livelihood in rural areas of the watershed. Watershed is characterised with traditional agricultural systems, and the majority of farmers are marginal farmers. Major crops grown in the watershed are ginger, paddy, wheat, maize, cardamom, pulses and vegetables. Other allied activities are animal husbandry and livestock farming. There is a strong traditional agroforestry base. The area supports four basic farming systems viz; agriculture, horticulture, agroforestry, and animal husbandry, all of which are livestock based and responsive to climate, topography, and resource availability. Traditional agriculture systems of the watershed lie between 400m to 2000m altitude. Farmers construct terraces wherever the land is suitable. Rain-fed terraces are used for two crops a year of maize, barley, finger millet, wheat or potato. All these are mostly for subsistence or bartering purposes, while cash crops and vegetables are grown in kitchen garden areas. Major crops grown in the watershed are ginger, paddy, wheat, maize, pulses and vegetables. Farmers intercrop rice with a traditional variety of *soybean*, *ricebean* and *urd* on terrace bunds. The rice-wheat, rice-mustard, rice–potato, rice–fallow, maize–rice–mustard (below 800m), and maize–rice–fallow at higher hills are conventional cropping systems on irrigated terrace rice lands. Most of the crops are grown as food crops from March to September. A large number of landraces of maize, paddy, buckwheat, beans, pulses, finger millets, yams, tubers and ginger are grown in rotation among these Maize holds the highest rank followed by paddy in the watershed. Maize is grown up to 2,700m elevation while paddy is grown up to 1500m.

Since forestry and agriculture are the predominant users of land, their quality (soils) and quantity (area) is directly related to the nature of landforms. This data would ultimately help to identify limiting resources as also the environmentally critical areas which can be delimited as hot spots for conservation or remediation. The evaluation of resources would also lead to understanding the impacts of various developmental activities on these resources on the one hand and the planning process on the other. Remote Sensing and Geographic Information System , approach which is one of the most prominent technology at present for spatiotemporal analysis is utilized, which is not possible through other conventional mapping techniques. The analysis and findings of the study have important policy implications for the sustainable land-use/cover practices in the Sikkim Himalaya. This data would ultimately help to identify limiting resources as also the environmentally critical areas which can be delimited as hot spots for conservation or remediation. The evaluation of resources would also lead to understanding the impacts of various developmental activities on these resources on the one hand and the planning process on the other.

Chapter 4 is titled as Assessment of land degradation, overland flow, soil erosion and nutrient loss. In this chapter assessment of land degradation is carried out. Several satellite-based GIS Modelling (e.g. RUSLE CORINE, PESERA models, etc.) and field-based (overland flow, soil and nutrient loss, farmer's perception based qualitative assessment etc.) land degradation assessment techniques are available for concluding the status of land degradation and soil erosion. In this chapter, field assessment techniques are analyzed; it involves and integrates quantitative and qualitative analysis of soil erosion in the Rani Khola watershed of Sikkim Himalaya. Overland flow, soil erosion and soil loss has been assessed with the data obtained from experimental plots covering different land use practices. In the subsequent section farmer's perception and knowledge of the soil erosion process and identification of erosion, indicators have been recorded in the watershed of Sikkim Himalaya.

Soil samples were collected from 4 locations covering all ecological zone viz. low, mid and high. Soil sampling points were selected from the surroundings of the delineated plots and one sample of approximately 100 g which was taken at each point from a depth of up to 15 cm, was sealed in a plastic bag and then transported to the laboratory for chemical and physical analysis. These samples were collected just before the rainy season, at the time of plot delineation and designated as parent soil. Following the collection of soil samples, twelve runoff sites were established in the experimental station. These were estimated using natural shallow surface runoff channels and artificially delineated plots. The delineated plot size was 3x3 m for estimation of overland flow and soil and nutrient loss; one plot was laid in each type of the land-use practice in each ecological zone. These plots were delineated with aluminium sheets (inserted in the soil for about 6 cm and remaining 15 cm exposed in the air) from all sides to prevent water likely to enter from adjacent areas. The overland flow and soil loss along the slope were estimated from the collecting tank after each rainfall event, and water samples were also collected for chemical analysis. Total runoff/overland flow was recorded to be highest in open land/barren land (8.63%) where there was no vegetation or grasses were found and it was prone to erosion in the rainy season. Runoff was recorded second highest for the large cardamom based agroforestry system (7.02%), which was mainly because of the steep slope, newly planted saplings and application of farm yard manur (FYM). The lowest overland flow was observed in terrace cultivation (4.69%), followed by and mixed cropping (4.84%) in the watershed.

In the context of soil loss, data revealed that in most of the case soil loss followed the rate of overland flow. Soil loss was least in the cardamom based agroforestry 323.47

tons/ha/yr followed by terrace cultivation 375.38 tons/ha/yr. Soil loss was estimated highest for the barren land 773.62 tons/ha/yr followed by mixed cropping 432.37 tons/ha/yr. It has also been observed that higher the slope length greater the erosion. Other factors such as rainfall intensity, duration and soil moisture, geological setting also influence runoff and soil erosion. All the farmers participated in the field survey agreed that they faced soil erosion in some or other form in their land. About 65 % of the farmers in all ecological zones responded that there is light or no soil losses in their field reason being the majority of the area is forested, strong traditional agroforestry base and indigenous SWC measures in the watershed. About 17% of the farmers accepted moderate soil erosion in all ecological zones where intensive cultivation is practised. Only 15-19% of the farmers have reported high to extreme soil loss in the fields, because of landslides, rills and gully formation and terrace failure in the fields.

Chapter 5 deals with soil, water and nutrient conservation practices and their respective cost-benefit analysis. Data obtained through questionnaire survey revealed that majority of the respondent families in the watershed are the nuclear and average size of the households is 4. Majority of the house are constructed with pakka material while wooden houses are mostly found in higher ecological zones, kaccha and mixed material houses were also observed during the survey in the higher ecological zone. The average numbers of rooms in the houses are 3. About 47% of the respondent farmers in all ecological zones are marginal with less than 0.5 ha of land. Farmers with medium size land holdings are 30% in all ecological zones while large landholding farmers were 18% in lower ecological zone and 25% in middle and higher ecological zones.

Several traditional SWC techniques are being practised in the watershed. Due to mountainous topography, these practices are essential to conserve water and minimise soil erosion. Apart from the soil and water conservation, these practices are also related to the livelihood of local farmers as agriculture is their primary source of income. Soil erosion is prevented by several mechanical, biological, agronomic and soil fertility management practices in the watershed. Terracing, contour bunding, crop rotation, mulching, agroforestry, conservation tillage are examples of these. All the conservation practices are largely determined by their construction and maintenance cost, availability of labours and resources, Slope of the area, Stability, lifetime period and production increasing capacity. Cost-benefit analysis of major indigenous SWC practices was also performed to assess the financial efficiency in the Rani Khola watershed. The analysis was carried out at farm level involving farmer's perspective on profitability because the impact of SWC measures is highly site-specific. The present analysis also evaluates the 'value' of each SWC practices by determining its net present value (NPV) and internal rate of return (IRR), which consists of the analysis of time horizon and the discount rate of the various SWC practices. A sensitivity analysis of the discount rates is also carried out for major SWC practices was also carried out to understand the feasibility of implementation.

The SWC practices in the watershed are economically beneficial results indicate that vegetative barriers, mixed cropping and agroforestry are financially more beneficial and fetched good returns to the farmers. Terrace cultivation with paddy as a major crop gives lower revenue on newly constructed terraces; however, after two years of initial investments higher returns are achieved and most preferred by the farmers of the watershed. Majority of the mechanical measures last longer and gives higher returns in the long term as compared to agronomic and biological measures. The payback period of biological and agronomic measures is less and higher revenue can be generated if the right combination of crops is given preference

During the field survey and focus group discussion farmers were asked about the environmental and economic sustainability of the SWC practices along with its social viability. Farmer's perception of environmental sustainability was largely determined by the effectiveness of SWC practice to reduce erosion while economic sustainability was largely based on higher production with minimum maintenance and labour cost. Indigenous knowledge of farmers in the watershed is effective for reducing soil erosion and improving the management of soil and water resources to fulfil the increasing demand for food. These practices are not only beneficial for maintaining natural resources, but they also provide higher yields which further increases the resilience of marginal farmers to fight problems like poverty and climate change. It helps them provide better livelihood opportunity using locally available resources.

Conservation practices which may seem financially beneficial to the farmers may not be sustainable and good for a long run while mechanical measure which is suggested by the farmers as costly, lasts longer and maintains the productivity level of the soil. SWC practices such as vegetative barriers, crop rotation and farmyard manure are practised by 100% of the farmers in the watershed while fallowing 17.6%, alley cropping 28.6% and crop residue burning 34.6% is minimum practised SWC practices of the watershed. In recent years due to various government programs, farmers have shifted towards greenhouses based horticulture, floriculture as it allows them to grow several cash crops throughout the year.

All the conservation practices reported by farmers in the watershed were based on different physiographic, financial and local conditions, as reported by the farmers mechanical measures used by farmers are for long term but also costly in maintenance on the other hand agronomic measure are seasonal and does not require much input cost, therefore practicing mechanical measures without incorporating biological, agronomical and soil fertility management practices cannot implement effective soil erosion control in hilly areas. Biological and agronomical measures are more beneficial to farmers in terms of finances as compared to mechanical measures, both biological and agronomical measures focus on increased productivity with a verity of crops throughout the year as a result of mixed cropping, crop rotation and agroforestry

Finally, chapter 6 provides insight on challenges and strategies for sustainable resource management in the study watershed. This chapter presents an analysis of the challenges faced by the farmers and potential sustainable strategy for their management. Farmers are well aware of the existing problems, as reflected in the questionnaire survey, field observation and focus group discussions. Majority of the farmers in the watershed are practising subsistence farming due to small landholdings and less productivity. Use of chemical fertilizers is banned in the Sikkim since 2005, and the state is using organic manure to sustain the production. But it has been identified that per hectare production of crops is comparatively low. The state is food-deficient and the requirement is fulfilled by import from neighbouring states. Due to this, the pressure on agricultural land is increasing to meet the increasing demand for food. Assessing the degradation in the watershed, landslides, mass wasting, slope or terrace failure, rill erosion, sheet erosion, river bank expansion are most prominent. Soil erosion is highest during monsoon season when runoff is high, and torrential rainfall lasts for many days. Taking into consideration the agricultural sector sheet erosion, formation of rills and gullies, slope failure, are the existing types of land degradation reported by the farmers, Apart from the problem of soil erosion which affects the overall yielding capacity of soil several other challenges are also confronted by them. These problems directly or indirectly affect the agricultural production and livelihood of the farmers in the long run. Various challenges faced by farmers are grouped into three major categories such as environmental challenges, socio-economic challenges and agronomic challenges. The environmental challenges include climatic challenges such as erratic rainfall, cold wave;

hailstorm, frost and other include water scarcity, loss of soil due to landslides, pollution caused by emerging industries. The socio-economic challenges include small and fragmented land holdings, existing poverty, higher investment cost, lack of alternative source of income while, the agronomic challenges include the problems related to cultivation and production such as soil erosion, low production, pests and disease, human-wildlife conflict and loss of indigenous knowledge system.

Majority of the farmers are practising various indigenous conversation techniques based on their socio-economic status and local physiographic conditions. However, there are some sustainable opportunities and potentials to minimise the impact of the problem of soil erosion, water scarcity and poverty by supporting innovative farming systems. If these innovative solutions are employed correctly such as the construction of more reverse sloping terraces to reduce soil erosion, investing in greenhouse/polyhouse based horticulture, floriculture for short term benefits whereas cardamom and mandarin based agroforestry may fetch long term sustainable benefits. These benefits can further strengthen by using an improved variety of seeds for higher production, constructing rainwater harvesting structures, preparation and production of more FYM, use of terrace gravity flow to collect livestock urine as well as the improved implication of existing state agricultural policies.

Various national and state level programmes to strengthen the food security, water availability and agricultural sustainability through horticulture and agroforestry have been introduced in last few decades such as Horticulture Mission for northeast and Himalayan States (HMNEH) 2001, National Bamboo Mission 2007, Sikkim Organic State Mission 2005, National Mission on Medicinal Plants (NMMP) 2009, National Food Security Mission 2007 (NFSM), Sikkim Dairy Mission 2009-2012, Sikkim Poultry Mission 2009-2012. Majority of these programmes have worked on the cluster demonstration, seed distribution, distribution of equipment, providing seed storage facility, increase fodder growth, season based training and to increase awareness. To conserve water in the region state policy such as Dhara Vikas Yojna has worked in reviving springs and streams that provide drinking water to over 80% of the state's rural households by involving villagers. Existing agricultural policies in the state have helped to support the sustainable agricultural approach.

It is the impact of traditional knowledge of farmers and state policies that the dense forest cover in the watershed has increased by 41.76 km^2 from 1988 to 2017 as indicated by the LULC analysis. We expect to see more policies and programmes that aim to provide direct benefits to marginal and medium scale farmers through high yielding seed variety, awareness programmes, floriculture and horticulture promotion programmes for small scale farmers. In planning and policies, we also expect to see more emphasis placed on cropping systems which will not only serve to reduce erosion but which will also lead to increased production, reduced costs and will more frequently encourage people to manage their land more sustainably.