Template/Pro forma for Submission

NMHS-Himalayan Institutional Project Grant

NMHS-FINAL TECHNICAL REPORT (FTR)

Demand-Driven Action Research and Demonstrations

NMHS Reference No.:	NMHS-2017/MG-04/480

Date of Submission:	2	5	0	4	2	0	2	3
	d	**d**	**m**	**m**	**y**	**y**	**y**	**y**

PROJECT TITLE (IN CAPITAL)

ENHANCEMENT OF THE QUALITY OF LIVELIHOOD OPPORTUNITIES AND RESILIENCE FOR THE PEOPLE IN THE INDIAN HIMALAYAS, THROUGH DESIGN OF INTERVENTION STRATEGIES AIMED AT MAXIMIZING RESOURCE POTENTIAL AND MINIMIZING RISKS IN URBAN-RURAL ECOSYSTEM

Project Duration: *from* (**22-12-2017**) *to* (**30-11-2021**).

***Submitted to*:**
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***Submitted by*:**
[*Dr K V Ramesh*]
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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, GBP NIHE 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, GBP NIHE 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	Letter of Head of Institution/Department confirming Transfer of Equipment Purchased under the Project to the Institution/Department
Annexure VI	**Details, Declaration and Refund of any Unspent Balance transferred through Real-Time Gross System (RTGS) in favor of NMHS GIA General**

NMHS-Final Technical Report (FTR) *template*

Demand-Driven Action Research Project

DSL: Date of Sanction Letter

2	2	1	2	**2**	**0**	**1**	**7**
d	d	m	m	y	y	y	y

DPC: Date of Project Completion

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

Part A: Project Summary Report

1. Project Description

i.	Project Reference No.	NMHS-2017/MG-04/480					
ii.	Type of Project	Small Grant		Medium Grant	√	Large Grant	
iii.	Project Title	**Enhancement of the quality of livelihood opportunities and resilience for the people in the Indian Himalayas, through Design of Intervention strategies aimed at maximizing resource potential and minimizing Risks in urban-rural ecosystem**					
iv.	State under which Project is Sanctioned	**Uttarakhand and Jammu &Kashmir**					
v.	Project Sites (IHR States covered) (Maps to be attached)	Upper Jhelum basin, Kashmir region (Srinagar, Pampore, Bijbehara, Khudwani and Gopalpora). **Annexure A**					
vi.	Scale of Project Operation	Local		Regional	√	Pan-Himalayan	
vii.	Total Budget/ Outlay of the Project	**2.424204** (in Cr)					
viii.	Lead Agency	CSIR Fourth Paradigm Institute, Bangalore.					
	Principal Investigator (PI)	Dr. K V Ramesh, Senior Principal scientist, CSIR 4PI, Bangalore					
	Co-Principal Investigator (Co-PI)	Prof Shakil Ahmad Romshoo, University of Kashmir Dr. V Rakesh, Senior Principal scientist, CSIR 4PI, Bangalore Shri Ranjan Joshi, Sc D, GBPNIHESD					

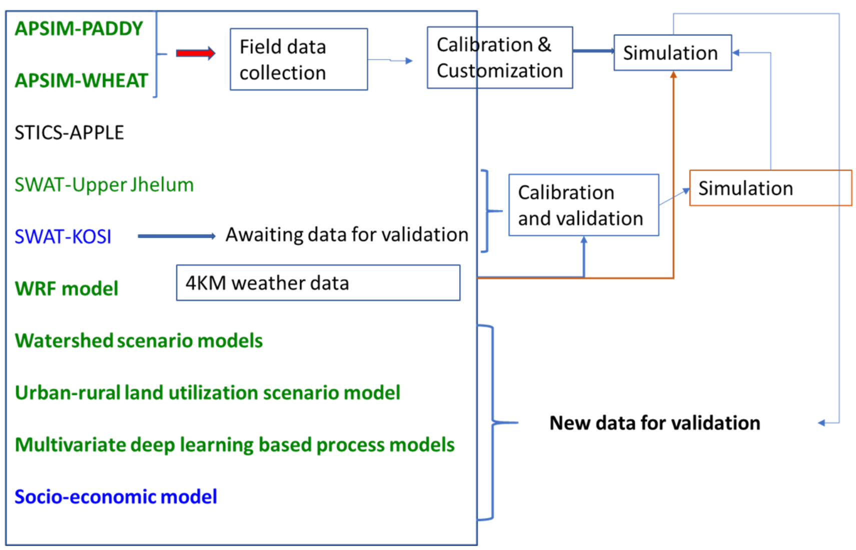
ix.	Project Implementing Partners	CSIR- Fourth Paradigm Institute (CSIR 4PI), NAL Belur Campus, Bangalore-560 037, India for developing system dynamical models and an integrated decision support system (DSS) for assessing policy management options for a sustainable ecosystem and enhanced livelihood for selected habitats of Jammu & Kashmir and Uttarakhand. Prof Shakil Ahmad Romshoo of Department of Earth Sciences, Hazratbal, Srinagar Kashmir, India-190006 for collecting ground truth and conducting survey related research and development component of Jammu & Kashmir in coordination with CSIR-4PI.G.B. Pant National Institute of Himalayan Environment & Sustainable Development (GBPNIHESD) for collecting ground truth and conducting survey related research and development component of Uttarakhand urban-rural ecosystem in coordination with CSIR-4PI.
	Key Persons / Point of Contacts with Contact Details, Ph. No, E-mail	PI: Dr. KV Ramesh, Senior Principal scientist, CSIR 4PI, Bangalore, Ph.No.: 080-25051351; Email: ramesh@csir4pi.in Co-PI: Dr V Rakesh, Senior Principal Scientist, CSIR 4PI, Bangalore, Ph.No: 080-25051358, Email: rakesh@csir4pi.in Co-PI: Prof. Shakil Ahmad Romshoo, University of Kashmir, J&K- Ph.No.: 9419010924; Email: shakilrom@uok.edu.in Co-PI: Shri Ranjan Joshi, Sc D, GBPNIHESD

2. Project Outcomes

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

The traditional urban-rural ecosystem of Uttarakhand and most of Indian Himalayan Region comprised of small townships surrounded by a number of villages which formed symbiotic system where rural areas catered to the urban demands of food items & labour, and urban areas provided the livelihood opportunities in education, health, transport, business and construction activities. The main economic activities of the people in Jammu and Kashmir are limited to agriculture, animal rearing, trade and recently, tourism Nowadays, mountain agriculture is in a phase of transition from traditional methods of cultivation to a more intensive, demand driven system. With passage of time, under the influence of socio-economic/ developmental changes, technological/ environmental constraints, climate change and market forces, this arrangement was disrupted resulting in livelihood crises forcing outmigration from hills and gradual breakdown of traditional livelihood systems and practices, predominantly affecting the livelihoods in rural areas. This study envisages to enhance the quality of livelihood by use of system dynamical modeling thru - i) Development/ Identification of strategies for resilient and sustainable of urban-rural ecosystem for enhanced quality of livelihood ii) Fine tuning of Human-NRM strategies for benefit maximization and improved carbon efficiency, iii) Policy options for better quality of life. Household survey, FDGs and specific PRA consultations were used for primary data collection and relevant information from secondary sources were also collected. Integrated modelling approach as shown below is developed for better understanding of the ecosystem

CUSTOMIZATION OF DYNAMICAL MODELS, CONSTRUCTION OF PROCESS MODELS, VALIDATION OF MODELS, SYNTHESIS OF SDM



The results reveal considerable increase in non-workers population due to decrease in number of marginal workers, contributed mainly by divergence, abandonment and lack of new participation in agriculture over the traditional mainstay of rural areas. The labor shortage, water scarcity/ shift in rainfall pattern, and crop invasion by wildlife are the major problems of agriculture, and absence of farmers' co-operatives/ marketing corporations, cold storage/ ripening chamber facilities, and certification/branding/packaging of local organic products are major issues affecting the horticultural performance in the region. From Socioeconomic survey along with modelling of Upper Jhelum Basin, show that people are converting their lands from agriculture to horticulture and this change is due to economic consideration but in some places, the land system change has occurred due to the depleting streamflow under changing climate.

The protection and encouragement of participation in agriculture through incentives/ technology support/ payments in line with PES, financial support as substitution to migrants' remittances/ livelihood diversification at village level, provisioning of cold storage/ warehouse/food processing units at community/ village cluster level, better community organization/ participation, community led market organizations, and soft loans for pre/post-harvest operations are some of the recommendations.

2.2. Objective-wise Major Achievements

S. No.	Objectives	Major achievements (in bullets points)
1	Development of strategies for resilient and sustainable urban-rural-ecosystems to enhance sustained quality of livelihood of people in *two representative Habitats over* the Indian Himalayas (one each from Jammu & Kashmir and Uttarakhand).	Trends of change in livelihood scenario were investigated in terms of changes - in occupation structure in Almora district, sectoral contribution to GSDP of Uttarakhand state for macro picture, and in terms of 5 capital assets i.e. Natural, Physical, Social, Human, and Financial Capitals for an understanding of current situation and strategy development; the scenario reveals – 1. Decline in contribution of Primary Sector from 40.10% in 1993-94% to 11.33% in 2019-20, and increase in total contribution of Secondary & Tertiary Sector from 59.90% to 88.67% for the same period. 2. Dip in contribution of agriculture to GSDP from 33.84% (1993-94) to 8.24% (2019-20), and increase in contribution of manufacturing from 14.19% to 34.33% and 'Trade, Hotels & Restra' 7.76% to 16.81%; suggesting switch in livelihood dependence from rural to urban pockets. 3. Comparison of occupation structure for Almora district for periods 1961 and 2011, shows decline in number of Cultivators as percent of total population from 35.23% in 1961 to 21.23% in 2011, and Marginal Workers from 37.52% to 15.60% which is quite significant. The category 'Non-Workers' shows a change from 18.15% to 52.10% equalling an increase from 70,000 to 3,25,000, while 'other workers' a domain of urban areas shows a rise from 8.50% to 9.99% i.e. from 32,798 to 62,201 persons; suggesting rising unemployment & declining rural employment, and an Increase livelihood opportunity in secondary sector in urban areas. 4. The data for gross sown and net sown area of Almora district, and production & productivity of major crops i.e. potato, wheat and total grains (including pulses) were compiled for the period 2002-03 to 2016-17, shows a decline for all which corroborates the findings relating to declining state of agriculture and dependent livelihoods. 5. In total 283 responses of different people like Literate/ Illiterate views, Economic Status Views, Gender based views and Age based views were collected from Anantnag, Shopian, Lidder Valley, Kulgam, Pampore and Srinagar.

2.	Test and validate the intervention strategies through development of a system dynamical model to enhance Livelihood of the selected Himalayan Habitats.	1.The above results revealed the agriculture & rural livelihood suffered the most, therefore a survey of 404 households was carried out in 36 villages, and a database on 5- capital assets (Natural, Physical, Human, Social & Financial capitals) 2. Hydrological model simulation is done for 1979-2019 for KOSI and upper Jhelum basin River basin. 3. APSIM wheat simulations complete, 4. APSIM paddy simulation 5. Multivariate deep learning-based process models are developed 6. LULC is being prepared for estimating for variability and trend (both annual and seasonal timescales) 7. High resolution WRF – canopy model is customized for Kosi and upper Jhelum region simulations are complete. 8. Crop phenology estimation for 2002-2020 is complete 9. DFIDs' Livelihood capital assessment for development of strategies (36 villages surveyed, N=403). 10. Participatory CLD (Causal Loop Diagram) – to map the cause and effect relation of the system component. **11.** Fuzzy cognitive Modelling: Functioning of livelihood system- Identification of overriding factors affecting rural livelihood system. **Its dynamics and validation need further investigation by using drone surveys, the work could not be carried out due to pandemic restrictions and resurgence.**
3.	Enhancement of human-natural resources management to achieve environmental and economic benefits whilst minimizing their carbon footprint	1.Input-output data was collected in joint surveys 2. Some practices of traditional of upland/ rainfed agriculture like fallow management, and crop rotation combinations etc. were documented 3. The problems of agriculture and horticulture etc. were identified by using pairwise rank matrix tool, for possible suggestions for enhanced human-natural resource management. 4. Value chain on marketing of horticultural crops crops were mapped & recommendations were derived. 5. Samples/ measurements on crop phenology/ plant growth, soil & grain samples from crop fields wheat/ paddy
4.	To provide policy options to achieve better quality of life for the selected Habitats and their prototypes in a sustained manner.	A few policy points based on the change in livelihood scenario & DFID's livelihood vulnerability framework survey results as pointed out in S.Nos. 1, 2 & 3(4) were deduced for validation by SDM models.

5.	Capacity and awareness building through stake holder interactions and design of viable intervention strategies for decision making and implementation that is also informed by the specificities of their traditional lifestyle.	1. To identify training and capacity building needs, responses of 20 groups of farmers each comprising 6-8 farmers of 6 villages, on 5 broad categories such as Production, Technological Support, Marketing, Policy Awareness, and Institutional Support were obtained, which revealed production enhancement, technological know-how, marketing as their major, training and capacity building preferences/ areas. 2. The various choices under each of these categories identified through group consultations were ranked based on the responses of survey of 24 groups, conducted in 9 villages. The results show that – A. on-farm quality seed production and breeding, and cultivation of off-season vegetable production under various production structures as major priority under production enhancement. B. Technologies for soil reclamation, and prevention of weed dispersal and invasion of alien species were reckoned as major preferences under Technological support category. C. Creation of FPOs & SHGs for better marketing network, and trainings on storage techniques and shelf live improvement were amongst the major preferences.

2.3. Outputs in terms of Quantifiable Deliverables*

S. No.	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations made, if any, & Reason thereof:
1.	Database of socio-economic (health, income, etc.), environmental, crop-vegetation and soil database for 3 years;	No. of New Database/ Datasets generated on the identified dynamics (No.); No. of Baseline surveys performed	PRA (total 8) and From Socioeconomic survey 283 samples in UJB and surveys 404 in Almora Demographic Profile of the study area- **1961-2011** Compilation of occupational trend- **1961-2011** Sectoral contribution to GSDP at factor cost in Uttarakhand- **1993-2020** Trend of Production/ Productivity of	

			major food crops- **1984-2017** Net/Gross Sown Area of the region- **2002-2017** Trend of Land Holding size and classes- **2000-2011** Soil and crop phenology data was collected from the three experimental sites for Paddy and Wheat crop. Value chain Analysis. Documentation of traditional cropping system. Data base development of 404 HHs from 36 villages survey for analysis of Livelihood vulnerability assessment. 250m resolution 8day NDVI & EVI data for the period 2002-2020 Remote sensing-based images from Landsat 1-5, 8 & Sentinel 2 images with less than 50% cloud cover is organized to estimate system variables 500m 16day leaf area index data for the period 2002-2020 Field data collection: 26 stream measurements, collected 120 soil samples and located 8 springs. Apart from this, 3000+ Leaf Area Index (LAI) readings, 530+ leaf properties, 124 Soil Moisture Sensor measurements and 124 W.E.T sensor measurements were taken. **Field Experiments** – Five villages- Sunoli, Dotiyal Gaon, and Mahat Gaon for wheat crop in Kosi watershed (ii) Collection and analysis of **1491 Soil** and **50 water** samples from Upper Jhelum Basin have been	

			carried out. Input data sets are prepared for the period 1979-2018 at 0.1-degree resolution Input data at 4km is under process for 2001-2016 Crop vegetation monitoring of phenology are being carried out for Wheat and Apple crop for the period 2002-2019.	
2.	Development of integrated System Dynamical model to test the behavioural response of Himalayan communities and specific ecosystem elements to different Socio-economic and environmental stresses;	No. of New Models tested/ validated	Hydrological model simulation is done for 1979-2019 for KOSI and upper Jhelum basin River basin. APSIM wheat simulations complete, APSIM paddy simulation Multivariate deep learning-based process models are developed LULC is being prepared for estimating for variability and trend (both annual and seasonal timescales) Deep learning-based LAI estimation model developed High resolution WRF – canopy model is customized for Kosi and upper Jhelum region simulations are complete. Crop phenology estimation for 2002-2020 is complete DFIDs' Livelihood capital assessment for development of strategies (36 villages surveyed, N=403). Participatory CLD (Causal Loop Diagram) – to map the cause and effect relation of the system component. Fuzzy cognitive Modelling: Functioning of livelihood system-	

			Identification of overriding factors affecting rural livelihood system.	
3.	Developing a decision support system by integrating SDM on GIS platform driven by the observed field and survey data related to various processes and phenomena for 3 main commercial crops in 3 states.	No. of Decision-support System developed for No. of Commercial Crops in IHR States; No. of Policy Guidelines and Legislative Mechanisms: Prepared and/ or Communicated; Publications and knowledge products (Nos.).	1. Rakesh V and K V Ramesh (2023), Leaf Area Index estimation over the Kosi Watershed in Central Himalaya from Sentinel-2 using Machine/Deep Learning Models and validation against in-situ measurements, International Journal of Applied Earth Observation and Geoinformation (under review) 2. Kiran Kumar V., K.V. Ramesh and V. Rakesh (2022), Optimizing LSTM and Bi-LSTM models for multivariate time series prediction and performance comparison with classical statistical models, Applied Intelligence (Under review) 3. Venkatesh Gowda P, Ramesh K V and V Rakesh, (2022) Improved learning by using a modified activation function of a Convolutional Neural Network in image. Expert systems with applications (Under review) 4. Romshoo, S. A., Yousuf, A., Altaf, S., & Amin, M. (2021). Evaluation of Various DEMs for Quantifying Soil Erosion Under Changing Land Use and Land Cover in the Himalaya. Front. Earth Sci, 9, 782128. 5. Rakesh V, K V Ramesh and EVS Prakasa Rao. “An Assessment of Potential Economic Gain from Weather Forecast Based Irrigation Scheduling for Marginal Farmers, Agricultural Sciences, 12(5), 503-612, 2021. 6. KV Ramesh, V Rakesh, EVSP Rao, Application of big data analytics and artificial intelligence in agronomic research, Indian Journal of Agronomy 65 (4), 383-395, 2021 7. Marndi, Ashapurna, K. V. Ramesh, and G. K. Patra. "Crop production estimation using deep learning technique." Current Science 121.8 (2021): 1073-1079. 8. Ipsita P, Rakesh V, Randhir Singh and G N Mohapatra, (2023) Impact of Urban Land Use representation in WRF model on short range forecasts during the pre-monsoon and monsoon seasons in India, Urban Climate (Under Review) 9. Purwar, S., Rakesh, V., Bankar, A., & Mohapatra, G. N. (2022). Relationship of height and intensity of Low-Level Jet stream with Indian summer monsoon rainfall. Theoretical and Applied Climatology, https://doi.org/10.1007/s00704-022-04301-3. 10. Singh, R., Rakesh, V. & Varma, A.K. (2022)	

			Association of winter vegetation activity across the indo-gangetic plain with the subsequent Indian summer monsoon rainfall. Climate Dynamics (2022). https://doi.org/10.1007/s00382-022-06426-7 11. Mohapatra, G., Rakesh, V., Purwar, S., & Dimri, A. P. (2021). Spatio-temporal rainfall variability over different meteorological subdivisions in India: analysis using different machine learning techniques. Theoretical and Applied Climatology, 145(1), 673-686. 12. A Johny, KV Ramesh, Equatorial Indian Ocean Response during Extreme Indian Summer Monsoon Years Using Reliable CMIP5 Models Ocean Science Journal, 17-31, 2020 13. A Johny, KV Ramesh, Developing reliable climate projections for the continental monsoon Regions, Journal of Climate Change 5 (2), 51-71, 2019 Capacity building and training need identification surveys/ FGDs -	

(*) 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/ Attachment
1.	New Methodology developed	2	Deep learning classification algorithm Deep learning based model for crop yield

S. No.	Particulars	Number/ Brief Details	Remarks/ Attachment
2.	New Models/ Process/ Strategy developed	1. APSIM-PADDY 2. APSIM-WHEAT 3. STICS-APPLE 4. SWAT-upper Jhelum and KOSI 5. High resolution WRF – canopy model 6. LSTM and Bi-LSTM models: crop production 7. LAI estimation-Upper Jhelum and Kosi 8. Fuzzy cognitive Modelling 9. Watershed Scenario models 10. Socio-economic Model	
3.	New Species identified	-	

S. No.	Particulars	Number/ Brief Details	Remarks/ Attachment
4.	New Database established	1. Primary data set based on DFID framework 2. Compiled GSDP data of Uttarakhand (1993-94 to 2019-20) 3. Field data collection: 26 stream measurements, collected 120 soil samples and located 8 springs. Apart from this, 3000+ Leaf Area Index (LAI) readings, 530+ leaf properties, 124 Soil Moisture Sensor measurements and 124 W.E.T sensor measurements were taken. 4. Collection and analysis of **1491 Soil** and **50 water** samples from Upper Jhelum Basin have been carried out. 5. Input data sets are prepared for the period 1979-2018 at 0.1-degree resolution climate data 6. Input data at 4km downscaled climate data for 2001-2016	
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		
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)		

4. New Data Generated over the Baseline Data

S. No.	New Data Details	Status of Existing Baseline	Additionality and Utilisation New data

5. Demonstrative Skill Development and Capacity Building/ Manpower Trained

S. No.	Type of Activities	Details with number	Activity Intended for	Participants/Trained			
				SC	**ST**	**Woman**	**Total**
1.	Workshops	1.Stakeholder consultation Workshop -6 1. Inception workshop & review workshop - 4	1a. Problem Consultation 1b.Farm Activities & Input-Output Info 2a. Orientation to Livelihood issues in Rural-Urban set-up 2b. Progress Assessment, survey & Fieldwork schedule			**28**	**183**
2.	On Field Trainings						
3.	Skill Development						
4.	Academic Supports						
	Others (if any)						

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)	Goal 1, 2, 3		
2.	Climate Change/INDC targets	Agriculture and Horticulture problems		
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	Stakeholder consultation at panchayat level	
2.	Govt Departments (Agriculture/ Forest)	Agriculture and Horticultural departments	
3.	Villagers	PRA workshop at selected villages	
4.	SC Community		
5.	ST Community		
6.	Women Group		
	Others (if any)		

8. Financial Summary (Cumulative)

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.	Plant canopy analyzer	Rs 7,21,740	Continuous data collection for future research
2.	Network attached storage	Rs 11,55,000	Data processing and model simulations
3.	Handheld GPS	Rs 24,990	Continuous data collection for future research
4.	Workstations	Rs. 8,80,598.82	Data processing and model simulations

5.	Automatic Rain Gauges	Rs. 880598.82	Continuous data collection for future research
6.	Handheld Air Temperature and Relative Humidity Sensor With Display Logger	Rs. 66737.34	Continuous data collection for future research
7.	Dc jack(N),Trackpad/Touchpad Keyboard flex cable for Apple Macbook	6726	
8.	Satellite Gsps connection	113601	
9.			

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	*2*	Upper Jhelum basin, Jammu and Kashmir state. Kosi watershed, Kumaun region of Uttarakhand state.
2.	Project Site/ Field Stations Developed	*6*	3 wheat fields (Matela, Sunaula, Dotiyal Gaon) and *3 apple gardens (New theed, Gopal Pora and Bijbehjara)* are geo-tagged for wheat plant growth, yield, phenology, soil nutrient dynamics and field management practice monitoring
3.	New Methods/ Modeling Developed	*10*	*1. APSIM-PADDY* *2. APSIM-WHEAT* *3. STICS-APPLE* *4. SWAT-upper Jhelum and KOSI* *5. High resolution WRF – canopy model* *6. LSTM and Bi-LSTM models: crop production* *7. LAI estimation-Upper Jhelum and Kosi* *8. Fuzzy cognitive Modelling* *9. Watershed Scenario models* *10. Socio-economic Model:*
4.	No. of Trainings arranged	*23*	FGDs for training needs scoping in rural pockets of study area
5.	No of beneficiaries attended trainings		
6.	Scientific Manpower Developed (Phd/M.Sc./JRF/SRF/ RA):	*6*	*JRF/SRF*
7.	SC stakeholders benefited		
8.	ST stakeholders benefited		
9.	Women Empowered		
10.	No of Workshops Arranged along with level of participation	*8*	*6- Stakeholders (4 in Kosi & 1 in Kashmir), 2- Inception (Kosi and Kashmir), Review & Experts consultation (Bangalore)/ Farmers, community representatives, experts, scientists, researchers*
11.	On field Demonstration Models initiated	*4*	Experimental plots for crop

			phenology for paddy & wheat seasons 1919-3 sites, 1920 - 3 sites, 1921-2 sites and apple 1 site
12.	Livelihood Options promoted		*Scoping work for livelihood quality enhancement*
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):	*10*	*Field data collection: 26 stream measurements, collected 120 soil samples and located 8 springs. Apart from this, 3000+ Leaf Area Index (LAI) readings, 530+ leaf properties, 124 Soil Moisture Sensor measurements and 124 W.E.T sensor measurements were taken.* ***Field Experiments** – Five villages- Sunoli, Dotiyal Gaon, and Mahat Gaon for wheat crop in Kosi watershed* *(ii) Collection and analysis of **1491 Soil** and **50 water** samples from Upper Jhelum Basin have been carried out.* *Input data sets are prepared for the period 1979-2018 at 0.1-degree resolution* *Input data at 4km downscaled climate data for 2001-2016* Soil and water analysis data, Satellite images, LULC maps, Agriculture and Horticulture maps
	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:	4	11	30+	

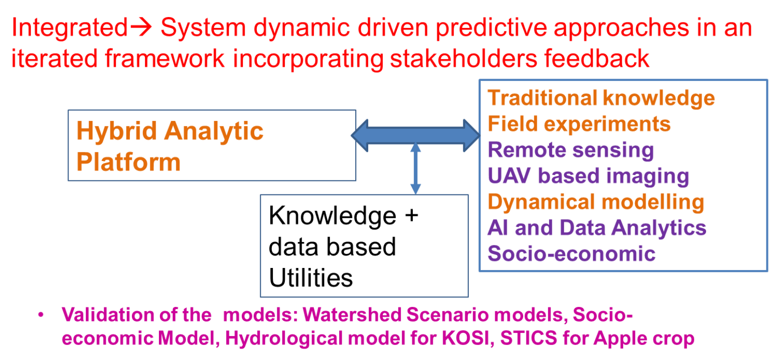
S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
2.	Book Chapter(s)/ Books:				
3.	Technical Reports				
4.	Training Manual (Skill Development/ Capacity Building)				
5.	Papers presented in Conferences/Seminars	10			
6.	Policy Drafts/Papers				
7.	Others:				

* 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	**Potentially insightful knowledge products generated by the project:**
	1. A **versatile digital database** designed to enable seamless abstraction and assimilation of data (environmental, crop, human) for diverse purposes- ready to be shared with NMHS data archives.
	2. Organization of **analytical steps for validation** of models by fusing classical and data analytic approaches
	3. Creation of the following **models* for analysis and synthesis**:
	    1. APSIM-PADDY
	    2. APSIM-WHEAT
	    3. STICS-APPLE
	    4. SWAT-upper Jhelum and KOSI
	    5. High resolution WRF – canopy model
	    6. LSTM and Bi-LSTM models: crop production
	    7. LAI estimation-Upper Jhelum and Kosi
	    8. Fuzzy cognitive Modelling
	    9. Watershed Scenario models
	    10. Socio-economic Model:
	4. Design of **model-based scenarios** for feedback learning from stakeholder interactions
	The findings provide a reflection on the changing livelihood scenario in Almora district**, revealing rising unemployment & declining state of agriculture** which is evident from the decline in - gross/net sown area, number of cultivators, and a considerable drop in percent share of cultivators to the total population contrary to increase in population, and division of families. The macro picture at state level in Uttarakhand as revealed from GSDP data also suggesting decline in percent contribution of primary sector & agriculture in particular also corroborates to this fact. As 90% of the population of Almora district still stays in villages where agriculture is most important sector providing livelihood, therefore, **there is an urgent need to protect & harness agriculture to its full potential.** Hence, some special policy & technology packages are therefore required to protect, promote, and conserve hill agriculture which besides livelihood enhancement would also yield other benefits in the form of conservation of traditional landraces, related indigenous knowledge systems, associated culture/ trades/ handicraft practices, better food and also help in curbing outmigration, evacuation of villages.

Replicability of Project	The study of value chain of horticultural crops i.e. Apple, plum, peach, apricot reveals that these items are marketed & sold through a traditional arrangement wherein the fruit crops from villages is collected & supplied by local agents to regional collection centre/agents, from where these crops are supplied to/ collected by interstate agents. There is a huge difference in the price at which these items are collected from the farmer and at which it is sold at the last point of sale. The farmers owe heavy debt to the regional/ interstate agents who supply them planting material, and loans for labour & packaging etc at high interest rate of 10-12% per season. If we take the cost of the hard work the farmers have to put in production of these crops, there margin very meagre, but nonetheless this activity provides them some cash which they use towards meeting their contingent requirements. Also nearly 20% of the produce remains unutilized as farm waste. Therefore, a farmers' owned value chain or that with greater participation of farmers at all level could perhaps help them in earning better margins, entrepreneurship development and expansion/ scaling-up of horticulture in the region. A soft loan to farmers to meet their production/ packaging expenses will help in reducing their debt burden and becoming debt free. Setting up a food processing centre/cold storage, and community-based production & marketing SHGs/windows can also help in reducing the wastage which will improve farmers' earning, and acceptance of farming as a profession/ enterprise of pride.
Exit Strategy	**Suggestion for Realizing the substantial potential of the knowledge products developed under this project.** To design and development of an **integrated hybrid analytic platform system for sustainable utilization of natural resources to enhance livelihood options** in some select agro-ecosystems of Himalayan region for the identified crops (Wheat, Paddy, apple and millets). 

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(PROJECT PROPONENT/ COORDINATOR)

(Signed and Stamped)

25 APR 2023

(HEAD OF THE INSTITUTION)

(Signed and Stamped)

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Place: Bangalore
Date: 25/04/2023

PART B: PROJECT DETAILED REPORT

1 EXECUTIVE SUMMARY

The "Enhancement of the quality of livelihood opportunities and resilience for the people in the Indian Himalayas, through Design of Intervention strategies aimed at maximizing resource potential and minimizing Risks in urban-rural ecosystem" is a collaborative project between four institutions: CSIR 4PI, Bangalore, University of Kashmir and GBPNIHESD in India. The project was approved in 2018. The traditional urban-rural ecosystem symbiosis which provided livelihood opportunities, through provisioning of demands and supplies of the system, in production, marketing, construction, education, health, etc. was sustained by a system of mutualism and reciprocal relationships evolved spontaneously over a long period of time. In recent decades, under the influence of socio-economic/ developmental changes, technological/environmental constraints, globalization, climate change, and ingress of markets this symbiosis was disturbed resulting in livelihood crises forcing outmigration from hills for jobs and gradual breakdown traditional livelihood systems and practices, predominantly affecting the rural areas. This project seeks to address this problem through application of System Dynamic Modelling and use of machine learning tools in the complex environment of Indian Himalayan Region by - identification and development of Intervention strategies for sustainable and resilient urban-rural ecosystem, testing and validation of these strategies through System dynamical modelling, deriving modeling outputs for efficient pareto-optimal 'human-natural resource management', providing policies for sustained improved quality of life, and capacity and awareness building through stakeholder interactions and strategies compatible to their traditional lifestyle. The project component at GBPNIHE was executed in the urban-rural set-up of Almora town within Kosi-Suyal watershed. The data on occupational category (1961-2011), trends of Gross/Net-Sown area , and production data of important crops, landholding classes etc. was collected from secondary sources, and primary data on socio-economic condition/ livelihood opportunities, DFID capitals indicators/elements, traditional sustainable agriculture practices, agriculture problems, market value chain, and awareness/capacity building needs etc. were collected through household questionnaire survey, FDGs, PRA consultations and informal interviews.

The long-term objective of the project is to generate the Horticulture and Agriculture maps of Upper Jhelum Basin for different time series, collection of the Crop-vegetation / Socioeconomic data, soil data, water sampling data and analysis. For Land system on screen digitization was done on the scale of 1:30000 scale in order to generate the Horticulture and Agriculture maps for year 1981, 1992, 2001, 2013 and 2019. For Land capability classification of Agriculture and Horticulture Weighted overlay analysis method (WOA) in ARC GIS was used to analyse the different parameters that have been assigned suitable knowledge- based weights. A ''Weighted overlay analysis'' (WOA) model was adopted in GIS to assign the class and theme-wise weights for input parameters and the weighted layers were integrated. The effective nine parameters were considered. The class and theme-wise weights were assigned in the model. After assigning of the weights, the nine parameters were integrated and the final map was generated. For Crop vegetation survey two different orchards in different watersheds were selected to generate the database for Crop yield monitoring, phenology, soil property and management practices and all these parameters were measured during the dormant stage, crop season and harvesting season in 2019 and 2020. Thirty-two sampling sites were selected to analyse 11 Water sampling Parameters these sites were taken along the length of the river for physicochemical analysis. Before collecting the water samples, all the sample bottles were washed with distilled water. For Socioeconomic Survey Questionnaire (RPA) was generated in order to better understand and assess perceptions, capacities and activities related to Climate Change impacts on crops, crop behavior and relevant adaptation policies/measures.

The General Livelihood Scenario, Rural Livelihood Vulnerability on DFID Framework, documentation of Fallow Management and related Crop combinations, and Mapping Value Chain of Marketed Horticulture Crops, agricultural problems and capacity building needs were studied. The results reveal considerable increase in the 'Non-Workers' population hence unemployment mainly contributed by decline in number of marginal workers and most importantly due to divergence, abandonment, and absence of new participation in agriculture as a livelihood activity. The results at state level as evident from the trends of contribution of agriculture to GSDP also testify to this fact, underlining the need for protection of agriculture through incentives, technology support, or some payments to people practicing agriculture. The growth of secondary and tertiary sectors in the study region appears very slow compared to that at state level, therefore there is a need to give it a push through livelihood diversification and promotion of tourism, industries/ land-use compatible to the hill environments.

The analyses of rural livelihood suggest requirement of special focus of strategies for strengthening of social and natural capitals which lie in the unsustainable range, and financial capital which shows limited sustainability. Efforts/ strategies are also required towards improving Physical and Human capitals to bring them from sustainable to progressively sustainable range. The focused efforts should be directed towards provisioning/ promotion/ enhancement of micro-irrigation, irrigation water, protected cultivation, crop and health insurance, community association/ participation, cultivation of fruit crops, cold storage/ seed bank, livelihood diversification/ alternative livelihoods, and migrant remittances/ financial support.

The modeling of DFID data on FCM shows outmigration, herd size, and net sown area as the major overriding factors affecting the livelihood in rural areas and therefore should be the intervention/ policy focus for livelihood sustainability. Migration which creates labor shortage for agriculture activities, also support livelihood through the remittances to migrant's families/ relatives. An alternative provisioning for these remittances through livelihood diversification or financial support can help in improving the situation. Simulations show better livelihood response for upland rural pockets for reduced migration and increased herd-size in valley areas. The Fallow Management for soil recovery and fertility management, is documented for its traditional knowledge, and as a resilient human-NRM adaptation against climate change. The labor shortage, water scarcity/ shift in rainfall pattern, and wildlife invasion of crops are the major problems of agriculture, and absence of farmers' co-operatives/ marketing corporations, cold storage/ ripening chamber facilities, and certification/branding/packaging of local organic products are major issues affecting the horticultural activity in the region.

The results showed that in UJB there were significant change in Agriculture and Horticulture during the period from 1981 to 2019. The study has revealed that LULC conversions are taking place which resulted in the decline in spatial extents of agriculture land (220048 ha) increase in horticulture (47085 ha). In this study weights were assigned to nine selected criterias to map the land suitability (LS) for agriculture/horticulture. The results revealed that more than 12° slopes are not considered for agriculture activities. Based on land capability of agriculture/horticulture the study area is grouped into 4 classes highly suitable (covers an area of 11%) moderately suitable (covers an area of 26%), marginally suitable (covers an area of 42%) and not suitable (covers an area of 21%). The database was generated for the selected apple orchard sites for the year 2019, 2020 and also paddy management practice data were also collected from the UJB. The data revealed that the apple production in the year 2019 was less due to the untimely snowfall in the month of November which is the harvesting season for some apple varieties and also witnessed damages to the apple trees. The analysis from the data of two seasons showed that excess rain in the flowering stage of apple also reduced the production of crop. From Socioeconomic survey of Upper Jhelum Basin it is analysed that people are converting their lands from agriculture to horticulture due to the economic benefits and also horticulture needs less water or irrigation. But from past few years the untimely snowfall and change in temperature is declining the quality and quantity of apples and is also becoming a major concern for apple growers.

Potentially insightful knowledge products generated by the project:

1. A versatile digital database designed to enable seamless abstraction and assimilation of data (environmental, crop, human) for diverse purposes- ready to be shared with NMHS data archives.
2. Organization of analytical steps for validation of models by fusing classical and data analytic approaches
3. Creation of the following models* for analysis and synthesis:
    1. APSIM-PADDY
    2. APSIM-WHEAT
    3. STICS-APPLE
    4. SWAT-upper Jhelum and KOSI
    5. High resolution WRF – canopy model
    6. LSTM and Bi-LSTM models: crop production

7. LAI estimation-Upper Jhelum and Kosi
8. Fuzzy cognitive Modelling
9. Watershed Scenario models
10. Socio-economic Model:

4. Design of model-based scenarios for feedback learning from stakeholder interactions

2 INTRODUCTION

2.1 Background of the Project

Himalayan communities are by and large self-reliant, and nature-dependent. They draw their livelihoods mostly from agriculture, horticulture, tourism, and animal husbandry. The traditional Urban-Rural Ecosystem of Himalaya was a closed, compact, and symbiotic system where villages in the vicinity of the small towns catered to urban demands and supplies for food and labor and this created livelihood opportunities in production, marketing, and transport in the Urban-Rural ecosystem. The urban areas provided employment/ job opportunities in education, health, construction, transport, & service sectors and thus a self-sustaining Rural-Urban Ecosystem Environment was maintained. The mutual dependence, small populations, and abundant resources supported this rural-urban ecosystem symbiosis which was sustained by reciprocal human-environment relationship protected by strong traditional institutions that safeguarded the interests of natural and social environment. Later in the face of increasing craze for jobs, outmigration, increased urban proliferation, market intrusions, globalization, climate change, and several other socio-economic reasons this symbiosis was gradually disrupted resulting in threats to livelihood, the system sustainability and resilience. The water scarcity in hills remained a limiting factor for hill agriculture and the topographic barriers stalled its growth, which restricted the rural populace to capitalize on the demands of the increasing urban population and compete with the market forces, adversely affecting the urban-rural transactions and livelihood linkages, and forcing outmigration from the rural to urban areas in the region and outside. The scenario build-up, have implications for rural areas, their agriculture production systems, the agri-biodiversity/traditional landraces, village industries, indigenous/ traditional knowledge base and the dependent livelihood systems. The unplanned growth of urban areas in recent decades resulted in problems of congested settlements, waste, traffic jams, air/water/ noise pollutions, etc. adversely affecting the natural resources, their amenity values and ecosystem services flows; hence, the sustainability and resilience of the system posing a threat to the sustainability of the tourism and associated livelihoods in the region. The outmigration and demographic changes are also resulting in weakening of institutions, environmental degradation, agriculture abandonment, and loss of opportunities in unorganized sectors in urban-rural ecosystem. The emerging situation have negative bearings in terms of contribution of rural sector to the economy, and increased dependence of urban areas on outside supplies, adversely affecting the rural livelihoods. Therefore, there is a need to sustain and conserve the co-existence of

Urban-Rural ecosystems and their concomitant gains through contemplation of suitable strategies and policies that could enhance the livelihood opportunities by harnessing of resource potential and risk minimization. This project seeks to explore these possibilities through use of system dynamical modeling in urban-rural ecosystems of the Himalayan states of Uttarakhand & J&K by analyses of changing livelihood scenario, and the resource and climate dynamics into account.

2.2 Overview of the Major Issues to be Addressed

Analyses of Changing Livelihood Scenario: understanding of the changing livelihood scenario was considered to be the most important factor for knowing the sectoral and occupational change occurring in the region so that prospective promising and problem areas could be identified for development of livelihood enhancement strategies and policy recommendations. In this context for understanding of the changing livelihood scenario at district level (microlevel) the occupational structure data of Almora district from 1961 to 2011 was compiled, and for a macro view and possible generalizations and confirmation of micro-picture/tends, the available data on the contribution of various sectors of economy to Gross State Domestic Product (GSDP) of Uttarakhand states from Niti-Aayog reports and secondary sources was compiled and synthesized. The data on urban and rural population dynamics for the above period was also taken into consideration for relevant conclusions.

Rural Livelihood Assessment through DFID Livelihood Vulnerability Framework: The standard DFID livelihood vulnerability framework which is based on the assessment of 5 – capital assets; namely – Physical Capital, Natural Capital, Human Capital, Social Capital, and Financial Capital was opted for local level livelihood vulnerability assessment of the rural pockets of the study area. The household survey-based asset scores as obtained per this framework and the values of parameters that are used to assign the score of each capital can be useful for identifying the broad areas for sustainable livelihood strategy development, policy solutions, spatial comparisons, intervention cues, and creating factor linkages for system response by use of appropriate modelling applications.

General State of Agriculture and Periodic Observations on Crop phenology and Soil Quality: Nearly 90% of the population of Almora district lives in rural areas where agriculture is main livelihood and subsistence support activity. In last few decades the due to host of socio-economic and developmental reasons and bio-physical constrains people's participation in agricultural activities is declining which is evident in the form of decreasing cultivated area, quantum of crop production, urban encroachment in adjoining rural areas, outmigration to urban areas resulting in deceleration of agricultural growth and diminished livelihood opportunities in the sector and its support activities resulting in livelihood problem in rural areas, affecting the urban-rural sustainability. The growing apathy and divergence from agriculture also have adverse bearings for the crop-biodiversity, associated traditional NRM institutions/ knowledge systems, and agri-enterprise development. Therefore, it was imperative to have an overview of agriculture in the region, its associated problems, and training and capacity building needs for conservation of agriculture, and related livelihood systems. Further, for recording of observations on crop phenology, plant growth, grain quality, etc., from paddy and wheat crop fields and soil samples for soil quality analyses were also arranged for crop productivity assessment, scenario projections and use in System Dynamical models for providing appropriate suggestions for an efficient management.

Documentation of sustainable Agricultural Practices and Market Value Chain Management: The upland agriculture in hills is mainly rainfed type; topography, water scarcity, and lack of mechanization are the main constraints restricting its development and growth. To overcome these challenges the hill communities have evolved some land fertility/ land management practices in the form of fallow management with suitable crop rotations and crop combinations for different field types. The efficacy of such practices/ systems needs to validated for agricultural land-use optimization for maximization of production and livelihood benefits through system dynamical modelling applications. So, to begin, the documentation of such practices was initiated for provide grounds to check modalities of SDM applications. In the review workshop, the study of value chain of agri-products was also emphasized; therefore, the value chain for fruit/ traditional crops supplied for sale from the study region was considered for investigation to suggest appropriate suggestions for improved benefits and better management.

Therefore, in this region of high ecological and social heterogeneity, the task is challenging and demands high interdisciplinary skills and vision to integrate different knowledge guided approaches to design development routes that streamline with environmental concerns in imaginative ways that incorporate the specificities of the Himalayan region. This research proposal is aimed at developing a computer model of specific Himalayan systems wherein the topography, climate variables, natural resources and societal requirements including health are coupled along with their feedback impacts to form a data and knowledge guided tool to optimize the desired variables under current and anticipated conditions of future change. The models would be constructed using actual data describing the land use pattern in the region, its natural resources especially exotic resources whose planned development may be enhanced together with that of human resources, as well as epidemiological factors that impact human health and progressively enriched through new directed surveys to capture the critical factors (tested by relative sensitivities) that determine the coupled human – natural ecosystem of the region. The Himalayan mountain ecosystem, at present, is facing the challenges created due to increasing aridity, warmer winter season, variability in precipitation, and unexpected frosts and storms, which largely affect the entire range of biodiversity, including agriculture and horticulture crops. Low Productivity and crop failures affecting many Himalayan Indigenous farming communities, who are increasingly facing food insecurity, thus increasing migration rate among mountain peoples in search of livelihood. Climate change is known to affect two most important agricultural inputs; water and temperature or agricultural productivity is sensitive to two broad classes of climate-induced effects; i) direct effects from changes in temperature, precipitation, and carbon dioxide concentrations and ii) indirect effects through changes in soil quality and the distribution and frequency of infestation by pests and diseases. Major drivers of climate change i.e. elevated CO_2 levels, increased temperature and depleted soil moisture therefore affect population dynamics of insect-pests and thus significantly enhance the extent of crop losses. The reasons put forth for the same include i) change in frost-thaw cycle, ii) use of fertilizers and pesticides, iii) increase in temperature and iv) less treatment of soil before sowing. There are reports of many exotic weeds invading the traditional rain fed agricultural areas. The changing temperature and precipitation pattern together with decreasing crop rotation and mixed cropping practices have been held responsible for the same. Growing incidences of crop infestation are also attributed to increased use of chemical fertilizers. Therefore, it is necessary to explore all possible ways of increasing the sustainable productivity and carrying capacity of the farming systems in the mountains in order to improve the livelihoods of marginal mountain households.

There is large scale migration of rural population to the urban centers in the Kashmir valley in search of better livelihoods. In absence of any policy, the urban environments are stretched beyond their capacity and thus adversely affecting the utilities and services. The system dynamics approach advocated in this research shall provide the policy and decision makers with a set of instruments to overcome the adverse impacts of migration and urban sprawl and thus improve the quality of livelihoods in the Himalayan regions.

i) The productivity of the saffron, which is a heritage crop in the valley, has shown significant decline during the last few years due to the environmental degradation and climate change observed in the valley. The outcome of various government policy aimed at rejuvenating the saffron production needs to be evaluated using a system dynamics approaches

ii) The massive land system changes, particularly the conversion of paddy to horticulture observed in the Kashmir Himalaya, is affecting various hydrological processes, human health and other sectors. There is need for informed interventions to make this change environmental friendly and sustainable.

2.3 Baseline Data and Project Scope

Himalayan communities are by and large self-reliant, and nature-dependent. They draw their livelihoods mostly from agriculture, horticulture, tourism, and animal husbandry. Varying aspects like altitudes slope and micro-climatic conditions result in considerable variation in temperature and rainfall which eventually lead to very high spatial variability in soil texture, vegetation, and cropping patterns in Himalayan states. Changes in temperature and rainfall in these areas also result in multi-faceted, negative and positive impacts on living organisms. The natural endogenetic and exogenetic forces coupled with human-induced climate change result in increased frequency and magnitude of multiple hazards like avalanches, landslides, earthquakes, flash floods, etc. These natural hazards result in accelerated soil erosion, rain water runoff, siltation and pollution of water bodies, drying up of springs, deforestation and degradation of forests, scarcity of fodder and fuel wood, overgrazing , forest fires, alterations in wildlife habitats and wildlife attacks, low crop yield, increasing wastelands and invasion of alien weeds, eroding biodiversity, shifting cultivation, etc. Most of these problems are interconnected and each of these combines to worsen the situation through positive feedbacks. The increasing shortage of basic resources such as viable cropland size, forests to sustain livestock, water for irrigation and drinking, marginal and rain fed holdings on difficult terrain, low soil fertility and low crop production, vagaries of climate, lack of infrastructure and market for processing and sale of on-farm and off-farm produce make it difficult to sustain the livelihood of the rural people. These factors coupled with other human needs and aspirations such as, better education and health facilities, job opportunities, etc. compel people to migrate and find out other mode of livelihood in the urban areas of the country. The aforementioned vicious cycle of degradation of natural resources and migration add fragility to the Himalayan ecosystem. The once rich heritage of common property recourses (e.g., forests and water) has crumbled and the invaluable indigenous knowledge on livelihood sustenance is dwindling. The expansion of regional townships, turning the prime land for construction is another major concern that has intensified the struggle for land, water and other civic amenities. Establishment of new industries and seasonal tourism has added to new dimensions of air, water and noise pollution in some of the areas. The project aimed at development of strategies for enhancement of quality livelihood opportunities within the urban-rural ecosystem/ set-up, which could be done by way of suggesting better production, marketing strategies by optimal resource allocation so that livelihood benefits are maximized. The project envisaged identification of efficient and resilient strategies/ options, and their validation by using system dynamical modeling. It also proposed to identify the training and capacity building needs for the implementation of identified strategies through sharing of SDM outcomes with stakeholders and provide a decision support by finetuning as per stakeholder's suggestions for different livelihood scenarios. As the livelihood is a very broad area, which needed complex system thinking and a time series data on different aspects of livelihood, therefore initially it limited its scope to agriculture based rural livelihoods which was amenable to system response modeling and where data availability was possible. This choice also depended on traditional dependence of large rural population on this sector.

The following baseline data was compiled and synthesized from secondary sources for achievement of objectives and their sub-elements -

i) Decadal demographic data of Almora district on population from 1961 to 2011 (Census Records) -Annexure I
ii) Data on occupational categories Almora district from 1961 to 2011 (Census Records) – Annexure II
iii) Crop Production data (2002-03 to 2016-17) - Annexure IIIA (District Statistical Handbook/s)
iv) Crop Productivity data (2002-03 to 2016-17) - Annexure IIIB (District Statistical Handbook/s)
v) Gross and Net Sown Area data for Almora district 2002-03 to 2016-17 (Agriculture Census Reports) – Annexure -IV ((District Statistical Handbook/s)
vi) Data on sectoral contribution to GSDP of Uttarakhand state factor cost at current price from 1993-94 to 2019-20 (Estimates of state domestic products of Uttarakhand 1993-94 to 2001-02; 1199-2000 to 2005-06; 2004-05 to 2013-14; 2011-12 to 2020-21PE; Directorate of Economic and Statistics, Govt of Uttarakhand) – Annexure -V
vii) Land Holding size and classes (Almora district)2000-01; 2005-06; & 2010-11 Annexure VI
viii) Fertilizer use Data (Almora district) 1984-85, 1992-93, 1993-94, 2000-01 to 2015-16 Annexure -VII

Therefore, in this region of high ecological and social heterogeneity, the task is challenging and demands high interdisciplinary skills and vision to integrate different knowledge guided approaches to design development routes that streamline with environmental concerns in imaginative ways that incorporate the specificities of the Himalayan region. This research proposal is aimed at developing a computer model of specific Himalayan systems wherein the topography, climate variables, natural resources and societal requirements including health are coupled along with their feedback impacts to form a data and knowledge guided tool to optimize the desired variables under current and anticipated conditions of future change. The models would be constructed using actual data describing the land use pattern in the region, its natural resources especially exotic resources whose planned development may be enhanced together with that of human resources, as well as epidemiological factors that impact human health and progressively enriched through new directed surveys to capture the critical factors (tested by relative sensitivities) that determine the coupled human – natural ecosystem of the region.

2.4 Project Objectives and Target Deliverables

The project has the following specific objectives:

- Development of strategies for resilient and sustainable urban-rural-ecosystems to enhance sustained quality of livelihood of people in two representative Habitats over the Indian Himalayas (one each from Jammu &Kashmir and Uttarakhand).
- Test and validate the intervention strategies through development of a system dynamical model to enhance Livelihood of the selected Himalayan Habitats.
- Enhancement of human-natural resources management to achieve environmental and economic benefits whilst minimizing their carbon footprint
- To provide policy options to achieve better quality of life for the selected Habitats and their prototypes in a sustained manner.

- Capacity and awareness building through stake holder interactions and design of viable intervention strategies for decision making and implementation that is also informed by the specificities of their traditional lifestyle.

3 METHODOLOGIES, STARTEGY AND APPROACH

3.1 Methodologies used for the study

Review of literature, household survey, use of PRA tools, phenological observations on paddy and wheat experimental plots, focused group discussions, and consultations meetings etc., were the common methods used for data and information collection for the study. The DFID Livelihood Vulnerability Framework comprising of 5-capital assets i.e. Physical Capital, Natural Capital, Human Capital, Social Capital, and Financial Capital and capital indicators which has been widely followed as a standard procedure for various livelihood vulnerability studies in different parts of the world (Chena et al., 2013; Rakodi, 1999; Wang et al., 2019; Zenteno et al., 2013) was used for collection of data on vulnerability assessment information and Fuzzy cognitive Modeling (FCM) and VENSIM tools were used for modeling of DFID data for system response.

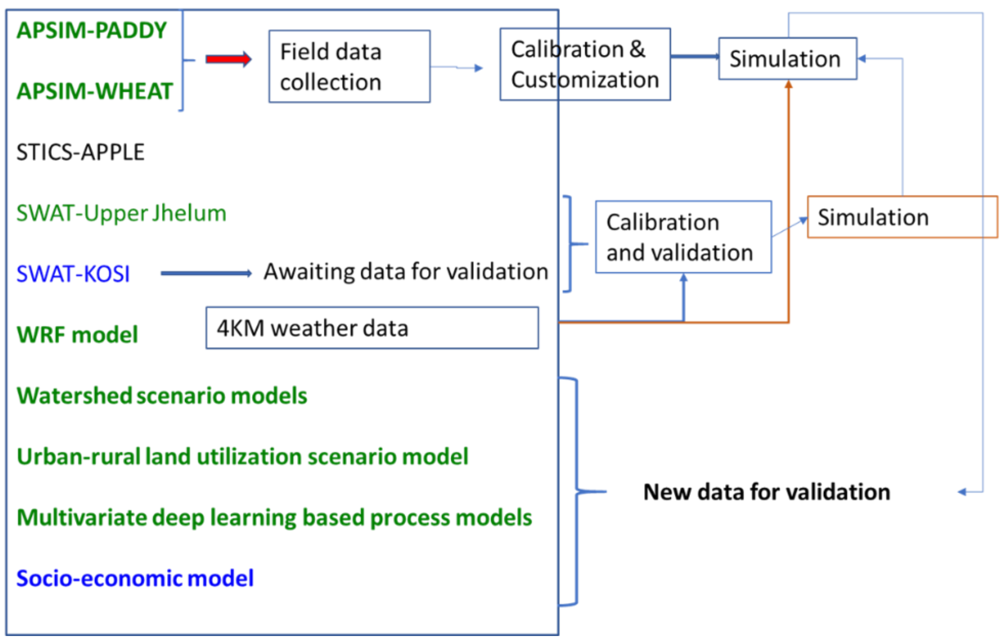
Literature review was done for understanding of typical issues/problems of the agriculture sector in the regions, sustainable practices of crop rotation/ crop combinations for fertility/ fallow management etc. and information was used for preparation of checklists for further investigations. The secondary information on demography, occupational structure, crop production statistics, Gross and Net sown area etc., for Almora district and sectoral contributions to GSDP of Uttarakhand state etc, was compiled from census records, Niti-Aayog, Uttarakhand’s Directorate of economics and Statistics Reports for orientation to changing livelihood situation in the district, general state of agriculture, and a macro view at state level for policy level generalizations.

Household surveys were conducted in 36 villages of the study region in the Kosi-Suyal watershed region in the Almora Town’s Urban- Rural set-up. The purposive random sampling was used for selection of villages to ensure representation of all village types from valley and upland areas. In all, 443 household were surveyed for socio-economic information, livelihood practices/ problems, and information on identified indicators used for assessment of ‘5 asset types’ as per the ‘DFID Livelihood Vulnerability Assessment Framework’ was collected as per the enclosed score scheme **(Annexure- IX**). After scrutiny, information on 404 households was compiled and the livelihood vulnerability/ sustainability of the rural areas based on the ‘obtained DFID score’ was evaluated for identification of broad areas for livelihood enhancement strategies. FGDs/PRA surveys for assessment of problems of agriculture and horticulture sectors etc., were carried out in 8 villages with 8 groups, and that for prioritization of training and capacity building needs FGDs (PRA survey) in 9 villages covering 23 groups; the PRA tools such as Problem Tree, Pairwise Rank Matrix, etc. were used.

Focused Group Discussions/ CLD Consultations at different villages were conducted to develop **Participatory Cause Loop Diagram** linking DFID indicators and capitals as a system component by taking production efficiency as a proxy indicator for livelihood opportunities. The Cause Loop Diagram (CLD) was further refined and modeled by using VENSIM machine learning tool, and the model having 20 components and 34 connections was run in Fuzzy Cognitive Modeling software (FCM package) for 6 iterations to find out the overriding factors affecting livelihood in the rural areas of the region and thereupon to identify/ suggest interventions and appropriate policy actions for sustenance and enhancement of livelihood opportunities. FDGs and were also conducted in villages producing horticultural crops and traditional crops for sale, and reginal agents were also interviewed for mapping of market value chain of these crops.

This study envisages to enhance the quality of livelihood by use of system dynamical modeling thru - i) Development/ Identification of strategies for resilient and sustainable of urban-rural ecosystem for enhanced quality of livelihood ii) Fine tuning of Human-NRM strategies for benefit maximization and improved carbon efficiency , iii) Policy options for better quality of life, Household survey, FDGs and specific PRA consultations were used for primary data collection, and relevant information from secondary sources were collected. Integrated modelling approach shown below to better understanding the ecosystem is shown below:

CUSTOMIZATION OF DYNAMICAL MODELS, CONSTRUCTION OF PROCESS MODELS, VALIDATION OF MODELS, SYNTHESIS OF SDM



3.1.1) Land System Change:

Mapping and identifying land cover/land use and its change is the most important, as well as the most widely researched, topic in remote sensing. Land cover/land use has been used extensively to derive a number of biophysical variables. Mapping land cover/land use accurately and efficiently via remote sensing requires good image classification methods. Unfortunately, there are numerous factors (e.g., image resolution and atmospheric condition) that could affect the effectiveness and accuracy of the classification algorithms. Among the new techniques for land cover/land use classification and change analysis, textural (spatial) analyses are gaining increasing attention from the remote sensing community (e.g., Briggs and Nellis, 1991; Dunn et al., 1991; Estreguil and Lambin, 1996; Frank, 1984; Jupp et al., 1986; Lambin, 1996; Lambin and Strahler, 1994; Pickup and Foran, 1987; Smits and Annoni, 2000; Crews-Meyer, 2002).

For the present study a Landsat MSS 1981, Landsat TM 1992, Landsat ETM 2001, Landsat ETM+ 2013 and Landsat OLI/TIRS image of September month were used as the satellite data source. Then Upper Jhelum Basin as study area was extracted from the images. On screen digitization was done on the scale of 1:30000 scale in order to generate the Horticulture and Agriculture maps of for year 1981, 1992, 2001, 2013 and 2019. Before on screen digitization, processing was done in order to rectify the image. Interpretation of various tones and texture were observed in order to classify the various classes accurately. Using on screen digitization of class Horticulture and Agriculture of 1981, 1992, 2001, 2013 and 2019 were generated. The land use classes were distributed and then area was calculated for Horticulture and Agriculture. Then percentage changes of each land use class were generated then preference was given on the base of highest change and thus categorization was done on the basis of the percentage change.

3.1.2 Land capability Classification

The methodology used in the current study is summarized in Figure 1.the The following algorithm have been used for finding the results

- Selection of related factors or criteria
- The determination of weights or relative significance of all factors based on the opinions of experts
- Weighted overlay analysis (WOA) method used to generate the promising results for agriculture and horticulture land suitability assessment.

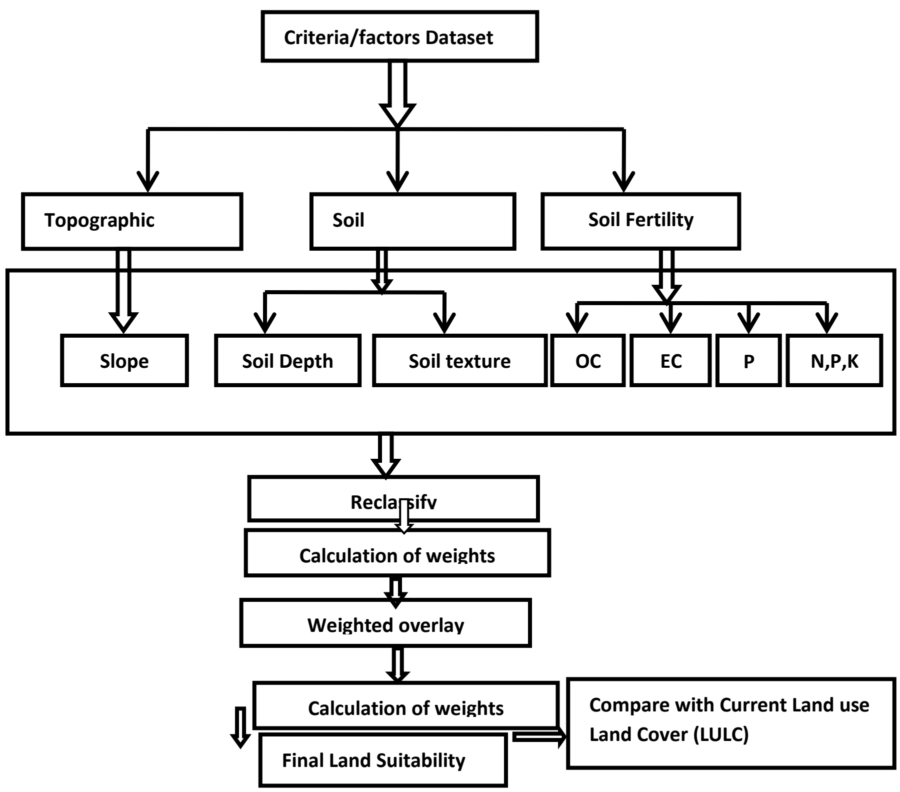


Fig.3 Showing flowchart of Land Capability classification

a) Topographic factors

- Slope

Slope is the important parameter in agricultural practices. It was prepared from STRM satellite data. It was further reclassified as shown in Table 1 and Fig 3; the 0-1 degree of the slope demonstrates the flat zone which is reasonable land for developing agriculture. 1-3 degree of the slope has some Steepness and is respectably reasonable for growing crop. 3–6-degree range of slope is the higher slope where upon it is not appropriate to develop growing crop because of surface run off of the rainfall water.(6–12) degree range as Steep,(12–20) degree range as Very steep The slope analysis is useful to detect the potential sites for agriculture (Bandyo padhyay et al., 2009; Rabia et al., 2013), watershed management (Steiner et al., 2000), afforestation (Bhagat, 2009), etc. The distribution of soil qualities i.e., soil depth, soil texture and availability of nutrients are varied with slopes (Datye and Gupte, 1984). Therefore, local variations in soil nutrients, minerals and agriculture productivity vary with soil depth and slope.

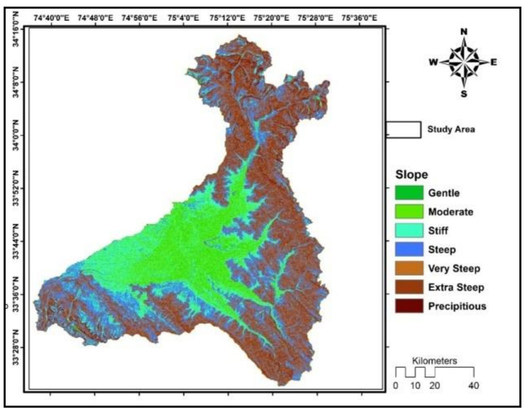


Fig.3.1 Showing spatial distribution of slope.

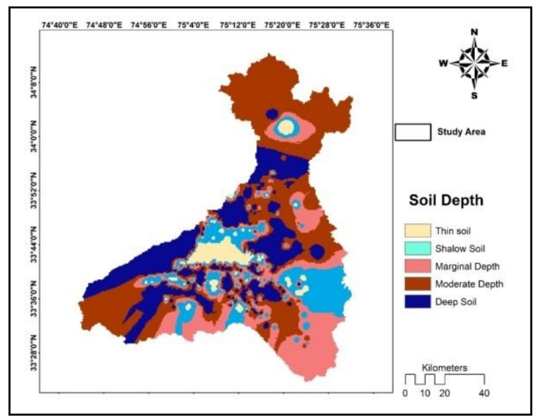


Fig.3.2 Showing spatial distribution of soil depth

b) Soil characteristic

- Soil depth

Fig 4.show the spatial distribution of Soil depth, the soil depth map was prepared from the soil data sets available on Bhuvan – NRSC. And was further reclassified as shown in table1 amongst the different soil characteristics, soil depth plays an important part in determining crop roots growth and the amount of water and air in the soil. Soil depths which are not deep and have lithic contact may restrict root growth, thus creating a suboptimal environment of shallow volume soil which negatively impacts the growth and yield of the crop.

- Soil texture

Soil texture sampling was carried out across the study area Texture is one of the important parameters of soil. Most of the physical characteristics of the soil depend upon texture class. Different texture classes occurred in the study area viz. loam (l), silty loam (sil), sandy loam (sl), sandy clay loam (scl). The spatial variability of soil texture classes is given in Fig.5 Amongst the different textural classification Loam soil sand clay loam soil were found major soil types in the study area.

- Soil organic carbon (OC)

SOC is ideal source of nutrients and plays important role in soil fertility, complex water and nutrient exchange processes in plant root zone and land degradation, SOC prevents plant growth and soil process in different climatic condition and agricultural practices. Soil organic matter varies spatially with natural soil quality and soil management. Therefore, SOC map was prepared using laboratory data and IDW interpolation technique the spatial distribution of OC is shown in Fig. 6.

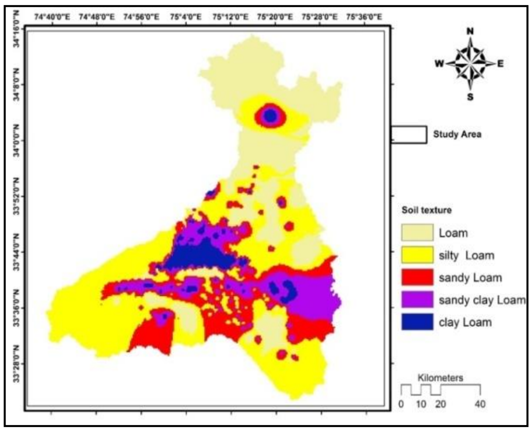


Fig.3.3 Showing spatial distribution of ST

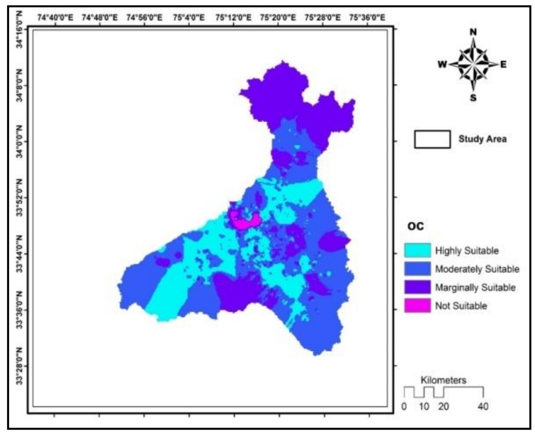


Fig.3.4 Showing spatial distribution of OC

- Soil fertility

Soil fertility refers to the ability of the soil to sustain plant growth fertile soil results in high yield and better quality of plants. Fertile soil is rich in fundamental nutrients, elements and minerals; the field work was carried out Soil samples (1491) were collected from the selected sites across the study area. These samples were analyzed in laboratory to detect physical and chemical properties i.e., pH, EC, OC, N, P and K, then these GIS layers was prepared using these values and IDW interpolation technique was used

- Soil electrical conductivity (ECe)

Soil electrical conductivity (EC) is a measure of the amount of salts in soil (salinity of soil). It is an important indicator of soil health. Optimal EC levels in the soil therefore range from **< 0.8(**dSm-[1]) too low EC levels indicate low available nutrients, and too high EC > 2.4**(**dSm-[1]) is Injurious to all crops. The spatial variability of ECe in the study area lies in the normal range as shown in Fig.7.

- Potential of hydrogen (pH)

Soil pH is playing the major role in nutrient availability, plant growth and productivity. pH below 7 is acidic and above 7 is alkaline. However, the optimum pH range for many plants is between 5.5 and 7.0. pH values in the study area varies from 5.7 to 7.8. The average value of pH is 6.5 and highly suitable for agriculture and plantation Fig. 8.

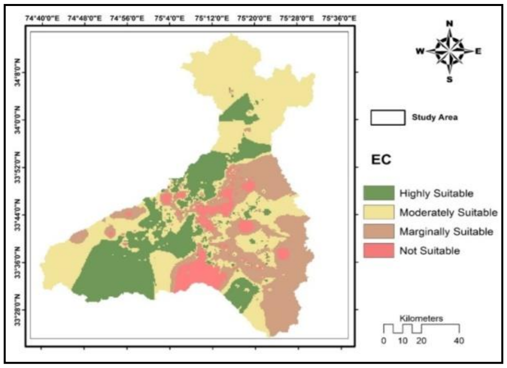


Fig.3.5 Showing spatial distribution of (ECe)

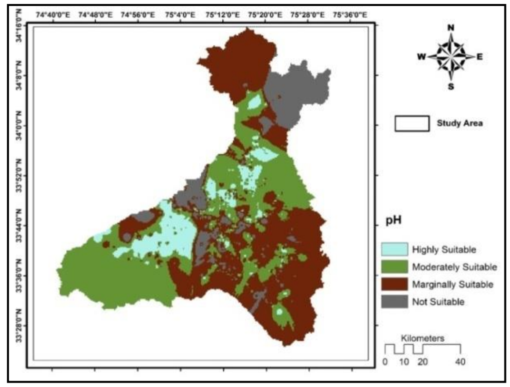


Fig.3.6 Showing spatial distribution of pH

- Nitrogen (N)

Nitrogen is essential for plant growth basically leaf and stem development and production. Soil samples collected from study area were analyzed to estimate amount of N. GIS layer of N was prepared using these values and IDW interpolation technique in GIS, the distribution of nitrogen is shown in Fig. 3.9.

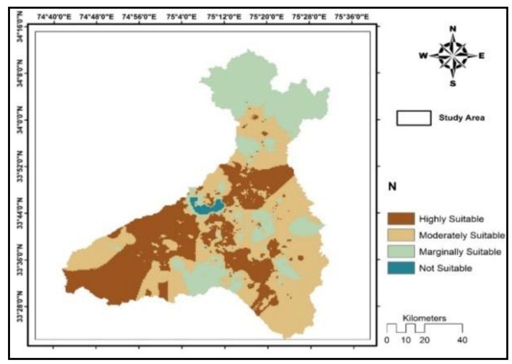


Fig.3.7 Showing spatial distribution of N

- Phosphorus (P)

Phosphorus is important for root formation and growth, crop maturity; stimulate flowering, seed production, etc. Acidic or alkaline soil required more P supply for healthy plant growth. A maximum value of P was estimated 51.8 kg/ha and minimum 8.9 kg. /ha with average value of 17.39 kg/ha P shows marginal suitability for agriculture in this area Fig. 3.10.

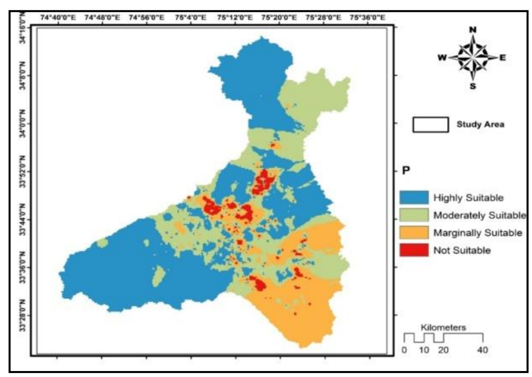


Fig.3.8 Showing spatial distribution of P

- Potassium (K)

Potassium is important for many functions of plants i.e. (1) photosynthesis activity, (2) adds stalk and stem stiffness, (3) disease resistance, (4) drought tolerance, (5) plumpness to grain and seeds, (6) firmness, texture, size and color of fruits, and (7) oil content in oil seeds. Potash deficiency losses plant's green color, turns yellow, the lower leaves

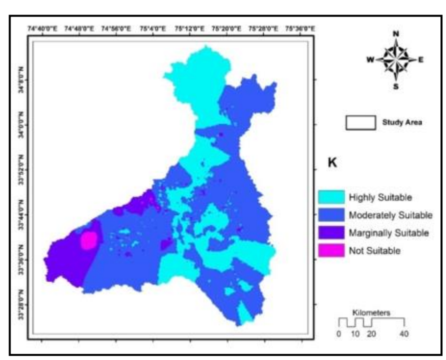


Fig.3.9 Showing spatial distribution of K

fall off and reduces productivity. Soil K content in the study area varied from 162.18 to 1000. kg ha-1 with an average value of 272.93 kg ha-1. Fig.11. Showing the study area falls in highly to moderately suitable

c) Reclassify

Reclassification spatial analyst tool in GIS was used to transform each parameter into the same scale of measurement. Then, priority weight was assigned for each parameter based on experts opinion.

d) Calculations of weight

Table1 shows the weight assigned to different input parameters researchers like Bandyopadhyay et al. (2009) and Akinci et al. (2013) have assigned the score for sub criterion i.e., distribution classes from 1 to 10 based on favorable conditions and limitations for agricultural practices. The higher score indicates maximum influence of sub-criterion whereas lesser score shows least suitability for agriculture. Expert opinion with GIS techniques helps us to ensure realistic applicability of data sets prepared for LSA The studies like (Bojorquez-Tapia et al.(2001), Joerin et al. (2001) and Kalogirou (2002) have used expert opinions to determine the criterion, Assign the ranks and calculate the weight. The eminent scholars with influenced publications of LSA were selected for expert opinions. Weight are numerical values to quantify the importance of different capability factors when determining land capability for some defined use. For example, the weights for the factor slope maybe 100 as compared to soil depth or soil texture with 50 when determining a particular land use to suggest that slope is twice as much important than soil depth for that land use.

e) Weighted overlay

Weighted overlay analysis method (WOA) in ARC GIS was used to analyse the different parameters that have been assigned suitable knowledge- based weights. A ‘‘Weighted overlay analysis’’ (WOA) model was adopted in GIS to assign the class and theme-wise weights for input parameters and the weighted layers were integrated. The effective nine parameters were considered. The class and theme-wise weights were assigned in the model. After assigning of the weights, the nine parameters were integrated and the final map was generated,

Land suitability Classification

By using the above model, the agriculture/ horticulture-based land suitability map was prepared. The relative classes consist of highly suitable, moderately suitable, marginally suitable, and not suitable

f) Validation

For the validation of the results obtained Land use/land cover (LULC) (2019) was used LULC classification of the study area gives us the idea about the present status of the land. And the findings of the results as we compared to the current LULC most of the lands are used against the capability classification of the land.

Table 3 showing Weights and scores**.**

Criteria	Weight Influence (%)	Sub-criterion (with ranges)	Score
Slope (°)	**36**	Gentle (0–1)	10
		Moderate (1–3)	10
		Stiff (3–6)	8
		Steep (6–12)	6
		Very steep (12–20)	4
		Extra steep (20–30)	4
		Precipitous (30–90)	1
Soil Depth (cm)	**15**	Deep soil	10
		Moderate depth	7
		Marginal depth	6
		Shallow soil	4
		Thin soil	1
Soil Texture	**11**	Loam soils with moderate to gentle slope	10
		Clay loam	7
		Loam soils on steep slope	4
Soil OC (%)	**8**	Highly suitable (0.61–1.00)	10
		Moderately suitable (0.40–0.60)	7
		Marginally suitable (0.20–0.40)	5
		Not suitable (<0.20)	1
EC(dSm^{-1})	**5**	Highly suitable (< 0.8)	10
		Moderately suitable (0.8 – 1.6)	7
		Marginally suitable (1.6 – 2.4)	5
		Not suitable (> 2.4)	1
pH	**7**	Highly suitable (5.00–7.3)	10

		Moderately suitable (7.3–8.0)	7
		Not suitable (>8)	1
N (kg/ha)	**6**	Highly suitable (>225)	10
		Moderately suitable (181–225)	7
		Marginally suitable (95–180)	4
P (kg/ha)	**6**	Moderately suitable (31–65)	7
		Marginally suitable (16–30)	4
		Not suitable (<15)	1
K (kg/ha)	**6**	Highly suitable (>360)	10
		Moderately suitable (181–360)	7
		Marginally suitable (121–180)	4

3.1.3 Water Quality Analysis:

In the present study 32 sampling sites were selected and 11 Water sampling Parameters were analysed. Thirty Two water sampling sites were taken along the length of the river for physicochemical analysis. Before collecting the water samples, all the sample bottles were washed with distilled water. Water sampling was done from 10:00 am to 03:00 noon. The samples were collected in airtight glass jars of 250 ml capacity. All the samples were transported to the laboratory for refrigeration and were analyzed within 48hr. Eleven physicochemical parameters were analyzed in the present study which includes pH, Alkalinity, Hardness, Chloride, TDS, Fluoride, Iron, Ammonia, Nitrite, Nitrate, Phosphate. Analysis was done for the Six Months Nov-May.

3.1.4 Crop-vegetation survey:

Field surveys of orchards in the study area were conducted from July 11, 2020. A total of 2 orchard plots were measured. During the survey of plot samples, a handheld GPS is used for precise positioning. Crop yield monitoring, phenology, soil property and management practices were carried out for New Theed, Srinagar Site and Gopal Pora, Anantnag Site. The present investigation was carried out during the year 2019 and 2020. The details of the study are given as under:

- <u>Leaf/fruit ratio</u>: The number of leaves per fruit of each experimental tree were counted and averaged.
- <u>Fruit Retention at harvest:</u> Fruit Retention= No. of matured fruits/No. of fruit-lets*100

- Yield/Tree: The crop harvested from each experimental tree was weighed and the average weight was expressed in Kg/tree.
- Fruit Length: Fruit length was measured with the help of Vernier caliper and the average is expressed in millimeters (mm).
- Fruit Diameter: The diameter of sampled fruit was measured with the help of Vernier caliper and expressed in millimeters (mm).
- Tree height: Height of each experimental plant was measured from the ground level to the tip of main branch with the help of measuring tape.

3.1.8 Socioeconomic Survey:

A Questionnaire (RPA) was generated in order to better understand and assess perceptions, capacities and activities related to Climate Change impacts on crops, crop behavior and relevant adaptation policies/measures. The survey collected a large range of data. However, this study used survey on perceptions of climate change, cropping patterns, crop behavior and adaptations made by farmers. Questions were used to ask farmers whether they had noticed long-term changes in mean temperature, mean rainfall, Agricultural and Horticultural productivity. Questions about Water and the constraints to adaptation were also posed. The study was used to analyze the potential impact of climate variability and climate change on Agricultural and Horticultural production as well as on water resources. The survey period was in the

month of March 2020 and October 2021. In total, 283 samples were collected from Anantnag, Shopian, Lidder Valley, Kulgam, Pampore and Srinagar. The views of different people like Literate/ Illiterate views, Economic Status Views, Gender based views and Age based views were collected.

3.2 Preparatory Actions and Agencies Involved

i) A brainstorming workshop on project development and associated activities were organized at Van Vigyan Bhawan, New Delhi on 19-20 Nov, 2017. During the workshop, project concept, activities were discussed and partners were identified; and project objectives were finalized along with tentative activities, approach and likely outcomes.

ii) After sanctioning of project One Inception workshop titled "System Dynamical modeling: Livelihood and water resources" was organized on 20 - 21 Nov, 2018 for orientation of livelihood opportunities and issues in Urban-Rural set-up, survey questionnaire design and project activity planning.

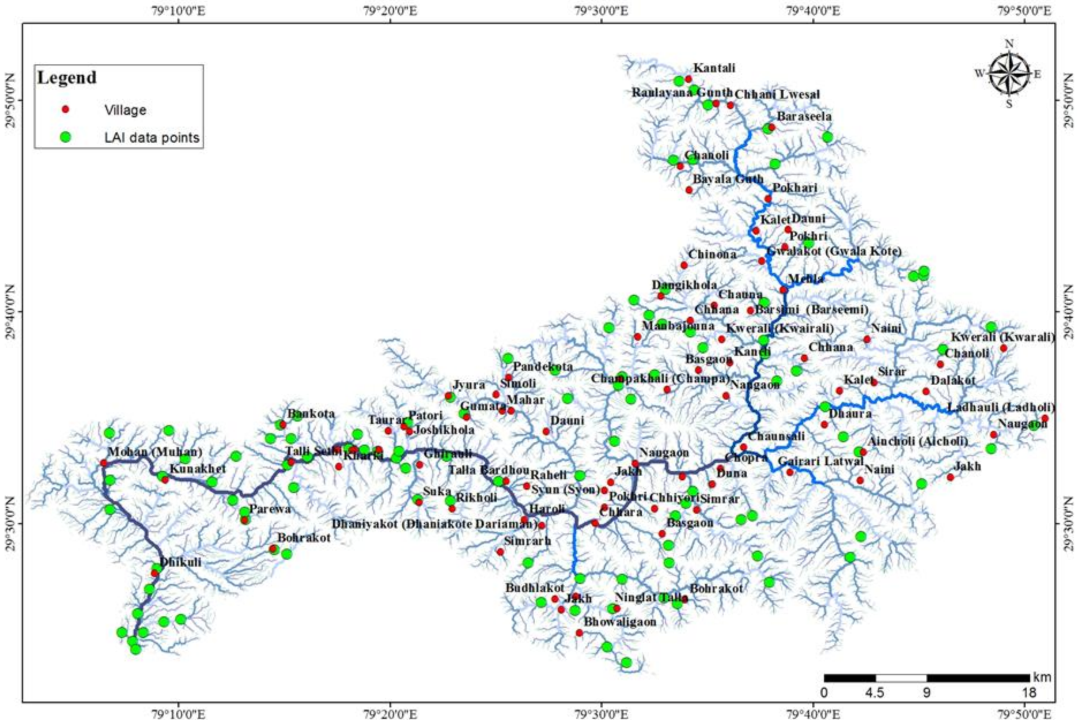
iii) A Review workshop on System Dynamic Modeling on Livelihood Enhancement and Water Resources was held at CSIR-4PI, Bangalore on February 15-15, 2020 where project progress was discussed, and a field survey plan for J&K and Uttarakhand was finalized; and assessment/ mapping of market value chain of agricultural & horticultural crops was emphasized.

The PI and representatives of CSIR-4PI Bangalore Workshop, the project proponent and the lead agency of the project, representatives of J&K University (Project Partner), and GB Pant National Institute of Himalayan Environment (Project Partner) were the main agencies involved in this.

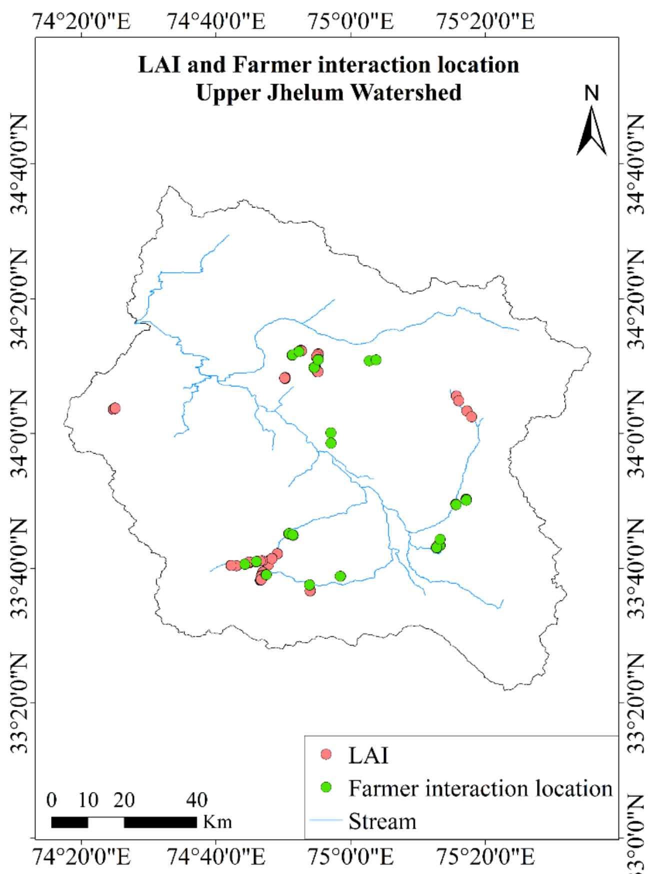
3.3 Details of Scientific data collected and Equipments Used

The details of the scientific data and equipments used in the study are as:

- Field data collection: 26 stream measurements, collected 120 soil samples and located 8 springs. Apart from this, 3000+ Leaf Area Index (LAI) readings, 530+ leaf properties, 124 Soil Moisture Sensor measurements and 124 W.E.T sensor measurements were taken.
- A total of 863 field validation points were collected in different watersheds using GPS.
- Horticulture and Agriculture maps for the year 1891, 1992, 2001, 2013 and 2019 were generated using Landsat images.
- Crop phenology data of Apple orchards from selected sites were collected for the year 2019, 2020. To measure the parameters like height of tree Circumference etc measuring tapes were used. Vernier Calliper was used to measure the length and diameter of fruit.
- The views of different people like Literate/ Illiterate views, Economic Status Views, Gender based views and Age based views were collected on Climate Change impacts on crops, crop behavior, climate change, cropping patterns, crop behavior and adaptations.
- Different soil parameters were collected viz., soil depth, OC, pH, EC, Nitrogen(N), Phosphorus(P) and Potassium(K) and soil texture.
- From 32 sampling sites 11 physicochemical parameters were analyzed in the present study which includes pH, Alkalinity, Hardness, Chloride, TDS, Fluoride, Iron, Ammonia, Nitrite, Nitrate and Phosphate.



Field survey and data collection points in Almora



Field survey and data collection points in Upper Jhelum

Secondary Data-

i) Demographic Profile (Almora district)- 1961-2011 (Annexure I)

ii) Occupational trend data (Almora district)-1961-2011 (Annexure II

iii) Production of major food crops (Almora district) 1981-82 to 1085-86; 1991-92 to 1993-94; 2002-03 to 20016-17- Annexure IIIA

iv) Productivity of major food crops (Almora district) 1979-80 to 1985-86; 1991-92 to 1993-94, 2002-03 to 20016-17 – Annexure IIIB

v) Sectoral /Gross Sown Area (Almora district) 2002-03 to 2016-17 – Annexure IV

vi) Contribution to GSDP at factor cost at current prices (Uttarakhand)1993-94 to 1919-20 Annexure V

vii) Land Holding size and classes (Almora district)2000-01; 2005-06; & 2010-11 Annexure VI

viii) Fertilizer Use Data (Almora district) 1984-85, 1992-93, 1993-94, 2000-01 to 2015-16 Annexure -VII

3.4 Primary Data Collected

i) Data on Crop Phenological Observations - Crop Phenological observations were recorded for paddy and wheat crops during their respective seasons from latter half of 2019 onwards. This information was recorded from five 1mx1m plots per site from 3 sites during 2019-20 seasons, and 2 sites during 2020-21. The data collected from each site included observed /average values of total number of plants/plot, plant height, root height, tiller height, number of grains, wet weight, and overnight dry weight. The Soil sample from these sites were also collected, dried, sieved and dispatched for further analysis for possible modelling use. This data collected on monthly basis from the representative sites from 2019-20 (Dotiyal gaun & Sunoli, Takula block; and Mahatgaun, Hawalbagh block), and 2020-21 (Dotiyalgaun, Takula block; and Sakar Hawalbagh block) and data was handed over to CSIR-4PI **(Annexure-VIII)**

ii) Household survey data- 443 household surveys were conducted for information on their socio-economic condition, livelihood activities and problems, and information on DFID capitals' indicators for livelihood sustainability/ vulnerability assessment, and after scrutiny 39 schedules were rejected and 404 schedules were selected for compilation and further analyses. The score schedule of DFID indicators/ elements is given in **Annexure – IX and DFID results (Figure) in Annexure X.**

iii) Participatory Rural Appraisal & FGDs (Focused Group Discussion)- 8 FGDs were conducted for understanding of problems of agriculture and horticulture in the study area; and 23 FGDs for identification of Capacity Building and Training Need Assessment.

iv) Value Chain Analysis- Informal interviews with structured survey questionnaires 28 and FGDs were carried out for mapping of market value chain for Horticulture fruit crops for understanding of its geographical extent, actors involved, and benefit distribution, and farmers' problem to make appropriate suggestions for better benefit sharing arrangements, and policy environment for farmers' support.

v) Fertilizer use data through farmers survey for Paddy, wheat, Potato (Takula Block – villages) **Annexure XI**

01.	Statistical Data	Household, Economic Status, Education, Livestock, Land types, cropping patterns, Issues related to climate, water etc
02.	Crop Phenology and Management Practices	Age of Tree , Age at which an apple tree first bears fruit, Max height of tree in years, Canopy height and width of tree, Diameter of the tree, Year of transplanting or sowing, Planting density(tree/ha), Orchard dimension (length and width in mm), Tree spacing (Row to Row and plant to plant in ft), Planting Depth, Matured fruit weight in grams, Yield per plant, Yield per ha, Yield of previous years, Fertilizer details, Irrigation details.
03.	Soil Data	Soil texture, Soil depth, OC, pH, EC, Nitrogen(N), Phosphorus(P) and Potassium(K).
04.	Water Quality Parameters	pH, Alkalinity, Hardness, Chloride, TDS, Fluoride, Iron, Ammonia, Nitrite, Nitrate and Phosphate.

3.5 Details of Field Survey arranged

The purpose of this survey was to collect the apple and paddy management practices and crop phenology parameters. To validate the Expansion of Horticulture and shrinkage of Agriculture 863 GPS field validation points were collected. A Questionnaire (RPA) was generated which includes different questions related Household, Economic Status, Education, Livestock, Land types, cropping patterns, Issues related to climate, water etc. This survey involved visits to the farmers households for face to face interview. In total, 283 samples were collected from Anantnag, Shopian, Lidder Valley, Kulgam, Pampore and Srinagar. Questionnaires were designed in a manner that minimizes respondent burden, while maximizing data quality. The following strategies were used to achieve these goals: 1. Questions were clearly written in a simple language 2. The questionnaire was of reasonable length; 3. The questionnaire includes only items that showed to be successful and useful. Number of Trainings and webinars were scheduled to surveyors about the field surveys, using the instruments in fields etc.

Household survey, selected PRA exercises, and Focussed Group discussions, consultation meetings, and field survey for phenological observations and soil sampling were the main survey approaches used for the study. The details of survey areas and activities undertaken are as under.

1. Survey for Crop Phenological Observations

S.N.	Year/ Crop Seasons	Experimental Sites for Wheat, Paddy Crops	Data / Activities
1.	2019-20	a. Village Dotiyal Gaun (Takula Block, Almora) b. Village Sunoli (Takula Block, Almora) c. Village Mahatgaun (Hawalbagh Block, Almora)	• Total number of plants, plant height, root height, tiller height, number of grains, wet weight and overnight dry weight. • Composite soil sample/site • Composite grain sample/ site, at crop maturity
2.	2020-21	a. Village Dotiyal Gaun (Takula Block, Almora) c. Sakar (Hawalbagh Block, Almora)	• Total number of plants, plant height, root height, tiller height, number of grains, wet weight and overnight dry weight. • Composite soil sample/site • Composite grain sample/ site at crop maturity

2. Household Survey for DFID Capital Indicators etc.

S.N.	Settlement Category	Block - Villages Covered	Number of Surveys (N)
1.	River valley Settlement	Hawalbagh Block - 4 Takula Block – 5; Dhari Block -1	92
2.	Mountain Settlement	Hawalbagh - 26, Lamgadha -10; Basiyachana - 7, Ramgadh -9, Dhari - 3, Takula -10, Tarikhet-1, Garur - 1, Dhauladevi -1, Dwarahat - 1	312

3. Participatory Rural Appraisal & FGDs (Focused Group Discussion)/ Meetings

S.N.	Interview/ FGD	Location Block	Participants
1.	Three FGDs and Interview	Hawalbagh (Barseemi Sauda, Katarmal, Balta)	Farmers, Researcher, Scientists, Community representatives, retired Village Development officer
2.	Interview	Bhaisiyachana (Salla, Jagsaun, Kanyura)	Farmers, Researcher, Community representative

3.	Two FGDs and Interview	Dhauladevi (Latoli, Bamanswal)	Farmers, local NGOs, Researcher
4.	Interview	Dwarahat (Binta)	Farmers, Researcher, Community representative
5.	Interview	Lamgada (Nerai, Ujyari, Chomu, Narayan Deval)	Farmers, Researcher, Community representative
6.	Two FGDs	Takula (Sunoli, Hadoli, Dotiyal Gaun, Amkholi)	Farmers, Researcher, Environmental Activists, community representative
7.	One FGDs	Dhari (Jaurasi, Cool, Baijiatana)	Farmers, Researcher, community representative
8.	One FGDs	Ramgadh (Kherda, Kamoli, Chapad)	Farmers, Scientists, Researchers

4. Stakeholders Consultation Meetings cum Workshops

S.N.	Venue/ Date	Organizers/ Activity	Participants
1.	Village Balta, Hawalbagh Block, Almora June 14, 2019	GBPNIHE and CSIR-4PI Subject Briefing, stakeholder views/ discussion, questionnaire response	Farmers, Researcher, Scientists, Community representatives, Retired officials/ persons
2.	Village Katarmal June 16, 2019	GBPNIHE and CSIR-4PI Subject Briefing, stakeholder views/ discussion, questionnaire response	Farmers, Researcher, Scientists, Community representatives, Retired officials/ persons
3.	Village Sunoli Thakula Block, Almora June 18, 2019	GBPNIHE and CSIR-4PI Subject Briefing, stakeholder views/ discussion, questionnaire response	Farmers, Researcher, Scientists, Community representatives, Retired officials/ persons
4.	Village Kherda/ Ramgarh Block, Nainital June 20, 2019	GBPNIHE and CSIR-4PI Subject Briefing, stakeholder views/ discussion, questionnaire response	Farmers, Researcher, Scientists, Community representatives, Retired officials/ persons
	Total		183 participants; Females - 28

3.6 Strategic Planning for each Activities

The subject livelihood in urban-rural ecosystems, covers a large number of activities and sectors, and its assessment by use of system dynamical modeling requires, a large set of time series data on various aspects, components, functions and processes of the system. Therefore, to achieve envisaged objectives, inception and review workshops, as mentioned in preparatory arrangements were organized. Later it was realized that project focus should be restricted to agriculture sector only which is amenable to system dynamic modeling. The activities/ data requirements were agreed, which were also modified depending upon information availability and field conditions, are given below.

Objective	Activity	Data Requirements (Source)
Objective-1: Strategies for sustainable urban-rural ecosystem….	Livelihood Scenario Analyses; Overview of state of agriculture Analyses based on DFID Framework data	Trends of demography, occupational structure, area under cultivation/ land-use, crop production (Secondary Info) Primary data on DFID capital indicators (Primary data, survey) GSDP data of Uttarakhand
Objective-2: Testing and validation of strategy through SDM….	System Dynamical Modelling for livelihood scenarios (CSIR-4PI) **Hydrological model simulation is done for 1979-2019 for KOSI and upper Jhelum basin River basin.** **APSIM wheat simulations complete,** **APSIM paddy simulation** **Multivariate deep learning-based process models are developed** **LULC is being prepared for estimating for variability and trend (both annual and seasonal timescales)** **High resolution WRF – canopy model is customized for Kosi and upper Jhelum region simulations are complete.** **Crop phenology estimation for 2002-2020 is complete** **DFIDs' Livelihood capital assessment for development of strategies (36 villages surveyed, N=403).** Participatory CLD (Causal Loop Diagram) – to map the cause and effect relation of the system	Climate, soil, crop phenology, fertilizer use, water use, labour use, input-output, production, transport/market price, value addition, etc (secondary info, field survey, Meetings)

	component. Fuzzy cognitive Modelling:: Functioning of livelihood system-Identification of overriding factors affecting rural livelihood system.	
Objective-2: Benefit maximizing/Impact minimizing Human-NRM strategies ….	To be achieved thru SDM applications (CSIR-4PI) Documentation of sustainable agriculture practice, Problems of Agriculture sectors Value chain mapping of agri/ horticultural crops	---Do---- Related cropping procedures, problem marix (Review/ PRA-FGDs/Survey) Supply points, actors, benefit sharing (FDGs & Interviews)
Objective-4: Policy options for better quality of life ….	Outcomes thru -SDM applications (CSIR-4PI) Analyses of survey & secondary data for objectives 1-3 & 4	(data for Modeling Applications (CSIR-4PI) Only Cues from other data/ Interpretations of results
Objective-5: Training & capacity building needs ….	Based on SDM outcomes and questionnaire survey	Pairwise rank matrix (PRA Survey)

4 KEY FINDINGS AND RESULTS

4.1 Major Research Findings

4.1.1 Land System Change

Land use Land cover mapping was done for Upper Jhelum Basin for the year 1981, 1992, 2001, 2013 and 2019. Two LULC classes were generated viz, Agriculture and Horticulture.

4.1.1 (a) Agriculture Mapping

Agriculture maps were generated for the year 1981, 1992, 2001, 2013 and 2019 shown in (Fig 4)

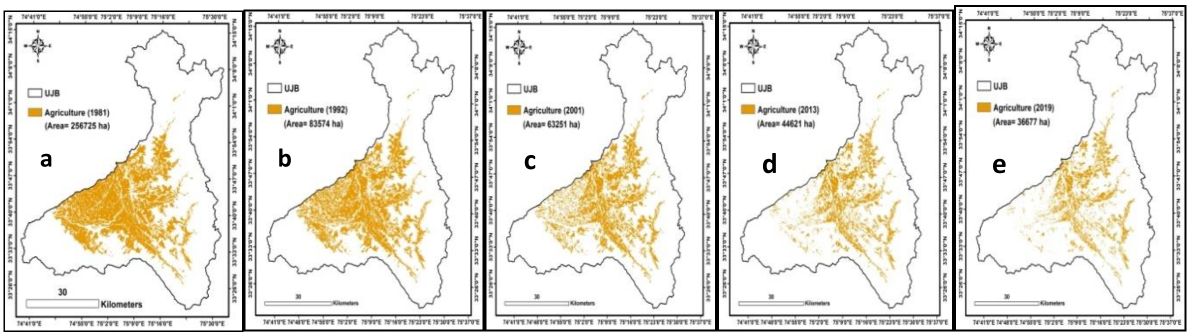


Fig 4 Showing the area of agriculture in 1981(a), 1992(b), 2001(c), 2019(d) and 2019(e)

4.1.1 (b) Horticulture Mapping

Horticulture maps were generated for the year 1981, 1992, 2001, 2013 and 2019 shown in (Fig 4.1)

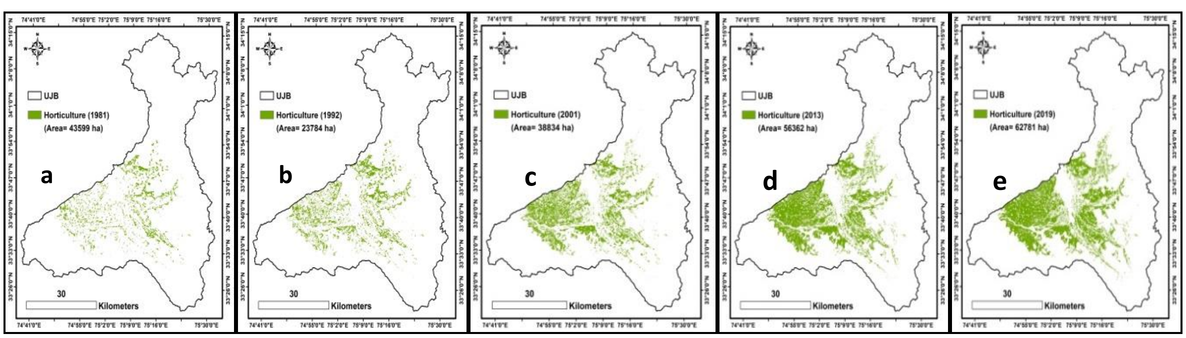


Fig 4.1 Showing the area of Horticulture in 1981(a), 1992(b), 2001(c), 2019(d) and 2019(e)

Agriculture in the Upper Jhelum Basin is very high as compared to horticulture because in old times there were no modernized due to which they used to depend on Agriculture. Agriculture was considered as the only lively hood commodity on which people spend most of time on its cultivation. There are number of reasons for the conversion of agriculture to horticulture one is economic reason. Horticulture is now considered as the most economic commodity as compared to Agriculture.

Table (4) Area statistics of Agriculture and Horticulture from 1981 to 2019 (in ha)

CLASS	AREA(ha) 1981	AREA(ha) 1992	AREA(ha) 2001	AREA(ha) 2013	AREA(ha) 2019

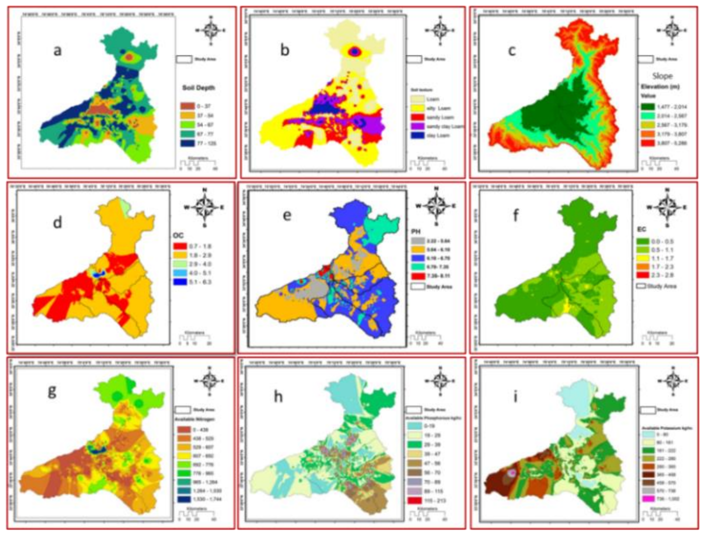
AGRICULTURE	256725	83574	63251	44621	36677
HORTICULTURE	15696	23784	38834	56362	62781

It was found that area under agriculture was 256725 ha in 1981, 83574 ha in 1992, 63251 ha in 2001, 44621 ha in 2013 and 36677 ha in 2019 with overall decrease of 220048 ha from 1981 to 2019. For horticulture in 1981 the area was 15696 ha, 23784 ha in 1992, 38834 ha in 2001, 56362 ha in 2013 and 62781 ha in 2019, so the change in the area of horticulture is 47085 ha from 1981 to 2019.

4.1.2 Land Capability Classification

1.Data base

In this study nine criteria have been selected i.e., soil depth (Fig 1a), soil texture (Fig1b), slope (Fig1c), soil organic carbon (OC) (Fig1d), potential of hydrogen (pH), (Fig1e), electronic conductivity (EC) (Fig 1f), Nitrogen(N), (Fig1g) Phosphorus(P) (Fig1h) and Potassium(K) (Fig1i). These nine factors under consideration are chosen by means of literature inputs and the availability of data. Satellite data was used for preparation of GIS layers i.e., soil depth. The 30 m spatial resolution DEM (digital elevation model) was used to generate slop map, whereas OC, pH, EC, Nitrogen(N),Phosphorus(P)and Potassium(K) and soil texture maps were estimated using IDW interpolation technique and laboratory data of soil analyses. The weights of selected criterion calculated in the WOA analyses were used in GIS environment to map the land suitability (LS) for agriculture/horticulture. LS for agriculture/ horticulture categorized into four classes i.e., highly suitable, moderately suitable, marginally suitable and not suitable.



(Fig. 4.2 a to 4.2 i.) Showing input GIS layers used for land suitability classification.

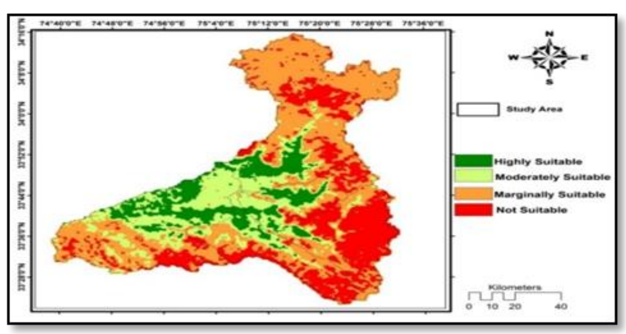


Fig .4.3. Showing Land suitability Classification

a) Highly suitable

Table 4 and Fig 4.3 shows in highly suitable class covers 38,654(ha) 11%, this land as classified into the, ‘Highly suitable’ is excellent for agriculture/horticulture. These land shave fertile soils having gentle to moderate slopes, with higher minerals and nutrients, normal ph.

The fallow lands lying in this class can be converted into agricultural lands, if irrigation facilities and required financial supports are available. However, these lands show minor limitations like moderate to marginal soil nutrients i.e., N, P and K which require external
inputs for optimum agricultural production.

b) Moderately suitable

Fig 4.3 and Table 2 shows moderately suitable lands for agriculture and Horticulture of the study area are estimated about 94,296(ha) 26%. These lands have stiff slopes, loam soil with moderate depth, these lands require additional inputs as well as efforts for intensive farm management practices for agriculture and horticulture.

c) Marginally suitable

Fig4.3 and table 2 show 1,56,049(ha) 42% of the total land of study area falls in ‘marginally suitable’ These lands have shallow soil with steep slope, low water retention capacities, and lesser nutrients as well as more erosions. Generally, more than 12° slopes are not considered for agriculture activities. These lands need to be protected from intensive soil erosion.

d) Not suitable

Fig 4.3and table 2 show 74,845(ha) 21 % of the total study area falls in the not suitable zone Precipitous slopes (<30°) with rocky surface, barrenness, thin and dry soils are classified into the class, The study area is considered environmentally sensitive zone which is to be protected and conserved. Therefore, agricultural activities cannot be carried out on medium to dense forest lands.

Table 4.1 Table showing Land suitability classification.

Suitability class	Area(ha)	Area (%)	Remarks
Highly suitable	38,654	11	Highly suitable land for Agriculture and Horticulture. Intensive agriculture is possible if irrigation facilities are available
Moderately suitable	94,296	26	Good land for arable farming under proper farm management practices

Marginally suitable	1,56,049	42	Medium suitability for agriculture/ Horticulture under careful farm management. Only terrace cultivation is possible. There is need to protections of land from intensive erosion and drainage
Not suitable	74,845	21	These lands are not suitable for agriculture. Areas under settlement, open rocks, road, dense reserve and protected forest are not considered for agriculture
Total	363,844	100	

4.1.3 Water Quality Analysis

<u>Associated LULC:</u>

In the present study 34 sampling sites were identified and different Land use Land cover classes (LULC) and associated classes were identified in the area. In Aru associated LULC was identified as Water and Agriculture. In West Lidder associated Land use land cover was Water,Forest. InGandapathnar,Munarwarsar,Grat Nar, Hajkut, Chhanahaij, Brariangan,Shinar, Sarbal Ziarat Sh ,Sruchhin, Nagabal associated LULC was forest. In Wachran,Tourist Hut,Dudal Nar,EastLidder, Bajinar Nekabatun,associated LULC was River Bed and Forest. In Chandanwari, Poshghati, Phraslun, Mamal, OwurNala,Ganeshpur,Aishmuqam Associated LULC was River Bed. In Palapur Associated LULC was River Bed, Horticulture. In Laripur, Pahalgam, Mattan, Sipin associated lulc was identified as Water. In Thajiwor, Gur, Hapatnar, Langanbal associated LULC was identified as Plantation.

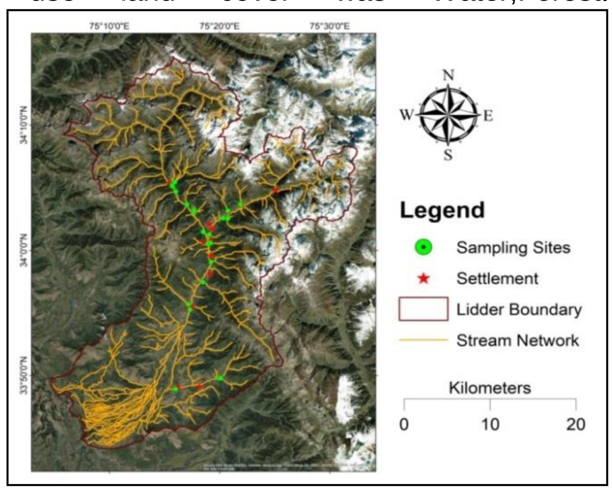


Fig (4.4): Associated LULC of sampling Points and identification of Settlement.

Water Quality Test: Water quality tests will give information about the health of the waterway. By testing water over a period of time, the changes in the quality of the water can be seen. Parameters that may be tested include temperature, pH, turbidity, salinity, nitrates and phosphates. Testing procedures and parameters may be grouped into physical, chemical, bacteriological and microscopic categories. Physical tests indicate properties detectable by the senses. Chemical tests determine the amounts of mineral and organic substances that affect water quality. Bacteriological tests show the presence of bacteria, characteristic of faecal pollution.

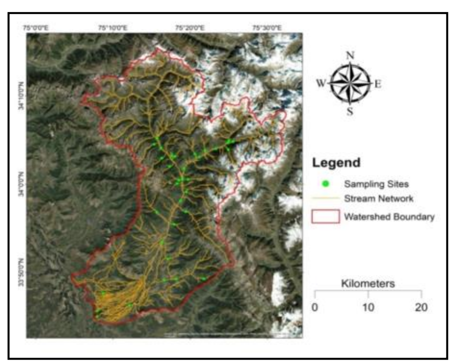


Fig (4.5): Showing the Sampling Sites in Lidder

<u>Physical tests:</u> Colour, turbidity, total solids, dissolved solids, suspended solids, odour and taste are recorded. Colour in water may be caused by the presence of minerals such as iron and manganese or by substances of vegetable origin such as algae and weeds. Colour tests indicate the efficacy of the water treatment system.

<u>Chemical tests:</u> pH, hardness, presence of a selected group of chemical parameters, biocides, highly toxic chemicals, and B.O.D are estimated.

Eleven physicochemical parameters were analyzed in the present study which includes pH, Alkalinity, Hardness, Chloride, TDS, Fluoride, Iron, Ammonia, Nitrite, Nitrate, Phosphate. Analysis was done for the Six Months Nov-May. Analysis of physicochemical parameters was done priority-wise. pH, nitrates, and phosphates. The table (see Annexure) and graphs are showing the physicochemical parameters from Nov-May of the selected sites.

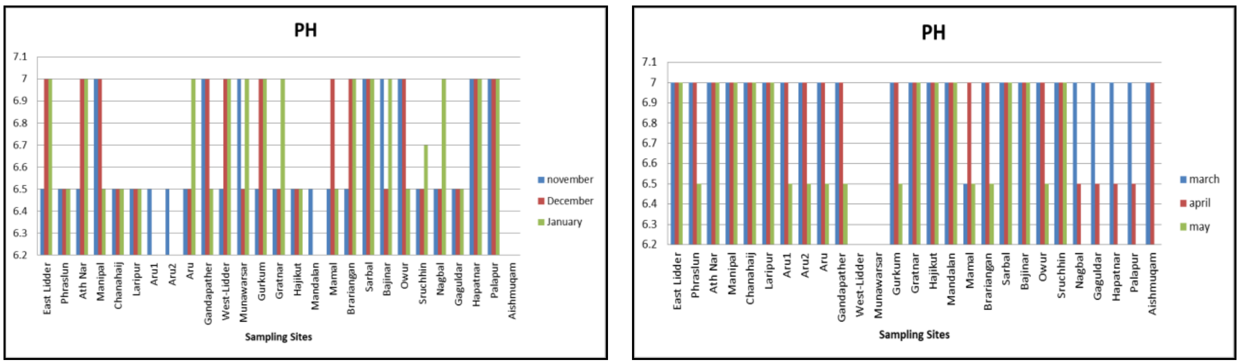


Fig (4.6): Graph showing the pH of Lidder watershed area.

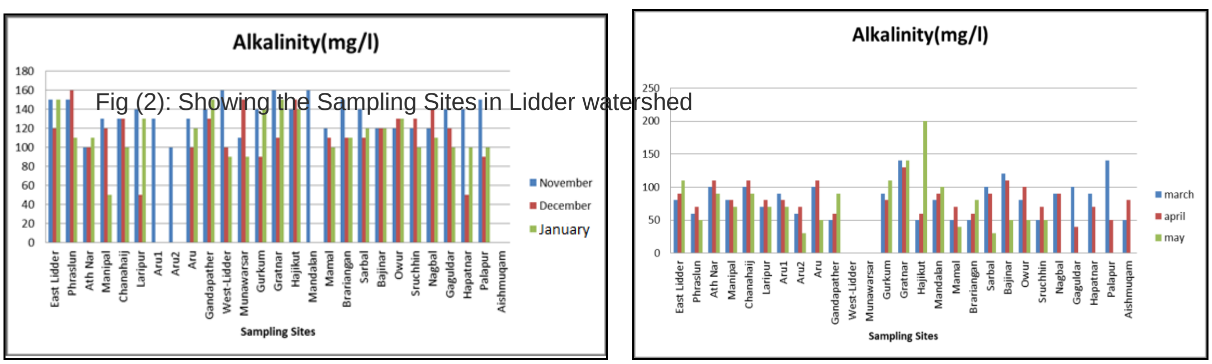


Fig (2): Showing the Sampling Sites in Lidder watershed

Fig (4.7): Graph showing the Alkalinity of Lidder watershed

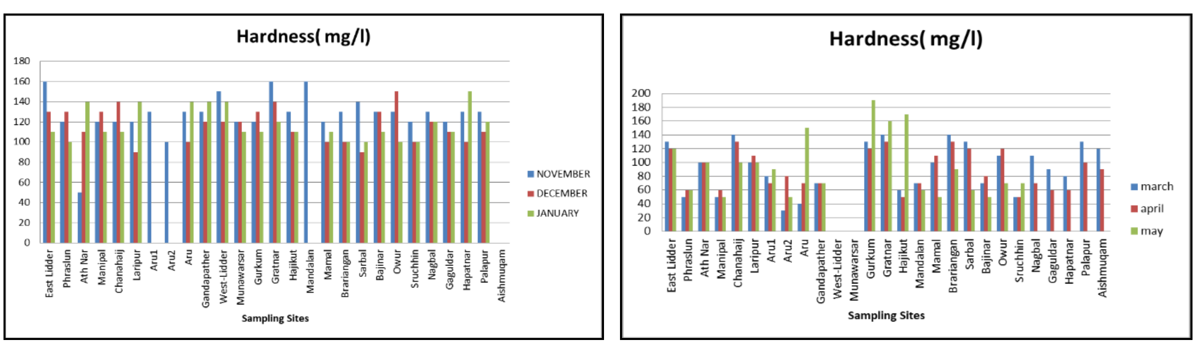


Fig (4.8): Graph showing the Hardness of Lidder watershed area.

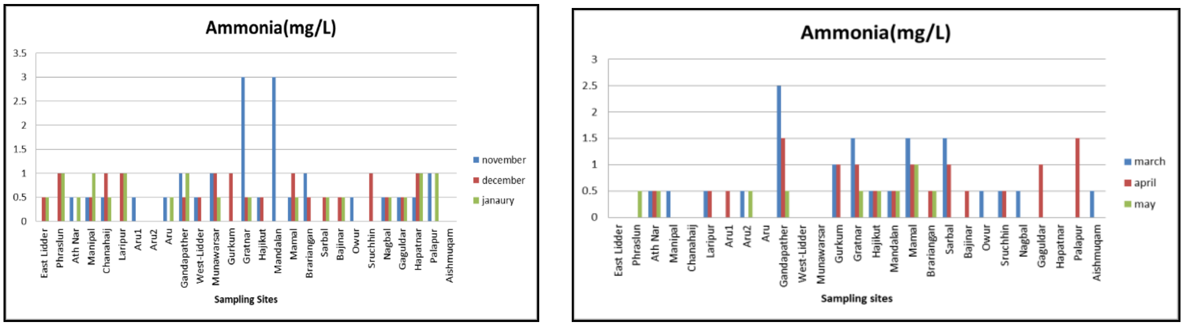


Fig (4.9): Graph showing the Ammonia of Lidder watershed area.

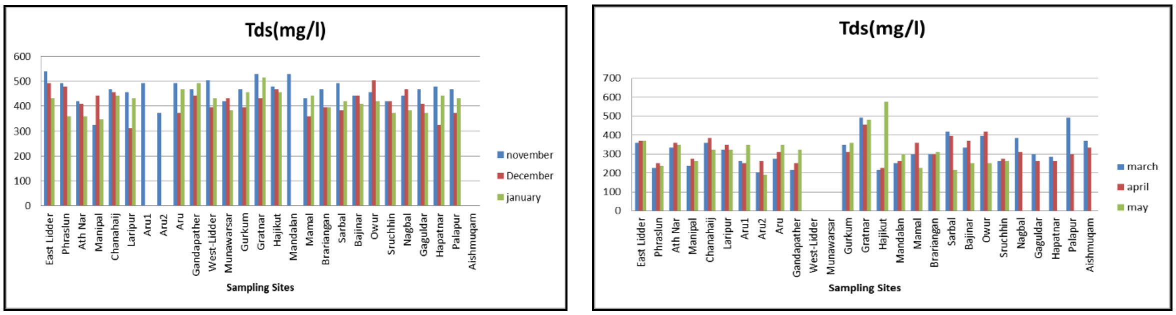


Fig (4.10): Graph showing the TDS of Lidder watershed area.

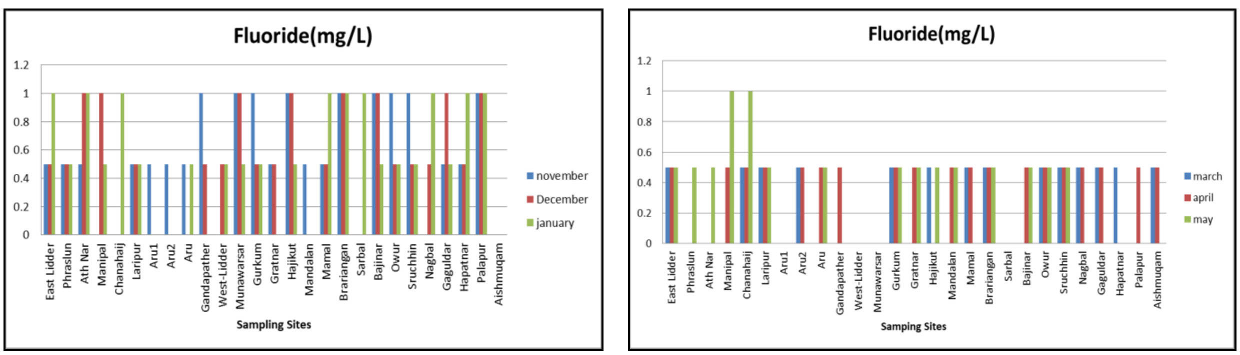


Fig (4.11): Graph showing the Fluoride of Lidder watershed area.

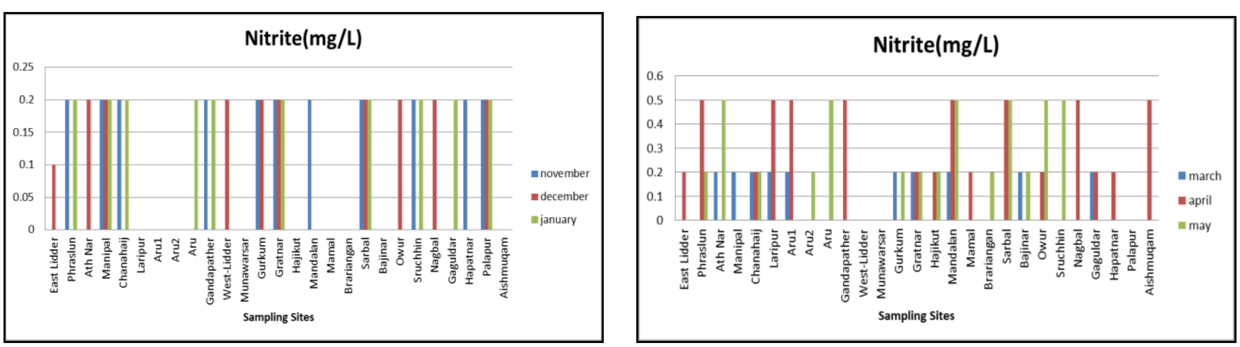


Fig (4.12): Graph showing the Nitrite of Lidder watershed area.

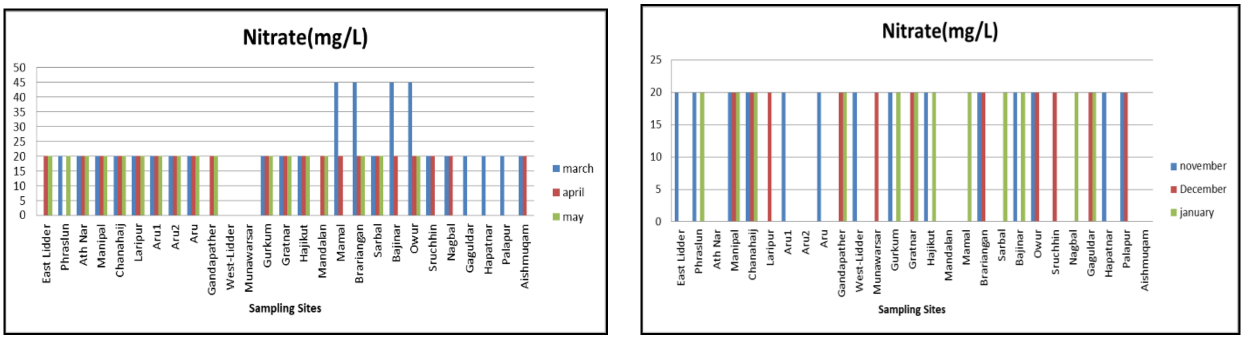


Fig (4.13): Graph showing the Nitrate of Lidder watershed area.

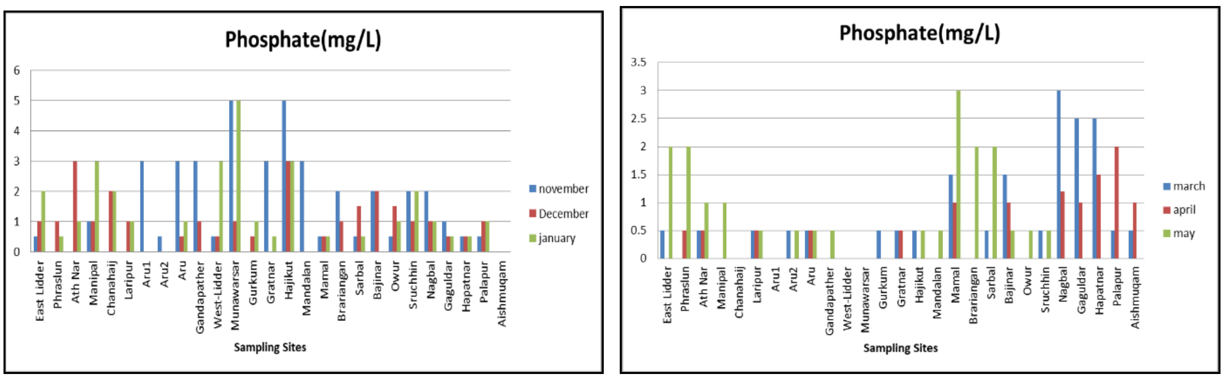


Fig (4.14): Graph showing the Phosphate of Lidder watershed area.

Seasonal Variation (Mean and Standard Deviation):

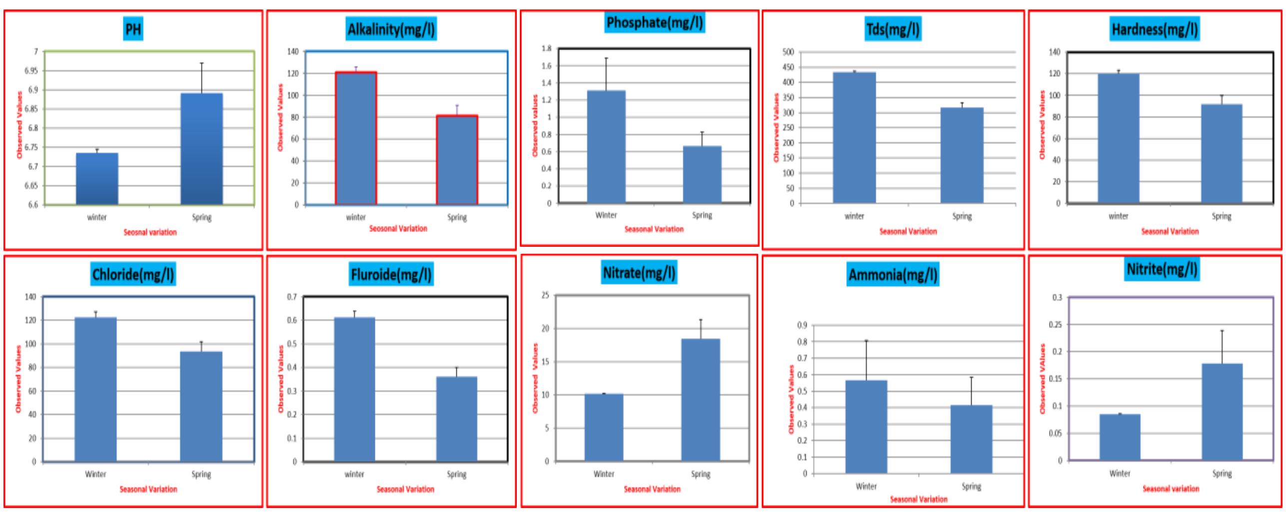
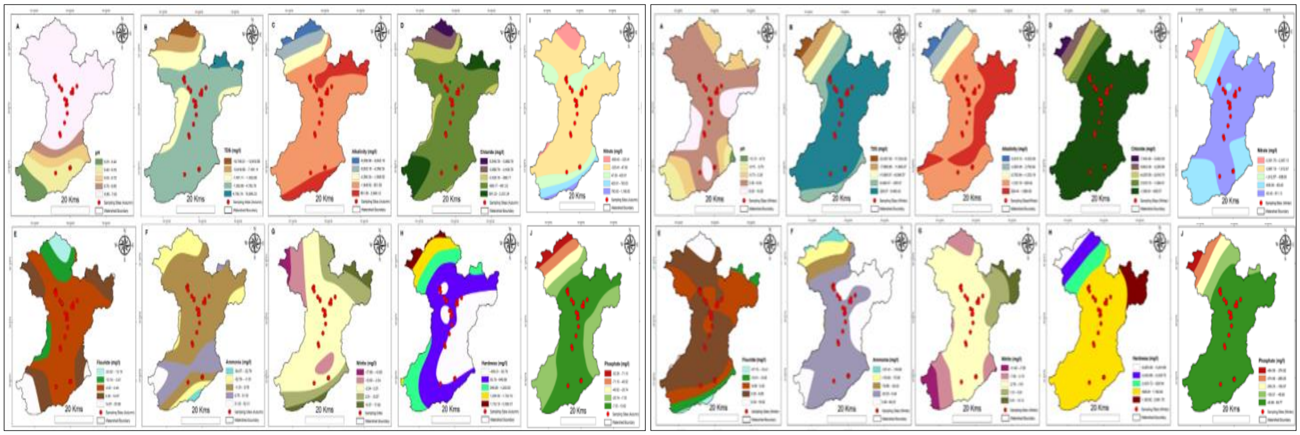


Fig (4.15): Graph showing the observed values of different parameters in Lidder watershed

Trend Analysis using Interpolation method:



Spring Trend   Winter Trend

Fig (4.16): Layout showing the trend analysis of different parameters in Lidder watershed area

These are the interpolation Diagrams of two seasons showing trend analysis of multiple parameters using interpolation method mentioned on the relative figures.

4.1.4 Crop Vegetation Survey

Crop vegetation monitoring for Apple yield, phenology, soil property and management practices were carried out for New Theed Srinagar Site, Gopal Pora Site and Bijbehara Site. In 2019, vegetation surveys of Apple orchards of different apple varieties were initiated to quantify and assess the crop behavior under different weather conditions and amount of fertilizers. Four trees of each Delicious and Star Crimson varieties were selected. Sampling was conducted in the month of July, harvesting season, at the start of the winter season, mid-winter and end of winter to measure vegetation height and other crop phonological parameters shown in the table (4.2) and the data from other sites are shown in (Annexure VII Table 12)

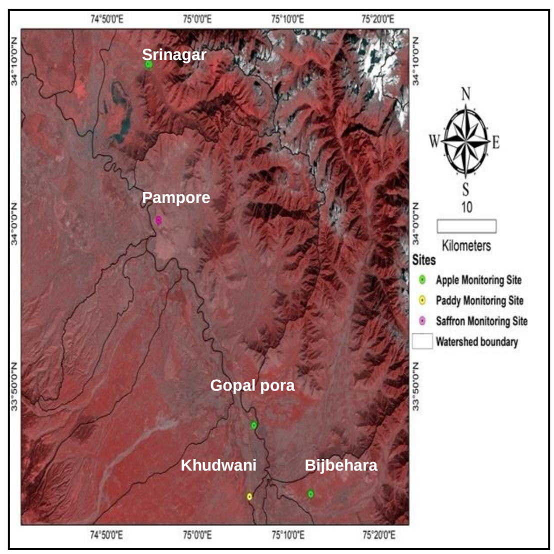


Fig (4.17) Showing Crop Monitoring

Table (4.2): Details of data from New Theed Apple Orchard

Golden Delicious 1	**Golden Delicious 2**	**Golden Delicious 3**	**Golden Delicious 4**	**Star Crimson 1**	**Star Crimson 2**	**Star Crimson 3**	**Star Crimson 4**
Long	Long	Long	Long	Medium	Medium	Medium	Medium
110	110	110	110	70	70	70	70

M-9	M-9	M-9	M-9	MM-106	MM-106	MM-106	MM-106
35 years	33	33	30	2	3	4	3
6.2	6.46	4.43	4.5	4.1	3.27	4.09	4.22
9	9	9	9	7	7	7	7
24	21	19	18	15	14	15	17
4.7	4.2	2.2	3.4	1.9	1.52	1.77	1.83
0.94	0.81	0.16	0.38	0.11	0.055	0.093	0.1
25	25	25	25	20	20	20	20
26*25	26*25	26*25	26*25	17*32	17*32	17*32	17*32
82	57	75	55	25	22	23	10
NA	NA	NA	NA	NA	NA	NA	NA
12	12	12	12	8	8	8	8
4.46	4.08	4.02	3.4	5.4	5.08	5.56	5.08
4.6	4.07	4.01	3.5	5.2	5	5.4	5
900	700	800	650	200	230	170	100
8 boxes	6 boxes	7 boxes	6 boxes	2 boxes	3 Boxes	2 Boxes	1 Box
Once in a year	Once in a year	Once in a year	Once in a year	Not done	Not done	Not done	Not done
1200	1200	1200	1200	700	700	700	700
May	May	May	May	May	May	May	May
Flood	Flood	Flood	Flood	Flood	Flood	Flood	Flood
NA	NA	NA	NA	NA	NA	NA	NA
N,P,K	N,P,K	N,P,K	N,P,K	N,P,K	N,P,K	N,P,K	N,P,K
Acc to Horticulture Schedule	Acc to Horticulture Schedule	Acc to Horticulture Schedule	Acc to Horticulture Schedule	Acc to Horticulture Schedule	Acc to Horticulture Schedule	Acc to Horticulture Schedule	Acc to Horticulture Schedule
1.99,0.14,1.16	1.94,0.14,1.23	1.92,,0.14,1.42	1.87,0.16,1.33	2.42,0.27,1.12	2.54,0.25,1.43	2.57,0.27,1.32	2.53,0.23,1.10
13	13	13	13	11	11	11	11
Broadcasting	Broadcasting	Broadcasting	Broadcasting	Broadcasting	Broadcasting	Broadcasting	Broadcasting
Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

3.1.5 Algorithm Development of LU/LC classification

CNN has the ability to extract the features of the training samples automatically and train the classifier on its own. The basic CNN requires a large amount of training data to perform well on classification tasks. However, with a proper configuration of CNN algorithm along with the suitable activation function, pooling, dropout, and optimizer, better performance from CNN can be achieved with less amount of training samples even without using any pre-trained model (Simonyan & Zisserman, 2014; Szegedy et al., 2015; He et al., 2016; Chollet, 2017; Krizhevsky et al., 2017). Hence, in order to achieve a good accuracy in classifications tasks, the knowledge of CNN architecture and the layers used in CNN are quite important. An important aspect in configuring CNN algorithm for specific application is hyperparameter tuning (Nakisa et al., 2018; Ottoni et al., 2022). Liu et al., (2020) deployed automated hyperparameter tuning algorithm to configure DL model and concluded that this method performs well for PolSAR image classification. Cyclical learning rate method is used (Smith, 2017) to vary the learning rate between reasonable boundary values and showed that this approach improved classification accuracy without tuning and often in fewer iterations.

Activation in CNN plays an important role in model accuracy since it helps in capturing the hidden inherent nonlinear pattern in data (Nworu et al., 2022). Activation function plays critical role in the effectiveness & training dynamics of deep neural networks (Biswas et al., 2022). Without activation function, CNN algorithm may return similar outputs like that of a classical linear regression model. One of the popular activation functions used in DL models is the Rectified Linear Unit (ReLU); compared to many other activation functions, ReLU takes less computational time during learning process. However, ReLU faces issues during learning process due to diminishing gradient though it is partially taken care during the back-propagation. Cao et al., 2017 used a randomly translated version of ReLU (RT-ReLU) to overcome overfitting issues of CNN and showed improved classification accuracy compared to ReLU. The effectiveness of an improved version of ReLU activation function in identification of disease type and severity in cucumber plant is shown by Agarwal et al., (2021). Nworu et al., 2022 examined the effectiveness of different variants of ReLU in x-ray image classification and concluded that ReLU6 outperformed others in terms of test accuracy.

These studies indicated that configuring CNN network through hyperparameter tuning and selecting suitable activation function is very critical for best performance before deploying such network for specific applications. In this backdrop, the major objectives of the present study are,

1. Improving the image classification accuracy by identifying optimal band combinations

2. To test the impact of newly proposed Modified ReLU (MReLU) activation function in image classification accuracy of best configured CNN through hyperparameter tuning.

Image classification using CNN is computationally intensive. The computational resources and time required will be more if we use a complex CNN algorithm. The novelties of this study, i.e., MReLU activation function, multispectral band combination, and hyperparameter tuning of CNN, have proven to achieve accuracy on par with complex CNN algorithms in image classification.

From the experimental results, we have found that the performance of the CNN algorithm in image classification can be significantly improved by using all bands of Sentinel-2 satellite images. Use of all spectral bands for classification outperformed all other band combinations in terms of classification accuracy with an overall accuracy of 98.62%, which is on par with the accuracy of 98.57% achieved by using pre-trained (ResNet-50) model in Helber et al. (2019) for the same data set. In experiments, which used multispectral band combination images, SGD optimizer performed better compared to others irrespective of learning rates. This result points to the opportunity to use higher learning rates for image classification. For RGB composite images, SGD, Adadelta, and Nadam optimizers performed well at lower learning rates but failed to perform well at the higher learning rates. In general, SGD, Adadelta, and Adamax optimizers were the best optimizers for classifying the multispectral images irrespective of the learning rate.

Model performance for different band combinations was better in classifying the Residential, Sea Lake, and Forest classes while performance was relatively poorer for classes like Industry, Permanent Crop, and Herbaceous Vegetation. To some extent, this problem is solved with the use of all spectral bands images. With MSB13, the classification accuracy for Industry class improved to 95.92% which is 7% higher than the accuracy of RGB composite data. In summary, this study substantiates the significance of using multispectral data in image classification compared to RGB composite data (Figure 3.10).

The accuracy of CNN algorithm using MReLU for MSB3 band combination was found to be higher by 1% compared to the accuracy with ReLU. The performance of the model for MSB6, MSB13 and ResNet-50 using MReLU was better compared to the performance of the model using ReLU. It is important that there was significant improvement in class wise performance of Industry, Permanent Crop, and Herbaceous Vegetation classes using MReLU where classification errors were typically high.

RGB 0.00012 Nadam 96.37

Class	Annual crop	Forest	HerbaceousVegeta	Highway	Industrial	Pasture	PermanentCrop	Residential	River	SeaLake
Annual crop	0.97	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00
Forest	0.00	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HerbaceousVegetation	0.00	0.02	0.93	0.00	0.00	0.01	0.02	0.02	0.00	0.00
Highway	0.00	0.00	0.00	0.97	0.01	0.00	0.00	0.01	0.00	0.00
Industrial	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.11	0.00	0.00
Pasture	0.01	0.01	0.02	0.00	0.00	0.96	0.00	0.00	0.00	0.00
PermanentCrop	0.02	0.00	0.02	0.00	0.00	0.00	0.94	0.01	0.00	0.00
Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	0.00	0.00
River	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	0.00
SeaLake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.99

(a)

R 0.00020736 Adamax 91.00

Class	Annual crop	Forest	HerbaceousVegeta	Highway	Industrial	Pasture	PermanentCrop	Residential	River	SeaLake
Annual crop	0.92	0.00	0.01	0.01	0.00	0.01	0.04	0.00	0.00	0.01
Forest	0.00	0.95	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HerbaceousVegetation	0.00	0.03	0.85	0.01	0.00	0.02	0.03	0.05	0.00	0.00
Highway	0.01	0.00	0.03	0.8	0.04	0.03	0.03	0.04	0.03	0.00
Industrial	0.00	0.00	0.00	0.01	0.9	0.00	0.01	0.07	0.00	0.00
Pasture	0.01	0.00	0.03	0.02	0.00	0.92	0.01	0.00	0.00	0.00
PermanentCrop	0.02	0.00	0.05	0.02	0.02	0.01	0.78	0.09	0.00	0.00
Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	0.00	0.00
River	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.95	0.00
SeaLake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1

(b)

G 0.00020736 SGD 93.03

Class	Annual crop	Forest	HerbaceousVegeta	Highway	Industrial	Pasture	PermanentCrop	Residential	River	SeaLake
Annual crop	0.89	0.00	0.01	0.01	0.00	0.01	0.04	0.00	0.03	0.00
Forest	0.00	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HerbaceousVegetation	0.00	0.02	0.87	0.01	0.00	0.01	0.03	0.04	0.00	0.00
Highway	0.01	0.00	0.01	0.91	0.02	0.00	0.02	0.02	0.01	0.00
Industrial	0.00	0.00	0.00	0.01	0.87	0.00	0.01	0.12	0.00	0.00
Pasture	0.01	0.00	0.02	0.00	0.00	0.94	0.01	0.00	0.01	0.00
PermanentCrop	0.01	0.00	0.04	0.01	0.03	0.01	0.89	0.02	0.00	0.00
Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	0.00	0.00
River	0.01	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.95	0.00
SeaLake	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.98

(c)

B 0.0001728 SGD 90.70

Class	Annual crop	Forest	HerbaceousVegeta	Highway	Industrial	Pasture	PermanentCrop	Residential	River	SeaLake
Annual crop	0.92	0.00	0.01	0.01	0.00	0.01	0.04	0.00	0.01	0.00
Forest	0.00	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HerbaceousVegetation	0.00	0.1	0.75	0.01	0.01	0.01	0.03	0.09	0.00	0.00
Highway	0.01	0.00	0.00	0.91	0.02	0.00	0.02	0.02	0.01	0.00
Industrial	0.00	0.00	0.00	0.01	0.76	0.00	0.00	0.22	0.00	0.00
Pasture	0.00	0.02	0.01	0.01	0.00	0.93	0.02	0.00	0.00	0.00
PermanentCrop	0.00	0.00	0.04	0.01	0.01	0.00	0.84	0.09	0.00	0.00
Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	0.00	0.00
River	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.97	0.00
SeaLake	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.98

(d)

MSB3 0.000743008 Adamax 96.70

Class	Annual crop	Forest	HerbaceousVegeta	Highway	Industrial	Pasture	PermanentCrop	Residential	River	SeaLake
Annual crop	0.98	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Forest	0.00	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HerbaceousVegetation	0.00	0.01	0.97	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Highway	0.00	0.00	0.00	0.97	0.00	0.00	0.01	0.01	0.01	0.00
Industrial	0.00	0.00	0.00	0.00	0.91	0.00	0.00	0.09	0.00	0.00
Pasture	0.02	0.01	0.01	0.00	0.00	0.96	0.00	0.00	0.00	0.00
PermanentCrop	0.01	0.00	0.08	0.01	0.00	0.00	0.88	0.02	0.00	0.00
Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	0.00	0.00
River	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.99	0.00
SeaLake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99

(e)

MSB6 0.0006 SGD 97.91

Class	Annual crop	Forest	HerbaceousVegeta	Highway	Industrial	Pasture	PermanentCrop	Residential	River	SeaLake
Annual crop	0.96	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Forest	0.00	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HerbaceousVegetation	0.00	0.02	0.93	0.00	0.00	0.01	0.01	0.03	0.00	0.00
Highway	0.00	0.00	0.00	0.96	0.01	0.00	0.00	0.01	0.01	0.00
Industrial	0.00	0.00	0.00	0.00	0.9	0.00	0.00	0.09	0.00	0.00
Pasture	0.01	0.00	0.01	0.00	0.00	0.97	0.01	0.00	0.00	0.00
PermanentCrop	0.01	0.00	0.01	0.00	0.00	0.01	0.92	0.04	0.00	0.00
Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	0.00	0.00
River	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.98	0.00
SeaLake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1

(f)

MSB13 0.00383376 SGD 98.62

Class	Annual crop	Forest	HerbaceousVegeta	Highway	Industrial	Pasture	PermanentCrop	Residential	River	SeaLake
Annual crop	0.98	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Forest	0.00	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HerbaceousVegetation	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Highway	0.00	0.00	0.00	0.97	0.01	0.00	0.00	0.01	0.01	0.00
Industrial	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.04	0.00	0.00
Pasture	0.01	0.00	0.01	0.00	0.00	0.98	0.00	0.00	0.00	0.00
PermanentCrop	0.01	0.00	0.01	0.00	0.00	0.00	0.98	0.00	0.00	0.00
Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	0.00	0.00
River	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.00
SeaLake	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1

(g)

Resnet_50 0.000358318 Adagrad 97.31

Class	Annual crop	Forest	HerbaceousVegeta	Highway	Industrial	Pasture	PermanentCrop	Residential	River	SeaLake
Annual crop	0.96	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00
Forest	0.00	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HerbaceousVegetation	0.00	0.00	0.94	0.00	0.00	0.01	0.02	0.02	0.00	0.00
Highway	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.01	0.00
Industrial	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.04	0.00	0.00
Pasture	0.00	0.01	0.02	0.00	0.00	0.96	0.01	0.00	0.00	0.00
PermanentCrop	0.01	0.00	0.01	0.00	0.01	0.01	0.95	0.01	0.00	0.00
Residential	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	0.00	0.00
River	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.99	0.00
SeaLake	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.98

(h)

Diagonal Values	Other Values
0.5-0.93	0.1-0.5
0.93-0.95	0.07-0.1
0.95-0.98	0.04-0.06
0.98-0.99	0.02-0.039
1	0-0.019

Fig. 3.10. Confusion matrix for different band combinations using ReLU; (a) RGB composite (b) R band (c) G band (d) B band (e) MSB3 (f) MSB6 (g) MSB13 (h)ResNet-50. In the diagonal elements of the matrix, green color values represent the highest classification accuracy and red color values represent the lowest classification accuracy. Title of each confusion matrix refers to band combination, learning rate, optimizer, and accuracy respectively.

3.1.6 Stream Flow simulation the Western Indian Himalayan region

Estimation of the changes in streamflow, evaporation and water yield associated with climate change plays an important role in devising long-term water resource management plan. Land use and land cover (LULC) change is one of the key driving elements responsible for altering the surface hydrology of a watershed and is a dynamic process driven by anthropogenic activity. Precipitation and snowmelt are the most significant meteorological parameters with respect to forcing and calibrating hydrological models, as its spatiotemporal variability considerably influences surface hydrology and water resource availability. The main objective of this study is to quantify the decadal changes in LULC and assess impact of orography as well as LULC changes in simulating the streamflow in the Upper Jhelum Basin of Western Himalaya for the period 1979 to 2018. The customised and configured version of Soil and Water Assessment Tool (SWAT) model is used to simulate and understand the climate impact on the streamflow variability in the upper Jhelum basin. Advanced land Observing Satellite – Phased Array type L-band Synthetic Aperture Radar (ALOS PALSAR, 12.5m), CARTOSAT (32m) and Shuttle Radar Topography Mission (SRTM, 30m) Digital Elevation Models (DEMs) along with LULCs at intervals of every 5 year from 2001 to 2019 are used to calibrate the model along with the sensitivity parameters using SWAT-Calibration Uncertainty Program (SWAT-CUP). The model simulations are carried out with multisource rainfall from AgERA5 (0.1º), IMD (0.25º) and TRMM (0.25º).

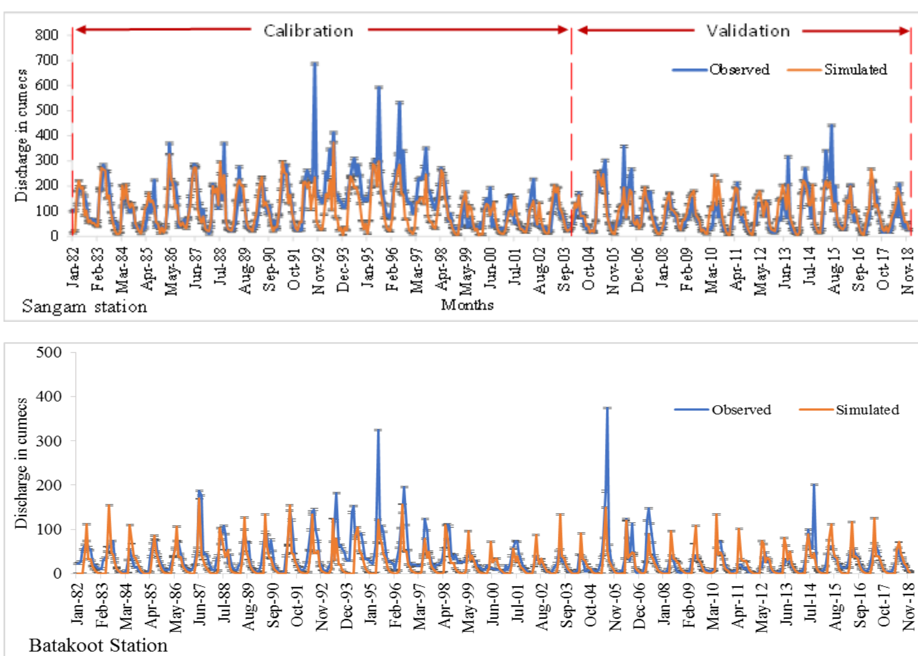


Fig. 3.11 Observed and Simulated (for calibration and validation phase) daily discharge data over Sangam (a) and Batakoot station (b)

The impact of LULC change was prominent in simulated surface parameters and simulations were more realistic when ALOS PALSAR and CARTOSAT DEMs were used. Model performance evaluation parameters such as Coefficient of Determination (R^2), Nash-Sutcliffe efficiency coefficient (NSE) and percentage bias (PBIAS) obtained were 0.77 (0.80), 0.80 (0.83) and 18.69 (10.69) respectively for ALOS PALSAR (CARTOSAT). Simulation with European Centre for Medium-Range Weather Forecasts Agricultural Reanalysis 5th Generation (AgERA5) rainfall data was closest with the observation with correlation and NSE of 0.77 and 0.80. It is noted that the annual streamflow for the whole watershed is decreased from 1979 to 2018 during the monsoon while snowmelt is found to be increasing in the summer season (Fig.3.11).

3.1.7 Leaf Area Index estimation over the Kosi Watershed in Central Himalaya

Application of ML/DL methods in retrieval of LAI is getting increasing attention in recent years. Although the ML/DL algorithm is fast and capable of capturing nonlinear relationships among variables, they are location dependent and time varying. DL algorithms fit a flexible model directly from the data to derive link between input (reflectance) and output (biophysical parameters). During the calibration, the model's hyperparameters are often changed to minimize prediction error. While doing this, the best generalization capabilities are required, rather than getting a good accuracy with the training set, latter could lead to an overfitted solution. The advantage of using ML/DL model over the traditional statistical models is its nonlinear fitting and capability in avoiding saturation issues with the indices based statistical models for high values of LAI. Interrelationship among samples can also be taken advantage of such that it can solve the problem of sample features with a large number of dimensions, and it has good generalization (estimation) and adaptive abilities (Dou et al., 2021; Luo et al. 2022, Ilniyaz et al. 2023). Compared to regression techniques, LSTM can theoretically obtain better estimation because the additional layers of the neural network allows it to learn extra information from the samples used in training resulting in improved estimation accuracy (Goodfellow et al., 2016). LSTM can be used in nonlinear problems and has the capability to express the complex relationship of independent and dependent variables when empirical relationship is formulated. It is good for problems involving complicated internal relationship among dependent and independent variables like the relationship of LAI with radiation spectrum in addition to the capability of handling the problems with large sample feasibility simultaneously. It has an advantage over traditional RNNs such that it avoids the problem of disappearing (or exploding) gradients and has the ability to learn longer time as memory cells where gates are used to create dependencies (Baek and Young, 2018; Dou et al., 2021). Crisóstomo et al., (2020) used Bidirectional LSTM (Bi-LSTM) for rice crop detection from Sentinel-1 time series data and showed that Bi-LSTM performance was superior to other ML based algorithms. Ramesh et al., (2020) showed that Bi-LSTM model reduced the error in wheat yield prediction over India to the order of 50% compared to conventional statistical models. Similarly, Tian et al., (2021) deployed Bi-LSTM for improving wheat yield estimates in the Guanzhong Plain, China. Bi-LSTM is successfully implemented for prediction of evapotranspiration, a crucial parameter in agricultural management (Yin et al., 2020) while Suryo et al., (2019) demonstrated application of Bi-LSTM in smart Agricultural management.

Estimation of LAI from Sentinel-2 will enable to depict ecosystem processes at high spatial resolution for decision making in natural resource management (Xie, 2022). High resolution of Sentinel-2 based LAI is useful in studying regional changes at watershed level such as carbon restoration, water management, erosion, air pollution and many other studies. This study is aimed to apply ML and DL algorithms for retrieval of LAI from Sentinel-2 images. In this study, we have considered two state-of-the-art ML and DL based models for the purpose of retrieval of LAI such as Support Vector Machine (SVM) and Long Short Term Memory (LSTM) respectively. Theoretically, LSTM network is capable of extracting more valuable information in the training samples through increasing the depth of LSTM layer and thereby improving retrieval accuracy. Four variants of LSTMs (Standard LSTM, Bidirectional LSTM, Stacked LSTM and Stacked bidirectional LSTM) are deployed for the retrieval of high resolution LAI over Kosi watershed, Uttarakhand, India using different VIs like Simple ratio (SR), Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (green NDVI), Enhanced Vegetation Index 2 (EVI2), Optimized Soil-Adjusted Vegetation Index (OSAVI), Red-Edge chlorophyll Index (RECI), Red-Edge Normalized Difference Vegetation Index (RENDVI), Red-Edge wide dynamic range vegetation index (REWDRVI), Green wide dynamic range vegetation index (GWDRVI), Wide dynamic range vegetation index (WDRVI). The key objectives of this paper are

1) Retrieval of LAI using Sentinel-2 images with different VIs using ML/DL techniques.

2) Examine the influence of the activation functions, number of hidden nodes, optimizer, batch size and number of training times (epochs) in LSTM on retrieval accuracy for the purpose of arriving at an optimal LSTM configuration.

3) Comparing the LSTM and SVM retrieved LAI from Sentinel-2 with Moderate Resolution Imaging Spectro Radiometer (MODIS) product by validating against in-situ measurements.

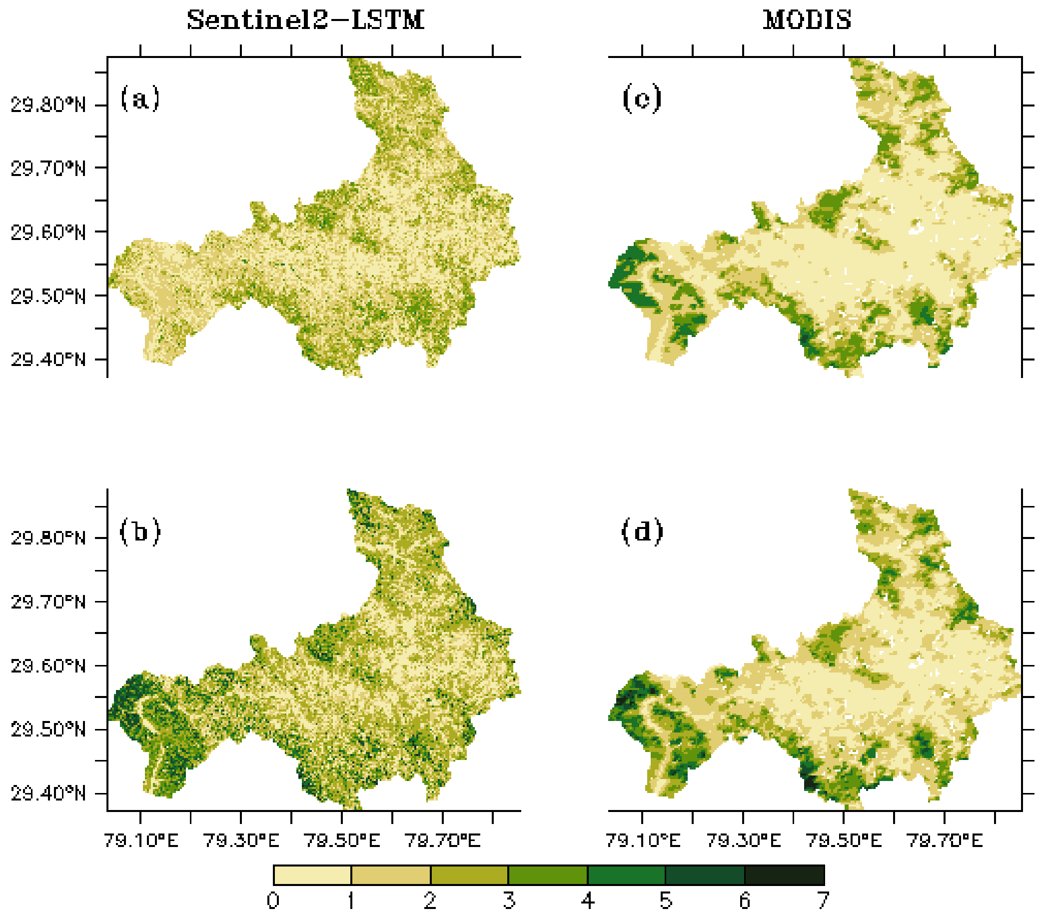


Fig. 3.12 Estimated Rendvi based Leaf area index using Bidirectional LSTM from Sentinel-2 image (Left panels) for (a) February and (b) November averaged over the period 2016-2020. The same is compared with MODIS LAI product (Right panel) for February (c) and November (d).

Four variants of LSTM were developed namely Standard LSTM, Bidirectional LSTM, Stacked LSTM and Stacked bidirectional LSTM and the accuracy of LSTM variants in retrieving LAI is compared with the performance of SVM model. The estimated LAI from these models are validated against in-situ measurements. Among the LSTM variants Bidirectional LSTM performed better in retrieving LAI and Rendevi based LAI retrieval errors were smaller compared to retrieval based on other VIs; MAPE was lowest (0.29) for Bidirectional LSTM compared to MAPE values of 0.33, 0.41, and 0.1.27 with Standard LSTM, Stacked LSTM and Stacked Bidirectional LSTM. It is also noted that model errors in LAI retrieval from Sentinel-2 based on the VIs were lower with Bidirectional LSTM when compared to SVM; MAPE for SVM was 0.56 compared to Bidirectional LSTM. The LSTM and SVM algorithms based estimated LAI and MODIS LAI product are compared with in-situ measurements. This analysis indicated that LAI derived from ML/DL methods is much superior to MODIS LAI product in terms of all the accuracy measures (eg. R^2 values for Bidirectional LSTM, SVM and MODIS were 0.99, 0.93 and 0.0003 respectively). In summary, the seasonal dynamics of vegetation and interannual variation in LAI is better depicted in high resolution LAI derived using LSTM from Sentinel-2 compared to MODIS LAI product; MODIS LAI hardly captures the seasonal vegetation changes (Fig. 3.12). This study presents the methodology of computing high-resolution high-quality LAI product from VIs derived from Sentinel-2 images using ML/DL techniques which have many applications like usage in dynamic numerical models to characterise land evaporation, photosynthesis and carbon uptake processes in addition to traditional usage like crop yield estimation.

4.1.5 Socioeconomic Survey:

Socio-economic Statistics form an important component in the development of the country and include a vast array of information on literacy and education; standard of living and poverty; labour force and employment; status of women and gender empowerment. For the purposes of the present study a questionnaire survey has been undertaken in order to better understand and assess perceptions, capacities and activities related to Climate Change impacts, cropping pattern and behaviour and relevant adaptation policies/measures. In total, 283 samples were collected in Upper Jhelum Basin. The views of different people like Literate/ Illiterate views, Economic Status Views, Gender based views and Age based views were collected. The survey collected a large range of data. Questions were used to ask farmers whether they had noticed long-term changes in mean temperature, mean rainfall, Agricultural and Horticultural productivity. Questions about Water and the constraints to adaptation were also posed. The exact formulation of the questions is included in Annexure VIII

It is analysed from the present study that majority of the views were from Literates around 60.9%, from Above Poverty Level (APL) around 74.8%, males were 86.8% and below 45 of age were 50.4%. By categorization on the basis of socioeconomic parameters i.e. Literacy, Economic Status, Gender and Age analysis was performed. It was found that 60% to 90% responses were in favor of climate change in all the four categories while as above 80% samples agreed that disasters have also been increased in their villages which are also affecting the yield of agriculture as well as horticultural production. 90% responses agreed that water level is decreasing in their villages. Above 80% people have converted their lands from agriculture to horticulture in all four categories because of low agricultural yield, Climate change and decrease in stream flow. It is analyzed by the views of people that the climatic condition are suitable for Horticulture and it also needs less water or irrigation. It is clearly understood by the analysis that farmers are adapting themselves by changing their Agricultural lands to Horticultural Lands which in turn is giving them economic benefits.

4.2 Key Results

- The results showed that in UJB there were significant in Agriculture and Horticulture during the period from 1981 to 2019. There is significant expansion of horticulture area noticed and on the other hand, there is decrease in agricultural area.

- In this study weights were assigned to nine selected criterias to map the land suitability (LS) for agriculture/horticulture. The results revealed that more than 12° slopes are not considered for agriculture activities. These lands need to be protected from intensive soil erosion.

- Eleven physicochemical parameters were analyzed in the present study which includes pH, Alkalinity, Hardness, Chloride, TDS, Fluoride, Iron, Ammonia, Nitrite, Nitrate, Phosphate. Analysis was done for the Six Months Nov-May. The analysis revealed that the pH value of Lidder watershed is between 6.5 to 7 which is considered suitable for drinking purpose.

- The generated database showed that in 2019 maximum damage was witnessed in selected Apple orchards due to the heaviest snowfall during the harvesting period.

It is analysed from the present study that people in Upper Jhelum Basin are converting their lands from agriculture to horticulture due to the economic benefits and also horticulture needs less water or irrigation. But from past few years the untimely snowfall and change in temperature is declining the quality and quantity of apples and is also becoming a major concern for apple growers.

General Livelihood Scenario*:* The assessment of changing livelihood scenario derived from comparison of census data of Almora district for 'occupational structure' for the periods 1961 and 2011 (Fig 1 & Annexure -2), gross/ net sown area from 2002-03 to 2016-17(Annexure 4), and percent contribution of sectors to GSDP of Uttarakhand from 1993-94 to 2019-20 (Annexure -5). The results of Almora reveal significant increase in 'Non-Workers' category of population from 70040 (18% of population) to 324295 (52%), significant decrease in 'Marginal Workers' from 143723 (37%) to 97133 (16%), increase in 'Other Workers' from 32798 (9%) to 62201 (10%), and a marginal decline in Cultivators' numbers from 135970 to 132129 but significant drop in their share in total population from 35% to 21%. The decline in Cultivators' share in population is very concerning considering an increase in rural population in the period by 1.56 times/ 56 % (Annexure I), and the family divisions that would have occurred as a result. A proportionate increase with population, otherwise, would have added 76143 cultivators to the lot. The results suggest rising unemployment and reduced participation/ abandonment/ absence of new participation in agriculture based rural livelihood activities.

The 'Other workers' which represent service sector a domain of urban areas though shows an increase but this is not enough to absorb the huge livelihood deficit created by Marginal-Workers and Non-Workers categories. The divergence from agriculture and wanning interest of rural people in agriculture as a livelihood activity is also evident from declining Gross/Net-Sown Area (Annexure -IV). The sectoral contributions (in percent) to GSDP of Uttarakhand (1993-94 to 1919-29) also reveals similar trends decline in agriculture's contribution from 33.84% to 8.24%. The divergence from agriculture which catered to the livelihood needs of majority in rural areas is a major factor responsible for livelihood deficit/ problem; therefore, there is a need to protect, restore, and improve participation in agriculture through suitable policies.

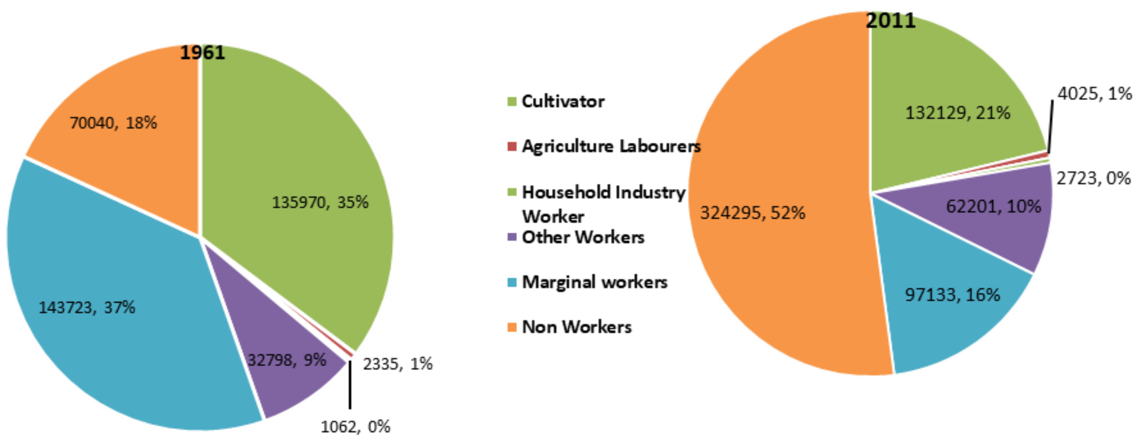


Fig 1. Change in composition of Workers and Non-workers in Almora District

Livelihood status in Rural Areas (DFID Framework Survey): The livelihood vulnerability/ sustainability in rural areas of the study area was assessed in terms of survey scores of Natural, Physical, Human, Social and Financial capitals arrived by summation of scores of identified indicators for each capital (**Annexure XII**). The results for the upland and valley areas and total area (Fig 2), reveal that these areas severely lack in terms of Natural, Social, and Financial capitals. Therefore, livelihood strategies should focus on strengthening of these capitals. The specific actions are required for crop/ health insurance, better community participation/ organization, agriculture diversification, irrigation facilities, ownership rights in forest, and additional income avenues/ financial support.

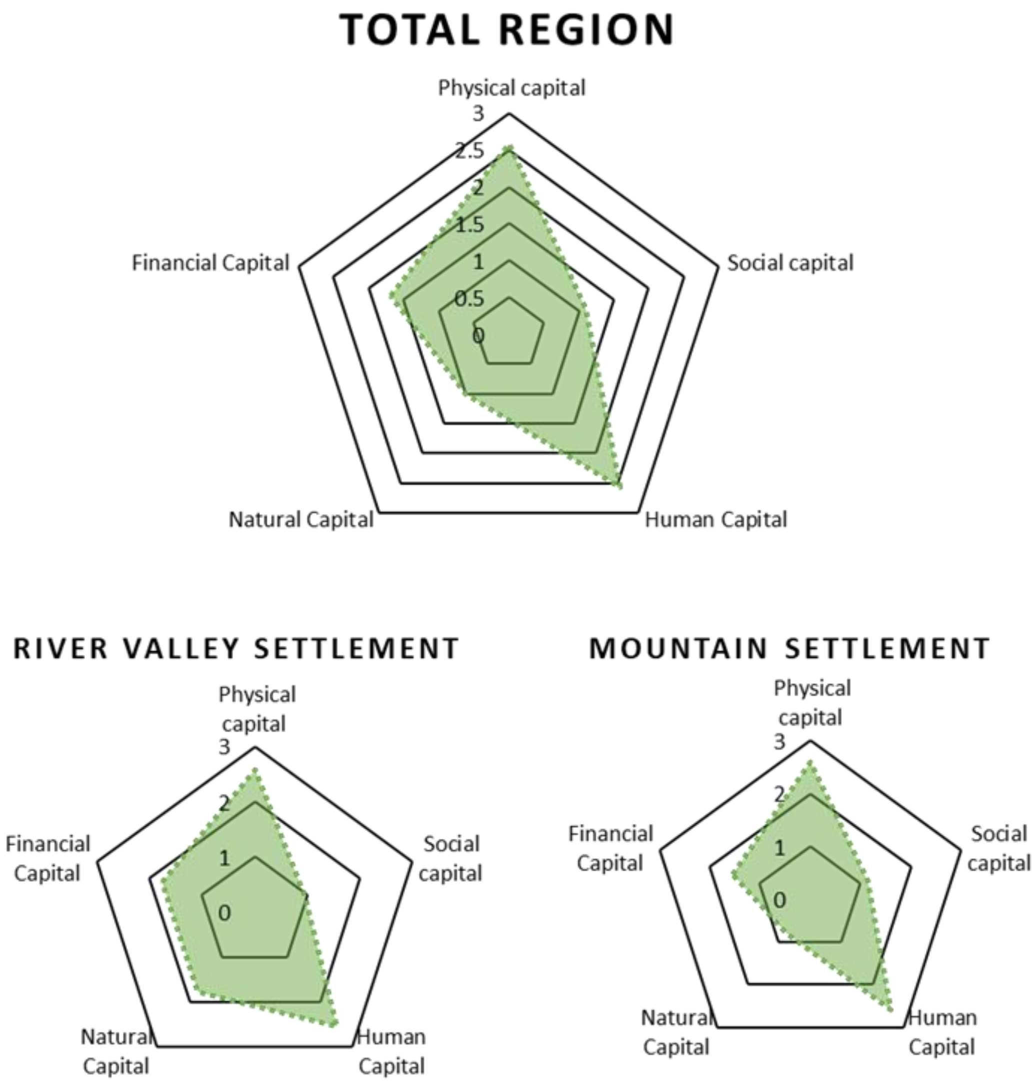


Fig 2. Rural Livelihood Vulnerability in Capital Terms (DFID Framework)

FCM Output of DFID Framework Data: The livelihood vulnerability assessment indicators and data were linked through Participatory Cause Loop Diagram for a system response taking production efficiency as a proxy indicator of livelihood, this diagram of linkages with 20 connectors and 34 transmitters was modelled and run in FCM for 6 iterations, the results are shown in **Fig 3**. The results show maximum centrality for Migration (2.68), followed by Herd size (2.61), and Net Sown area (1.39), suggesting these as major factors affecting the production and livelihood, and therefore should be considered as important factors for livelihood strategy development.

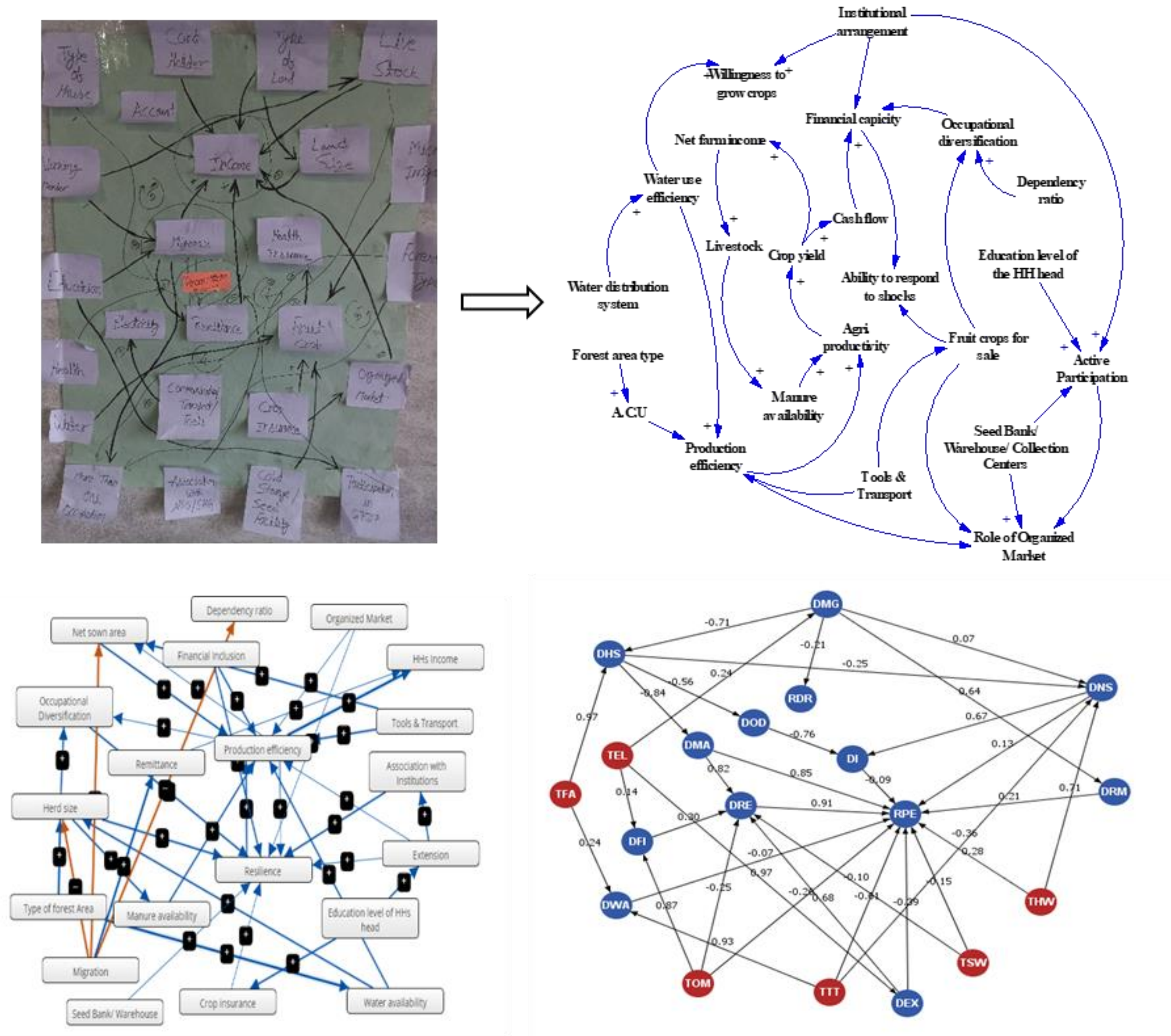


Fig 3. a) Participatory Causal loop Diagram b) Causal loop diagram digitized in 'Vensim'
c) Cognitive map of the livelihood system, grey boxes are proxy indicators of the functioning of the livelihood and taken here as an input vector to the model from DFID's framework (see Annexure 1). Positive relation is depicted by blue line while negative is represented by red and indicates negative relationships between concepts d) Iteration result of Cognitive model

Sustainable Human-NRM Practices (Fallow management crop rotations/combinations): The Fallow Management is a climate resilient sustainable agriculture practice of water scarce rainfed agriculture dominant upland areas, which is used for nutrient recovery and soil fertility management. Under this system usually a routine of cultivating 3 crops in 4 crop seasons (3 crops in 2 years) and keeping the crop field fallow for 1 season is a standard practice, which is followed by cultivation of specific crop combinations/ rotations helping in nutrient enrichment and soil recovery of the fallow land. The specific routine of crop combinations/ crop-rotation/ cropping systems and practices that are followed were noted and compiled in Table 1 **(Annexure -XIII).**

Table 1.Traditional Crop Combination/Rotation Systems used for Fallow Management in Upland Agriculture

Table: 1 a Traditional Crop rotation system in Uttarakhand Central Himalaya						
	Year 1		**Year 2**		**Year 3**	
Plot No.	**Season 1**	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**
Plot 1*	Paddy	Wheat	Paddy	Wheat	Paddy	Wheat
Plot 2**	Sorghum/ Maize, Soyabean	Red Lentil	Sorghum/ Maize, Soyabean	Red Lentil	Sorghum/ Maize, Soyabean	Red Lentil
Plot 3**	Paddy, Sesame, Maize	Wheat, Red Lentil, Flax (Linseed), Mustard, Barley	Finger Millet, Pearl Millet	Barley	Paddy, Sesame, Maize	Wheat, Red Lentil, Flax (Linseed), Mustard, Barley
Plot 4**	Finger Millet, Black gram, Rice Bean, Soyabean, Horse gram, Sorghum, Amaranthus	Oat	Paddy, Sesame, Maize	Wheat/Barley	Finger Millet, Black gram, Rice Bean, Soyabean, Horse gram, Sorghum, Amaranthus	Barley
Plot 5*	Red gram, Chilli	Wheat	Red gram, Chilli	Wheat	Red gram, Chilli	Wheat
Table: 1 b Traditional Fallow management system in Uttarakhand Central Himalaya						
Plot 5***	Barnyard Millet, Foxtail Millet	Fallow	Amaranthus	Fallow	Red gram	Wheat/Barley/Fallow
Plot 6***	Paddy, Barnyard Millet	Fallow	Buck Wheat	Fallow	Amaranthus	Oat/Fallow
Plot 7***	Black gram	Mustard	Finger Millet	Fallow	Horse gram	Flax (Linseed)/Fallow
Plot 8***	Finger Millet, Pearl Millet	Fallow	Fallow	Barley/Mustard	Fallow	Fallow
Plot 9**	Buck Wheat	Fallow	Fallow	Fallow	Buck Wheat	Oat/Fallow
Plot 10***	Green gram, Finger Millet	Fallow	Paddy	Barley	Black gram	Fallow

Season 1 (Sowing Time- Mid April- Mid June, Harvesting Time- Sep- Mid Oct), Season 2 (Sowing Time- Oct- Mid Nov, Harvesting Time- March- April)

***One year to complete the rotation. ** Two years to complete the rotation. *** Three or more years to complete the rotation depends on rainfall, soil structure, and local circumstances.**

Baranaja- Twelve crops in Kharif season. (Finger Millet, Black gram, Rice Bean, Soyabean, Horse gram, Sorghum, Amaranthus, Barnyard Millet, Maize, Pearl Millet, Foxtail Millet, Buck Wheat)

Satnaj- Seven crops are mixed and sown in a single field/plot in Kharif season. (Finger Millet, Black gram, Rice Bean, Soyabean, Horse gram, Sorghum, Amaranthus)

Punchnaj- Five crops are mixed and sown in a single field/plot in Rabi season. (Wheat, Lentil, Flax (Linseed), Mustard, Barley

Value Chain of Horticultural Crops: The Ramgarh, Mukteshwar, Kherda-Mauna area of the study area, is a rich fruit belt, which supplies peach, plum, apple, and apricot for sale to different parts of the country; these operations are managed through system of a value chain managed by group of individuals comprising of persons from villages, regional agents, interstate agents, and persons/ agencies involved in transport of collection and supply of these items. The value chain process mapping developed through interviews ang GDGs is shown in Fig 4 **(Annexure-XIV),** the debt burden of farmers to interstate agents for the loan they provide to them at high rate i.e. 10-12% per season for purchase of planting and packaging material is a major problem that reduces their bargaining problem forcing them to sell/ supply their produce thru them restricting them to organize for their business interest to associate with or create their own market chain.

The growers pointed out that more than 20% of the farm produce is unutilized and becomes waste due to overripening, inappropriate plucking, inadequate storage, wildlife damage, and as farm discard; its conversion to value added products can minimize their losses, the necessary infrastructure and training/ incentives for food processing enterprises would help them in this regard.

Problems and Awareness & Capacity Building Needs : The problems of agriculture and horticulture as allied activity identified by using problem matrix are shown in **Annexure XVA & Annexure XVB**, which reveal labor shortage, water scarcity & shift in rainfall pattern, and wildlife invasion of crops as the major problems of agriculture and absence of - farmers' co-operatives and marketing corporations, cold storage/ ripening chamber facilities, arrangements for certification/branding/packaging of local organic produce as major problems in the growth of horticulture activity. The awareness/ training/capacity building needs identified through PRA are shown in **Annexure XVI**, training / capacity building on SWC & soil reclamation techniques, off-season vegetable cultivation in shed-nets, better community organizations, Farmer to Farmer trainings, social mobilization for agriculture promotion, and awareness about Govt's training programs/ subsidy schemes, are the major needs identified through survey.

Market Map of Horticulture Value chain and Actors involved in the Process:

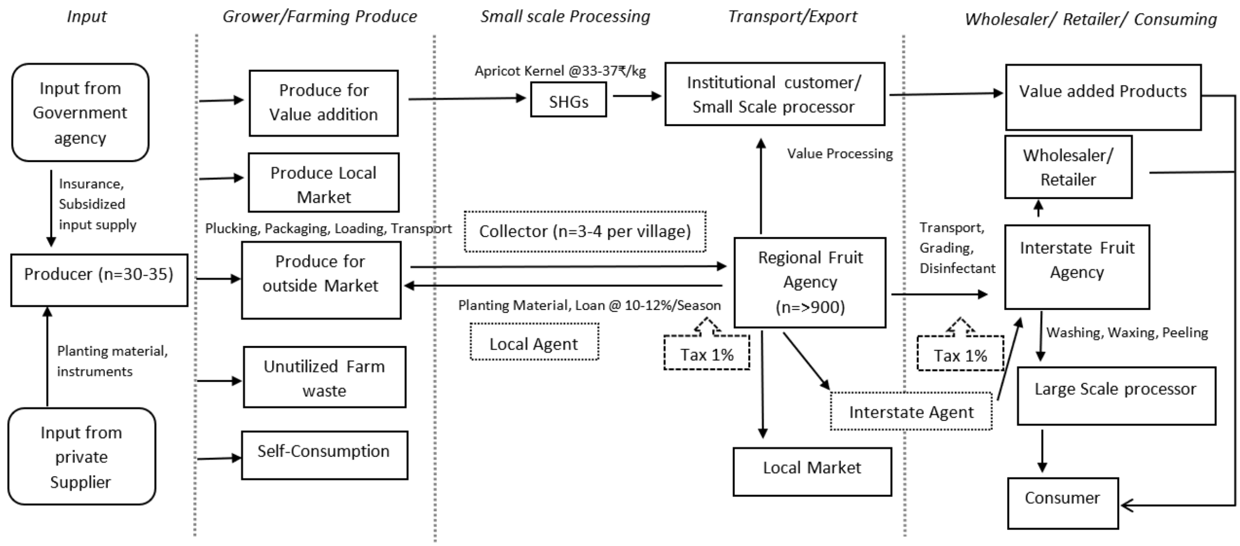


Fig.4 Existing Value chain of Horticulture Produce in the Region

4.3 Conclusion of the study

The analyses of micro picture of livelihood at district level suggests significant rise in unemployment from 18% of population in 1961 to 52% of 2011 population; abandonment of agriculture, divergence from, and absence of new participation in agriculture appears to be the major reason behind this change which is also evident from declining gross/ net sown area in the district. The GSDP data of the Uttarakhand state for periods 1993-94 to 2019-20, also corroborates to this showing a decline in percent contribution of Agriculture to State's GSDP from 33.84% to 8.24%. This is a concerning development, and there is an immediate need to protect agriculture as an important livelihood activity.

The spectacular growth of secondary and tertiary sector in the state, their total contribution to GSDP rising from 59.90% to 88.67%, which would have absorbed the livelihood gap arising from agriculture, is not matched by number of 'Other Workers' in Almora which was merely 9% of population in 2011 (1% increase from 1961 composition), also suggesting a lag in growth of theses sectors, hence needs efforts to promote growth in secondary and tertiary sectors.

The agriculture is the major livelihood activity of the rural areas, in Almora 90% of the population still lives in villages and livelihood opportunities related to demands of 10% of the population cannot bridge the huge livelihood gap that has generated over the years. The agriculture in present scenario, still has unutilized excess capacity for development, therefore, there is a need to revive interest in agriculture through technology/ mechanization, incentives, and provision of some packages in line with PES for practicing agriculture. This besides enhancement of livelihood and sentiment building will also help in protecting the agri-biodiversity/ landraces, related NRM institutions, and associated IKS and cultural practices of rural communities.

The Assessment of rural livelihood based on 'DFID Framework' reveals – that the region needs policies for strengthening of all capital types for progressive sustainability, and special efforts are required for enhancement of Social and Natural capitals which are close to unsustainable range, and Financial capital which shows Limited Sustainability. The livelihood enhancement strategies should gear focus on provisioning of irrigation water, protected cultivation, crop and health insurance, community associations/ participation, cultivation of fruit crops, cold storage/ seed bank, cash provisioning through livelihood diversification/ alternative livelihoods.

The FCM modeling of DFID data shows migration, herd-size (ACU), and net-sown area as three most important parameters affecting the livelihood, and the enhancement strategies should focus on strengthening of these elements. Migration which creates labor shortage for agriculture activities, also support livelihood through the remittances to migrant's families/ relatives. An alternative provisioning for these remittances through livelihood diversification or financial support can help in improving the situation. Simulations for increase in migration shows better livelihood response for upland rural pockets, and herd-size in valley areas.

The labor shortage, water scarcity/ shift in rainfall pattern, and wildlife invasion of crops are the major problems of agriculture, and absence of farmers' co-operatives/ marketing corporations, cold storage/ ripening chamber facilities, and certification/branding/packaging of local organic products are major issues affecting the horticultural activity in the region.

The debt burden of fruit growers to regional agents reduces their bargaining power and restricts them to traditional value chain, provision of soft loans for pre/post-harvest operations can improve their profit prospects and bargain capacity. The farmers loss in terms fruit waste (20% of the orchards produce) can be avoided by installing cold storage/warehouse/food processing facilities at community/ village cluster levels.

Land system changes analyzed in Upper Jhelum Basin from satellite images Landsat images of 1981, 1992, 2001, 2013 and 2019. The study has revealed that LULC conversions are taking place which resulted in the decline in spatial extents of agriculture land (220048 ha) increase in horticulture (47085).

Based on land capability of agriculture/horticulture the study area is grouped into 4 classes highly suitable (covers an area of 11%) moderately suitable (covers an area of 26%), marginally suitable (covers an area of 42%) and not suitable (covers an area of 21%). The current land suitability of the study area can be enhanced by applying appropriate interventions such as soil and water conservation, integrated soil fertility management, moisture harvesting structures, and agronomic practices.

- Eleven physicochemical parameters were analyzed in the present study which includes pH, Alkalinity, Hardness, Chloride, TDS, Fluoride, Iron, Ammonia, Nitrite, Nitrate, Phosphate. Analysis was done for the Six Months Nov-May. The analysis revealed that the pH value of Lidder watershed is between 6.5 to 7 which is considered suitable for drinking purpose.

- The database was generated for the selected apple orchard sites for the year 2019, 2020 and also paddy management practice data were also collected from the UJB. The data revealed that the apple production in the year 2019 was less due to the untimely snowfall in the month of November which is the harvesting season for some apple varieties and also witnessed damages to the apple trees. The analysis from the data of two seasons showed that excess rain in the flowering stage of apple and also reduced the production of crop.

- By categorization on the basis of socioeconomic parameters i.e. Literacy, Economic Status, Gender and Age analysis was performed. It was found that 60% to 90% responses were in favor of climate change in all the four categories while as above 80% samples agreed that disasters have also been increased in their villages which are also affecting the yield of agriculture as well as horticultural production. 90% responses agreed that water level is decreasing in their villages and above 80% people have converted their lands from agriculture to horticulture in all four categories because of low agricultural yield, Climate change and decrease in stream flow.

5 OVERALL ACHIEVEMENTS

5.1 Achievement on Project Objectives

i) Livelihood scenario for Almora district was assessed from Census Occupational Structure data for 1961-2011 was study area level generalizations, which was cross varied by macro view derived from Uttarakhand State's GSDP data, and objective related inferences were deduced for determining broad focus of sustainable livelihood strategies/ policy cues. Inference were also supported by appropriate secondary information.

ii) The rural livelihood scenario was assessed by following DFID Livelihood framework, and areas of intervention focus were identified, the sub-elements for livelihood strategies/ policy, based on respective scores as per DFID framework were also suggested.

iii) Overriding factors affecting livelihood in rural part of study area were also identified by using Fuzzy Cognitive Modelling (FCM).

iv) Climate resilient traditional practice of Fallow Management and routine of crop combinatios/ rotation were documented.

v) Market Value chain of horticultural crops in the study region was mapped, and problems of agriculture/ horticulture and training capacity building needs were identified.

vi) The following primary and secondary data was collected and compiled.

   a) Primary data of 404 households on DFID capital indicators/elements, socio-economic conditions, livelihood activities

   b) Crop Phenological data from the representative experimental sites.

   c) Secondary data on Demographic Profile of the study area (1961-2011), Occupational trends (1961-2011), Sectoral contribution to GSDP at factor cost in Uttarakhand- (1993-94 to 2019-20), Trend of Production/ Productivity of major food crops- (1984-2017), Net/Gross Sown Area (2002-03 to 2016-17), Land Holding size and classes- (2000-01 to 2010-11)

- Landsat 3/7/8 data (1981,1992, 2001, 2013 and 2019) were procured for the Upper Jhelum Basin for generation of Apple and Paddy maps.
- Crop vegetation monitoring of phenology and soil properties have been carried out for Apple crop for two selected Orchards in New Theed, Srinagar and Gopal Pora, Anantnag.
- In total 283 responses of different people were collected from Anantnag, Shopian, Lidder Valley, Kulgam, Pampore and Srinagar.
- Different GIS Layers were generated like slope map, whereas OC, pH, EC, N, P and K and soil texture maps were estimated using IDW interpolation technique and laboratory data of soil analyses.

- Land suitability map was generated for agriculture and horticulture and categorized into four classes i.e., highly suitable, moderately suitable, marginally suitable and not suitable
- Collected and analysed 1491 Soil samples from Upper Jhelum Basin.
- Eleven physicochemical parameters from 32 sites were analyzed which includes pH, Alkalinity, Hardness, Chloride, TDS, Fluoride, Iron, Ammonia, Nitrite, Nitrate, Phosphate. Analysis was done for the Six Months Nov-May.

Potentially insightful knowledge products generated by the project:

5. A **versatile digital database** designed to enable seamless abstraction and assimilation of data (environmental, crop, human) for diverse purposes- ready to be shared with NMHS data archives.
6. Organization of **analytical steps for validation** of models by fusing classical and data analytic approaches
7. Creation of the following **models* for analysis and synthesis**:
    1. APSIM-PADDY
    2. APSIM-WHEAT
    3. STICS-APPLE
    4. SWAT-upper Jhelum and KOSI
    5. High resolution WRF – canopy model
    6. LSTM and Bi-LSTM models: crop production
    7. LAI estimation-Upper Jhelum and Kosi
    8. Fuzzy cognitive Modelling
    9. Watershed Scenario models
    10. Socio-economic Model:
8. Design of **model-based scenarios** for feedback learning from stakeholder interactions

The findings provide a reflection on the changing livelihood scenario in Almora district**, revealing rising unemployment & declining state of agriculture** which is evident from the decline in - gross/net sown area, number of cultivators, and a considerable drop in percent share of cultivators to the total population contrary to increase in population, and division of families. The macro picture at state level in Uttarakhand as revealed from GSDP data also suggesting decline in percent contribution of primary sector & agriculture in particular also corroborates to this fact. As 90% of the population of Almora district still stays in villages where agriculture is most important sector providing livelihood, therefore, **there is an urgent need to protect & harness agriculture to its full potential.** Hence, some special policy & technology packages are therefore required to protect, promote, and conserve hill agriculture which besides livelihood enhancement would also yield other benefits in the form of conservation of traditional landraces, related indigenous knowledge systems, associated culture/ trades/ handicraft practices, better food and also help in curbing outmigration, evacuation of villages.

5.2 Establishing New Database/Appending new data over the Baseline Data (max. 1500 words, in bullet points)

- Agriculture and horticulture maps for Upper Jhelum Basin were generated for the year 1981,1992, 2001, 2013 and 2019.
- Phenological parameters of Apple crop were collected from two selected Orchards in New Theed, Srinagar and Gopal Pora, Anantnag.
- From socioeconomic survey 283 responses of different people were collected from Anantnag, Shopian, Lidder Valley, Kulgam, Pampore and Srinagar.
- Land suitability maps were generated for agriculture and horticulture
- Collected and analysed 1491 Soil samples
- Eleven physicochemical parameters like pH, Alkalinity, Hardness, Chloride, TDS, Fluoride, Iron, Ammonia, Nitrite, Nitrate, Phosphate from 32 sites were analyzed.
    - Scenarios were built for river valley and mountain settlements by increasing the centrality of the component systems of FCM models by 1.5/2/2.5/3 times to observe the effect on the underlying components. Tables 8 & 9 below describe the effect of land and adult cattle unit on production efficiency and the migration effect on Production Efficiency by decreasing the indicator centrality by 0.8/0.6/0.4/0.2 times.

Table 8: Desirable (to increase) adaptation strategies in FCM model component

Centrality of PE (Production Efficiency)	Change in Centrality of PE in various Scenarios				
	Variable (CS)	1.5 CS	2 CS	2.5 CS	3 CS
Total Region (2.68)	Land (0.34)	3.01	3.28	3.5	3.58
	ACU (0.32)	3.09	3.2	3.62	3.8
Mountain Settlement (2.60)	Land (0.34)	3.19	3.37	3.54	3.69
	ACU (0.32)	3.2	3.38	3.5	3.7
River Valley Settlement (2.80)	Land (0.36)	2.98	3.16	3.34	3.44
	ACU (0.33)	2.92	3.4	3.72	3.89

Table 9: Undesirable (to decrease) adaptation strategies in FCM model component

Centrality of PE (Production Efficiency)	Change in Centrality of PE in various Scenarios				
	Variable (CS)	0.8 CS	0.6 CS	0.4 CS	0.2 CS
Total Region (2.68)	Migration (0.74)	3.12	3.23	3.74	3.9
Mountain Settlement (2.60)	Migration (0.77)	2.93	3.26	3.76	4.2
River Valley Settlement (2.80)	Migration (0.64)	3.22	3.35	3.48	3.61

Demographic Profile of the study area- **1961-2011**

Compilation of occupational trend- **1961-2011**

Sectoral contribution to GSDP at factor cost in Uttarakhand- **1993-2020**

Trend of Production/ Productivity of major food crops- **1984-2017**

Net/Gross Sown Area of the region- **2002-2017**

Trend of Land Holding size and classes- **2000-2011**

Soil and crop phenology data was collected from the three experimental sites for Paddy and Wheat crop.

Value chain Analysis.

Documentation of traditional cropping system.

Data base development of 404 HHs from 36 villages survey for analysis of Livelihood vulnerability assessment.

250m resolution 8day NDVI & EVI data for the period 2002-2020

Remote sensing-based images from Landsat 1-5, 8 & Sentinel 2 images with less than 50% cloud cover is organized to estimate system variables

500m 16day leaf area index data for the period 2002-2020

Field data collection: 26 stream measurements, collected 120 soil samples and located 8 springs. Apart from this, 3000+ Leaf Area Index (LAI) readings, 530+ leaf properties, 124 Soil Moisture Sensor measurements and 124 W.E.T sensor measurements were taken.

Field Experiments – Five villages- Sunoli, Dotiyal Gaon, and Mahat Gaon for wheat crop in Kosi watershed

(ii) Collection and analysis of **1491 Soil** and **50 water** samples from Upper Jhelum Basin have been carried out.

Input data sets are prepared for the period 1979-2018 at 0.1-degree resolution

Input data at 4km is under process for 2001-2016

Crop vegetation monitoring of phenology are being carried out for Wheat and Apple crop for the period 2002-2019.

5.3 Generating Model Predictions for different variables (if any) (max 1000 words in

- **Hydrological model simulation is done for 1979-2019 for KOSI and upper Jhelum basin River basin.**
- **APSIM wheat simulations complete,**
- **APSIM paddy simulation**

- **Multivariate deep learning-based process models are developed**
- **LULC is being prepared for estimating for variability and trend (both annual and seasonal timescales)**
- **High resolution WRF – canopy model is customized for Kosi and upper Jhelum region simulations are complete.**
- **Crop phenology estimation for 2002-2020 is complete**
- **DFIDs' Livelihood capital assessment for development of strategies (36 villages surveyed, N=403).**
- Participatory CLD (Causal Loop Diagram) – to map the cause and effect relation of the system component.
- Fuzzy cognitive Modelling:: Functioning of livelihood system- Identification of overriding factors affecting rural livelihood system

5.3 Technological Intervention (max 1000 words)

5.4 On field Demonstration and Value-addition of Products (max. 1000 words, in bullet points)

5.5 Promoting Entrepreneurship in IHR

5.6 Developing Green Skills in IHR

5.7 Addressing Cross-cutting Issues (max. 500 words, in bullet points)

The agriculture based rural livelihoods are highly climate dependent, the climatic events and shift affects the productivity of agricultural and fruit crops and increases the risk of crop damage. During the surveys, the shift in rainfall patterns, and water scarcity has also been reported as one of the major problem affecting the agricultural performance in the study region. The FDGs with fruit growers in Mauna-Kherda area revealed that of late the growers are facing difficulties in the "Production and Germination" of new Apricot plants in low-lying areas of the region; and Peach and Plum crops in the region are getting infected by 'Taphrina fungus' where high humidity followed by rain induces 'catkin' disease (leaf curl) in plants. The system dynamical component includes climate as an important factor for discerning productivity changes for identified crops i.e. paddy, wheat etc.

The agricultural activities in the rural pockets of hills are mostly performed by women folk, recommendations of the study for incentivizing agriculture, use of new technologies, development food processing/ warehouse etc infrastructure, PES mechanism for practising agriculture will regenerate their interest, bring familiarity with new techniques/ technology, and increase male participation in agricultural activities, and help improving their lot. The recommendations of the project though are not gender specific, but will indirectly support their cause.

6 PROJECT'S IMPACTS IN IHR

6.1 Socio-Economic Development (max. 500 words, in bullet points)

The livelihood scenario analyses provide an overview of changing livelihood pattern in the study area, economic situation at state, and raises alarm for protection of agriculture through incentives, subsidies, technological applications, which has implications for socio-economic development of the region. This also makes one to contemplate upon the likely interventions that can be done to improve the rural livelihood situation, and building a strong base for rural economy.

The changing socio-economic dynamics in the region, such as demographic patterns, occupational patterns, declining net/gross sown area under cultivation, and contribution to GSDP (gross state domestic product) of the primary sector, providing important data that policymakers can use to develop policies related to sustainable livelihood opportunities, sustainable natural resource management, and conservation of traditional knowledge base in farming system to achieve economic and environmental benefits. Supporting policies are needed in the study region to strengthen the overall capital system, which will improve social and natural capital as well as human, financial, and physical capitals. System analysis reveals Land type, Herd Size and Migration are the overriding factors affecting the livelihood response in the study region and policies should be aimed to improve these indicators.

Value chain Analysis of Horticulture and Traditional crops finds debt burden of the region's growers," "inadequate storage facilities," "inadequate infrastructure assistance at the cluster/ village level," and "lack of processing industries," all of which hinder the production efficiency. Minimum price protection for the fruit crop, low interest loans, technological interventions, market reform, and diversification through alternative crops such as herbs and spices can help in improving the condition of the growers in the region.

6.2 Scientific Management of Natural Resources In IHR (max. 500 words, in bullet points)

6.3 Conservation of Biodiversity in IHR (max. 500 words, in bullet points)

6.4 Protection of Environment (max. 500 words, in bullet points)

6.5 Developing Mountain Infrastructures (max. 500 words, in bullet points)

6.6 Strengthening Networking in IHR (max. 700 words, in bullet points)

7 EXIT STRATEGY AND SUSTAINABILITY

7.1 How effectively the project findings could be utilized for the sustainable development of IHR (max. 1000 words)

The project envisages the application of system dynamical modelling for developing strategies for achieving enhancement of quality of livelihood opportunities in urban-rural system of IHR, which involves study of urban-rural livelihood linkages, threats etc for prescription of policy solutions by a holistic system analyses. This a novel approach probably being attempted for the first time in complex and data deficient IHR environment. The sustainable livelihood means management of livelihood for all from the available set of resources on long term basis. The part covered by us is only a small component of the project, where livelihood scenario is examined which shows growing imbalance due to stagnation in agriculture. A concern for protection and promotion of agriculture is raised. Agriculture is a type renewable resource management practice which provides us with a variety of fruits, vegetables, pulses, food grains on a periodic basis for subsistence etc., abandonment of agriculture in long run might lead to diversion of agricultural land for other purposes and our increased dependence on outside supplies adversely affecting the sustainability in the long run. Therefore, the protection/ revival of agriculture is very important for livelihood sustainability and sustainable development of the region. The livelihood analyses on DFID framework, also provides a multi-dimensional view of livelihood situation for focused actions. The problems of agriculture/ and training needs are also identified, which might be useful in sustaining agriculture and for sustainable development of the region.

7.2 Efficient ways to replicate the outcomes of the project in other parts of IHR (Max 1000 words)

Agriculture situation in the state is more or less same, therefore, its protection and promotion can be safeguarded by promulgation of policies, and provisioning of incentives; technology should be provide for production enhancement.

7.3 Identify other important areas not covered under this study needs further attention (max 1000 words)

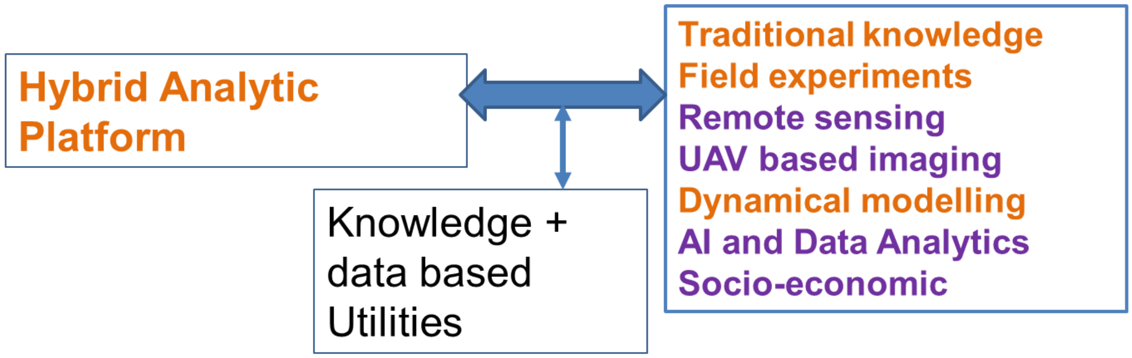
7.4 Major recommendations for sustaining the outcome of the projects in future (500 words in bullets)

Agriculture situation in the state is more or less same, therefore, its protection and promotion can be safeguarded by promulgation of policies, and provisioning of incentives; technology should be provide for production enhancement.

Suggestion for Realizing the substantial potential of the knowledge products developed under this project.

To design and development of an **integrated hybrid analytic platform system for sustainable utilization of natural resources to enhance livelihood options** in some select agro-ecosystems of Himalayan region for the identified crops (Wheat, Paddy, apple and millets).

Integrated→ System dynamic driven predictive approaches in an iterated framework incorporating stakeholders feedback



- **Validation of the models: Watershed Scenario models, Socio-economic Model, Hydrological model for KOSI, STICS for Apple crop**

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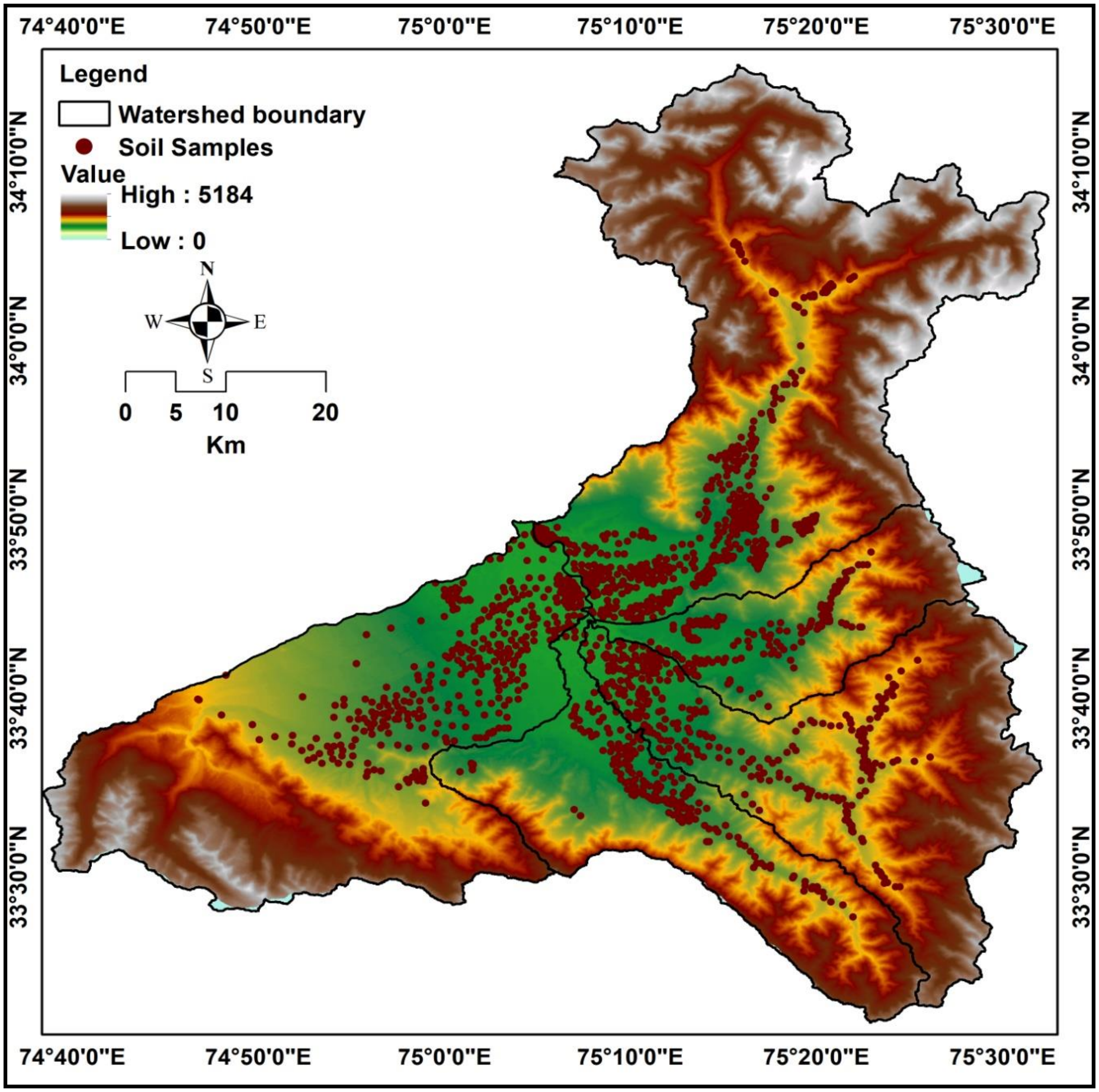
Annexure VII

Soil database generated for the Upper Jhelum Basin.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33°50'0"N
33°40'0"N
33°30'0"N
Legend
Watershed boundary
Soil Samples
Value
High : 5184
Low : 0
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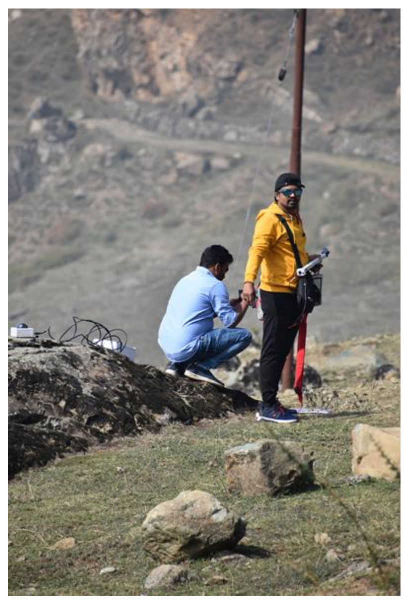
Annexure IX

FIELD PHOTOGRAPHS















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SOP for running ingredient models of SDM

1. Simulation of environmental variables
2. Simulation of crop phenology and yield
3. Simulation of Water budget

Instruction to compile and run Weather Research and Forecasting (WRF) Model Version

Components of the model to be installed

Get the source code from following link

http://www.mmm.ucar.edu/wrf/users/download/get_sources.html

i. **WPSVX (WRF Pre-Processor)**
ii. **WRFVX (WRF Model)**

Get the WRF-ARW user guide for instructions to compile and run from the following link http://www.mmm.ucar.edu/wrf/users/docs/user_guide_V3/contents.html

WRFV3.1.1 (WRF Model) installation

Before compiling WRF code on a computer, check to see if the netCDF library is installed. This is because one of the supported WRF I/O options is netCDF, and it is the one commonly used, and supported by the post-processing programs.

If the netCDF is installed in a directory other than /usr/local/, then find the path, and use the environment variable NETCDF to define where the path is.

To do so, type

setenv NETCDF path-to-netcdf-library

Often the netCDF library and its include/ directory are collocated. If this is not the case, create a directory, link both netCDF lib and include directories in this directory, and use environment variable to set the path to this directory.

For example,

netcdf_links/lib -> /netcdf-lib-dir/lib

netcdf_links/include -> /where-include-dir-is/include

setenv NETCDF /directory-where-netcdf_links-is/netcdf_links

If the netCDF library is not available on the computer, it needs to be installed first. NetCDF source code or pre-built binary may be downloaded from and installation

instruction can be found on the Unidata Web page at http://www.unidata.ucar.edu/.

WRF source code tar file can be downloaded from http://www.mmm.ucar.edu/wrf/download/get_source.html. Once the tar file is unzipped (gunzip WRFV3.TAR.gz), and untared (tar –xf WRFV3.TAR), and it will create a WRFV3/ directory.

The steps to compile and run the model are:

1. configure: generate a configuration file for compilation

2. compile: compile the code

3. run the model

Go to WRFV3 (top) directory and type

./configure

and a list of choices for your computer should appear. These choices range from compiling for a single processor job (serial), to using OpenMP shared-memory (smpar) or distributed-memory parallelization (dmpar) options for multiple processors, or combination of shared-memory and distributed memory options (dm+sm). When a selection is made, a second choice for compiling nesting will appear, select option1 (basic)

For example, on a Linux computer, the above steps may look like:

```
./configure
> setenv NETCDF /usr/local/netcdf
> setenv WRFIO_NCD_LARGE_FILE_SUPPORT 1
> ./configure
```

To compile the code, type

```
./compile em_real
```

When the compile is successful, it will create three executables in the main/directory:

ndown.exe, real.exe and wrf.exe.

real.exe: for WRF initialization of real data cases

ndown.exe : for one-way nesting

wrf.exe : WRF model integration

WPSVX (WRF Pre-Processor) installation

The WRF Preprocessing System uses a build mechanism similar to that used by the WRF model. External libraries for geogrid and metgrid are limited to those required by the WRF model, since the WPS uses the WRF model's implementations of the WRF I/O API; consequently, *WRF must be compiled prior to installation of the WPS* so that the I/O API libraries in the WRF external directory will be available to WPS programs. Additionally, the ungrib program requires three compression libraries for GRIB Edition 2 support; however, if support for GRIB2 data is not needed, ungrib can be compiled without these compression libraries.

Required Libraries

Where WRF adds a software layer between the model and the communications package, the WPS programs geogrid and metgrid make MPI calls directly. Most multi-processor machines come preconfigured with a version of MPI, so it is unlikely that users will need to install this package by themselves.

Three libraries are required by the ungrib program for GRIB Edition 2 compression support. Users are encouraged to engage their system administrators for the installation of these packages so that traditional library paths and include paths are maintained. Paths to user-installed compression libraries are handled in the `configure.wps` file by the `COMPRESSION_LIBS` and `COMPRESSION_INC` variables.

1) JasPer (an implementation of the JPEG2000 standard for "lossy" compression)

http://www.ece.uvic.ca/~mdadams/jasper/

Go down to “JasPer software”, one of the "click here" parts is the source.

```
> ./configure
> make
> make install
```

Note: The GRIB2 libraries expect to find include files in "jasper/jasper.h", so it may be necessary to manually create a "jasper" subdirectory in the "include" directory created by the JasPer installation, and manually link header files there.

2) PNG (compression library for "lossless" compression)

http://www.libpng.org/pub/png/libpng.html

Scroll down to "Source code" and choose a mirror site.

```
> ./configure
> make check
> make install
```

3) zlib (a compression library used by the PNG library)

http://www.zlib.net/

Go to "The current release is publicly available here" section and download.

```
> ./configure
```

```
> make

> make install
```

WPS Installation Steps

The WPS source code tar file can be downloaded from http://www.mmm.ucar.edu/wrf/download/get_source.html.

Download the `WPSV3.TAR.gz` file and unpack it at the same directory level as

WRFV3,

At this point, a listing of the current working directory should at least include the

directories WRFV3 and WPS. Change to the WPS directory and issue the configure command followed by the compile command as below.

```
> cd WPS

> ./configure
```

- Choose one of the configure options

```
> ./compile >& compile.output
```

After issuing the compile command, a listing of the current working directory should reveal symbolic links to executables for each of the three WPS programs: geogrid.exe, ungrib.exe, and metgrid.exe. If any of these links do not exist, check the compilation output in compile.output to see what went wrong.

Running the WPS

There are essentially three main steps to running the WRF Preprocessing System:

1. Define a model coarse domain and any nested domains with *geogrid*.

2. Extract meteorological fields from GRIB data sets for the simulation period with

ungrib.

3. Horizontally interpolate meteorological fields to the model domains with *metgrid*.

Copy the namelist.wps provided to WPS directory.

Download the geogrid data for running WRF Preprocessing System (geog.tar.gz, full set, 13 GB when untared) from http://www.mmm.ucar.edu/wrf/download/get_source.html. Change the "geog_data_path =" to the directory where geog.tar.gz is untared.

Link all the initial data provided to the WPS directory as follows

```
./link_grib.csh /initial data directory/* ./
```

Run the following executables

./geogrid.exe

Will create files like geo_em*.nc

./ungrib.exe

Will create files like `FILE:2005-07-*_*`

```
./metgrid.exe
```

Will create files like `met_em.d*.2005-07-*`

Running the WRFV3

Copy the namelist.input file provided to WRFV3/run directory

Link or copy the WPS generated `met_em.d*. files to` WRFV3/run directory

Run the real.exe

mpirun –np no. of processor real.exe

will generate files wrfinput_d* and wrfbdy_d*

Run the wrf.exe

mpirun –np no. of processor wrf.exe

will generate file wrfout_d01_2005-07-25_12:00:00

WRF Configuration for Benchmark

Domain (set max_dom = 1 or more in namelist.input)

Number of grid points in X and Y direction (set e_we = 2401, and e_sn = 1861 in namelist.input)

Number of vertical levels (e_vert = 28 in namelist.input)

Time step for WRF integration(set time_step = 10 in namelist.input)

Set top of atmosphere (set p_top_requested = 5000 in namelist.input)

Horizontal resolution in X and Y direction (set dx = 4000 and dy = 4000 in namelist.input)

Forecast period (set run_days = 02 in namelist.input)

Time interval to save output (set interval_seconds = 3600 in namelist.input)

Physics options (set the folloing options

mp_physics = 6,

ra_lw_physics = 1,

ra_sw_physics = 1,

radt = 4,

sf_sfclay_physics = 1,

sf_surface_physics = 1,

bl_pbl_physics = 1,

bldt = 0,

cu_physics = 1,

cudt = 5,

isfflx = 1,

ifsnow = 0,

icloud = 1,

surface_input_source = 1,

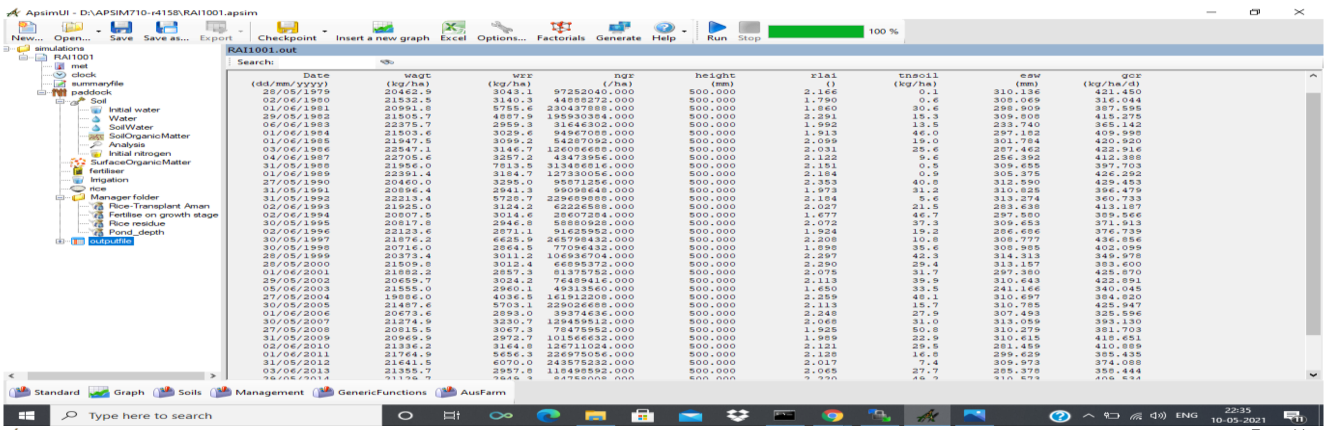
num_soil_layers = 5,

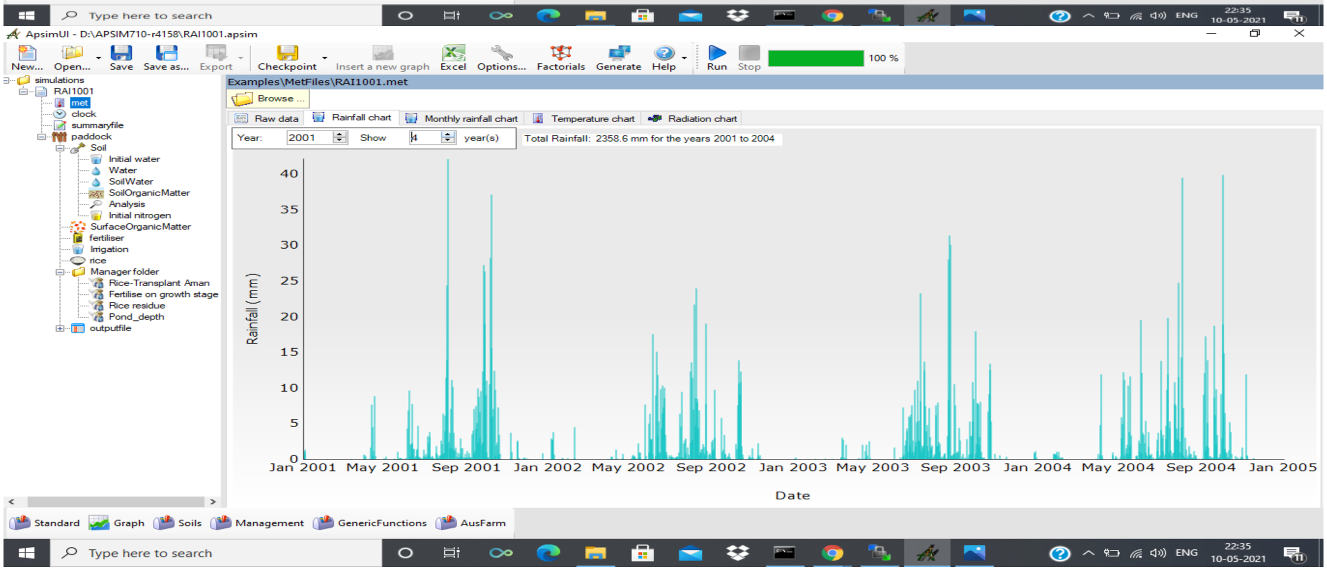
sf_urban_physics = 0,

in namelist.input)

SOP for APSIM model simulation

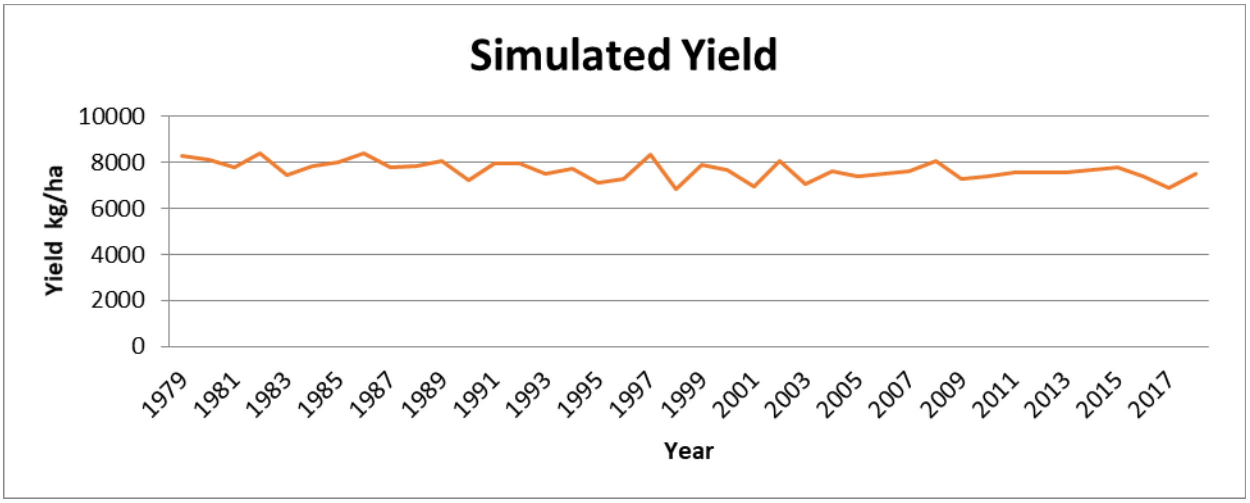
- Calibration of the phenology sub-model of APSIM-Oryza model and validation of RNR 15048 variety which is grown in Tungabhadra command area.
- Calculating the genetical coefficients of RNR 15048 variety by using daily maximum and minimum temperature data and meteorological data.
- Processing the model for number of iterations to get the yield which is significantly related to field measured yield





- Tuning the coefficients because the simulated yield of a Rice/wheat for rabi season less compare to experimental data.
  - "A methodology for estimating phonological parameters of rice cultivar utilizing data from common variety trials"
  - "APSIM evolution towards a new generation of agricultural systems simulation"
  - "Flowering response of rice to photoperiod and temperature: a QTL analysis using a phenological model"

- calculating development rate for new rice variety by taking averages of all the years using meteorological data.
- Simulation of the yield of rice



- Rice cultivar calculated values for APSIM –Oryza model
  DVRJ ="Development rate in juvenile phase (oCd-1)"=0.000610
  DVRI ="Development rate in photoperiod-sensitive phase (oCd-1)"=0.000613
  DVRP ="Development rate in panicle development (oCd-1)"=0.000750
  DVRR ="Development rate in reproductive phase (oCd-1)"=0.001006
  MOPP ="Maximum optimum photoperiod (h)"=11.50
  PPSE ="Photoperiod sensitivity (h-1)"=0.0
- Preparation of the farmers field table from the primary data

Sl. No	Parameters	Field 1	Field 2	Field 3	Field 4
1	Farmer Name				
2	Lattitude	15°18’49.3”	15°17’14.9“	15°31’17.6“	15°31’19.9“
3	Longitude	76°19’01.6"	76°19’40.9“	76°37’42.8“	76°37’42.9“
4	Variety Name				
5	Duration of Variety	120-125	120-125	125-130	125-130
6	Sowing Date	December 18	December 15	December 10	December 2
7	Transplanting Date	Janaury 20	Janaury 23	Janaury 9	Janaury 2
8	No. of seedlings per hill	3	3-4	4	4
9	No. of hills / m2	35-45	40-45	40-45	40-45
10	Juvenile stage in DAT	15	20	17	15

11	End of vegetative stage in DAT	45	50	45	45
12	50% flowering in DAT	65	70	65	70
13	Physiological maturity in DAT	85	90	90	90
14	Harvesting in DAT	90	95	95	95
15	No of grains / m2	-	-	-	-
16	single grain weight (g)	-	-	-	-
17	Yield (kg/ha)	6250	6570	7320	7434
18	Biomass yield (kg/ha)	-	-	-	-
Irrigation details					
19	Irrigation amount (mm)	50	50-60	50-60	50-60
20	No of irrigation	15-20	18-20	20-22	20-22
21	Irrigation method	Flood	Flood	Flood	Flood
Fertiliser management					
22	Date of fertilizer (N, P and K) application (DAT)	15,30 and 50	12,30,45 and 60	15,30 and 55	10,25,45 and 60
23	Amount of fertilizer (kg/ha)	650-700	700-750	850-1000	850-1000
24	Type of fertilizer	Urea, Complex and MOP	Urea, NPK, Potash, Complex and Patera	Urea, Complex ,NPK and Potash	Urea, Complex ,NPK and Potash
25	Depth of fertliser application (mm)	50	50	50	50
26	Fertiliser application method	Broadcasting	Broadcasting	Broadcasting	Broadcasting
Farmyard manure / green manure applied, if any					
27	Name of organic fertiliser	Compost	Compost	Compost	Compost
28	Amount of organic manure (tonnes/ha)	4-5	4-5	5-6	5-6

SOP for SWAT simulations

9 Introduction

SWAT is a popular model among many watershed hydrologists who are interested in studying the impact of agricultural activities and land use management on the overall watershed health including streamflow and water quality. The objective of this tutorial is to expose users to some of the basic functionalities of ArcSWAT, and how to use it to create a SWAT model for a watershed. This exercise is developed by using data for Cedar Creek in northeast Indiana, but the process can be duplicated for any other watershed in the United States by using a digital elevation model (DEM) and landuse data. For areas, outside the United States soil data will also be needed in addition to DEM and landuse.

10 Computer Requirements

You must have a computer with latest windows operating system, and the following programs installed:

1. ArcGIS 10.8.2
2. ArcSWAT 2012

Make sure ArcSWAT 2012 is installed on the system. It can be downloaded from the following link: http://swatmodel.tamu.edu/software/arcswat. You need to have administrative access to install ArcSWAT on your computer.

11 Data Requirements and Description

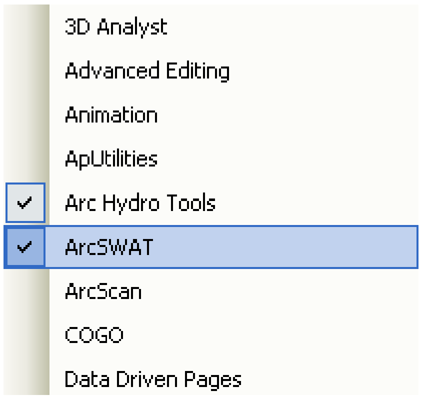
This tutorial requires the following datasets:

(1) DEM for the study area

(2) Land use land cover
(3) Soil type

12 Getting Started

Open ArcMap to create an empty document. If ArcSWAT toolbar is not loaded in the map document. **Right click** on the menu bar to see a menu of all the available tools and **select** *ArcSWAT* as shown below.

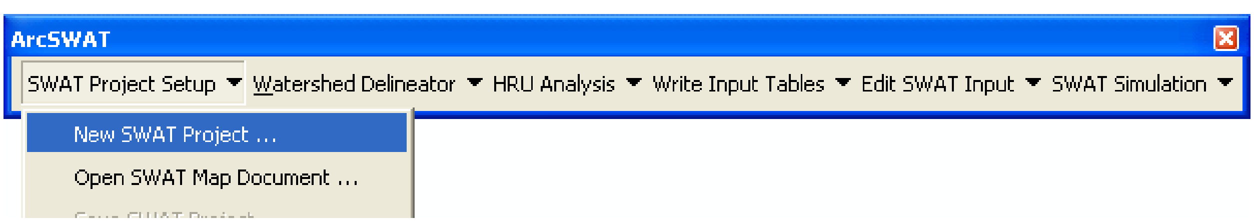


You should now see that the ArcSWAT toolbar added to the map document as shown below. You can leave it floating or you may dock it in one of ArcMap menubars.

Similarly add Spatial Analyst extension and **activate** it by ***clicking*** on *Customize→Extensions…*, and **checking** the box next to *Spatial Analyst*.

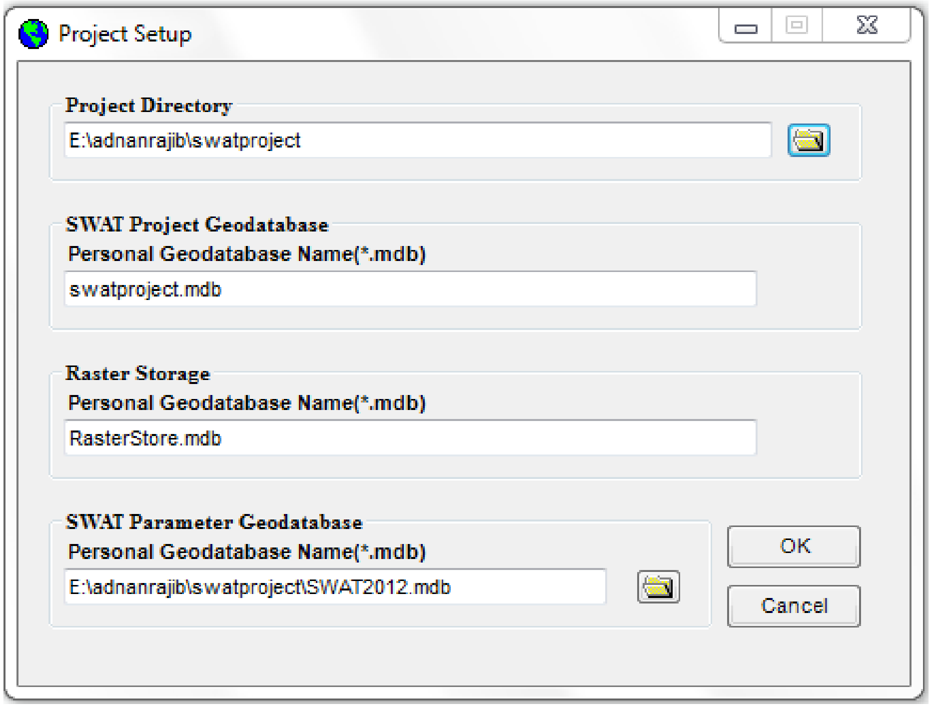
13 Project Setup

The first step in using ArcSWAT is to set up a project so that necessary folders and databases arecreated to store all the data. **Click** on *SWAT Project Setup→New SWAT Project.*



If you get a message asking to save the current map document, **click** No, and proceed.

After few seconds, you should get the *Project Setup* window as shown below. Locate the project directory (Example: E:\yourlastname\swatproject). The swat project geodatabase, raster storage geodatabase and the SWAT parameter geodatabase automatically get a name. Click *OK*. After few seconds, you should get a project set-up done message. Click *OK* to proceed. If you want to make a SWAT model in your personal computer, it is preferable that you create your project folder in C: drive inside the SWAT folder (where the ArcSWAT has been installed).



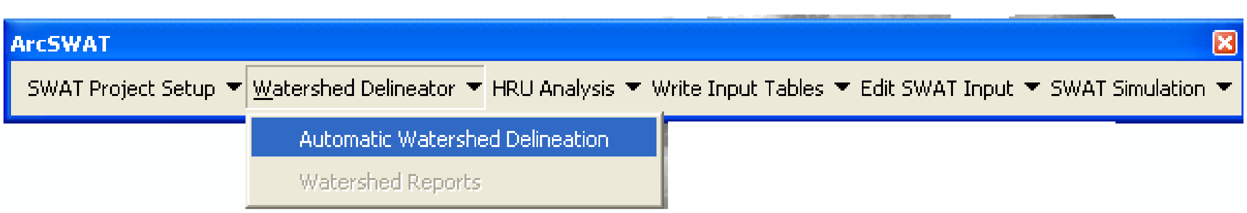
The ArcMap document will now be saved with the name of the directory you specified, and *project.mdb* and *RasterStore.mdb* will also be created in your working directory. After the project setup is done, go ahead and start the watershed delineation process.

14 Adding Data

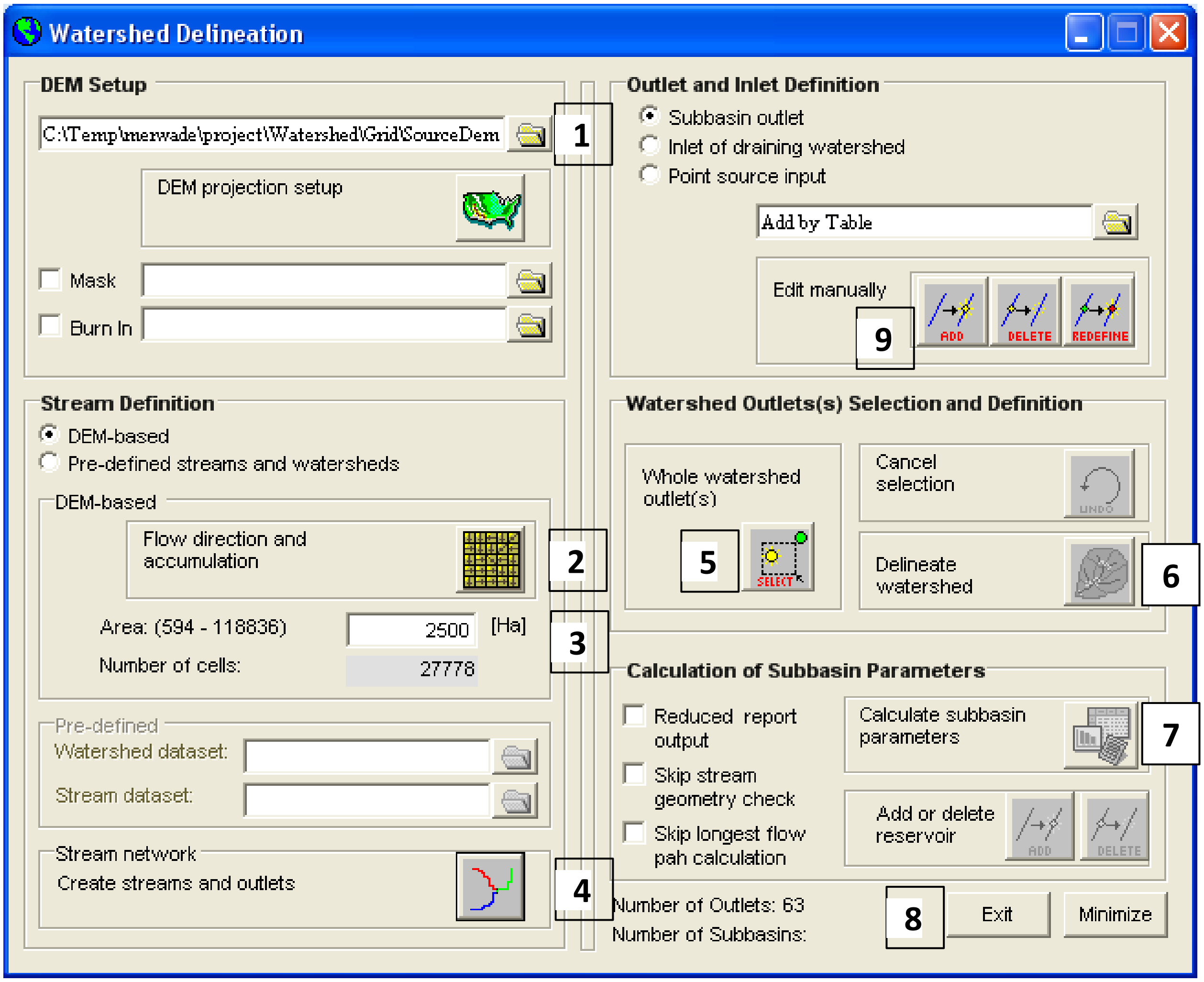
Add the DEM and landuse for your study area to the map document. They should be in an appropriate projected coordinate system.

15 Nate Watershed Delineation

Click on *Watershed Delineator→Automatic Watershed Delineation* as shown below.

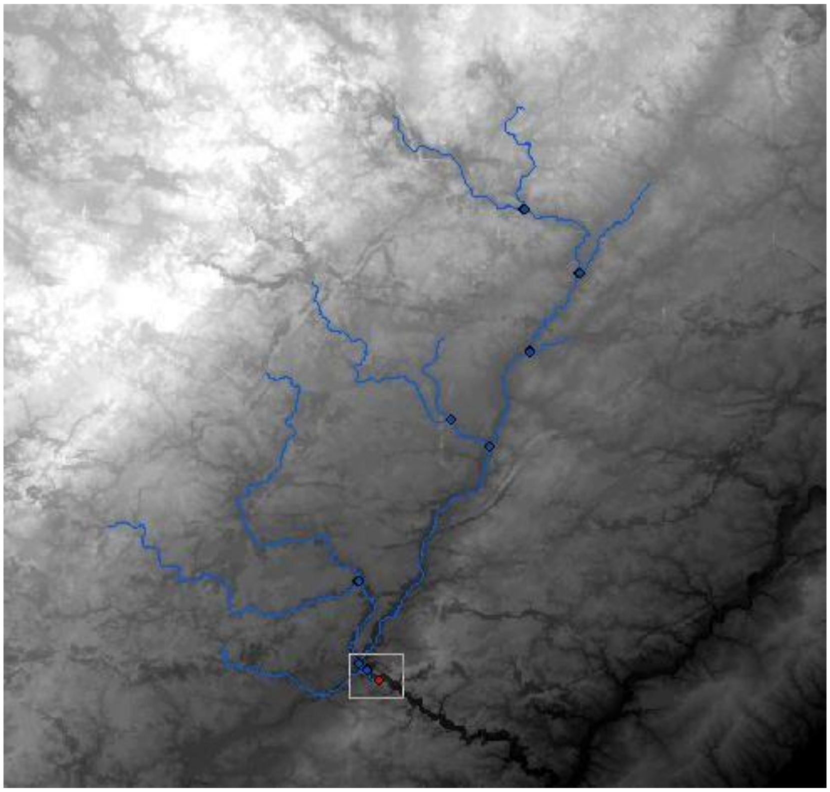


Once the watershed delineation window is activated, **click** on the open file button (#1 in the figure below) in DEM setup portion, and then **click** on select from map, and then **select** *your project DEM*. **Click** *OK*. You will see that the name of the DEM will change to SourceDEM. Lets **skip** the Mask and Burn in option, and proceed to creating flow direction and flow accumulation grids. By leaving the default DEM based option unchanged in the stream definition portion, **click** on *Flow direction and accumulation* button (#2 in figure below).



After flow direction and flow accumulation is complete, the area box will be populated with some number. This is the critical stream area threshold that you will use to define the stream network. For your project, if the watershed area is X km^2 (**what is the area of the watershed that you are delineating?**) and you are using a threshold of y%, then the area that you will use is Xy/100 and then you need to convert this area into Ha. The conversion factor is: 1 km^2 = 100 Ha. For this exercise, you will use 3% threshold area to define the stream network. So change the *Area* accordingly (#3 in the figure above), and click the *Create stream and outlets* button (#4) to create stream network, subbasins and outlet for each of the subbasin.

Next, in the watershed outlets selection and definition, click on the select *Whole watershed outlet*button (#5), and then select your desired outlet location using the cursor as shown below (**the outlet location is the USGS gaging point that is provided to you)**. You can use the *undo* button if you have mistakenly selected a wrong outlet. If outlet does not exit at the point you are interested in, use the Add button in *Edit Manually* frame (#9 in the figure above) to add a point, and then do the selection using the outlet (#5) button.



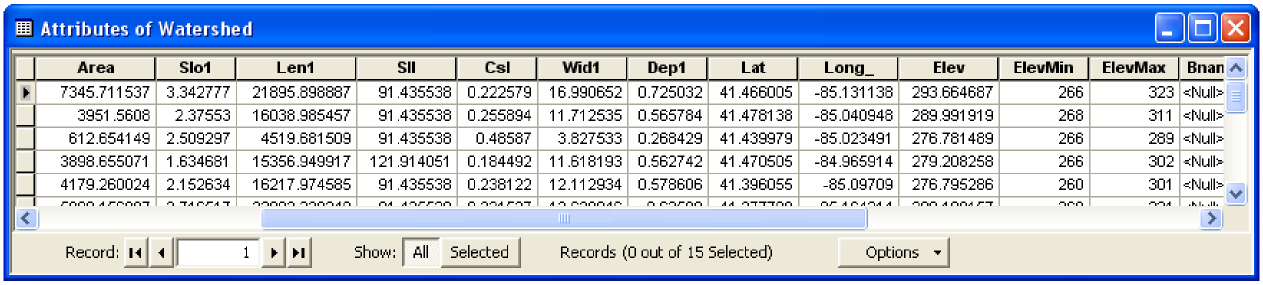
After the outlet is selected, the *Delineate watershed* button (#6) will be activated in green. Click on the delineate watershed button to delineate the watershed. Click OK on the delineation done message. After the watershed is delineated, you will see that a polygon feature class with sub-basins is added to the map document. If you open its attribute table (shown below), you will see that it does not have any hydrology or watershed specific attributes (e.g., slope, elevation).

Attributes of Watershed

OBJECTID *	Shape *	GRIDCODE	Shape_Length	Shape_Area
1	Polygon	1	74663.0496	73457115.374517
2	Polygon	2	49198.679	39515607.996882
3	Polygon	3	15029.9262	6126541.490254
4	Polygon	4	51307.194	38986550.706045
5	Polygon	5	55848.61	41792600.237912
6	Polygon	6	77366.2746	50881569.971676

Record: 1 Show: All Selected Records (0

The final step in watershed delineation is to generate parameters/attributes for all the sub-basins. Click on the *Calculate subbasin parameters* button (#7) to populate the watershed feature class with necessary attributes for SWAT model. Be patient because this process takes some time. After all attributes are calculated, click OK on the final message box. Now open the attribute table (if you closed it), and you will see that it has more attributes as shown below.



Attributes of Watershed

Area	Slo1	Len1	Sll	Csl	Wid1	Dep1	Lat	Long_	Elev	ElevMin	ElevMax	Bnan
7345.711537	3.342777	21895.898887	91.435538	0.222579	16.990652	0.725032	41.466005	-85.131138	293.664687	266	323	<Null>
3951.5608	2.37553	16038.985457	91.435538	0.255894	11.712535	0.565784	41.478138	-85.040948	289.991919	268	311	<Null>
612.654149	2.509297	4519.681509	91.435538	0.48587	3.827533	0.268429	41.439979	-85.023491	276.781489	266	289	<Null>
3898.655071	1.634681	15356.949917	121.914051	0.184492	11.618193	0.562742	41.470505	-84.965914	279.208258	266	302	<Null>
4179.260024	2.152634	16217.974585	91.435538	0.238122	12.112934	0.578606	41.396055	-85.09709	276.795286	260	301	<Null>

Record: 1 Show: All Selected Records (0 out of 15 Selected) Options

Close the attribute table. You are done with delineating the watershed and creating sub-basins for a specific threshold area. Exit the watershed delineation window by clicking on Exit. After you exit, the program will do some more processing, cleaning-up of data, etc. so wait until all this is done. Save the map document.

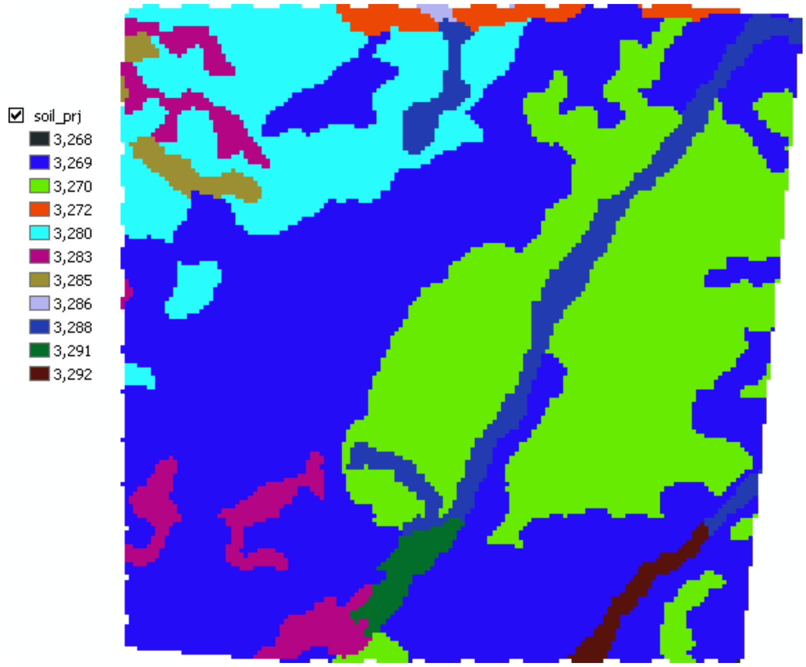
After you are done with watershed delineation, the next step is to create HRUs by using land use, soil and elevation (slope) information.

16 HRU Analysis

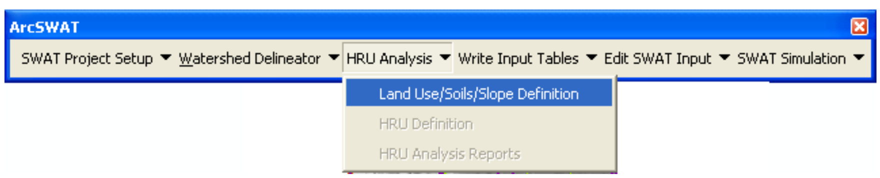
Preparing STATSGO Soil Data

When you install ArcSWAT, a raster with STATSGO soil data for the entire United States is stored where your ArcSWAT is installed. Typically at \ArcSWAT\Databases\SWAT_US_Soils.mdb. Browse to this mdb file, and add the raster (named as **stastgo_grd**) to the map document. Next, you will clip this raster to the DEM for the study area. Clipping is done by using ArcToolbox in ArcMap. In ArcToolbox, go to Spatial Analyst Tools→Extraction→Extract by Mask. Use your original DEM as the Mask during this clipping. In order to use this clipped soil raster, it should have the same coordinate system as the other data in your map document. The soil grid has geographic coordinates so go ahead and project this raster by using ArcToolbox. In ArcToolbox, go to Data Management Tool→Projections and Transformations→Raster→Project Raster. You can import the projection from one of the existing layers in the map document or the original DEM.

For your study area, name the clipped projected soil raster as soil_prj, which should look like the following:

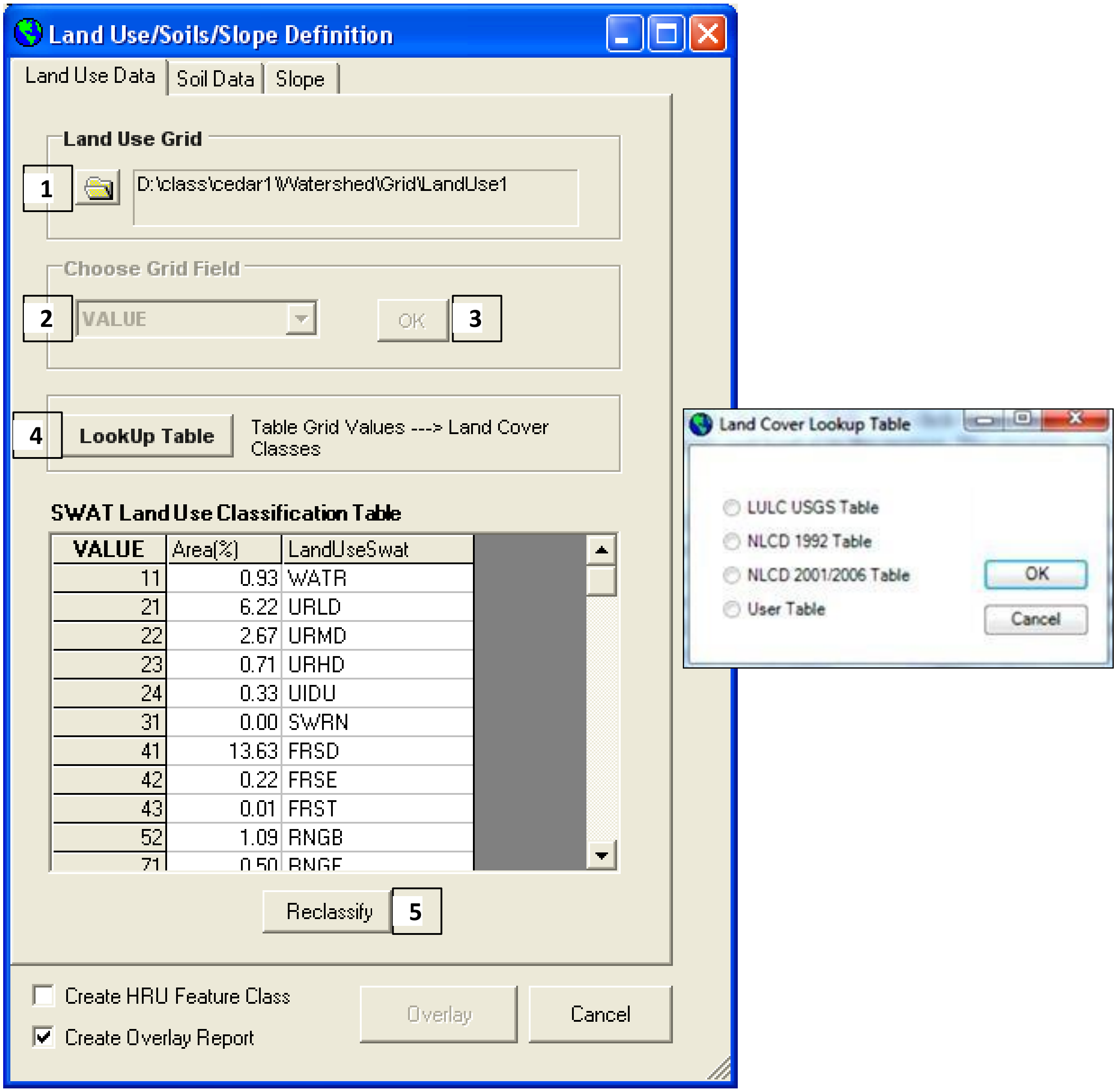


With the soil analysis done, we are now ready for HRU analysis. On the ArcSwat toolbar, click on *HRU Analysis→Land Use/Soils/Slope Definition* as shown below.



The landuse/soils/slope definition window has three tabs for land use, soil and slope each. Lets work with land use first. Click on the open file button (#1 in the figure below) to load the land use data. In the next window, select land use data from disk, and click Open. Browse to the projected landuse raster in your working directory and load it in the project. The program will clip the data before loading it in the project.

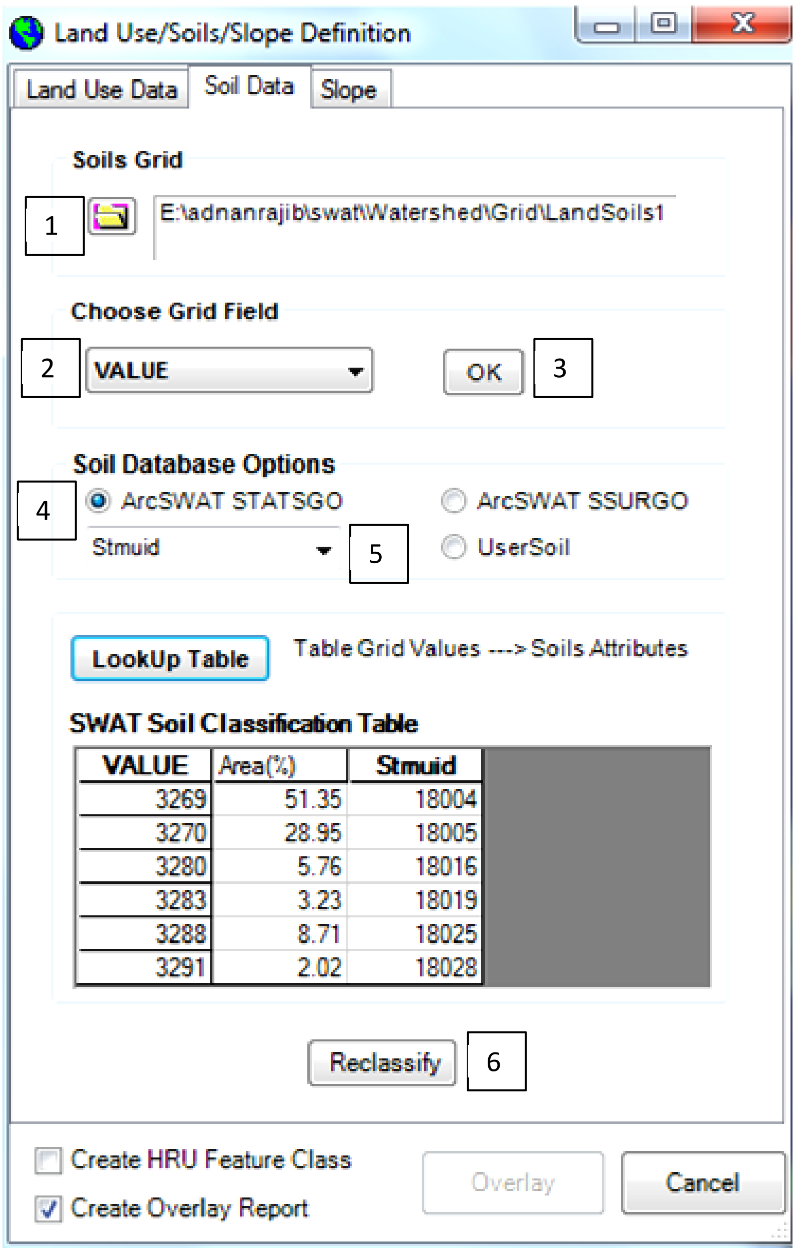
Next, select *VALUE* for the choose grid field (#2), and click *OK* (#3). Land use data typically comes with numbers (values) for each land use type so we will use a look-up table to relate these numbers to specific land use types. Click on *LookUp Table* (#4), and select *NLCD 2001/2006*. Even though we are using NLCD 2006 data, the landuse description has not changed between the two, so choosing NLCD 2001 for LookUp table is fine. This will create a description for each land use number in the SWAT land use classification table. Finally, click on *Reclassify* (#5) to finish the land use data processing portion of HRU analysis.



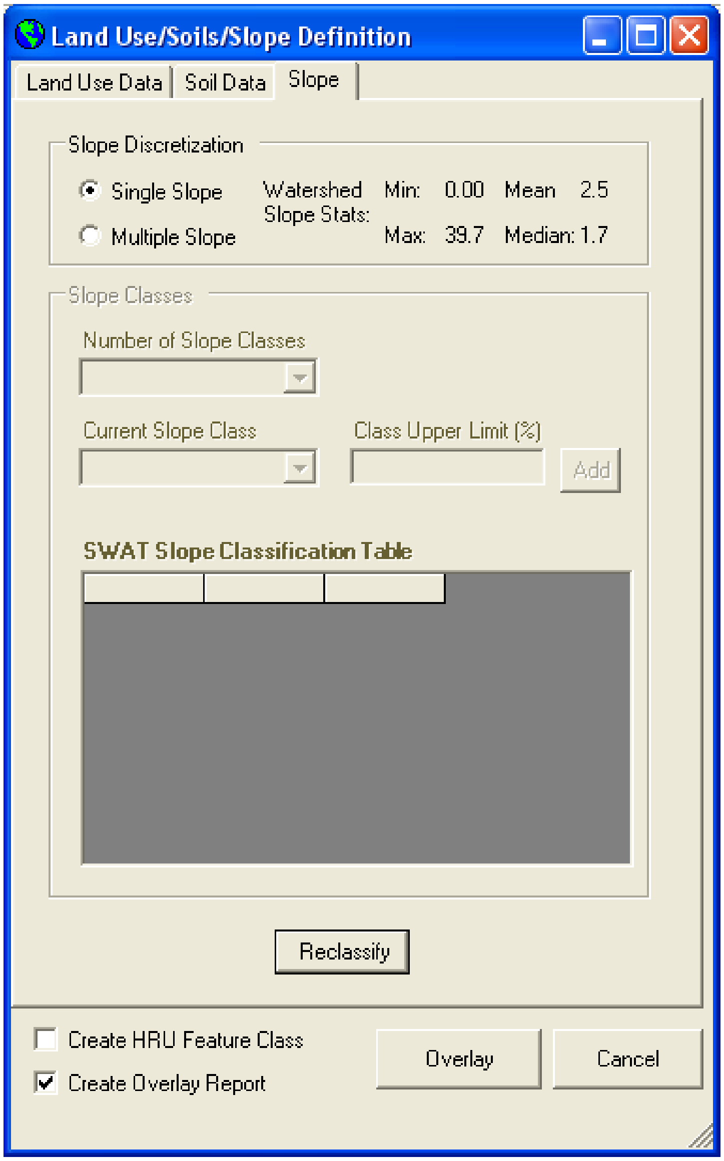
After processing land use data, click on the Soil Data tab.

To process soil data, click on the open Soils Grid button (#1), load soils dataset from disk, and browse to your clipped projected soil raster that you just created, and click Select. This step will take your input raster, and then clip that raster to the watershed area. This process sometimes takes longer depending on the size of your watershed so please be patient.

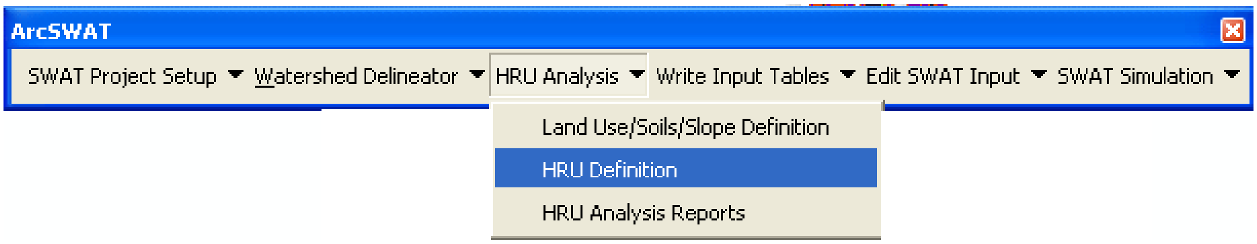
After the soil data are loaded, choose *VALUE* (#2) as the grid field, and click *OK*(#3). This will add all numerical values present in the landsoil dataset to the SWAT soil classification table. You will see that for each value there is an area associated with each soil type. The next step is to link these numerical values to a certain soil type. This is done by done by using either a lookup table or using one of the STATSGO attributes. In order to use the lookup table, it is necessary to define what attribute in the lookup table corresponds to the soil type. In the options frame, click on *ArcSWAT STATSGO* (#4) and then *Stmuid* (#5) from the drop-down list. This will add Stmuid field to the SWAT soils classification table and the corresponding Stmuid. Finally, **click** on *Reclassify* (#6). This will finish the soil data processing for HRU analysis. In ArcSWAT2012, you can also work with SSURGO soil database.



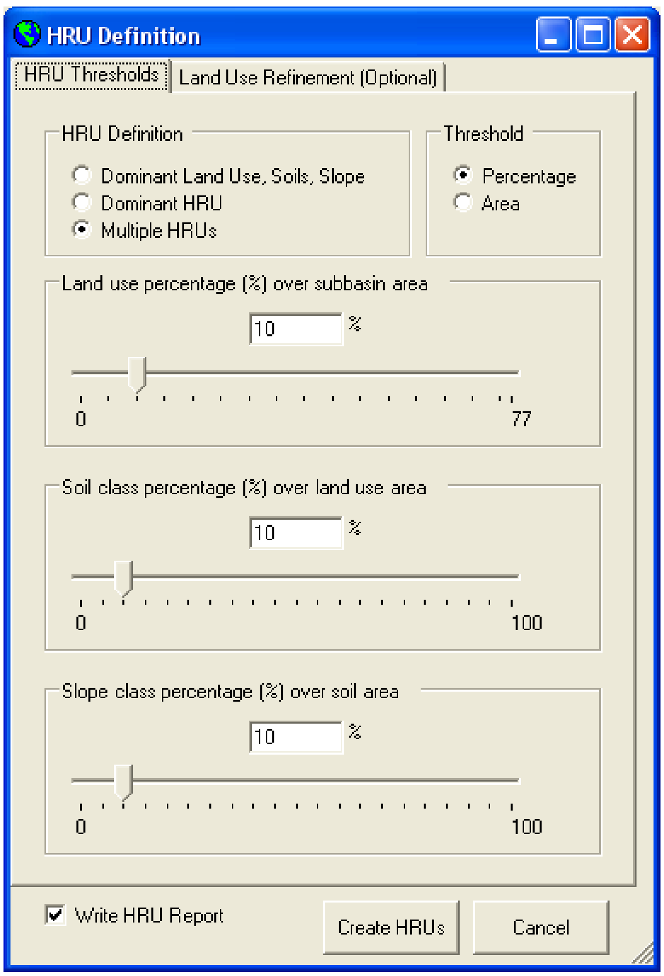
After soil data processing, the next step is to assign slope attributes to each HRU. Click on the *Slope* tab. To keep the process simple (and also considering that Cedar Creek is a relatively flat region), use the single slope option in the soil discretization frame, and click on *Reclassify*. This will complete the processing of landuse, soil and slope data for HRU analysis. Finally, click on Overlay button to create combined information on land use, soil type and slope, which will then be used to create HRU based on the threshold specified by the user. Close the Landuse/soil/slope definition window.



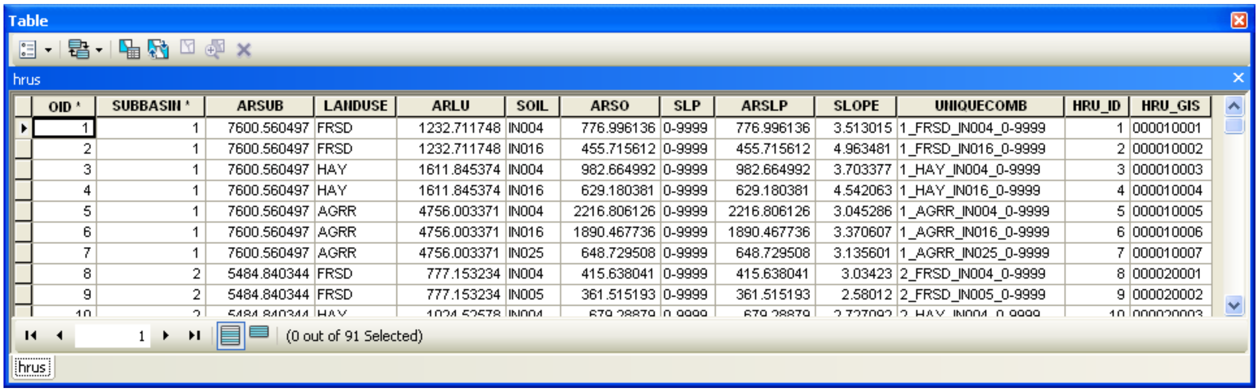
To create HRU by using the combined land use, soil and slope data, click on *HRU Analysis→HRU Definition*



Leave the default options of *Multiple HRUs* in HRU Definition frame, and Percentage in the Threshold frame. For this exercise, use a threshold value of 10% for land use, soil and slope, and click Create HRUs. Note that because we are using a single slope value, the threshold for slope does not really matters in this exercise.



A table called hrus will be added to the map document, and if you open that table, you will see that several (around 100) HRUs with unique combination of landuse, soil and slope are created for the study area. These combinations are listed in the UNIQUECOMB field as shown below.



OID	SUBBASIN	ARSUB	LANDUSE	ARLU	SOIL	ARSO	SLP	ARSLP	SLOPE	UNIQUECOMB	HRU_ID	HRU_GIS
1	1	7600.560497	FRSD	1232.711748	IN004	776.996136	0-9999	776.996136	3.513015	1_FRSD_IN004_0-9999	1	000010001
2	1	7600.560497	FRSD	1232.711748	IN016	455.715612	0-9999	455.715612	4.963481	1_FRSD_IN016_0-9999	2	000010002
3	1	7600.560497	HAY	1611.845374	IN004	982.664992	0-9999	982.664992	3.703377	1_HAY_IN004_0-9999	3	000010003
4	1	7600.560497	HAY	1611.845374	IN016	629.180381	0-9999	629.180381	4.542063	1_HAY_IN016_0-9999	4	000010004
5	1	7600.560497	AGRR	4756.003371	IN004	2216.806126	0-9999	2216.806126	3.045286	1_AGRR_IN004_0-9999	5	000010005
6	1	7600.560497	AGRR	4756.003371	IN016	1890.467736	0-9999	1890.467736	3.370607	1_AGRR_IN016_0-9999	6	000010006
7	1	7600.560497	AGRR	4756.003371	IN025	648.729508	0-9999	648.729508	3.135601	1_AGRR_IN025_0-9999	7	000010007
8	2	5484.840344	FRSD	777.153234	IN004	415.638041	0-9999	415.638041	3.03423	2_FRSD_IN004_0-9999	8	000020001
9	2	5484.840344	FRSD	777.153234	IN005	361.515193	0-9999	361.515193	2.58012	2_FRSD_IN005_0-9999	9	000020002
10	2	5484.840344	HAY	1024.52578	IN004	679.28879	0-9999	679.28879	2.727092	2_HAY_IN004_0-9999	10	000020003

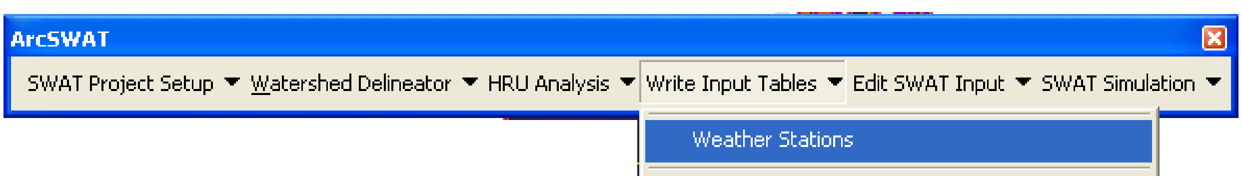
If you want to learn more about the HRUs that are created and their combination, you can select HRU Analysis→HRU Analysis Reports look at land use, soil and slop distribution and the final HRU distribution.

17 Creating Input Files/Tables

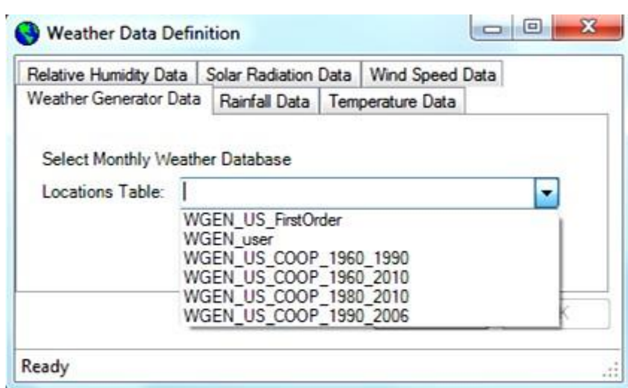
After all geoprocessing is done on DEM, land use, and slope data to create sub-basins and HRUs, the next step is to create input files for SWAT including weather data.

17.1 Weather Data

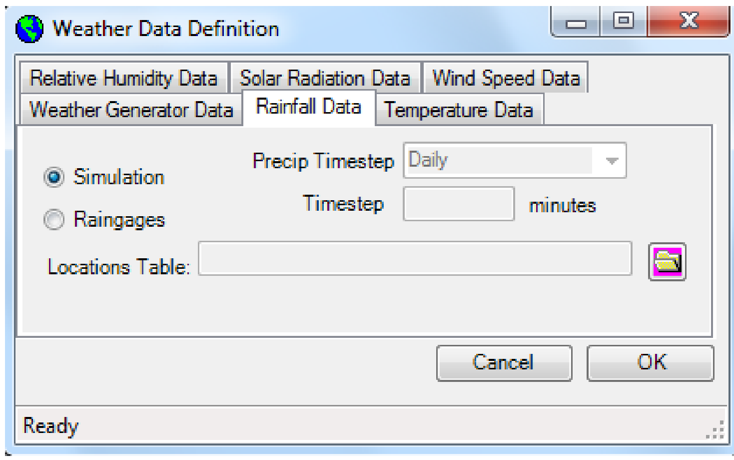
To create weather input for SWAT, click on *Write Input Tables→Weather Stations*



There are two options to input weather data. The first option is to use the weather geodatabase from SWAT, and the second option is to use your custom database. For this exercise, we will just use the internal weather geodatabase within SWAT. In the Weather Generator Data tab, select *WGEN_US_COOP_1980_2010* from the locations table drop down menu to load the data.



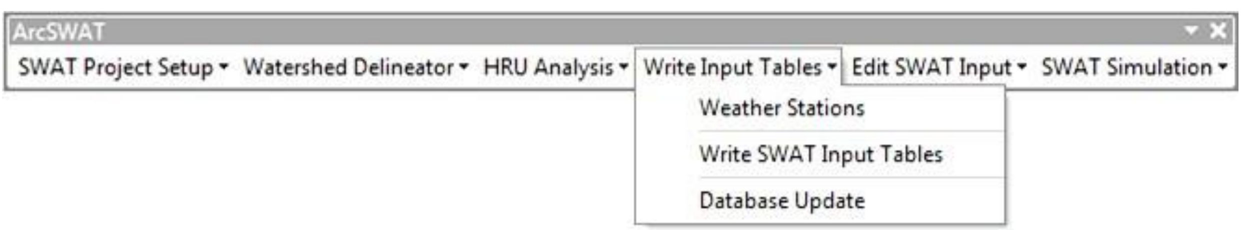
Next, in the Rainfall Data tab, leave the *Simulation* option checked with daily precipitation time step. Selecting simulation option means that the data will be generated through the internal weather generator within SWAT. Similarly for Temperature, relative humidity, solar radiation and wind speed, leave the *Simulation* option checked.



Finally, click OK. This will create a weather database for the study area.

17.2 Other Input Files

After generating weather database, you can create all other input files by selecting *Write Input Tables→Write SWAT Input Tables*.



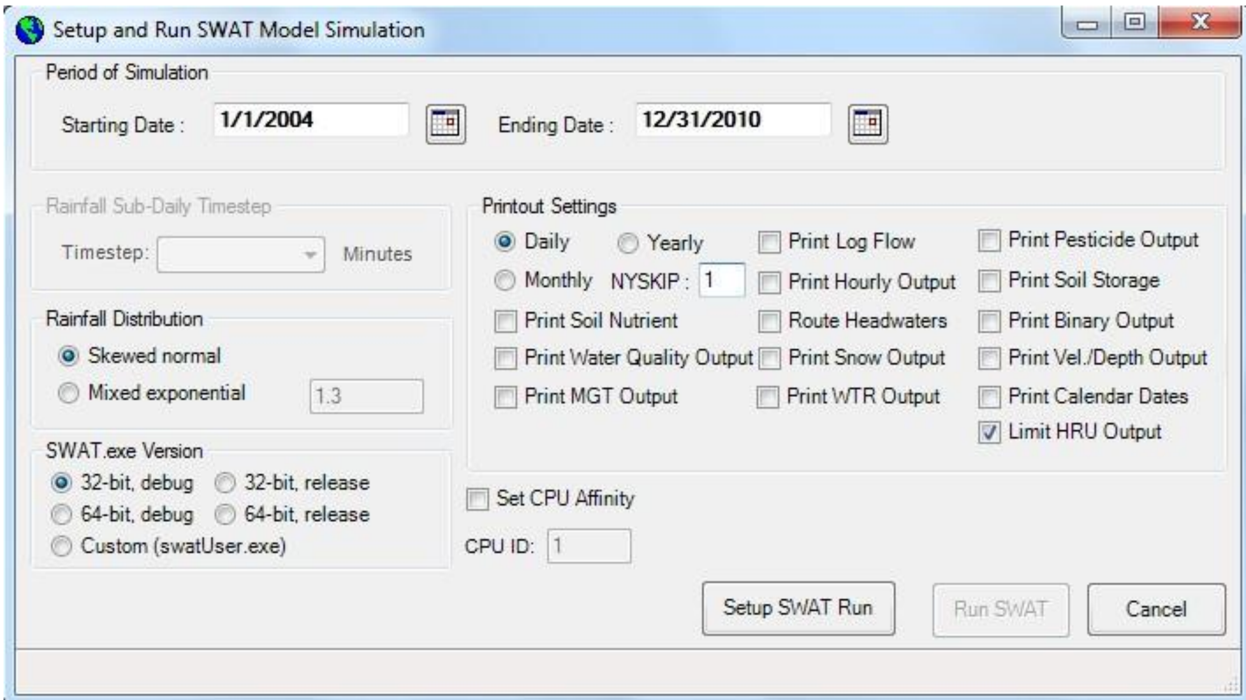
A new window will pop up named as 'Write SWAT Database Tables'. There, click on *Select All* and then click on *Create Tables*.

If you get a message asking about default Manning's n, choose Yes or OK, and proceed. Similarly, choose Yes in all the subsequent messages which may show up. You should get a final message saying all input tables were created. Now you are ready to run the simulation!

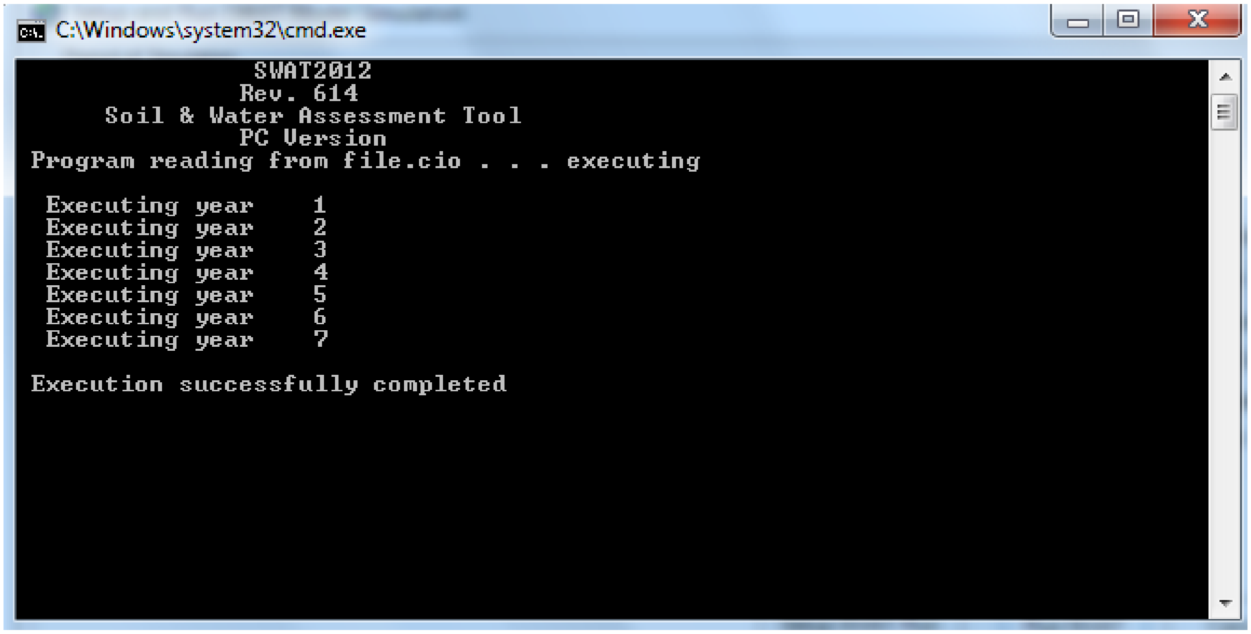
18 Running SWAT Simulation

Click on *SWAT Simulation→Run SWAT*

Set the period of simulation from 01/01/2004 to 12/31/2010 and change the printout settings to daily, and leave other default options unchanged. NYSKIP means model simulation warm-up period and in this class we will put NYSKIP=1. Click on *Setup SWAT Run*. After getting the finished swat setup message, click on *Run SWAT*.



While SWAT is running, you will see a DOS window showing you the progress, and after the simulation is done, you will get a final simulation done message.



After getting a successful simulation message, close the SWAT simulation setup window. You are now ready to read and visualize the model output.

19 Output Analysis

When you are done with running your SWAT model, your project folder will contain the following items as seen in the figure below. Find a folder called ***TxtInOut*** inside the ***Scenarios*** folder, which holds all the input/output information for the model that you just created.