A Project Proposal

On

Understanding landslide kinematics using IoT and development of a site-specific landslide early warning system using AL/ML

In collaboration with

Space Technology Incubation Centre, NIT - Agartala

July-2023

Space and Atmospheric Science Group

North Eastern Space Applications Centre

Department of Space, Government of India

Umiam-793103, Shillong, Meghalaya

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1) Title of the Proposal:

Understanding landslide kinematics using IoT and development of a site-specific landslide early warning system using AL/ML

2) Main Problem & Challenges:

- There is inadequate ground data available that gives information about the landslide kinematics from the sensors.
- Continuous data on landslide kinematics helps to understand the slope failure and will be useful in developing a real-time landslide monitoring and alert system.
- Deploying the system in locations which are vulnerable to landslides (Halflong/Sonapur) test location and get the parameters from each sensor.

3) Objective:

- Design of a platform for a landslide Detection and warning system using pore water pressure sensor, tilt sensor, soil moisture sensor and weather parameter (temperature and humidity) sensors, 3-axis accelerometer/motion sensors, rain gauge sensor.
- To make provision for the display of the data from the sensors at the measuring station and send the data to an application server from which warning messages can be generated based on the data analysis in case of a landslide.
- Implementation of the sensor node by deploying it in multiple locations in landslide vulnerable areas in Northeast India.
- Development of software tools for data reception, transmission, and analysis under various wireless sensor communication methods.
- The most crucial aspect of the project is to determine the sensors' threshold values for the particular study regions of Halflong and Sonapur so that these values may be used to trigger genuine alarms.

4) Scope:

The scope of the project is to understand the landslide kinematics and to develop a prototype of Real-time landslide Detection and alert system using wireless sensor network caused by geological, hydrological effects and human activities. It is important to study the landslide induced vibrations that occur inside the earth surface, to analyse those vibrations and to correlate them with the landslide events. For this sensor nodes shall be deployed at landslide prone area with multiple power options. Microcontroller unit will send sensors data using LoRa radio frequency which doesn't require any internet connection over there due to this, power consumption of this module is also very less. That means system will have a very longer battery life. The developed sensor node shall be installed at least at two distinct locations (Halflong/ Sonapur) and operated for a few months. The data collected will be validated with similar data from other sources. The data transmission channels shall be checked for their robustness.

5) Scientific / Technical Need Aspect

Landslides are one of the major catastrophic disasters, caused by geological, hydrological, and human activities. It is important to study the landslide-induced vibrations that occur inside the earth's surface, to analyse those vibrations, and to correlate them with the landslide events. Though there are systems for monitoring landslides, there is an urgent need for improving them for better monitoring of the landslide-prone areas and earlier warning dissemination. This landslide Detection system aims for the development of an affordable landslide monitoring system based on a wireless sensor network for efficient data collection of landslide precursor signals.

6) Stake holders:

ISRO, NESAC, NRSC, NIT AGARTALA

7) Product / Service Marketability:

As the product is envisaged to be a low-cost and easily deployable system, due to its low cost many sensor nodes could be deployed in landslide-prone hilly areas. However, cable-based monitoring systems are costly, require continuous maintenance, and are limited in their communication flexibility. To overcome these limitations, wireless sensor networks and Internet of things are a viable alternative technology. So, the entire prototype of the landslide Detection system should be very suitable for marketing as a product.

8) Brief description:

Widespread devastation, numerous road crashes and deaths caused by landslides in several parts of the country throughout the year have turned the spotlight on the urgent need for its early Detection or monitoring systems to reduce landslide-induced fatalities by providing early and accurate warnings so that traffic can be stopped on certain routes and people are relocated to safer places in time. According to statistics shared by the Home Ministry in Parliament, nearly 6,800 people lost their lives in the country over the past three years due to hydro meteorological calamities such as flash floods, landslides and cyclones and West Bengal has recorded the highest deaths among all states. So, an early warning system can be used to minimize the impact imposed by landslide on human, damage to property and loss of live.

There will be four unique attributes to the WSN system. First, it has the ability to mimic biological systems, where the high accuracy and reliability of the whole sensor network are achieved through the proper interaction among low-cost sensors placed close to each other. Second, the sensor network will dynamically configure itself in the event of any nodal failure, thereby forming a self-healing and self-organizing network. Third, the landslide Detection system’s signals will be provided online, enabling researchers to study the signal variations and patterns on a real-time basis. Fourth, the system will be capable of achieving globally optimal decisions without the need to send all the collected data to a fusion-centre. The WSN system is comprised of high-accuracy, commercially available sensor-embedded earth probes, such as pore pressure sensors, moisture sensors, strain gauges, geophones, tilt meters, and inclinometers, and a large, dense wireless sensor network that provides a comprehensive matrix of geotechnical data from the deployment site. Data will be transmitted using a LoRa transmitter to the gateway. The gateway will receive all the signals from various sensor nodes and then send the data to a network server using WI-FI, LAN, or an internet connection. These sensor nodes will be powered primarily by DC power sources that can be recharged using a solar panel. The system will allow data logging at a user-defined interval ranging from one minute to one hour. Overall, the Wireless Sensor Network System for Landslide Detection will be able to provide large-scale data collection algorithms, power optimization schemes, scalability for field deployment, remote network configuration, data fusion for multiple data types, and network heterogeneity. Furthermore, it will be able to investigate the interaction among nearby sensors, which were designed to increase overall network reliability, decrease the probability of congestion around sink nodes, and provide scalability and tolerance against the breakdown or standby of some sensors.

In India, excluding the permafrost regions in the north, about 0.42 Million km2 areas of the landmass (12.6%) is landslide-prone which are spread over 19 odd numbers of States/Union Territories and are spreading over more than 65,000 villages in hilly/ mountainous areas (NDMA, 2019). North Eastern Region (NER) falls in the medium to high and high category of the Global Landslide Susceptibility Map. Relatively immature topography, fragile geologic base and active tectonics makes this region more susceptible to landslides. NER receives much rain fall because of its geographic and climatic conditions and located in Seismic zone.

Susceptibility of a region or area to landslide is mostly attributed to some causative factors, like topographic slope of the specific geo-environment, that is, the geometry of the rock-bed, rock-type/lithology(permeability and transmittivity of the rock layer type and the composition of different rock layers, geomorphology, aspect, anthropogenic factors such as land-use land-cover changes over time, drainage density, topographic wetness; which is a derived factor from drainage density and rock-type, geological discontinuities like curvature, lineaments or presence of faults lines, and the antecedent rainfall intensity etc. while there are some triggers for the landslide, which, if absent, a landslide might not happen although the area is susceptible to landslide based on the causative factors mentioned above. These triggers include heavy rainfall intensity or in some cases, seismic activity.

It is generally believed that when in a naturally sloping geological structure, like a valley, the lithology is made of subsequent layers of rocks which are alternatively porous and non-porous to liquid water, the surface water accumulated upslope may infiltrate to the lower rock layers where they cannot infiltrate anymore and hence increases the pore pressure in that layer. If this pore pressure exceeds some threshold value governed by the rock type, its weathering, presence of air cracks etc, a landslide process can initiate at that specific layer which can then form into a sliding landslide or rolling landslide depending on the geometry of the rock-bed. This evolution can be aided by increased surface / subsurface drainage density which can reduce the infiltration and increase the topographic wetness. Such kinds of drainage can be found as regular phenomena in the study area, especially in Meghalaya, Sikkim, Arunachal Pradesh and other hilly areas of the North Eastern India. Also, the North Eastern India is highly seismically unstable and the whole region is under seismic zone-5. Such vulnerability is largely due to presence of few major faults and lots of minor faults. The effect is such that lots of areas in the region have favourable causative factors for a landslide and seismic disturbances cause as triggers for landslides. However, the most important trigger for landslides in the region is high to very high rain rate (exceeding 100 mm/Hr also sometimes) which causes water infiltration through the porous layers and then get accumulated in impervious layers. As a result, the pore pressure builds. Also, the weathering causes soil particles to get mixed with water and causes generation of slip surface/slip plane which slowly dictates the evolution and anatomy of the landslide.

To be able to give an effective landslide warning, it is therefore essential to be able to predict/measure the pore pressure at the layer of accumulation and the rate of build-up of pore pressure with the rain rate. These two measurables, one external and another subsurface play the most important roles in causing the landslides and hence are two most critical observables. To calculate these two parameters, the project will include a portable disdrometer/rain gauge type of instrument with high accuracy rain rate measurement as well as a pore pressure sensor placed at a suitable depth corresponding to the slip surface/slip plane.

The most important part of the project is to establish the threshold values for such pore pressure and Rain Rate-Pore Pressure regression for specific areas chosen in the study such that these values can be used for raising actual warnings. Based on the actual outcomes (Landslide/no Landslide), a Machine Learning (ML) model can be run to adjust the threshold values over project duration to get good success rate. Slowly but surely, if all factors are taken into consideration and weights are adjusted suitably, such a ML model can produce good results over a sufficient time of testing involving at least 2-3 seasons of monsoon.

Knowledge of the causative factors of landslide for an area is of essence which can be accessed from an available landslide susceptibility map, a Geographical Information System (GIS) Map which shows susceptibility of a region based on the causative parameters. Such maps can be made from satellite imagery in the optical band of frequencies as well as from microwave band of frequencies. While optical data offers ease of interpretation, they are often lacking the required resolution, availability (due to revisit time of the satellite) and often masked by environmental factors such as cloud cover and rain, most prominent during the most critical times, unfortunately. Such issues can sometimes render the optical imagery next to useless. One solution to this is using high resolution Unmanned Aerial Vehicle (UAV) platforms to get better resolution and availability while they are mostly free from cloud cover related issues due to the altitude of their flight. However, these can also not be flown during rainy times, one of the major drawbacks. Microwave frequencies can penetrate the ground and hence, can give subsurface information up to few centimetres depending on the frequencies used with lower frequency bands (P & L) offering better penetration than higher frequency bands (S & C). While this may sound lucrative, often in this specific region, these signals face frequency interference issues and scattering from forest cover and underlying information cannot be obtained. As many hilly regions of the region are densely forested, microwave imagery is not of equal potence as for plain/naked land. However, a combination of good resolution optical and microwave imagery from satellites/UAVs may solve the problems mentioned above when used in tandem in complimentary manner.

Another factor of importance is the scale of such susceptibility maps. While the higher resolution maps are desirable, Geological Survey of India (GSI), the nodal agency in the country for generating such maps, provides 1:50,000 scale maps. However, NESAC has an inventory of 1:25,000 scale maps of large areas of the region along the Shillong-Silchar-Aizawl Highway, one of the most landslide prone stretch of the region. Finally, NESAC also has 1:10,000 scale maps of Guwahati city. Using all these available Landslide Susceptibility Maps, vast areas of the region can be used as a test area. Most prominently, areas in Sonapur (Meghalaya), Aizawl (Mizoram) and along Shillong-Guwahati Highway, Sikkim can be considered for placement of the sensors. Some sites with less landslide risks, like in Tripura can be considered for checking the behaviour of the thresholds and performance of the model.

Accordingly, the following instruments will be required for getting Rain Rate and Pore Water Pressure.

1. Digital/ Tipping Bucket Rain Gauge (For instantaneous Rain Rate).
2. Pore Water Pressure Sensor (For Pore water pressure).

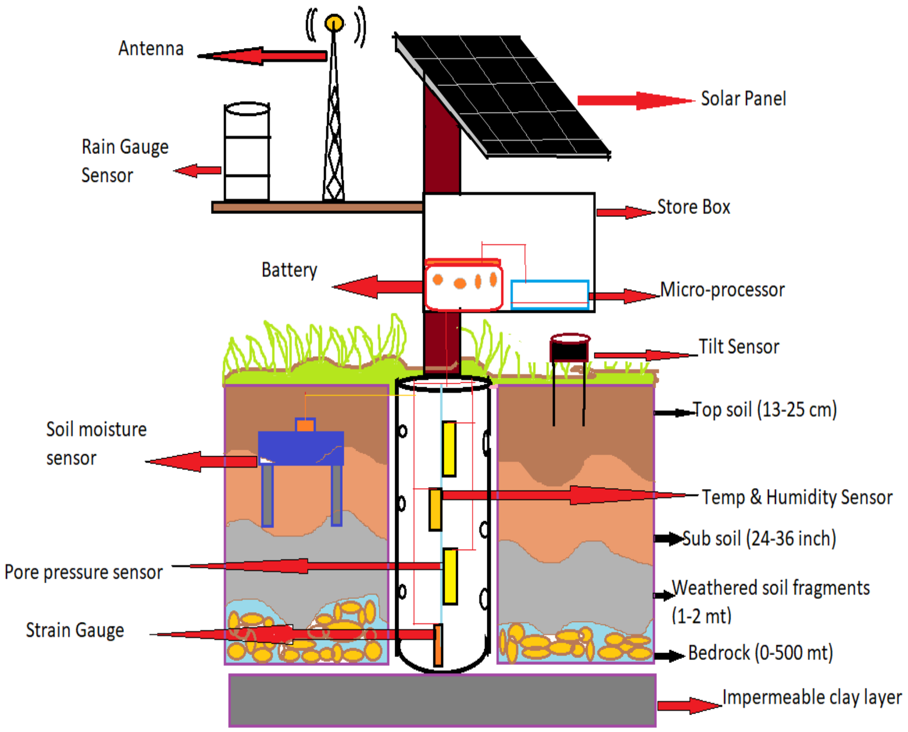

Figure 1: Schematic Diagram of the proposed system

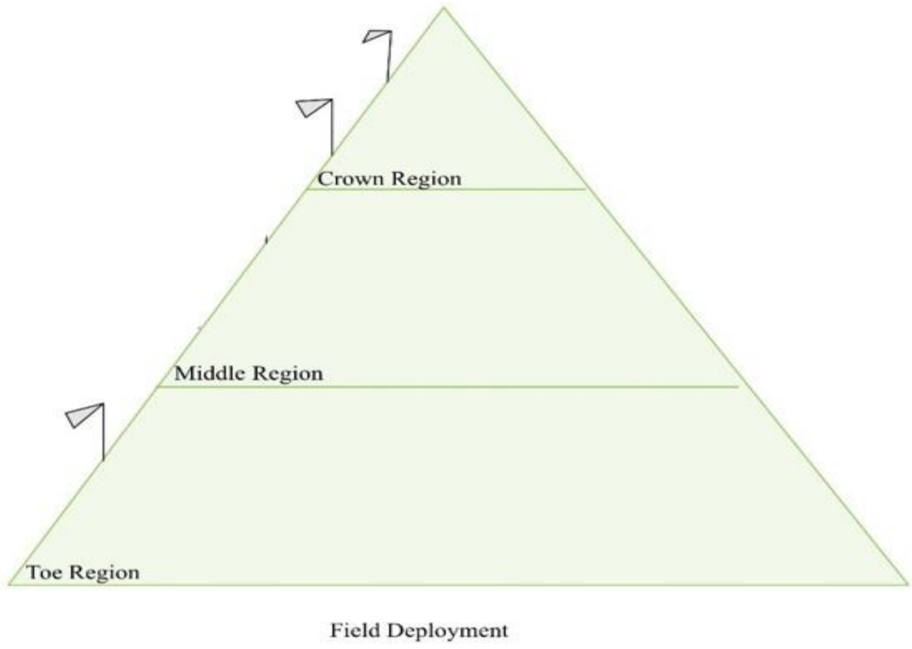

Figure 2: Field Deployment of Sensor Nodes

9) Experimentation / Studies / Field Work:

Figure 3 shows the block diagram of the proposed system setup of microcontroller based Real-time landslide Detection and alert system using wireless sensor network. Interfacing of water pressure sensor, rain gauge sensor, tilt sensor, DHT-22 (Temperature and Humidity), GPS, with Arduino board. Then the sensors data along with position coordinates of dedicated sensor node will be send to the end user using LoRaWAN technology.

Figure 4 shows the block diagram of sensor node wireless communication using LoRaWAN technlogy. LoRaWAN (long range wide area network) is a specification of wide area network used for very-long distance communication with low power consumption but also at low data rate. LoRaWAN is a prototypical Internet-of-Things (IoT) technology, because its chips are cheap and consume little energy. Moreover, in IoT, many sensors often only need to periodically report small amounts of data, so high datarates are not called for.

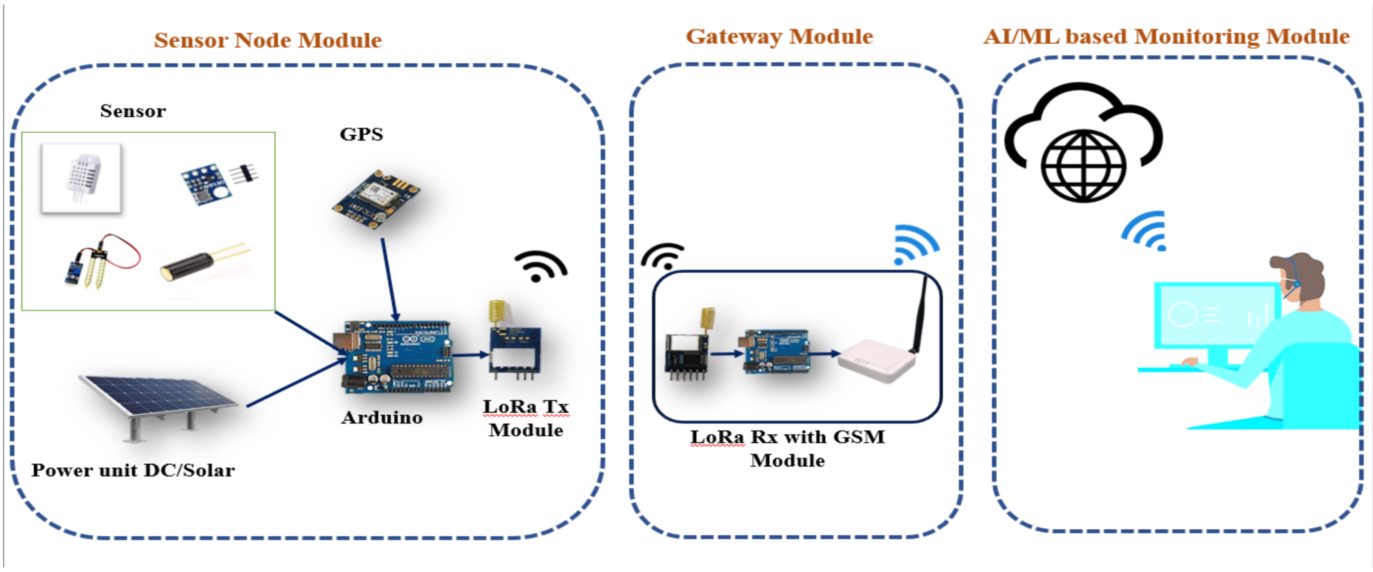

Figure 3: Block Diagram for the proposed device

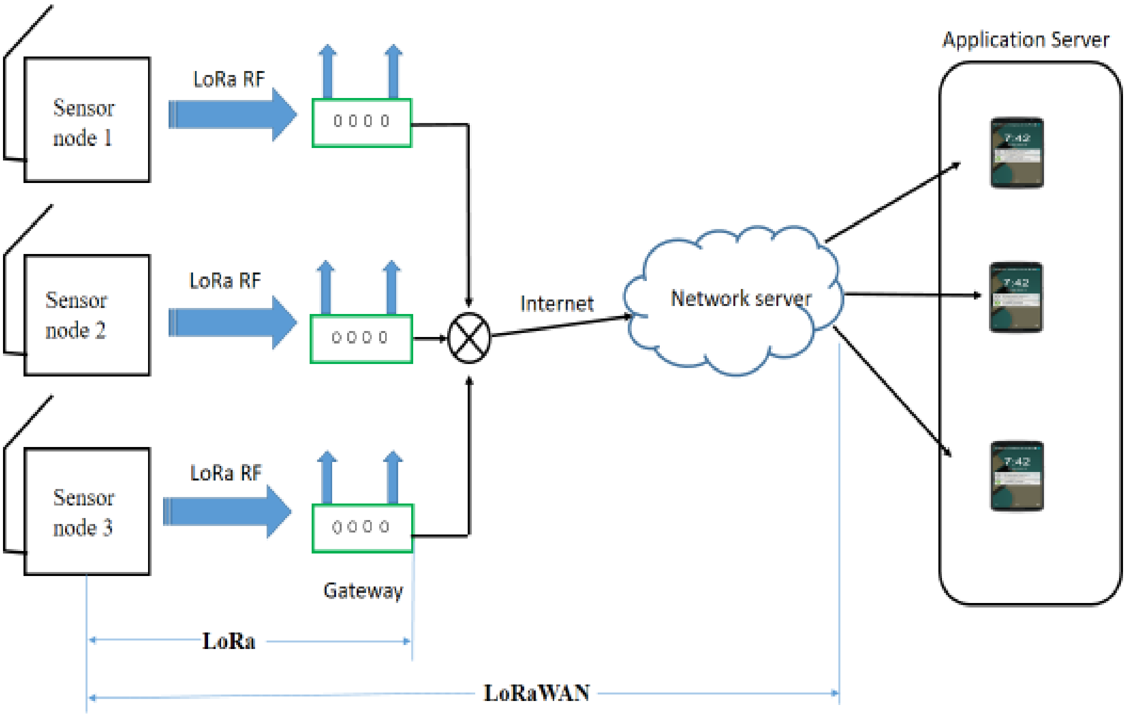

Figure 4: Sensor network using LoRaWAN Technology

LoRaWAN architecture consists of gateways, network-servers, and application-servers. The IoT nodes – often built on Arduino and Rasberry Pi – that communicate via LoRaWAN send messages via LoRa radio frequencies in the unlicensed ISM band. When such a message is received by a gateway, which is connected to the Internet, it sends the message to the network-server, which filters duplicate messages and performs some additional tasks. The application-server collects the messages and presents them to the right users.

- The working principle of a LoRa transceiver can be understood through the following steps:

- **Modulation:** The transmitter uses a modulation technique called Chirp Spread Spectrum (CSS) or chirp modulation.
- **Data Encoding:** The data to be transmitted is first encoded, typically using techniques like error-correcting codes. This encoding helps in detecting and correcting errors that may occur during transmission.
- **Chirp Generation:** The encoded data is then converted into a chirp signal. A chirp is a signal that sweeps linearly across a range of frequencies over time. The frequency of the chirp changes at a constant rate, and this rate is one of the key parameters that determine the communication range.
- **Spreading Factor:** LoRa supports different spreading factors, which determine the duration of each chirp symbol. Spreading factor values can range from 7 to 12, with higher spreading factors providing longer range but lower data rates.
- **Amplification:** The chirp signal is then amplified to an appropriate power level for transmission.
- **Transmission:** The amplified chirp signal is transmitted using an antenna. The transmission frequency is typically in the sub-GHz range (e.g. 868 MHz, 915 MHz) to take advantage of the better propagation characteristics at these frequencies.
- **Reception:** On the receiving side, a LoRa receiver with a matched spreading factor and frequency range can demodulate the received signal to extract the encoded data.
- **Decoding:** The received chirp signal is then decoded to retrieve the original data.

- **Data Processing:** The decoded data is processed further, and if necessary, additional layers of communication protocols are applied to ensure reliable data transfer between the transmitter and the receiver.

10)Machine Learning based Landslide Prediction:

Accurate early prediction of landslides is the most effective solution to disaster management due to landslide. The proposed landslide-monitoring device contains several sensors such as soil moisture, rainfall intensity, tilt, pore water pressure etc. which continuously sense different environmental information over a long period. Hence, the size of the monitoring data will be huge and it is quite impractical to analyze the data manually. The artificial intelligence-based machine learning (ML) approach can act as an efficient tool for automated analysis of sensor data and accurate early prediction of landslides. Reliable prediction of landslides using ML through topographic data, geological data, satellite images, forecast data etc. are extensively studied in the literature. The studies also suggest that the standard approaches such as artificial neural network (ANN), support vector machine (SVM), random forest, Ensemble techniques etc. can effectively predict landslides.

In the proposed landslide prediction framework data from different sensor nodes are wirelessly transmitted through the LoRA module to the gateway and uploaded to the data processing system through standard GSM service. Each received sensor data contains time-series information of different environmental monitoring parameters over time. The suitable operation of ML approaches requires an effective feature matrix. Different handcrafted features like statistical features, and transform domain features will be calculated from the sensor time-series data and will be applied to the predictor. The effectiveness of the ML-based technique is highly determined by the size of the training dataset, class balancing and as well as data variation while the training process. The proposed ML-based landslide prediction framework also demands a standard training dataset for the accurate prediction of landslides in test-case scenarios. In such context, sensor data of landslide and non-landslide environments will be captured over a couple of years in different time-interval. A standard dataset for the training of the ML classifier will be prepared from the sensor data received throughout the years. With sufficient training of the ML classifier, the accurate prediction of future landslides will be done in real-time. The proposed data processing and ML-based landslide prediction system will be developed in open-source Python programming. The proposed framework also includes an early alert system in terms of short message service on successful prediction of landslides.

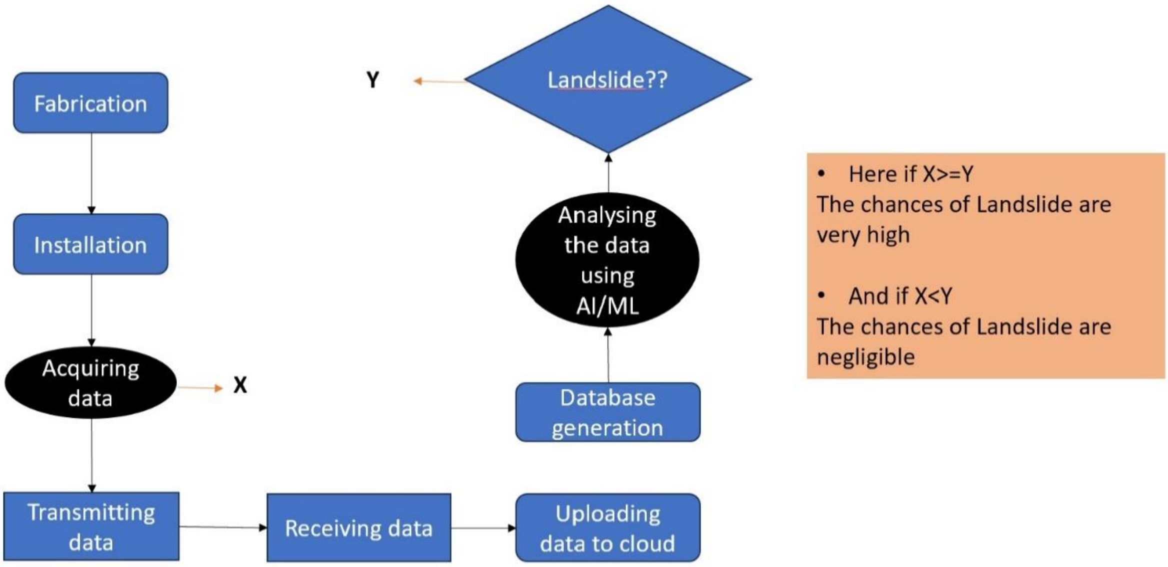

Fig. 5. Flow Chart of the proposed system

Fig 5 shows flow chart of the proposed system.

- Firstly, interfacing of all the sensors will be done one by one.
- Then comes the installation of the sensor nodes in the test locations.
- On successfully installing the sensor nodes, data acquiring (eg: X) will start.
- After the data is acquired, transmission of data through LoRa module will take place.
- The data is then received in the receiver and is uploaded to the cloud for data analysis.
- An AI/ML algorithm will be utilized to learn the landslide occurrence scenario over time.
- Threshold value will be observed (eg:Y) in case of landslide.
- Now if the acquired data (X) is equal or greater than threshold value (Y), there is a high chance of landslide to occur.
- And if the acquired data (X) is less than threshold value (Y), the chances of landslide is negligible.

11) Landslide Prone Areas in North-East:

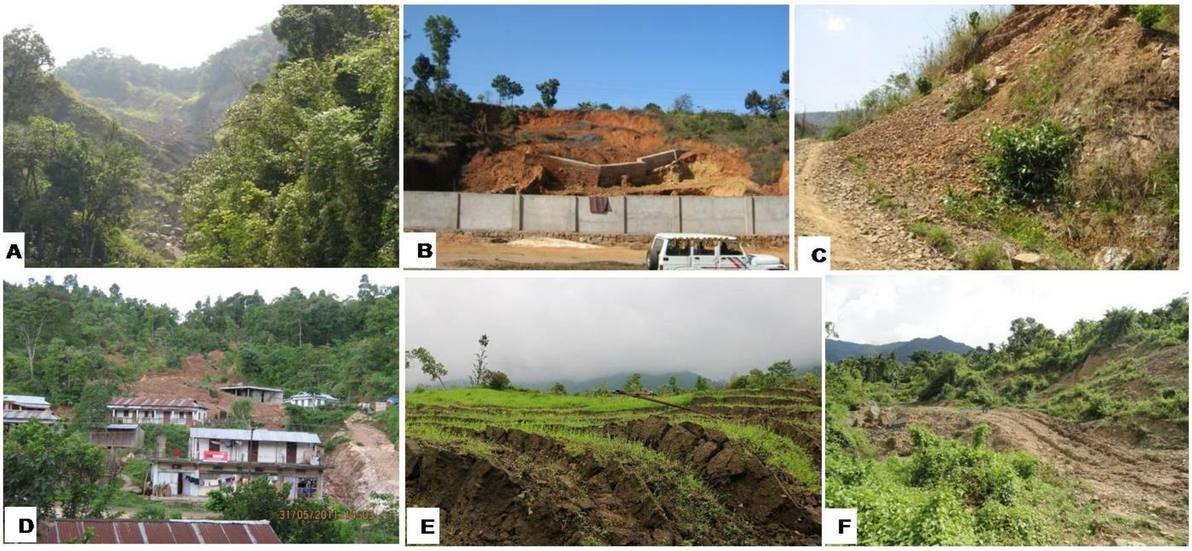

Fig. 6(A-F): -Landside in Manipur, Meghalaya and Assam

Fig. 7:-Landside in Halflong and Sonapur

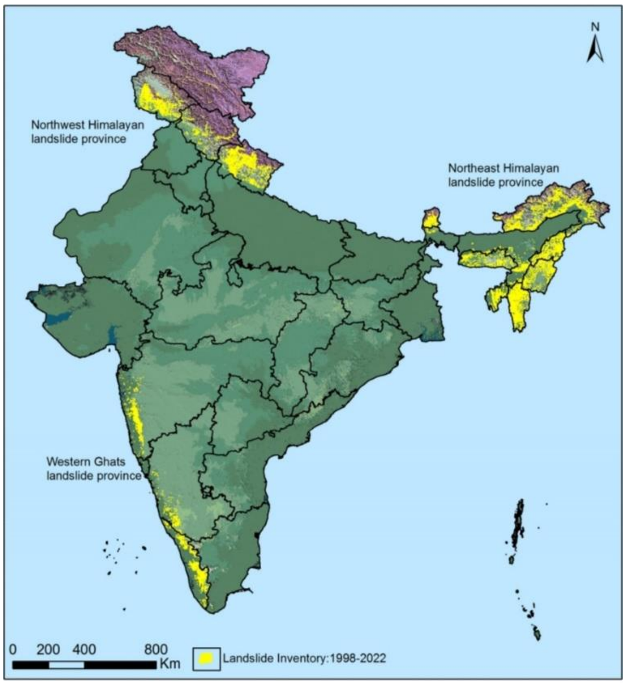

Fig 8 (a). Landslide inventory of India

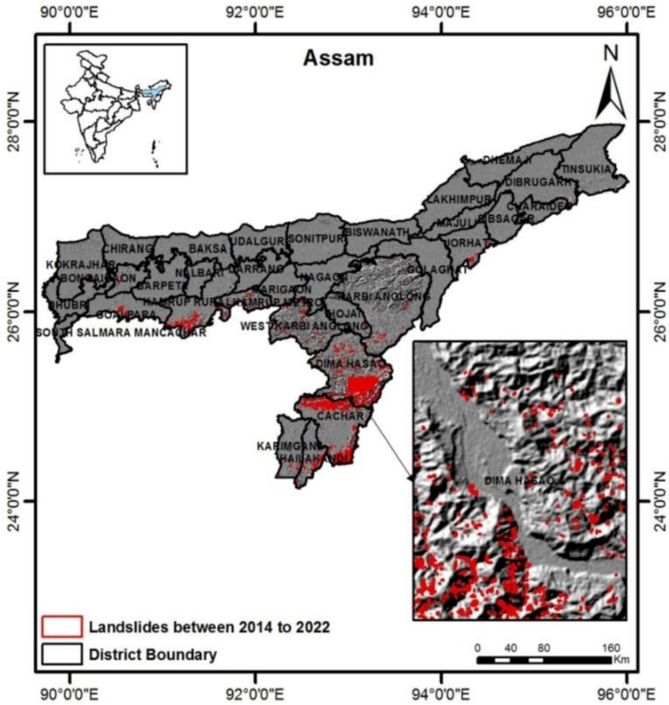

Fig 8 (b). Landslide inventory of Assam

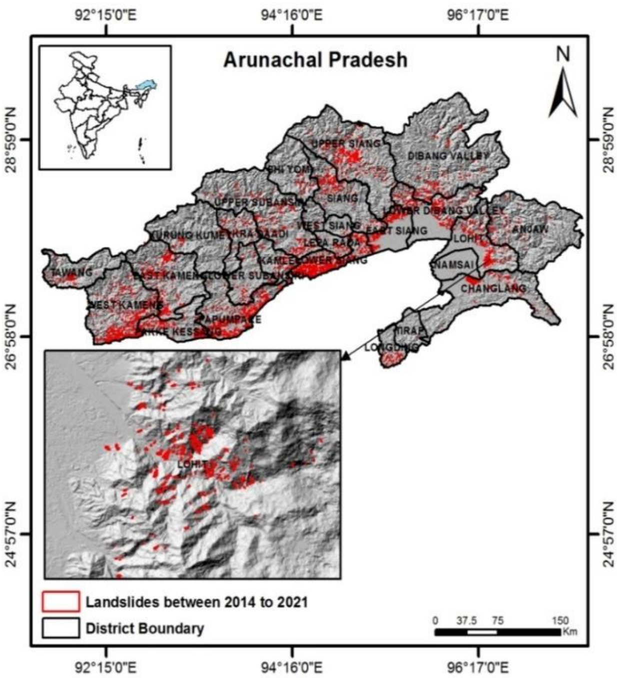

Fig 8 (c). Landslide inventory of Arunachal

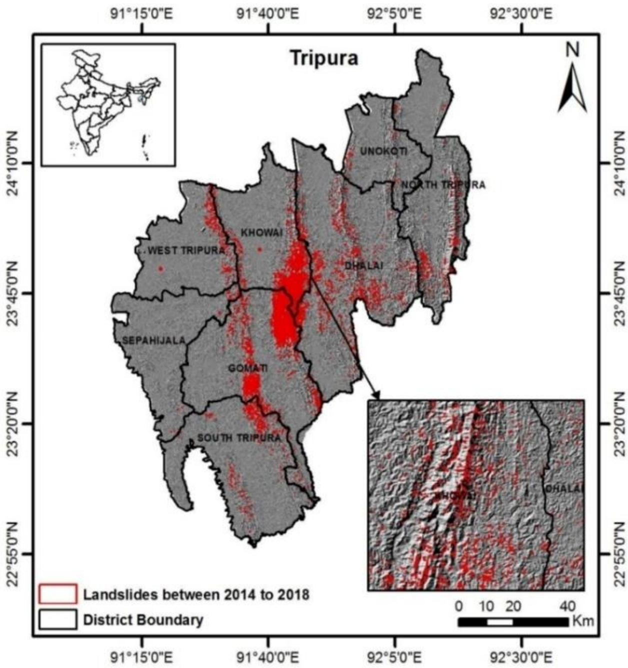

Fig 8 (d). Landslide inventory of Tripura

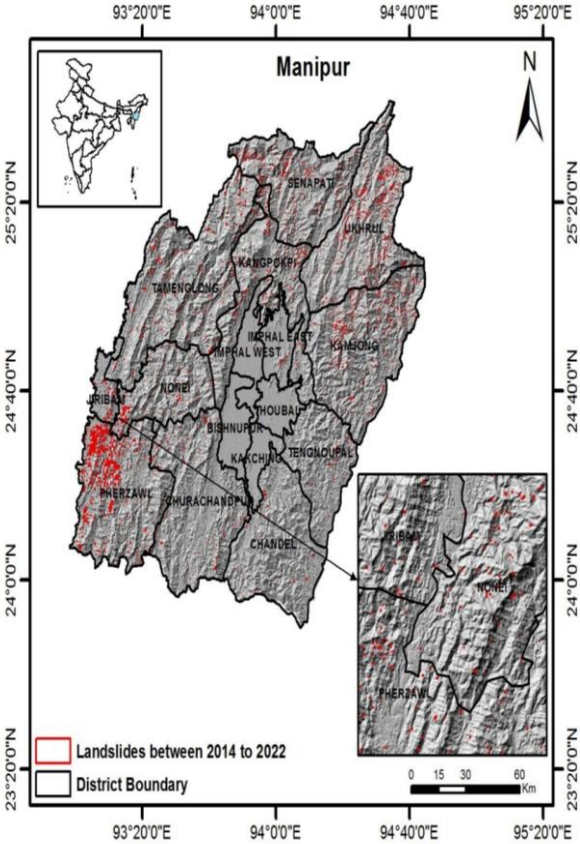

Fig 8 (e). Landslide inventory of Manipur

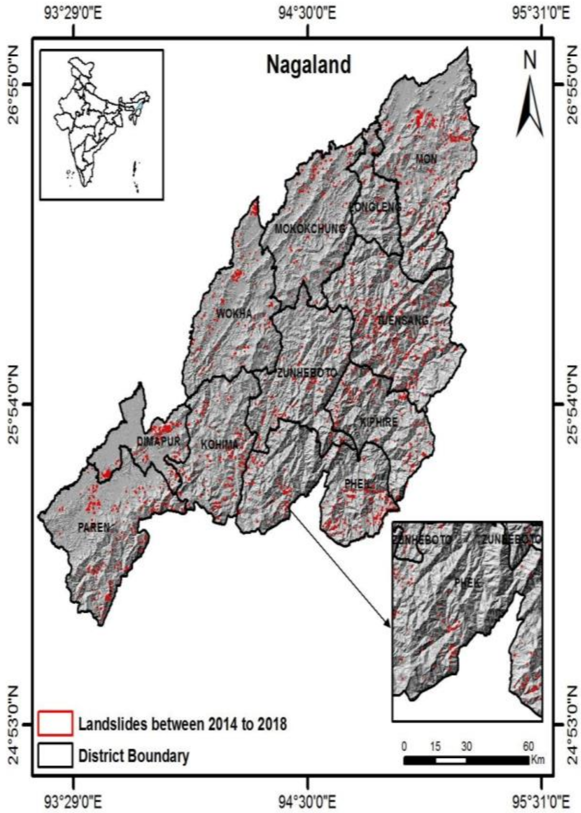

Fig 8 (f). Landslide inventory of Nagaland

Fig 8(a). to **Fig 8(f).** gives Landslides mapped using high-resolution satellite data of different north-eastern states.

12) Required Components:

 **1. Arduino UNO** Arduino is a microcontroller. It runs only one Program again and again.	 **2. Temperature and Humidity Sensor** It is a device that uses a capacitive humidity sensor and a thermistor to measure the surrounding air and shows a digital signal
 **3. Strain Gauge** Used to measure strain	 **4. Tilt Sensor** Measures the slope or the angle of objects.
 **5. Soil Moisture Sensor** Used for detection of moisture in the soil.	 **6. Pore Water Pressure Sensor** Used for detection of pore water pressure of the soil.
 **7. LoRa module** Used for long range communication	 **8. Solar Panel** It absorbs sunlight as a source of energy to generate direct current
 **9. Automatic/Digital Rain Gauge (ARG01)** To measure the instantaneous rain intensity.	 **10. GPS Module** It provides the position of the system to which it is connected.
 **11. LCR Pro1/Pro Plus** It is used for components verification and sorting, laboratory and service center, in-field repair.	 **12. 3-axis accelerometer sensor** A 3-axis accelerometer is used to calculate the pitch and roll of the drilling bit.

13) Expected Results:

The major outcome of the project shall be as follows:

I. An integrated system for real time landslide Detection which will act as a sensor node and the values of real time sensor data will travel by LoRa RF which will further uploaded into the network server using LoRa gateway at a longer distance.

II. The developed sensor node shall be deployed over landslide prone areas, they will communicate with their respected LoRa gateway which is kept at very longer distance.

III. Provision of real time data display at mobile/web page. And in case of landslide, based on the data analysis alert/warning message will generate.

14) Deliverables:

The project shall have the following deliverables

- A complete System for landslide Detection.
- Implementation of the developed sensor nodes by deploying it in landslide-prone areas (Halflong/ Sonapur) test locations.
- Installation of software tools and hardware required for transmitting (LoRa gateway, sensor nodes) and receiving of real time data in display module.
- Data analysis and alert message generation in case of landslide.

15) Project duration: Three (3) Years

16) Detail of Students working on the project:

Interested M.Tech & B.Tech students for the project are listed below-

M.Tech & B.Tech. Students	**Year And branch**
Ms. Rituparna Bhattacharya	M.Tech 2nd Year Communication Email:rituparnabhattacharya135@gmail.com
Ms. Nandita Debnath	M.Tech 2nd Year VLSI Email: dnandita963@gmail.com
Mr. Deepak Kumar	3rd Year ECE Email : dk2030965@gmail.com
Mr. Shreyas Channeshappa Shetty	3rd Year ECE Email: shreyasshetty311202@gmail.com
Mr. Rachit Jhunjhunwala	3rd Year ECE Email: jhunjhunwalarachit@gmail.com
Ms. Arpita Saha	3rd Year Civil Email: arpitasaha1426@gmail.com
Ms. Debadrita Nath	2nd Year ME Email: nathdebadrita4@gmail.com
Mr. Kundan kumar	3rd Year ECE Email: kundan51kk@gmail.com
Mr. Debajyoti Roy	3rd Year ECE Email: deba9862@gmail.com

17) Milestone:

The quarterly milestones to be achieved while executing the project including the responsible organisation to executing the corresponding component is described below:

Sl. No.	**Milestone (months)**												**Work Elements**	**Responsible Organization**
	3	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**		
1.													Purchase of materials and components, PC, software (if any)	NIT Agartala
2.													Design, development and testing of the sensor nodes, drilling, cutting, PVC based material designing and their implementation.	NIT Agartala
3.													PCB layout design, PCB fabrication and component Assembling. On field Testing of the developed device	NIT Agartala, NESAC
4.													Data transmission over LoRaWLAN, and data analysis. Realization of final end product.	NIT Agartala, NESAC

18) Budget:

Total budget required for the project is Rs 31,54,000 (Rupees Thirty-one lakhs fifty-four thousand only) spared over three years. The budget break up is provided below:

S.N	Items	1st Year	2nd Year	3rd year	Total
1	Human Resource (One JRF)	3,72,000	3,72,000	N. A	7,44,000
2	Procurement of Equipment and all other accessories	8,00,000	3,50,000	1,50,000	13,00,000
3	Consumables	40,000	60,000	50,000	1,50,000
4	Contingency	50,000	50,000	20,000	1,20,000
5.	Installation, brickwork, box fitting& labor costs	80,000	1,00,000	1,00,000	2,80,000
6.	Other Costs (Characterization Outsourcing, Testing, fabrication cost, patents, electrician cost etc.)	70,000	1,00,000	1,50,000	3,20,000
8.	Travel (NESAC, NITA, Test zone, Site visit, etc)	75,000	85,000	80,000	2,40,000
	Total	**14,87,000**	**11,17,000**	**5,50,000**	**31,54,000**

19) Describe the Societal application part of the outcome of this project:

The developed landslide monitoring system can measure unsaturated soil behaviour, which causes shallow landslides on natural slopes, in real time. It was possible to quantitatively evaluate landslide hazards in the analysis domain and create spatial classifications of landslide hazard levels based on the long-term monitoring results so that some requisite action could be taken before the landslide. It may save hundreds of people's lives in that particular location, which will ultimately benefit society.

20) Describe, how it is going to generate business:

The product is expected to be very cost-effective, and it usually costs around Rs. 2 crores globally. Wireless sensors are becoming increasingly popular because sensor nodes are small, simple, and inexpensive, requiring no cabling to connect them to one another or to a control center, and they can be used in a variety of disaster management and environmental monitoring applications. This is how this project can generate a huge business.

21) Describe how it will help start-ups:

As of date, there is no industry that produces such an integrated system for landslide monitoring. Landslides are the third biggest natural disasters in the world, with India experiencing the biggest bulk of them: 15 percent of the country is prone to landslides, and India has the highest number of landslide deaths in the world. So to reduce fatalities and damage, a greater number of sensor nodes need to be installed. Therefore, constant monitoring is very demanding, and our proposed design is going to play a vital role for the public's benefit. As the system is expected to be cost-effective, it will be a very motivating and ideal platform for start-ups.

22) Describe how it will help students to become future entrepreneurs:

The complete project is associated with social, technical, experimental, and testing fields. The involved students will get a chance to develop a new and compact product. They will also learn about methods of sensor networks, data collection, data transmission, PCB design, and digital archiving. It will motivate students, as this project is for societal benefit. This should therefore motivate students to become entrepreneurs in the future.

23) Other Details (if any): NIL

Annexure 1

The tentative budget of the proposed instrument (for a single sensor node).

SN	Components	Application	Estimated Price (Rs.)(Tentative)	Measurement Range
1	Arduino or equivalent system/ components compatible to the circuit or module	Microcontroller	3000/-	Fast response
2	DHT22 or equivalent components compatible to the circuit or module	Temperature and Humidity sensor	700/-	Temp:(-40 - 80°C) Humidity: (0-99.9%)
3	LoRa module Sx178, rlyr890 module or equivalent system/ components compatible to the circuit.	Transceiver for long Range communication	5,000/-	915 MHz

4	SOLAR PANNEL, Charger & Battery or equivalent system/ components compatible to the circuit or module	Power supply	7,500/-	20 W, 12 V
5	Tilt Sensor compatible to the circuit or module	Measure the slope or angle or tilt of objects	500/-	Supply voltage: 3.3 V to 5V. Maximum output current :15mA
7	LoRa Gatewayor equivalent components compatible to the circuit or module	transceiver	30,000/-	Low power, bidirectional communication
8	Digital/Tippling bucket Rain Gauge Sensor	Rain fall intensity measure.	45,000/-	203mm
9	Soil Moisture sensor or equivalent components compatible to the circuit or module	Soil moisture detection	2,000/-	0.05-5 ppm
10	Strain Gauge	To measure the strain	600/-	0.005
11	Pore Water Pressure sensor	To measure the water content of the soil	2,000/-	90kPa to 1MPa
12	DATA LOGGERor equivalent components compatible to the circuit or module	Storing data	1000/-	Working voltage: 3-5volt
13	JUMPER WIREor equivalent components compatible to the circuit	Connecting wires	2,000/-	Connecting wires (male to male and male to female all type)
14	Bread Board, Varo Board	For connecting and Testing of components	700/-	At initial stage for Testing of circuit.

15	GPS module or equivalent components compatible with the circuit or module	Lat, Long, Time	1000/-	Input: 3-5 volt Tracking sensitivity: -161dBm Position accuracy: 2.5m
16	3-axis accelerometer/motion sensors	It is used to calculate the pitch and roll of the drilling bit.	2,000/-	The 3-axis accelerometer consists of three -5 to +5g accelerometers that are mounted on a block.
17	Miscellaneous	Drilling, cutting, PVC-based material, IP 67 waterproof casing, etc.	60,000/-	If any additional components are needed
Total (Tentative) cost			**Rs. 1,63,000**	

A total of 5 sensor nodes (approx.) will be deployed in a test location vulnerable to landslide in Northeast India.

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