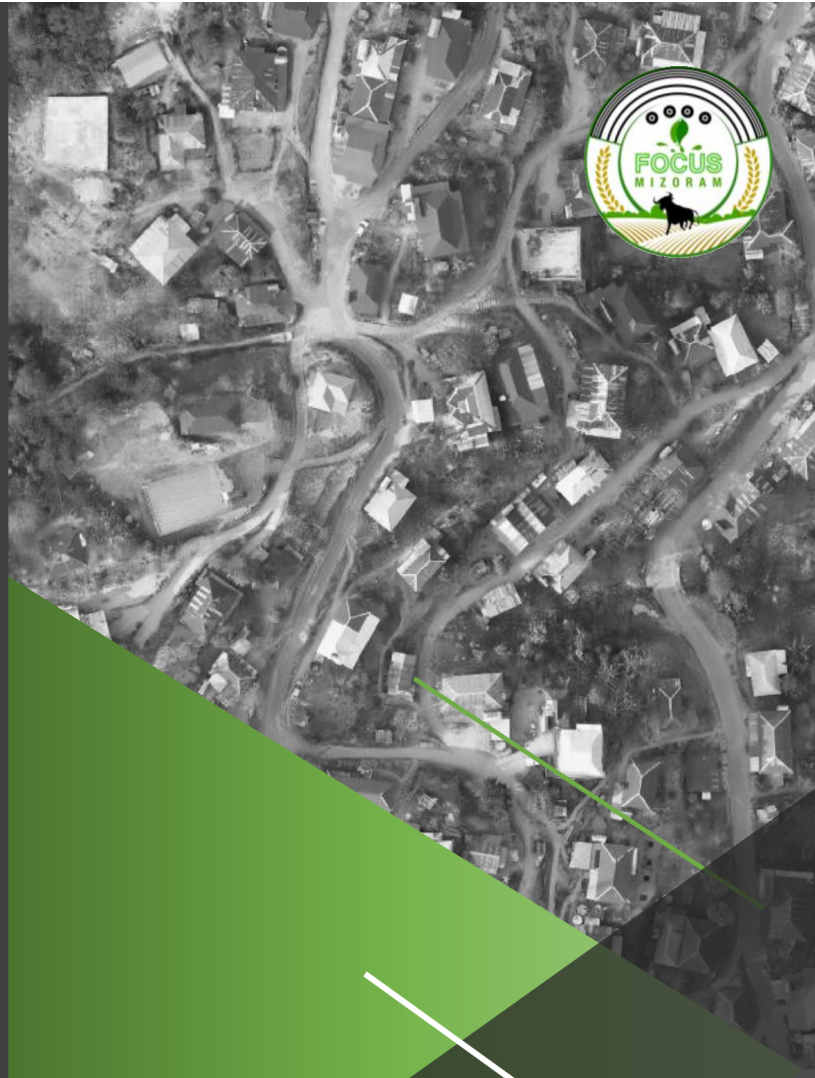
THETA Enerlytics

Case Studies, Climate Impact Assessment & Other Studies

Report on Collaborative Research for Identifying Potential of UAV Based Mapping and Planning in areas of Agriculture, Irrigation, Watershed, Management Interventions for Khawrihnim, Mamit, Mizoram.

for
Fostering Climate Resilient Upland Farming System in the Northeast
Govt. of Mizoram



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Final report on Collaborative Research for Identifying Potential of UAV Based Mapping and Planning in areas of Agriculture, Irrigation, Watershed, Management Interventions, Khawrihnim, Mamit, Mizoram

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Project report, 3 Months

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- Pre-field Investigation
- Project Inception Meeting
- Low Altitude Aerial Data Acquisition
- Soil Sampling
- Post-field Procedures
- Land suitability analysis
- Watershed Intervention

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UAV survey, DGPS, Soil sampling

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Executive Summary

The "Society for Climate Resilient Agriculture in Mizoram (SCRAM)" has received financing from the International Fund for Agricultural Development (IFAD) of $35.30 million towards the cost of Fostering Climate Resilient Upland Farming System in the Northeast (FOCUS), Mizoram. FOCUS has awarded contract to Theta Enerlytics for providing certain services pertaining to the project. Theta's field-based team has carried out UAV based aerial imaging and soil sampling for the purpose of driving soil fertility.

IFAD is an International Fund for Agriculture Development' under UN with headquarters in Rome, Italy and having its regional office at New Delhi. IFAD has taken up a Project in Mizoram through Government of India (Ministry of Finance, Department of Economic Affairs, South Block, New Delhi. The IFAD team, visited Mizoram for a number of times, studied and surveyed the State and then chalked out formulation Plan (Draft Aide Memoire) which has been submitted to the Government of Mizoram. The Project is named 'Fostering Climate Resilient Upland Farming System'. In order to implement this project, GoM has established a society named 'Society for Climate Resilient Agriculture in Mizoram' (SCRAM) under the DoA where Chief Secretary of the State is the Chairman.

The objective is to establish the feasibility of sustainably increasing agricultural productivity and farmer incomes through a distinct agricultural development approach by integrating agriculture, Crop Monitoring irrigation, and water management using precise agriculture information system innovations(UAV) in Khawrihnim village, district- Mamit, Mizoram.

This Final report comprises details of Theta's field-based surveys, pre- and post-field procedures and other activities taken up during the course of the Project. Total area covered by UAV survey in Khawrihnim village is 18.27 sq km by acquiring total 1353 with 74 flight plans. The UAV survey was completed in 22 days from 5th March 21 to 27th March 21. In addition, total 101 number of soil samples were collected using standard operating procedure (SOP) approved by government of India.

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Project Definition

Project Terms of Reference

The International Fund for Agricultural Development (IFAD) is aiding the Republic of India for the purpose of financing the FOCUS (Mizoram) in the form of loan(s) and grant(s). A financing agreement or agreements has/have been signed between IFAD and the borrower/ [recipient]; dated 25th January 2018 The overall objective of the project is to increase agricultural income of 64,500 households and to enhance their resilience to climate change. This would be achieved through the development objective of increasing the environmental sustainability and profitability of farming systems practiced by highland farmers. FOCUS-Mizoram covers 272 villages in 24 circles/blocks of 4 districts in the state. The districts covered under the project are Champhai, Kolasib, Serchhip and Mamit. The project is expected to be completed by 2024.

FOCUS has three components, namely, 1) Improved jhum management, 2) Value Chain and Market Access and 3) Project Management and Knowledge services. The Project components emphasis to increase the agricultural income of those targeted households in the project districts and to enhance their resilience to climate change. The Govt. of Mizoram (GoM) is implementing FOCUS project through the Project Management Implementation Unit (PMU) under the Directorate of Agriculture at Aizawl and through District Management Units (DMUs) in the four districts of Mizoram viz., Champhai, Kolasib, Serchhip and Mamit. The project has selected a model village, Khawrihnim at Mamit District, Mizoram as initial pilot project for study of climate impact assessment and other case studies.

Objectives

a. Sustainable water management: Achieving sustainability of groundwater sources and surface water sources envisaged to take place through community-based approaches with public support striving to reach a situation over a meaningful period of time in which the annual water extraction from this aquifer is limited to the annual ground water recharge. This estimation will help in identification of opportunities for water savings and increasing water productivity; support the decision process for water allocation; and general water audits etc.
b. Agricultural productivity enhancement: Consultant would assist Focus in providing the Water sustainable availability for Agriculture purposes to Implementation Agency of FOCUS department to prepare a detailed agricultural productivity enhancement plan for village level with an objective to increase agriculture and water productivity of suitable agriculture and horticulture crops, improve water use efficiency, provide options for shifting to less Water Intensive Jhumming cultivation habits.

c. Cadastral Based Crop Monitoring
d. Soil Nutrient Mapping & Fertilizer Distribution Advisory
e. Land Suitability for crop cultivation & Jhum Land Cultivation
f. Irrigation Infrastructure Mapping including surface waterbodies, reservoir, canal command area and identification of total area under irrigation
g. Crop acreage and productivity estimation using multi-spectral satellite images
h. Water pricing link with irrigation infrastructure and land holding farmer
i. Agriculture Information System Rollout & Hosting
j. Water resource management Planning & intervention
k. Forest Management Tools (Demarcation of Reserve Forest
l. Survey / Identification of suitable farm link road

Scope of Work

The scope of work is:

i. Cadastral/Village/GP boundaries overlay on UAV Data
ii. Soil productivity mapping and productivity enhancement advisory
iii. Land Suitability for crop cultivation & Jhum Land Cultivation
iv. Irrigation Infrastructure Mapping including surface waterbodies, reservoir, canal command area and identification of total area under irrigation
v. Water pricing link with irrigation infrastructure and land holding farmer
vi. Agriculture Information System Rollout & Hosting
vii. Water resource management Planning & intervention
viii. Forest Management Tools (Demarcation of Reserve Forest area)
ix. Identification of suitable Farm Link Road

Study Area

Khawrihnim is a medium size village located in Reiek Block of Mamit district, Mizoram with total 168 families residing. The area is accessible through a 42km long all-weather metaled road from Aizawl, the state capital. The Khawrihnim village has population of 935 of which 462 are males while 473 are females as per Population Census 2011. In Khawrihnim village population of children with age 0-6 is 154 which makes up 16.47 % of total population of village. Average Sex Ratio of Khawrihnim village is 1024 which is higher than Mizoram state average of 976. Child Sex Ratio for the Khawrihnim as per Census is 1110, higher than Mizoram average of 970. Khawrihnim village has higher literacy rate compared to Mizoram. In 2011, literacy rate of Khawrihnim village was 98.85 % compared to 91.33 % of Mizoram. In Khawrihnim Male literacy stands at 99.23 % while female literacy rate was 98.47 %. As per constitution of India and Panchyati Raj Act, Khawrihnim village is administrated by Sarpanch (Head of Village) who is elected representative of village.

Climate

Meteorological data other than rainfall are available only in Aizawl. The average maximum and minimum temperature recorded during 2007 to 2012 are 29°C in April and 12°C in January. The humidity ranges from 91% to 99% in the rainy season and 80% to 87% in the dry season. The wind is generally mild, being observed at Aizawl Airport ranging from 1.0 m/sec in the rainy season to 0.4 m/sec in the dry season. The valleys are hot and wet during summer and in the upper reaches it stays comfortably cool. It has a pleasant climate of 110C in winter and 20 to 300C. However, the effect of global warming has been experienced here with data showing increase in rise in mean and maximum temperature over the last 10 years. There is also frequent occurrence of violent storms during March and April that come from Northwest Direction. Mizoram receives an average rainfall of about 3000mm in a year and this is evenly distributed and it is not drought or flood prone. Many studies available on the observed trends and variability of rainfall and also extreme rainfall events over India, but all the studies are based on past 100 years or more data and also the recent years are not included. Also, there are limited studies on district rainfall trends and variability of Mizoram state. Indian Meteorological Department (IMD) (2020) reported all the analysis of observed rainfall patterns, trends and variability have been done based on recent past 30 years (1989-2018) that will help to have idea of the recent changes for climate change adaptation and management by the state authorities.

District	June	July	August	September	Monsoon
Aizwal	430.9	412.4	447.3	369.7	1660.3
Champhai	335.0	332.2	347.8	299.7	1314.7
Kolasib	433.6	435.5	494.7	368.9	1732.6
Lawngtlai	455.2	469.1	385.0	354.0	1663.3
Lunglei	459.9	468.8	502.5	407.8	1839.0
Mamit	412.3	340.9	434.0	351.1	1538.3
Saiha	447.6	418.4	443.4	401.9	1711.3
Serchhip	453.5	422.2	393.0	336.8	1605.5

Table.1: Mean Rainfall statistics for the districts of Mizoram for the four monsoon months, southwest monsoon season and annual

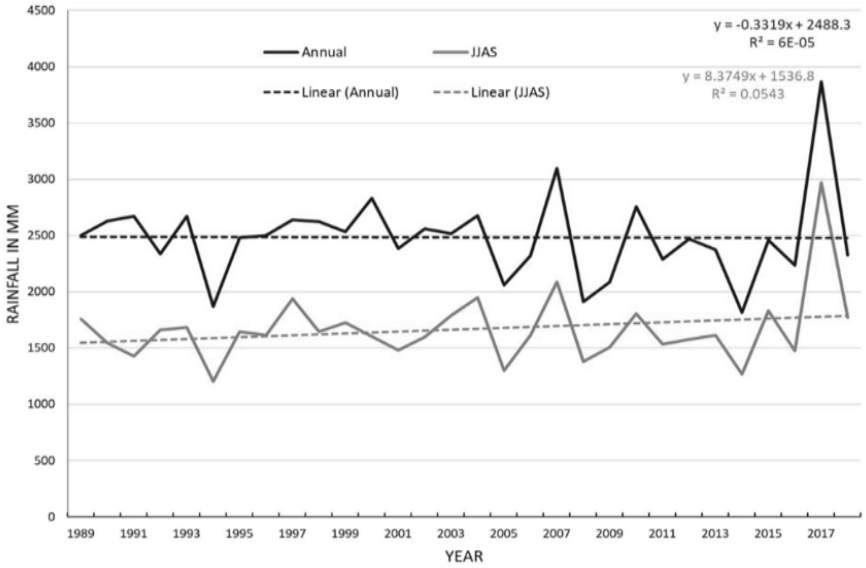


Fig.01 Time series of rainfall in mm for the southwest monsoon season and annual trends

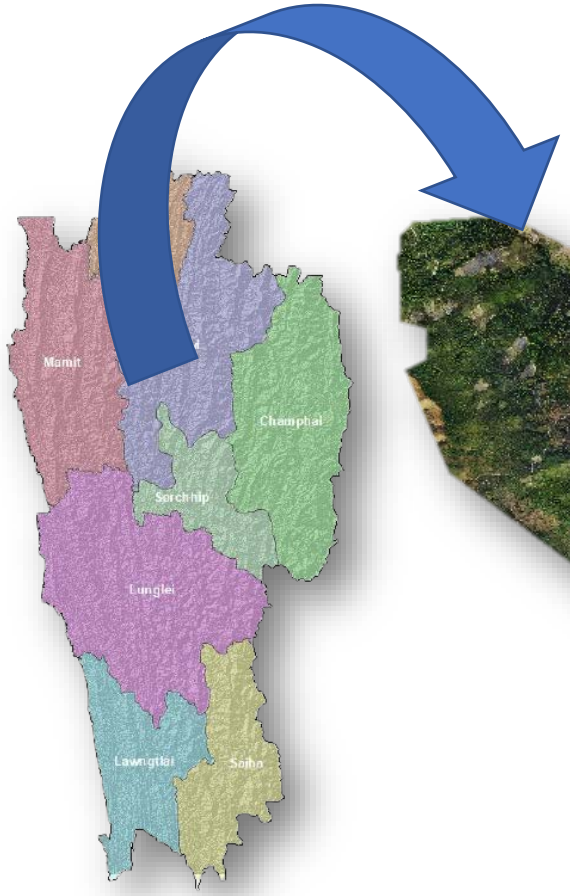


Fig. 02: Mizoram District Map showing area of study

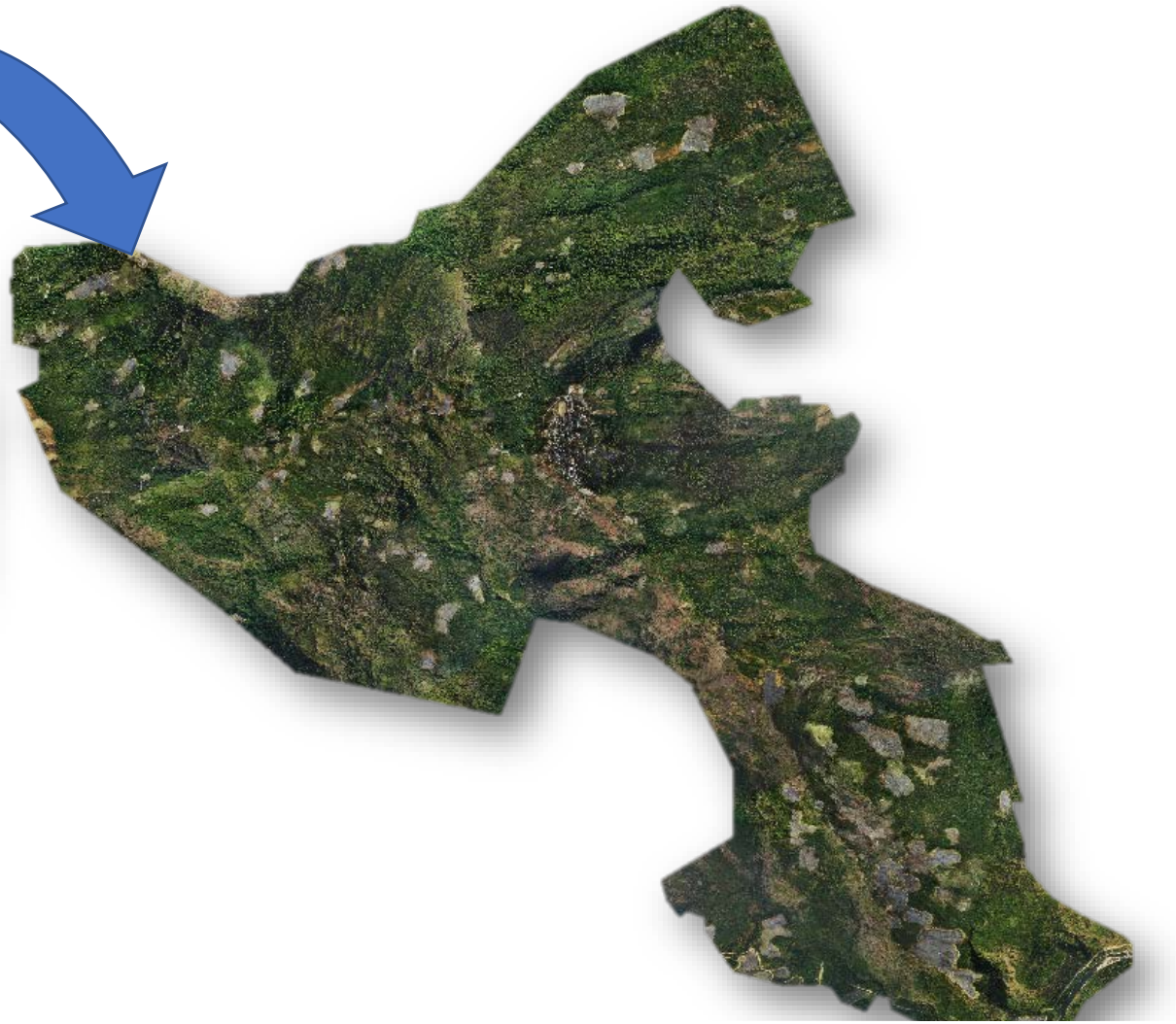


Fig. 03: Study area draped over open-source satellite imagery

Introduction of UAV based advanced Geosocial Techniques in North East Region

Why Theta Enerlytics uses Drones Imagery in North East Region of India?

North East Region of India is mostly a hilly region and covered with thick jungle. Satellite imagery in such region have very poor resolution (more than 100cm/Pixel) also DSM and DTM models have very poor accuracy (1.5 to 2 Meters). With such data any GIS Analysis like Slope analysis, Measurements, Hydrological studies gives very poor results (less than 60% accurate).

Geospatial Data collected by Theta Enerlytics using Drone have a pixel resolution of 3cm and XYZ accuracy of 5cm. This data has enabled us in proper demarcation of properties, road boundaries, rivers etc. Also, with this data identification of new and old Jhum Cultivation Lands, different crops and plants was easy and accurate.

We have also performed different Hydrological studies, Slope analysis, Nutrient mapping on this data which is highly accurate. We have also generated a 3D model of the site using this drone data which is not possible with satellite data.

Drone Data Vs Remote Sensing Data

Lightweight, portable unmanned aerial vehicles (UAVs) or 'drones' are set to become a key component of Agriculture, Water resource Management, Forestry and urban mapping and planning are getting popular in use day by day. In practical these are Key departments are growing need for fine-scale responsive data, which cannot be delivered from satellites or aircraft in a cost-effective way. Such a capability is needed where minor details need to be addressed for planning and management of each sector, especially in spatially heterogeneous dynamic Jhum land cultivation. In this Study, we had demonstrated the step change in Mapping and Planning in areas of agriculture Irrigation, watershed and Forestry management and Planning of intervention process understanding that could be delivered if FOCUS employed UAVs. We would like to state that over the years, expectations for resolution and fast delivery of aerial data for micro-level studies have been significantly raised. Real-time visual intelligence is absolutely critical to complete the common operational picture of many industrial sectors as well as micro-ecosystem. Much of our work using UAVs offer the unique ability for users to get their own data, on their own time frame.

Benefits of UAV Survey over traditional Survey Methods

Surveying with a drone offers enormous potential to GIS field. With a drone, it is possible to carry out topographic surveys of the same quality as the highly accurate measurements collected by traditional methods, but in a fraction of the time. This substantially reduces the

cost of a site survey and the workload of specialists in the field.
Unlike Satellite imagery, drones can fly at a much lower altitude, making the generation of high-resolution, high-accuracy data, much faster, less expensive and independent of atmospheric conditions such as cloud cover.

Difference between Traditional Satellite Data and Drone Data

Satellite Imagery	Drone Imagery
Available Satellite imagery is at least 12 months old	Drone Imagery is as current as the Project
Orthomoasic and Elevation Models have a resolution of 60cm/ Pixel or higher	Orthomoasic and Elevation Models have a resolution is <3cm / Pixel
Accuracy of XYZ Coordinates lines in the range of 90 cm or more	Accuracy of XYZ Coordinates lines in the range of 3cm or less

Advantage of UAV Data over Satellite Imagery

Land Survey and Cartography-
Survey drones generate high-resolution orthomosaics and detailed 3D models enable high-accuracy cadastral maps to be produced quickly and easily, even in complex or difficult to access environment also extracting features such as signs, curbs, road boundaries, markers, fire hydrants and drains is easily possible which in Satellite Imagery it is not possible.

Precise Measurement-
As Drone data is <3cm accurate, measurements done on this data will have error <1%. Also due to high resolution DSM Model any Volumetric analysis can provide 98% accurate results which is crucial for any Road construction of mining project.

Slope Monitoring-
It is possible to extract slope measurements from DTMs and DSMs generated by drone imagery. Knowing the steepness of the ground's surface, the areas can be classified and used for slope monitoring purposes and with Orthomosaic taken at different times, it is possible to detect changes in earth movement and to measure its velocity. This data can help predict landslides and prevent potential damage to roads, railways and bridges.

Urban Planning-

The development of increasingly dense and complex urban areas requires intensive planning, therefore its time-consuming and collection of data becomes expensive. Drones can collect large amount of up-to-date data in a short period of time with less staff compared to traditional method. The images produced in this way allow planners to examine the existing social and environmental conditions of the sites and consider the impact of different scenarios which is not possible with satellite imagery.

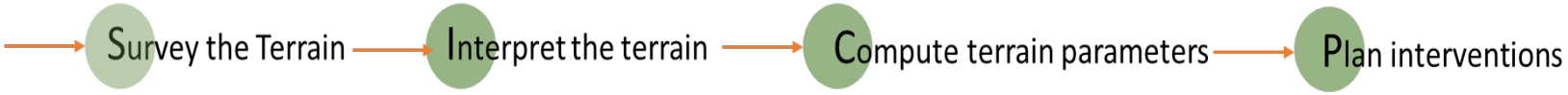
Agriculture-

Drone can carry Multispectral Camera which is essential for advanced agricultural techniques. Even though some satellite system provides multispectral data but due to its low quality the analysis results are not accurate, whereas Multispectral Data collected using drone is of very high quality and any GIS analysis performed on it highly accurate.

UAV Data Acquisition

Pre-field Investigation

The advantage of using UAVs for terrain characterization and subsequent decision making for various purposes such as watershed management, agriculture competitiveness planning and land resource development planning is it offer the unique ability for users to get their own data on their own time frame. In addition, it provides a greater amount of detail in comparison of satellite data as it enables the study at 1:100 scales. Keeping the scope of work in view, a customized pre-field planning and preparation is conducted.



Aerial Data Acquisition

Comparing to conventional helicopters, quad-rotor systems are more stable in flight with reduced vibration and have the mechanical advantage of not requiring a large, variable pitch rotor-unit and have ability for vertical take-off and landing. Three quad-rotor UAV were used for aerial data acquisition. As per the DGCA policy for drone flying, the quad-copter falls under 'micro' category and if flown below

200 feet above ground level. Therefore, the flying height was limited and not more than 200 feet. A 20-megapixel camera is mounted at the bottom center of selected UAV. The camera was further connected to UAV gimbal stabilizer that records all angular movements along all three axes

Fig 04: Quad-copter UAV used for aerial survey work

Table 2.0: Survey parameters	
Geodetic coordinate system	WGS84
Reference ellipsoid	WGS84 a (semi-major axis) = 6378137.00 m f (oblateness) = 1/298.257223563
Horizontal coordinate system	UTM (Zone 28N) False Easting (eastward distance): 500,000.0 m False Northing (northward distance): 0.0 m Central Meridian: 75.00000000 Scale Factor: 0.99960000 Latitude of Origin: 0
Height Unit	Meter

Flight Planning

Fig 5 Bird's eye view showing sub-areas in southern part of study area

A flight planning consists of pre-defined flight lines which shows where the aerial photographs are to be taken and parameters (specifications) which outlines the specific requirements such as scale, flying height, end lap, side lap, tilt and swing round (yaw) tolerances, etc. in addition, Flight planning must ensure photographic coverage of the entire area to be mapped in a minimum air time. On-board Global Positioning System (GPS) is of great help to ensure that the photographs are really aimed at correct points. The area of interest was sub-divvied into 74 sub-areas, keeping the flight duration in view.

The photographs overlap shall be sufficient to obtain stereoscopic coverage. It was made confirmed that the overlap in line flight shall be average 70 % and the overlap of parallel strips of photography (side lap) shall average 30 %.

Project Inception Meeting


Meeting with FOCUS Staff


Meeting with village council members and president, village council

Before starting a project, achieving team alignment is essential for efficacy and efficiency. If team members are not aligned on why the project is important to FOCUS, it may not fit into the bigger picture for an organizational framework, what the highest priority items are and what trade-offs FOCUS is willing to make, then the project is likely to go off-track or miss sponsor expectations. Similarly, project sponsors that are not aligned with the team likely have unrealistic expectations for the capabilities, quality and timelines for project delivery. Typically, individual team members do not interact with the project sponsors very much in their daily routine. High fidelity interactions with the whole team are far more effective for aligning a team than many emails, documents, and conference calls. Usually, it is not possible to have high-fidelity interactions with the completely extended team every single day due to geography, stakeholder availability, and schedules; but the entire extended team can certainly get together for a single day. At Pivotal, one effective approach Theta uses to ensure team alignment is a single full-day meeting. Therefore, a kick-off meeting was held dated 4th March 2021 between the Theta's field-based team and the FOCUS officials. The meeting provided an opportunity to synchronize up and discuss everything that will guide the project to success. The purpose of a kick-off meeting is to lay the foundation for a successful project—it was an opportunity to ensure the FOCUS officials and the project team are on the same page with the scope, goals, budget, timeline, and everything in between. The agenda was to

discuss Introduction of team members and their roles, project background, project purpose, scope, field-based data acquisition and sampling Plan, collaboration with local community, next steps after completion of fieldwork etc. Next day team met VCP and other council members of Khawrihnim village and started the work with their permission.

Field-based Operations

As a standard practice, UAV is flown in strips to cover the designated area. The UAV was flown with a 70 % forward overlap and a 30 % side lap as an essential requirement from the aerial mapping point of view to obtain data both on polarimetry and heights using the stereoscopic principle of observation. Since the quad-copters has limited flight time up to 25 minutes, the area of interest is sub-divided into 74 sub-blocks Fig 5 Proposed Flight line path demonstrated in Fig 6. Total 12 ground control points were marked and surveyed using Galaxy G1 dual frequency RTK differential GPS for the purpose of better triangulation in building bundle

GCP N^{o}	Longitude	Latitude	Elevation (m.)
GCP1	92.62924542	23.63897857	515
GCp2	92.61152126	23.62474098	1085
GCP3	92.60329955	23.61914861	962
GCP4	92.62214701	23.6224992	1135
GCP5	92.64352754	23.60680017	619
GCP 6	92.63606338	23.59985521	425
GCP 7	92.64273392	23.59604746	418
GCP 8	92.63505484	23.61806579	979
GCP9	92.62858456	23.61089582	789

GCP 10	92.63166916	23.63040126	879
GCP 11	92.62021054	23.63169131	976
GCP 12	92.59636372	23.62716933	1198

Table 03: DGPS surveyed ground control points

Setting up Soil Sampling SOP and Training

Industry standard procedures for the collection of representative soil samples has been followed for analysing soil's nutrients and other parameters for deriving current and potential suitability for crop cultivation. The representative sampling ensures the accurate characterization of site conditions. Procedures for obtaining representative samples, quality assurance/quality control (QA/QC) measures, proper documentation of sampling activities and recommendations for personnel safety are well addressed and subsequently, training is provided to local field staff.

Soil samples may be recovered using a variety of methods, dependent on the depth of the desired sample, type of terrain, the type of sample required (disturbed vs. undisturbed), and the soil type. Grid-based equal interval samples cannot be collected due to accessibility issues on steeply sloping areas. Therefore, undistributed samples have been collected covering majority of the area of interest. Field-based team has used handheld GPS (Garmin) followed by sampling logbook, shovel, tape measures, sterilized plastic bags etc. the sample bags are properly sealed and marked with location number and geographic coordinates. Total 101 samples were collected from area of interest. List are enclosed as annexure I

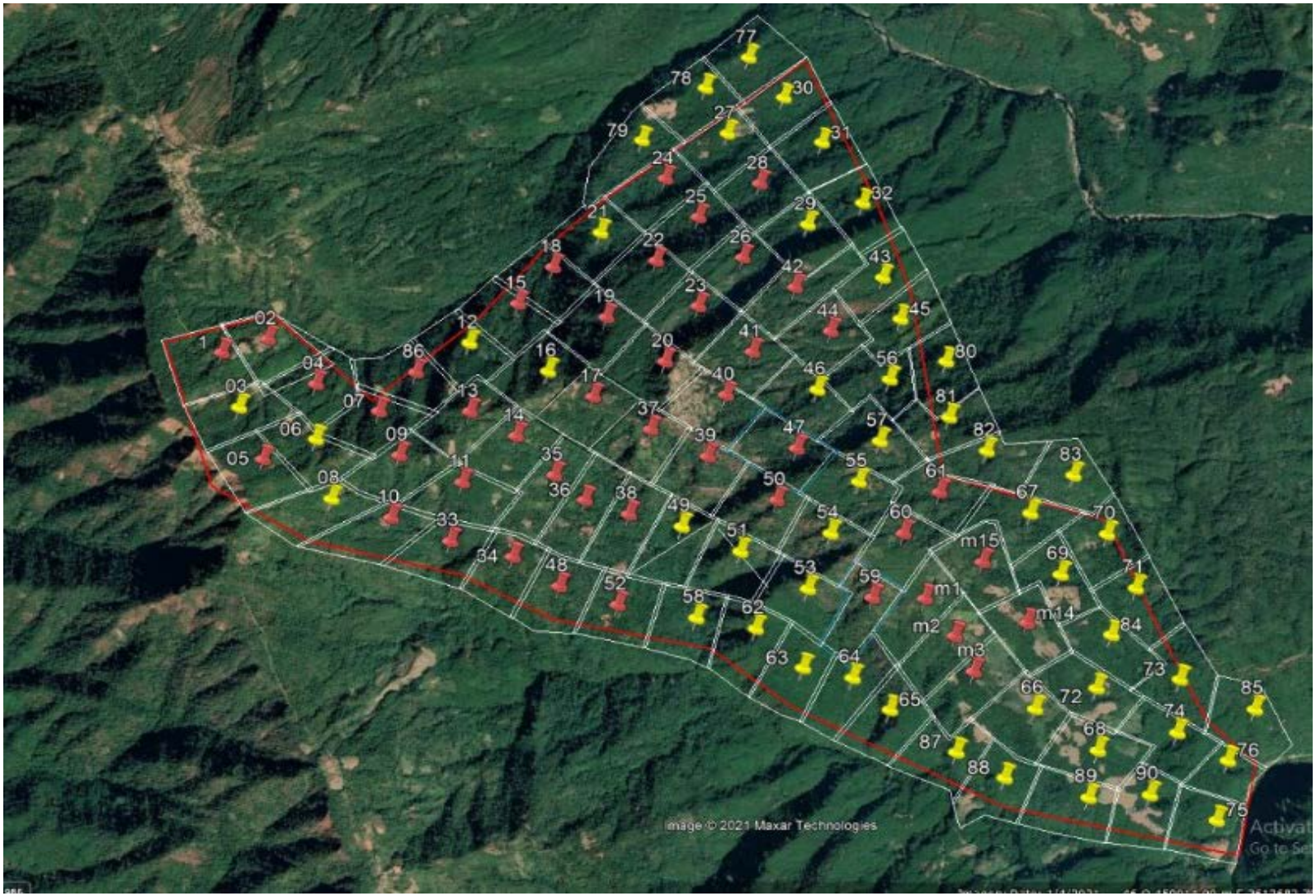


Fig 06: Flight planning at a glance showing distribution of sub-areas and centroids

Fig 07. Sampling location distribution in area of interest

Assigning flight plan to UAV

UAV ready for vertical take-off

Taking soil Samples

Post-field Work Flow

Photogrammetric workflow-The work progressed according to the workflow shown in Fig 07. For photogrammetric purpose, Agisoft PhotoScan Professional version 1.4.0 is used. Processing of images includes the following main steps:

Loading Aerial Photographs - Total 1353 number of aerial photographs were added and that are further inspected. High oblique, in-focus and out-focus photographs were removed manually.

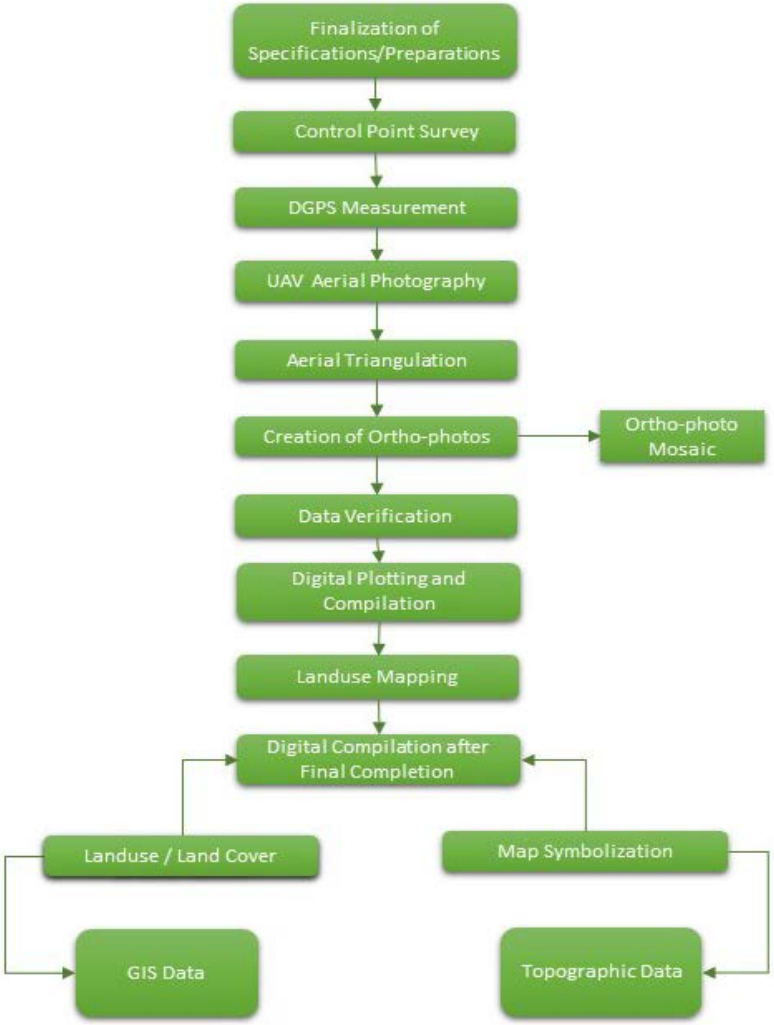
Aligning photos - Once photos are loaded, they were aligned. At this stage, the automated process finds the camera position and orientation for each photo, generate automatic tie points then, and builds a sparse point cloud model. An Automatic Tie Point is a 3D point and its corresponding 2D key points that are detected automatically in the images and are used to compute its 3D position. A Manual Tie Point is a point without 3D coordinates that is marked by the user in the images. It can be also be used to asses and improve the reconstruction accuracy.

Building Dense Point Cloud - The next step was to generate and visualise a dense point cloud model. Based on the estimated camera positions the program calculates depth information for each camera to be combined into a single dense point cloud.

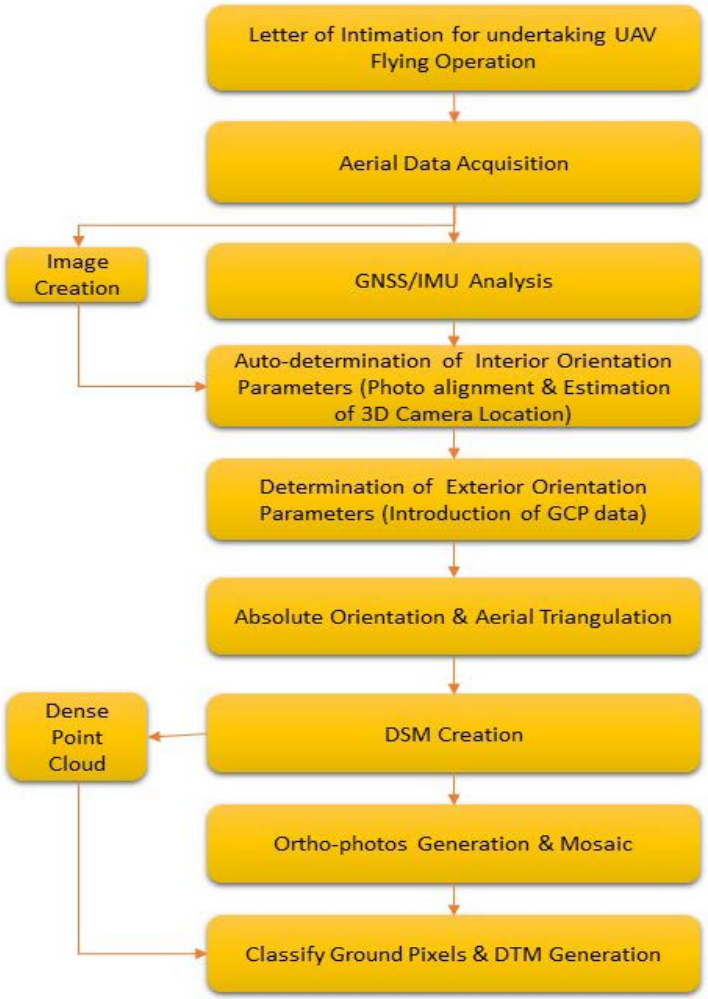
Building 3D Mesh (TIN) - The Next step connects each set of three adjacent points into a triangular face, which combine seamlessly to produce a continuous mesh over the surface of 3D model. For this purpose the software computes Delaunay triangulation for a given set **P** of discrete points in a plane is a triangulation DT(**P**) such that no point in P is inside the circumcircle of any triangle in DT(**P**). Delaunay triangulations maximize the minimum angle of all the angles of the triangles in the triangulation.

Building Texture - Texture is change in tone or colour per unit area, in a qualitative manner. The texture-mapping mode determines how the object texture will be packed in the texture atlas. Proper texture mapping mode selection helps to obtain optimal texture packing and, consequently, better visual quality of the final model. For current 3D model, 'Adaptive Ortho-photo' mode was chosen. In the adaptive orthophoto mapping mode the object surface is split into the flat part and vertical regions. The flat part of the surface is textured using the orthographic projection, while vertical regions are textured separately to maintain accurate texture representation in such regions.

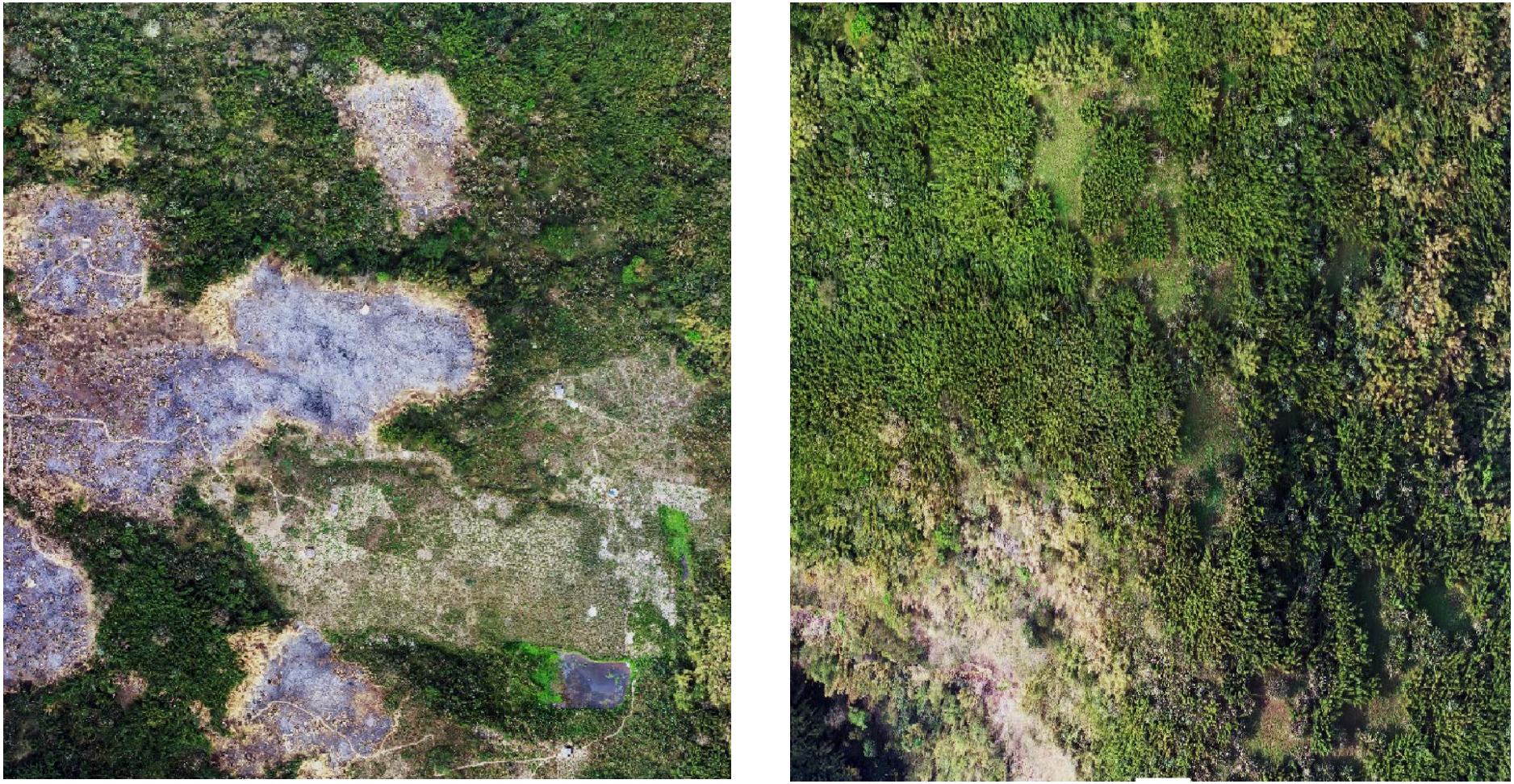
DSM & Ortho-photo Mosaic Generation - The DSM and DTM were computed at ground pixel size 20cm. PhotoScan facilitates to ortho-rectify based on both mesh as well as DSM and then prepares ortho-mosaic.



Process Flow Chart 01: Project workflow management



Process Flow Chart 02: Photogrammetric Workflow



A **B**

Fig 08: High Resolution Sample of UAV Based Imagery Acquired **A.** Partly processed ortho-imagery exhibiting current and older Jhum land, sparse vegetation, foot path, tracks and dry pond made for Rain Water Harvesting **B.** Vegitationa d Plantation

Ortho-photo Mosaic

An UAV image will, in practice, never have the same scale at every point. Corrections therefore need to be applied to get an image with a uniform scale, to ensure uniform scale thematic mapping such as landuse/ land cover. That means that the image has to be transformed from a central projection to an orthogonal projection. In areas where the terrain is flat, corrections for tilt are enough. The correction process is called ortho-rectification. When the terrain is not flat (settlement, industrial areas), relief distortions have to be eliminated which requires elevation data that usually is presented in the form of a DSM. The image is then ortho-rectified, which means that the image is cleared from scale distortions and relief displacement due to terrain height and camera tilt, resulting in the same scale everywhere in the image. An orthorectified image is called orthoimage or orthophoto which is a pre-requisite prior to landuse thematic mapping. An orthophoto is an image transformed from perspective projection, to orthogonal projection by the performance of corrections for tilt and relief displacement (Fig. 1a & b). Using orthophoto and DEMs in combination makes it able to extract 3D coordinates of points.

(a) **(b)**

Figure 9: (a) processed ortho-rectified photograph showing built-up area in Khawrihnim village (**b)** Road edge showing in ortho image

Figure 10: ortho-rectified photograph showing areas Current and old Jhum land

Image Interpretation

Image interpretation is the most basic operation of remote sensing analysis, consisting of manual identification of features in a remote sensing image through visual interpretation. The UAV orthorectified mosaic provides immense information from macro to micro level i.e., Jhum land HUT (taking care of their Jhum Fields. The ortho-imagery was interpreted and landuse map is prepared, based on basic interpretation elements i.e., shape, size, shadow, colour, texture, pattern and association. The UAV imagery facilitates us to understand spatial pattern of cropping as well as classify data up to crop level identification. Fig. 2 reveals some examples from study area showing different crops and variation in vegetation.

The landuse mapping was carried out using on-screen image interpretation and spatial entity was created using ArcGIS 10.4 platform. Once the spatial entity is created, attribute at different level of classification have been assigned for each polygon (Fig.12).

Referential Refinement

Once the ortho-imagery is classified, an accuracy assessment matrix is prepared using random sampling method to check the accuracy. Based on field-based learning and sample sites, the classified image has then undergone a referential refinement procedure. Attributes and coding of individual landuse classes are rectified and statistics was generated. Most of the study area lies under various class of forest class (Dense, moderately dense & open) (81.65%) whereas the second noteworthy class is Jhum land which includes Current and Abandon Jhum land (Older)land that occupies around 13.67 % of total study area. Systematic planning of watershed management practices such as SGT, Contour Bund, MPT, other rain water harvesting tank and plantation etc. may lead to transformation of these forest and Jhum Land into lands with multiple usage which raised farmer income.

a

b

c

d

e

f

Fig 11 UAV imagery exhibits different land-cover – (a), (b) dense and moderatly dense forest, (c) plantation area (d) opern forest area (e) Showing river driainge (f) temporary Hut for taking care of jhum agriculture lands

Terrain Characterization

Geomorphology

Physiographically, the terrain is mountainous with prominent relief. Hill ridges are trending in the NW-SE direction. Parallel to sub parallel anticlinal hill ranges, synclinal narrow valleys form deep gorges are evident. Basically, these are structural hills. The process of denudation and weathering is still continuing in response to various natural forces. One of the dominant forces of formation of such landforms is exertion by running water. Based upon lithology, relief, drainage, and structural pattern, the area is divided into major units -

Denudo-structural Hills - Major portion of the district is occupied by Denudo-structural hills which are predominantly argillaceous comprising shale, siltstone and mudstone, fine grained and compact sandstone with occasional limestone. This major form has been further divided as follows:

Low linear ridges - These are low elevated hills and occupy outer flank of structural folds. They have gentle to moderate slopes and possess gully erosion. The main drainage system is controlled by strike of the formations and shows slight meandering pattern. The main rock types represent a mixture of arenaceous as well as argillaceous assemblages, comprising shale and fine to medium grained, friable sandstone.

Moderate linear ridge - Moderate linear ridges occupy about 90% of the district. The main constituents are hard and compact sandstone, shale and siltstone, alterations of Bhuban Formation. The ridges show serrated top and hogback pattern, which are highly dissected and separated by intervening 'V' shaped narrow valleys.

Valleys - The valleys have limited aerial extend trending North-South direction. These valleys are found in the structural depressions in between low linear ridges of fine to medium grained, friable sandstone with subordinate shale of Bhuban group of rocks.

Hydrology

Surface configuration like relief, slope and dissection are important factors which affect the development and pattern of drainage system of the area. The study area is a triangular hill having 3 major faces – southwest, eastern and northwest and lacks perennial waterbodies though the seasonal streams are evident will small rills joining at places. The state of Mizoram is drained by a number of rivers, streams and rivulets of various patterns and length, out of which Tlawang river is Mizoram's longest river with its tributaries – Teirei and Tut. The Tlawang river flows in vicinity of area and the eastern and southern faces of study area contributes to Tlawang river through its slopes and

small rills and streams. The region receives a considerable amount of rainfall during summer and most of streams are ephemeral in nature. The volume of Tlawang river is limited in dry season, whereas it swells rapidly during monsoon season. It has been interpreted that the running water is the most decisive agent which has sculpture landforms of the region.

Hydro-geologically, the entire area of Mamit district is occupied by semi-consolidated formations of denude-structural hills belonging to Bairal Formation of Oligocene age and the Surma formation of Miocene age with limited extent of linear rolling valleys. The study area comprising low linear ridges is characterized by low permeability and infiltration capacity. The moderate linear ridges at higher elevation, comprise hard and compact sandstone and shale. This unit is also characterized by very low permeability and infiltration capacity that acts as run off zone. Ground water potential is low. No ground water abstraction structures are noticed in the study area.

In general, the terrain is tectonically young and immature. The occurrence of ground water in such terrain is mainly restricted to weak zone such as fracture, lineament and weathered residuum. These tectonic elements create seepage conduits, which are sources of spring. These springs in the vicinity of area utilized as a main source of water supply to the populace. The exiting water supply for drinking purpose is mainly from those rainwater tapped through gravity drainage in monsoon season. Other than this, the villagers are dependent on pumped water from Tlawang river in the valley portion.

N^{o}	Slope in Degree	Area (Ha)	Total Area (%)
1	0-20	613.85	33.60
2	20-40	399.68	21.88
3	40 to Above	813.47	44.52
	Total	1827.00	100.00

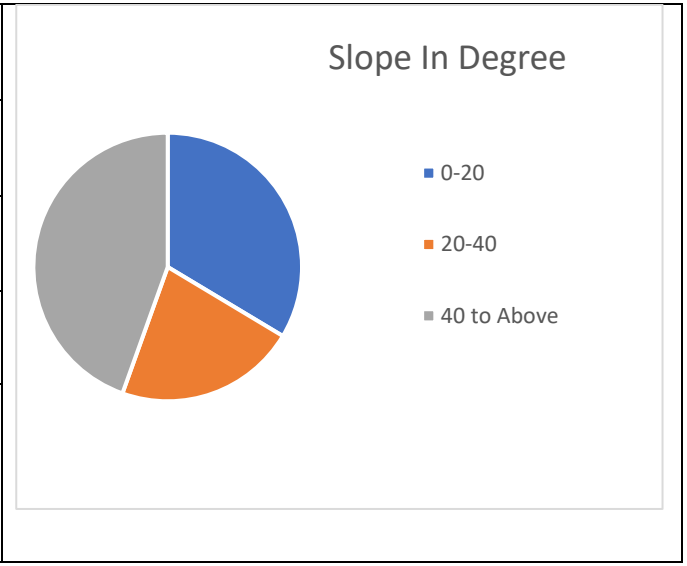


Table 4: Slope distribution in study area

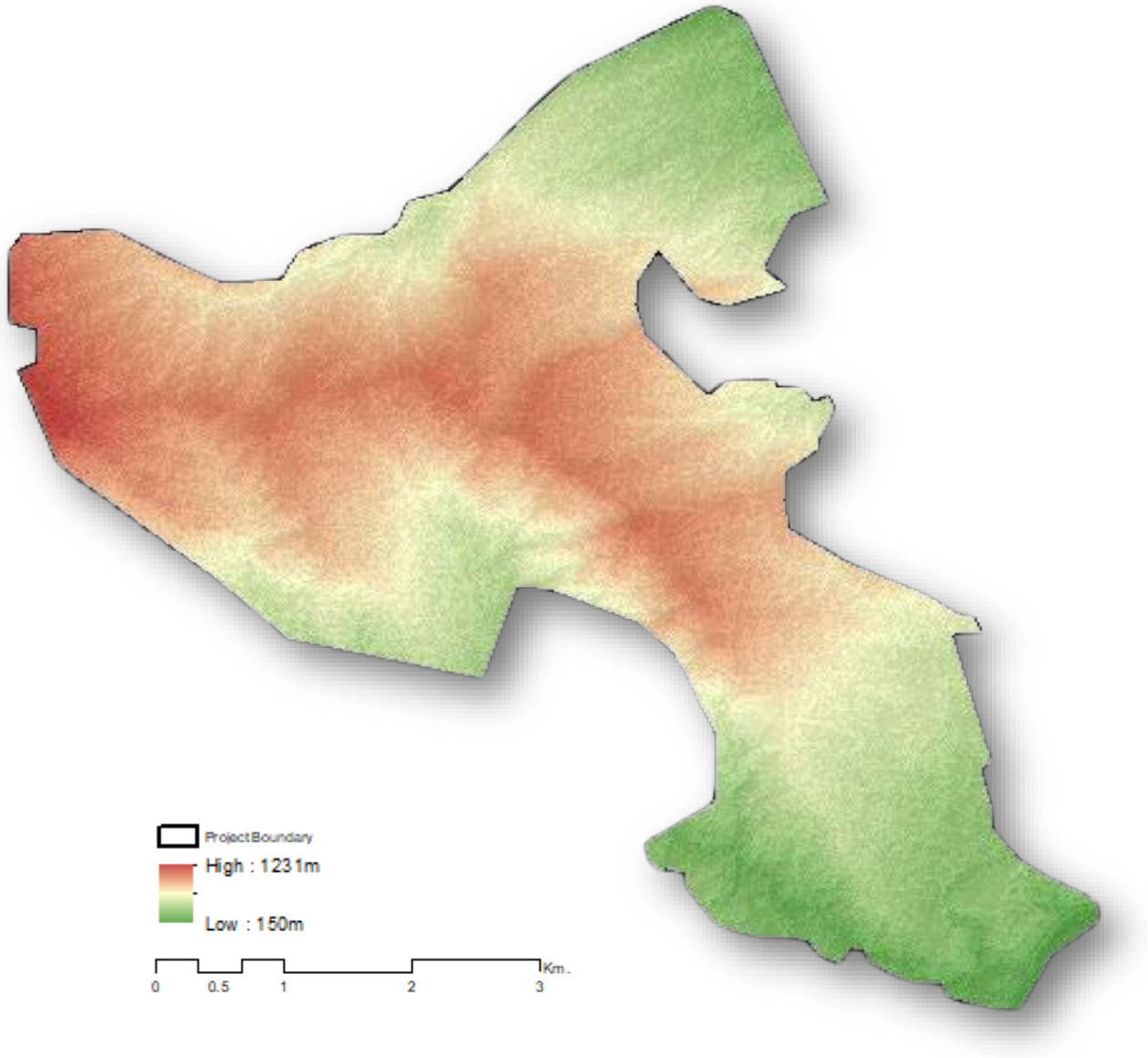


Fig 12: Digital elevation model of study area

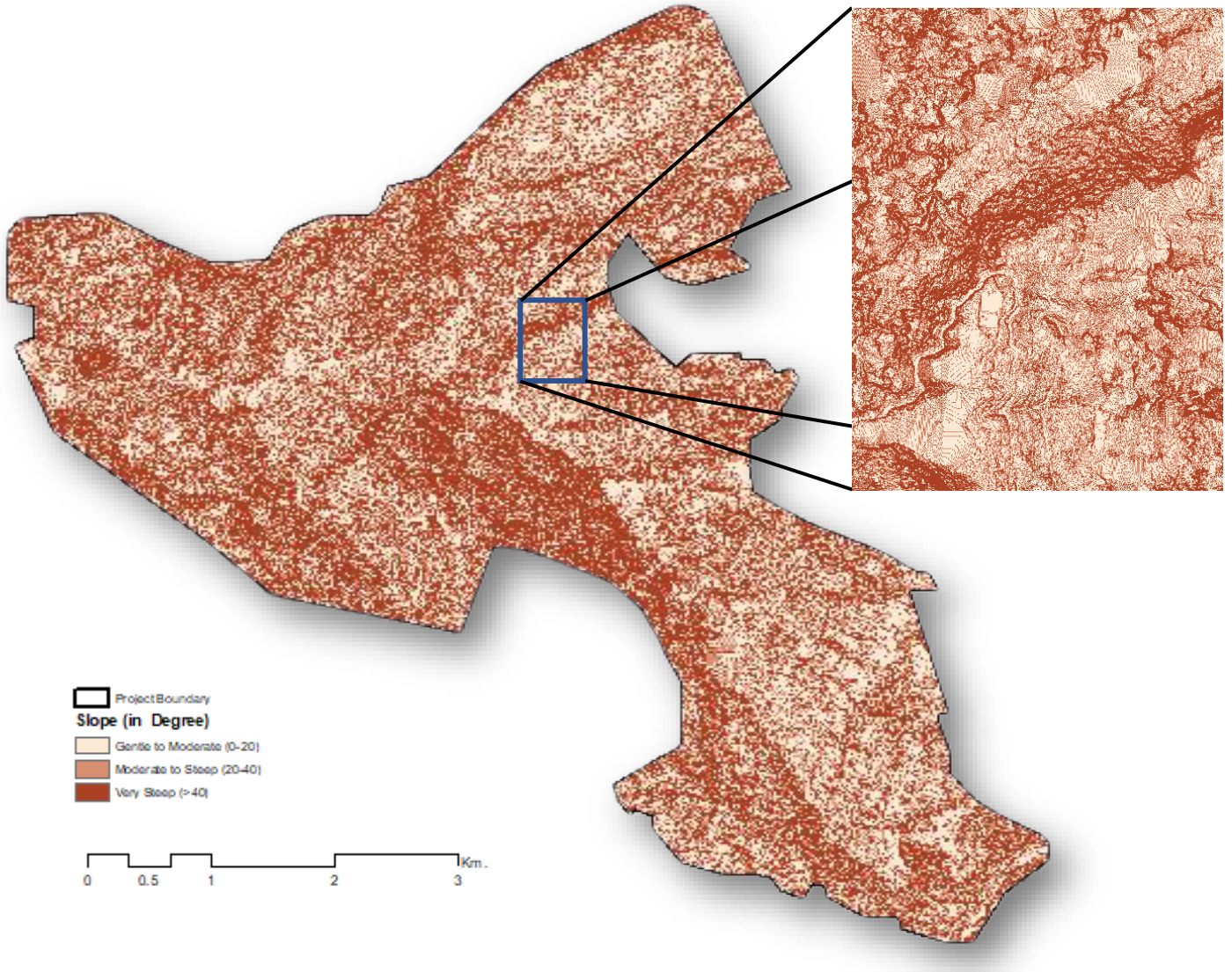


Fig 13: Slope distribution map of study area

N^{o}	Class	Area (Ha)	% of Total Area
1	149 - 400	269.51	14.75
2	401 - 600	394.32	21.58
3	601 - 800	453.17	24.80
4	801 - 1000	511.12	27.98
5	1001 - 1200	174.24	9.54
6	1201 & above	24.64	1.35
	Total	**1827.00**	**100.00**

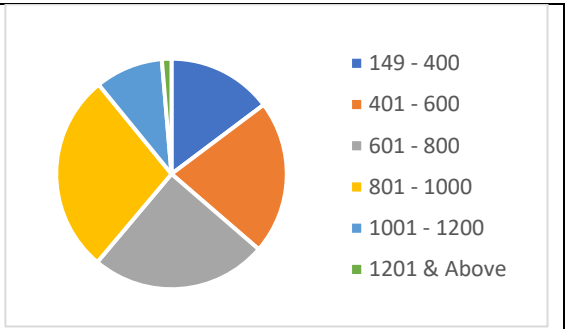


Table 5 : Elevation Distribution in study area

Jhum Cultivation and Land use

The history of shifting cultivation can be traced back to around 8,000 BC in the Neolithic period, which witnessed a remarkable and revolutionary shift in humankind's mode of food production – from hunter- gatherers to food producers. Since the beginning, shifting cultivation has been characterized by rotation of fields rather than rotation of crops, the exclusive use of human labour, absence of draught animals and manuring, use of dibble stick or hoe, and short periods of occupancy alternating with long fallow periods to assist the regeneration of vegetation, culminating in secondary forests. Shifting cultivation fields and their surrounding forests provide two alternative sources of subsistence for the dependent community.

Changing perceptions about shifting cultivation in Northeast India

Jhum lands are generally located on hill slopes where sedentary cultivation cannot be developed easily. They hold that felling of trees and clearing of bushes accelerates soil erosion and accentuates variability of rainfall, which may lead to droughts or floods. The overall impact is the decline in soil fertility. The agro-ecosystems lose their resilience characteristics as a result of which village households dependent on shifting cultivation face shortage of food, fuel wood and fodder.

Recent analyses of the issue have shown that traditional shifting cultivation (long cycle >10 years), generally prevalent in places where population densities are low and in remote places, appears to be good as it provides food security and livelihood without causing any significant degradation of land. However, the distorted shifting cultivation (short cycle < 5 years), a consequence of increasing land use pressure, is not good land use and therefore requires to be transformed.

The departments of agriculture, horticulture and rural development generally promoted conversion of jhum to settled agriculture, along with the use of fertilizers, high yielding varieties, irrigation and introduction of a variety of models which were not suited to the available skills and man power, topography, food preferences and land tenure system. Sericulture and horticulture were successful only in areas where there was a market for the produce. Spectacular results were noted in the State of Tripura through promotion of rubber plantation. This was mainly because of assured market availability and financial and technical support. Tea, cashew nut, coffee, floriculture, passion fruit were also introduced as alternatives to shifting cultivation and these were successful in areas connected to the market. We see convergence amongst the departments which are currently addressing these issues as per their own understanding and scope, as best way forward. The solution to Jhum cultivation is only possible with a holistic perspective. In fact, most personnel implementing the Jhum control or rehabilitation schemes should be exposed to successful models outside the state so that they can experiment or undertake any activity beyond the mandate of their department to make the scheme successful.

Jhum Cultivation in Mizoram

In the hilly region, Mizoram shifting cultivation, locally known as Jhum, continues to be a dominant mode of food production and the economic mainstay of many rural households. The process of shifting cultivation in the region begins with the selection of a plot on or near the hill side or jungle by the village elders or village council, clan leaders and households, usually from October to December. In some tribes, the community as a whole is collectively responsible for clearing the selected jhum plots, while in others the clearing of trees and shrubs is done by the respective family to whom the plot is allotted. At the time of allotment of plots, the size and workforce in the family are taken into consideration. The area allotted per family varies from half hectare to one hectare among different tribes and in different part in the region.

The process of clearing the plots, which can take over a month, is labour intensive and undertaken almost entirely with indigenous and traditional equipment. Households remove useful biomass – big branches, trunks and boles – for house building, timber and fuelwood requirements, while the remaining debris is left to dry. The dried slash as well as the standing tree trunks in the cleared area are set on fire between February and March, care being taken to ensure that fires do not spread out of control during firing operations. The ashes are then scattered over the ground and dibbling of seeds begins soon after, before the advent of monsoon. The dibbling and planting of

seeds is the exclusive job of women. The men broadcast seeds of crops like millets and small millets, whereas crops like maize, pulses, cotton, sesame and vegetables are dibbled by women.

In shifting cultivation, the soil is never ploughed or irrigated. After sowing, the shifting cultivators tend to the crops regularly by removing weeds. In some places the crop is protected from stray cattle and wild animals by fencing the fields with bamboo.

Many shifting cultivators in the region have the custom of constructing a hut in the field to look after the crop. Shifting cultivators in general practice mixed cropping but the composition of crops varies from tribe to tribe within the region. In mixed cropping, soil exhausting crops like rice, maize, millets, cotton and soil enriching crops like legumes are grown together. These crops are harvested at different periods, thereby providing the farmers sequential harvesting and a variety of foods throughout the year. The land is cropped for two or three years and thereafter fallowed to allow it to recuperate.

Traditionally, shifting cultivators grew only food grains and vegetables. However, most communities have shifted to cultivation of cash crops such as ginger, turmeric, pineapple and jute, among others. Among food grains, the traditional varieties of rice, followed by maize, millet, Job's-tears and small millets are the principal crops. Among vegetables, a variety of legumes, potato, pumpkins, cucumbers, yams, tapioca, chillies, beans, onion and arum are cultivated. In fact, the choice of crop is mostly consumption oriented. Ginger, linseed, rapeseed, perilla, orange, pineapple and jute are the important cash crops grown in jhum fields. The cash crops are mostly sold in the nearby weekly markets and in recent years, to a growing market in urban settlements and larger towns and cities.

Current Jhum Cultivation

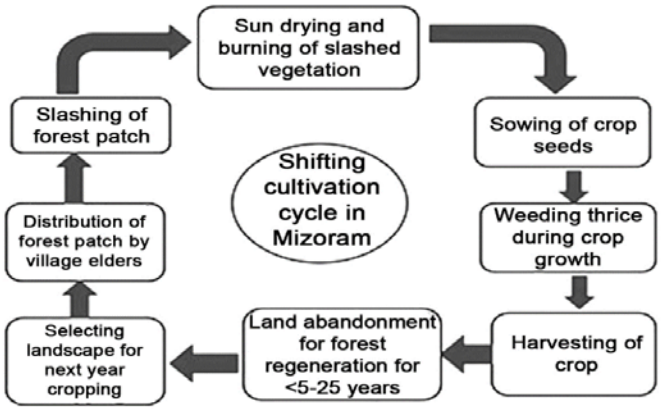


Fig. 14 Jhum cultivation cycle in Mizoram

Shifting cultivation commonly known as Jhumming is still a prominent farming system practiced by farmers in the study area, mostly in small patches/land holdings near forests and settlements. The jhum plots are small in size and irregular in shape. The current jhum are always associated with young abandoned jhum and secondary
forests. The location of jhum is related both to altitude and slope. Sites above 1200 mts are thus seldom jhumed. The percentage of Jhumming is found to be highest on the gentler slopes and progressively decreases on steeper slopes. It covers an area of145.44, which accounts for 7.94% of the total area of the Villages.

Old Jhum Cultivation

In the present study, young abandoned jhum of approximately up to three years are considered. It covers an area of 104.31 ha, which accounts for 5.71% of the total area of the village. Patches of young abandoned jhum are found to be distributed all over the study area, closely associated with current jhum, settlement areas and forest blanks. Depending on how long the land is left fallow and phyto-geography, there can be vegetative variations among young abandoned jhum consisting of young bamboo shoots, tree seedlings and saplings.

Current trends in land use in Mizoram

As a result of various land-use policies implemented over the past two decades, several trends are now apparent, including: (1) poor forest regeneration due to shortened fallow periods in the jhum cycle; (2) reduced agricultural productivity due to decreasing soil fertility; (3) conversion of community land to private ownership; (4) increasing Shifting cultivation on steep slopes of landlessness and social insecurity following the privatization of land; (5) conversion of shifting cultivation land into exotic plantations, including Eucalyptus spp.,Tectona grandis, Aleurites fordii, Jatropha curcas, several bamboo species, red oil palm (Elaeis guineensis), rubber (Hevea brasiliensis) and so on, reducing land available for cultivation of subsistence food and cash crops; (6) loss of authority by traditional community institutions; and (7) government encouragement of afforestation of jhum lands and consequent migration of the rural poor to urban areas.

Relationship of Jhum Cultivation and Slope and elevation

Shifting cultivation locally known as Jhum cultivation in Khawrihnim village has strong relation with slope. Though the distribution of jhum fields is highly found in 0-40 degree slopes it spreads rapidly at high degree slope area. The jhum plots are highly found in 40 degree and 69-degree slope. Excessive Jhumming induced highly degraded forest area for livelihood. The rugged topography always encourages people to practice their traditional method of cultivation. The available land in 20- and 40-degree slope is not sufficient for highly increased people to feed. The land area for settle cultivation is negligible for them to survive. So, they rush to the dense forest area and degraded the virgin forest cover for shifting cultivation.

N^{o}	Slope in Degree	Area (Ha)	Total Area (%)
1	0-20	114.02	45.65
2	20-40	71.48	28.62
3	40 to Above	64.25	25.73
	Total	**249.75**	**100.00**

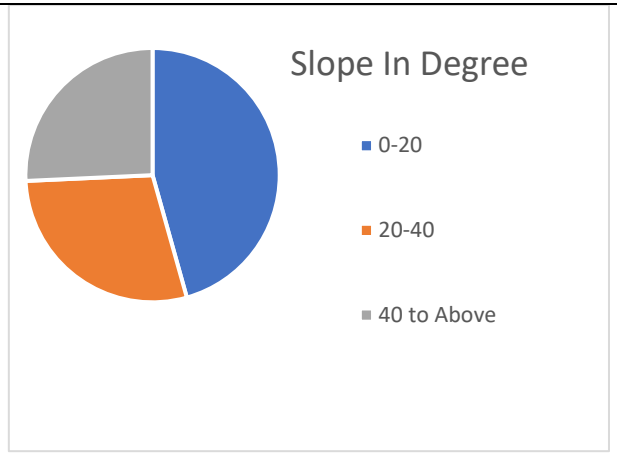


Table 6: Relation of Jhum cultivation distribution over with Slope and Elevation

74.47 % area of total Jhum land falls under slope category 0-40. Remaining 25.73% area of jhum land falls under slope category more than 40 degrees. In Khawrihnim village, Jhum plot is mainly found in 150 to 1200m elevation. Digital Elevation Model shows total area of project area is 1827.40 ha and Jhum area is 249.75 ha. Out of 249.75 ha of jhum land is under 150-400 m elevation which is 14.04 percent of total Jhum area. Shifting cultivation area under 401 to 600 m elevation is 34.88 i.e., 21.75% area under 601 to 800m elevation is 54.33 ha., area under 801 to 1000 m is 49.19 ha, area under 1001 to 1200 m is 19.84 ha in village area and more than 1201-meter elevation area under 4.23 ha of village area. Area under jhum cultivation in the hill slope increased because population in the study area increased. Area under plain topography in the study area is less so people encroached forest land for jhum cultivation. People used to practice land for jhum as easy means of stay with arrangement of jhum plot with the help of village owner at lease. Now a days, new generations are not interested to engage themselves in age old practice so they hand over their land to the outsiders for practicing jhum at lease. The village has less plain area so they shifted to high altitude area for slash and burn.

..

N^{o}	Class	Area (Ha)	Area (%)
1	149 - 400	35.06	14.04
2	401 - 600	87.10	34.88
3	601 - 800	54.33	21.75
4	801 - 1000	49.19	19.69
5	1001 - 1200	19.84	7.95
6	1201 & above	4.23	1.69
	Total	**249.75**	**100.00**

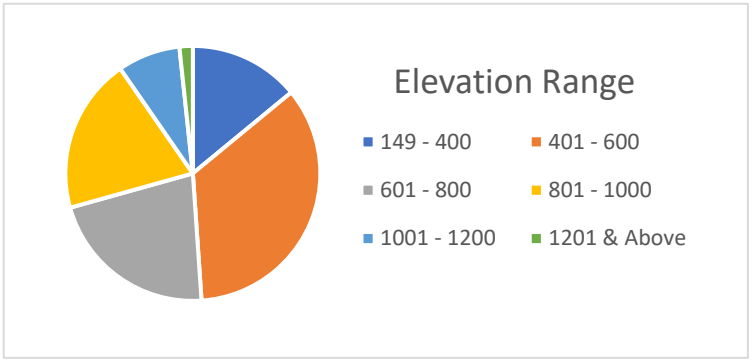


Table 7: Elevation Range distribution in Jhum Cultivation

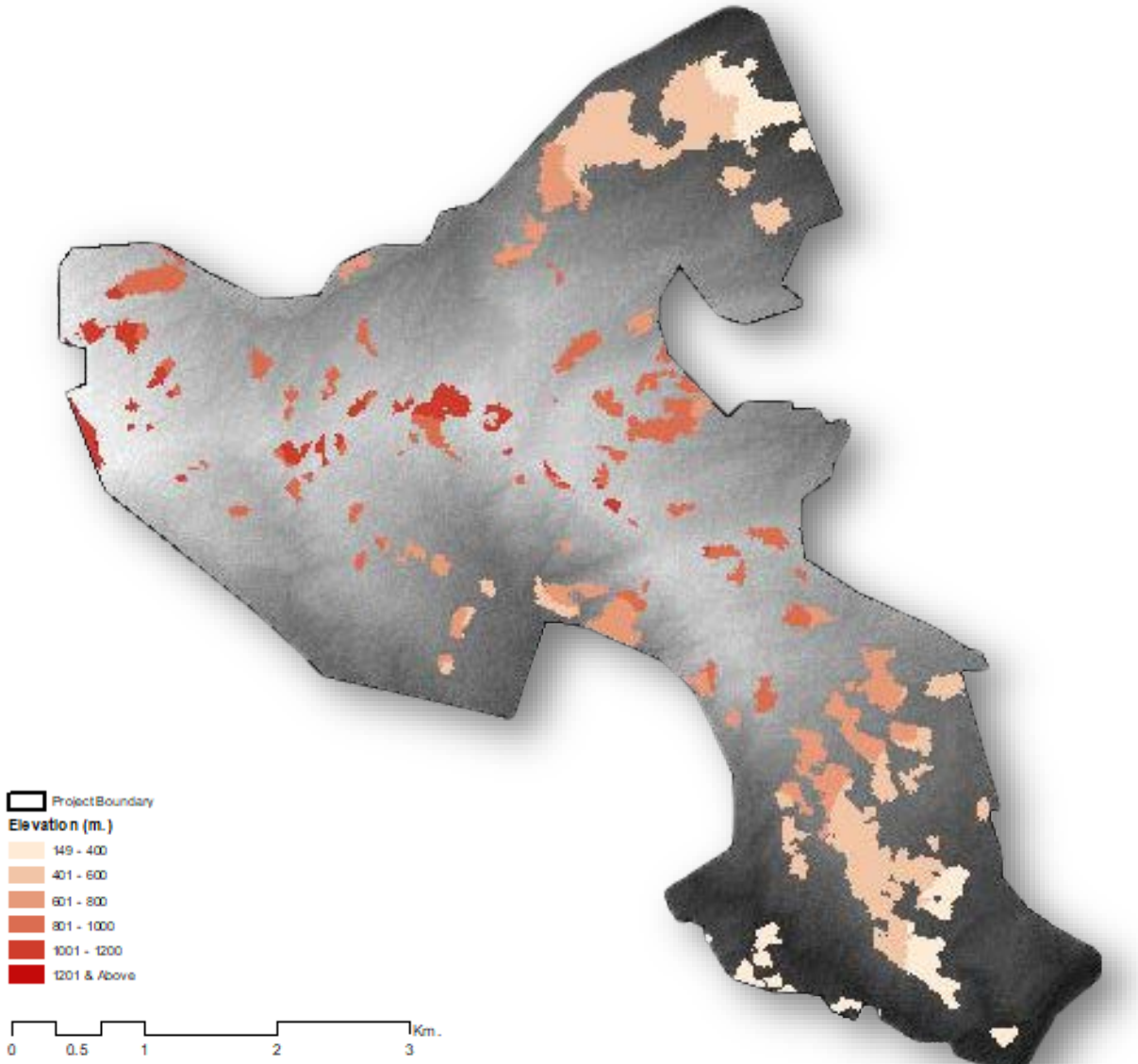


Fig 15: Slope distribution map of study area

Forest

Accurate and reliable forestry data can be obtained by means of continuous monitoring of forests using advanced UAV based survey and GIS technologies, which provides a major opportunity for the development of smart forestry. Traditional data analysis cannot meet the performance requirements of current ground-based forestry applications, however, with the improvement of the precision and acquisition speed of data can pave way for concept of smart forestry. Smart Forest,is based on digital forestry, using cloud computing, Internet of Things, mobile Internet, big data and other new generation information technology. Smart forestry can make forest management digital, perceptual, interconnected, and intelligent. In the present scenario of Khawrihnim village total forest area is 1528.29 ha which is 83.71% of the total village area. This demarcated forest area further classified in to three class based on density of canopy cover of the area. These are given below-:

Dense Forest

This class includes natural forests, which are not disturbed by any biotic factors like shifting cultivation and other human activities. The crown density of this class is very thick. Evergreen and semi-evergreen forests cover major portion of this area. It covers an area of 535.95 Ha, which accounts for 35.07% of the total area of the Khawrihnim village.

Moderately Dense Forest

The forests that have a crown cover neither too thick nor too thin are classed under this category. It covers an area of 701.24 ha, which accounts for 45.88% of the total area of the district. It is distributed throughout the district and found in close association with dense forests. The vegetation of this forest is more or less similar with those species found in dense forests. The only difference lies in the crown density of these forests.

Open Forest

As the name of this class implies, the forest under this category has a thin crown cover. This type of forest includes forest, which were once disturbed and affected by biotic factors like shifting cultivation and human activities. These forests are characterized by those lands where shifting cultivation had been practiced and then left fallow for over a year; the resultant new vegetation of which, regenerated to form new forests. It covers an area of 254.92 Ha, which accounts for 16.88% of the total area of the village. Forests of this class are distributed throughout the village area in small patches usually associated with current jhum land and adjoining abandoned jhum lands.

Plantation:

Apart from forest class, we have classified one another class of plantation. This class usually found near the current jhum land and abandon jhum land. It covers an area of 36.19 ha which accounts for 2.37 % of total village area. In this area we have found banana, papaya and orange plantation.

Landuse Class	Area (Ha)	Area (%)
Dense Forest	535.95	35.07
Moderately Dense Forest	701.24	45.88
Open Forest	254.92	16.68
Plantation	36.19	2.37
Total	**1528.29**	**100.00**

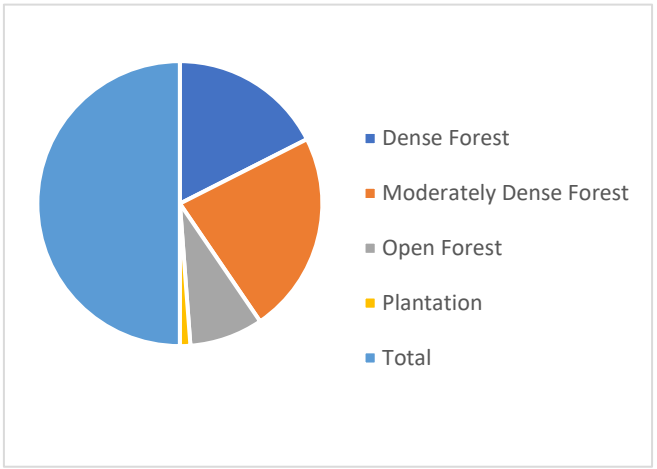


Table 8: Forest Status of Study area

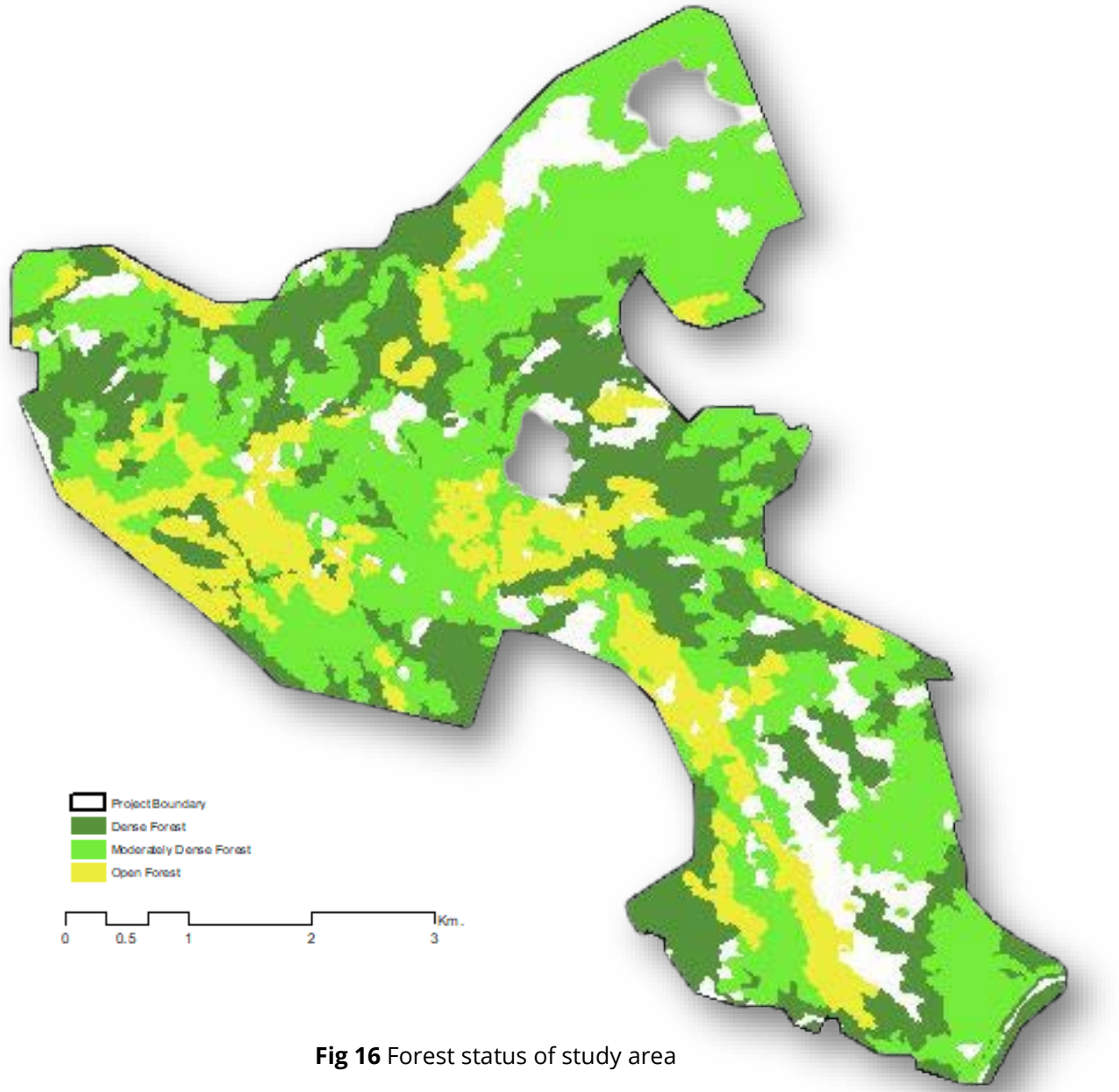


Fig 16 Forest status of study area

Land use and Landcover:

Landuse Class	Area (Ha)	Area (%)
Built up	45.91	2.51
Dense Forest	535.95	29.33
Current Jhum	145.44	7.96
Jhum (Older)	104.31	5.71
Moderately Dense Forest	701.24	38.37
Open Forest	254.92	13.95
Plantation	36.19	1.98
River	3.45	0.19
Total	**1827.40**	**100.00**

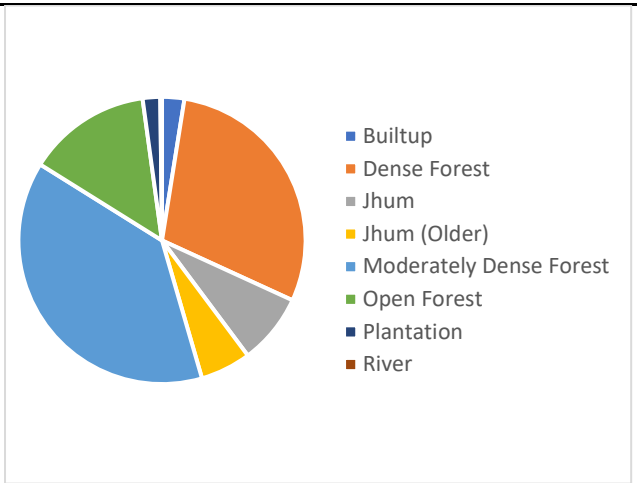


Table 9: Landuse / Land cover statistics of study area

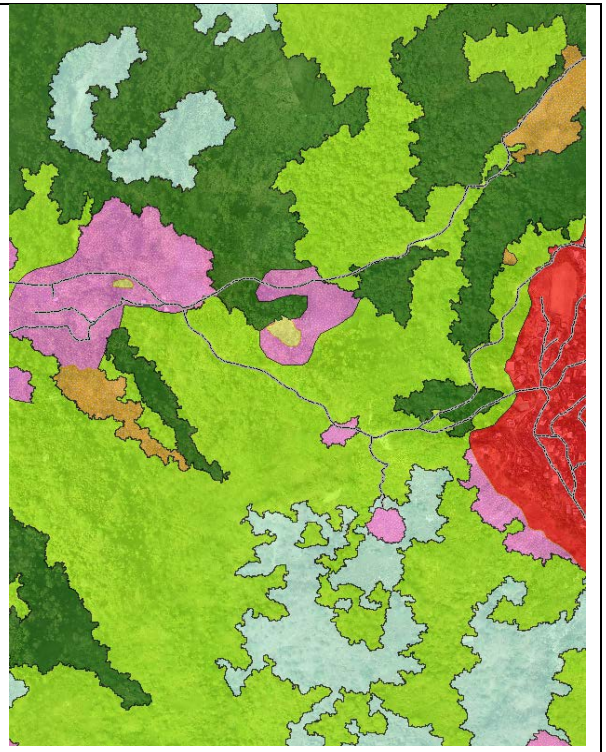


Fig 17: Landuse / Land cover draped over aerial imagery mosaic

Most of the study area lies under Forest class (83.71%) whereas the second noteworthy class is Jhum land (current and older jhum land) that occupies around 13.57% of total study area. Built –up area is 2.51% contributing on total village area, last but not least tlwang river also part of this landuse of project area Systematic planning of watershed management practices, slope management such as SGT trenches, contour bunds, fish pond/tanks; plantation etc. may lead to transformation of these open and moderately dense forest area into lands with usage.

Fig 18: Landuse / Land cover of study area

Soil Nutrient Mapping

Khawrihnim village area for nutrient mapping to help land managers optimize their nutrient use and reduce movement of nutrients off-farm which can even cause contamination of waterways.

The distribution of major nutrients like Nitrogen, Phosphorous, and Potassium (NPK) and other micro nutrients in soil will be mapped and monitored as well as fertilizer advisory will be made available through web-enabled Dashboard.

The already rectified, Geo-referenced and Mosaicked satellite imageries and cadastral/village/GP spatial layers will be used as base for soil nutrient mapping. The bidder will have to create the dynamic Dashboard based GIS integrating the existing dataset on soil nutrients/Soil Health as provided by Dept. The bidder is to create the GIS analytical layers on soil nutrients using the dept. datasets and further create the fertilizer advisory as per the standard logic, in accordance with line department. The bidder will also have to perform GIS analysis, as per the specifications provided by department and submit the same in desired format.

Soil nutrients are essential factors that reflect farmland quality. Nitrogen, phosphorus, and potassium are essential elements for plants, while silicon is considered a “quasi-essential” element. This study investigated the spatial distribution of plant nutrients in soil in a hilly region of Khawrihnim. A total of 101 soil samples were collected from farmland topsoil (0–20 cm) for the analysis. After comparing the prediction accuracy of the different methods, we used the inverse distance weighting method to analyse the spatial distribution of plant nutrients in soil. 101 Soil Samples were collected from study area. These sample are given for test in laboratory results of which are awaited. 10 Duplicate samples were inserted as a part of QA/QC measures. Laboratory test for following 12 parameters is done –

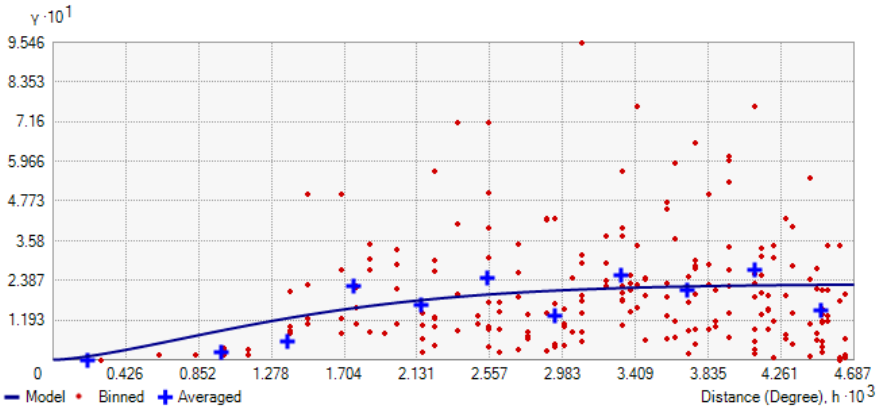
Basic Properties	**Macro-nutrients**	**Secondary-nutrients**	**Micro-nutrients**
pH	Nitrogen	Sulphur	Zinc
EC (Electrical Conductivity)	Potassium		Iron
OC (Organic Carbon)	Phosphorus		Copper
			Manganese
			Boron

Table 10: Nutrient Contents in Soil

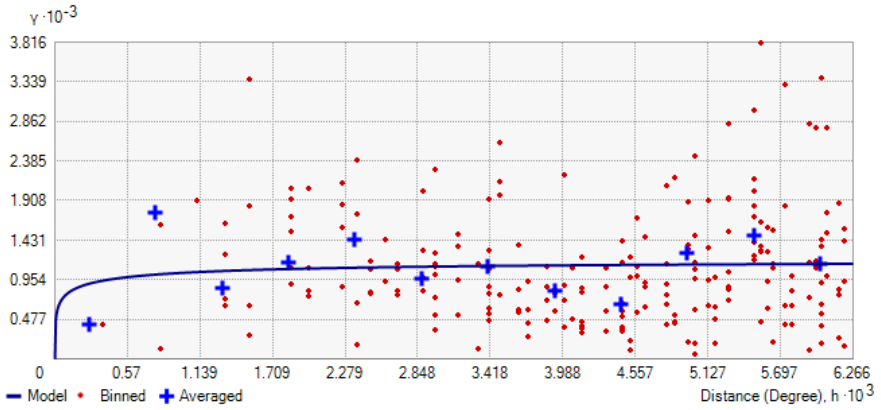
The quality level of analytical data is dependent upon the quality assurance/quality control (QA/QC) techniques employed by a laboratory. And it becomes necessary to perform a quality check and understanding the values distribution, their spatial auto-correlations and distance before pursuing the interpolation of test results. Semivariograms were computed for each parameter pertaining to soil test and their statistical behaviour was analysed.

The Semivariograms depicts the spatial autocorrelation of the measured sample points. Once each pair of locations is plotted, a model is fit through them. There are certain characteristics that are commonly used to describe these models. The semivariogram and covariance functions quantify the assumption that things nearby tend to be more similar than things that are farther apart. Semivariogram and covariance both measure the strength of statistical correlation as a function of distance.

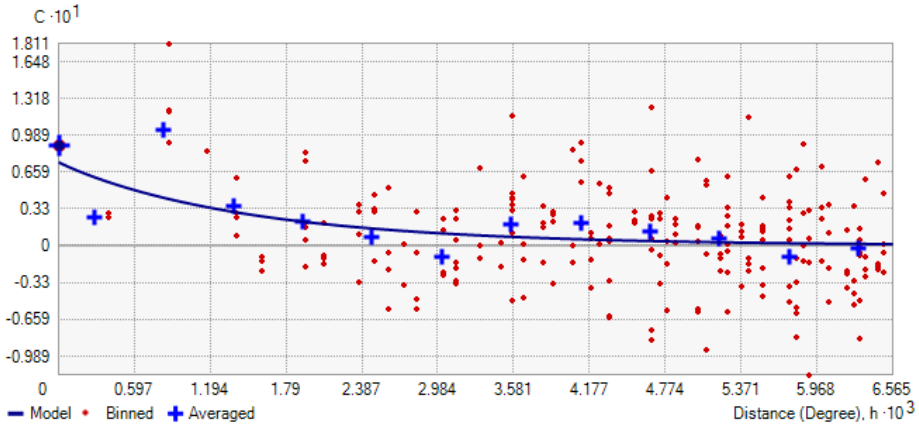
The process of modeling semivariograms and covariance functions fits a semivariogram or covariance curve to our empirical data. The goal is to achieve the best fit, and also incorporate user's knowledge of the phenomenon in the model. The model will then be used in user's geostatistical predictions. When fitting a model, explore for directional autocorrelation in soil test data. The sill, range, and nugget are the important characteristics of the model. If there are measurement errors in the data, user can use a measurement error model.



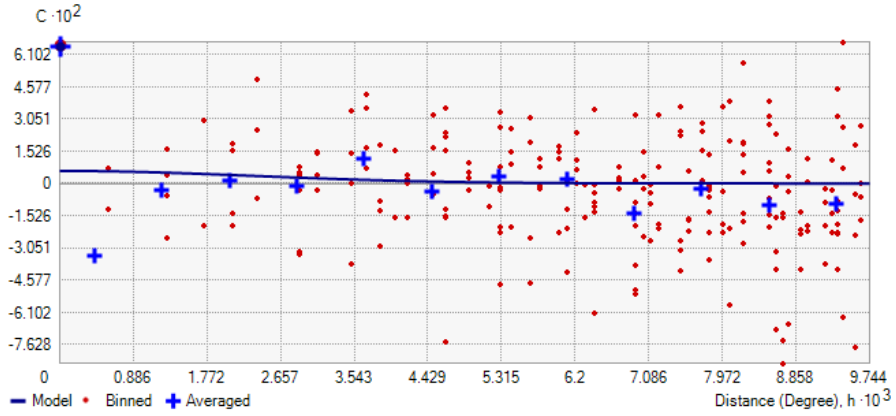
pH



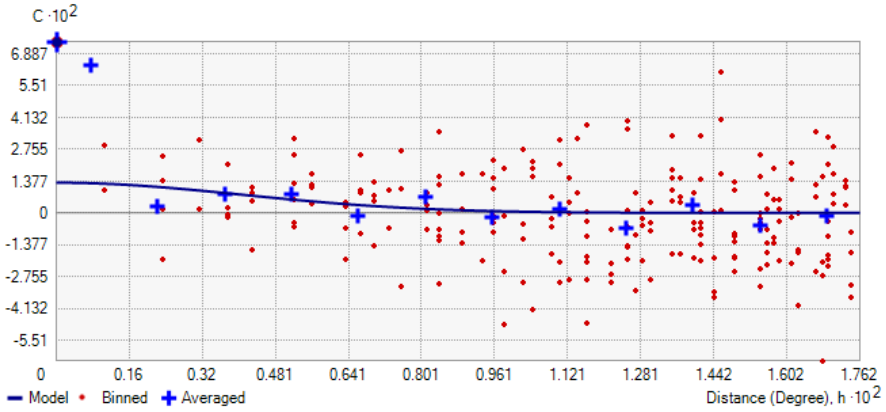
Electrical Conductivity as EC



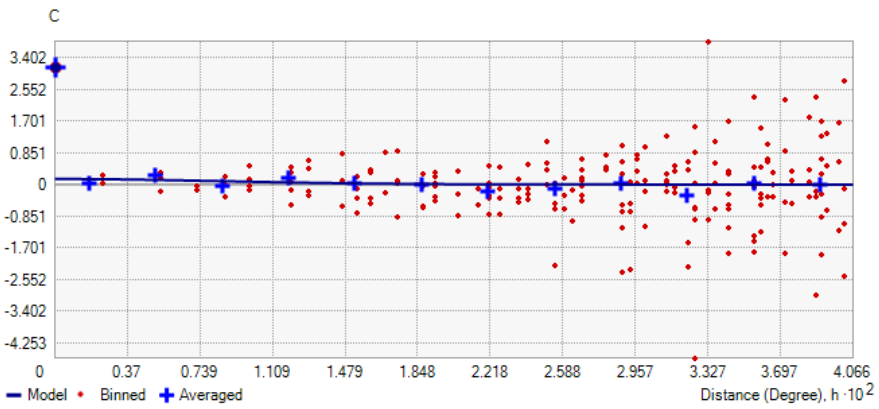
Boron



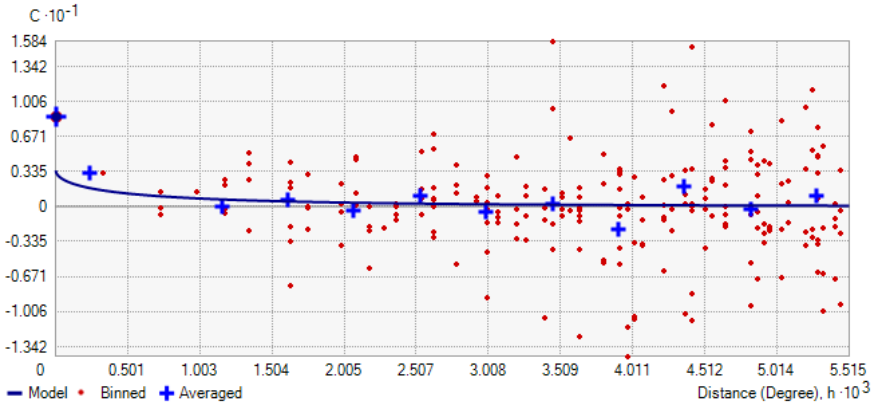
Potasium as K



Nitrogen as N



Manganese



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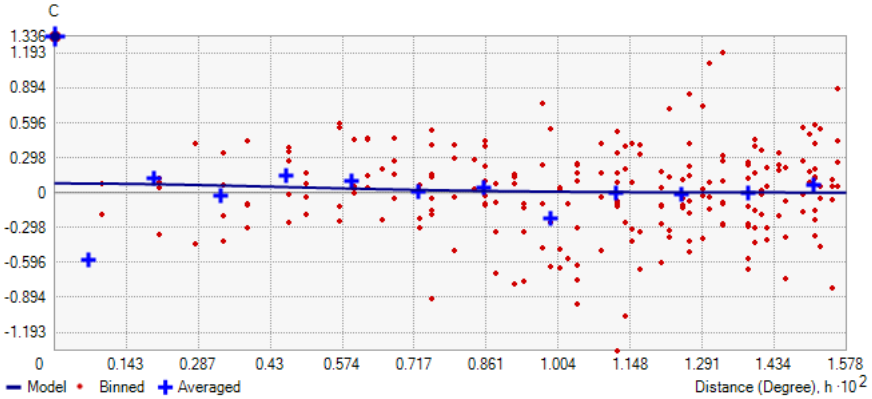
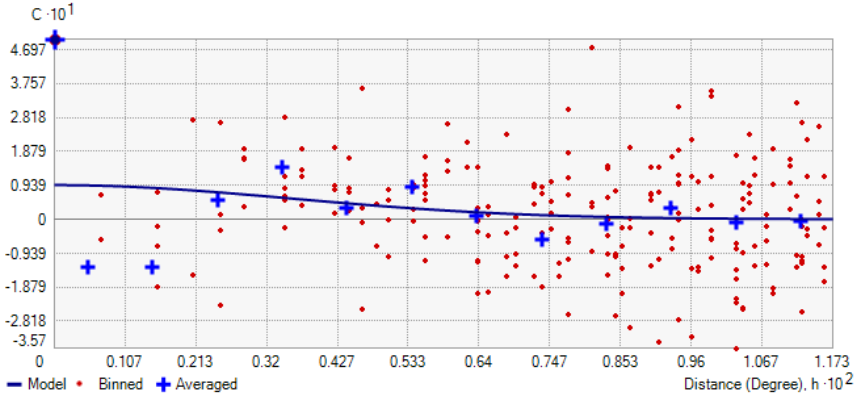
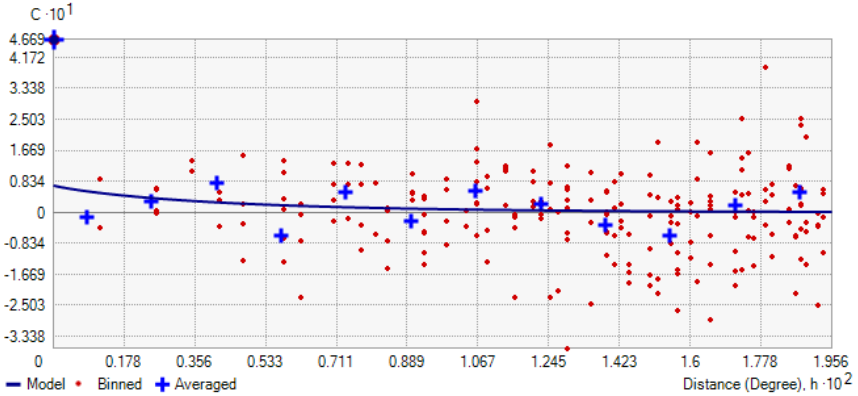


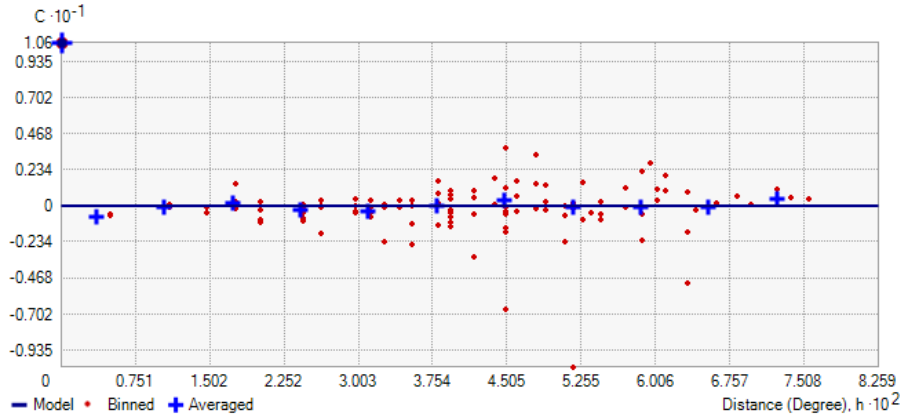
Zinc



Copper



Organic Matter



Phosphorus

Fig. 19 Semi variograms of soil sample test results used for identifying nuggets, analysing the spatial correlation and result quality assessment purpose

Soil nutrients are important indicators of cultivated land quality, which is determined by two aspects: soil fertility and spatial location. Soil fertility, which is closely related to the concentrations of soil nutrient elements, is the foundation of soil productivity. Soil nutrient elements can be classified into essential, beneficial, and toxic elements. Essential elements are critical for all plants under all growth conditions, and can be divided into two categories on the basis of their essentiality: (1) macro elements that are required in high amounts, e.g., nitrogen (N), phosphorus (P), and potassium (K), and (2) micro elements that are required in lower amounts, e.g., zinc, manganese and copper. A sufficient supply of soil nutrients allows plants to grow and develop normally, and the abundance and chemical form of nutrients directly determines whether the soil is fertile. Therefore, it is essential to measure the concentrations of soil nutrient elements to estimate farmland quality as well suitable sites for crop.

Geostatistical methods as a predictive tool have been extensively utilized. There have been many studies of soil nutrient properties in recent years. For example, some studies have assessed soil nutrient conditions in the northeast region of India. Some researchers have attempted to analyse the spatial variability of soil nutrient properties in farmland in New Zealand and India, or in a sandy loam soil in Croatia.

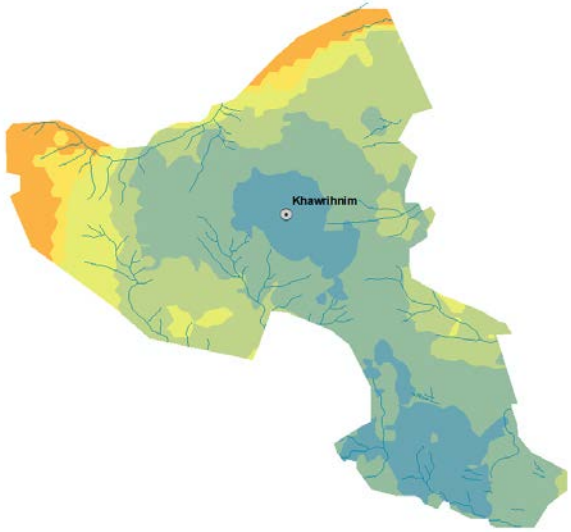
In these studies, although different factors were chosen for the evaluations to address different research purposes, the indexes generally included soil organic matter, mineral nutrient elements, and other soil properties, such as pH. Among the mineral nutrient elements,

macronutrients have been studied more than micronutrients, especially the essential elements N, P, and K, which are among the most important indicators commonly used to analyse soil fertility.

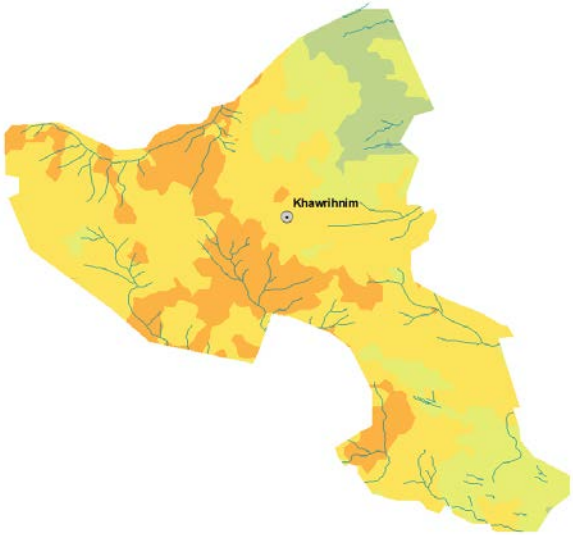
Silicon is the second most plentiful element in the Earth's crust, accounting for nearly 29% of the total content of the crust. Generally, Si plays an important role in soil. In aquatic ecosystems, Si along with N and P are the main biogenic elements that maintain net primary productivity (NPP). Silicon also has a great impact on the growth and development of plants in natural ecosystems due to its unique function of alleviating the deleterious effects of abiotic and biotic stresses in plants.

Soil nutrient properties can vary spatially due to many factors, such as pedogenic processes, climate, parent material, topography, and human influences. When the soil nutrient content exhibits high spatial variability, it is difficult to estimate soil nutrient status among regions based directly on the different geographical features. Geostatistics have been widely used to explore spatial uncertainty in recent decades. They can be used to describe the spatial distribution of a variable and to predict its value between sampling points. This study uses one of the most advanced geostastical method known as kriging. Kriging depends on computing an accurate semivariogram model from which estimates of variance can be calculated. A sufficient number of samples are needed to develop an accurate semivariogram that can represent the autocorrelation of the soil property under consideration. On the other hand, soil properties may be interdependent. The property of interdependency suggests that we can estimate a property whose values are difficult to measure from other properties whose values are easier to determine.

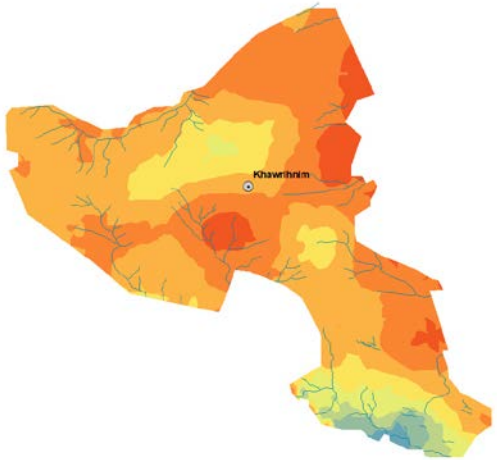
The main objectives of the study were to (i) measure the total nitrogen (TN), available phosphorus (AP), available potassium (AK), and (ii) determine the optimal model fitted and its parameters; and (iii) assess the spatial variability of the selected soil nutrient elements and analyse their spatial distribution.



a



b



c

Fig 20:

(a) The total nitrogen overall shows a trend of increasing from hilltop to lower slopes.

(b) The higher phosphorus occupies mostly the backslopes of hill questa whereas moderate distributed is evident at dip slops.

(c) Moderate distribution of potassium is noted at middle slops whereas the higher values are distributed at lower slopes.

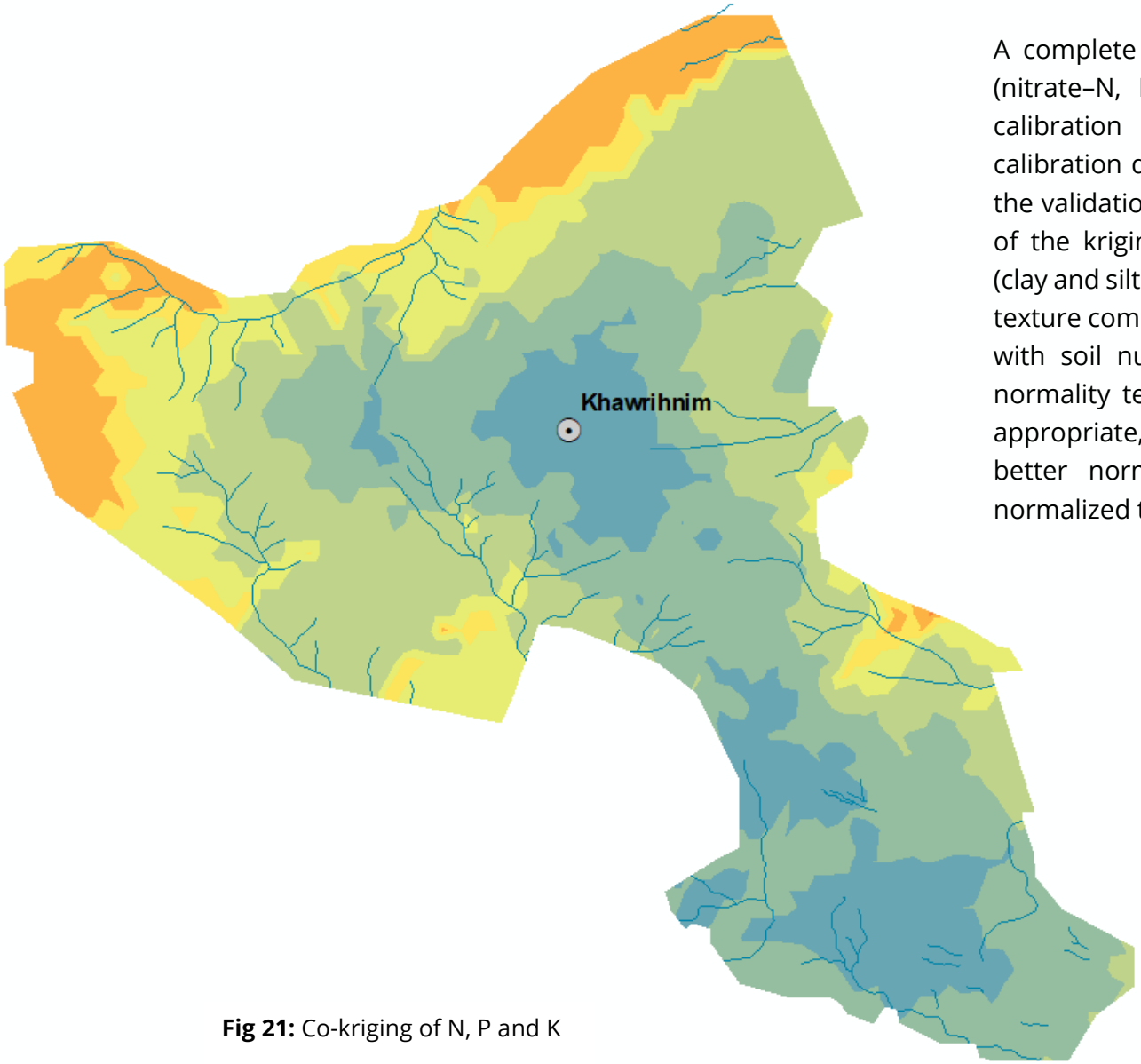
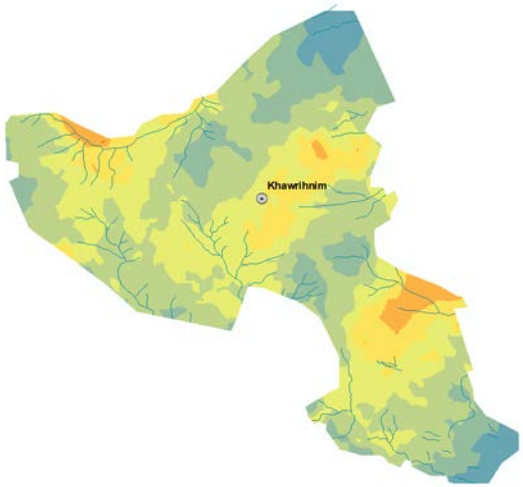


Fig 21: Co-kriging of N, P and K

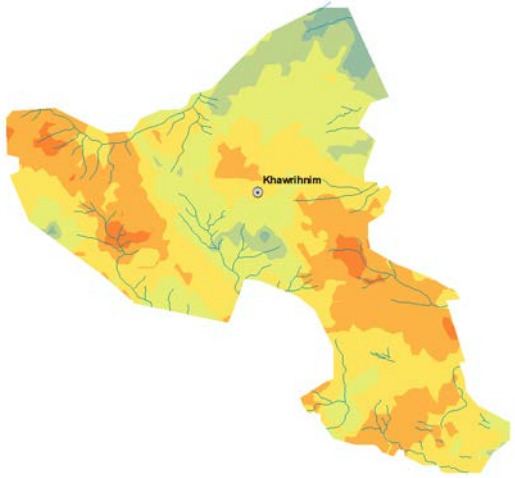
A complete data set for each of the primary variables (nitrate–N, P, K) was partitioned into two subsets: a calibration data set, and a validation data set. The calibration data set was used in the kriging analysis, and the validation data set was used to evaluate the accuracy of the kriging procedure. Two soil texture components (clay and silt) were used as auxiliary variables. Another soil texture component (sand) was found to be less correlated with soil nutrients and was not used in the study. A normality test was performed for each data set. When appropriate, the data set was log–transformed to create a better normal distribution. Each data set was also normalized to a zero mean and unit variance.

Finally, a geostatistical technique, cokriging, was applied to estimate values at the validation sites by using the calibration data set, with soil nutrients value (P &K) as auxiliary variables. The generalized cokriging estimator is defined as a linear combination of all the available sample data.

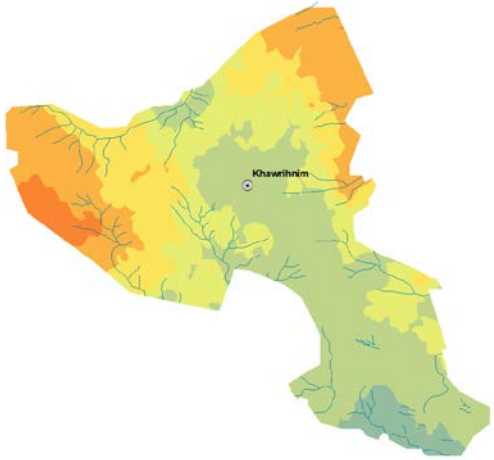
co-kriging of N, P and K shows deficiency in major soil nutrients at the dip slopes which is considered to be most suitable land from slope distribution point of view.



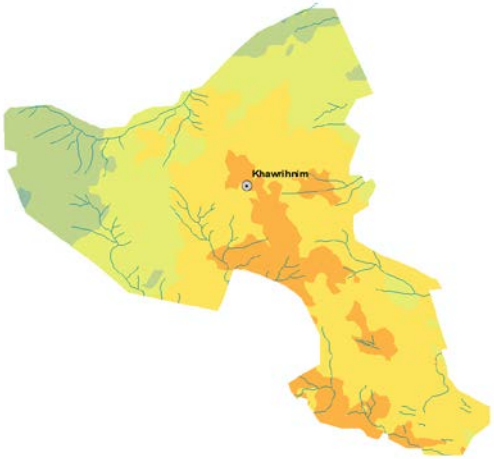
pH



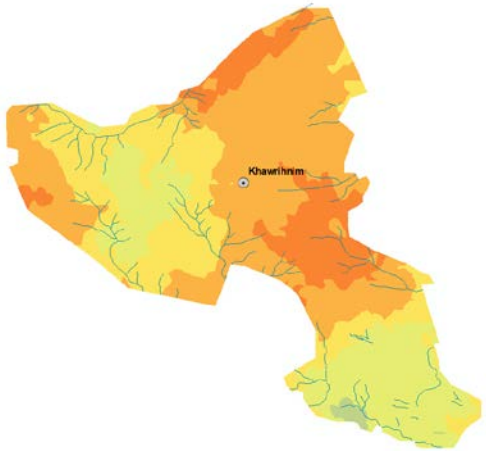
EC



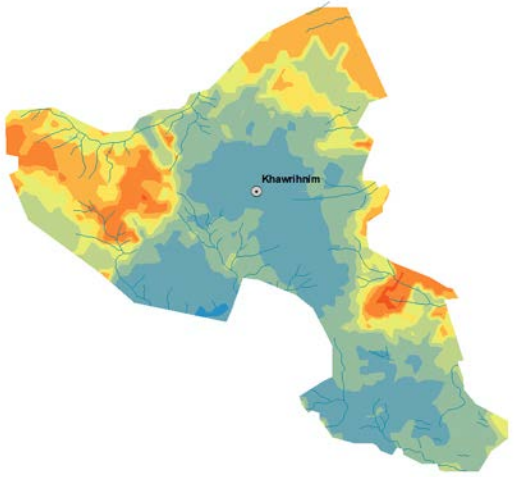
Organic matter



Mn



Fe



Zn

Fig. 22: Soil Nutrient Mapping

Soil erosion and nutrient loss due to Jhum Cultivation

Soil erosion under shifting cultivation is highly erratic from year to year depending on rainfall characteristics. On the basis of Soil erosion modelling on steep slopes (44 - 53 %) have indicated the soil loss to the tune of 40.9 tons per hectare and the corresponding nutrient losses per hectare are 702.9 kg of organic carbon, 145.5 kg of P_2O_5 and 7.1 kg of K_2O (Munna Ram and Singh, 1993). The soil loss from hill slopes (60 – 79 %) under first year, second year and abandoned jhum was estimated to be 147, 170 and 30 t/ha/year. During first few years of clearing, carbon and nitrogen levels decrease rapidly. The serious adverse effect of Jhumming is soil erosion, which is mainly of splash and wash types. As the soil in the upper reaches in a ridge are exhausted in the process, the cultivator's move to the adjoining lower elevation.

generalises Soil Erosion calendar of Jhumming cultivation.

Month	Agricultural operation	Erosion problem	Soil erosion (t/ha)	
			Minimum	Maximum
January, February, March April	Plot selection, forest cutting, burning and clearing of hill slopes and sowing begins	Displacement of loose soil materials to downhill and rolling down of earthworm casting, soil erosion as above and wash due to rains	0.0	22.4
May	Sowing / weeding	Heavy soil wash, faint riling at foot hills on slit deposits	0.2	61.9
June	Weeding	Heavy wash of soil aggregates	0.2	45.4
July	Weeding, harvesting begins	Heavy wash of soil aggregates, crop root exposed, farm soil visible	1.8	21.9
August	Harvesting and occasional weeding	Soil wash continues	1.0	29.6
September	Harvesting	Soil erosion appreciably reduced	0.1	13.8
October	Harvesting	Soil erosion appreciably reduced	0.0	2.7
November	Harvesting	No erosion, moss turns brackish	0.0	0.0
December	Harvesting/threshing and carrying to home	No erosion	0.0	0.0
Whole year total	**Shifting cultivation on steep slope**	**Heavy soil wash**	**3.3**	**201.4**

Jhum cultivation starts with cutting and burning of trees and leads to degradation of forest or deforestation in the hilly areas where they used the land to do jhum. Deforestation has negative effects on the environment which ultimately leads to climate change which nowadays a matter of global concern. Deforestation may also affect the flora and fauna existing in the forest. One of the most vital negative environmental impacts of shifting cultivation is the damage that causes to the soil system. It accelerates the soil erosion and nutrient loss manifold. The changes in the soil properties of shifting cultivation sites need to be documented and regularly monitored to bring about an improvement in the areas under the practice of shifting cultivation over the centuries.

Soil loss (t/ha)	Anticipated productivity losses
<12	No change in land productivity
12-15	50% of area of very productive land shows a diminishing trend to productive land, the remainder remains unchanged
50-100	100% of all productive land shows a diminishing trend by one productive class
101-200	50% of the area of all productive land is converted to suitable land, the remainder shows diminishing trend by one productive class
>201	The entire area of productive land is converted to not suitable class

Table 11 Showing Relationship Between soil erosion and decline of land productivity.

Site Suitability Analysis for Jhum Cultivation

This Site suitability is a function of crop requirements and soil/land characteristics. Matching the land characteristics with the crop requirements gives the suitability. So, 'Suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use.' (FAO). Besides the land/soil characteristics socio-economic, market and infrastructure characteristics are the other driving forces that can influence the crop selection. Site suitability is an interdisciplinary approach. Determination of optimum land use type for an area involves integration of data from various domains and sources like soil, terrain characteristics, socio-economic conditions, climatic parameter to market management.

The present popular methods that are followed for land suitability analysis include ranking and ratings, weighted summation, requirement matching etc. Here the weights are arbitrarily chosen, and are aggregated using simple Boolean overlay methods.

Selection of Site Suitability Evaluation Criteria

The process of selecting the criteria is iterative in nature. UAV survey based landuse, analytical study of soil fertility mapping and understanding of slop based jhum cultivation are tools that aid in the selection of evaluation criteria. The following evaluation criteria are considered to address the land suitability decision- making.

1. Soil nutrient mapping
2. Terrain characteristics; - Slope, jhum land distribution on slope and elevation
3. Fertility mapping – result of soil analysis
4. Landuse distribution
5. Climatic parameter- rainfall, temp,
6. Irrigation facility available
7. Market access
8. Social-economic parameter also has important role of site suitability

On the basis of multicriteria decision analysis, we have demarcated land suitability in to five classes on raking basis which shows low to very high suitable lands.

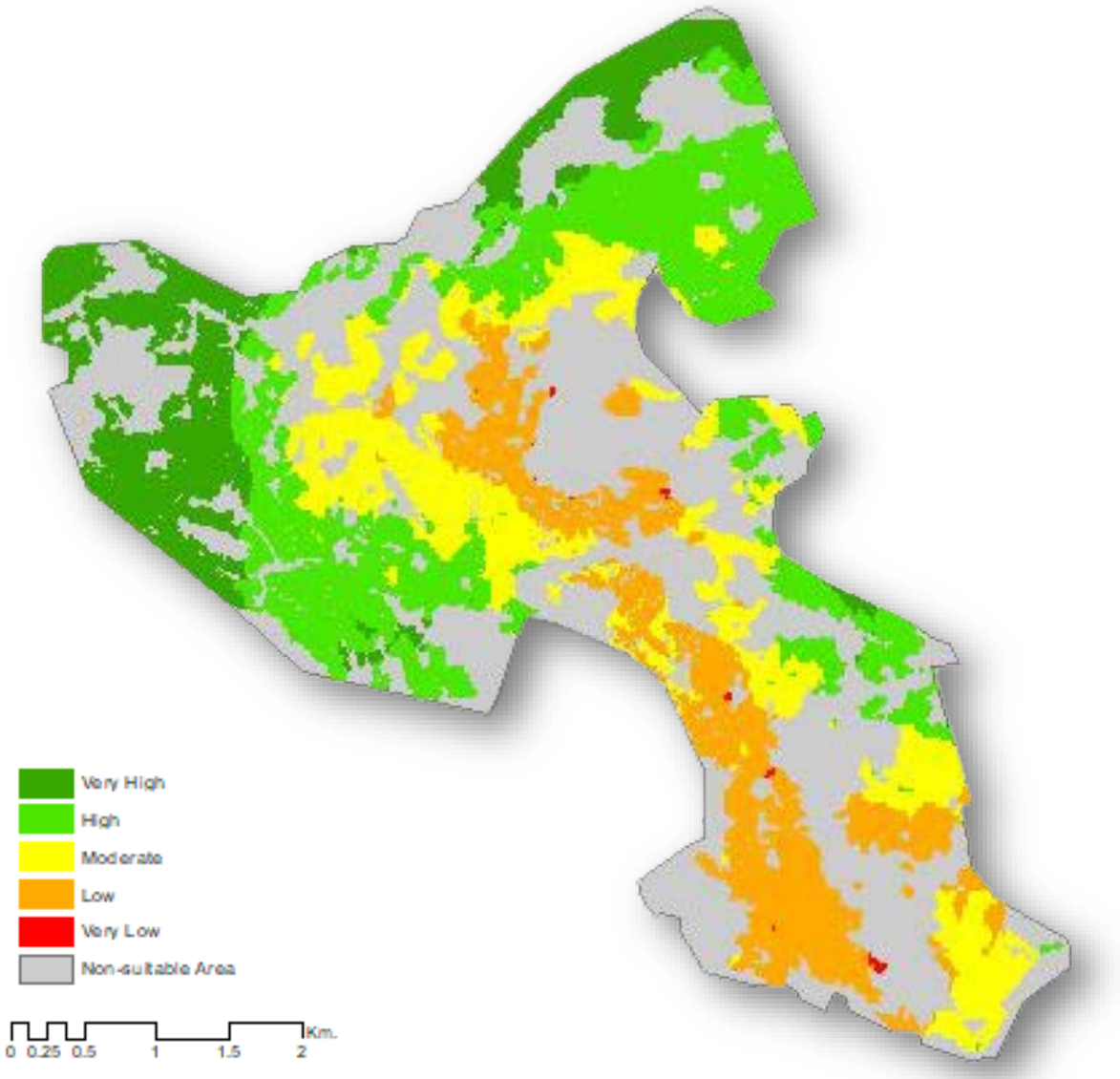


Figure 23: Site suitability for Jhum land cultivation

N^{O}	Suitability Class	Area	Area (Ha.)
1	High	1379395.957	137.9396
2	Low	839134.2517	83.91343
3	Moderate	1074300.58	107.4301
4	Very High	773095.9149	77.30959
5	Very Low	9873.322257	0.987332
	Total	**4075800.026**	**407.58**

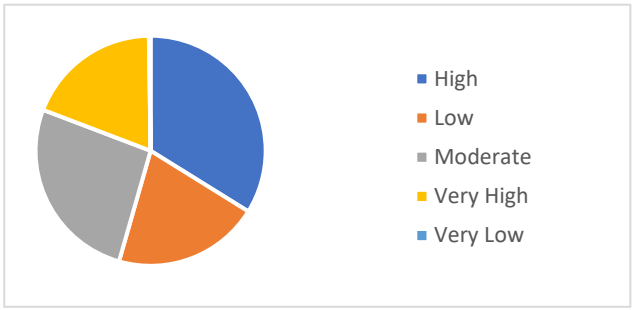


Table 12: Site suitability for Jhum land cultivation

Water resource Planning and Management

Digital elevation models (DEMs) represent the total topography, surface flow is one of the more important data sources for deriving variables used by numerous hydrologic models. A key characteristic of DEM-derived hydrological parameters such as stream network, flow direction, flow accumulation, sinks, embarkments is the spatially factor portrayal of the watershed as far as topography, vegetative, or land use/cover, soils that represent the hydrologic procedures of infiltration, evapotranspiration, and runoff. This further contributes in planning a variety of interventions for surface water and groundwater management. Drainage network, drainage density, drainage frequency, bifurcation ratio, stream ordering, flow direction, accumulation, sink holes, slope and slope aspects and topographic wetness index are few parameters to be derived using LAAMS DEM. On the other hand, groundwater data including well inventory, data from state and central ground water departments shall be compiled in form of GIS data layer, when the information will be shared by the relevant department. This would help in planning groundwater management related interventions.

Watershed Delineation

ArcMap 10.4 spatial analyst module was used for the purpose of automatic watershed delineation. The key input was DEM that have been created using UAV photogrammetry. The main steps are as below –

i. **Creating shape file of Study Area –** Initially a shape file comprising area of interest boundary is created, to impose the computation limitation within study area.

ii. **Seasoning of DEM -** After getting the DEM, there is need to fill the depressions if any in the DEM to get avoid false routings. Using the fill tool in hydrology tool box in the spatial analyst and the DEM as the input file, the sinks in the surface raster is filled so as to removes small imperfections in the data

iii. **Flow Direction Raster generation -** The filled DEM is used to prepare the Flow Direction grid using Flow direction tool, available in the hydrology tool box in spatial analyst extension. It creates the raster with flow direction to the steepest neighbouring cell down the slope and used to determine the direction of flow of water in the given topography. Direction of flow must be known for each cell, because it is direction of flow that determines the ultimate destination of water flowing across the surface.

iv. **Flow Accumulation Raster -** It is done using hydrology tool box and the output shows the drainage path based on the flow direction raster. In addition, it shows the accumulation of flow in each cell whereas the maximum accumulated path gives the drainage path.

v. **Determining Pour Points -** After getting the flow accumulation raster, pour points are required to determine watershed pertaining to the flow path. We created a point shape file for determining the pour points. These pour points are determined in the path using flow accumulation raster. Adequate care should be taken that the pour point lies in the line of flow accumulation.

vi. **Watershed Delineation -** Using the watershed tool in hydrology tool box, 8 macro-watersheds were delineated. The input required are the flow direction raster and the pour point shape file. If there are multiple watersheds in given area, the watersheds corresponding to the drainage paths also can be determined, just in case of study area given (Fig. 25)

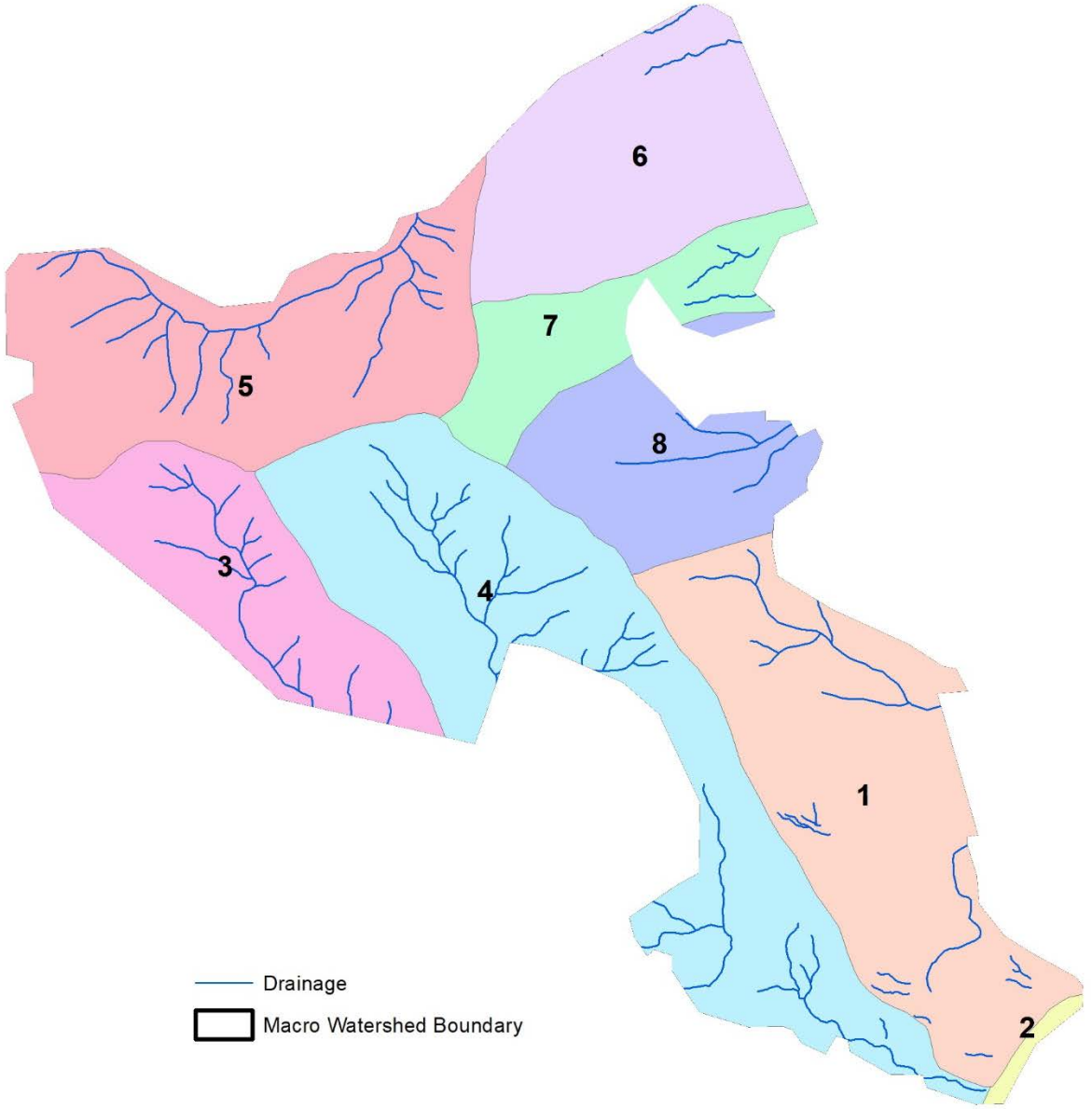


Figure 24: Macro watershed delineation of the Study Area

Planning the interventions

Four Waters concept can come very handy in the Hilly terrain i.e., Mizoram for countering capturing of runoff water and subsequent damage i.e., landslide and others disaster. This low-cost technology can increase recharge of groundwater by four times and provide thrice the benefit than conventional models. The methodology of the Four Waters concept revolves around the harvesting of available runoff (rain water, groundwater, underground water & in situ soil moisture) in rural areas by treatment of catchment, proper utilization of available water harvesting structures, renovation of the non-functional water harvesting structures & creation of new water harvesting structures.

The landuse layer would be helping in determining arable and non-arable lands for planning the interventions accordingly. GIS based decision making models shall be prepared using set of multiple criteria involving hydrological parameters, slope, DEM, landuse, waterbodies and cadastre layers. Separate decision-making model for each intervention shall be prepared. For example, staggered trenches (SGT) and contour continuous trenches (CCT) shall be planned in non-arable land but as a standard practice, the slope required for SGT is 6 to 40 percent and up to 20 percent for CCT.

Following are the interventions that shall be planned -

The landscape of a watershed determines where we can stop water and how. The planning of interventions shall be in fitness of scientific criteria, locally available labour and raw material.

Staggered Trenches (SGT)

Staggered contour trenches are a simple, low-cost method of checking the velocity of runoff in the ridge area of any watershed. A staggered trench is a trench dug along a contour line. Digging a trench along a line that is at the same level increases the chances of containing runoff for a longer period of time within the trench. In the hilly area of a watershed a contour trench is a simple and inexpensive solution to slowing down surface runoff and reducing soil erosion.

Total 761 staggered trenches covering 7612m length are planned in study area. Zig-zag pattern shall be followed. The objectives are to slow down the velocity of runoff, checking soil erosion and improving local soil moisture profile. Following criteria is used as per scientific approach of interventions planning –

i. Land type – non-arable
ii. Slope range - 6 – 20 %
iii. Terrain type – Hilly (avoid rocky strata)
iv. Suitable length – 500 running meter in one Ha.

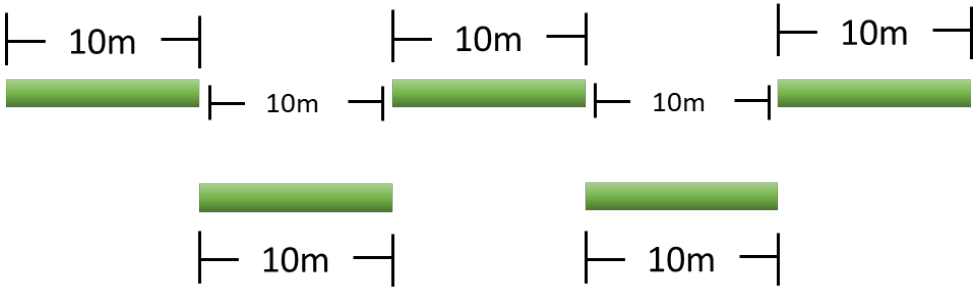
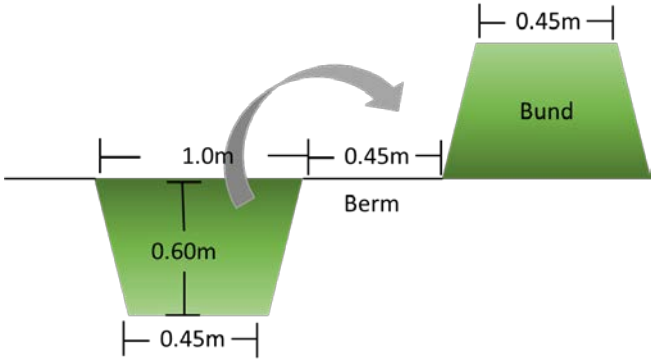


Figure 25: Planimetric View of Proposed Staggered Trenches



$$\text{Earthwork for SGT} = \frac{(1.0+0.45)}{2} \times 0.60 \times 10 = 4.35\ m^3$$

Formula 1: Volume Calculation for a standard 10m SGT

Figure 26: Cross Sectional View of Proposed Staggered Trenches

Developing Fish Ponds

Fishery is land based activity for economic upliftment of the rural fish farmers, focus on inland fisheries will help in realizing the goal of doubling the income of farmers. There is vast scope for development of fisheries by developing infrastructures like fish ponds by

utilizing high amount of surface run-off at hill slops of study area that will be providing nutritional security and livelihood support to the rural mass. Team theta has identified 79 suitable locations along with computation of nano-catchments for fish ponds development. Providing assistance and basic training will bring tangible improvement in socio-economic standing for expected fish farmers. The Newly Launched Fisheries FPO Policy of the Government can be utilised for this purpose. It is Also suggested that Recirculatory Aquaponic. Greenhouse System be Set Up under the FFPO Model in the Form of a Cooperative Society or FPC (Farmer Producer Company) This type of aquaculture is found mostly in the ponds which are adjoining the main river course where favourable conditions like clayey soils exist. Fish farms are seen extensively in the middle parts of the watershed where extensive plain lands exist with clayey soils. Fish farms having considerably bigger size may also serve as the sources for drip-irrigation.

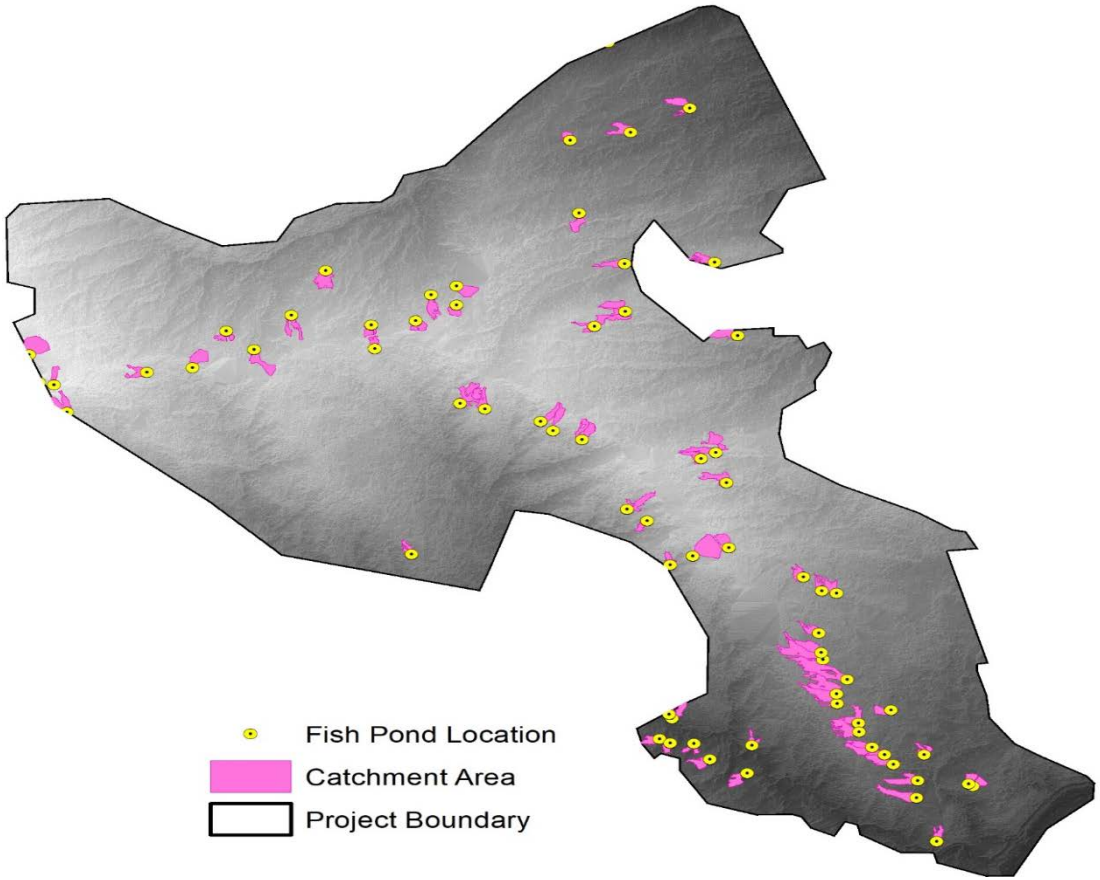


Fig 27: Map showing Suitable fish pond locations and Catchment Area

Irrigation Infrastructure Mapping

Irrigation in crop land management plays a major role in determining the future food security of the state. Evaluating and Improving performance of Irrigation system is of paramount importance in the field of agriculture. Keeping this in mind, the department wants all irrigation infrastructures to be mapped and disseminated through web enabled GIS based dashboard.

For this purpose, the already Geo-referenced and Mosaicked UAV images used. That further have to integrate the existing dataset with the cadastral data provided by the focus and concern department but Study area comes under rainfed zone. There are no existing irrigation infrastructures in the area. There is only one river stream in downslope of the village and there is no water pumping facility available in the village. Therefore, irrigation infrastructure map will not be included in this report for the Model Village Pilot.

There are several options in Irrigation Infrastructure development for water resources such as diversion of river water, construction of reservoir, and/or pumping the groundwater. Since the state has steep ground slope in general, the unit cost for development of reservoir will be relatively high. Agriculture in study area is still extensive, and intensive farming through utilization of groundwater is not feasible all the time either. Considering this situation, the diversion of river water using gravity irrigation system can be a priority in the water resources development planning in principle.

Water invoicing link with irrigation infrastructure and land holding farmer

In India, irrigation water invoicing is mostly based on crop area, which is both labor-intensive and prone to error. Moreover, as it sets arbitrary charges on irrigation water use, agrarian communities do not welcome it. Lack of transparency in the process for water deliveries and consequent under reporting of irrigated area limits the realization of potential water charges. Generally, The State water charges are assessed by the Irrigation Department and collected by the Revenue exchequer. In addition, water pricing reforms are identified that will encourage farmers to reduce their water use per unit of output.

In Current scenario two major methods for pricing water: area-based pricing, volumetric pricing. Presently water invoicing is carried out in the following manner.

Area-based water charges are fixed charges, based on the area irrigated or “supposed” to be irrigated. They are often calculated by dividing the total area irrigated into the O&M costs of providing irrigation water, which basically follows the average cost pricing principle. The disadvantage of this pricing method is that, once the irrigated area decision is made, the water charge will have no effect on farmers’ water consumption, because the marginal cost of applying additional quantities of water per hectare is zero. The

advantage is that it is simple to calculate, easy for farmers to understand, and the implementation costs are lower than for volumetric pricing because water deliveries do not have to be measured. Also, assuming 100 percent collection rates, charges per hectare, based on average direct cost, result in full recovery of direct costs. Although it gives farmers no incentive to reduce water use per hectare, it is still widely used in many systems throughout the world due to the simplicity of its implementation. Area-crop–based pricing systems vary the charge per hectare irrigated by type of crop. The water price variation among crops depends on the policymakers' objectives. If they want to encourage efficient use of water, the high water-consuming crops such as rice, should have higher prices per hectare. Volumetric water pricing, the charge is based on the amount of water delivered. The economic optimal pricing rule requires that price should be set equal to the marginal cost of providing the water, and it requires accurate measurement of water through meters. The advantage of this pricing method is that it encourages farmers to limit their water use. Also, it is easy to understand in the sense that you pay for the quantity of water delivered to your farm. However, it has several disadvantages. First, the implementation costs can be high because meters are required, and they have to be honestly read and reported. Second, marginal cost pricing does not allow full cost recovery in the case of decreasing average costs. But due to a lack of Irrigation infrastructure and the fact that the Study Area comes under village council, Water Invoicing cannot be determined for the Target Study area of the Model Village, and can only be taken up in the Actual Project after the Pilot.

Identification of Farm Link Road

Existing Road network constructed by State PWD with total length of 12.94 kms, connecting district/sub-divisional/block Hqrs, satellite towns and even important villages have substantially improved road communication system. But the existing road networks needs further to be supplemented by a network of Agri Roads connecting the prospective farming areas. Moreover, increased developmental activities in Agri-Horticultural and agro-forestry sector as envisaged under various programmes underline the urgency for such road networks as would facilitate easy and timely access to various inputs and transportation of crops for marketing or storage. It is proposed to construct Agri Road covering all villages categorizing villages on strength of households, no. of farms, Volume and type of Produce as well as Shelf Life and Perishability.

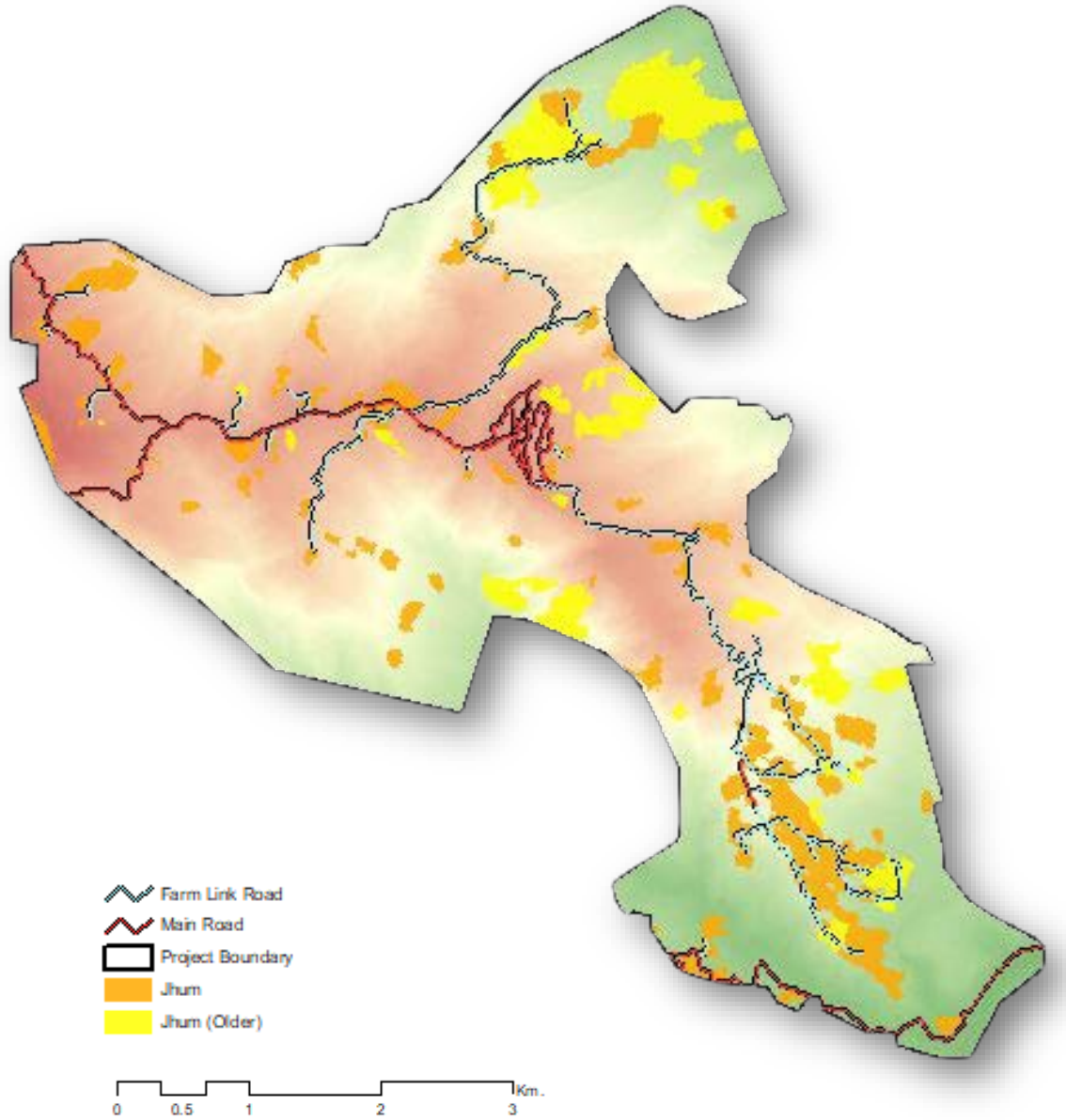


Fig 28: Map showing Suitable Farm link road

Dashboard for Climate Change study: Online Platform

Theta Enerlytics has developed online portal for Data Visualization and Analytics services named “Heliware” using Helicam, Web GIS and Augmented Reality through its ‘Heliware – Suite of Services’. Through our services, you would get an easy access to high precision data in an online 3D and Augmented environment giving you the power to visualize, analyze and control the data to enable well informed decisions across the lifecycle of your capital projects - right from the preplanning/ design phase to the execution and operation phase.

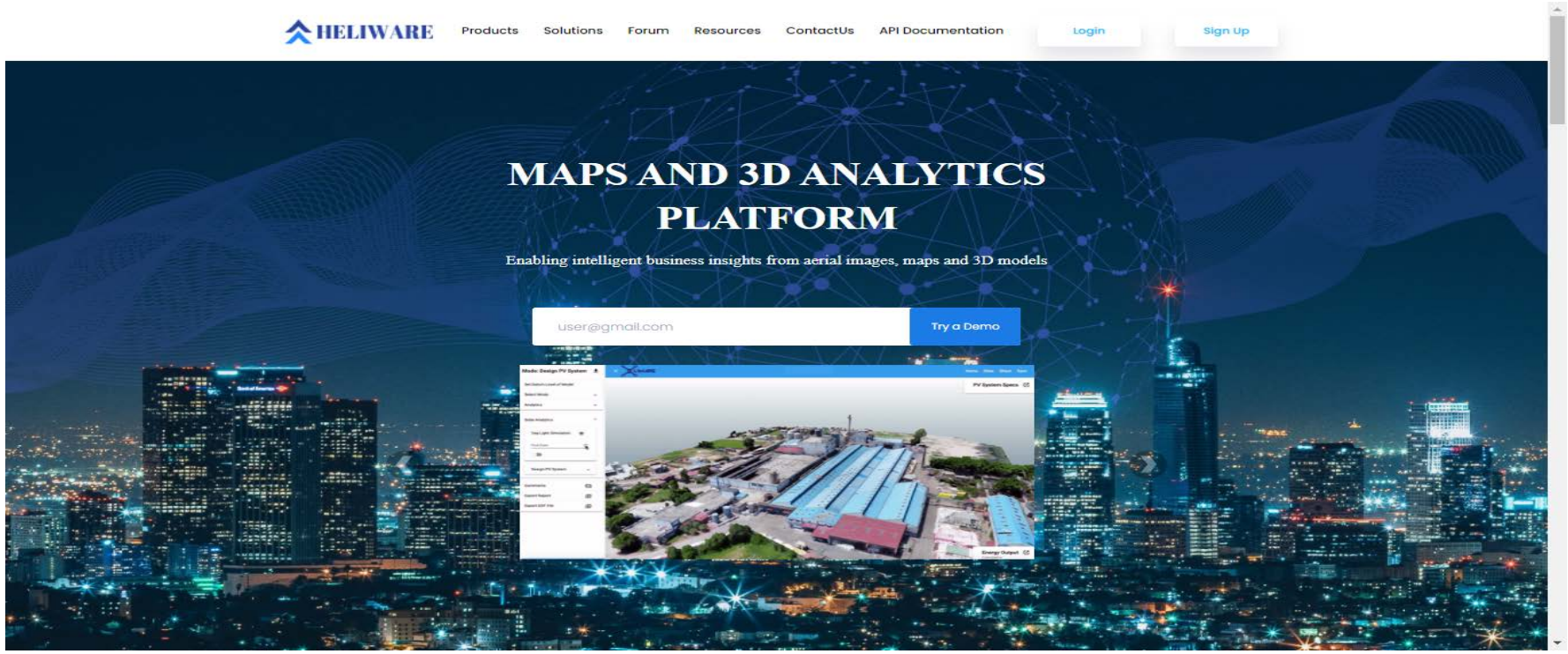


Fig. 29 Interactive online dashboard for climate change studies

Development of Online portal:

There is growing needs for web-based GIS for easy and fast dissemination, sharing, displaying and processing of spatial information which in turns helping in decision making for climate change studies and other impact studies. In order to make a cost-effective implementation, operation and maintenance of spatial information over the web, a cheaper yet feature rich alternative to commercial software is required which can be fulfilled by Open-Source GIS platform.

The geospatial data service system is supposed to provide launching of computational procedures and visualization of their results. The cartographical web services to be realized as an integral part of the system implement the differentiation of the user's access rights and provide functional capabilities to work with raster (Geotiff) and vector (Shapefile, PostGIS) geospatial data using OGC WMS, WFS, and WPS based on the Geoserver and GeoWebCache software.

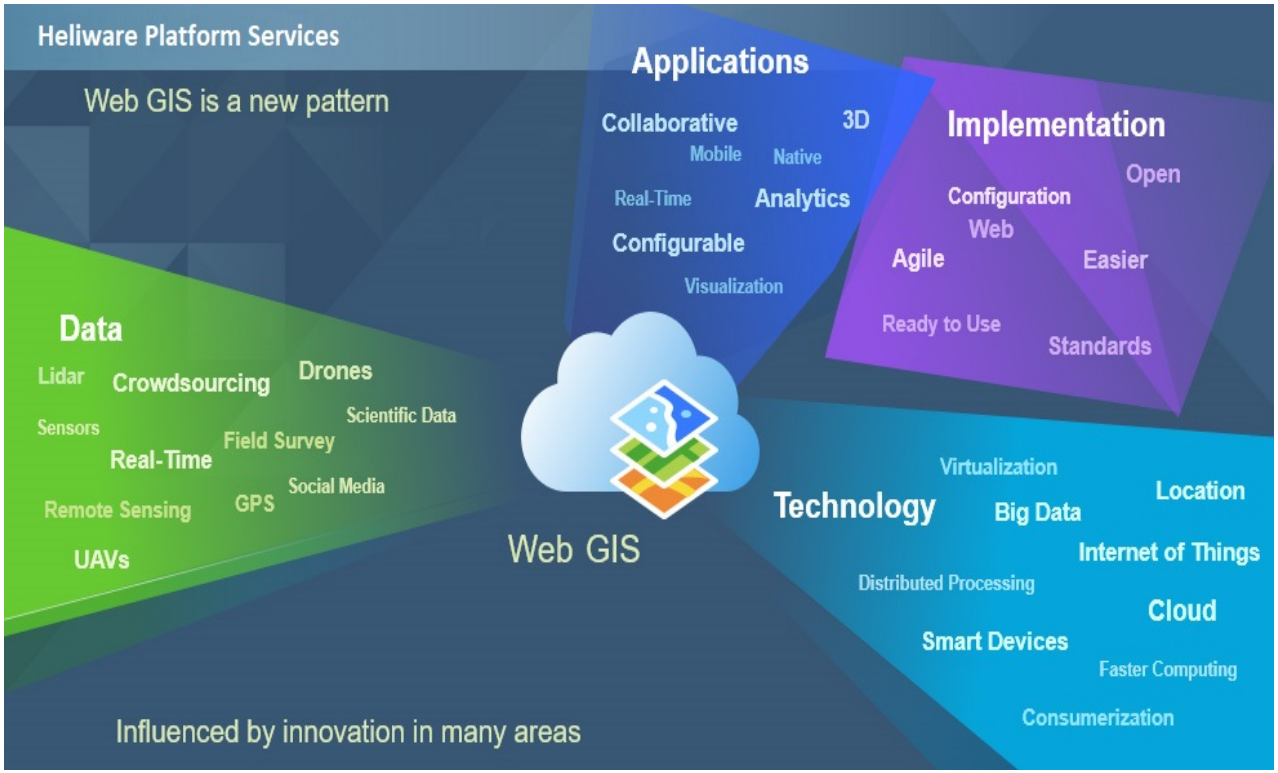


Fig. 30 Showing capability of Heliware Portal (End to End Solution)

Heliware for climate change studies:

In order to analyse growth stages of agriculture in near real-time to determine field-specific crop status and discover crop growth trends, there is a need to develop and rollout an Agriculture information system & climate change studies, wherein all the datasets which will be created in the aforementioned mapping systems will be utilized to decipher appropriate scenarios. These datasets are:

- Crop Map
- Landuse Land Cover map
- Agricultural parcel mapping
- Soil Nutrient Map
- Site Suitability Mapping
- Land Suitability Mapping
- Watershed Intervention Map
- Forest Demarcation map
- Farm Link Road demarcation
- Demarcation of households

For powerful visualization and analytics, the map or models, HELIWARE will play major role in following ways:

When data is uploaded in Heliware, it will direct go through the Digital Ocean cloud and get stored in AWS database. Where you can change request or future redevelopment, up gradation when required on Single sign-on, authentication module.
Heliware supports unlimited Desktop client connection. Desktop GIS applications with the capability to consume WMS/ WFS services should be able to connect and use data from the server.

Heliware supports database check in – check out / two-way replication functionalities hence maintaining the parent child relationship of Master Database.

Heliware is the complete suite to do server-side geo-processing tasks.

Main features for Heliware catalog are:

- Capability to serve and consume REST, SOAP & OGC Complied web services.
- support for OGC services such as WMS WFS, WCS, WFS-T, KML, CSV etc.,
- various encodings such as KML, RSS, JSON, ebXML, vector or raster map and models datasets.

- Geo-processing features are: Visualize you 2D, 3D map or model with Zoom in, Zoom Out, Fit to Layer, Scale, zoom by rectangle, previous view, next view, draw polyline/polygon, flood stimulation etc.

For accessing the Heliware portal, having facility of user registration, login and maintain the multiple projects together.

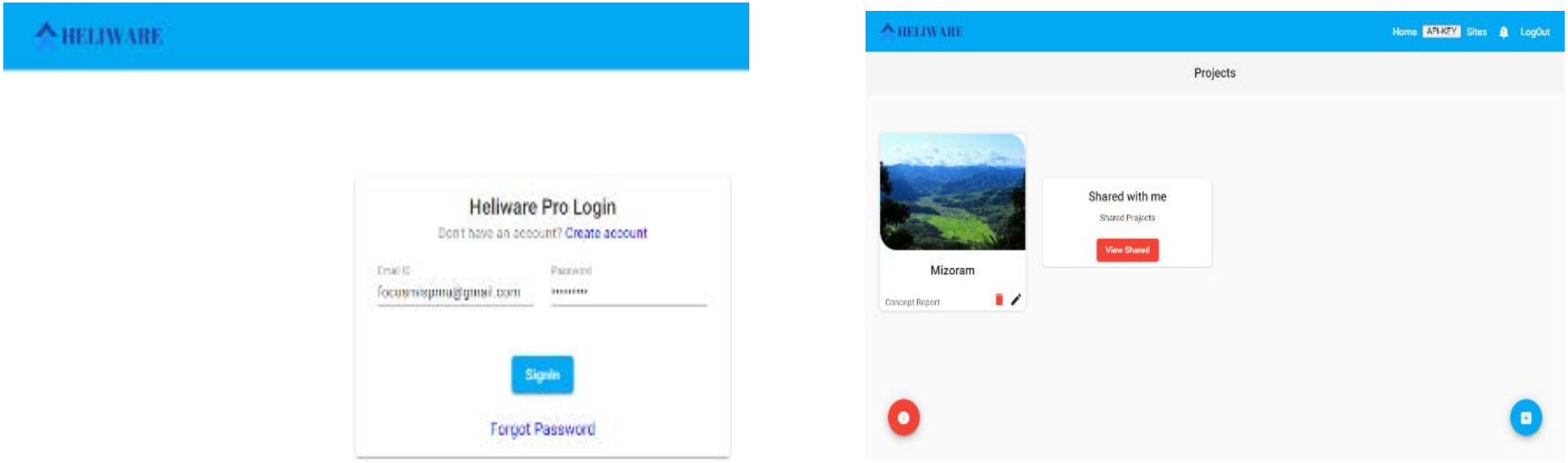


Fig. 31 login portal and project dashboard

- Heliware having many analytics feature Measurement of length, Angle and Area; Contour & Slope Map Creation; Cross-Section & Volume Analysis; Annotation etc within the separate layers.

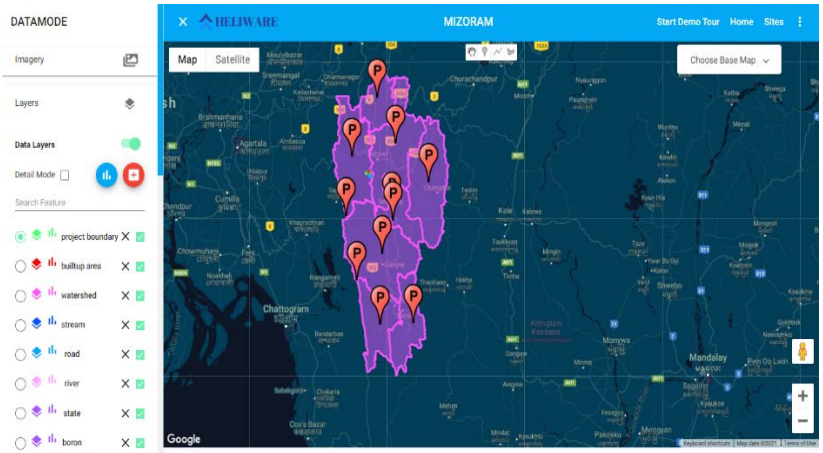


Fig 32 (a): visualization and digitization the features attributes with layer by layer in Heli-GIS

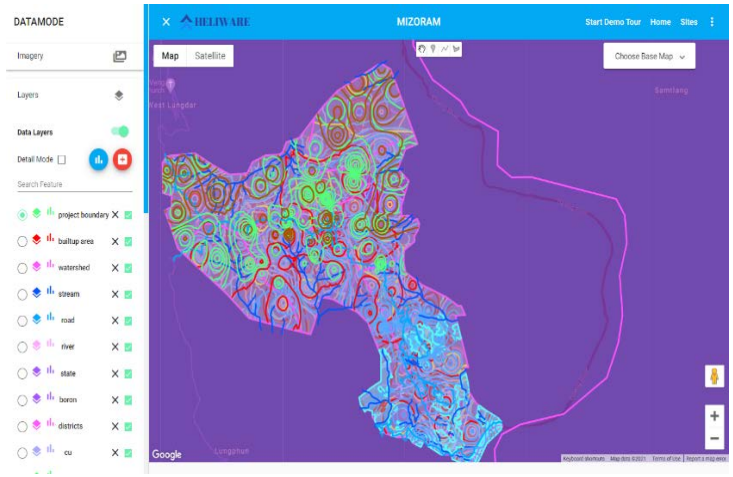


Fig 32 (b): slopes and contours layer and also minerals layers are visualized

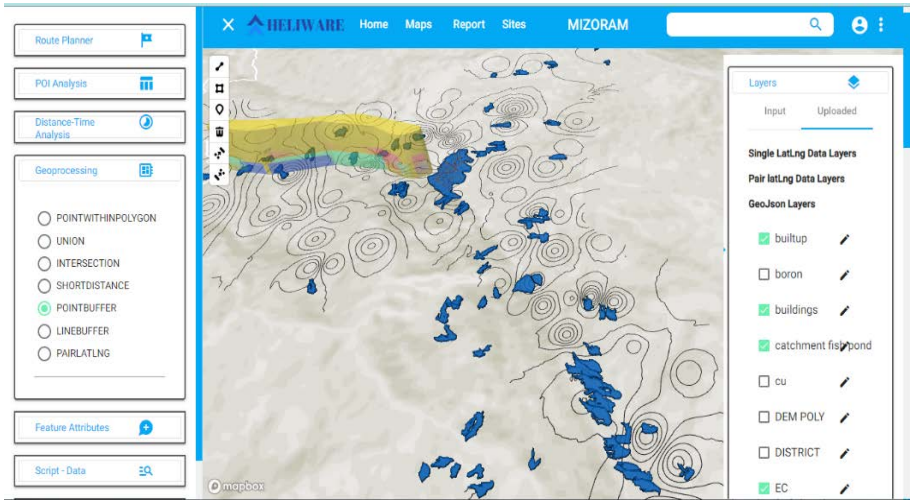


Fig 32 (c): Mizoram data in Heli-AI with all different layers

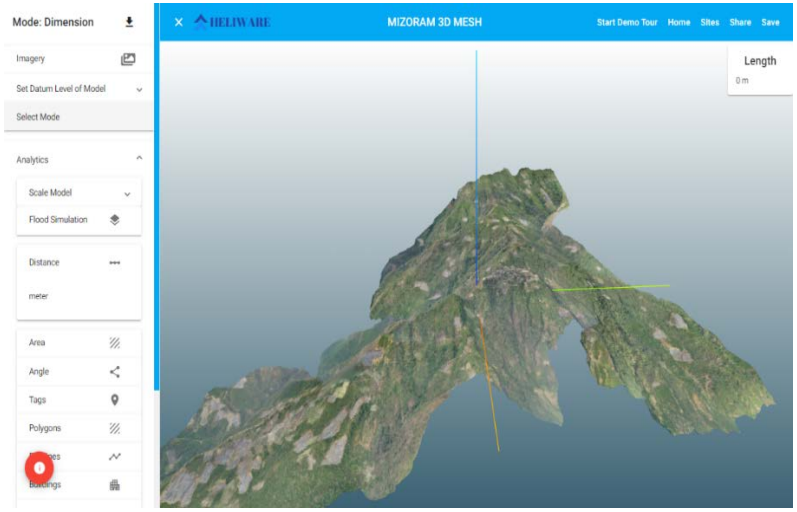


Fig 33 .3D model of project area

- Heli AI also allows you to filter the data and query building with each different layers with following features:
  1. Geo-processing tools

2. POI analysis
3. Data scripting
4. Time distance analysis with isochrones.
5. Data unification.

- Users also Can share in private and public ways and download it.

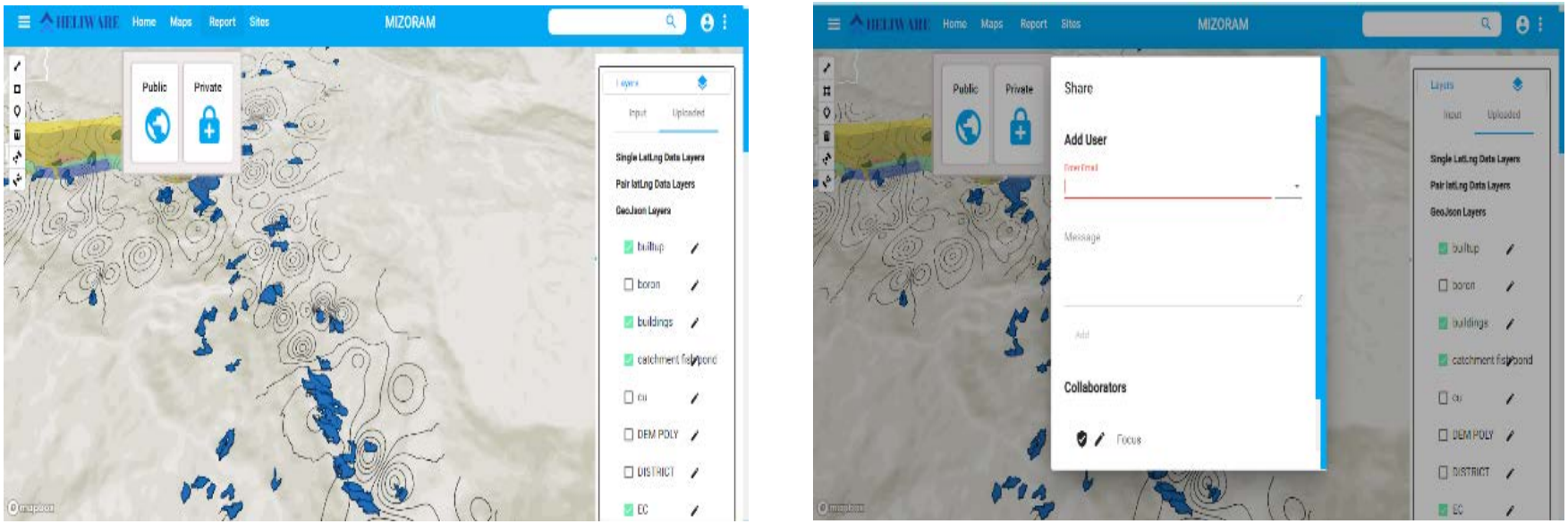
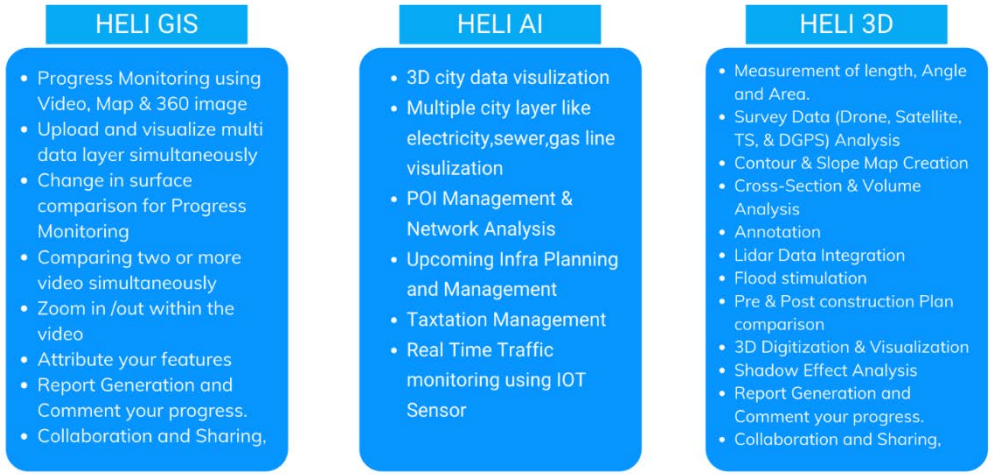


Fig 34. share & collaboration and download your data.

HELIWARE FEATURES DASHBOARD

Fig. 35. Big picture of Heliware portal for climate Change Studies



- **Heli GIS:** A light and efficient cloud-based data storage, visualization and analytics platform. With no software or hardware requisite, generate user required output data with ease on the go. Where user can do separate analysis or multiple analysis on same time. User can view multiple layers at time. All basic facilities are available in Heli GIS tier
- **HELI 3D:** FOCUS can use 3D to see your data in its true perspective, to make better decisions, and to communicate your ideas more effectively and efficiently. HELI 3D leads the way in 3D GIS. Heli 3D is a robust, scalable and secure platform for 3D geospatial data. The combination of cloud computing and Artificial Intelligence in 3D view enables mapping, surveying and inspection. Heli 3D enables the construction of detailed 3D site models and also providers a slew of tools to interact with the model.
- **HELI AI:** Issues like housing availability, sustainability goals, and economic changes are compelling cities to better plan for the future. Heli AI enables planners and design professionals to collaborate across teams with a web-based 3D application that supports scenario planning and impact assessment. Heli AI enables the digital transformation of city and regional planning to encourage collaboration with community stakeholders and help all groups work toward a more sustainable future. Being able to rapidly visualize and analyze projects can help urban planners to be more proactive and less reactive in the planning process. Our solutions make it simple to collaborate on projects for internal agencies, consultancies and public stakeholders - increasing planning productivity and improving community engagement.

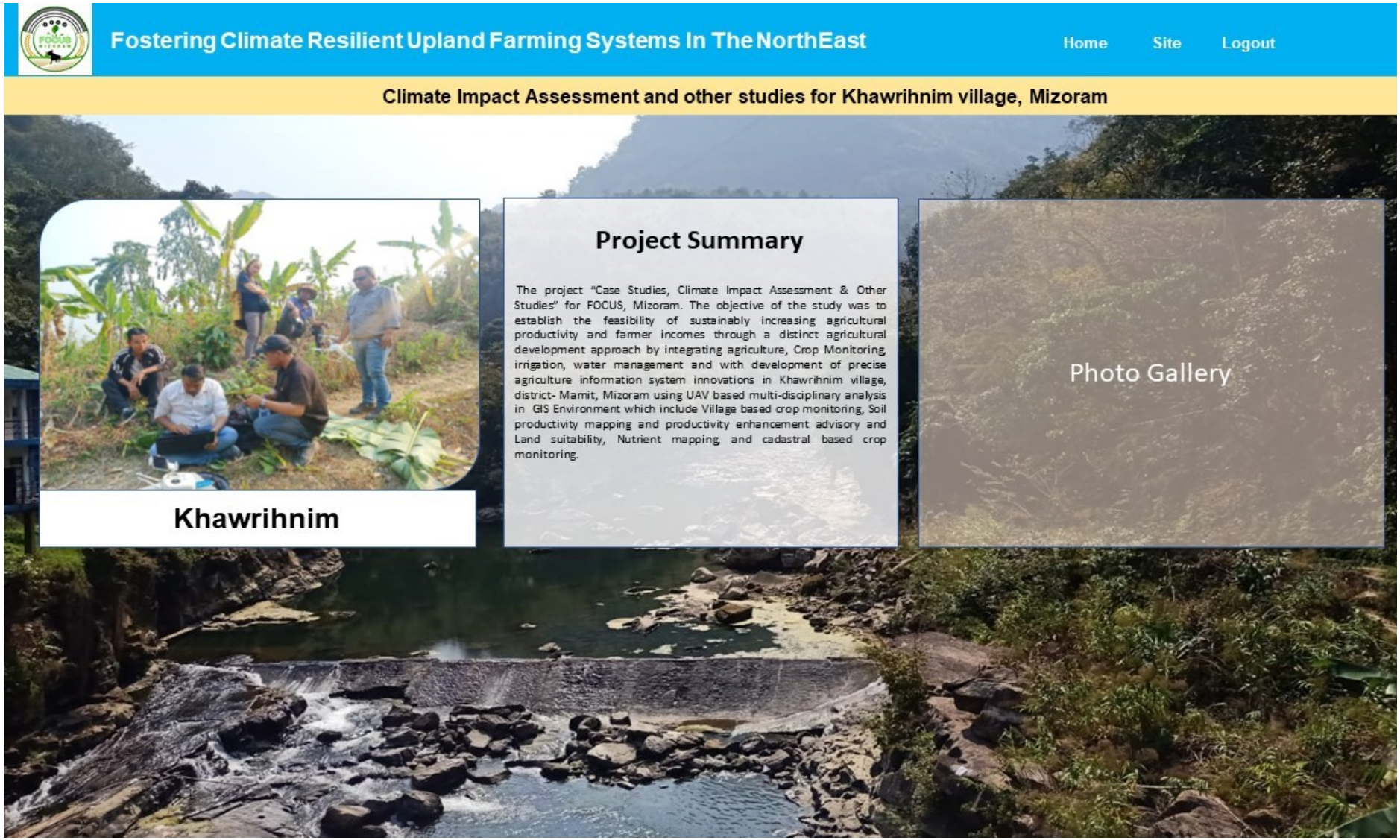


Fig 36. Dashboard home page

Recommendations

Fertilizer Advisory

Intensive agriculture, while increasing food production, has caused second generation problems in respect of nutrient imbalance including greater mining of soil nutrients to the extent of 10 million tons every year depleting soil fertility, emerging deficiencies of secondary and micronutrients, decline of water table and its quality of water, decreasing organic carbon content, and overall deterioration in soil health. Indian soils not only show deficiency of primary nutrients (Nitrogen, Phosphorous and Potassium) but also of secondary nutrients (Sulphur, Calcium and Magnesium) and micro nutrients (Boron, Zinc, Copper and Iron etc.) in most parts of the country. Besides the three primary nutrients (N, P, K), deficiency of Sulphur and micro nutrients like Zinc and Boron in many Areas and of Iron, Manganese and Molybdenum in some States, has become a limiting factor in increasing food productivity

The declining crop production due to repeated cultivation on the same plot of available flat land and terraces in Mizoram is attributed to deficiency of major plant nutrients like Nitrogen, Phosphorus and Potash, and also of one or more micronutrients viz Calcium, Magnesium, Sulphur, Iron, Manganese, Boron, Zinc, Copper, Molybdenum, Chlorine and Selenium in the soils. Heavy rainfall area with hilly terrain like Mizoram also naturally lack Calcium and Magnesium as a result of leaching, and the soils in most part of the state are acidic where beneficial bacteria in the soils became deactivated to supply nutrients to the plant.

The acid soils occur primarily in high rainfall, hilly/mountainous and coastal regions. The soils are under different land uses for growing of food crops, horticulture & plantation crops and forests. The highly leached soils are generally poor in fertility and water holding capacity. A substantial area with pH value less than 5.5 is more problematic with severe deficiencies of phosphorus, calcium, magnesium and molybdenum and toxicities of aluminium and iron. The average productivity of one tonne/ha of the soils is very low.

Following recommendations have been made on the basis of analysis of 101 soil samples for different soil parameters:

- Promote effective and environmentally sound management of plant nutrients.
- Addition of lime neutralizes soil acidity, increases microbial activity & nutrient availability and improves the physical condition of soil.

Use of organic manures and Mycorrhizal Biome Development:

Regular application of well decomposed organic matter in acid soils is essential to prevent sudden fluctuation of soil pH as it improves the buffer capacity of soils. Moreover, it increases the availability of P and reduces the toxicity of Fe and Al in acid soils. Fresh mulches (mostly

weed biomass) of Ambrossia, Lantana etc. also reduces the adverse effect of soil acidity substantially. Mycorrhizal fungi are critical members of the plant microbiome, forming a symbiosis with the roots of most plants on Earth. Most plant species partner with either arbuscular or ectomycorrhizal fungi, and these symbioses are thought to represent plant adaptations to fast and slow soil nutrient cycling rates. Thus, arbuscular and ectomycorrhizal plant species traits complement and reinforce these fungal strategies, resulting in nutrient acquisitive vs. conservative plant trait profiles. Mycorrhizal plants differ systematically in nitrogen and phosphorus economic traits. Differences are maximum in temperate latitudes, where ectomycorrhizal plant species are more nitrogen use- and phosphorus use-conservative than arbuscular mycorrhizal species. This difference is reflected in both aboveground and belowground plant traits and is robust to controlling for evolutionary history, nitrogen fixation ability, deciduousness, latitude, and species climate niche. Furthermore, mycorrhizal effects are large and frequently similar to or greater in magnitude than the influence of plant nitrogen fixation ability or deciduous vs. evergreen leaf habit. Ectomycorrhizal plants are also more nitrogen conservative than arbuscular plants in boreal and tropical ecosystems, although differences in phosphorus use are less apparent outside temperate latitudes. Our findings bolster current theories of ecosystems rooted in mycorrhizal ecology and support the hypothesis that plant mycorrhizal association is linked to the evolution of plant nutrient economic strategies.

Nutrient Management:

Integration of organic and inorganic sources of nutrients along with lime. Application of organic manures in combination with inorganic fertilizers and lime proves to be an excellent package for improving productivity and health of acid soils. Application of FYM @ 5t/ha along with lime @ 10% of lime requirement and inorganic fertilizers @ 50% of recommended dose has consistently increased soybean productivity by 60%, groundnut by 70% and maize by 33% over recommended dose of fertilizers.

Phosphorous deficiency is more conspicuous in the acid soils of North Eastern States. The problem of P deficiency in the acid soil regions has to be tackled largely through the application of adequate amount of suitable type of P fertilizer and by adoption of proper management practices. In most of the acid soils, sizable amount of the applied water-soluble P (eg. SSP, DAP etc) gets fixed and becomes unavailable to plants. Without adequate P, root growth is restricted particularly in the presence of high concentration of soluble Al and Mn. Superiority of rock phosphate or mixture of rock phosphate and super phosphate in suitable Lime sludge @ 40% Agril. Lime @ 40% LR proportion (3:1 or 1:1) depending on the pH of the soil, over superphosphate alone has been established. In unlimed soil, use of rock phosphate would reduce the expenditure on P fertilization because of its residual effect on subsequent crops. Rock phosphate can be used to its best advantage by application to a legume in rabi season and the residual effect being utilized in the following kharif upland crops. Application of indigenous rock phosphate as a source of P in long duration crops (eg. horticultural crops) hold promise

Crop Scheduling

Adopting crop rotation to maintain soil & crop health. Crop rotation prevents soil depletion, maintain soil fertility, reduce soil erosion, control insect-pests, disease & weeds and also decrease the need for inorganic supplements.

Selection of suitable crops and varieties

One of the main points of consideration while choosing crops has to be the local needs and preferences besides their agricultural suitability therein. Traditionally, farmers of acid soil regions have been growing rice irrespective of the type of land (Upland, Medium land & low land). Rice has certain degree of tolerance to soil acidity. On the other hand, cultivation of highly sensitive (towards soil acidity) field crops such as soybean, French bean, pigeon pea etc. should be tuned accurately to liming and/or other ameliorative measures. The horticultural crops are seen to have tolerance or affinity to specific soil pH and according to soil reaction these are classified into following groups:
i) Slightly tolerant to acid soils **ii)** Moderately tolerant to acid soils **iii)** Highly tolerant to acid soils

Livestock based farming system and multiple use of manure for field application & biogas production. Biogas slurry excellent source of organic manure. Adoption of integrated farming system approach (complementarity of crop-animal-fish-birds' multipurpose trees-horticulture) for household food security and efficient resource utilization.

Agro-forestry intervention with use of multipurpose indigenous species and hedge row species for stabilization of hilly slopes along with productivity augmentation using the Process Developed by Japanese Botanist Akira Miyawaki, commonly Referred to as the Miyawaki Method.
The Miyawaki method of reconstitution of "indigenous forests by indigenous trees" produces a rich, dense and efficient protective pioneer forest in 20 to 30 years, where natural succession would need 200 years in temperate Japan and 300 to 500 years in the tropics. Success requires compliance with the following phases:
Rigorous initial site survey and research of potential natural vegetation. Identification and collecting of a large number of various native seeds, locally or nearby and in a comparable geoclimatic context. Germination in a nursery (which requires a technique for some species, for example, those that germinate only after passing through the digestive tract of a certain animal, or that need a particular symbiotic fungus, or a cold induced dorming phase, etc.).
Preparation of the substrate if it is very degraded (addition of organic matter/mulch (for example with 3–4 kg of rice straw per square metre, to replace the protection afforded by surface humus and leaf litter) and (in areas with heavy or torrential rainfall) planting mounds for tap-root species that require a well-drained soil surface. Hill slopes can be planted with more ubiquitous surface roots species (cedar, Japanese cypress, pine, etc.)

Plantation respecting biodiversity inspired by the model of the natural forest. Miyawaki implements and recommends unusually dense plantation of very young seedlings (but with an already mature root system : with symbiotic bacteria and fungi present), for example 30 cm oaks from acorns, raised in a nursery over two years. Density aims at stirring competition between species and the onset of phytosociological relations close to what would happen in nature (3 to 5 plants per square metre in the temperate zone, up to 5 or even 10 seedlings per square metre in Borneo);
Plantations randomly distributed in space in the way plants are distributed in a clearing or at the edge of the natural forest, not in rows but staggered.
The results show that this method, if properly applied, quickly produces a multi-layered forest and according to him, a soil with a microbial and acari composition quickly approaching that of a normal primary forest. Miyawaki method has gained popularity around the world and is being used by 100 plus countries for rapid forest regeneration and combating soil erosion. Bamboo, being an indigenous crop, is an ideal candidate to be focussed on keeping in mind the commercial value as well as benefits provided state and central governments in their Respective Bamboo Missions.

Pairing of Complementary plants and Companion Planting

The Use of Agronomists may be Deployed to Come Up with a comprehensive plan for Area wise pairing of Companion Plants for creation of a symbiotic Root Ecosystem Increasing the Resilience of plants to Harsh Weather Changes,Climate Change and for reduction of need for fertilizers and Pesticides.

Cadastral Based Crop Monitoring

The Real Estate Cadastre (REC) is the core of land management systems, although it is understood and managed in a different way, adapted to state and national laws. In India, in recent years, there is a trend to harmonize the old-fashioned hard copy cadastral maps with other available information layers and to focus cadastral databases on building a 2D Cadastre. As per the jhum land allotment policy of Mizoram administration / land revenue department and village council authority are having systematic process of shifting cultivation. A shifting cultivator is allotted for a jhum field through a lottery system by the village council. The area to be cultivated is decided by the cultivator on the basis of size and working capacity of his family. The forested fallow is slashed and cleared from December to January. The burning is done in March to April. Rice is sown mostly from the middle of April to the middle of May. Weeding is done twice or thrice from July to September, and rice is harvested from the end of October until the beginning of November. After the harvest, the land is left fallow and vegetative regeneration is allowed on it until the land becomes reusable. So, theta's field-based team has contacted various levels of government administration as well as the local village community office, there is no cadastral map available without which the overlay process cannot take place, and was mutually agreed by focus officials in the initial meeting (04.03.2021) at their office. However, Theta's

office-based team will put efforts to identify such boundaries if depicted on aerial imagery and overlay the village boundary in the dashboard. Therefore, we recommend that FOCUS get cadastral mapping done for areas for which map is not available.

Strategy for Sustainable Development/Alternatives of Jhum Cultivation Areas:

Sustainable agriculture in respect of Mizoram region should entail development of managements systems that ensure adequate supply of food, fibre and fuel to the growing population. These systems must simultaneously ensure improving living standard of people by efficient utilization of all-natural resources including land and water and external inputs in a practical and profitable manner while enhancing the environmental safety.

There is a need to support the jhumia families with some secondary employment opportunities, such that they can support their livelihood needs throughout the year. The same in turn will be a great stride towards curbing the menace of ever shortening of fallow period, and thus conserving forest and environment. Large scale government support and initial investment to integrate allied employed opportunities e.g., scientific bee keeping, mushroom cultivation and commercial poultry farming may be of immense help. Promotion of bamboo and other abundantly available local resources-based handicrafts may be a viable option for the same. Apart from utilizing to the highest extent alternate land use options including agroforestry and non-traditional land use practices, dedicated and structured educational drives, demonstrations and training efforts by the grassroots level organizations to explore allied and non-farm employment opportunities will add to the sustainability of jhum based livelihood and at the same time help in restoring the length of fallow, forest and environment. To increase income of the Jhumia families formation of FPOs can be a long term and sustainable solution.(Please refer to the section on Strategies for Doubling Farmer Income)

There is, therefore, an urgent need to develop sustainable agricultural strategy for hill areas of Mizoram region to conserve soil, water and ecology while carrying out various agricultural practices. Various scientific studies and approaches suggest that mixed land use systems are better in the hilly areas, from the conservation as well as production point of view. Further, the system should be so designed so as to meet the various needs effective land and water management techniques i.e., watershed management programme integrating soil conservation measures, land development, agriculture, plantation crops, horticulture, animal husbandry, fishery and forestry should be considered as vital and most important. These alternatives are discussed below.

Agricultural Land Use System

The agronomic crops can be adopted on hill slopes up to 50 % gradient where soil depth is greater than 1.0 m. Contour bunding at 0.5 to 1.0 m vertical interval draining into a common grassed waterway is an essential requirement. The criteria for selection of crops should be based on the priority of crops that are already grown in the area, crops which have market potential such as spices (Chilli, Ginger, turmeric)

and introduction of rabi crops such as mustard potato, pea etc. in the irrigated area. Rice crop should be preferred in lower terraces. In general, ridge should be kept under fuel-fodder-timber trees, which can be planted, based on the requirement of farmers. On steep slopes about 30 % of land is to be occupied under bunds and terrace risers. These areas have a great potential for taking fodder crops.

Horticultural and Plantation Crops Land Use System

Slope of land for horticultural and plantation crops use should preferably be less than 100 %. Soil depth must be minimum 1.0 m. Contour bunds at 2-meter vertical interval, half-moon or crescent shape circle should be made at the location of planting, grassed waterways and making of few bench terraces at the lower slope towards foothills for growing vegetables and pineapple are essential conservation measures. The agro-climatic condition of Khawrihnim is ideal for cultivation of plantation crops. papaya as a plantation crop was introduced in the region very early while other plantation crops such as Citrus, and Orange etc. were introduced initially with the idea of providing alternative method of livelihood for the farmers doing shifting cultivation.

Agri–Horti–Silvipastoral Land Use System

This system comprises land use at the foothills with agricultural crops, horticulture in the mid portion of the hill slope and silvipastoral land use towards the top of the hill. Land up to 100 % slope having soil depth greater than 1.0 m can be used for Agri-horti-silvi-pastoral system. SGT, Contour bunds, bench terraces, half-moon terraces, grassed waterways and stilling basins are the conservation measures required for the treatment of land. For betterment of Agri Horti silvipastoral land use System dividing watershed into three tier system viz., upper area under pasture and silviculture for rearing livestock (goats and pigs), middle area under horticulture including orange guava and pineapple and remaining lower area under agriculture for cultivation of cereals, pulses, vegetables, spices, fodder, etc.

Multi-Storey Cropping Land Use System

This is highly productive, sustainable and very practicable system. To increase the cropping intensity multi-storey crop combination consisting of crop of varying canopy orientation and rooting have also been developed which entails differential harvesting of solar energy and recycling of nutrients of variable depth based on the principle of canopy dimension and rooting pattern. One crop combination is coconut + black pepper + pineapple.

Livestock-based Land Use System

For livestock-based land use system, the land up to 100 % slope with minimum 0.5 m soil depth can be utilized for livestock farming. Contour bunds, trenches and grassed waterways are minimum requirement of land treatment. Crops and cropping pattern of such land uses will differ depending on the type of enterprise. The fodder production system has to ensure stability of fertility status of soil, availing

the opportunity of moisture supply towards maximum fodder production for larger period during the year and conservation of fodder for lean season.

A land use model for resource conservation in sloping land

A land use model (0.53 ha, 30-40% slope) involving natural forest, fodder crops, leguminous cover crops, intercropping of maize + legume, residue management, conservation tillage, micro rain water harvesting structure (5 x 4 x 1.5 m3) etc. were implemented for climate resilient agriculture in hills.

Integrated Approach for Improvement of Jhum Cultivation Areas

The wide variations in cropping and yield patterns under jhum practiced by over a hundred tribes under diverse ecological situations should be continued, where transfer of technology from one tribe/area to another alone could improve the jhum, valley land and home garden ecosystems. For example, emphasis on potatoes at higher elevations compared to rice at lower elevations has led to a manifold increase in economic yield despite low fertility of the strong acid soils at higher elevations.

- Jhum cycle should be a minimum of ten years (this cycle length was found critical for sustainability when jhum was evaluated using money, energy, soil fertility biomass productivity, biodiversity and water quality as currencies) by greater emphasis on other land use system such as the traditional valley cultivation or home gardens.
- Where the jhum cycle length cannot be increased beyond the five-year period that is a great concern in the region, re-design and strengthen the agroforestry system incorporating ecological insights on tree architecture (e.g. the canopy form of trees should be compatible with crop species at ground level so as to permit sufficient light penetration and provide fast recycling of nutrients through fast leaf turnover rates. Local perceptions are extremely important in tree selection for introduction into the cropping and fallow phases of jhum.
- Improvement in nitrogen economy of jhum at the cropping and fallow phases by introducing nitrogen-fixing legumes and non-legumes.
- Making use of some of the important bamboo species, highly valued by tribes, which can concentrate and conserve important nutrient elements such as N, P, and K. They could also be used as wind breaks to check wind-blown loss of ash and nutrient losses in water.
- Speeding up the fallow regeneration after jhum by introducing fast growing native shrubs and trees.
- Condensing the time-span of forest succession and acceleration restoration of degraded land based on an understanding of tree growth strategies and architecture, by adjusting the species mix in time and space.

Strategies for Doubling Farmer Income via formation of Farmer Producer Organizations

Growth in agriculture and allied sectors positively impacts the well-being of farmers in particular and the country at large. Agriculture in India is dominated by small and marginal farmers, who constitute about 85 percent, with around 40 percent share in the total marketable surplus. To make agriculture more sustainable and to improve the livelihood of farmers adequate attention needs to be given to raise agricultural income. For **doubling the farmer income by 2022**, a three-pronged strategy focusing on development initiatives, technology and policy reforms is essential. Achieving the goal of doubling farmer income will reduce the disparity between farm and non-farm income, promote inclusive growth and attract youth towards farming profession. **Collectivization of farmers into FPO** is one of the best solutions for increasing the farmers income.

Small holders had a mean farm size of 0.5 hectare and that too in 5 to 10 small plots. The small holding size will not produce enough food to support the family. Such small holders constitute the vast majority of farmers in the developing countries including India. Because they are scattered individuals, they have little or no bargaining power or political influence in securing loans from scheduled banks (fewer than 4% of small holders have agricultural credit cards) and very few smallholder farmers carry crop insurance against natural calamities, etc.

In addition, smallholders are especially vulnerable to climate change-aggravated weather events, like untimely rains (especially at harvest times), severe droughts and floods, hailstorms and pest infestations, any of which can wipe out their crops. They also continue to suffer from market uncertainties as most agricultural policies (and institutional support) tend to favour large farmers and agricultural or food corporations

Collectivization of Farmers into FPO enable their members to access financial and other inputs and services, including appropriate technologies for farming. The FPOs also organize collection, processing, storage and marketing of their members' produce in high-value markets at an optimal price. These actions by the FPOs have thus reduced transaction costs and allowed the FPCs to enter into a partnership with private and public sector companies for purposes of supplying farm produce on more equal terms.

The details complete details of FPOs in given in **Annexure-III**

Concept Note on –Sustainable Landscape Management and Livelihood Promotion in Mizoram

Background

The farmers in the North Eastern states of India especially Mizoram have been practicing Jhum or shifting cultivation since hundreds of years. It is an integral part of the socio-cultural life of Mizos and the main source of income of the marginal farmers (Jhumias). At present, net area sown in Mizoram is only 5.5%, of which, 16.9% area is devoted to shifting cultivation and about 54% people, living in the rural areas, are practicing it. Though Jhum cultivation has provided the rural communities with food, fibre and energy, the high frequency and intensity of the practice has led to a decline in agricultural productivity in Jhum areas over the years. It has also steered land and soil degradation, biodiversity loss, climate change and natural calamities like floods. A large number of Jhumias still practice shifting cultivation and grow subsistence cereals because of socio-cultural linkages even after being faced with numerous hurdles like terrain inaccessibility, soil infertility, steep slopes, and distance to Jhum plots etc. Reduced duration of Jhum cycle due to population pressure has also resulted in yield reduction (by nearly 50 %) as the land does not get sufficient time to recover.

Approach

The need of the hour is to have an alternative method of agriculture, which is climate smart, and will also provide the farmers with a means of sustainable livelihoods. Replacing subsistence crops with economically viable crops and converting shifting cultivation-land use systems into permanent plots can make agriculture profitable and support livelihoods, provided they are sustainable in the given socio-ecological systems. A two-pronged strategy based on value chain and climate resilience would prove efficient in the long run.

Proposed Interventions

1. Value chain approach

- **Extending technical assistance for better cultivation practices** Focus on the ODOP crops (Mizo chilli, Passion fruit, Turmeric, Pineapple, Mango and Ginger) and the most important cash crops of Mizoram (e.g. Maize, Soybean, Mustard, Potato, Cabbage, Brinjal. Banana, Mango etc.) to bolster financial gains from agriculture

➢ **Aggregation support for farm operations, value addition and marketing**

In traditional Jhum cultivation fallow vegetation is manually slashed, left to dry, and cleared from the field by burning before crop cultivation. With the exception of labour, slash-and burn farmers use few or no external inputs. There are several problems associated with slash and burn like rise in soil temperature, adverse effects on soil microbial biomass and organic matter, reduced cation exchange capacity (CEC) and increased risk of nutrient leaching etc. To combat these ill effects of slash and burn, custom hiring centres can be engaged, and mechanized land clearing can be carried out as a free service to Jhumias.
As Jhumias shift to more and more market oriented, commercial, and remunerative crops, collectivization and value addition can improve their bargaining power. To overcome the major challenges of the existing marketing system like involvement of intermediaries, creating market linkages through private partnerships, access to market information etc will be undertaken for them to realise the best value for their produce. Steps will be initiated for value addition of products, ensuring opportunities for large scale involvement of the rural youth and women. Under-utilised crops like medicinal plants from shifting cultivation areas have potential for being developed and promoted as health foods.

2. Climate smart approach

➢ **Technology enabled advisories for land use planning and managing Jhum** cultivation Reliable data on temporal variation and extent of Jhum in terms of area, population and geographical distribution is not readily available and this issue needs to be addressed for the effective implementation of any project. UAV based approach can be effectively harnessed to determine the area affected and temporal changes in area under Jhum. Land use planning exercise for each village can determine/record present land use as well as future/planned land use changes in addition to facilitating identification of land uses that need to be conserved and managed for ensuring continuity of ecosystem services.

➢ **SALT (Sloping Agriculture Land Technology)** is a low labour-and-input intensive method which involves creation of hedge rows of nitrogen fixing plants which control soil loss and surface run-off while improving soil fertility. Horticultural crops and trees are cultivated on the strips in between the hedge rows. It is a climate friendly and sustainable form of settled agriculture which provides food for the family, and marketable produce from horticultural crops for income generation.

- **Afforestation for Carbon Sequestration** Indiscriminate expansion of cash crop plantations has resulted in the drastic erosion of forest cover and depleting ecosystem services that are irreversible. The Jhum lands which are fallow will be developed into a multi-layered canopy of vegetation through large scale plantation of fast-growing timber, bamboo and other economically important species resulting in biodiversity conservation and carbon sequestration. A production unit that grows planting stock (seedlings and saplings) of forest trees and shrubs by the local community can also be envisioned.

  There is an untapped potential for voluntary carbon trading given the inherently significant organic carbon content in the soil. This can be further augmented through promotion of carbon sequestration opportunities in agriculture such as low input intensive sustainable agriculture, zero tillage, regenerative agriculture etc. Establishment of a local voluntary carbon trading market involves

  i) A verifiable baseline capturing agroecological indicators

  ii) Generation of verified carbon units (VCUs) which can direct carbon finance to the project beneficiaries through land management operations mentioned above

  iii) Validation and verification for carbon emission reduction, generation of VCUs and selection of appropriate methodologies require involvement of accredited private players using technologies like AI,IoT sensors and satellite-based mapping

  iv) On the ground activities call for collectivization of farmers to promote sustainable land management practices and aggregation of carbon credits at a landscape level (river basin/valley/watershed)

  v) Opportunities for exploring carbon transactions with large public/private sector undertakings in the state can leverage project incentives at a faster pace

Way Forward

A consultative process placing communities at the core of planning and development needs to be adopted. Prioritization of landscapes based on the extent of degradation, opportunities for intervention using horticultural crops and value addition through marketing and processing infrastructure will be required. Financing opportunities that can build on existing resources such as CAMPA funds for undertaking compensatory afforestation, assisted natural regeneration, conservation and protection of forests, infrastructure

development can reduce the burden on communities and governments for large-scale roll out of the program across the State. A robust monitoring and evaluation framework jointly developed with IFAD that establishes a baseline, identifies, and maps suitable outcomes enhancing institutional capacities of local bodies will be designed and incorporated. Land use planning and management agreements with local communities will need legitimization through existing institutional mechanisms; by way of formal MoUs with community organizations. Biodiversity registers of forest patch developed with local communities can bring together important location specific information on biodiversity resources and ecological processes affecting them leading to conservation oriented local practices. A Project Management Unit (PMU) to assist in project execution and delivery of outcomes bringing together local institutions, technology providers and markets will ensure sustainability of the interventions.

Smart Jhum Techniques and carbon sequestration

Combining Various Techniques such as Zero Waste Farming, Miyawaki Method for Accelerated development of Forest Canopy, the Above-mentioned areas can be converted in a small window of time to Green Agroforest bearing indigenous species of Fruit Bearing trees, Medicinal Plants and Bamboo's. Which would generate more than enough Revenue to cover Costs of Implementation and Maintenance of this Activity. A Forest Canopy can be generated within a period of two years and not only yield fruit but also earn the company Carbon Credits. Benchmarking and assessment of **the amount of carbon sequestration using UAVs-using drones and UAVs it is now possible to assess, quantify, and prove the amount of carbon Captured through accelerated planting Activities and the project would be eligible for Carbon Credits.**

Carbon sequestration is the process of capture (through photosynthesis) and long-term storage of atmospheric carbon dioxide. Sequestration is possible through a range of processes, including those occurring naturally in plants and soils. In recent years, carbon sequestration and reduced emissions from avoided deforestation have received more attention as methods to help reduce the buildup of greenhouse gases in the atmosphere.

Biological growth involves the process of a plant utilizing from the atmosphere. The plant draws the carbon into its cells and releases oxygen back into the atmosphere. The destruction of biological matter essentially reverses this process: Carbon is released back into the atmosphere, where carbon combines with oxygen to form CO2.

Forests and soils sequester atmospheric CO2 within their biomass or in organic matter that is stored in the ground. Ocean's store most of the world's carbon, but forests and soils store most of the carbon sequestered within land. Forestland includes the aboveground biomass, belowground biomass, dead wood, litter, and soil organic carbon.

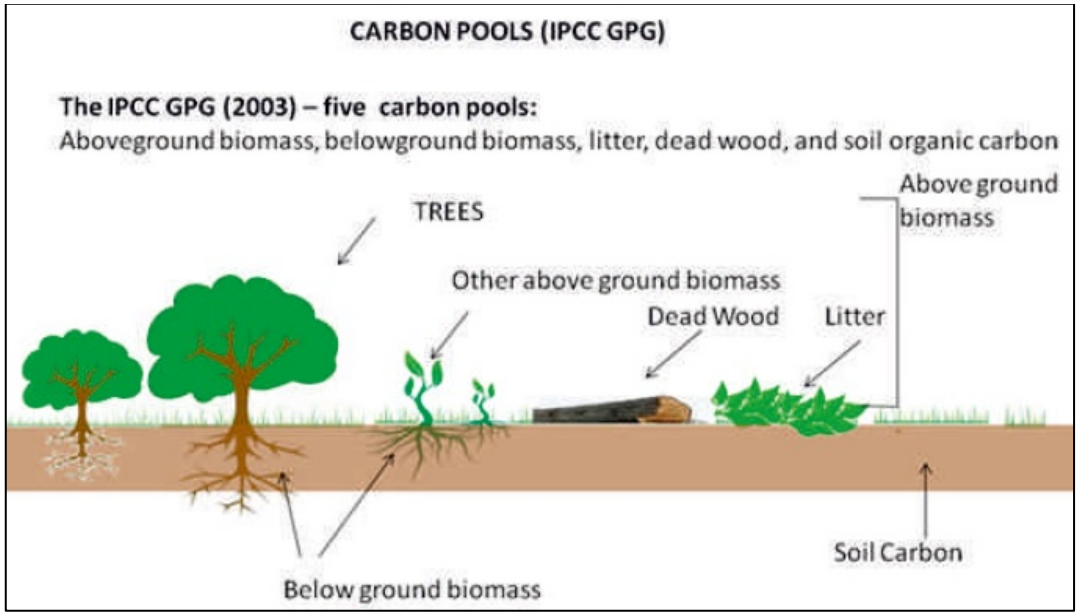


Fig. 37: Different Forest Carbon Pools

1. Carbon Sequestration in Forest:

In forests, carbon is sequestered within tree biomass. More than 50% of dry tree biomass is carbon. Biomass can be any part of a living or nonliving tree tissue, for example, the trunk, branches, leaves, or roots. In cells, carbon is stored within plants' cell walls. Plant cells, unlike animal cells, have cell walls that provide structure and support for the organism. Cell walls are made of fibers of cellulose and/or lignin. Carbon is needed to build cellulose and lignin compounds and therefore becomes sequestered within the plant tissue.

Although forests are able to sequester a lot of carbon, they also release some CO2 back into the atmosphere. CO2 is also released into the atmosphere when debris or a dead tree (or any other type of vegetation) begins to decompose. As bacteria break down the tree

biomass, the CO2 is released. Decomposition can be slowed down if the forest canopy is thick enough to prevent sunlight from reaching the forest floor. In addition to natural decomposition, another source of released CO2 is tree harvesting. How quickly the carbon is released depends on what the trees are harvested for. For example, trees cut down to make short-lived products such as paper will release carbon very quickly. However, trees used to make long-term products such as furniture or lumber will sequester the carbon for a long time and will continue to act as a carbon sink until the wood decays. Fires, as well as decomposition, can release a large amount of carbon sequestered within forests. As fires burn, trees release CO2 back into the atmosphere.

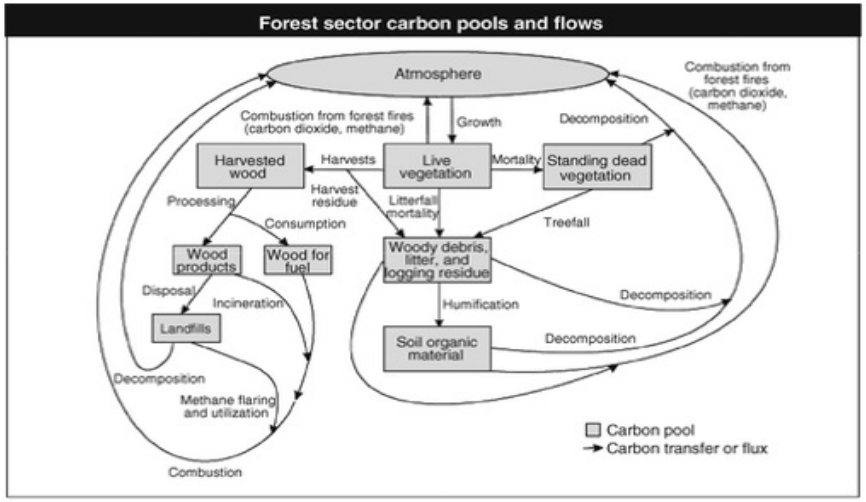


Fig. 38: Forest Carbon Sequestration Cycle

Figure 2 displays the various ways carbon can be released from forests. As Figure 1 shows, growth is the only way that CO2 is sequestered by forests. Although forests release CO2 into the atmosphere, forests are carbon sinks.

2. Carbon Sequestration in Soil:

Soil carbon sequestration is a process in which CO2 is removed from the atmosphere and stored in the soil carbon pool. This process is primarily mediated by plants through photosynthesis, with carbon stored in the form of SOC.

The sequestration of carbon in soils depends on a number of factors depending on whether it is abiotic or biotic. Abiotic soil carbon sequestration depends on clay content, mineralogy, structural stability, landscape position, soil moisture and temperature regimes. Biotic soil carbon sequestration on the other hand depends on management practices, climate and activities of soil organisms.

The carbon stock in forest soils play a large role in global carbon cycle due to the large expanse of forest ecosystems estimated at 4.1 billion hectares globally. The forest ecosystems contain more than 70% of global soil organic carbon (SOC) and forest soils are believed to hold about 43% of the carbon in the forest ecosystem to 1 m depth. However, unfortunately this high carbon content inherent in natural forest soils is easily depleted by decrease in the amount of biomass (above and below ground) returned to the soil, changes in soil moisture and temperature regimes and degree of decomposability of soil organic matter due to difference in Carbon-Nitrogen ratio and lignin content. Anthropogenic activities such as deforestation or conversion of forests to agricultural land also deplete the soil organic carbon (SOC) stock to large extent.

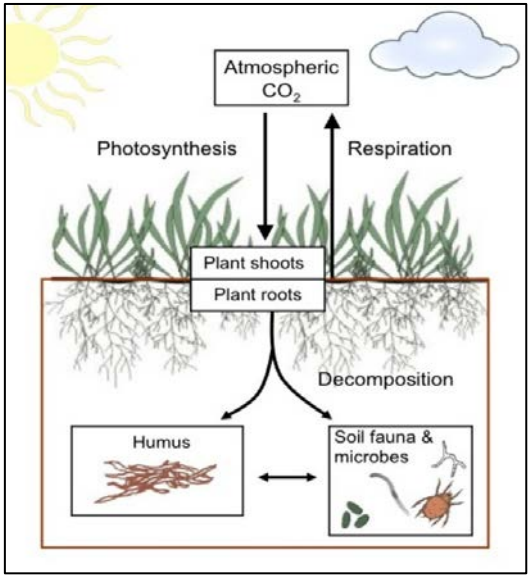


Fig. 39: Carbon Sequestration Cycle in Soil

Figure 3 given above shows the Carbon Sequestration Cycle in Soil. Carbon balance within the soil (brown box) is controlled by carbon inputs from photosynthesis and carbon losses by respiration. Decomposition of roots and root products by soil fauna and microbes produces humus, a long-lived store of SOC.

Himachal Pradesh is situated in the north-western part of the Himalayas where soil is very diverse in character depending upon altitude, vegetation cover, slope, structure and stage. The major soil group found in the state are Black Soil, Red Soil and Mountain and Hill Soils.

Black and Red soils are deficient in nutrients like phosphate, nitrogen, lime and humus. Their depth varies from 1-70 cm and may be light to dark brown in color. Mountain and Hills Soils of the area are very thin and mixed with pebbles and gravel in many regions. The texture varies from sandy to sandy loam. All this make the soil very acidic to neutral in nature and the organic matter content of these soil ranges from 1 to 5 percent. All this largely affect the amount of carbon sequestrated back in the soil. Soil organic carbon density also get influenced and vary with the amount of depth and their chemical properties.

3.Mapping Tree CD and CPA of Individual tree

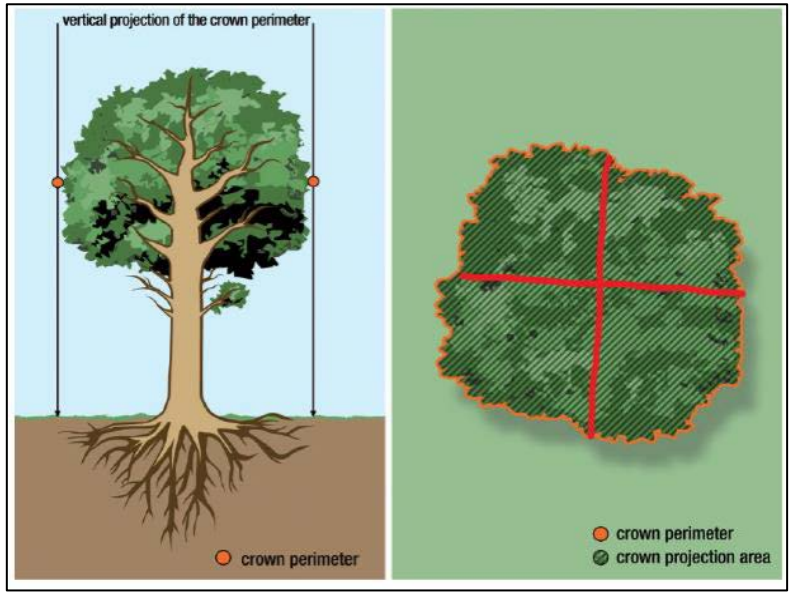


Fig. 40: Measurement of Crown Projection Area

Tree Crown Diameter (CD) and Crown Projection Area (CPA) represent the canopy cover of trees in two dimensions which measured in meter and meter square respectively. Crown of the tree represents the information of growth of tree, shadow, and stream, purify air particles, wind protection as well as biomass and carbon sequestration which affected by species, the age of the tree, resources supply, habitat, location and environment.
The crown of trees can be estimated using UAV images, some researches have proved that there is high correlation between the areas of crown of trees or crown projected area (CPA) and diameter at breast height (DBH). Therefore, CPA can be used to calculate volume or biomass of trees.
This can be mapped by Manual On-screen Digitizing of Tree Crown Area in each recorded individual tree on the ortho-mosaic image of UAV. Manual on-screen digitization of CPA was done by delineating the crown area of each individual tree. After that, the area is calculated to represent CPA and then CPA is used to generate CD using Statistical Tools in GIS software.
A unique ID number was also generated for each of the trees. This ID number of trees was applied in the manual on-screen digitizing to generate CPA, assessed the CHM and derived CD.

Extracting individual Tree Height of CHM-

Extracting individual tree height derived from CHM was done using CPA area using the Spatial Analyst Tool in ArcGIS software.
In this case, CHM was overlaid and masked by the shapefile of CPA. Furthermore, the zonal statistic was run to calculate the maximum value in the CHM, which is the highest point in the canopy. Afterwards, the CPA of the individual tree is converted into a point feature. Then, the maximum value of CHM within CPA for every individual tree was used to retrieve tree height derived from UAV CHM. The value of tree height is retrieved from the maximum number within the crown area.

Relationship between trees height and CHM-

Structure from motion (SfM) technique using basic photogrammetry and computer vision offers capabilities to retrieve three-dimensional information of trees structure using point cloud of very high spatial resolution and by assessing trees Crown height model (CHM) is a SfM product which is calculated as a relative height using DSM and DTM.

Calculation of Aboveground Biomass-

Aboveground biomass is estimated using an Allometric equation which is a mathematic equation to calculate biomass using Tree Crown Diameter derived from UAV acquired images through onscreen digitization. The biomass allometric equations have been developed with the assumption that tree dimension (tree diameter) has high correlation with biomass. In this study, Tree Crown diameter, trees height and wood density has been used in the allometric equation to calculate biomass. The allometric equation which was used to calculate biomass is based on Chave et al., (2014).

$$AGB = 0.0509 * WD * DBH^2 * H$$

Where, AGB= above ground biomass (kg/tree), WD= wood density, DBH= tree diameter (cm), and H= trees height (meter)

Calculation of carbon stock and carbon sequestration

Carbon stock was estimated using the above ground biomass (ABG) and the conversion factor (CF). Conversion factor that was used to calculate carbon stock was in the amount of 0.5 (Brown, 2002; IPCC, 2006).

$$C = ABG * CF$$

Where, C= carbon stock, ABG= above ground biomass, CF= conversion factor (0.5)

Estimating Carbon from Organic Matter in Soil and Forest Floor

To estimate carbon in forest soil and forest floor, 2 set of soil samples were collected from each sample plot. For data on forest floor, i.e., non-woody litter and humus, forest floor of each plot was first swept and material so collected was weighed and was kept for carbon analysis. Then, a pit of 30 cm X 30 cm was dug and a composite sample of soil of around 200 grams was kept for organic carbon analysis in the soil. Sample of soil and humus were got analyzed from the standard soil labs and were used for calculation.

Land Use and Land Cover Mapping using UAV Imagery

Land Use and Land Cover Mapping was also done for the study area by classifying the total area into various classes dominant in the area. This will be performed in a GIS software package using Supervised Classification method. Supervised Classification is a technique of image classification of raster images acquired through satellite or drone. In supervised classification, training samples first are first selected and classified image based on the chosen known samples. The training samples are key because they will determine which class each pixel inherits in your overall image. So, basically to run a supervised classification, it involves following 3 steps:

a) **Select training areas**- In this step, training samples for each land cover class need to create is selected.
b) **Generate signature file-** At this point, Handholding agency will take training samples for each and every class. The signature file holds all the training sample data collected up to this point.
c) **Classify-** In this step, signature file is used as input which has the training samples to classify the image and run the tool for classification using Maximum Likelihood Classifier method.

The output received from last step was Land Use and Land Cover Map of the target Area along with its area estimation details. Then this LULC Map was used as input in InVEST Carbon Model to estimate the carbon sequestration of each LULC classes of the area.

Carbon Stock Estimation using InVEST- Carbon Model

The InVEST Carbon Storage and Sequestration Model estimates the current amount of carbon stored in a landscape and values the amount of sequestered carbon over time. First it aggregates the biophysical amount of carbon stored in four carbon pools (aboveground living biomass, belowground living biomass, soil, and dead organic matter) based on land use/land cover (LULC) maps provided by users. If the user provides a future LULC map, the carbon sequestration component of the model estimates expected change in carbon stocks over time. The carbon model can also optionally perform scenario analysis according to the Reducing Emissions from Forest Degradation and Deforestation (REDD) and REDD+ frameworks.
InVEST's Carbon Storage and Sequestration Model belongs to a family of multi-service, modular design of InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) which provides an effective tool for balancing the environmental and economic goals of these diverse entities.

How it Works?

Using maps of land use and land cover types and the amount of carbon stored in carbon pools, this model estimates the net amount of carbon stored in a land parcel over time and the market value of the carbon sequestered in remaining stock.

- The model maps carbon storage densities to land use/land cover (LULC) raster which may include types such as forest, pasture, or agricultural land. The model summarizes results into raster outputs of storage, sequestration and value, as well as aggregate totals.
- For each LULC type, the model requires an estimate of the amount of carbon in at least one of the four fundamental pools described above.
- The model simply applies these estimates to the LULC map to produce a map of carbon storage in the carbon pools included.
- Outputs of the model are expressed as Mg of carbon per pixel, and if desired, the value of sequestration in currency units per pixel.

Annexure – I Soil Sample Analysis

ID	Lat	Long	Elevation	Location	PH	E.C (1:2) µS/cm	OM %	Available Phosphorous as P kg/ha	Boron as B mg/kg	Sulphur as S %	Potassium as K %	Total Nitrogen as N %	Mn (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)
1	23.6103	92.63621	851	Khawrihnim	5.24	202.00	2.78	24.63	1.16	<0.01	0.70	1.22	3.53	29.73	4.56	2.86
2	23.6075	92.63830	753	Khawrihnim	5.56	182.00	2.39	32.54	1.51	<0.01	0.70	1.22	3.19	22.08	4.90	2.31
3	23.60399	92.63696	671	Khawrihnim	4.98	169.00	2.82	31.15	1.24	<0.01	0.58	1.23	3.64	22.28	4.85	2.56
4	23.61043	92.63763	823	Khawrihnim	5.13	182.00	3.00	30.53	1.08	<0.01	0.46	1.25	3.49	27.64	4.62	2.10
5	23.62507	92.62268	1122	Khawrihnim	5.26	209.00	2.66	27.86	1.11	<0.01	0.69	1.21	3.07	23.05	4.33	2.75
6	23.62515	92.62434	1079	Khawrihnim	5.82	144.00	1.69	33.70	0.54	<0.01	0.16	0.32	5.39	24.54	2.12	1.44
7	23.62633	92.62408	1078	Khawrihnim	5.56	149.00	0.72	21.40	0.48	<0.01	0.21	0.44	6.39	22.68	3.14	0.47
8	23.62073	92.62436	1096	Khawrihnim	5.72	177.00	0.66	31.50	0.68	<0.01	0.73	0.72	7.46	27.69	1.93	0.60
9	23.622245	92.62273	1116	Khawrihnim	5.34	124.00	2.18	33.60	0.88	<0.01	0.17	0.34	6.46	20.13	5.32	0.65
10	23.60968	92.63396	980	Khawrihnim	5.45	143.00	2.06	37.10	0.97	<0.01	0.32	0.28	7.28	22.91	4.17	1.72
11	23.61465	92.63432	955	Khawrihnim	4.98	233.00	0.92	28.90	0.74	<0.01	0.24	0.77	3.20	26.85	2.57	1.32
12	23.62671	92.62755	982	Khawrihnim	4.87	165.00	1.81	24.20	1.01	<0.01	0.38	1.04	6.83	22.46	1.21	1.00
13	23.62468	92.61825	1136	Khawrihnim	4.64	191.00	2.81	32.10	1.05	<0.01	0.27	0.62	6.29	19.71	2.10	1.58

14	23.62522	92.61311	1080	Khawrihnim	5.21	130.00	2.26	29.20	1.02	<0.01	0.20	0.39	2.33	21.07	5.87	0.79
15	23.62501	92.61108	1087	Khawrihnim	4.46	161.00	2.96	26.20	0.88	<0.01	0.18	1.11	5.97	16.63	3.41	1.18
16	23.62848	92.61934	1060	Khawrihnim	5.21	233.00	3.88	34.30	0.78	<0.01	0.12	0.98	7.80	25.09	4.23	0.97
17	23.62785	92.62231	989	Khawrihnim	4.78	236.00	0.81	26.70	0.84	<0.01	0.20	0.81	4.36	24.02	2.47	1.17
18	23.62573	92.61509	1089	Khawrihnim	4.87	138.00	1.48	27.10	0.41	<0.01	0.14	1.01	5.37	23.84	4.39	1.49
19	23.63188	92.61995	962	Khawrihnim	4.62	130.00	1.52	35.30	0.56	<0.01	0.18	1.20	5.58	24.03	3.49	1.93
20	23.63044	92.6274	852	Khawrihnim	5.10	125.00	3.40	26.50	0.65	<0.01	0.23	1.14	6.56	24.29	5.96	1.44
21	23.62008	92.59998	1068	Khawrihnim	4.78	165.00	3.35	27.80	0.74	<0.01	0.41	1.18	6.36	25.34	3.24	1.33
22	23.62336	92.60831	1100	Khawrihnim	5.10	245.00	3.74	28.60	0.65	<0.01	0.16	0.85	5.10	24.40	5.25	0.89
23	23.62145	92.6071	1040	Khawrihnim	5.32	205.00	2.94	32.50	0.88	<0.01	0.32	0.98	4.49	19.53	4.20	1.75
24	23.62455	92.61515	1045	Khawrihnim	5.18	109.00	3.20	27.60	0.98	<0.01	0.24	0.74	5.10	27.55	2.58	2.05
25	23.62173	92.61973	932	Khawrihnim	5.74	132.00	2.81	28.60	1.01	<0.01	0.27	0.88	7.94	23.52	0.78	1.33
26	23.61732	92.61076	914	Khawrihnim	4.65	167.00	2.30	32.40	1.04	<0.01	0.17	1.12	5.39	27.27	3.40	0.43
27	23.61315	92.61475	726	Khawrihnim	4.87	209.00	2.50	30.40	0.86	<0.01	0.16	1.21	6.39	22.44	1.09	0.51
28	23.61338	92.6162	688	Khawrihnim	5.34	143.00	2.21	34.30	0.74	<0.01	0.18	1.21	7.15	21.15	2.46	1.87
29	23.61862	92.63424	1132	Khawrihnim	4.32	177.00	2.76	31.70	0.41	<0.01	0.13	1.14	5.88	25.49	4.01	1.61

30	23.61846	92.63219	1020	Khawrihnim	4.75	237.00	2.52	32.70	0.45	<0.01	0.23	0.87	7.40	25.15	4.44	1.64
31	23.61767	92.63165	1043	Khawrihnim	4.57	175.00	2.73	26.50	0.87	<0.01	0.20	0.74	7.07	25.14	3.35	0.56
32	23.61563	92.63071	1050	Khawrihnim	5.74	146.00	1.66	34.70	0.75	<0.01	0.31	1.12	6.77	26.45	2.03	1.61
33	23.63476	92.63251	671	Khawrihnim	5.44	150.20	3.28	26.80	0.87	<0.01	0.28	0.48	7.60	22.30	4.30	1.42
34	23.6326	92.62771	839	Khawrihnim	5.24	222.00	1.94	31.20	0.65	<0.01	0.23	1.03	7.20	29.85	2.37	1.79
35	23.63372	92.60017	1155	Khawrihnim	5.65	161.00	0.76	33.70	0.45	<0.01	0.18	1.21	6.77	20.74	3.23	0.86
36	23.62592566	92.61608975	1090	Khawrihnim	4.68	195.00	2.40	28.60	0.82	<0.01	0.21	1.18	8.03	24.85	1.10	0.65
37	23.59935	92.63948	564	Khawrihnim	4.71	161.90	1.84	33.20	0.68	<0.01	0.23	0.67	8.05	24.54	4.78	1.86
38	23.60074711	92.63966116	585	Khawrihnim	5.32	157.00	1.38	27.60	0.54	<0.01	0.21	0.82	7.88	22.37	2.11	1.64
39	23.60164	92.6384	618	Khawrihnim	4.85	232.00	2.69	26.70	1.04	<0.01	0.12	0.56	5.28	23.13	2.19	0.86
40	23.60257	92.63779	645	Khawrihnim	5.87	139.00	1.55	24.30	0.98	<0.01	0.30	0.83	4.77	20.93	2.75	1.87
41	23.60397	92.63694	683	Khawrihnim	4.96	140.00	2.60	28.40	1.14	<0.01	0.21	0.72	6.12	21.93	2.65	1.01
42	23.60557	92.63622	721	Khawrihnim	5.41	166.00	1.72	27.30	0.74	<0.01	0.15	0.54	7.43	21.63	2.73	1.57
43	23.6073	92.63615	770	Khawrihnim	5.67	226.00	2.00	26.30	0.87	<0.01	0.19	0.65	6.61	25.13	3.71	1.62
44	23.61044	92.63762	818	Khawrihnim	5.86	120.00	2.04	24.80	0.62	<0.01	0.14	1.02	7.02	25.01	4.14	1.97
45	23.61033	92.63622	843	Khawrihnim	5.41	183.00	1.28	27.60	0.78	<0.01	0.16	1.29	6.22	21.62	5.49	2.33

46	23.61002897	92.63943245	734	Khawrihnim	6.35	228.00	0.98	26.80	0.45	<0.01	0.24	1.13	8.40	23.26	4.91	1.26
47	23.60818	92.64207	677	Khawrihnim	4.96	184.00	2.95	27.00	1.15	<0.01	0.20	0.84	8.65	23.05	4.58	1.80
48	23.6064	92.64108	629	Khawrihnim	4.64	154.00	1.93	30.10	0.87	<0.01	0.16	0.59	7.45	22.04	1.62	1.43
49	23.60115	92.64417	468	Khawrihnim	4.87	148.00	1.93	26.40	0.74	<0.01	0.31	0.67	5.31	21.47	3.58	2.23
50	23.59879	92.64401	412	Khawrihnim	5.62	136.00	1.08	23.30	0.66	<0.01	0.29	0.82	6.58	20.29	2.63	0.88
51	23.60026	92.64199	485	Khawrihnim	5.71	229.00	1.84	31.90	0.78	<0.01	0.10	0.67	7.08	17.00	3.26	1.87
52	23.62069764	92.63020503	963	Khawrihnim	4.53	163.10	2.59	27.60	0.89	<0.01	0.19	0.52	7.21	20.00	1.17	1.21
53	23.6177709	92.62385187	737	Khawrihnim	5.21	129.00	2.52	28.07	1.16	<0.01	0.63	1.22	3.93	23.56	4.67	2.79
54	23.62708649	92.6338575	746	Khawrihnim	4.98	177.00	2.17	25.10	1.20	<0.01	0.78	1.23	3.24	23.41	4.37	2.82
55	23.62944216	92.62130584	747	Khawrihnim	4.76	145.00	1.64	31.20	1.21	<0.01	0.35	0.96	6.56	19.34	2.02	1.24
56	23.62272018	92.61327516	999	Khawrihnim	5.64	152.00	1.26	32.80	0.65	<0.01	0.14	0.77	6.77	23.40	5.05	1.62
57	23.6204121	92.61331086	892	Khawrihnim	5.30	140.40	2.84	33.40	1.10	<0.01	0.18	1.14	7.62	21.03	2.16	1.50
58	23.61585544	92.61391762	797	Khawrihnim	5.32	138.00	1.88	25.40	1.22	<0.01	0.17	0.53	4.39	17.75	2.06	0.62
59	23.6115962	92.63302469	1001	Khawrihnim	4.17	216.00	1.91	23.10	0.64	<0.01	0.21	0.82	7.10	23.29	3.17	0.97
60	23.6115843	92.63043108	930	Khawrihnim	5.30	157.00	2.15	24.20	0.54	<0.01	0.26	0.97	8.20	24.38	1.72	1.57
61	23.61186984	92.64079363	764	Khawrihnim	5.42	181.00	2.36	32.08	1.24	<0.01	0.67	1.23	3.77	29.25	4.39	2.67

62	23.59461875	92.64510045	363	Khawrihnim	4.85	138.00	2.18	26.65	1.55	<0.01	0.16	1.23	3.97	23.76	4.29	2.26
63	23.59721236	92.64816996	392	Khawrihnim	4.53	176.00	0.95	33.20	1.02	<0.01	0.19	1.11	6.53	21.86	4.08	2.26
64	23.59476151	92.64886	345	Khawrihnim	4.57	123.00	3.01	28.25	1.12	<0.01	0.57	1.21	3.29	27.92	4.29	2.90
65	23.60557914	92.64255443	621	Khawrihnim	5.64	175.00	3.19	28.08	1.13	<0.01	0.87	1.22	3.08	25.14	4.24	2.85
66	23.60422285	92.64044861	606	Khawrihnim	4.39	164.00	2.37	24.98	1.55	<0.01	0.66	1.22	3.82	26.12	4.80	2.68
67	23.60982648	92.63238224	910	Khawrihnim	4.91	185.00	2.42	25.38	1.31	<0.01	0.86	1.21	3.32	28.18	4.12	2.53
68	23.61079016	92.64519563	625	Khawrihnim	5.34	170.00	2.58	28.38	1.32	<0.01	0.35	1.23	3.54	21.90	4.31	2.19
69	23.61828546	92.63698649	829	Khawrihnim	5.40	220.00	2.41	30.20	1.24	<0.01	0.37	1.22	3.85	29.14	4.46	2.59
70	23.63067055	92.63463083	780	Khawrihnim	5.68	128.00	2.98	29.07	1.10	<0.01	0.75	1.24	3.80	21.78	4.26	2.26
71	23.64234181	92.63231085	428	Khawrihnim	4.59	158.00	3.22	26.34	1.39	<0.01	0.75	1.21	3.21	23.28	4.06	2.79
72	23.64230612	92.62824197	490	Khawrihnim	5.26	148.00	2.95	28.14	1.40	<0.01	0.11	1.23	3.05	29.08	4.31	2.60
73	23.64030737	92.62842043	527	Khawrihnim	4.44	168.00	2.66	24.88	1.17	<0.01	0.32	1.24	3.65	20.21	4.45	2.23
74	23.64045014	92.62456571	593	Khawrihnim	4.32	130.00	2.25	28.23	1.19	<0.01	0.62	1.21	3.87	27.65	4.14	2.61
75	23.63698802	92.62449432	635	Khawrihnim	5.57	152.00	2.41	24.13	1.18	<0.01	0.83	1.23	3.44	28.91	4.35	2.69
76	23.64027168	92.63241793	458	Khawrihnim	4.66	142.00	3.26	28.40	1.17	<0.01	0.76	1.24	3.29	21.60	4.28	2.64
77	23.6441621	92.63131148	401	Khawrihnim	4.47	117.00	2.53	27.67	1.37	<0.01	0.28	1.24	3.44	23.20	4.64	2.16

78	23.63149147	92.59686878	1091	Khawrihnim	5.28	213.00	2.20	24.66	1.27	<0.01	0.61	1.20	3.84	29.39	4.08	2.21
79	23.62970687	92.59376358	1241	Khawrihnim	4.40	161.00	3.08	24.57	1.19	<0.01	0.51	1.21	3.45	25.49	4.91	2.02
80	23.62592353	92.59579802	1266	Khawrihnim	4.26	202.00	3.00	29.64	1.36	<0.01	0.67	1.24	3.20	21.10	4.06	2.40
81	23.62860042	92.60268656	935	Khawrihnim	5.16	197.00	2.87	30.08	1.11	<0.01	0.75	1.23	3.18	23.76	4.51	2.56
82	23.62371063	92.60133027	1129	Khawrihnim	5.58	152.00	3.20	25.36	1.22	<0.01	0.12	1.21	3.14	23.74	4.28	2.37
83	23.62785089	92.59876045	1102	Khawrihnim	5.44	175.00	3.16	32.22	1.42	<0.01	0.21	1.24	3.55	28.18	4.95	2.93
84	23.61889222	92.61078863	927	Khawrihnim	5.49	209.00	2.41	23.68	1.55	<0.01	0.91	1.23	3.81	20.56	4.87	2.68
85	23.61935622	92.60282933	986	Khawrihnim	5.23	126.00	2.58	25.98	1.53	<0.01	0.61	1.22	3.88	28.10	4.54	2.75
86	23.62288972	92.61564273	963	Khawrihnim	4.92	162.00	2.18	24.90	1.15	<0.01	0.92	1.25	3.13	24.38	4.99	2.21
87	23.6198916	92.62028268	911	Khawrihnim	4.67	115.00	2.70	26.00	1.38	<0.01	0.95	1.21	3.17	23.72	4.03	2.66
88	23.61874946	92.61467905	820	Khawrihnim	5.75	179.00	2.58	30.70	1.06	<0.01	0.54	1.25	3.28	22.87	4.26	2.16
89	23.61560857	92.63802156	768	Khawrihnim	5.44	160.00	3.10	31.36	1.30	<0.01	0.95	1.24	3.18	21.29	4.96	2.82
90	23.62421032	92.62849182	954	Khawrihnim	5.71	215.00	3.07	30.24	1.33	<0.01	0.53	1.24	3.52	29.13	4.40	2.79
91	23.62421032	92.63234654	813	Khawrihnim	5.55	142.00	2.47	24.69	1.24	<0.01	0.85	1.20	3.09	27.63	4.06	2.13
92	23.62956411	92.61071724	921	Khawrihnim	5.49	132.00	2.43	31.01	1.16	<0.01	0.54	1.22	3.65	21.65	4.31	2.30
93	23.63138439	92.61282307	812	Khawrihnim	5.67	191.00	2.29	25.19	1.20	<0.01	0.56	1.21	3.41	24.83	4.32	2.57

94	23.6313487	92.59497711	1179	Khawrihnim	5.26	212.00	2.98	30.31	1.49	<0.01	0.16	1.22	3.28	20.33	4.70	2.49
95	23.62217588	92.59711862	1275	Khawrihnim	5.60	129.00	2.83	31.78	1.19	<0.01	0.19	1.24	3.43	26.34	4.03	2.43
96	23.61864238	92.60878988	996	Khawrihnim	4.95	223.00	2.45	25.24	1.39	<0.01	0.68	1.25	3.36	23.57	4.69	2.22
97	23.61518026	92.618855	585	Khawrihnim	4.73	202.00	2.24	32.35	1.06	<0.01	0.67	1.24	3.13	28.08	4.52	2.75
98	23.61871376	92.61864085	807	Khawrihnim	5.48	172.00	2.88	26.02	1.14	<0.01	0.82	1.24	3.25	29.28	4.65	2.07
99	23.60447269	92.64483871	514	Khawrihnim	4.70	210.00	3.13	28.95	1.43	<0.01	0.95	1.20	3.31	23.46	4.56	2.33
100	23.59540694	92.6422332	428	Khawrihnim	5.15	173.00	2.39	26.25	1.42	<0.01	0.15	1.23	3.10	25.99	4.08	2.81
101	23.6350101	92.62048493	814	Khawrihnim	5.18	147.00	2.76	26.71	1.33	<0.01	0.39	1.22	3.53	27.37	4.63	2.72

Annexure – II Fish Pond Location

ID	X	Y	ID	X	Y	ID	X	Y
1	460821	2611208	26	462682	2612803	51	463520	2609750
2	458525	2612754	27	461625	2612110	52	463701	2609437
3	458637	2612663	28	461237	2612267	53	463708	2609562
4	458616	2612623	29	461096	2612309	54	463248	2610122
5	458779	2612444	30	461076	2613026	55	463246	2610194
6	458695	2612460	31	460931	2613097	56	463306	2610297
7	458488	2612515	32	460842	2612910	57	463169	2610442
8	458852	2612244	33	460608	2612708	58	463158	2610493
9	458838	2612196	34	462523	2609718	59	463143	2610634
10	459309	2612535	35	462429	2609831	60	463246	2610928
11	459567	2612567	36	462306	2610013	61	463161	2610944
12	459763	2612835	37	462288	2610044	62	463057	2611043

13	460330	2613274		38	462234	2609866		63	462629	2611259
14	460590	2612880		39	462296	2609836		64	462425	2611196
15	460134	2612951		40	462734	2609615		65	462297	2611133
16	459920	2612699		41	462761	2609818		66	461944	2610905
17	462406	2614458		42	463818	2609119		67	462089	2611181
18	462068	2614281		43	464021	2609522		68	462165	2611453
19	461941	2614937		44	463999	2609537		69	462049	2611537
20	461723	2614223		45	463746	2609750		70	462557	2611949
21	462550	2613334		46	463557	2610074		71	462472	2611904
22	462036	2613325		47	463370	2609978		72	462615	2611731
23	461777	2613693		48	463374	2609915		73	461793	2612044
24	461864	2612870		49	463569	2609678		74	461555	2612175
25	462040	2612975		50	463448	2609806		75	461076	2613162

Annexure – III Details of Farmer Producer Organizations (FPOs)

FPOs: The power of collectivization

The collectivization of farmers into FPOs (Cooperatives/SHGs/FIGs/producer Company) will generate benefits of economies of scale and help in overcoming the problems associated with fragmented land holdings. Aggregating producers into FPOs will also usher in advantages such as scope for value addition and higher price through activities like sorting, grading, packaging, and processing, facilitates the availability of quality inputs and farm machinery, better access to credit, technology, capacity building, processing and production Capability, and marketing options. In Mizoram, our focus will be on the formation and promotion of gender inclusive, FPOs, especially of small and marginal producers in the identified districts with the aim to improve productivity, facilitate adoption of good agricultural practices and technology, promoting an enabling environment with access to knowledge and inputs, develop direct marketing capacity and thereby increasing the producers' share in consumers' rupee and boosting the livelihoods. Doubling farmer income can be achieved mainly through two approaches.

1. Production driven approach

a) Improving crop productivity and crop diversification:

The increase in population and rising demand for land for non-agricultural use has considerably reduced the share of arable land. The only feasible option to increase agricultural production is to improve the crop productivity. Enhancing access to irrigation and adopting good agricultural practices are very instrumental in improving crop productivity. Ensuring efficient supply of hybrid seeds/ high yielding variety seeds/ planting materials to the farmers, promoting crop/site specific farm mechanization and inclusion of cash crop cultivation (spices, medicinal and aromatic plants etc.) in the jhum land are some areas of improvement.

Crop diversification through high value horticultural crops (strawberry, grape, dragon fruit, king chilli, bird's eye chilli, capsicum, French bean, etc.), floriculture (Anthurium, Lilium, Gerbera) should be promoted for enhancing farm income. Paddy cum fish culture, apiculture, sericulture, scientific mushroom cultivation etc. are some alternative ways of securing extra income for the farmers and improving their livelihoods, but Paddy cum fish culture should be taken up preferably near river Banks to avoid Groundwater Depletion. Skill development of rural youth for hi-tech modern crop production system like hydroponics also offer promising avenues for improved farm income. Organic farming and on farm conservation of local landraces of different cultivated crop species (maize,

birds eye chilli, ginger, turmeric, French bean, soybean etc) along with organic certification can fetch premium price for agricultural produce.

b) Soil and Water Management:

Regular soil health testing and adaptation of integrated nutrient supplementation strategy should be adapted to improve soil health and nutrient efficient crop production system in jhum lands. Construction of community level low-cost water harvesting structures with suitable irrigation infrastructure facilities are essential to increase the net cultivation area as well as average cropping intensity. Use of micro irrigation techniques like drip and sprinkler irrigation should be promoted to have sufficient irrigation supply to farm during Rabi season.

c) Development of on farm practices and precision agriculture technologies:

Providing state-of-the-art, advisory support will help reduce the costs, increase the efficiency of operations, and result in higher returns for the farms and FPOs. On-farm support services targeting the FPO beneficiaries including periodic weather advisories, sowing-to-harvest crop advisories (soil and water deficiency advisory, nutrient deficiency advisory, plant protection advisory) will be provided which help farmers make informed decisions that lead to better crop output. Crop advisory to farmers by way of multispectral imaging using UAVs giving real time on ground information to farmers about crop health, irrigation requirement, soil moisture status etc will help in optimizing the use of water/fertilizers/pesticides leading to enhanced crop yield. Custom hiring center with drones and electric tractors will be established in the cluster for ensuring better crop health and improved production and productivity as drone-based Nutrient and Fertilizer Spraying reduce water and Nutrient/Pesticide wastage by at least 30% while ensuring no Crop Damage.

2. Building agribusiness for resource optimization and risk management

a) Infrastructure development for post-harvest handling:

There is an urgent need to provide a conducive environment for farmers to excel in post-production activities. Farmers are unable to hold on to their produce and improve price realization due to in adequate, on-farm and near-farm storage. The need of the hour is to facilitate the accessibility of post-harvest infrastructure for the farmers across the state to fetch good market price for off-season supply of farm produce. Existing cold storage capacity in the State is sparse and is confined mostly to certain crop types and not integrated with other requirements. Gap needs to be fixed on priority considering the perishable nature of horticulture produce and their potential in boosting the farmers' income. Integrated pack houses within the cluster for primary processing activities like sorting,

grading, and packing storage facilities including hermetic storage solutions close to the farmgate and storage linked with warehouse receipt finance should be encouraged. Providing logistics connectivity through refrigerated/insulated transport is also essential to reduce the loss associated with post-harvest handling of agricultural produce.

b) Value addition and processing:

Emphasis on the establishment of multi-purpose agro-processing units for processing and value addition with focus on ODOP crops and cash crops of Mizoram will be given topmost priority. For this, the Self-Help Groups (SHG)/Cooperatives/Farmer Producer Companies will be given necessary support in terms of handholding, with provisions of needed credit and policy incentives.

c) Market linkage:

Market intelligence and ICT services should be strengthened to bring better benefits tothe farmers by enhancing the reach of farmers to multiple markets. Use of technology-based interventions to ensure pricing transparency, demand prediction, product traceability and supply chain optimization should be supported. Enabling price discovery mechanisms through digital applications will help farmers in taking informed decisions and preventing distress sale. In order to overcome any adverse situation in the marketing of farm produce arising due to environmental or other reasons, emerging and export markets will be identified apart from the existing traditional markets. Private partnerships will be fostered for accessing export oriented international markets.

d) Facilitating farm-to-fork forward and backward linkages:

To facilitate farm-to-fork linkages, primary focus will be on building the capacities of FPOs to develop realistic business plans and link the production with market-demands tapping into platforms such as e-NAM and direct marketing avenues available in the sector. Public Private Partnerships (PPPs) based models for input aggregation, procurement, and handholding of FPOs, strengthening backward and forward linkages with the private sector should be explored. The present agricultural marketing system suffers from distortions like multiple intermediaries and levies, lack of vertical integration, poor infrastructure, restrictions on the movement of agricultural commodities, amongst many others. Thus, limited market choices and the lack of transparency have been major barriers in the better price realisation for farmers.

For efficient marketing of perishable and non-perishable commodities, aggregation platforms have to build in close proximity to farm gate which would facilitate a transparent system by eliminating the middlemen. A targeted production and delivery system is crucial for supply chain optimisation, and this could be achieved through contract farming. Contract farming offers regular and consolidated

demand to farmers and an assured exchange against predetermined quality and quantity, allowing farmers to vertically integrate with specific and organised market channels. Food processing units can also be encouraged to enter into some form of contracted supply for their feedstock from producers.

Formation of FPOs: Process Flow

Farmers in a village can form a group for the purpose of leveraging collectives through economies of scale in production and marketing of agricultural and allied sector and apply for FPO registration either under Part IXA of Companies Act or under Co-operative Societies Act of the concerned States. Approach will focus on the formation and promotion of gender-inclusive, Farmer Producer Organizations, especially of small and marginal producers in the identified clusters with the aim to improve crop productivity, facilitate adoption of good agricultural practices and technology, promoting an enabling environment with access to credit, knowledge, and inputs, develop direct marketing capacity and thereby increasing the producers' share in consumers' rupee and boosting the livelihoods.

Benefits of forming FPOs

- ➢ Members of FPO will have better bargaining power and they can buy or sell commodities at competitive price.
- ➢ Better access to credit with Government Guarantee upto Rs. 2 Crores, technology, and capacity building for doubling farm income.
- ➢ Opportunity to access government funding from schemes like formation and promotion of FPOs, Agriculture Infrastructure Fund etc.
- ➢ Facilitates the availability of quality inputs and farm machinery at low cost by setting up input and custom hiring centres.
- ➢ Opportunities for pre- and post-harvest infrastructure like green house, cold storages, warehouses, processing units etc.
- ➢ Scope for value addition and higher price through activities like sorting, grading, packaging, processing etc.
- ➢ Improved marketing options due to aggregation of agri produce and elimination of middlemen.
- ➢ Provision for market information about the produce offering better and remunerative prices.
- ➢ Scope for higher income generating activities like seed production, cruelty freebee keeping, mushroom cultivation etc.

1. Preliminary Work

a. Identification of product specific clusters Based on the recommendations of Implementing Agency (IA) a geographical area is identified within one or two blocks, wherein agricultural and allied produce such as horticultural produce of similar or of almost similar nature

is grown / cultivated, so that FPO can be formed for leveraging economies of scale in production and marketing. This will also cover organic produce and natural farming. There should be good scope for integration of technology within the identified cluster.

b. Diagnostic study Diagnostic study including baseline survey should be carried out to assess the preliminary situation of the farmers and current situation of farming in the area. The study should also indicate one or more livelihood activities that are predominant in the area in which there is a potential for increasing returns through aggregation. The potential interventions in terms of infrastructure, services, etc. required in the value chain of agricultural and horticultural produce including post-harvest management and marketing will be identified. Baseline survey provides the data related to the current prevailing situation of farming to establish the base figures based on which future outcome indicators can be measured to understand the change contribution. Random sampling techniques including structured household-level interviews and open-ended focus group discussions with a variety of stakeholders will be employed for the purpose.

c. Feasibility analysis will be conducted to establish a case for promotion of FPOs in the prevailing specific regional/environmental context (financial, technical, legal, political, socio-cultural, environmental, economic and resource feasibility). This will cover the socio-economic conditions of the community, assessment (volume, value, and market access) of the availability of commodity/service around which producers will have to be organized and the centrality analysis. Primary and secondary data on the factors affecting commodity procurement/inputs/production/storage/marketing and Cost-benefit and break-even analysis for the proposed activity/activities will also be determined.

2. Mobilization of farmers

Awareness camps will be conducted to educate communities and partners and socialize the benefits of FPOs, encouraging subscription of membership among small and marginal farmers in the identified clusters.

a. Inception meeting A series of meetings will be organised (with the help of influential village leaders, Agriculture Dept, NGOs, and Gram Panchayat) with village community to educate the farmers about the benefits of collectivization and need for FPO formation.

b. Cluster-wise farmer communication outreach will be carried out by distributing pamphlets, brochures, posters etc. in the identified clusters to educate rural community about the benefits of FPO program.

c. Identification of focus groups and Cluster-level Focus Group Discussions The approach will target farmer collectives including primary farmer groups, based on their preference and approach towards FPO formation. Participatory Rural Appraisals (PRA), Focus Group

Discussions (FGDs), problem analysis and collective resource mapping to identify priority interventions will be taken up as part of the mobilization exercise.

d. Village meetings to identify the potential farmers and local/opinion leaders Village meetings convened by the ground team will identify the potential farmers and opinion leaders through a bottom-up, participatory process. A representative group of proactive people will be identified from among the producers who will serve as opinion leaders.

e. Discussion on District wise planning of Volume Produce and its benefits.

f. Orientation of FPO leaders Meetings will be organised with FPO leaders to educate them about the findings of feasibility study, need and impact of collective action and formation of FPOs, proposed action plan, value addition, and market and other linkages. The potential socio-economic benefits of FPO formation and their implication on shareholding members are to be shared with them.

g. Exposure visits of farmers and opinion leaders Farmers will be motivated to join FPOs by planning field visits to successful FPOs or by arranging deliberation from the representatives of popular FPOs. This will further strengthen the understanding of the identified group of producers and help in clarifying concepts and methodologies to potential members as compared to classroom training.

3. Organising and Formalising

Farmer-members cohesively located with similar interests are to be mobilized to form a small informal group of 15-20 members (Farmer Interest Groups, FIGs). Formation of core groups to ascertain the sustainability and transparency of FPO business will also be undertaken. To form a Co-operative Society, it is essential to find 10 individuals who share a common objective, and they need to convene meeting of all members and pass resolutions for the constitution, name of the society and opening of bank account. The entire process needs to be done unanimously. Free and fair elections will be conducted for the selection of trustworthy and dedicated board (min of 30% women) whose primary duty is to protect the interest of the FPO/FCPO and motivating the group towards self-sustainability. Training of BODs on roles, responsibilities, management, and capital/equity mobilization will also be carried out during this period. Promotion and capacity building of women led FPOs (min of 10%) will be prioritized. Capacity building efforts targeting the Board of Directors and FPOs will cover topics such as strategic planning and business development, financial management, and operational planning. These will be covered in modules per the stage of maturity of the FPO and the nature of operations. Regular and cyclical tracking of learning outcomes and capacity gaps of the office-bearers and Board of Directors will be pursued. A perspective planning exercise will be carried out considering traditional strengths and identified gaps under baseline survey. Advisory support for central and state government sponsored schemes and aid for

improving the financial strength of the group to spend on its infrastructure and services will be identified. The various business opportunities for FPOs, will be analyzed based on the value chain of crops. The need for training will be assessed and the members of FPOs will be imparted training in the relevant areas like improved agricultural practices and integrated pest and nutrient management. Preparation of business plan will also be facilitated. After collection of entrance fee and share capital from all the prospective members of the society and opening bank account, application for registration will be submitted to the Registrar of Societies of the concerned jurisdiction along with necessary documents.

4. Post-FPO formation Stage

Post registration compliances (administrative/legal) will be fulfilled, and first General Body Meeting will be conducted within 90 days of incorporation. List of FIG members willing to join FPOs will be finalised and share capital collection to get matching equity grant fund from GOI Scheme will be completed. Capacity building of farmer members of FPOs is very crucial in strengthening backward and forward linkages leading for efficient value chain interventions. This will be achieved by skill development of members, extension management, providing technological platforms and market intelligence. Trainings and modules for good agricultural practices and certification will be conducted to make farmers aware of international standards which enable them in getting premium price for their produce in international export-oriented markets.

5. FPO establishment stage

Once FPO is physically established, providing services for system development will be targeted for strengthening of FPOs. Operating system including accounting system, MIS, HR system will be developed to run the day-to-day activities. Market linkages are essential in creating value addition for the FPOs. Methodology will focus on creating value proposition for all stakeholders including input providers, aggregators, farmers and FPO leaders. Market linkages will be created at all nodes of the value chain to increase the effectiveness of the intervention and improve the shareholder value. FPOs will be assisted through handholding support to engage input providers, aggregators, private sector solution providers in specific areas including transportation, logistics, advisory services etc. This will help leverage on the private sector innovations at scale and offer customized solutions to FPOs. Activities targeting buyer-seller interactions and integrating regular interaction between stakeholders involved in the value chains will be given emphasis.

Handholding and business support

a. Facilitating business development through farm-to-fork forward and backward linkages:

To facilitate farm-to-fork linkages, approach will primarily focus on building the capacities of FPOs to develop realistic business plans and link the production with market-demands tapping into platforms such as e-NAM and direct marketing avenues available in the sector. Public Private Partnerships (PPPs) based models for input aggregation, procurement, and handholding of FPOs, strengthening backward and forward linkages with the private sector would be explored. The present agricultural marketing system suffers from distortions like multiple intermediaries and levies, lack of vertical integration, poor infrastructure, restrictions on the movement of agricultural commodities, amongst many others. Thus, limited market choices and the lack of transparency have been major barriers in the better price realisation for farmers.
For sustaining these linkages, consistent support will be offered in coordination, outreach, and marketing. Methodology will focus equally on strengthening the backward and forward linkages as mentioned below-

Backward linkages:

i. Facilitating strong institutional arrangements for the distribution of quality agri inputs like seeds, fertilizers, pesticides in a timely manner by aggregating demand of inputs of FPO members and organizing last mile delivery at their doorstep.
ii. Setting up of custom hiring centres for farm machinery such as tractor, Power tiller, harvester, weeder, thresher etc.
iii. Arrangement of micro irrigation system for improving water use efficiency from 60% to 90% which results in productivity enhancement of more than 30%
iv. Providing precision-agriculture inputs to improve farm profitability of FPO members.

Forward linkages:

There is thus an urgent need to provide a conducive environment for FPOs to excel in post-production activities which also is one of the foremost reasons for FPOs not being able to build the required momentum. FPOs with limited technical knowhow of processing, branding, and marketing, and without sufficient capital are unable to compete with established local/national/multi-national brands in the open market. Towards improving the competence of FPOs in the project areas, the efforts will attempt:

i. Promoting the reach of farmers to multiple markets through the use of information technology linkages and online marketing platforms
ii. Enabling price discovery mechanisms through digital applications which help farmers in taking informed decisions and preventing distress sale
iii. Integrated pack houses within the cluster for primary processing activities like sorting, grading, and packing
iv. Storage facilities including hermetic storage solutions close to the farmgate to prolong shelf-life and reduce pest-infestation and encouraging storage linked with warehouse receipt finance
v. Establishment of food processing units for processing and value addition
vi. Providing logistics connectivity through refrigerated/insulated transport
vii. Use of technology-based interventions to ensure pricing transparency, demand prediction, product traceability and supply chain optimization.

b. On-farm advisory support using real-time digital inputs using precision agriculture tools:

State-of-the-art, advisory support that will help reduce the costs, increase the efficiency of operations, and resulting in higher returns for the farms and FPOs are also envisioned. On-farm support services targeting the FPO beneficiaries including periodic weather advisories, sowing-to-harvest crop advisories (soil and water deficiency advisory, nutrient deficiency advisory, plant protection advisory) will be provided which help farmers make informed decisions that lead to better crop output. Crop advisory by way of multispectral imaging using UAVs which give real time on ground information about crop health, irrigation requirement, soil moisture status etc helping farmers to optimize the use of water/fertilizers/pesticides leading to enhanced crop yield, will be provided.

c. Promoting income augmentation of farmers, institutional strengthening, and capacity building of FPOs through convergence with national and sub-national schemes:

Opportunities will be identified through a wider multi-stakeholder process with the farmers, market actors and government agencies. This will cover areas including augmenting and supporting the current livelihood opportunities, identification of additional income generating opportunities, opportunities for aligning with government schemes and programs, and convergence with schemes targeting FPO support. The Govt. schemes both national and state sponsored will be identified based on the FPO mandate in consultation with the members. The various schemes available for FPO success include those which are exclusively for infrastructure establishment like the Agriculture

Infrastructure Fund (AIF), those which cater to primary and secondary processing like PM Formalization of Micro Food Processing Enterprises scheme (PM-FME scheme), those supporting the forward and back ward linkages under PMKSY etc.

6. Management Systems Development

Without a systematic arrangement for flow of data and interpretation, it would not be possible for FPO management to get relevant information for decision making process. For the effective functioning of a FPO, financial, human resources, stock and inventory, procurement and quality management, marketing, internal audit, and internal conflict resolution management systems should be developed which aid in decision making. It also helps the CEO / Manager of FPO to analyse problems, visualize complex subjects and product development. Management Information System (MIS) uses information for collecting and communicating information and each and every operation of an organisation requires a separate information system of its own to keep a track of it. MIS in accounting is designed to store and aggregate financial data and the reports generated by the accounting MIS include profit-and-loss statements, accounts receivable tracking and other financial statements. Human resource information systems handle employee data whereas nonfinancial MIS is to know the socio-economic status of members after joining the FPO and to keep track of the improvement in socio-economic condition of the members.

7. Scaling up business of FPO

To facilitate business growth and expansion, FPOs will be federated based on their need of processing, and marketing of produce. During this stage focus will be on long term sustainability rather than on short term financial goals. Branding and domestic/international trading of quality produce will be endorsed. Mizoram is strategically placed to become a hub for export of processed and raw agriproduce to Neighbouring ASEAN Countries. Secondary and tertiary value addition and marketing will need to be targeted by promoting commodity specific federations. For strengthening the FPO ecosystem, policy advocacy, decisions on branding, packaging and market channels will be provided. Custom hiring center with drones and electric tractors will be established in the cluster for ensuring better crop health and improved production and productivity. In order to overcome any adverse situation in the marketing of farm produce arising due to environmental or other reasons, emerging and export markets will be identified apart from the existing traditional markets. Private partnerships will be fostered for accessing export oriented international markets.

8. Phase-out Systems for post-project sustainability

Approach will place a strong emphasis on creating a sustainable environment for FPO development. Suitable measures will be taken to guarantee that FPOs are guided in planning, implementing, and operationalizing the business plans through and beyond the project period. For ensuring self-sustainability of the FPOs, it is imperative that farmers have access to viable sustainable options during the entire cycle of crop production and marketing. These include establishment of seed production units in farmer's field, production of farmyard manure from the farm waste, biogas production as an energy source from agricultural waste, use of biopesticides and insecticides etc.

9. Monitoring and Review

Monitoring is aimed at improving the efficiency and effectiveness of conducting the business so as to derive maximum benefits. The implementing agency will monitor how efficient the Handholding agency has been in implementing the project in terms of its success of the set targets. Desk and field level monitoring and periodical evaluation of performance of various stakeholders like farmer members, governing board of directors and service providers will also be carried out by the funding agency. FPO performance grading tools would cover areas like FPO membership, governance, management, infrastructure, training, convergence with govt. schemes, market linkages, record keeping, annual turnover etc.

Approach

1. The increasing demand for quality agricultural products and the need to increase the efficiency of entire agricultural value chain to ensure remunerative prices to farmers and affordable price to consumers have necessitated the process of aggregating small and marginal farmers through the formation and promotion of FPOs. This enable them to take advantage of economies of scale and access to information. The strategy for promotion of Farmer Producer Organizations is in line with the Government of India's approach to double the farm income in a time-bound manner.

2. Our approach will focus on strengthening gender-inclusive, farmer collectives or Farmer Producer Organizations, especially of small and marginal producers, across several states, with the aim to improve productivity, facilitate adoption of good agricultural practices and technology, promoting an enabling environment with access to credit, knowledge and inputs, develop direct marketing capacity and thereby increasing the producers' share in consumers' rupee and boosting the livelihoods.
   2.1 The approach rests on three pillars, namely:

- Facilitating business development through farm-to-fork forward and backward Linkages
- On-farm advisory support using real-time digital inputs to FPOs using digital innovations
- Promoting income augmentation of farmers, institutional strengthening, and capacity building of FPOs through convergence with national and sub-national schemes

3. Handholding agency will follow a results-based approach in these three focus areas using a 'multi-sector approach', facilitating the synergy between the sub-sectors in agriculture, natural resource management and economic development for holistic sustainable development.

4. To facilitate farm-to-fork linkages, the approach will primarily focus on building the capacities of FPOs to develop realistic business plans and link the production with market-demands tapping into platforms such as e-NAM and direct marketing avenues available in the sector. Public Private Partnerships (PPPs) based models for input aggregation, procurement, and handholding of FPOs, strengthening backward linkages with the private sector would be explored.

5. Handholding agency will mainstream state-of-the-art, advisory support that will help reduce the transaction costs, increase the efficiency of operations, and result in higher returns for the farms and FPOs. This will include advisory solutions for different nodes of the value chain, including land preparation, input procurement, precision-farming, crop-weather advisories, storage, grading and marketing of farm produce. In addition, the approach will also focus on reducing the risks of small-holder farmers by integrating locally relevant, financial and insurance products built on crop-weather indices.

6. Handholding agency's approach will place a strong emphasis on creating and sustaining an enabling environment for FPO development. This will include leveraging the government schemes and support available for promotion and strengthening of FPOs in various states. The approach will focus on addressing the capacity constraints and gaps identified through extensive consultation, dialogues, review, and sectoral analyses. As a part of the capacity development plan, income augmentation avenues for the farmers will be identified and developed in close consultation with the FPOs, government departments and civil society agencies. A multi-stakeholder approach focusing on livelihood planning, capacity development and institutional strengthening will be adopted.

Methodology To Be Adopted

I. Stages of FPCs Formation and Development Process

1. Village study and preliminary identification

2. The village study/profile shall be conducted by the team in the prescribed format.

3. The findings of the profiling may indicate one or more livelihood activities that are predominant in the area and involve a sizeable number of the poor/women, in which there is a potential for increasing returns through aggregation. Aggregation can be done for supply of inputs (seeds/QPM, and nutrients etc.), management of resources (water, common land etc.), processing/ value addition, marketing of produce. .

4. Identify the activity/s and what can be done through aggregation. Prepare a brief note on the feasibility analysis

II. Diagnostic study and Feasibility Analysis

Keeping in view the objectives of the study, detailed feasibility study will be conducted. This would include the following.

1. Prepare formats/questionnaires/interview schedules as required for each crop.

2. **Social mobilization for formation of FPOs**

The needs and priorities of farmer community will be taken into consideration while mobilizing farmers for FPO formation. Identification and training of local leaders who can cater to the requirements of FPOs will be done on a priority basis. Social mobilization with the help of influential village leaders, opinion makers, NGOs and Gram Panchayat office bearers will be undertaken through a participatory and consultative process. Participatory rural appraisals focus group discussions, problem analysis and collective resource mapping to identify priority interventions will be taken up as part of the mobilization exercise. Farmers should be motivated to join FPOs by planning field visits to successful FPOs or by arranging deliberation from the representatives of popular FPOs. Group led decision and action by the FPO members will be done for strengthening and nurturing FPOs. Platform for community level meeting will be provided for identification of objectives and setting of FPO goals. Formation of

core groups to ascertain the sustainability and transparency of FPO business will be undertaken. Training of BODs in various fields including organizational structure, vision building, business operations and management, leadership development and communication skills will be conducted.

3. **Community Background Study in which the farmer group will be established:**
   - The living conditions of different socio-economic groups in the community
   - The needs of the farming community, especially of the small and medium land holding farming community
   - The way the community solves its problems (e.g. does it use traditional methods and/ or involvement or assistance of outside organizations?)
   - Social patterns in the community including who talks to whom and why
   - Informal and formal organization of men and women (both mixed and separate)
   - Links between the community and supply of services and who controls them

4. Preliminary assessment of availability of the commodity/service around which producers will have to be organized – volume, value, market access
5. Centrality analysis: Whether the commodity/activity is central/significant in the minds of the community. Whether it contributes (or has potential to contribute) significantly to their livelihood portfolio?
6. Data collection: Collect relevant secondary and primary data on the commodity in question and the related factors affecting its procurement/inputs/production/storage/marketing.
7. Cost-benefit and break-even analysis for the proposed activity/activities of the organization.

III. Report and Action Plan

1. Prepare a consolidated report, including proposed action plan.

This exercise would support to prepare "Road Map/ Action Plan" for further initiatives to be taken for the formation of Farmer producer Organizations.

Phase II: Formation of Farmer Producer Organization

1. Organizing
2. **Cluster Identification** – Cluster areas are to be selected in consultation with the respective State Government departments. However, it should be ensured that a cluster of 300-500 farmers should be formulated, within one or two blocks, identifying 10 to 15 contiguous villages of a particular district.

3. Identification of opinion leaders: Identify opinion leaders from among the producers and form a representative group of proactive people.

4. Orientation of leaders: Share the findings of the feasibility study and discuss the need for formation of an organization to utilize the potential of the particular livelihood activity.

5. Discussion with village community - Involve the leaders group to organize a series of meetings of the village community (Gram Sabhas) to discuss the following:
   - Necessity for collective action
   - Values in collective action
   - Findings of feasibility study
   - Proposed activities, product- value addition, linkages etc.
   - Proposed action plan

This communication with the people needs to be repetitive and cannot be done in one meeting.

6. Training and exposure of producers: Organize trainings for producers on concepts and roles of the FO& FPC and their own roles as members. If possible, also organize exposure visits to similar community organizations in the nearby area.

IV Formalizing

1. **Visioning:** Facilitate formulation of vision and mission of the collective with the promoters. Develop with them the values on which organization should be based.

- **Objectives and plans – Identify specific and realistic goals/objectives to inform the development of work plans and budgets. Some basic questions addressed through focus group discussions can help to identify formulation of objectives**

2. Design an appropriate organization – objectives, activities, structure, rules, legal form and basic operating system (work flow) – in consultation with the leaders. Provide them complete information on each aspect and facilitate decision-making.

   - **Identify rules including obligations of group members to ensure the smooth running of the group and avoid conflict within the group**
   - **Identify responsibility for leadership, coordination of logistics**

3. Facilitate the election of the Governing Board/ Management Committee and office bearers, as required depending on the legal form of the organization. Facilitate framing of Vision, Mission, and Goals and draft the byelaws and other applicable resolutions with the board. Also facilitate the formation of subcommittees, as required, and clarify their roles and responsibilities.

4. **Opening of bank account:** Facilitate opening of a bank account, with signatories as per the byelaws of the organization.

5. Collect share capital and other necessary fees: Collect the share capital, membership fees as applicable from members and deposit in the bank account.

6. **Registration:** Complete the documentation required for registration and follow-up the process of registration. The Board/office bearers should take responsibility of these activities; Handholding agency should have a facilitation role. Obtain the following from the Registrar's office.

   -Registration certificate
   -Approval of Board
   -Copy of Byelaws
   -Instructions for operating bank account

V. Systems Development

1. Operating system: Facilitate detailing of the Operating system, including the accounting system and document in the form of a manual in the local language. The Operating system of such organizations would include different elements, indications.
2. Information system: A manual/semi-automated MIS will have to be developed for the organization, as customized software may not be available for different activities.
3. HR system: In case the organization has hired significant number of staff, the HR system will have to be developed as well. Otherwise, the system for roles and responsibilities, authority, compensation/remuneration etc. of the Executive board/operational sub-committee members who run the day-to-day operations should be developed.
4. Planning and review: Formulate a process and template for Business planning. Also develop a system of reviewing theperformance against the plan.
5. Prepare the manual in vernacular and circulate to Management Committee/board.

VI. Business planning

1. Facilitate development of a broad Business plan.
2. Obtain feedback on the plan

VII. Linkages with other organizations

1. Facilitate long term collaborations with institutions/individuals such as input suppliers, service providers like funding/ research institutions as applicable, buyers etc.

VIII. Monitoring and review

1. Monitor the operations and governance of the institution closely through reports and visits.
2. Review the performance jointly provides guidance for overcoming problems.

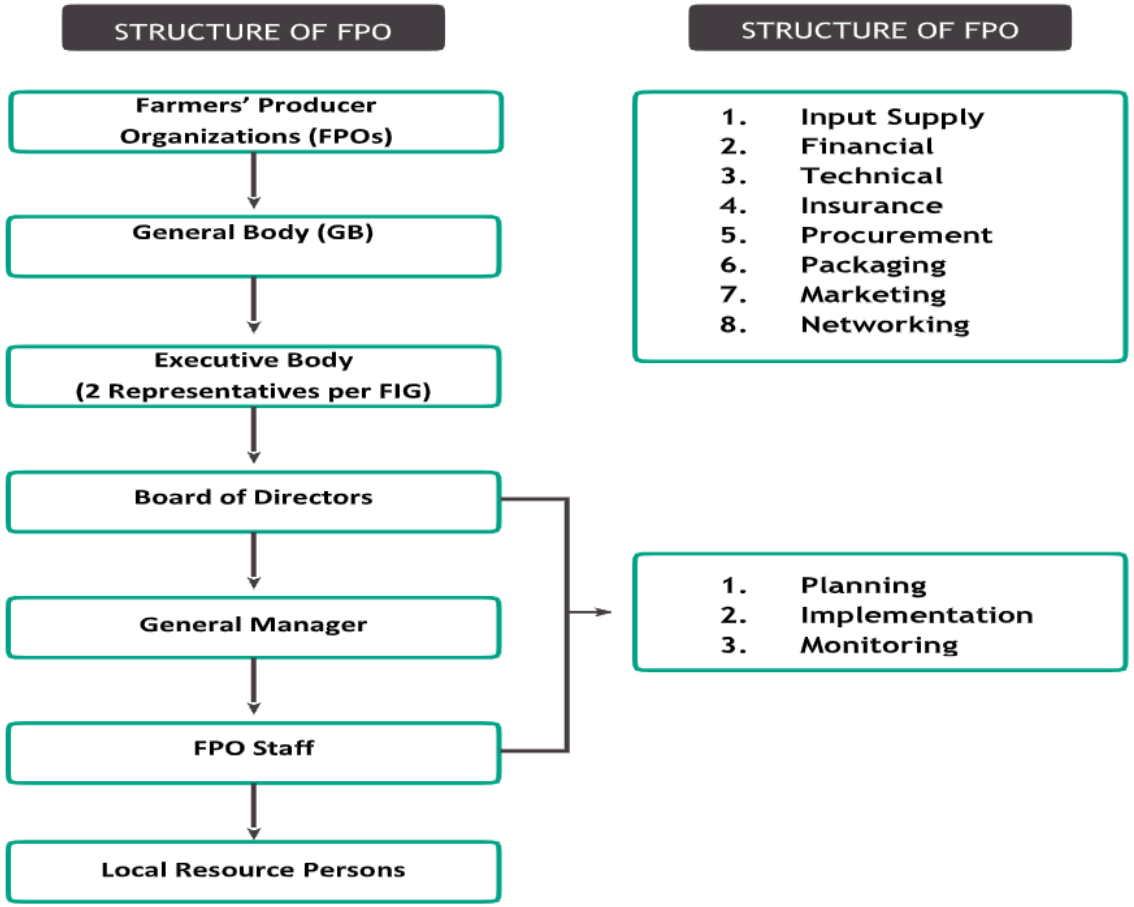


Fig.41 FPO Service Model

Ix. Post Formation of Farmer Producer Company Activities

1. Marketing/Sales Tie-Up with Reputed Traders/Wholesalers/Exporters and Industries
2. Market linkages are essential in creating value addition for the FPOs. Our proposed methodology will focus on creating value proposition for all stakeholders including input providers, aggregators, farmers and FPO leaders. Market linkages will be created at all nodes of the value chain to increase the effectiveness of the intervention and improve the shareholder value. FPOs will be assisted through handholding support to engage input providers, aggregators, private sector solution providers in specific areas including transportation, logistics, advisory services etc. This will help leverage on the private sector innovations at scale and offer customized solutions to FPOs.
3. Creation of work plan activities targeting buyer-seller interactions and integrating regular interaction between stakeholders involved in the value chains. The approach and methodology will also customize the needs and requirements based on specific crop value chains, socio-economic contexts in which the FPOs operate and the value chain gaps identified.
4. Handholding agency should follow the following methodology that will focus equally on strengthening the backward and forward linkages as mentioned below:

Backward linkages

- Facilitating the distribution of quality Agri inputs like seeds, fertilizers, pesticides in a timely manner by aggregating demand of inputs of FPO members and organizing last mile delivery at their doorstep
- Setting up of custom hiring centers for farm machinery such as harvester and tractor.

Forward linkages

- Promoting the reach of farmers to multiple markets through the use of information technology linkages and online marketing platforms
- Enabling price discovery mechanisms through digital applications which help farmers in taking informed decisions and preventing distress sale
- Integrated pack houses within the cluster for primary processing activities like sorting, grading, and packing
- Storage facilities including cold storage, closer to the farmgate for ensuring better returns to farmers and encouraging storage linked with warehouse receipt finance
- Establishment of food processing units for processing and value addition of agricultural produce

- Providing logistics connectivity through refrigerated/insulated transport
- Branding of farm produce by federating the FPOs thereby facilitating business growth and expansion
- Use of technology-based interventions to ensure pricing transparency, demand prediction, product traceability and supply chain optimization

5. Business development through income augmentation and on-farm support services

5.1. Handholding agency will adopt suitable measures to ensure the FPOs are guided in planning, implementing, and operationalizing the business plans through the project period. Opportunities will be identified through a wider multi-stakeholder process with the farmers, market actors, government agencies, coordinated by CBBO. This will cover areas including augmenting and supporting the current livelihood opportunities, identification of additional income generating opportunities, opportunities for aligning with government schemes and programs, and convergence with schemes targeting FPO support. The Govt. schemes both national and state sponsored will be identified based on the FPO mandate in consultation with the members. The various schemes available for FPO success include those which are exclusively for infrastructure establishment like the Agriculture Infrastructure Fund (AIF), those which cater to primary and secondary processing like PM Formalization of Micro Food Processing Enterprises scheme (PM-FME scheme), those supporting the forward and back ward linkages under PMKSY etc.

5.2. An indicative list of govt. schemes for FPO business and their benefits are presented below:

Scheme	Purpose	Benefits
For infrastructure facilities along the entire value chain		
Agriculture Infrastructure Fund (AIF)	Post-Harvest Management Projects like warehouses, pack house, cold chain, primary processing, logistics etc and projects for building community farming assets	Interest subvention of 3% per annum up to a limit of Rs. 2 crores for a maximum period of seven years. Credit Guarantee coverage for a loan of up to 2 crores

PM Formalization of Micro Food Processing Enterprises scheme (PM-FME scheme)	Support for common infrastructure and capital investment support for FPOs along their entire value chain for sorting, grading, assaying, storage, common processing, packaging, marketing etc.	Credit-linked capital subsidy @35% of the eligible project cost with a maximum ceiling of Rs.10 lakh
Financial Assistance under Agriculture and Processed Foods export promotion scheme of APEDA	For integrated pack house facilities, cold chain strengthening and processing facilities of horticultural crops.	Up to 40% of the total cost subject to a ceiling of Rs. 100 lakhs
For Horticulture		
Mission for Integrated Development of Horticulture (MIDH)	i) Production of planting material (Hitech Nursery)	100% to public sector limited to Rs 100 lakh/unit and in case of private sector, credit linked back-ended subsidy @ 40% of cost, subject to a maximum of Rs. 40 lakh/unit, for a maximum of 4 ha
	ii) vegetable seed production	Assistance will be provided @ 100% of total cost to public sector. For private sector, assistance will be 50% of cost as credit linked back ended subsidy. Assistance will be available for a maximum area of 5 ha @ per beneficiary
	iii) High density planting (mango, guava, litchi, pomegranate, apple, citrus etc). Integrated package with drip irrigation.	Maximum of Rs. 0.60 lakh per ha. (40% of cost) for meeting the expenditure on planting material, cost of drip system, INM/IPM, canopy management

Irrigation		
Pradhan Mantri Krishi Sinchai Yojana (PMKSY)	For convergence of investments in irrigation at the field level, expand cultivable area under assured irrigation, improve on-farm water use efficiency, enhance the adoption of precision-irrigation and other water saving technologies	The pattern of assistance payable under the micro irrigation scheme will be 55% for small and marginal farmers and 45% for other farmers
Micro Irrigation Fund (MIF)	To supplement the efforts of Per Drop More Crop Component (PDMC) of Pradhan Mantri Krishi Sinchayi Yojana in an effective and timely manner	For innovative integrated projects, including projects in the Public-Private Partnership (PPP) mode and also for incentivizing micro irrigation through an additional (top-up) subsidy over and above the one available under PMKSY-PDMC guidelines and for covering additional areas.
Farm Mechanization		
Sub-mission on Agricultural mechanization (SMAM)	i) financial assistance for procurement of agricultural machinery and equipment ii) Post harvest equipment for food grains, oil seeds and horticultural equipment's	40% subsidy per machine/beneficiary subject to a maximum permissible subsidy based on the type of farm machinery 50 % subsidy per machine/beneficiary subject to a maximum permissible subsidy of 1.5 lakhs
Insurance		
Livestock insurance Scheme	To provide protection mechanism to the farmers and dairy farmers against any eventual loss of their animals	Cattle insured at maximum of their current market price. The premium of the insurance is subsidized to the tune of 50% which is borne by the Central Government

Pradhan Manthri Fasal Bhima Yojana (PMFBY)	Insurance protection for food crops, oilseeds, annual horticultural/commercial crops	Uniform maximum premium for all farmers i) Kharif 2% of sum insured, I) Rabi 1.5% of sum insured iii)Annual horticultural crops 5% of sum insured The difference between the actual premium and rate of insurance payable by the farmers will be equally shared by Centre and state.

5.3. Identification and implementation of on-farm support services targeting the FPO beneficiaries including periodic crop-weather advisories, digital information on crops, agro-ecosystems, weather patterns to inform precision agricultural practices in the region, which has been proven to increase the income from farming. Handholding agency will ensure that farmers have access to viable sustainable options during the entire cycle of crop production and marketing. These include establishment of seed production units in farmer's field, production of farmyard manure from the farm waste, biogas production as an energy source from agricultural waste, use of bio pesticides and insecticides etc. In order to overcome any adverse situation in the marketing of farm produce arising due to environmental or other reasons, emerging and export markets will be identified apart from the existing traditional markets. Private partnerships will be fostered for accessing export oriented international markets.

5.4. Advisory support to FPO beneficiaries will target crop-specific and market-specific opportunities, thereby customizing information availability to farmers and increasing the farm output in the select areas. Farmers should be provided crop advisory by way of multispectral imaging using UAVs which give real time on ground information to farmers about crop health, irrigation requirement, soil moisture status etc which helps to optimize the use of water/fertilizers/pesticides leading to enhanced crop yield. Additional income augmentation opportunities like beekeeping, pisciculture, solar powered charkha, cultivation of medicinal and aromatic plants etc. will be identified in consultation with the subject matter experts, farmer leaders and FPO members as applicable to diversify the farm activities and to improve the livelihood of farmers. Crop diversification based on market demand and Public Private Partnership (PPP) models will be actively pursued. These income augmentation schemes will further leverage additional government and financial support through convergence with existing schemes and programs.

5.5 Capacity Building

5.5.1 Capacity building of farmer members of FPOs is very crucial in strengthening backward and forward linkages leading for efficient value chain interventions. This will be achieved by skill development of members, preparation and execution of business plan, extension management, providing technological platforms and market intelligence, organising exposure visits etc. Trainings for skill development and modules for organic farming and certification will be conducted to make farmers aware of international standards which enable them in getting premium price for their produce in international export-oriented markets.

5.5.2 Capacity building efforts targeting the Board of Directors and FPOs will cover topics such as strategic planning and business development, financial management, and operational planning. These will be covered in modules per the stage of maturity of the FPO and the nature of operations. Regular and cyclical tracking of learning outcomes and capacity gaps of the office-bearers and Board of Directors will be pursued. Capacity development strategy will be discussed with stakeholders and FPOs based on the requirements identified at the inception and appropriate touch points identified in consultation with Department.

6. Management, Monitoring and Reporting Systems

Component-wise separate checklist should be designed to collect the information based on the following quantitative and qualitative indicators:

A) **Quantitative:** Information of each farmer pertaining to land holding, area under cultivation of each crop, crop production and productivity level, soil fertility status, source of irrigation and their application, use of fertilizer/herbicides and their application, mode and types of the training organized, networking with market players, presence of State research institutions, interaction and tie-up with other stakeholders like eligible lending institutions and other financial institutions as well as government schemes available for extending due support etc.

B) **Qualitative:** This consist of both close and open-ended questions to capture the economic status of each farmer (registered under FPO project), perceptions, expectations, income generation and problems/ constraints faced by the farmer, if any suggestions for project modifications for more effective implementation of the programmed in future.

Work Plan for FPO Project Implementation

		Year 1				Year 2				Year 3			
Sl. No	**Activities**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
	Community Mobilization												
1	Baseline survey	■											
2	Cluster identification	■	■										
3	Value chain identification	■	■										
4	Feasibility study in the cluster area	■	■										
5	Diagnostic study to identify gaps and potential activity interventions	■	■										
6	Cluster-finalization	■	■										
	FPO Establishment												
1	Registration of FPOs identified			■	■								
2	Business plan preparation and execution			■	■	■	■						
3	Adoption of good agricultural practices				■	■	■	■	■	■	■	■	■
4	Supply chain development and establishing market linkages		■	■	■	■	■						

5	Interface with various stakeholders at the cluster level												
6	Promoting social cohesiveness amongst members of FPOs												
7	Federating FPOs for business growth and expansion												
8	Establishment of pre=harvest and post-harvest infrastructure												
	Convergence with Govt. schemes and Equity/ Credit Guarantee Support												
1	Mobilization of Equity Capital												
2	Assistance in facilitating credit guarantee mechanism												
3	Assistance in availing benefits under different Central/State Govt. Schemes												
	Capacity Building Support												
1	Identification of training needs												
2	Developing training modules												
3	Training of BODs on roles, responsibilities, and management of FPOs												

4	Conduct Basic Training Workshops and Exposure trips												
	Management, Monitoring and Reporting Systems												
1	Review and monitoring of the field team												
2	Generating MIS reports/information in the required data sheets												
3	Periodical submission of progress report on all specified target activities												
4	Developing rating tool for FPOs												