



Flood Inundation Mapping Using Dual-Polarization C-Band Synthetic Aperture Radar (SAR) in Google Earth Engine for Kaziranga National Park-2020

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Abstract: Every year, the Indian state of Assam, which lies in the heart of Southwestern Monsoon belt, receives excessive rainfall. The existence of long ranges of mountain belts on the northern and northeastern frontiers of the state causes the surface runoff to flow down the vast alluvial plains, causing the rivers to swell up. The mighty river Brahmaputra flows through the Kaziranga National Park thereby killing and injuring hundreds of animals. Animals adapt naturally to floods but when the waters hit a certain level, they gravitate towards safer, higher ground in the Karbi Anglong hills. Over the years, the highway is getting increasingly tough to cross. A few of the nine wildlife corridors on the highway — Panbari, Haldibari, Bagori, Harmati, Kanchanjuri, Hatidandi, Deosur, Chirang and Amguri — are choked by traffic. Therefore, Initiatives recommends the need for landscape-scale conservation. Optical data does not stand adequate to meet the requirements for flood analysis in the region during the monsoons. Synthetic Aperture Data, on the other hand, makes the study of the Brahmaputra basin possible even during the cloudy monsoons. SAR sensors work by emitting microwave radiation and are sensitive to the “roughness” and “wetness” of the target. Google Earth Engine(GEE), a cloud based platform for planetary based geospatial analysis, brings about computational ways to monitor, study and predict high impact societal and surface phenomenon like floods. The research aims to analyze flooding in the Brahmaputra Valley, with special reference to Kaziranga National Park using dual polarization C-band data in the GEE platform. The study aims to identify and classify the inundated areas and introduce further prospects of visual data analysis.

Index Terms - Southwestern Monsoon, SAR, GEE, Dual Polarization

I. INTRODUCTION

BACKGROUND

The Indian state of Assam has a total geographical area of 78,438 square kilometers. The state is located between 900-960E and 240—280N. The Brahmaputra river forms a tectono-sedimentary basin in the state which is 760km long and 80-90km wide. The basin receives an annual rainfall of about 230cm. During the monsoons, the Brahmaputra river traversing across the state causes large scale damage to life and property in the form of floods.

The floods historically rejuvenate croplands and alluvium deposits. Therefore, it is undeniable that the ecology of the region cannot survive without floods. However, the Brahmaputra changes its course frequently, making it impossible to control floods by traditional methods like construction of embankments. The wildlife in Kaziranga and Manas National parks, two of the most biodiverse regions of northeast India, have been severely affected by floods. As per media reports, ‘90% of the Kaziranga National Park is reportedly submerged’ in floodwater in 2020.

It has therefore become imperative that we take necessary steps to control floods and properly plan human settlements and animal corridors in the region. Our research aims to study the Brahmaputra River Basin by using Synthetic Aperture Data. The study objectivizes on how the river has changed its course over time, how and where floods take place, what percent of ecological reserves get affected, soil erosion and how floods have impacted settlements and wildlife over the years. The prominent researches conducted by Kushwaha and others in 1999 reveal that there has been significant reduction in rhino habitats due to flooding. The research is expected to lay a foundational basis on which further planning can be done for flood control, settlement planning, establishment of animal corridors, wildlife highland shelters and sustainable agriculture.

II. STUDY AREA:

KAZIRANGA NATIONAL PARK

The Kaziranga National Park (KNP) stretches from 26o 35’ N to 26o 45’ N and from 93o 05’E – 93o 40’ E. Having a length of 40km (25mi) in length from east to west and a breadth of 13km from north to south [2], the national park is spread across the districts of Nogaon and Golaghat in the state of Assam. [1] The national park has a total area of about 429 sq. km (166 sq. mi)[2], which is one of the largest protected areas for wildlife in northeastern India. The boundary of the national park is demarcated by the Brahmaputra river in the north and the Karbi Anlong hills in the south. The region predominantly has a flat terrain, with elevation varying from 55m t 75m [3] above the sea level and distinguished by east to west incline. The park is a mosaic of eastern wet alluvial grasslands, alluvial plains, semi evergreen forests, tropical moist evergreen forests, eastern Dillenia swamp forest, wetlands and sandy islands [4].

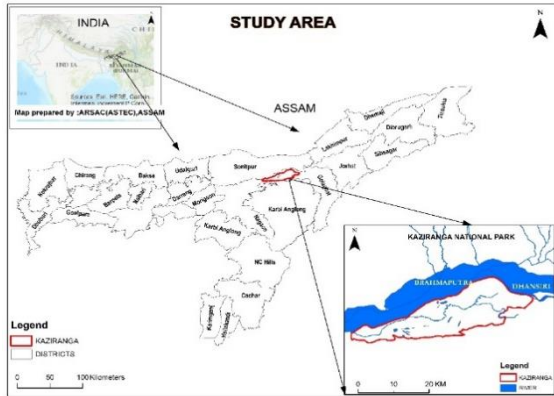


Fig 2.1: Location of KNP



Fig 2.2: Optical imagery of KNP

The National Park is characterized by four different types of vegetation: alluvial inundated grasslands, alluvial savannah woodlands, tropical moist mixed deciduous forests and tropical semi evergreen forests [4]. Numerous small rivers and channels flow through the region and ultimately drain into the Brahmaputra river. The Mora Diphlu , Diphlu and Mora Dhansiri [5]are some prominent rivers in the region. Relicts of older channels of river flow have resulted in the formation of ‘ox-bow’ lakes, locally known as beels. There are about 9 beels of area 50-150 ha inside the park. Some of these lakes have silted up, resulting in the formation of swamps and marshes. Consequently, there has been an increase in area with long grass and comparative reduction of area with short grass [2].

The national park experiences a sub-tropical type of climate. The winter season, usually between November and February, is moderately cold and dry. The summers are characterized by hot and wet climate. The monsoons last from June to September and are responsible for most of Kaziranga’s annual rainfall (2,220 mm) [6]. The floods are an annual phenomenon and causes 50-70% [2]of the total land area to submerge under water. The Karbi Anlong hills, which form natural highlands, do not get flooded. Erosion and shifting of Brahmaputra causes a lot of change in area of the park every year. The flood also causes widespread destruction to flora and fauna. [7]

Sl. No.	Land Cover Type	Area (sq. km)	% Area
1	Woodland	114.01	27.95
2	Short Grass	12.30	3.01
3	Tall Grass	248.85	61.01
4	Beels	24.32	5.96
5	Jiya Diphlu	3.96	0.97
6	Mora Diphlu	2.84	0.70
7	Sand	1.62	0.40
	Total	407.90*	100

Table 2.1: Land Coverage in Kaziranga National Park (extracted from Kushwaha, 1997)

Sl. No.	Vegetation Type	Percentage Composition
1.	Moist mixed deciduous forests	29.13
2.	Grasslands	51.91
3	Water logged/ beel	6.62
4	Swamp/marshy area	5.21
5	Sand	7.12

Table 2.2: Vegetation Composition in Kaziranga National Park (extracted from Barua and Goswami, 1996)[8]

*Excludes eroded area/ area submerged by Brahmaputra due to change in river course.

The western part of Kaziranga is mainly covered by grassland. The tall ‘elephant’ grass is found on the higher grounds and short grass is found on low lying areas around water bodies. Grasslands are characterized by scattered trees and shrubs like Bombax ceiba, Dillenia indica, Careva arborea etc. The evergreen/ deciduous forests are characterized by tall and dense vegetative species like Aphanemixis polystrachya, Talauma hodgsonii, Garcinia tinctoria etc.[9]

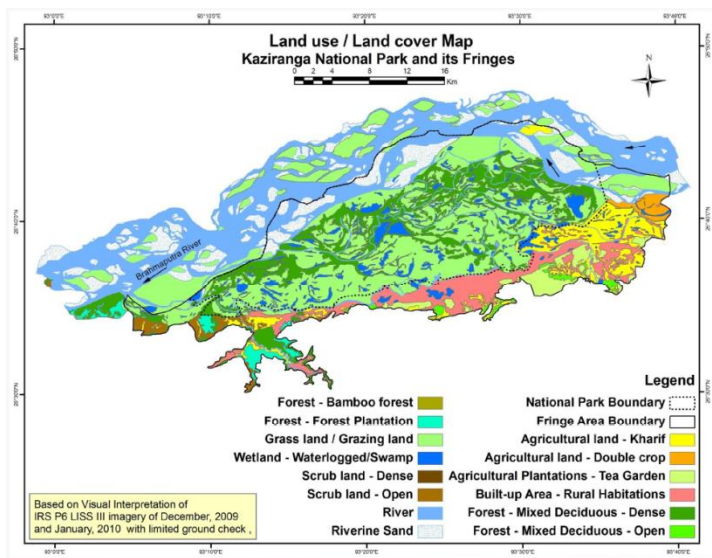


Fig 2.3: Classified map of KNP

III. PLATFORM & DATA USED:

The Google Earth Engine is a cloud based platform for accessing high performance computing resources for processing very large geospatial datasets. The platform gives the opportunity to develop algorithms to produce systematic data products or employ interactive resources supported by the Google Earth Engine platform. The platform consists of a multi-petabyte analysis ready data catalog co-located with high performance computational services. The features can be accessed through application programming interface (API) supported by an interactive development environment (IDE). That enables prototyping and visualization of results. The platform has a large collection of publicly available geospatial satellite and aerial imagery datasets in optical and non-optical wavelengths and environmental and climatic variables. The dataset mainly comprises of remote sensing imagery including Landsat, Sentinel-1 and Sentinel-2 archives. The data catalog is continuously updated at the rate of 6400 images per day from active missions.

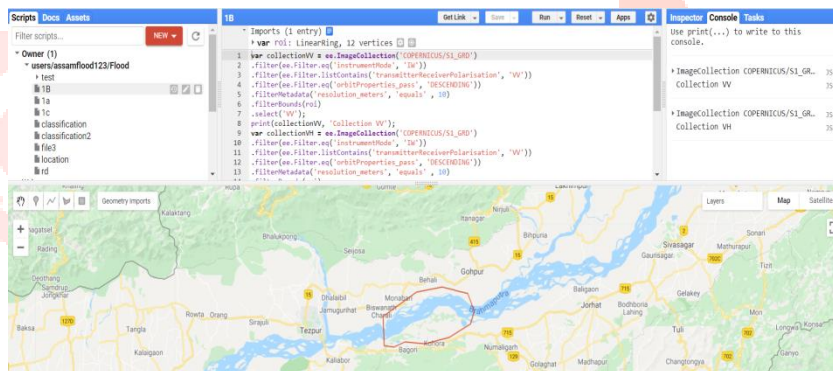


Fig 3.1: Google Earth Engine Code Editor Window

IV. CWC DATA:

The Brahmaputra River originates from Angsi Glacier of the Kailash Ranges in the Tibet. The river basin is 2900km long, most of which lies in Tibet. The river traverses a distance of 900km in India, of which 700km lies in the state of Assam. In its way through Assam, the river is joined by 20 important tributaries on its north bank and 13 important tributaries on its south bank. Besides, there are several small brooks and streams which join the Brahmaputra along its course. The water discharge by its numerous tributaries in Assam result in heavy during the monsoons.

The Central Water Commission (CWC) maintains detailed record of the water levels in different river systems across the country. The CWC is a technical organisation that works under the Ministry of Jal Shakti of the Government of India. The body provides consultation to various state governments on water bodies issues and coordinate with various governments at different levels for conservation, control and utilisation of water resources.

The landscape and drainage of Kaziranga National Park is influenced by several small streams and rivers like Dhansiri, Mora Dhansiri, Diphlu etc. and the mighty Brahmaputra. However, the CWC does not maintain flood record data for all the rivers and streams flowing through the region. The Commission maintains river monitoring stations at Nimatighat, Jorhat (Brahmaputra river), Numaligarh, Golaghat District (South Dhansiri River), Tezpur, Sonitpur District (Brahmaputra river) and Kampur, Nagaon District (Kopili River), all at a radius of 100km from the heart of Kaziranga National Park. The following tables shows the data collected from the CWC stations. Each table shows the warning level, danger level and highest flood level recorded at the respective places. The analysis of flood forecast and actual flood level has been done to analyse the severity of the floods in KNP in July, 2020.

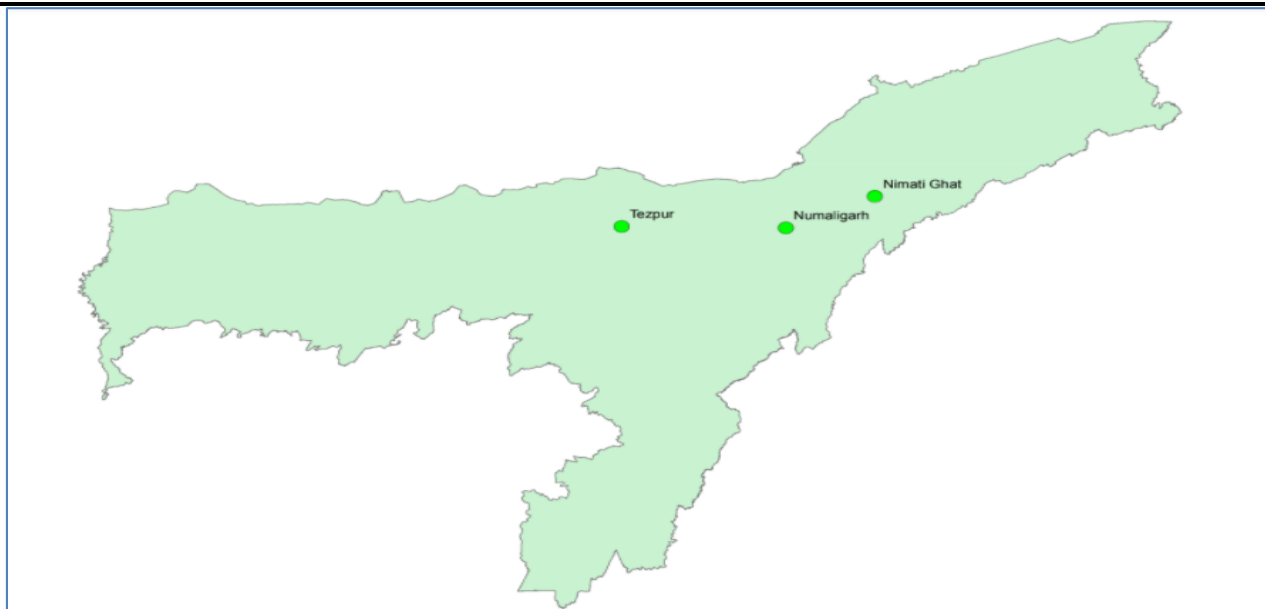


Fig 4.1: Location of CWC river monitoring stations- Tezpur, Numaligarh and Nimati-Ghat

Table 4.1: Flood record data, Nimatighat Station (Brahmaputra River), July 2020.

DATE	WARNING LEVEL(m)	DANGER LEVEL(m)	HIGHEST FLOOD LEVEL(m)	ACTUAL WATER LEVEL(m)
01/07/2020	84.04	85.04	87.37	85.77
02/07/2020	84.04	85.04	87.37	85.68
03/07/2020	84.04	85.04	87.37	86.64
04/07/2020	84.04	85.04	87.37	85.59
05/07/2020	84.04	85.04	87.37	85.7
06/07/2020	84.04	85.04	87.37	85.69
07/07/2020	84.04	85.04	87.37	85.79
08/07/2020	84.04	85.04	87.37	85.91
09/07/2020	84.04	85.04	87.37	86.06
10/07/2020	84.04	85.04	87.37	86.44
11/07/2020	84.04	85.04	87.37	87.13
12/07/2020	84.04	85.04	87.37	87.35
13/07/2020	84.04	85.04	87.37	86.93
14/07/2020	84.04	85.04	87.37	86.44
15/07/2020	84.04	85.04	87.37	86.16
16/07/2020	84.04	85.04	87.37	85.97
17/07/2020	84.04	85.04	87.37	86.04
18/07/2020	84.04	85.04	87.37	86.18
19/07/2020	84.04	85.04	87.37	86.36
20/07/2020	84.04	85.04	87.37	86.71
21/07/2020	84.04	85.04	87.37	87.08
22/07/2020	84.04	85.04	87.37	86.95
23/07/2020	84.04	85.04	87.37	86.62
24/07/2020	84.04	85.04	87.37	86.26
25/07/2020	84.04	85.04	87.37	86.05
26/07/2020	84.04	85.04	87.37	85.97
27/07/2020	84.04	85.04	87.37	85.76
28/07/2020	84.04	85.04	87.37	85.57
29/07/2020	84.04	85.04	87.37	85.54
30/07/2020	84.04	85.04	87.37	85.78
31/07/2020	84.04	85.04	87.37	85.81

Table 4.2: Flood record data, Numaligarh Station (Dhansiri River), July 2020.

DATE	WARNING LEVEL(m)	DANGER LEVEL(m)	HIGHEST FLOOD LEVEL(m)	ACTUAL WATER LEVEL(m)
01/07/2020	76.42	77.42	80.16	77.59
02/07/2020	76.42	77.42	80.16	77.53
03/07/2020	76.42	77.42	80.16	77.31
04/07/2020	76.42	77.42	80.16	77.17
05/07/2020	76.42	77.42	80.16	76.78
06/07/2020	76.42	77.42	80.16	77
07/07/2020	76.42	77.42	80.16	77.85
08/07/2020	76.42	77.42	80.16	77.81
09/07/2020	76.42	77.42	80.16	77.78
10/07/2020	76.42	77.42	80.16	77.64
11/07/2020	76.42	77.42	80.16	77.99
12/07/2020	76.42	77.42	80.16	78.51
13/07/2020	76.42	77.42	80.16	78.58
14/07/2020	76.42	77.42	80.16	78.26
15/07/2020	76.42	77.42	80.16	78.04
16/07/2020	76.42	77.42	80.16	78.31
17/07/2020	76.42	77.42	80.16	78.54
18/07/2020	76.42	77.42	80.16	78.17

19/07/2020	76.42	77.42	80.16	77.87
20/07/2020	76.42	77.42	80.16	77.74
21/07/2020	76.42	77.42	80.16	77.93
22/07/2020	76.42	77.42	80.16	78.08
23/07/2020	76.42	77.42	80.16	78.05
24/07/2020	76.42	77.42	80.16	78.04
25/07/2020	76.42	77.42	80.16	78.45
26/07/2020	76.42	77.42	80.16	78.24
27/07/2020	76.42	77.42	80.16	77.99
28/07/2020	76.42	77.42	80.16	78.13
29/07/2020	76.42	77.42	80.16	78.25
30/07/2020	76.42	77.42	80.16	78.57
31/07/2020	76.42	77.42	80.16	78.18

Table 4.3: Flood record data, Tezpur Station (Brahmaputra River), July 2020

DATE	WARNING LEVEL(m)	DANGER LEVEL(m)	HIGHEST FLOOD LEVEL(m)	ACTUAL WATER LEVEL(m)
01/07/2020	64.23	65.23	66.59	65.44
02/07/2020	64.23	65.23	66.59	65.19
03/07/2020	64.23	65.23	66.59	65.09
04/07/2020	64.23	65.23	66.59	64.99
05/07/2020	64.23	65.23	66.59	64.9
06/07/2020	64.23	65.23	66.59	64.89
07/07/2020	64.23	65.23	66.59	64.91
08/07/2020	64.23	65.23	66.59	64.96
09/07/2020	64.23	65.23	66.59	65.13
10/07/2020	64.23	65.23	66.59	65.32
11/07/2020	64.23	65.23	66.59	65.81
12/07/2020	64.23	65.23	66.59	66.24
13/07/2020	64.23	65.23	66.59	66.55
14/07/2020	64.23	65.23	66.59	66.39
15/07/2020	64.23	65.23	66.59	65.96
16/07/2020	64.23	65.23	66.59	65.59
17/07/2020	64.23	65.23	66.59	65.41
18/07/2020	64.23	65.23	66.59	66.44
19/07/2020	64.23	65.23	66.59	65.49
20/07/2020	64.23	65.23	66.59	65.71
21/07/2020	64.23	65.23	66.59	66.03
22/07/2020	64.23	65.23	66.59	66.29
23/07/2020	64.23	65.23	66.59	66.32
24/07/2020	64.23	65.23	66.59	66.15
25/07/2020	64.23	65.23	66.59	65.9
26/07/2020	64.23	65.23	66.59	65.74
27/07/2020	64.23	65.23	66.59	65.62
28/07/2020	64.23	65.23	66.59	65.45
29/07/2020	64.23	65.23	66.59	65.27
30/07/2020	64.23	65.23	66.59	65.35
31/07/2020	64.23	65.23	66.59	65.47

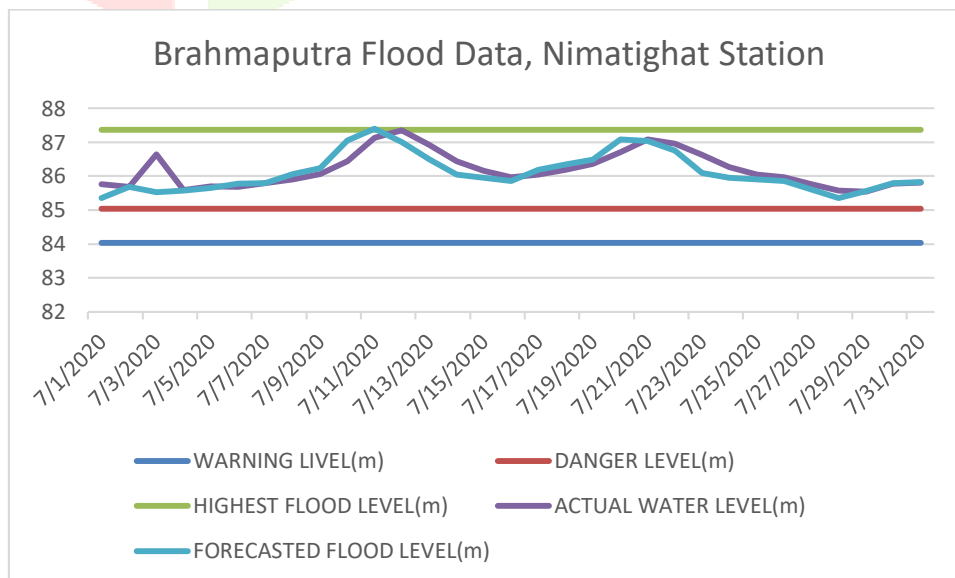


Fig 4.2: Brahmaputra Flood Data Graph, Nimatighat Station, July 2020

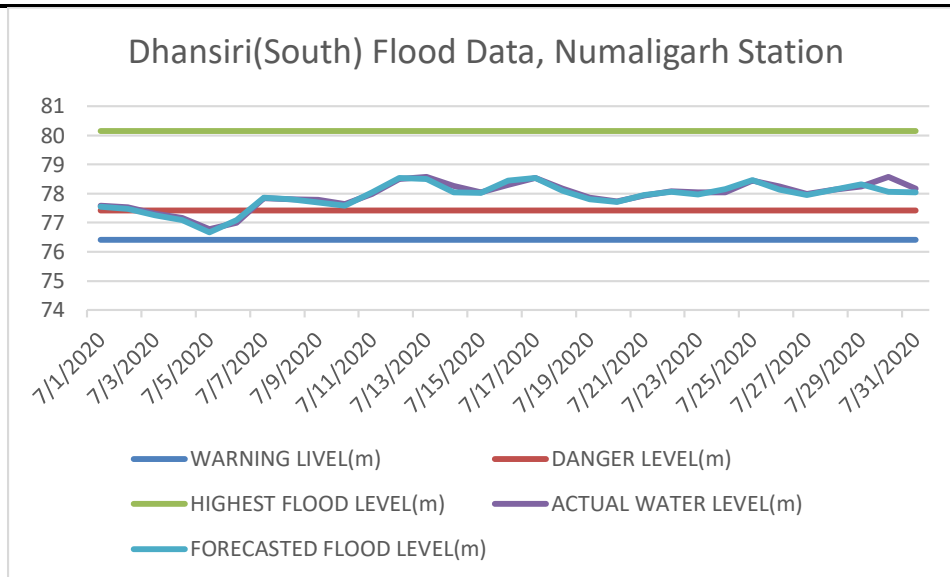


Fig 4.3: Brahmaputra Flood Data Graph, Numaligarh Station, July 2020

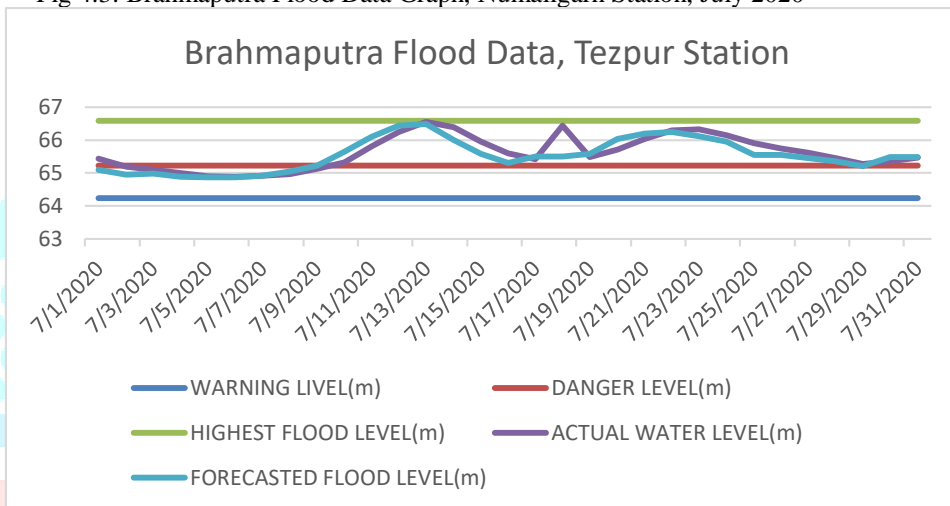


Fig 4.4: Brahmaputra Flood Data Graph, Tezpur Station, July 2020

From the graphs, it can be clearly inferred that all the three river monitoring stations had their highest monthly flood level record between 11th Jul, 2020 and 15th Jul, 2020. In Nimatighat, Jorhat, the actual flood level surpassed the predicted flood level around 3rd Jul, 2020. The water level rose close to the highest observed value around 12th Jul and 21st Jul, 2020. In case of Numaligarh station, the highest flood level of the month was observed around 13th Jul and 17th Jul, 2020. The forecasted and observed water levels were nearly same in the station, indicating that there was no abnormal flooding observed. In case of Tezpur station, the highest flood level of the month was observed around 13th Jul and 18th Jul, the latter showing unusual increase over the predicted level. Thus, it can be clearly inferred from the graph that the Brahmaputra river was mostly flowing above danger level in the month of July. Since the KNP is located very close to these river observation stations, it can be inferred that the region was too impacted by widespread floods.

V. METHODOLOGY AND ANALYSIS:

The case study is carried out with sentinel-1 C- band synthetic Aperture Radar in GEE platform. In the first step, we executed is by importing Image collection i.e. COPERNICUS/S1_GRD with resolution of 10 meter and Interferometric wide swath Imagery. The imageries are ortho-corrected, radiometric calibrated. The imageries are terrain corrected using 30m SRTM data. The following analysis is done by using ascending orbit properties pass as we are interested in recent change in trends. The two set of imageries are dual polarized ('VV', 'VH') and are between December-2019 to July-2020. They are selected based on CWC flood forecasting graph and available data set in GEE platform provide by Copernicus programme. In the third step we applied Speckle filters to remove granular noise based on focal mean is due to the interference of waves reflected from many elementary scatters. These are applied to both the image with a radius of 50. Before we run the classification and regression algorithm, we have to collect training data to "train" the classifier from the both pre and post flood imageries. This involves collecting representative samples of backscatter for each land cover class of interest. We have selected five six classes i.e 'Open water Permanent', 'Open water Flooded', 'Grassland', 'Dense Forest', 'flooded vegetation', 'URBAN'.

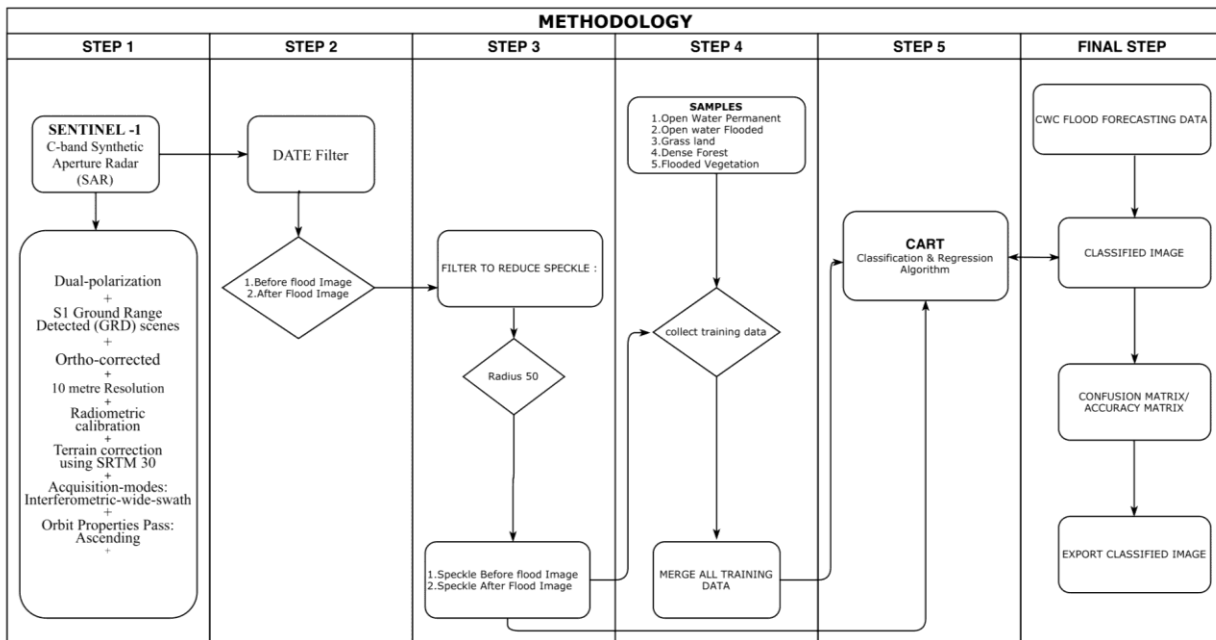


Fig. 5.1: METHODOLOGY DETAILING THE PROCESS OF STRING METRIC ALGORITHM IMPLEMENTATION

The training data is created by overlaying the training points on the image. The next step is to merge them into a single collection, called a Feature Collection. We will use the Feature Collection created to extract backscatter values for each landcover class identified for both the images that will be used in the classification. The step Five which define the process of classification for both the imageries are based on classification and regression(CART), is one of the oldest and most fundamental algorithms. The purpose of the analysis conducted by classification or regression tree is to create a set of if-else conditions that allow for the accurate prediction or classification of a case. We run the classification by applying the knowledge from our training areas to the rest of the image and display the results using the mapping function.

The result will be rendered with those class numbers and colors. The Classified image result is then correlated with Central Water Commission (CWC) flood forecasting Observation data. Moreover we performed Confusion matrix accuracy, to find how classifier was able to correctly label resubstituted training data.

VI. MATHEMATICAL MODEL:

CART and decision trees like algorithms work on the principle of recursive partitioning of the training set for obtaining subsets that are as pure as possible to a given target class. Each node of the tree is associated to a particular set of records T that is split by a specific test on a feature. For example, a split on a continuous attribute A can be induced by the test $A \leq x$. The set of records T is then partitioned in two subsets that lead to the left branch of the tree and the right one.

$$T_l = \{t \in T: t(A) \leq x\}$$

And

$$T_r = \{t \in T: t(A) > x\}$$

Similarly, a categorical feature B can be used to induce splits according to its values. For example, if $B = \{b_1, \dots, b_k\}$ each branch i can be induced by the test $B = b_i$.

The divide step of the recursive algorithm to induce decision tree takes into account all possible splits for each feature and tries to find the best one according to a chosen quality measure: the splitting criterion. If your dataset is induced on the following scheme

$$A_1, \dots, A_m, C$$

Where A_j are attributes and C is the target class, all candidates splits are generated and evaluated by the splitting criterion. Splits on continuous attributes and categorical ones are generated as described above. The selection of the best split is usually carried out by impurity measures. The impurity of the parent node has to be decreased by the split. Let (E_1, E_2, \dots, E_k) be a split induced on the set of records E , a splitting criterion that makes use of the impurity measure $I(\cdot)$ is:

$$\Delta = I(E) - \sum_{i=1}^k \frac{|E_i|}{|E|} I(E_i)$$

Standard impurity measures are the Shannon entropy or the Gini index. More specifically, CART uses the Gini index that is defined for the set E as following. Let p_j be the fraction of records in E of class C_j

$$p_j = \frac{|\{t \in E : t[C] = c_j\}|}{|E|}$$

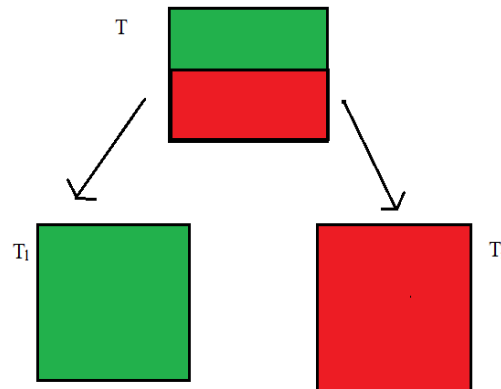
then

$$Gini(E) = 1 - \sum_{j=1}^Q p_j^2$$

Where Q is the number of classes.

It leads to a 0 impurity when all records belong to the same class.

As an example, let's say that we have a binary class set of records T where the class distribution is $(1/2, 1/2)$ - the following is a good split for T :

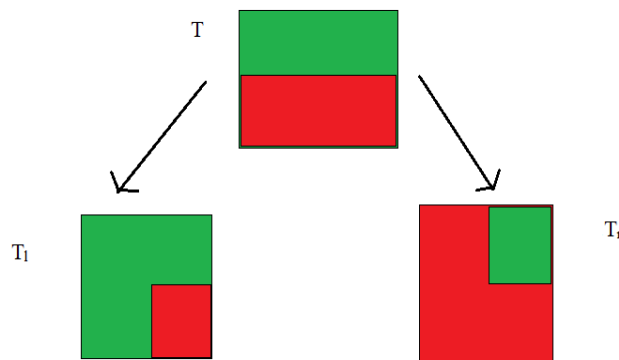


The probability distribution of records in T_l is $(1,0)$ and the T_r 's one is $(0,1)$. Let's say that T_l and T_r are the same size, thus $|T_l|/|T| = |T_r|/|T| = 1/2$.

We can see that Δ is high:

$$\Delta = 1 - 1/2^2 - 1/2^2 - 0 - 0 = 1/2$$

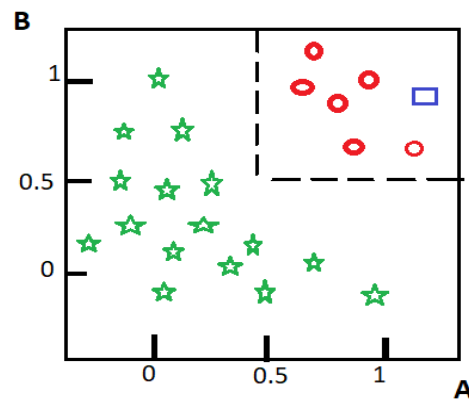
The following split is worse than the first one and the splitting criterion Δ reflects this characteristic.



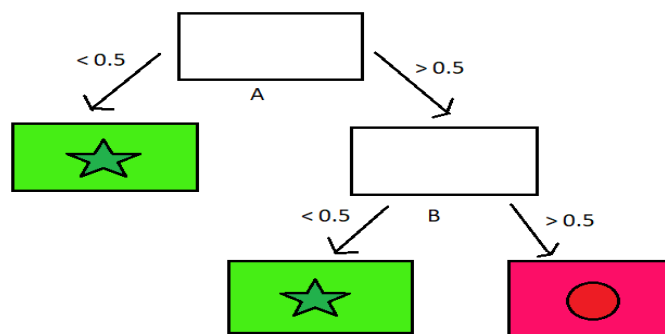
$$\Delta = 1 - 1/2^2 - 1/2^2 - 1/2(1 - (3/4)^2 - (1/4)^2) - 1/2(1 - (1/4)^2 - (3/4)^2) = 1/2 - 1/2(3/8) - 1/2(3/8) = 1/8$$

The first split will be selected as best split and then the algorithm proceeds in a recursive fashion.

It is easy to classify a new instance with a decision tree; in fact, it is enough to follow the path from the root node to a leaf. A record is classified with the majority class of the leaf that it reaches. Say that we want to classify the square on this figure that is the graphical representation of a training set induced on the scheme A, B, C , where C is the target class and A and B are two continuous features.



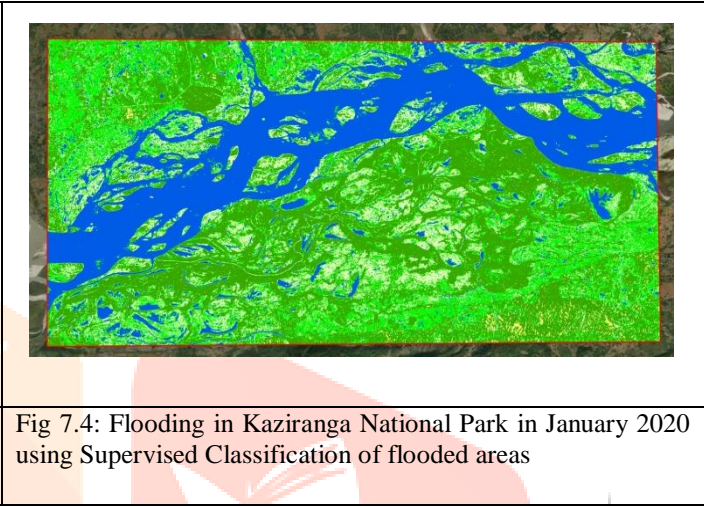
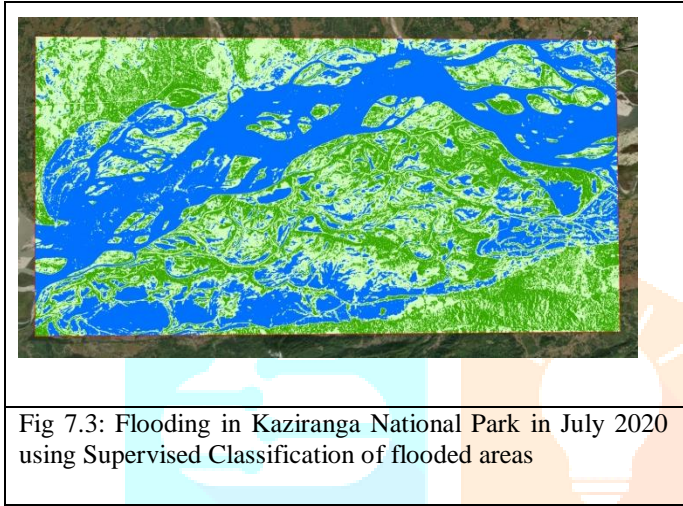
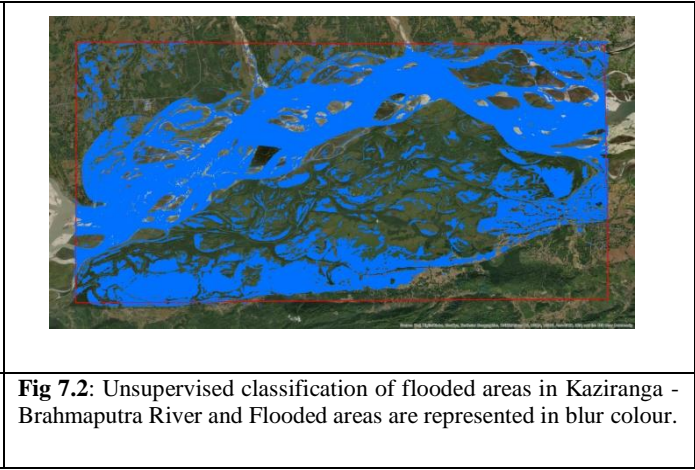
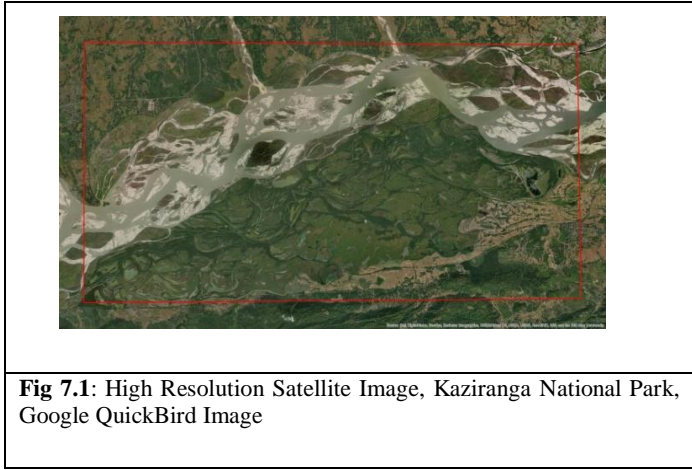
A possible induced decision tree might be the following:



It is clear that the record square will be classified by the decision tree as a circle given that the record falls on a leaf labeled with circles. In this toy example the accuracy on the training set is 100% because no record is mis-classified by the tree. On the graphical representation of the training set above we can see the boundaries (gray dashed lines) that the tree uses to classify new instances.

VII. Result and discussion

Upon analysis of Synthetic Aperture Radar Data obtained from Sentinel-I(10 m) on GEE platform, the following classified data was obtained. Fig 6.1 shows Digital Globe Quickbird which is roughly 65cm pan-sharpened (65 cm panchromatic at nadir) high resolution optical satellite imagery. We conducted both supervised and unsupervised classification to compare and see the change in result for the delineation of water bodies for the month of July, 2020. The result of unsupervised classification for flooded areas included the river flow and the grassland under water, the result as shown in figure 6.2 was obtained. The blue coloured areas depict the flooded regions in KNP in the month of July. In addition to this, further determination of how different types of vegetative features and settlements around KNP are affected during floods, a supervised classification was done on GEE platform using Classification and regression algorithm, separately showing different surface features- grasslands, water bodies, dense forests and human settlements- for the months of July and January 2020 (Fig 6.3 and Fig 6.4 respectively). The total area under water for the month July is 39356.80 (ha) and for the month January is 26932.36 (ha). When we compare our results with data of central water commission flood forecast data of numligarh and nearby station for the month of January and July, than we clearly see that our results are convincing and the delineation of water bodies along with classification for other features for the two set of Imageries can be taken into account for administrative decisions.



Area under water-July,2020	Area under water –January,2020
39356.80 (ha)	26932.36 (ha)

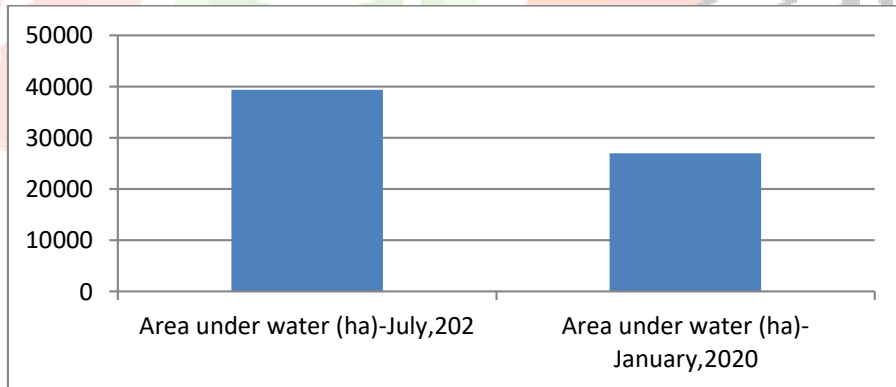


Fig 7.5: Graph showing total area in KNP under water after peak monsoon rainfall (July, 2020) and before monsoon season (Jan, 2020).

VIII.ACCURACY ERROR MATRIX

Accuracy error matrix shows the land use classes present in our study area (KNP).we are concerned more about classification of water bodies and therefore we have identified five classes i.e. (open_water_permanent, Grassland, Agriculture_land, Dense_forest, urban) for the month of January,2020. We have taken two different classes for two set of imageries because in the initial stage of our classification, we couldn't delineate flood on the month of January. Moreover the classification of dense forest with respect urban area is difficult in SAR data as both have high backscattering value. Error matrix is computed comparing the result obtained by the image- interpretation using CART algorithm. The overall accuracy for the month of January, 2020 is 92.28 % whereas the overall accuracy matrix for the month of July is 87.35%. The classes for the month July, 2020 are (open_water_permanent, open_water_flooded, Grassland, Dense_forest, urban).These levels of accuracy are satisfactory and acceptable in the very early stage of the work.

		Referenced data					Total
		Open_water_Permanent	Grassland	Agriculture_land	Dense_forest	urban	
Classified data	Open_water_Permanent	304	0	10	0	8	322
	Grassland	0	79	1	0	0	80
	Agriculture_land	0	0	160	0	0	160
	Dense_forest	0	0	0	56	0	56
	urban	34	0	0	0	30	64
	Total	338	79	171	56	38	682

		Referenced data					total
		Open_water_Permanent	Open_water_flooded	Grassland	Dense_forest	urban	
Classified data	Open_water_Permanent	302	24	0	0	0	326
	Open_water_flooded	0	195	20	0	0	215
	Grassland	0	0	64	14	0	78
	Dense_forest	0	0	0	184	32	216
	urban	24	0	0	0	43	67
	Total	326	219	84	198	75	902

To verify if the classification is correct, we have taken certain parts of the kaziranga national park and have tried to verify the result by comparing three types of Satellite imagery data - QuickBird, Sentinel-I SAR data and unsupervised classification of flooded areas as obtained from the analysis mentioned above.

Case-I

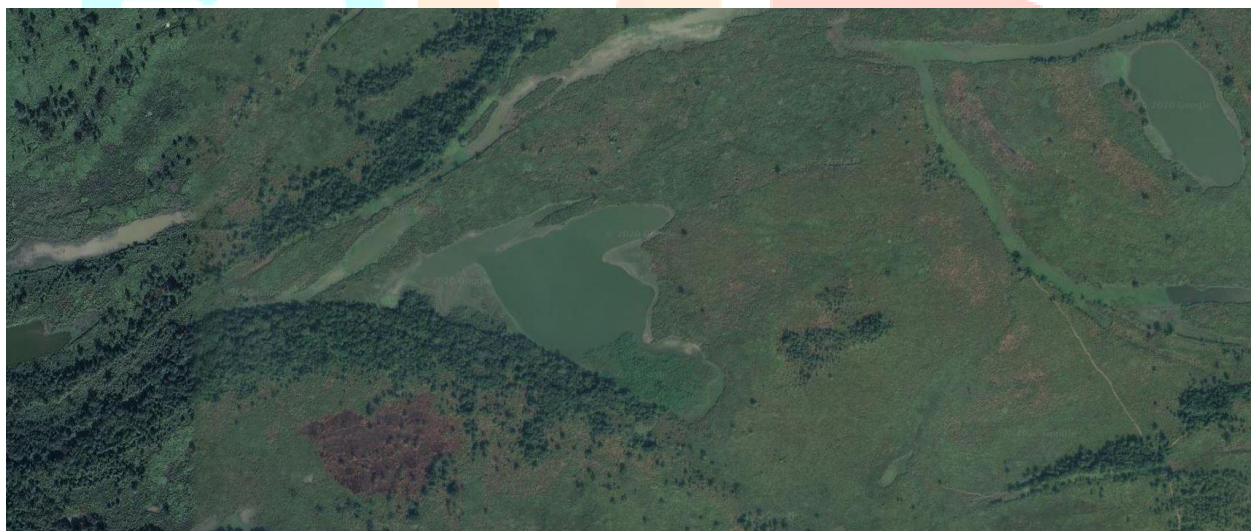


Fig 8.1: High resolution QuickBird Optical imagery showing a small lake in KNP.

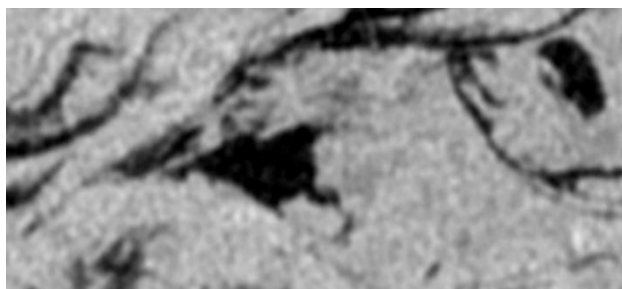


Fig 8.2: Sentinel- I SAR dual color resolution image showing water bodies in Fig 8.1 in July. The black coloured regions depict the water body. It can be clearly seen that water level in the lake increases during the monsoons in July, thus demarcating flooding.

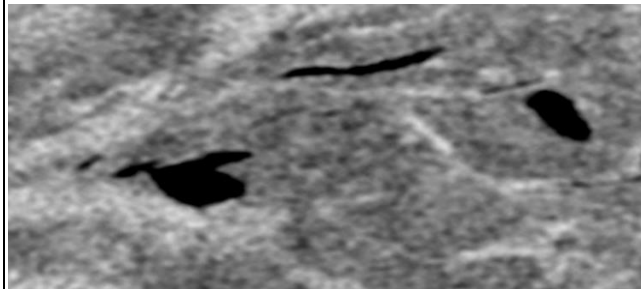


Fig 8.3: Sentinel- I SAR dual color resolution image showing water bodies in Fig 8.1 in January, 2020. The black coloured regions depict the water body. Due to the lower level of rainfall in January, it is clearly seen that water level in these low-lying areas remarkably go down.

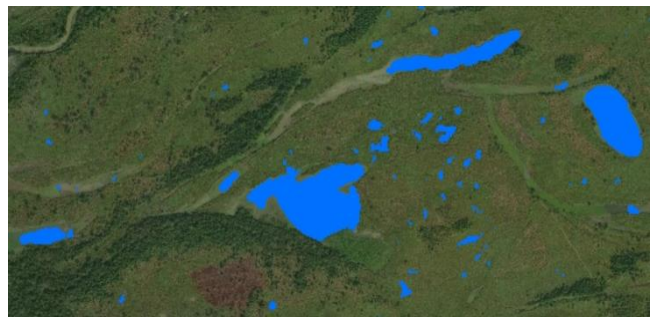
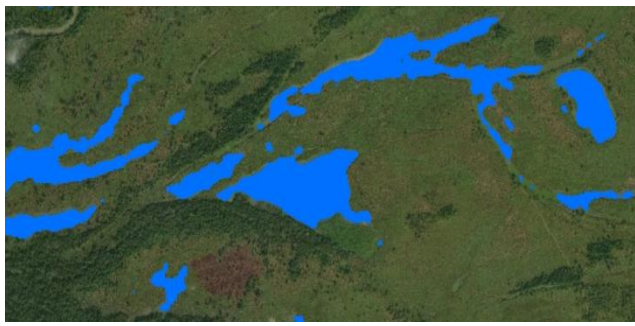


Fig 8.4: Unsupervised Classification showing water bodies in Fig 8.1 in month of July (in blue colour).

Fig 8.5: Unsupervised Classification showing water bodies in Fig 8.1 in month of January (in blue colour).

Case- II



Fig 8.6: High resolution QuickBird Optical imagery showing the intersection between KNP and human habitats. The light brown coloured areas represent the agricultural lands.

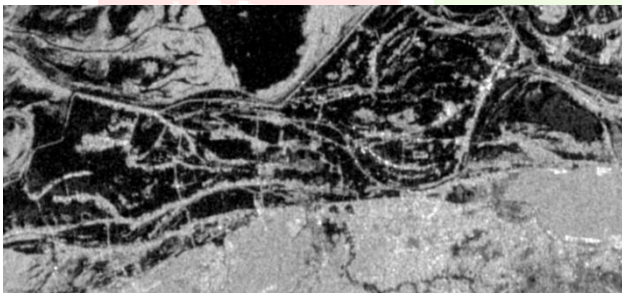


Fig 8.7: Sentinel- I SAR dual color resolution image showing flooded regions for area under consideration in Fig 8.6 in July, 2020. The black coloured regions depict the agricultural lands and other low-lying areas that get submerged under water during the monsoon.

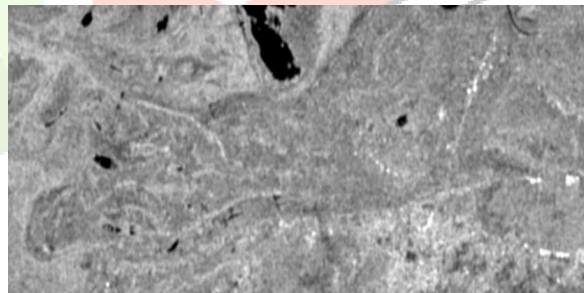


Fig 8.8: Sentinel- I SAR dual color resolution image showing area under consideration in Fig 8.6 in January, 2020. The black coloured regions depict the permanent water bodies. Since there is very little rainfall in January, most of the areas remain dry and there is no flooding.



Fig 8.9: Unsupervised Classification showing flooded areas in month of July in blue colour

Fig 8.10: Unsupervised Classification showing permanent water bodies in month of January in blue colour

Case-III



Fig 8.11: High resolution QuickBird Optical imagery showing a section of KNP having grasslands and dense forests.

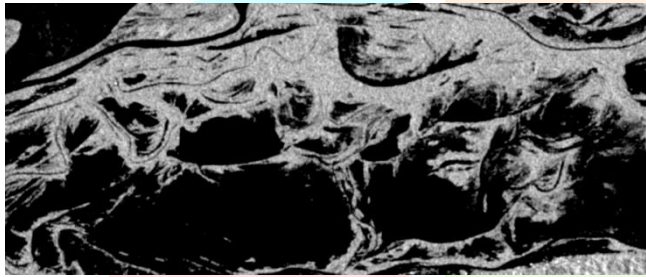


Fig 8.12: Sentinel- I SAR dual color resolution image showing flooded regions for area under consideration in Fig 8.11 in July, 2020. The black coloured regions depict the grasslands and other low-lying areas that get submerged under water during the monsoon.

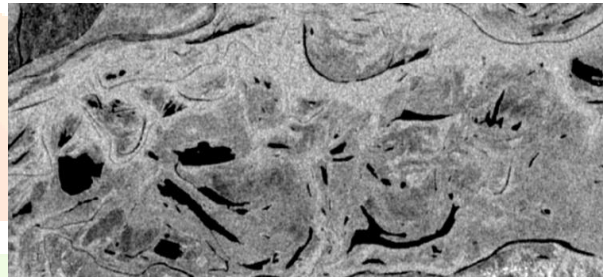


Fig 8.13: Sentinel- I SAR dual color resolution image showing area under consideration in Fig 8.11 in January, 2020. The black coloured regions depict the permanent water bodies. Since there is very little rainfall in January, most of the grasslands remain dry and there is no flooding.

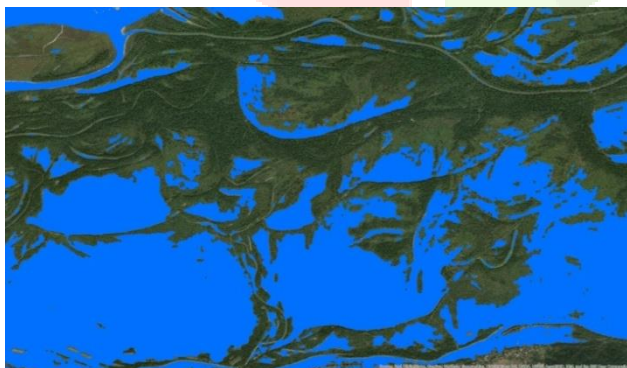


Fig 8.14: Unsupervised Classification showing flooded areas in month of July in blue colour

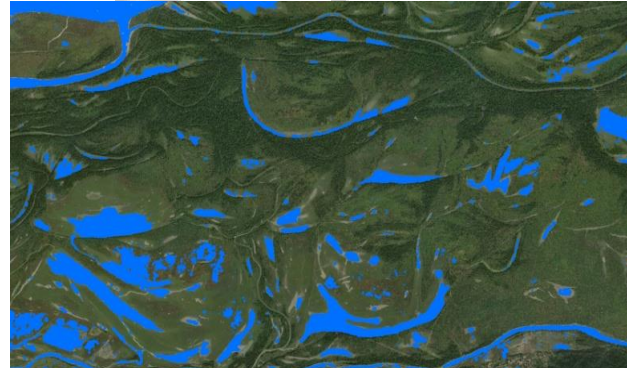


Fig 8.15: Unsupervised Classification showing permanent water bodies in month of January in blue colour

IX. CRITICAL ANALYSIS:

In this study, flood mapping has been done through progressive steps. First, detection of flood areas was done with the help of semi-automatic extraction from satellite image. The data was then refined with the help of related ancillary data. However, study points out of capabilities of spaceborn sensors to map a flood event depends on several factors like time of satellite path in regards to the time of the flood, spatial resolution, land use and morphology of the flooded area, data processing technique etc.

Even though the SAR data is beneficial in terms of flood data acquisition in cloudy days or at night, however, on analysis of Sentinel-I data, some inherent errors were found. The presence of dense urban areas and forests affects SAR and multi-spectral flood mapping and the methodology requires a more complex approach for greater accuracy. High spatial resolution is required to perfectly differentiate between urban areas and dense forests in certain regions to similar values of back scattering and double bounce of reflected radiation in both cases. The lower spatial resolution of Sentinel-I (10m) makes it a limiting factor for free satellite data use. This necessitates the use of field surveys and optical imagery for further verification of accuracy.

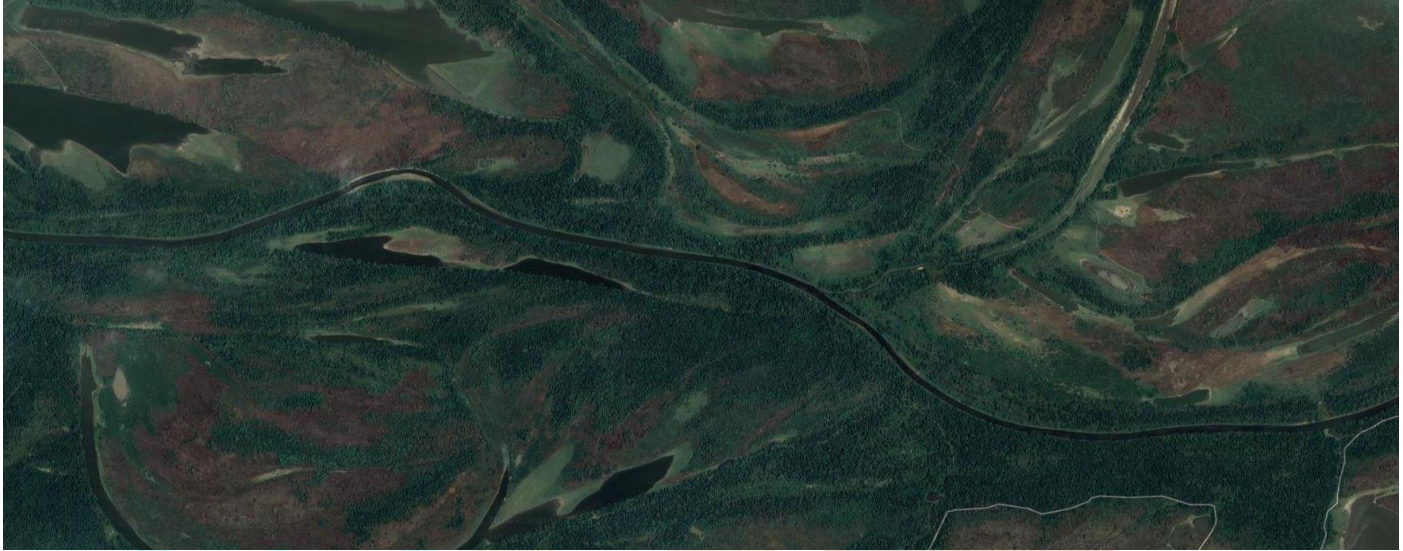


Fig 9.1: High Resolution Optical Image Showing a Part of KNP

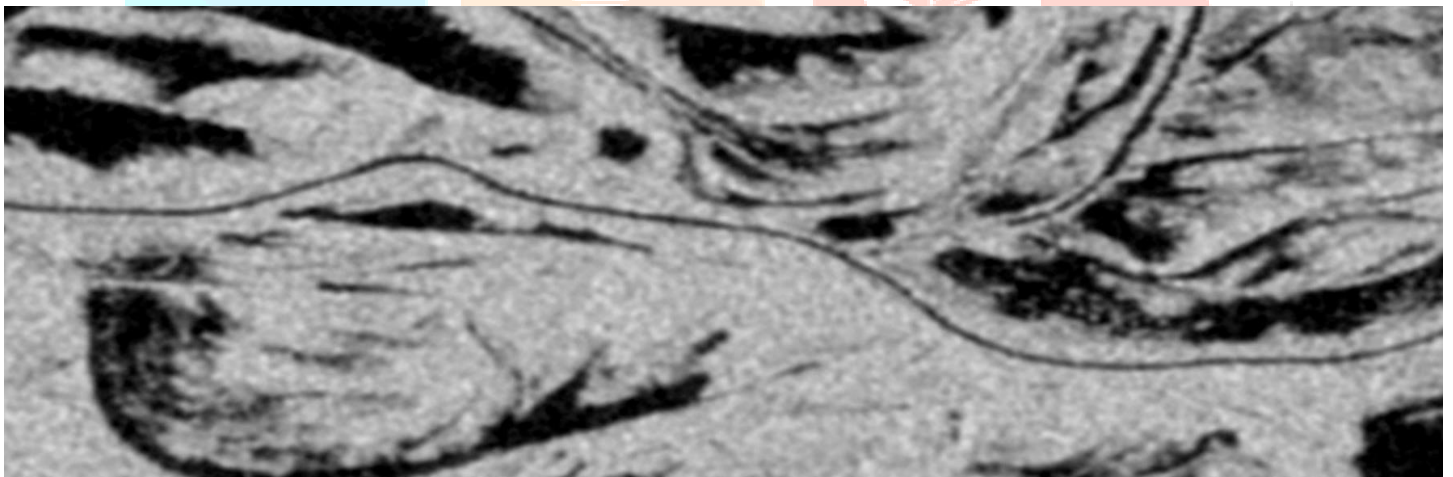


Fig 9.2: Sentinel SAR Imagery of Fig 9.1

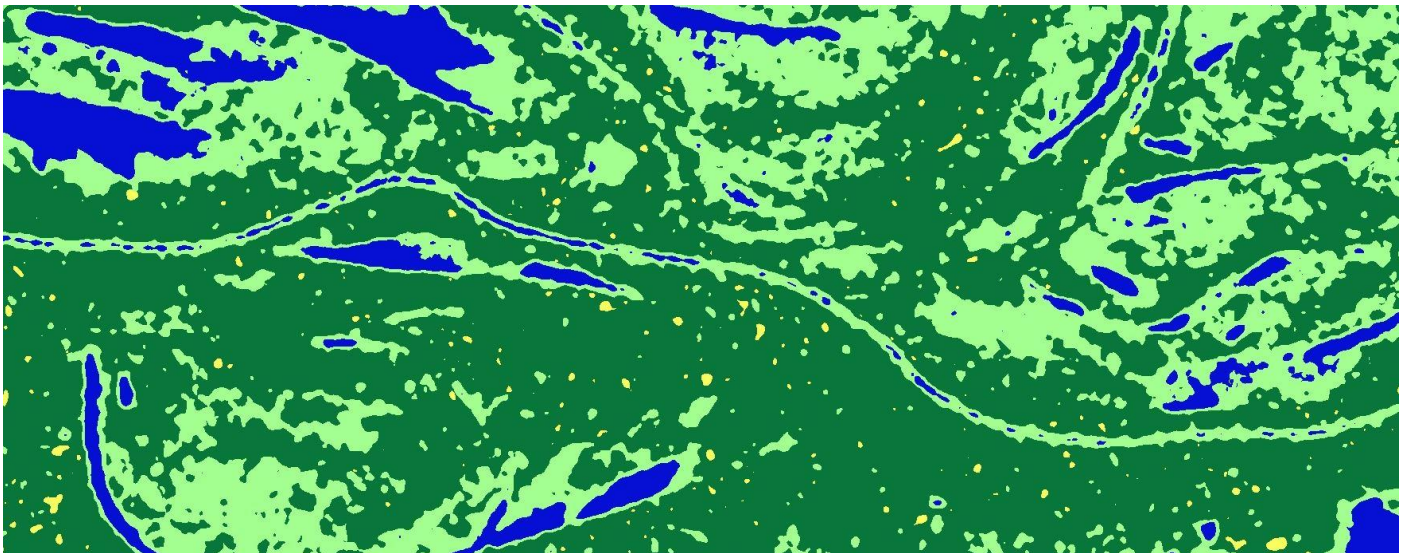


Fig 9.3: figure showing inherent errors in classification. The yellow areas depict the urban areas; however there are no urban areas in the region. The edge of the river and river in some places appears green because of relative lower resolution of Sentinel-I which fails to find distinction between grasslands and water surface in some areas due to similar back scattering values.

X. CONCLUSION:

The results and finding for the study area are one step forward for achieving the objective. The approach also suggests that our process to attain the result is in right direction to obtain the final goal. Our observation and critical analysis of the steps completed opens up new light to investigate the areas in an improved way with modification in our algorithm and code. Many new items need to be incorporated in the future like the digital Elevation Model, watershed layer, increase in sample size with respect to CWC flood forecast data, and high-resolution data.

ETHICAL APPROVAL

No ethical approval is required.

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AUTHOR CONTRIBUTION

MA: Code Development, execution, writing original draft

PK: Conceptualization, execution, writing original draft, data curation, data analysis, editing

US: Supervising, editing final draft

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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