Python Based Modelling of Flood Damage Assessment Using High-Resolution Aerial Imagery

Sumaira Kousar[1*], Saira Batool[2], Syed Amer Mahmood[3], Amer Masood[4], Safdar Ali Shirazi[5], Jahanzeb Qureshi[6], S M Hassan[7]
[1,5]Institute of Geography, University of the Punjab
[2]Center of Integrated Mountain Research, University of the Punjab
[3,4,6,7]Department of Space Science, University of the Punjab
***Correspondence:** * sumaira.geog@pu.edu.pk, saira.cimr@pu.edu.pk, amer.spsc@pu.edu.pk, amermasood.spsc@pu.edu.pk, shirazi.geog@pu.edu.pk, zeb.spsc@pu.edu.pk,
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Flood is a natural disaster that can cause devastating impacts on the community, infrastructure, and the environment. UAVs enable to compute the extent of the flood and to identify the vulnerable areas prone to future flooding, assisting in the formulation of effective mitigation strategies. This study presents a case study of Barwai Khwar, Swat, Khyber Pakhtunkhwa (KPK), pre-flood image attained from Google Earth Pro and the post-flood aerial imagery was collected by using unmanned aerial vehicles (UAVs). To capture the detailed visual information of the flood-affected region and to assess the extent of the flood damage the acquired imagery was then processed by using advanced image processing algorithms to extract essential information, such as inundation extent, floodwater depth, and changes in land cover. This procedure assists in evaluating the precise damage assessment and development of effective recovery and mitigation strategies. Results revealed that the 2022 flood in Barwai Khowar's large agricultural land was submerged (14758.9 perimeters), leading to a significant loss in crop yield and potential long-term impacts on food security. Additionally, critical infrastructure, including roads, bridges, and buildings suffered substantial damage. The destructed area of the retaining wall is 2184m (2km), housing damage is 1074.9m and 82.6 m of Nullah was calculated in this region. Moreover, the application of such technologies can facilitate more informed and timely responses to natural disasters, enhancing the overall resilience of communities and ecosystems.

Keywords: Flood Assessment, UAV Dataset, High-Resolution Aerial Imagery, Global Navigation Satellite System, Ground Sampling Distance

Introduction

Flood is a natural calamity that is more prevalent and devastating because of the mass-scale agricultural destruction, and damage to infrastructure, environment, and community [1], [2]. Climate Change, excessive melting snow/glaciers, and elongated rainfall are the chief factors causing floods [3]. Moreover, anthropogenic activities, topographic conditions, socio-economic vulnerabilities, deforestation, and rate of urbanization in the vicinity of the river determine the frequency and intensity of the flood [4]–[7].

Climate change is significantly impacting weather conditions (increased precipitation, snow melting, and rising sea levels) that augment flood disasters in the world [8]. Approximately 9 percent of the world's land area is considered flood-vulnerable area including China, South Korea, Eastern Africa, Bangladesh, the Philippines, and coastal regions of North and South America which affect 37.7% of the world's population. Yangtze River Basin in China and Bangladesh are highly flood-risk areas and these are densely populated countries with intensive agricultural activities [5]. Flood is at the top of the list among all the natural catastrophes. One important component of global flood damage assessment is the evaluation of economic losses. Due to the flooding events globe is facing a loss of 1 trillion US$ every year. Currently, Asia is facing the highest flood destruction among all the continents of the World (Aribisala et al., 2021).

Flood is a frequent occurring disaster in Pakistan and has been damaging the country since 1982. Torrential rain, global warming, and rapid snow and glacier melting cause flooding in the Indus River Basin (Shah et al., 2023). The most affected provinces are Khyber Pakhtunkhwa (KPK), Baluchistan, Sind, and some districts of Punjab. Wide-spreading flooding is observed in the monsoon season from July to September [11]. According to the report of the Pakistan flood in 2022, total damage and economic loss exceeded 30 billion US $ which caused starvation in the most flooded region of Pakistan (Govt of Pakistan, 2022). The sectors that suffered the most flood damage are housing US dollar 5.6 billion agriculture, food, and livestock [13].

Traditional methods of damage assessment, such as ground surveys can be time-consuming, costly, and often limited in scope. However, at present Geographical Information System (GIS) Remote Sensing (RS) and Drone (UAVs) imagery are widely used for flood risk, damage assessment, and monitoring. These are the more authentic and efficient techniques for mitigation, management, and effective planning in flood zones. Most of the studies used drone imagery for flood mitigation and recovery (Rahman et al., 2023; Whitehurst et al., 2022).

45% area of the Swat River basin is at high to moderate flood risk and 55% area comes under low to very low flood threat [14]. This study focuses on the Barwai Khwar 11km long eastern tributary of Swat River, KPK, which has witnessed a history of intense Riverine flood incidents. Utilizing high-resolution aerial UAV imagery, this research aims to execute a comprehensive pre and post-flood analysis, enabling a detailed examination of the region's susceptibility to floods, its resilience, extent, and magnitude in the region of such natural hazards. Additionally, the study will highlight vulnerable areas that are more prone to future flooding. The magnitude and frequency of the flooding events are intensifying due to torrential rainfall and rising temperatures. [4], [17], [18].

The findings of this research work will contribute to the field of flood damage assessment by evaluating the effectiveness and utility of high-resolution aerial imagery and remote sensing techniques. The results will provide valuable information for decision-makers, disaster management authorities, and policymakers to develop more effective flood response plans and strategies for Barwai Khwar and similar flood-prone regions [19]. The Flood of 2022 damaged the agriculture, transport, and housing structure. The basic purpose of the study is to provide spatial flood susceptible areas to assess the damage area and type (O. Yilmaz, 2022; Mcgrath & Gohl, 2022).

By executing the analysis in GIS on high-resolution Drone imagery, an accurate and detailed understanding of flood damage in Barwai Khwar, Swat, KPK has been measured. This research produced maps of highly susceptible flood zones. The results of this study have the ability to develop more resilient communities and increase disaster vigilance in this region. The flood in Barwai Khwar, Swat, KPK, resulted in significant damages, altering the landscape and posing challenges to the affected communities.

Objectives:

- The aim of this study is to present a procedure for the updating of boundary conditions of hydrodynamic parameters based on UAV-born data.
- To provide High-resolution aerial imagery of the affected areas, capturing fine-grained details of the flood's extent and severity. This images helps in identifying damaged infrastructure, submerged buildings, and altered landscapes, allowing for a rapid initial assessment of the flood's immediate effects.
- To delineate a very effective means of online apprising of flood inundated maps and their verifications.

Novelty:

The novelty of this research is because, unfortunately, the acquisition of Ariel's photograph and satellite imagery is costly. In addition, the temporal resolution is restricted by weather conditions, On the other hand, Remote Sensing UAVs are becoming tremendously popular due to their flexibility and decreeing cost. UAVs provide precise and up-to-date, river shoreline, channel geometry, and vegetation. In this study the novel procedure of updating the distributing flood routing and updating flood parameters.

Study Area:

Barwai Khwar is located in the beautiful Swat Valley of Khyber Pakhtunkhwa (KPK), Pakistan, and has a historically rich area with a diverse landscape. However, like many regions in KPK, Barwai Khwar is vulnerable to various natural hazards, including floods, landslides, and earthquakes. Among these, floods have emerged as one of the most frequent and devastating disasters in this region. This case study focuses on Barwai Khwar to gain insights into flood-related events by employing high-resolution aerial imagery for flood damage assessment and disaster management.

The absolute location of Barwai Khwar is 72°20'30"E to 72°24'0"E and situated in the upper extent of the Swat Valley, approximately 30 kilometers northeast of the district capital, Mingora. It is surrounded by magnificent mountains, including the Hindukush and Karakoram ranges, making the region prone to rapid runoff during heavy rainfall events. Agricultural activities are very pronounced here because of the fertile plains found across the region. Several small streams flow through the region, congregating into the Swat River, which traverses the valley. The proximity of Barwai Khwar to the river and its tributaries is highly susceptible to frequent floods, particularly during monsoon seasons. During monsoons, heavy and persistent rainfall causes a significant increase in water flow in the streams and the Swat River. The combination of heavy rainfall, steep topography, and poor drainage systems can result in flash flooding in low-lying areas. These floods can have devastating impacts on the community in the form of damage to crops, infrastructure, and properties, as well as posing threats to human lives.

Material and Methods:

Detailed and high-resolution pre-flood satellite imagery of Barwai Khwar, Swat, was acquired from Google Earth Pro on 12th June 2022. The post-flood imagery was taken through a Drone (DJI Phantom 4 Pro version 2.0) from low altitudes in July 2022, making it feasible to extract detailed information about the Earth's surface by comparing these images, the extent of the damage caused by the floods, identify the affected areas and aid in relief and recovery efforts [15], [21]. The acquired data was post-processed using photogrammetry tools and software, with reference to ground control points collected by GNSS equipment. To perform damage assessment using pre-flood imagery, several key steps need to be taken to ensure accurate and reliable results. Acquiring a high-quality image needs geo-referencing and image enhancement for accurate spatial damage assessment. After that Identification of Regions of Interest (ROIs) is indispensable to Identify and mark areas of interest that are potentially affected by the flood, including urban centers, infrastructure, agricultural lands, and water bodies.

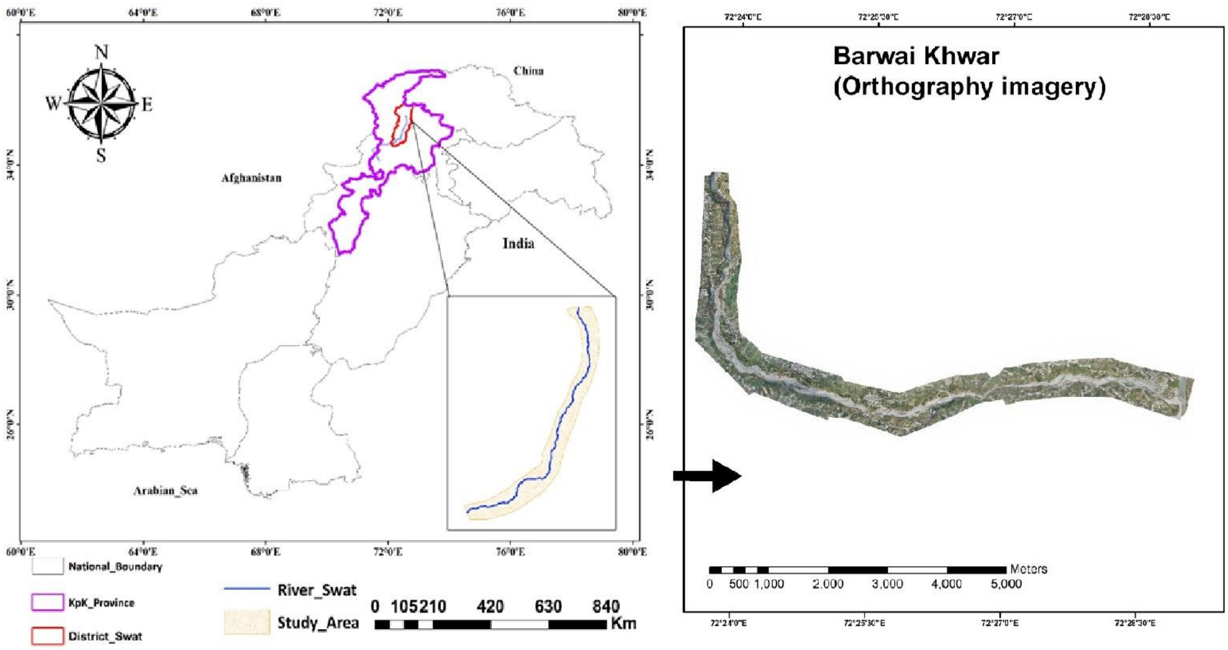

Figure 1: Location of Barwai Khwar, District Swat, Pakistan.

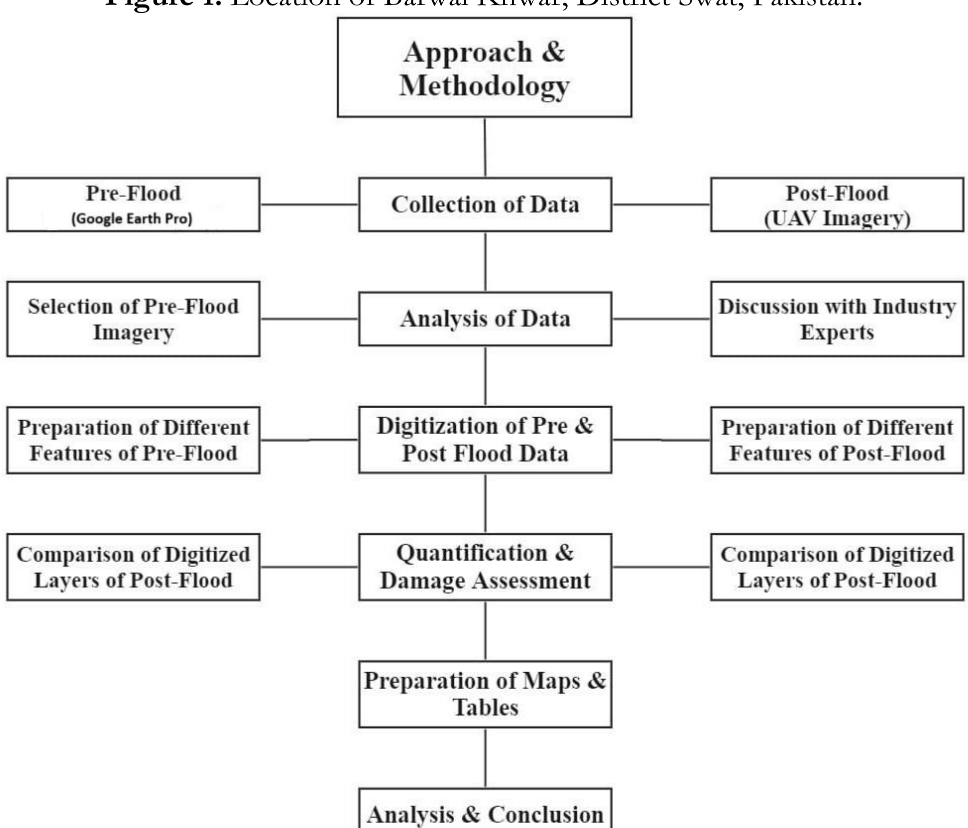

Figure 2: Methodological flow chart

Under mentioned Python based code is capable of extraction of satellite image after each hour from earth explorer website and to examine the extent of flood and its processing to determine the flood extent.

```
import time
from selenium import webdriver
from selenium.webdriver.common.keys import Keys
from selenium.webdriver.chrome.service import Service as ChromeService
import requests
# Set up the ChromeDriver (make sure you have ChromeDriver installed and its path set properly)
chrome_service = ChromeService("path_to_chromedriver")
driver = webdriver.Chrome(service=chrome_service)
def login_to_earth_explorer(username, password):
   # Open Earth Explorer
   driver.get("https://earthexplorer.usgs.gov/")
   time.sleep(2)  # Allow the page to load
   # Log in
   driver.find_element_by_id("username").send_keys(username)
   driver.find_element_by_id("password").send_keys(password)
   driver.find_element_by_name("_eventId_proceed").click()
   time.sleep(2)  # Allow the page to load
def search_sentinel_2_imagery():
   # Search for Sentinel-2 imagery
   search_bar = driver.find_element_by_id("simple-search-input")
   search_bar.send_keys("Sentinel-2")
   search_bar.send_keys(Keys.RETURN)
   time.sleep(2)  # Allow the page to load
def download_latest_sentinel_2_image():
   # Click on the first result (assuming it's the most recent)
   driver.find_element_by_class_name("result-title").click()
   time.sleep(2)  # Allow the page to load
   # Click the "Download Options" tab
   driver.find_element_by_id("tabLabelDownloadOptions").click()
   time.sleep(2)  # Allow the page to load
   # Find and click the "Download" button for Level-1C product
   download_button = driver.find_element_by_xpath("//button[contains(text(), 'Level-1C')]")
   download_button.click()
   # Extract the download link
   download_link = driver.find_element_by_class_name("single-order-download-
button").get_attribute("href")
   # Download the image using requests
   response = requests.get(download_link)
   with open("sentinel_image.zip", "wb") as f:
      f.write(response.content)
if __name__ == "__main__":
   username = "************"
   password = "*************"
   login_to_earth_explorer(username, password)
   while True:
      search_sentinel_2_imagery()
```

```
        download_latest_sentinel_2_image()
        print("Downloaded latest image. Waiting for an hour...")
        time.sleep(3600)  # Wait for an hour (3600 seconds)
import cv2
import numpy as np
def compute_water_extent(image_path):
    # Load the image
    image = cv2.imread(image_path)
    # Convert the image to HSV color space
    hsv_image = cv2.cvtColor(image, cv2.COLOR_BGR2HSV)
    # Define the lower and upper bounds for detecting water in HSV color space
    lower_bound = np.array([90, 100, 100])
    upper_bound = np.array([120, 255, 255])
    # Threshold the image to get a binary mask
    mask = cv2.inRange(hsv_image, lower_bound, upper_bound)
    # Find contours in the mask
    contours, _ = cv2.findContours(mask, cv2.RETR_EXTERNAL, cv2.CHAIN_APPROX_SIMPLE)
    # Calculate the total area of water
    total_water_area = 0
    for contour in contours:
        total_water_area += cv2.contourArea(contour)
    # Calculate the percentage of water area in the image
    total_image_area = image.shape[0] * image.shape[1]
    water_extent_percentage = (total_water_area / total_image_area) * 100
    return water_extent_percentage
if __name__ == "__main__":
    image_path = "path_to_your_image.jpg"
    water_extent_percentage = compute_water_extent(image_path)
    print(f"The extent of water in the image is approximately {water_extent_percentage:.2f}%")
import cv2
import numpy as np
def assess_damages(reference_image_path, damaged_image_path):
    # Load the reference and damaged images
    reference_image = cv2.imread(reference_image_path, cv2.IMREAD_GRAYSCALE)
    damaged_image = cv2.imread(damaged_image_path, cv2.IMREAD_GRAYSCALE)
    # Compute absolute difference between the images
    difference = cv2.absdiff(reference_image, damaged_image)
    # Threshold the difference image to identify changes
    _, thresholded_diff = cv2.threshold(difference, 25, 255, cv2.THRESH_BINARY)
    # Find contours in the thresholded difference image
    contours, _ = cv2.findContours(thresholded_diff, cv2.RETR_EXTERNAL,
cv2.CHAIN_APPROX_SIMPLE
    # Calculate the total area of damage
    total_damage_area = 0
    for contour in contours:
        total_damage_area += cv2.contourArea(contour)
    # Calculate the percentage of damage area in the image
    total_image_area = reference_image.shape[0] * reference_image.shape[1]
    damage_percentage = (total_damage_area / total_image_area) * 100
    return damage_percentage
```

```
if __name__ == "__main__":
    reference_image_path = "path_to_reference_image.jpg"
    damaged_image_path = "path_to_damaged_image.jpg"
    damage_percentage = assess_damages(reference_image_path, damaged_image_path)
    print(f"The estimated damage percentage is approximately {damage_percentage:.2f}%")
```

In the post-flood data analysis for damage assessment in Barwai Khwar, the collected images were processed and masked in Agisoft Metashape and Pix4D software. For the focal length of 18mm, 35 sets of images were taken from 150m altitude and each set contained about 150 to 170 images. Each image needs to be orientated, which means that the exact position of the image needs to be determined within a coordinate system. An interior orientation as well as an exterior orientation needs to be done. An interior orientation is done to establish the relation between the camera-internal coordinate system and the pixel coordinate system, while the exterior orientation is done to calculate the relation between image and object coordinates. An image taken from the Drone never has the same scale at every point. Therefore, Corrections need to be applied to adjust all the images on the same scale. It means the image has to be transformed from a central projection to an orthogonal projection. In the second phase of the study, the focus shifted to digitizing layers Roads, Built-up Areas/Houses, Dry Nullah, Active River cks, Bridges, Agriculture Land, Retaining Walls, Water Tanks, and Mosque) by using satellite imagery. Digitization involves manually tracing and marking damaged structures, infrastructure, and other affected elements visible in the satellite images to create a comprehensive record of the pre-flood and post-flood conditions for further analysis,

Results:

The pre-flood and post-flood analysis of Barwai Khwar using high-resolution aerial imagery provided valuable insights into the extent of damage and changes in the landscape caused by the flood event. On 25 August, Pakistan announced a state of emergency in response to the flooding**.** On 1 September 2022, residents of Madyan in Pakistan's Swat Valley walk past homes damaged by the flooding. Continuous monitoring and analysis of such data are crucial for adapting to the dynamic natural environment and minimizing future flood impacts. The flood event in Barwai Khwar, Swat, KPK, had far-reaching consequences that reshaped the landscape and impacted the lives of the local population.

Land cover analysis revealed significant alterations caused by the flood, particularly in agricultural areas and settlements. Floodwaters and sediment deposition transformed once-productive lands, posing challenges to agriculture and livelihoods. Additionally, the flood's force and velocity caused erosion in some areas, leading to the loss of fertile topsoil and natural habitat. To minimize future impacts, a comprehensive understanding of the environmental and socioeconomic consequences is essential. Implementing measures that address both immediate recovery and long-term resilience will be vital in supporting the affected communities and safeguarding the region against similar events in the future.

After the flood, the active river flow significantly impacted and altered the landscape in Barwai Khwar, Swat, KPK. The forceful flow of floodwater damaged and reshaped large portions of agricultural land as shown in the above pre-flood image from point A to B, eroding fertile topsoil and posing challenges for farmers. Moreover, one retaining wall, which likely served as a flood defense structure, was unable to withstand the intensity of the flood, leading to its failure.

The area between points C and D (Figure 4) experienced extensive damage to agricultural land due to the forceful flow of floodwaters**.** The flood resulted in the destruction of one bridge in the region between points C and D. The high-velocity floodwaters and debris might have caused the bridge's structural integrity to fail, disrupting transportation and connectivity in the area. The force of the flood likely overwhelmed one retaining wall in this stretch. This wall, designed to hold back floodwaters and prevent damage to surrounding areas, could not withstand the immense pressure, leading to its failure and leaving the adjacent areas exposed to further flooding and erosion risks.

Between points E and F (Figure 5), there is a relatively smaller area of agricultural land that exhibits signs of damage, contrasting with the surrounding regions. The damage likely results from natural factors such as erosion or soil degradation, possibly exacerbated by adverse weather conditions. Furthermore, in this specific section, two retaining walls have also been affected, likely due to the increased pressure or impact from the damaged land. The cause of the damage could be linked to factors like improper drainage, lack of maintenance, or a recent natural event. Addressing these issues promptly is crucial to prevent further deterioration and safeguard the agricultural land and retaining walls in the area.

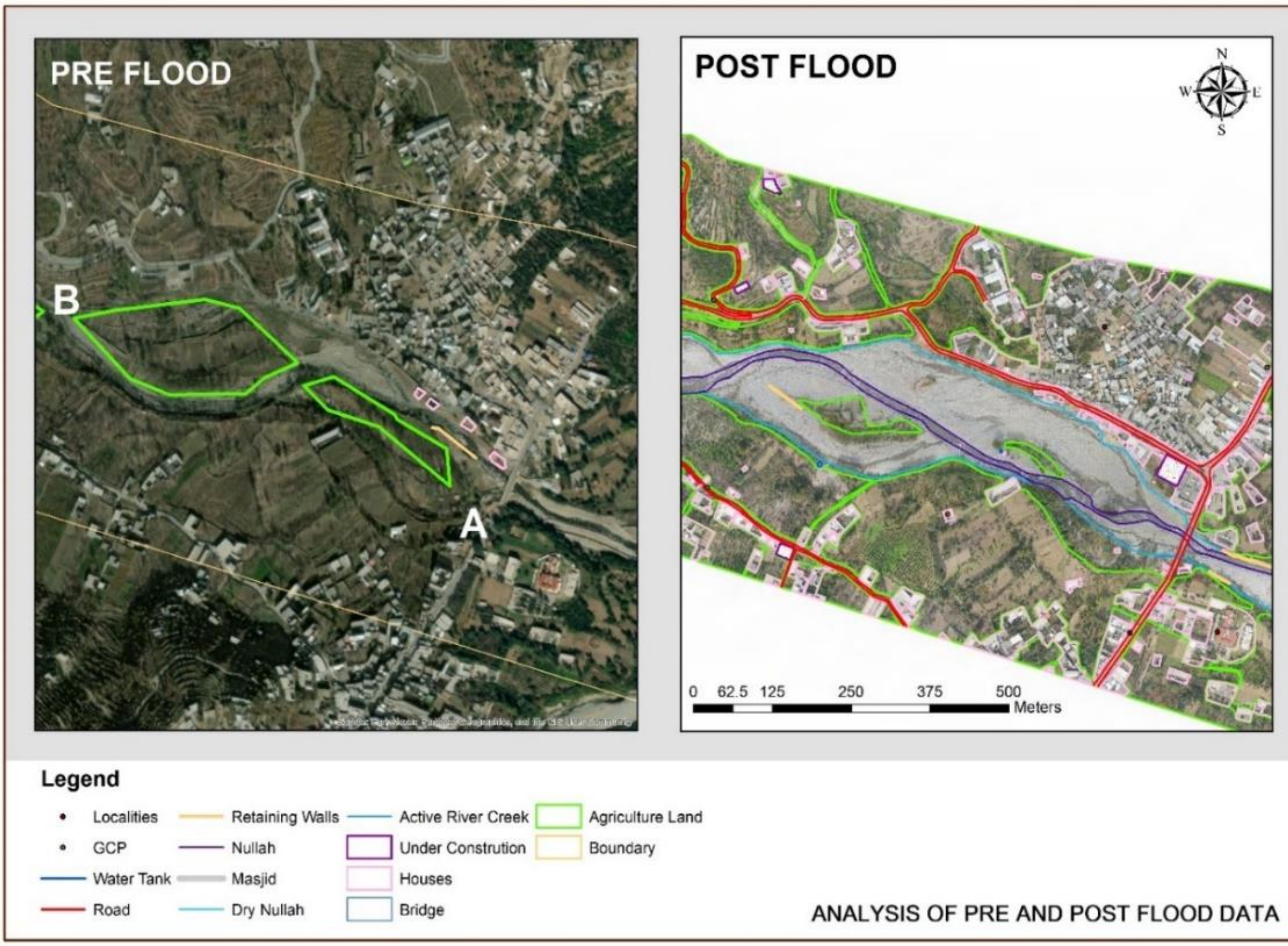

Figure 3: Analysis of Pre and Post Flood Data from point A to B

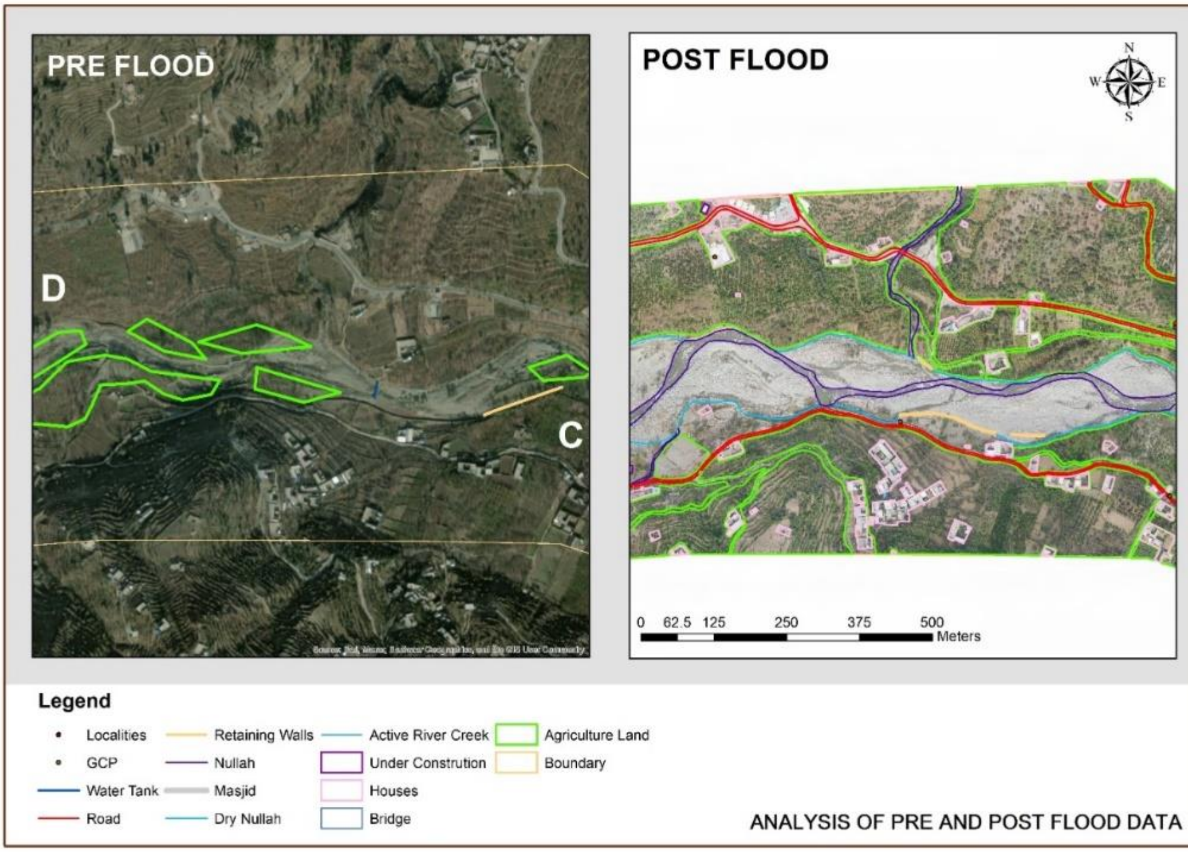

Figure 4: Analysis of Pre and Post Flood Data from point C to D

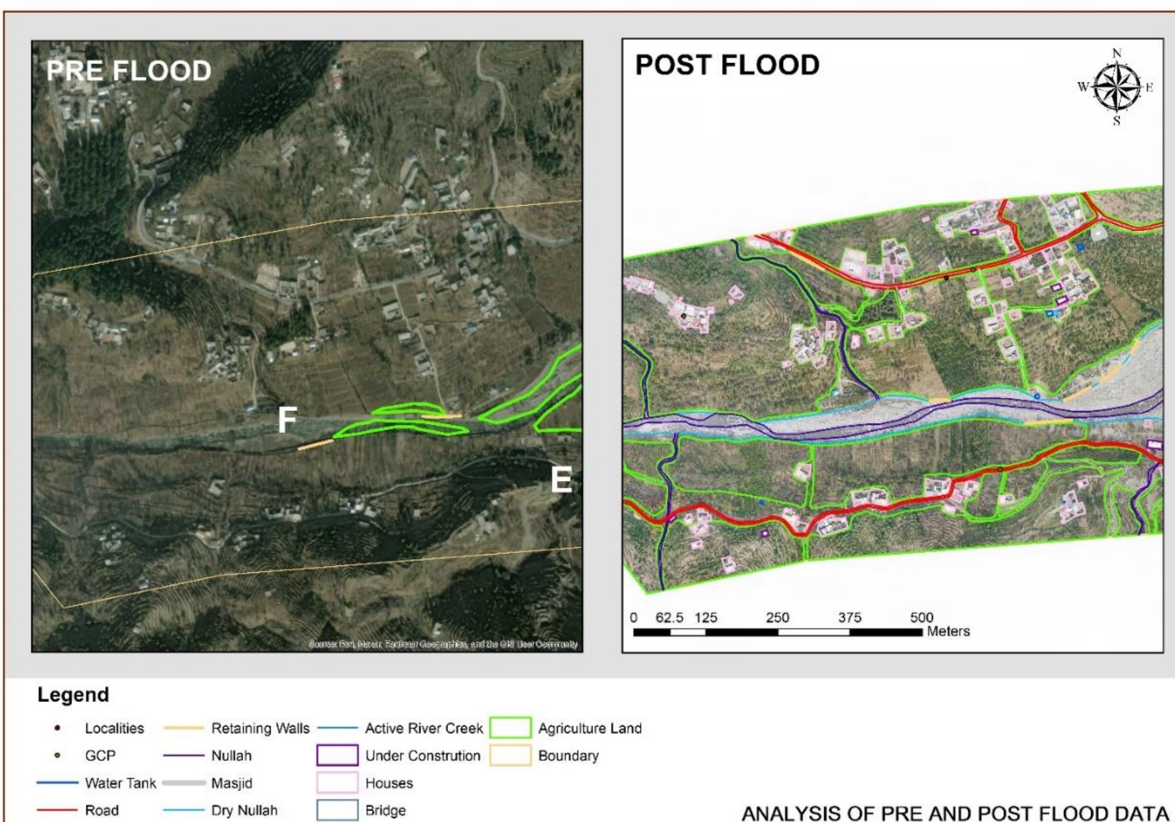

Figure 5: Analysis of Pre and Post Flood Data from point E to F

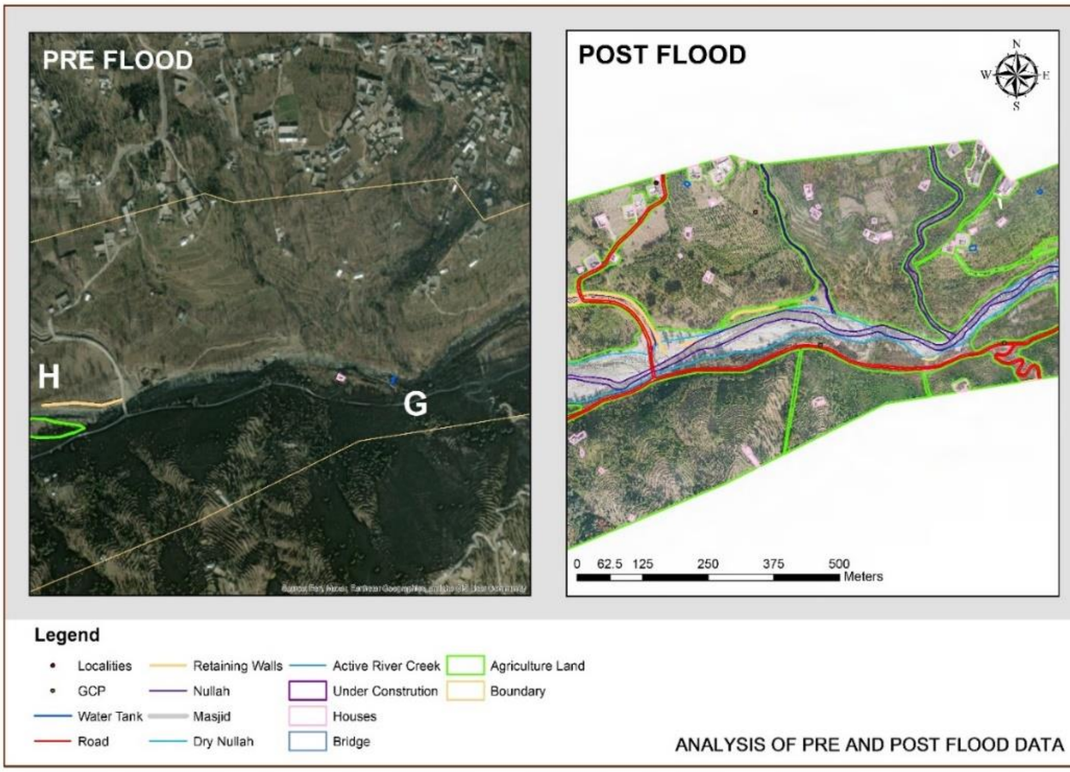

Figure 6: Analysis of Pre and Post Flood Data from point G to H

Between points G and H (Figure 6), the area is marked by a mix of varying impacts from a previous disaster. The agricultural land in this region has experienced the least damage compared to other areas nearby. This suggests that the local farmers might have taken effective measures to protect their crops and fields during the calamity, showcasing their resilience and ability to adapt.

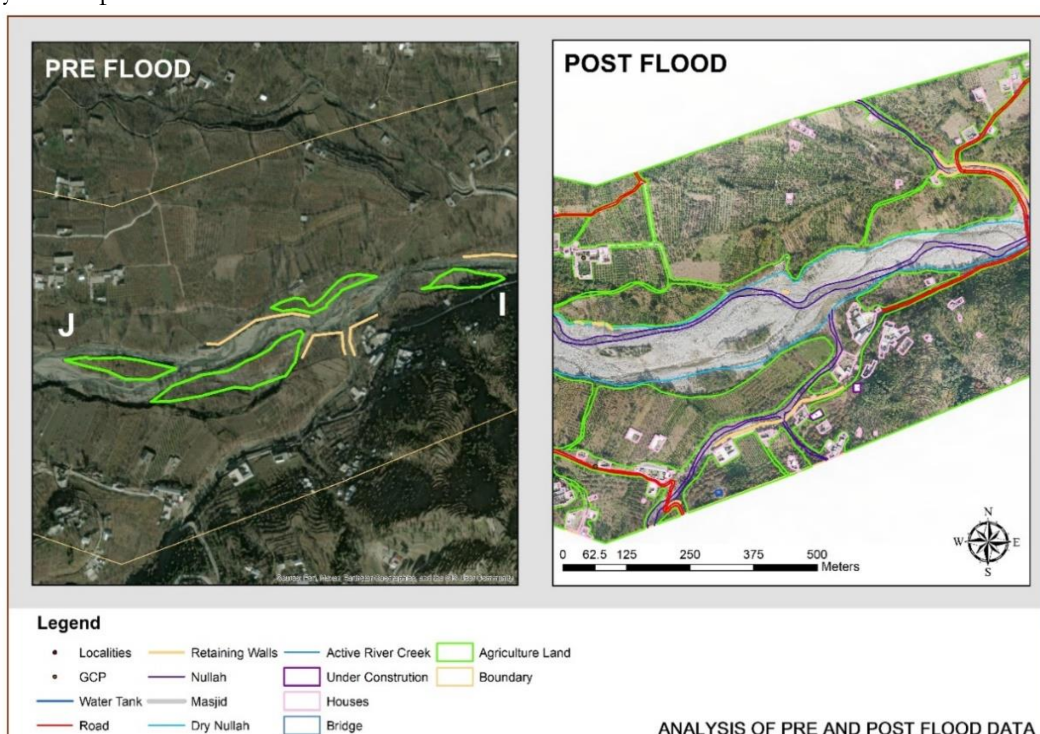

Figure 7: Analysis of Pre and Post-Flood Data from point I to J

However, there is evidence of some structures being affected by the disaster. One house near a collapsed bridge has suffered damage, indicating the destructive force of the disaster on buildings in the area. Additionally, a retaining wall is also damaged, reflecting the challenges in maintaining infrastructure during such events. Overall, this landscape demonstrates the complex nature of disasters, with certain areas faring better due to the proactive efforts of the farming community, while others show the impact on buildings and structures in the vicinity.

Between points I and J, (Figure 7) the landscape reveals the devastating impact of the flood, particularly on retaining walls and agricultural land. In this area, around four to five retaining walls have been severely damaged, indicating the immense force and water pressure brought by the flood. The destruction of these walls might have contributed to the flooding, exacerbating its effects on the surrounding land. Moreover, the agricultural land in this region has suffered significant damage, with portions of it being reshaped or even relocated due to the force of the floodwaters. This implies that the flood not only caused immediate damage but also altered the topography and layout of the farmlands, posing further challenges to the local farmers.

The region between points K and L (Figure 8) was devastated by a destructive flood, leading to extensive damage across the area. Two residential areas were severely affected, leaving properties and homes in ruins. Additionally, a substantial retaining wall collapsed, posing a further threat to the stability of the region. The floodwaters also wreaked havoc on a large scale of agricultural land, causing substantial damage to crops and agricultural infrastructure. The aftermath of the flood necessitated urgent response and recovery efforts to repair and rebuild the damaged residential areas, reconstruct the collapsed retaining wall, and rehabilitate the agricultural land to restore livelihoods and stability to the affected communities.

In the region from point M to N (Figure 9), the flood has primarily impacted a large area of agricultural land, with minimal damage to other structures or infrastructure. The floodwaters likely inundated the agricultural fields, leading to soil erosion, crop damage, and possible contamination from floodwaters. However, due to the absence of significant damage to residential areas or infrastructure in this specific region, the focus of the response and recovery efforts would primarily be on agricultural rehabilitation.

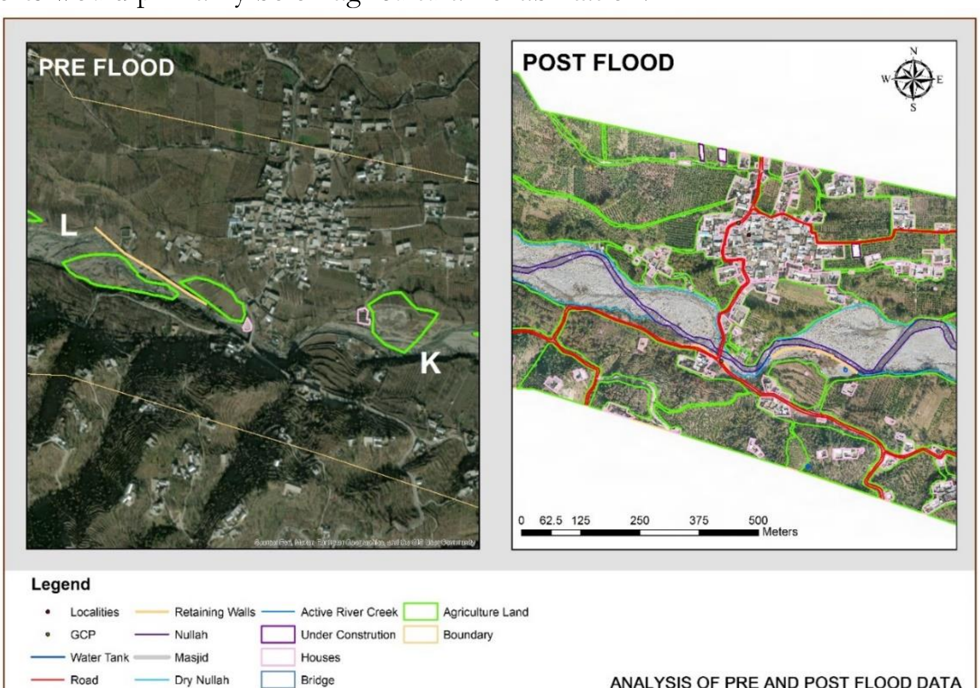

Figure 8: Analysis of Pre and Post Flood Data from point K to L

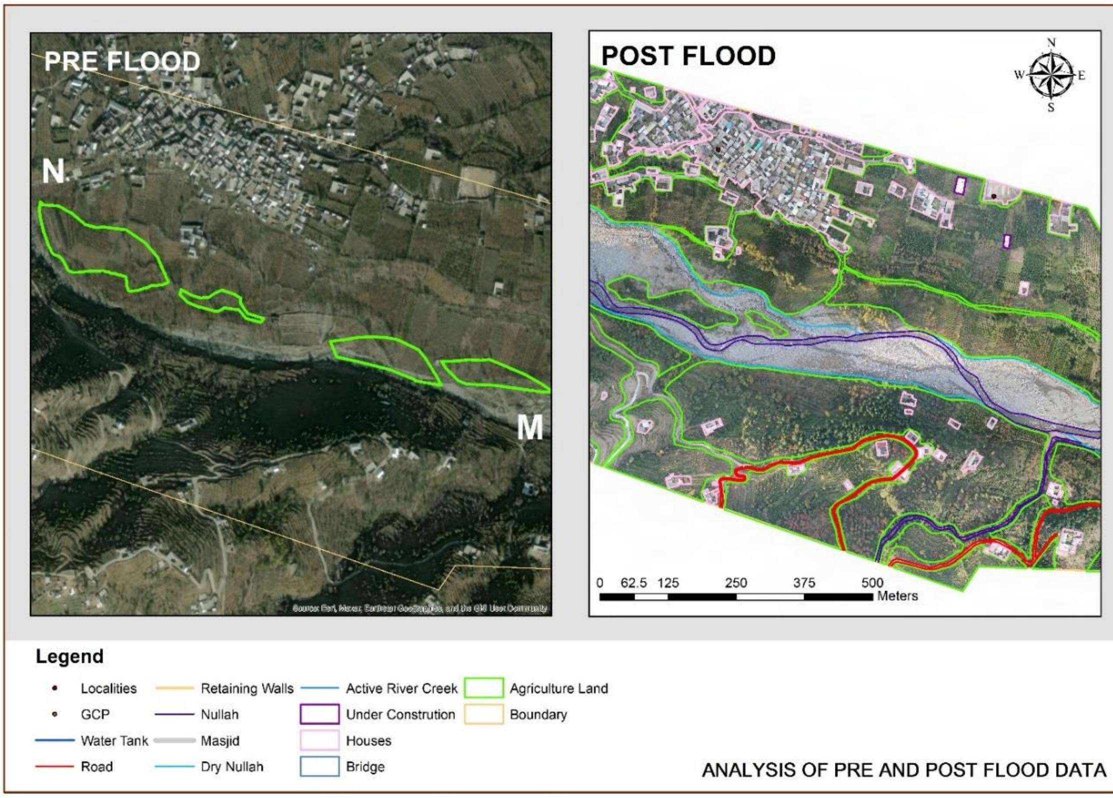

Figure 9: Analysis of Pre and Post Flood Data from point M to N

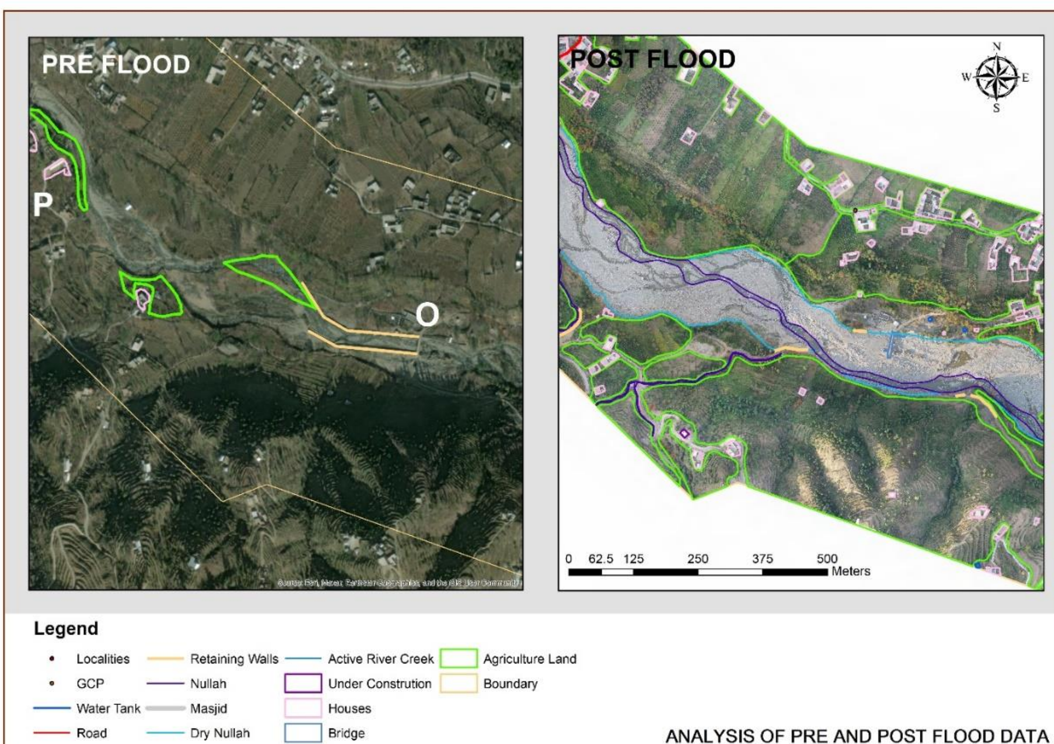

Figure 10: Analysis of Pre and Post Flood Data from point O to P

The next area, extending from point O to P (Figure 10), experienced significant damage during the flood. The floodwaters caused extensive destruction to a large portion of agricultural land in the region, leading to soil erosion, crop loss, and potential contamination. Alongside this, a crucial long length of retaining wall, which was attached to a bridge in the area, was also severely damaged, posing risks to the stability of the bridge and further hindering transportation and connectivity. Furthermore, one house located near the agricultural land was affected by the flood, resulting in structural damage and potential displacement of residents.

The area between points Q and R (Figure 11) has experienced significant damages caused by the flood, affecting both residential areas and agricultural land. The floodwaters have inundated and damaged several residential properties, leading to structural damage and rendering homes uninhabitable. Residents in this area may have faced displacement and loss of belongings due to the flood's impact. Additionally, the flood has wreaked havoc on the agricultural land in this region, resulting in soil erosion, crop damage, and potential contamination.

Between points S and T (Figure 12), the flood has caused multiple damages, including three retaining walls, and a small area of agricultural land damage that has been affected. The collapse or damage of the three retaining walls poses a risk of further erosion and instability in the area. The floodwaters have also impacted a portion of agricultural land, resulting in crop loss and soil damage, which could affect local farmers' livelihoods.

In the region between points U and V (Figure 13), there is evidence of flood damage, including a damaged retaining wall and affected areas of agricultural land. The flood has caused one retaining wall to collapse or sustain damage, potentially leading to land instability and posing risks to nearby infrastructure or transportation routes.

Between points W and X (Figure 14), the width of the Nullah has decreased, resulting in the minimization of flood flow. While this reduction in water flow may seem beneficial, it has still caused damage to one retaining wall and small areas of agricultural land. The decreased flood flow can lead to a gradual accumulation of water, causing localized flooding in certain areas. This has resulted in damage to a retaining wall, which might have been unable to withstand the pressure from the accumulated water. Additionally, the small areas of agricultural land in this region have been affected by water stagnation, resulting in soil waterlogging, decreased crop productivity, and potential crop damage due to prolonged submersion.

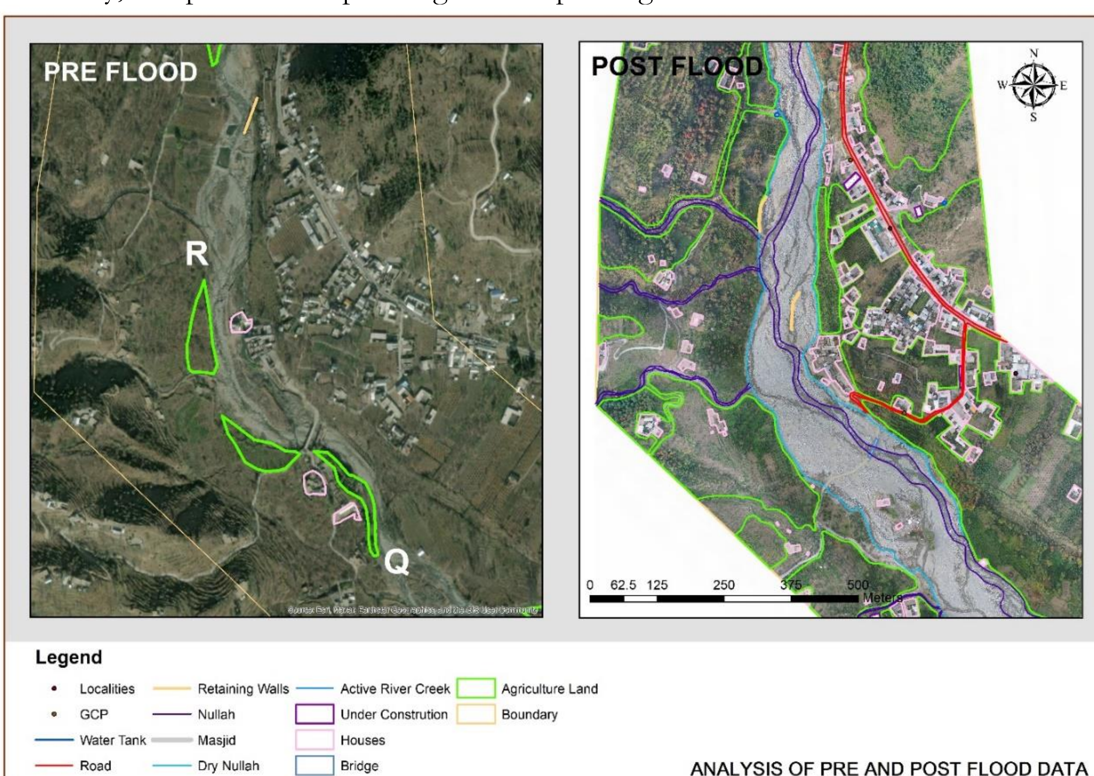

Figure 11: Analysis of Pre and Post Flood Data from point Q to R

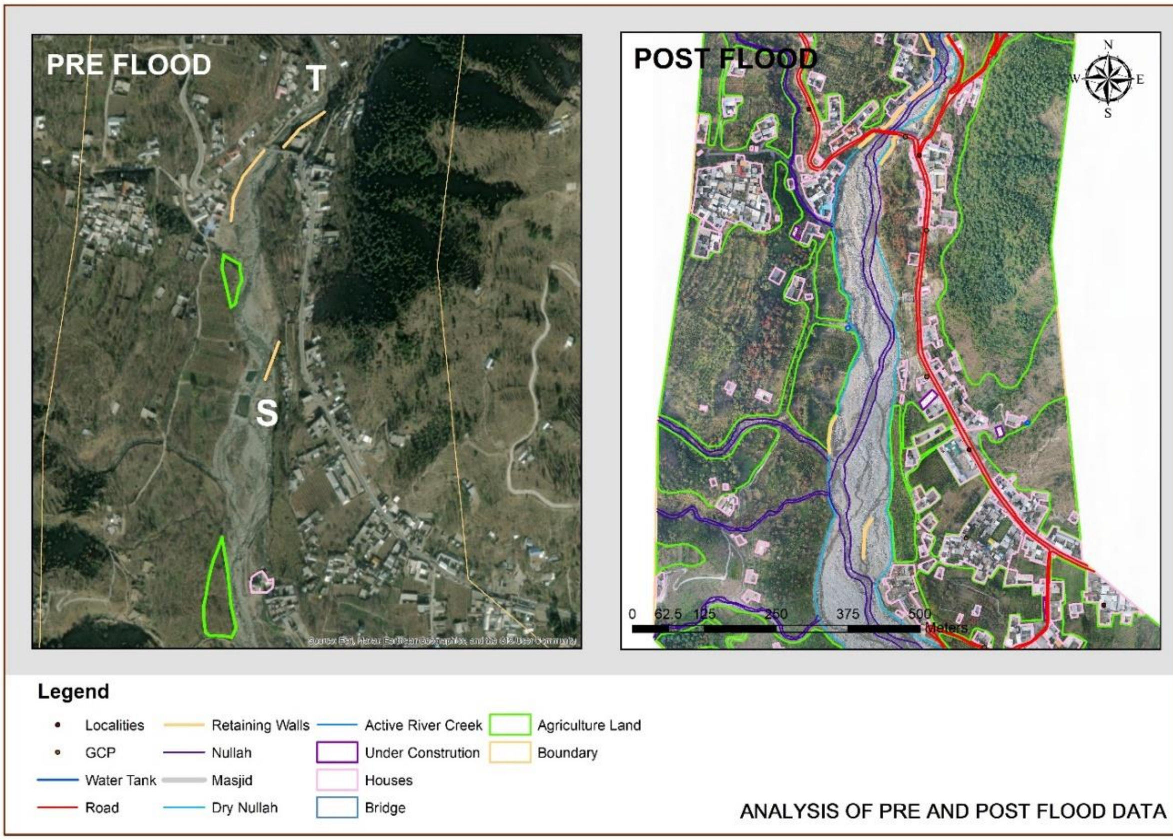

Figure 12: Analysis of Pre and Post Flood Data from point S to T

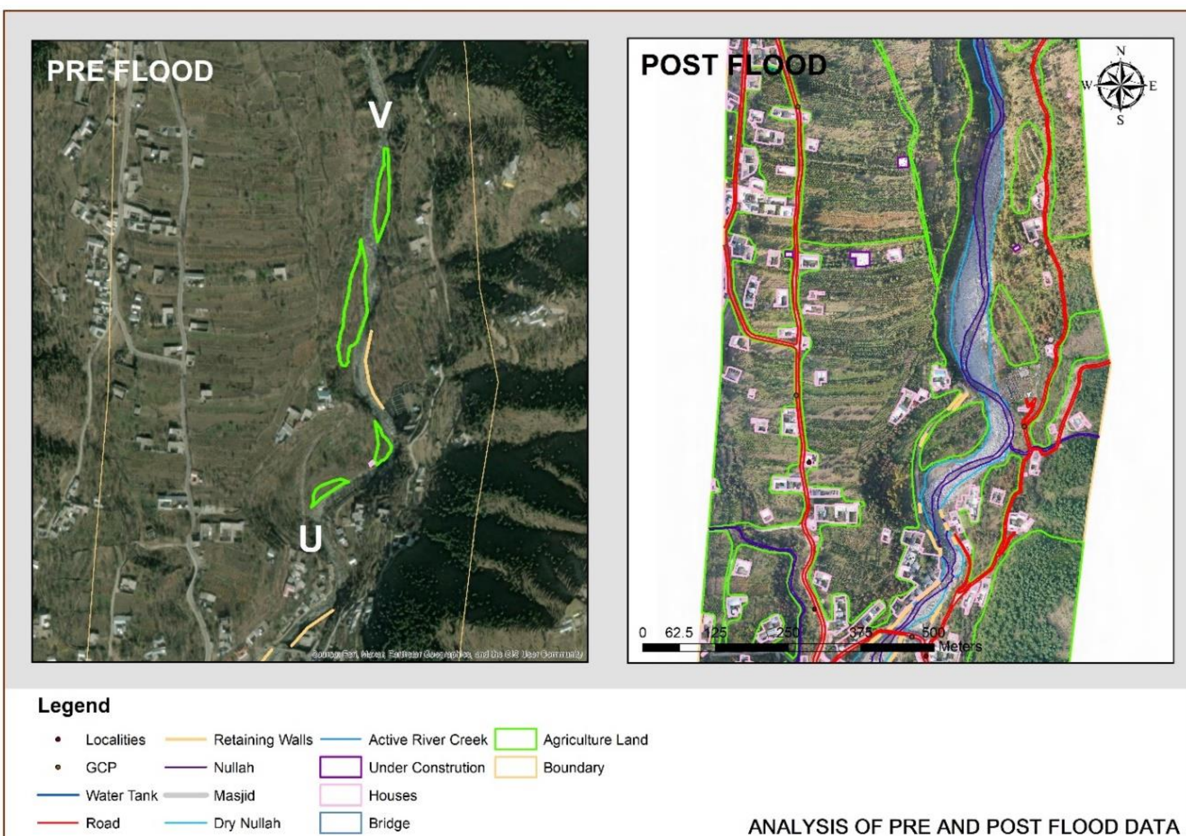

Figure 13: Analysis of Pre and Post Flood Data from point U to V

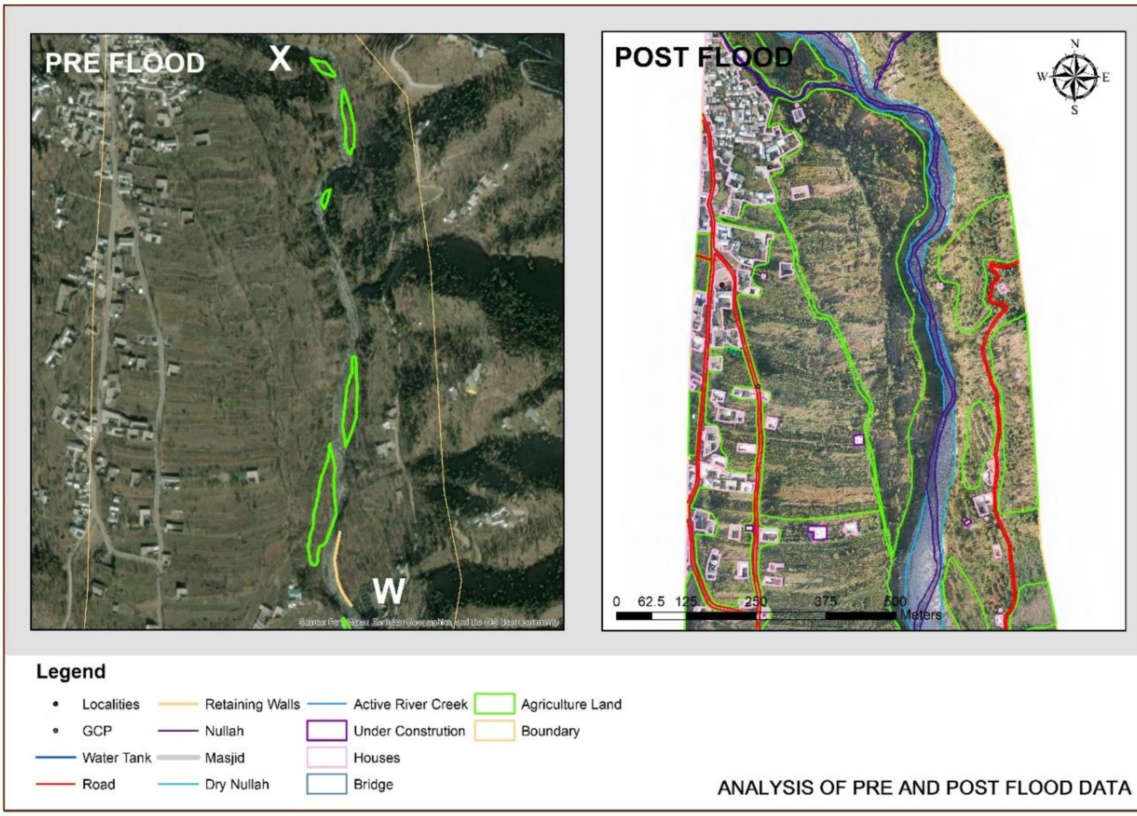

Figure 14: Analysis of Pre and Post-Flood Data from Point W to X

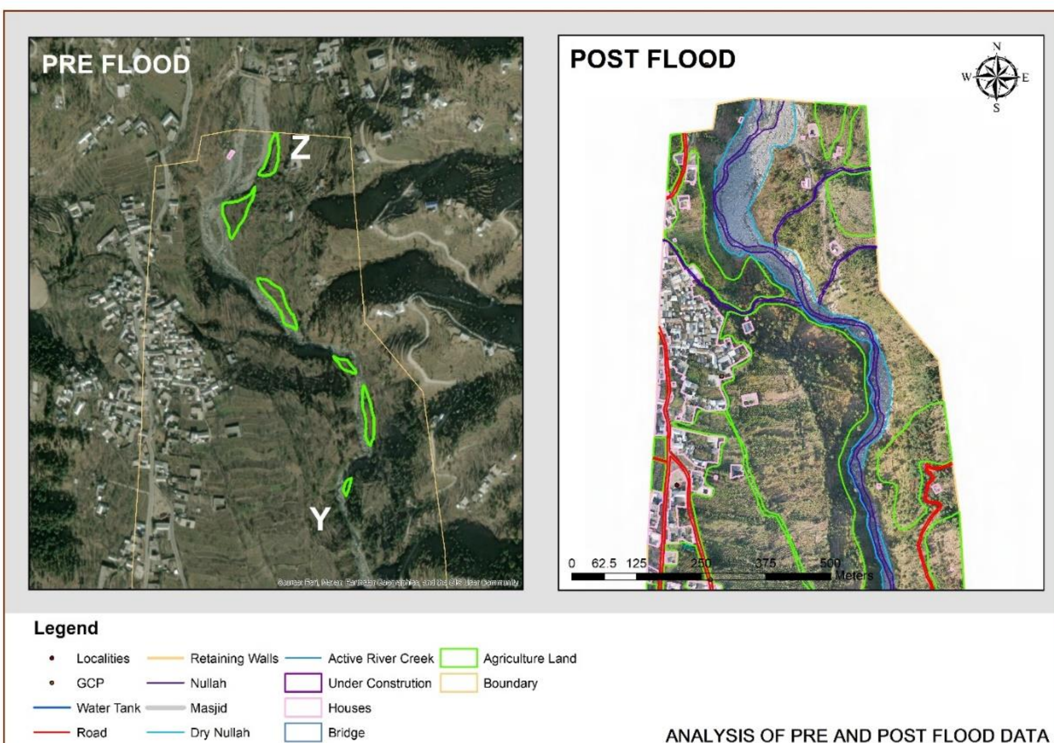

Figure 15: Analysis of Pre and Post-Flood Data from Point Y to Z

Between points Y and Z (Figure 15), the flow of the flood has decreased, which may initially seem like a positive development. However, despite the reduced flood flow, the area has still experienced significant damage, particularly to agricultural land and houses. The decrease in flood flow might lead to water stagnation and prolonged inundation, negatively impacting the agricultural land.

High-resolution imagery provides an accurate depiction of the damage caused by floods, such as infrastructure destruction, according to Table 6, the 14758.9 m (14.8km) extensive agricultural area of Barwai Khwar damaged in the flood of 2022 and the percentage of agricultural land loss is highest among all. The destruction area of the retaining wall is 2184m (2km) and housing loss is 1074.9m and the damaged area of Nullah is 82.6m.

Table 1: Damage Length of Retaining Walls

Sr. No	Geographical Location		Retaining wall
	Longitude	Latitude	Perimeter (m)
1	72°28'38.71"E	35° 4'31.10"N	83.9
2	72°28'8.22"E	35° 4'35.39"N	141
3	72°27'26.56"E	35° 4'33.99"N	65.2
4	72°27'18.00"E	35° 4'32.21"N	59.3
5	72°26'20.27"E	35° 4'24.51"N	152
6	72°26'9.65"E	35° 4'19.12"N	113
7	72°26'6.63"E	35° 4'18.41"N	148
8	72°26'1.49"E	35° 4'19.68"N	215
9	72°25'19.55"E	35° 4'21.07"N	283
10	72°24'20.15"E	35° 4'36.13"N	267
11	72°24'20.39"E	35° 4'34.09"N	215
12	72°23'48.93"E	35° 5'8.33"N	68.8
13	72°23'46.94"E	35° 5'18.15"N	139
14	72°23'50.72"E	35° 5'21.41"N	93.8
15	72°23'54.50"E	35° 5'35.90"N	140

Table 2: Damage Area of Houses

Sr. No	Geographical Location		Houses	
	Longitude	**Latitude**	**Area (m^2)**	**Perimeter (m)**
1	72°25'39.11"E	35° 4'23.33"N	645	109
2	72°26'39.70"E	35° 4'26.46"N	87	38.8
3	72°25'27.71"E	35° 4'17.23"N	317	72
4	72°24'3.55"E	35° 4'36.40"N	665	108
5	72°23'54.34"E	35° 4'46.27"N	1438	144
6	72°23'56.53"E	35° 4'44.68"N	996	160
7	72°23'50.34"E	35° 4'53.22"N	1075	131
8	72°23'54.46"E	35° 5'30.68"N	37	25.1
9	72°28'41.45"E	35° 4'30.26"N	348	76.7
10	72°28'39.56"E	35° 4'32.04"N	260	66.1
11	72°28'37.51"E	35° 4'32.92"N	166	52.4
12	72°28'36.50"E	35° 4'33.51"N	151	49.8
13	72°23'43.03"E	35° 6'17.99"N	86.3	42

Table 3: Damage Area of Agriculture Land

Sr. No	Geographical Location		Agriculture Land	
	Longitude	Latitude	Area (acres)	Perimeter (m)
1	72°24'46.28"E	35° 4'28.59"N	0.75	367
2	72°24'37.64"E	35° 4'32.58"N	4.65	656
3	72°24'13.20"E	35° 4'38.41"N	1.47	429
4	72°28'33.87"E	35° 4'31.57"N	2.29	602
5	72°28'10.69"E	35° 4'37.29"N	0.69	240
6	72°27'49.97"E	35° 4'38.47"N	1.22	400
7	72°27'52.73"E	35° 4'36.81"N	1	338
8	72°27'44.02"E	35° 4'38.30"N	0.88	307
9	72°27'40.30"E	35° 4'36.18"N	4.72	866
10	72°27'33.82"E	35° 4'36.70"N	2.14	599
11	72°27'24.33"E	35° 4'34.36"N	0.3	262
12	72°27'23.85"E	35° 4'33.26"N	0.7	477
13	72°26'17.29"E	35° 4'22.79"N	0.87	344
14	72°26'6.52"E	35° 4'21.69"N	0.89	474
15	72°25'59.17"E	35° 4'17.28"N	3.17	704
16	72°25'50.90"E	35° 4'16.58"N	1.25	450
17	72°25'42.44"E	35° 4'18.20"N	2.74	419
18	72°25'24.74"E	35° 4'18.88"N	1.34	350
19	72°25'6.33"E	35° 4'24.88"N	1.56	442
20	72°25'17.05"E	35° 4'20.30"N	2.54	547
21	72°25'0.21"E	35° 4'26.46"N	2.24	475
22	72°23'56.68"E	35° 4'45.59"N	1	504
23	72°24'1.87"E	35° 4'39.62"N	1.1	412
24	72°23'50.29"E	35° 4'48.52"N	1.38	380
25	72°23'46.04"E	35° 5'12.77"N	0.46	208
26	72°23'45.88"E	35° 5'0.07"N	1.45	396
27	72°23'50.51"E	35° 5'22.80"N	0.23	171
28	72°23'53.54"E	35° 5'28.42"N	0.25	172
29	72°23'52.93"E	35° 5'40.08"N	1.26	464
30	72°23'54.69"E	35° 5'45.63"N	0.58	333
31	72°23'52.57"E	35° 5'57.34"N	0.1	78.9
32	72°23'54.01"E	35° 6'2.29"N	0.37	241
33	72°23'52.14"E	35° 6'5.36"N	0.13	116
34	72°23'46.86"E	35° 6'9.51"N	0.56	271
35	72°23'45.94"E	35° 6'18.04"N	0.37	202
36	72°23'43.71"E	35° 6'14.37"N	0.62	259
37	72°28'21.78"E	35° 4'35.88"N	8.48	803

Table 4: Damage Length of Bridges

Sr.No	Geographical Location		Nullah
	Longitude	Latitude	Length (m)
1	72°27'58.24"E	35° 4'35.77"N	15.4
2	72°26'43.61"E	35° 4'26.64"N	23.6

Nullah Width:

The total length of the nullah is 11378 meters with latitude (35° 4'30.59" N) and longitude (72°28'48.49"E).

Table 5: Width of Nullah

Sr. No	Geographical Location		Nullah	
	Longitude	Latitude	Width	Length (m)
1	72°23'46.20"E	35°6'17.07"N	Maximum	75.9 m
2	72°25'1.05"E	35°4'29.68"N	Minimum	6.97 m

Table 6: Linear Features of Nullah

Sr. No	Linear Features	
	Damage Features	Damage length(m)
1	Bridge	39
2	Retaining Walls	2184

Table 7: Surface Area Features of Nullah

Sr. No	Surface Area features		Damage Area (Perimeter)
	Damage Features	Damage Area (m^2)	
1	Houses	6271.3	1074.9
2	Agriculture Land	225612.25	14758.9

Discussion:

Drone technology has emerged as a valuable and efficient method for flood damage assessment and evaluating the impact of flooding on landscapes [22], infrastructure, and communities. There are many aspects of flood damage assessment such as rapid and comprehensive data collection, which can be used to assess the extent of the flood damage, identify affected structures, roads, and infrastructure, and estimate the overall impact on the environment [23]. In Figure 5 large portions of agricultural land are damaged and reshaped during pre-flood image from point A to B, eroding fertile topsoil and posing challenges for farmers. The total damaged area of agricultural land due to flood is 225612.25 (m^2) houses are 6271.3(m^2) respectively. Accuracy and precision is a valuable aspect of Drone technology as it enables the accurate identification of damages to residential and agricultural land and retaining walls, roads, and other critical infrastructure. Safety and accessibility are ensured by using a drone, to get access to hazardous areas (Quoc 2020). The residential areas were also severely affected, with approximately 5 to 6 residential areas experiencing flood inundation. This resulted in damage to houses, and infrastructure, and disruptions to the lives of the affected communities. Comparison and monitoring, data integration and analysis, and resource allocation are also prominent features of this state-of-the-art. Moreover, the agricultural land in this area has been negatively impacted, with crops being damaged or destroyed due to floodwaters. Farmers in the area may need assistance in reclaiming and reshaping the land, replenishing soil nutrients, and replanting crops to restore agricultural productivity and ensure food security for the community Soil erosion and potential contamination may have further compounded the agricultural losses. The river's floodplain substantially expanded, leading to the inundation of agricultural land, built-up areas, and settlements. Crucial infrastructure, including roads and bridges, faced damage or were washed away by the force of the floodwaters, severely hampering accessibility and mobility within the region.

Finally, the impacts varied across the region, with agricultural land, retaining walls, and residential areas being the most affected. Urgent recovery efforts are necessary to restore stability and livelihoods in the aftermath of this natural disaster. Additionally, measures to improve flood resilience, infrastructure maintenance, and disaster preparedness should be prioritized to mitigate the impact of future events. Collaboration between local authorities, communities, and relevant stakeholders will be essential in rebuilding and safeguarding the region against future floods.

Conclusion:

After the flood in Barwai Khwar, Swat, Khyber Pakhtunkhwa (KPK), the landscape showed different levels of damage and impacts at various locations. The forceful flow of floodwaters significantly altered the region, causing extensive damage to agricultural land, residential areas, retaining walls, and infrastructure. From point A to B, the active river flow reshaped large portions of agricultural land, eroding fertile topsoil and posing challenges for farmers. One retaining wall, likely serving as a flood defense structure, failed to withstand the flood's intensity. This led to localized flooding and further erosion risks. The residential areas in this region experienced severe inundation, damaging houses, and infrastructure, and disrupting the lives of the affected communities. Between points C and D, the forceful flow of floodwaters caused extensive damage to agricultural land, leading to the destruction of one bridge. Additionally, the flood overwhelmed a retaining wall, impacting the surrounding areas. At points E and F, a relatively smaller area of agricultural land displayed damage, possibly from natural factors like erosion or soil degradation, with two retaining walls also affected. Between points G and H, the area depicted a mix of varying impacts from the disaster. While agricultural land in this region fared better, one house near a collapsed bridge suffered damage, indicating the destructive force on buildings (Quoc et al., 2020). A retaining wall was also damaged, highlighting infrastructure challenges during such events. From points I to J, the flood's force led to extensive damage to retaining walls and agricultural land, causing flooding and reshaping of the land. Between points K and L, the region suffered from severe damage to residential areas, retaining walls, and agricultural land, necessitating urgent recovery efforts. Between points M and N, a large area of agricultural land was affected, demanding rehabilitation for the farming community. From point O to P, the floodwaters damaged agricultural land and a retaining wall attached to a bridge. Between points Q and R, both agricultural land and residential areas experienced significant damage. At points S and T, the flood caused damage to three retaining walls and a small area of agricultural land [25], [26]. Between points U and V, a damaged retaining wall and affected agricultural land were observed. From points W to X, the reduced flood flow still damaged a retaining wall and small areas of agricultural land. Between points Y and Z, the decreased flood flow caused damage to agricultural land and one house. In conclusion, the flood in Barwai Khwar, Swat, KPK, resulted in substantial damages, altering the landscape and posing challenges to the affected communities.

Recommendations

Based on the conclusion drawn from the flood in Barwai Khwar, Swat, KPK, the following recommendations are crucial to address the challenges posed by the disaster and enhance the region's resilience against future floods:

- Rehabilitation of damaged infrastructure, such as roads, bridges, and utilities, must be prioritized to facilitate access and improve connectivity within the region.
- Strengthening disaster preparedness is crucial to respond effectively to future floods. Establishing robust early warning systems, community drills, and contingency plans can help minimize the loss of life and property during emergencies.
- Implementing sustainable land use planning practices is essential to reduce the vulnerability of communities to floods. Identifying and protecting floodplains, restricting construction in high-risk areas, and promoting resilient agricultural practices can prevent future flood-related damages.
- Conducting awareness campaigns and providing training to local communities on flood risk management and response can empower them to take proactive measures and safeguard their lives and property during flood events.
- Encouraging collaboration between local authorities, communities, NGOs, and other relevant stakeholders is vital to developing and implementing effective flood management strategies. Partnerships at various levels will help mobilize resources, expertise, and support for sustainable

recovery and preparedness efforts.

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