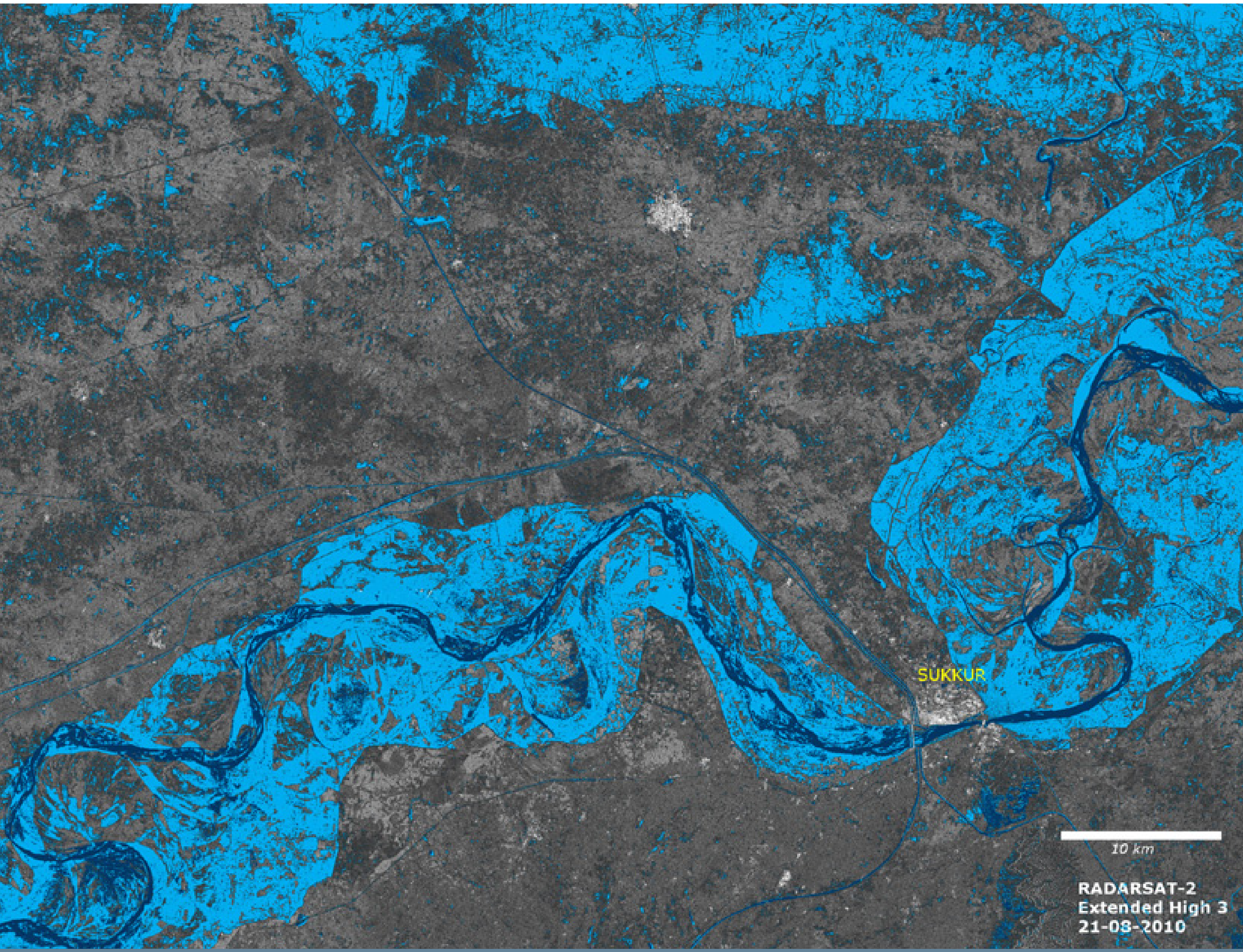
SUPARCO



Effective use of Space-based information to monitor disasters and its impacts

Lessons Learnt from Floods in Pakistan

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Effective use of Space-based information to monitor disasters and its impacts

Lessons Learnt from Floods in Pakistan

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Acronyms

ADB	Asian Development Bank
AJK	Azad Jammu and Kashmir
AWS	Automatic Weather Station
CRS	Crop Reporting Services
CSA	Canadian Space Agency
DLR	German Aerospace Center
DNA	Damage Needs Assessment
FAO	United Nations Food and Agriculture Organization
FATA	Federally Administered Tribal Areas
GB	Gilgit Baltistan
GIS	Geographic Information Systems
GLOF	Glacial Lake Outburst Flood
ICIMOD	International Centre for Integrated Mountain Development
IDP	Internally Displaced Person
IFAS	Integrated Flood Analysis System
ITP	Institute of Tibetan Plateau
KPK	Khyber Pakhtunkhwa
MAF	Million Acre Feet
MINFA	Ministry of Food & Agriculture
MINFSR	Ministry of Food Security & Research
MODIS	Moderate Resolution Imaging Spectroradiometer
NADRA	National Database & Registration Authority
NDMA	National Disaster Management Authority
NDVI	Normalized Difference Vegetation Index
PITB	Punjab Information Technology Board
PKR	Pakistani Rupee

PMD	Pakistan Meteorological Department
RIM	Regulated Irrigation Measurement
RS	Remote Sensing
SAR	Synthetic Aperture Radar
SDI	Spatial Data Infrastructure
SPARCENT	Space Application & Research Centre
SUPARCO	Pakistan Space & Upper Atmosphere Research Commission
UNITAR	United Nations Institute for Training and Research
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
UNOOSA	United Nations Office for Outer Space Affairs
UN-SPIDER	United Nations Platform for Space-based Information for Disaster Management and Emergency Response
USOFDA	United States Office of Foreign Disaster Assistance
USGS	United States Geological Survey

Foreword

In recent years, natural disasters have occurred frequently around the world and have been responsible for an enormous loss of life and property. Disaster management is a problem synonymous worldwide.

In recent times, Pakistan is one of the countries that has suffered from the onslaught of natural disasters in quick succession. A massive earthquake in 2005 killed more than 73,000 people, injured 100,000 people and destroyed large numbers of houses, schools, hospitals, roads and bridges, worth billions of rupees. The devastating floods of 2010 and 2011 resulted in a high number of human casualties as well as an enormous loss of property, causing immeasurable suffering to the Pakistani people. Frequency of natural disasters is on the rise due to extreme weather conditions and global climate changes. The situation in the prevention of and response to natural disasters has also become more serious and complicated.

Due to huge geographical size of the flood/rain affected regions, the extent and nature of damage cannot be properly quantified in a short time through manual field surveys alone.

Earthquake on 8 October 2005, killing more than 73000 people

Communities in distress - Super flood in Pakistan in 2010

The inaccessibility of disaster affected areas further adds to the complexity of relief and response work. In such a scenario satellite imagery is a valuable tool to generate and establish a quick footprint of a disaster. It provides crucial input for the planning of relief supplies by assessing damage to transport networks, finding escape routes and potential shelter sites for displaced people. For a prolonged disaster, such as the Pakistan floods of 2010, satellite based monitoring of the affected areas was very helpful in identifying the extent and dynamics of the disaster. Due to the revisit capability of earth observation systems, it can efficiently provide rapid mapping products of disaster stricken areas.

This booklet describes how space based information was used to monitor the floods of 2010, 2011, 2012 and 2013, and the lessons learned from these experiences. The information extracted from the satellite images provided vital information for planning and executing relief, early recovery operations and mitigation efforts. The purpose of this booklet is to utilize such experiences to enhance preparation, response and management of disasters in the near future.

Imran Iqbal
Member
Space Applications & Research

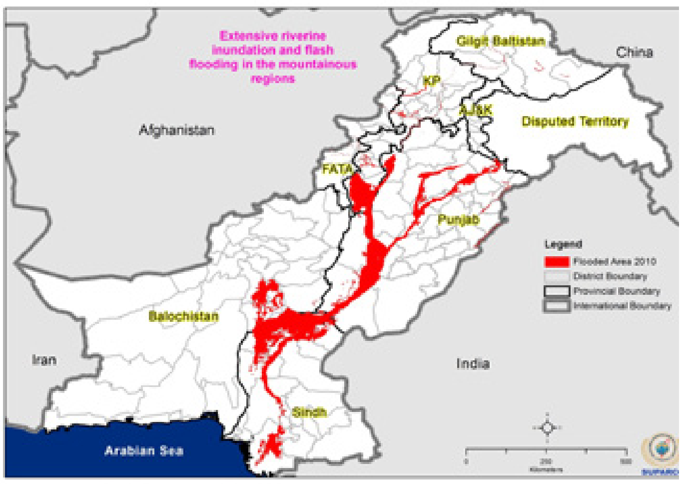
1. Chronicle-Floods 2010-2013

The summer rainfall in Pakistan is generally during the periods of July to September. Monsoons from the Bay of Bengal are the main source of these rains. However, the mid-latitude westerly disturbances sometimes also contribute to the summer rainfalls. There is a well marked monsoon season from July to mid-September in which the majority of the country receives rainfall. The floods, flash floods and torrential rains from the hills are a phenomenon of common occurrence in Pakistan, usually during a monsoon. These episodes, on occasions, are largely detrimental to the economy, damaging crops, settlements, households, infrastructure and exterminating livestock and other valuable assets.

The years of 2010, 2011, 2012 and 2013 witnessed the worst floods in the history of Pakistan, damaging crops, infrastructure, and settlements. This resulted in a significant loss of livestock while causing an unimaginable and prolonged suffering amongst the affected population.

1.1 Floods 2010

The monsoon season in 2010 started with a normal tempo until mid-July. The devastating rain started around 18 July and ended on 10 September. The largest amount of rain was received from 28 to 29 July, 2010. Another intense rainfall system was observed between 5-9 August.



Cumulative Flood Extent - 2010

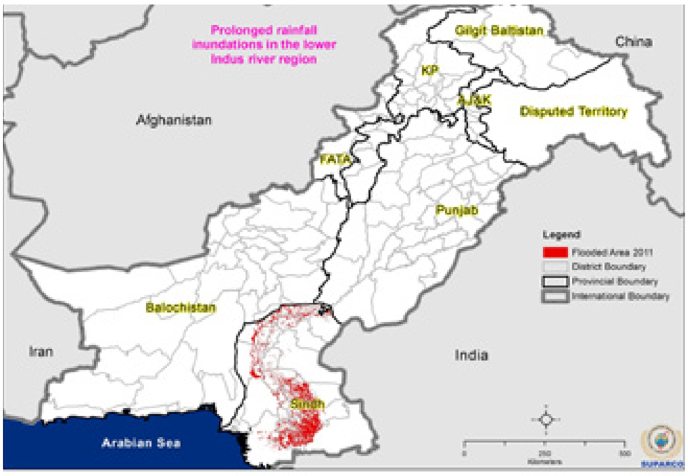
Floods in Rajanpur District in 2012
Image: NDMA

The rainfall systems during July and August were due to the interaction of a monsoon and mid-latitude westerlies. The Rainfall data is collected across the country by meteorological stations operated by Pakistan Metrological Department (PMD).

There are five large rivers that flow through the country from north to south, namely the mighty Indus and its tributaries i.e. Jhelum, Chenab, Ravi and Sutlej. The initial outburst started from River Swat, causing damage in the Swat valley during the last week of July. The Indus River breached its embankments upstream of Taunsa Barrage in Punjab and at Tori/ Ghauspur of Sukkur Barrage. Large areas were subject to flooding by the breaches of the river embankments; additionally caused by flash floods and torrential rain in the catchments of rivers and creeks. In total, 6 million ha of geographic area was inundated in Pakistan. The affected cultivated area was 3.3 million ha; consequently, 2.3 million ha of crops were destroyed.

1.2 Floods 2011

The monsoon of 2011 was manifested by remarkably high rainfall in South Asia. In Pakistan, there was wide spread rain. However, the major thrust of rainfall was in the Sindh province, where cumulative rainfall varied from 400mm to a little over 1299mm. These rains inundated large areas in Sindh and other provinces causing damage to crops, infrastructure and human settlements. The combined consequence of these detriments was a severely disrupted national economy.

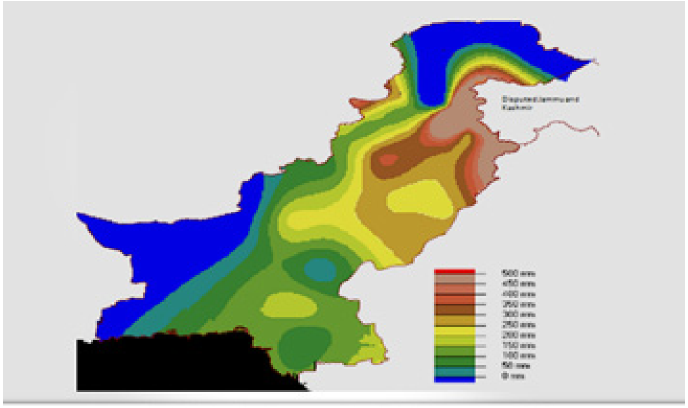


Cumulative Flood Extent - 2011

The Sindh coastal area is a low gradient area; consequently, any flooded water will recede at a slow pace. For the first time, the residents of the Thar Desert and its upper reaches had to be evacuated by boat. A large number of farmers lost their livestock during the evacuation due to the non-availability of fodders and fatal exertions. In the severely affected areas, there was hardly an area free of the hazard of stagnant water.

1.3 Floods 2012

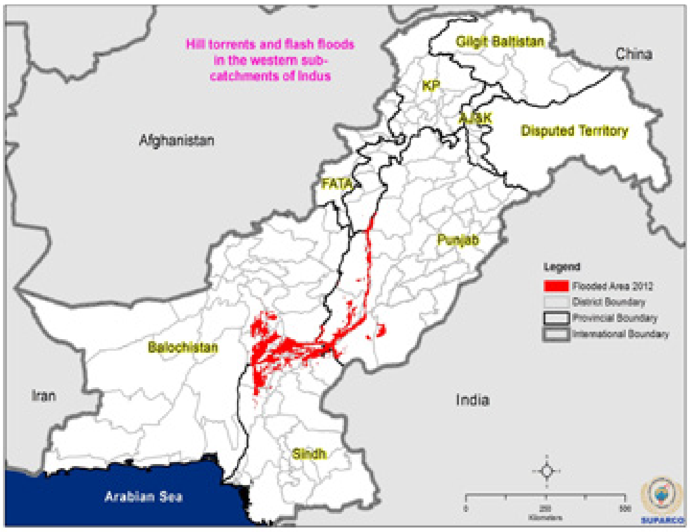
The monsoon in 2012 was late; it started in August and intensified during the month of September. During the first half of September, wide spread rains were experienced throughout the country, this severely affected the areas of Punjab, Sindh and Balochistan. Between 9 and 11 September, Jacobaabad, Larkana, Sukkur, Thatta and Tharparkar in the Sindh region received heavy rains, resulting in rainfall inundations. In Punjab, Rahim Yar Khan, Sahiwal, Okara, Jehlum, Mandi Bahaudin, DG Khan and Rajanpur experienced an extensive and continuous down pour from 8 to 12 and then 19 to 23 September. Balochistan, Naseerabad and Jafarabad also received heavy rains resulting in hill torrents in the Suleman Range. Heavy rains affected Southern Punjab, Sindh and Baluchistan with almost 24 to 26 hours of continuous rain, which affected thousands of people with the vast majority left displaced. Several deaths, injuries and damaged property were reported.



Spatial distribution map of rainfall - Monsoon 2012

The image below shows the rain fall graph for Punjab and Sindh in September.

Satellite images from MODIS were processed to map the flooded areas. MODIS images showed a synoptic view of the flooding in Punjab, Sindh and Balochistan. This information was provided to authorities involved in flood monitoring and mitigation. The timely assessments of the flood also helped in the dewatering process. Heavy rains affected Southern Punjab, Sindh and Baluchistan with almost 24 to 26 hours of continuous rain, which affected thousands of people with the vast majority left displaced. Several deaths, injuries and damaged property were reported.

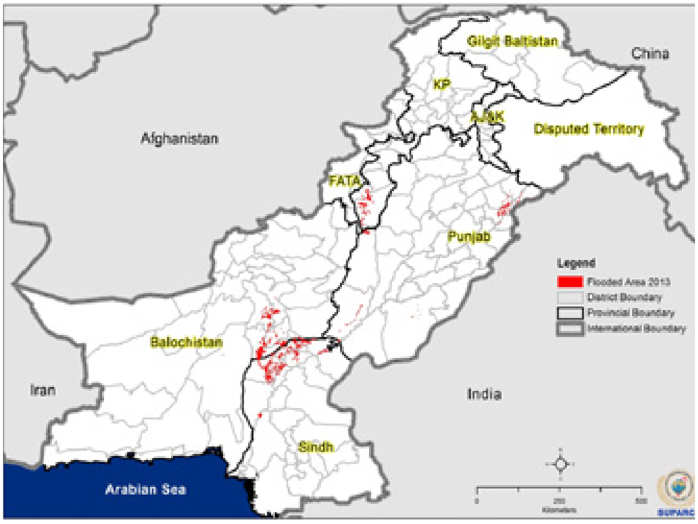


Cumulative Flood Extent - 2012

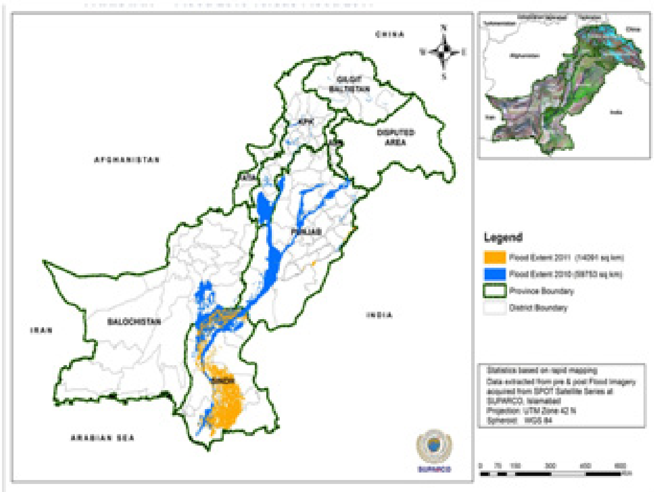
1.4 Floods 2013

The year 2013 was the fourth consecutive year in which heavy rains and floods hit the central and eastern parts of the country. SUPARCO took an active role in monitoring the progression of the floods and prepared rapid situation assessment reports of the resulting inundation using medium-resolution satellite data whereas a detailed assessment was undertaken through high-resolution satellite data and field validations. The information was then shared with the concerned government organizations as well as international agencies. Recession of flood water was also monitored in order to assess the extent of the damage caused by floods to agricultural land as well as to provide assistance in rehabilitation efforts.

Flood in Pasrur, Sialkot



Cumulative Flood Extent - 2013



Impact of Floods 2011 compared with 2010

1.5 Impact of Floods

Pakistan suffered the worst floods in its history back to back in 2010 and 2011. According to the National Disaster Management Authority (NDMA), the Floods in 2010 affected an area proportional to one fifth of the country, claiming over 2000 lives and injuring 3000 people. Flash floods and landslides triggered by monsoon rains caused severe damage to the infrastructure in the affected areas. Entire villages were washed away, urban centres were flooded, homes were destroyed, and thousands of acres of crops and agricultural lands were damaged with major soil erosion occurring in some areas.

The 1.04 million cusecs (measuring the flow rate of 1 cubic foot per second) of water flowing from north to south through the provinces of Punjab and Sindh have broken the century-old record of 0.9 million cusecs experienced in the flooding of 1901.

2. Information Needs to Respond to the Disaster Event

Immediately after a disaster, the need of information pertaining to the affected areas is in high demand by various sectors involved in rescue/ relief to early recovery. This information is usually in the form of initial assessment reports, tabular data, maps, trends analysis etc.

Aqua/Terra Satellite Ground Receiving Station in Karachi

In the aftermath of the floods the following information on the spatial stage was immediately needed by different agencies involved in the rescue and recovery operations:

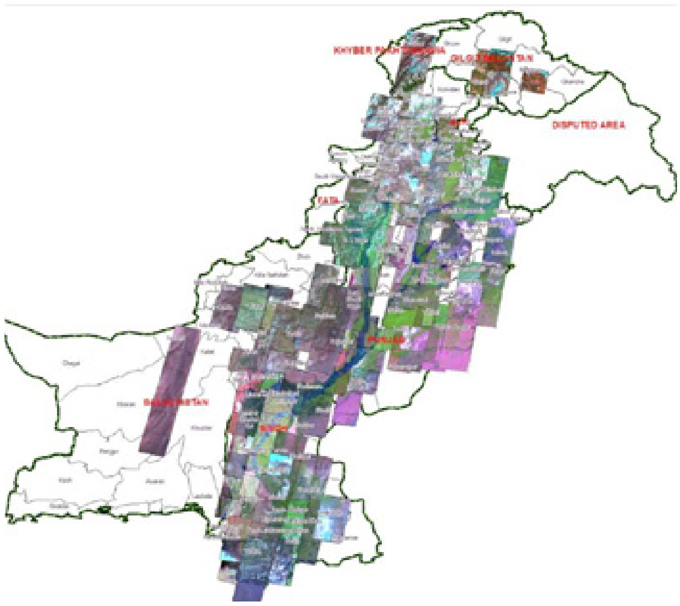
- The housing sector required the identification of the settlement areas to establish baseline data on the populated places that were affected by the flood.
- The transport sector called for a rapid analysis of the damage (extent of flooding) to the complete road network (km affected) by type of road – National Highway, Provincial Highways, Farm to Market/Rural Access roads, and Katcha/ unpaved roads in each region – KP, FATA, Punjab, Sindh, Balochistan, AJK and GB.
- The agriculture sector required a rapid mapping assessment of crops (sugarcane, rice, cotton, maize) affected (i.e. inundated).

Furthermore, the space-based information products would not contribute to a better emergency response if the flow of disaster information is too slow and end-users do not have the technical capability to evaluate the information received and integrate it into their plans. Generating space-based information products requires specialized skills. To be successfully utilized, it requires strong institutional support through an appropriate disaster management strategy, clear data sharing arrangements, and a willingness to cooperate across different governmental and non-governmental institutions.

2.1 SUPARCO-Satellite Ground Stations

SUPARCO has been utilizing space technology to mitigate the effects of disasters by providing timely satellite data based map products, spatial-temporal analysis and situation update reports to the federal and provincial disaster management agencies. The high resolution satellite imagery from SPOT 4 and 5 is directly acquired at SUPARCO's Satellite Ground Station in Islamabad, while moderate resolution imagery from Terra and Aqua satellite is received at the Ground Station in Karachi. These images

SPOT Satellite Ground Receiving Station Islamabad



Coverage index map SPOT 4 & 5 satellites

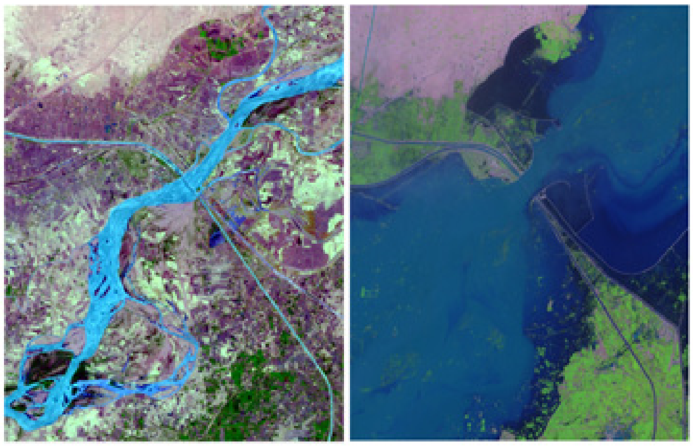
have been used in a detailed investigative work carried out during the floods. The information developed was provided to the National Disaster Management Agency (NDMA) and other agencies associated with monitoring disasters. This information presented an impact analysis of previous disasters, which included floods.

SUPARCO provided valuable information during the earthquake of 2005 and the floods of 2007 & 2010 & 2011 to NDMA, the UN and other agencies involved in the disaster relief operation. Besides this, SUPARCO continued to monitor and provide the much needed information to the concerned authorities on the state of flood bunds and flood situations as and when required. SUPARCO, in coordination with other departments, can utilize available space based information to provide the necessary inputs to find a long term solution to manage floods.

2.2 Use of satellite images pre, during and post disaster

At the time of the floods, SUAPRCO was fortunate to have trained staff in place, satellite ground receiving stations for reception of data from SPOT constellation and Aqua / Terra satellites. It had also established a link with the UN-SPIDER programme as the regional support office. Additionally, institutional knowhow was available to deal with the disaster as SUPARCO was involved in the management of the 2005 earthquake in Pakistan.

Multi-date multi-resolution satellite images of the flood affected areas were retrieved from the available archive to examine the pre-flood situation. However, a fresh set of data was required to assess the situation as it unfolded on a day to day basis.



Guddu Barrage: Pre-flood on 2 June 2010 (left) and post-flood on 12 August 2010 (right)

For that reason a satellite analysis of the area was undertaken as depicted hereunder:

• SPOT constellation was programmed through Spot Image for imaging the affected areas. Data was downloaded at the ground station in Islamabad; reception of data on a daily basis.

• Aqua & Terra satellite data was received and processed in Karachi for daily monitoring of the affected areas on a regional scale.

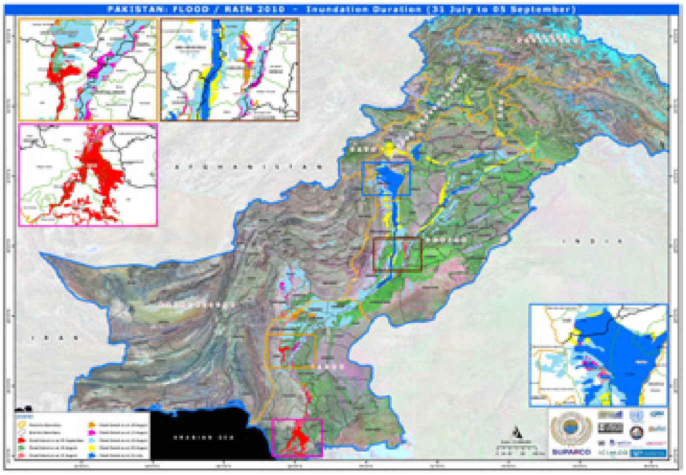
• Through the International Charter: Space and Major Disasters data was received from Landsat, Geoeye, and QuickBird.

After the acquisition of satellite images, the following steps were performed to generate different sets of information products:

- Data Processing
- Database Development
- Comparative Analysis
- Damage Estimation
- Flood Monitoring

2.3 Assessment of the disaster situation using satellite imagery

The SUPARCO Space Application and Research Center, located in Islamabad has significant expertise and experience in agricultural related satellite imagery analysis and mapping work. It also has specific experience in analyzing satellite data to develop detailed and regular crop masks at district level definition. These masks, overlaid on the 2010 and 2011 Monsoon Flood inundation shape files, were utilized to estimate the geographic area that was cropped and affected by the floods.



Flood 2010 - Inundation Duration 31 July to 5 September 2010

MODIS sensor data of 250 meter resolution acquired on a daily basis at the Space Application and Research Center in Karachi was used to develop layers for inundation of water and inundation maps. These vector layers were made available to the experts in the Space Application & Research Center in Islamabad. This Centre has developed a database on agricultural areas of crops by district (agricultural masks). These agricultural masks were overlaid on the inundation shape files to estimate part of the geographic area that was under agriculture and was affected by floods.

Moreover 2.5m high resolution data from the SPOT-5 satellite acquired at the Islamabad Station was used to improve the quality of the spatial data. Field validation was carried out on sample areas by real time GPS surveys and an analysis of time series satellite images.

Considering a high likelihood of monsoon flash and riverine floods during monsoon seasons, the government authorities dealing with the agricultural sector should take account of the potential hazards to crop, livestock and inland fisheries production as well as food and nutrition security and cash supply for the rural population in the flood-prone areas.

Due to climate change and glaciers melting, the monsoon rainy season could remain longer than average. It is anticipated that flooding would occur in those areas where breaches in flood

Enlarged image of the river at Kamra, Attock District in June 2012

Enlarged image of the river at Kamra, Attock District in August 2012 protection embankments and siltation of irrigation canals have not been adequately addressed and where soil remains saturated from the effects of previous flooding.

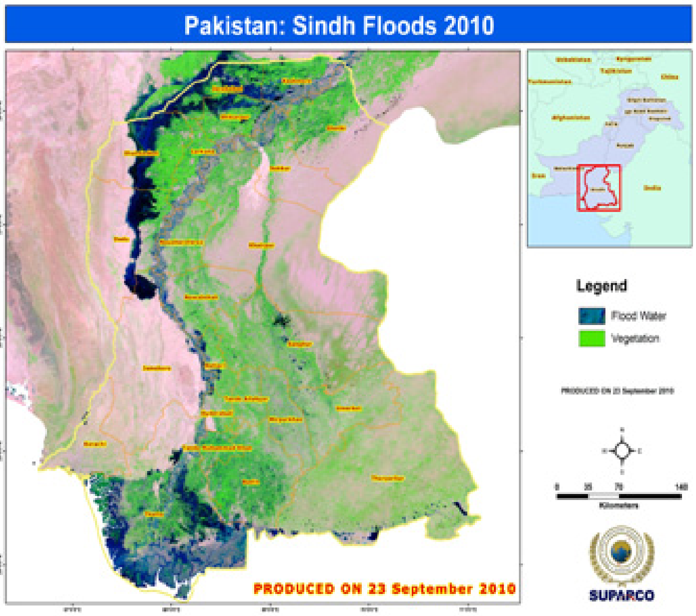
However, in low-lying areas where land inundates for long periods, flooding can be useful to flush out any accumulated salts – conditional on the de-silting of drainage ditches. Updated and reliable information on flood prone areas available through satellite images can potentially be utilized to assess damages to crops in case of floods. This facilitates the decision making process to address the preparedness and mitigation planning in a holistic manner.

Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2)

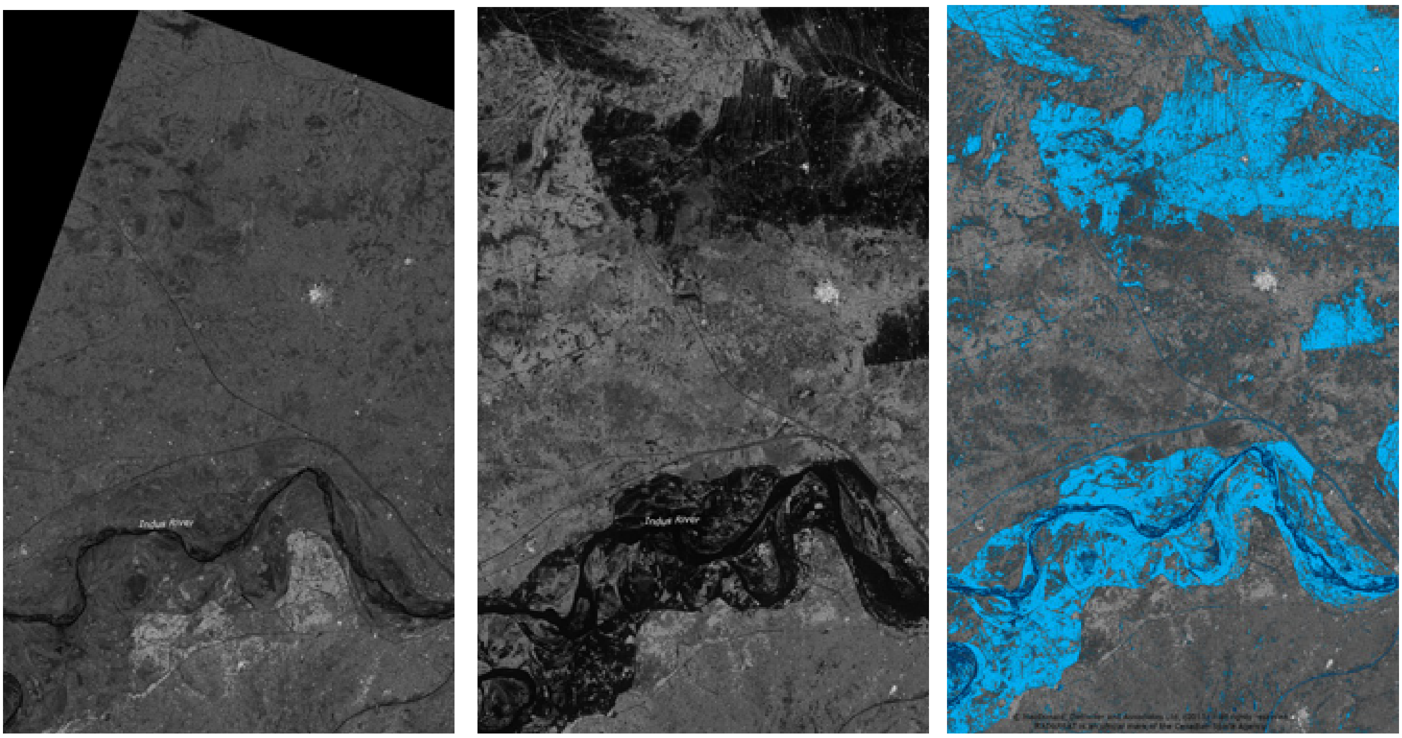
AVNIR-2 is a visible and near infrared radiometer for observing land and coastal zones. It provides 10-m spatial-resolution image and 70-km swath on the ground.

Assessment of stagnant water in Sindh was provided to the President Secretariat on a daily basis from 12 November 2010 to 3 January 2011 for monitoring rehabilitation work.

The stagnant water on 12 November was 312,972 ha and on 3 January 2011, it was 107,899 ha.



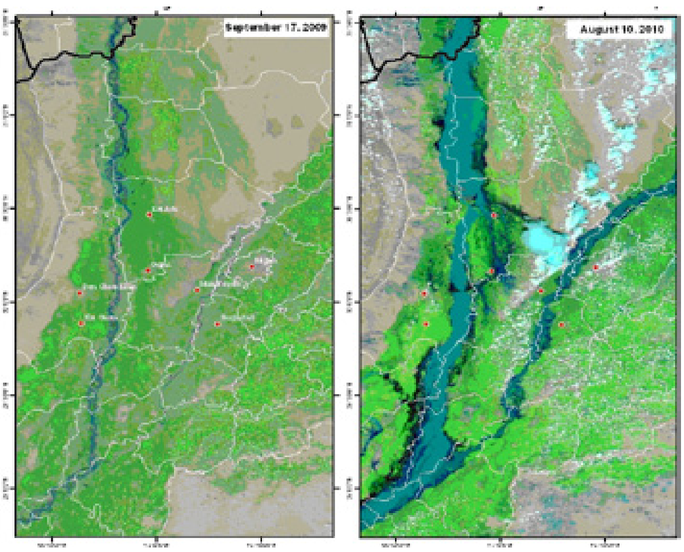
Satellite maps of the ponded areas provided by SUPARCO were also used for planning of dewatering activities by the Provincial Sindh Government. During the periods of flooding, there were occasions when optical imagery was totally or partially cloudy and it was difficult to monitor the ground situation. This gap was filled with the Synthetic Aperture Radar (SAR) imagery available from ALOS PULSAR. The Radarsat images were provided through the UN-SPIDER mechanism.



Synthetic Aperture Radar (SAR) imagery provided through the UN-SPIDER mechanism

3. Space Technology Products and Services

SUPARCO used both satellite-based Remote Sensing (RS) techniques and Geographic Information Systems (GIS) to provide an analysis of flood related damages and mapping of the affected regions of Pakistan. Satellite imagery can fill in the gaps of information, provide coverage of inaccessible terrain and in some areas provide unique data not possible to obtain from ground surveys. The geographical area covered in this context was all the affected areas of Azad Jammu and Kashmir, Balochistan, Gilgit Baltistan, FATA, Khyber Pakhtunkhwa, Punjab, and Sindh.



On request of several organizations, the following imagery derived products of the flood affected areas based on rapid mapping were generated and provided on an urgent basis:

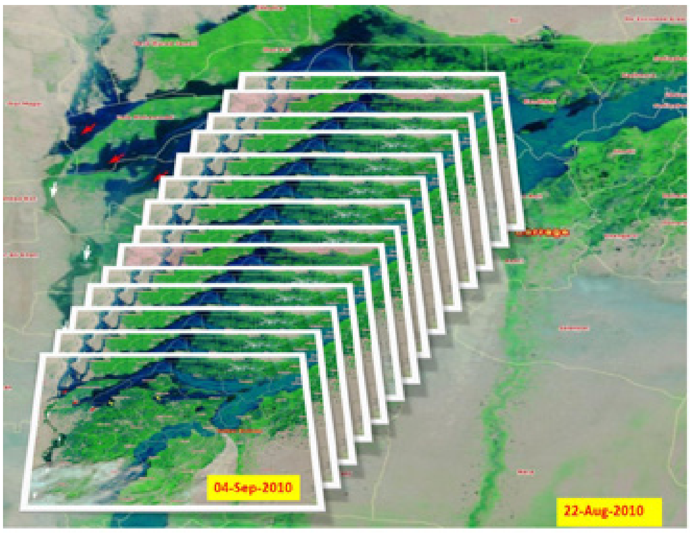
- Cumulative flood extent map, using both medium and high resolution data on a daily basis
- Crop damage assessment map and a daily update to Ministry of National Food Security
- Preliminary Damage Analysis of the affected areas
- Flythrough of Nowshehra city, Chasma and Sukkar barrages generated from Satellite imagery.

A post event detailed damage assessment included the provision of the following assessments to different organizations based on the spatial extent:

- Monitoring of the recession of water
- Hazard assessment and elements at risk mapping
- Crop damage assessment
- Thematic Mapping & time series analysis
- Evacuation route plans
- Identification sites for reconstruction
- Update hazard, vulnerability and risk database

3.1 Daily flood extent update

During the floods, SUPARCO updated inundation maps on a daily basis. The district-wise information on inundation of geographic areas and agricultural areas was developed on the same frequency. The information on agricultural areas was further apportioned into crops:



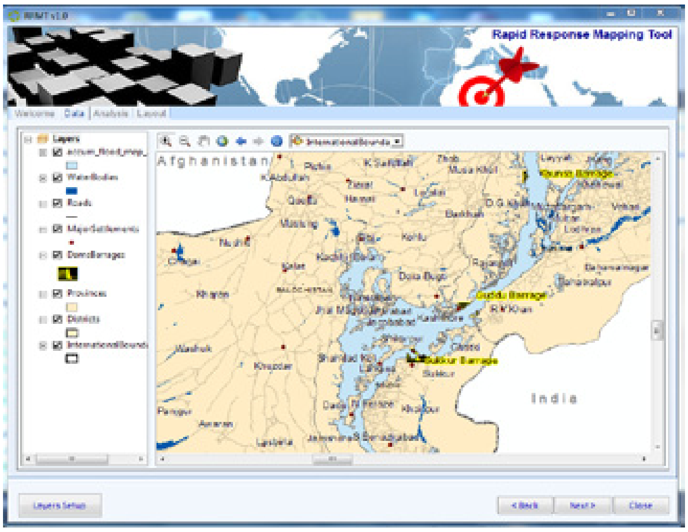
Daily Data Acquisition of MODIS

wheat, cotton, sugarcane, rice and other crops. All this data as well as the maps developed were provided to the Ministry of Food and Agriculture and Planning Commission on a regular basis.

3.2 Rapid Mapping Tool

Contribution of Space Based Inputs to the Decision Making Process

During emergency situations the requirement for quick mapping of a large area with frequent situation updates is a daily requirement. Therefore, the need for a Rapid Response Mapping Tool (RRMT) arose. This tool was custom built, an ArcGIS Engine based tool that enables automatic creation of maps according to the user criteria. The purpose of this application is to create professional and standardized maps in the shortest possible time and to simplify map development to just a few clicks.



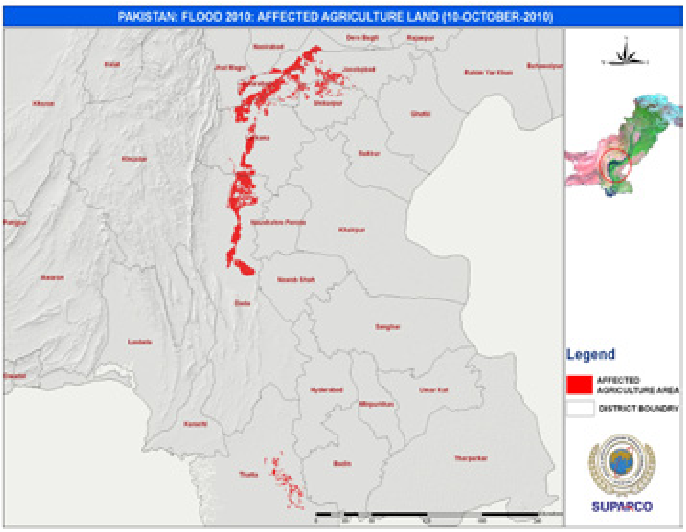
The tool provides different analysis results for a range of datasets e.g. in case of a disaster, it can provide an estimation of the affected settlements and infrastructure, as well as provide an aggregated and separated calculation of the affected area, etc. It is very useful in emergency situations like a natural disaster.

The tool uses three types of data that contains administrative boundaries, infrastructure and disaster overlays. Depending on the selection of the user, disaster reports can be generated on different administrative boundaries. The generated reports display the current disaster situation of the affected area using the latest downloaded satellite images. It also calculates the damage statistics dynamically by overlapping disaster and infrastructure overlays.

The tool uses geo-processing capabilities of ArcEngine to slice different infrastructure and disaster layers on the basis of selected administrative boundaries.

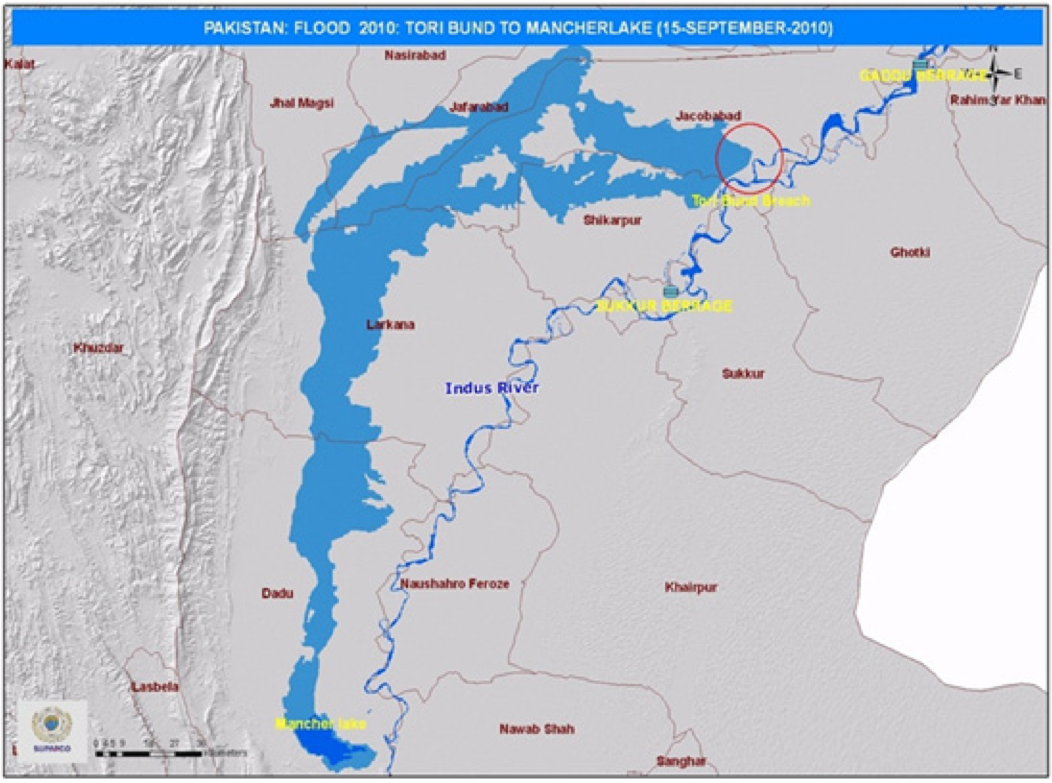
3.3 Thematic Mapping

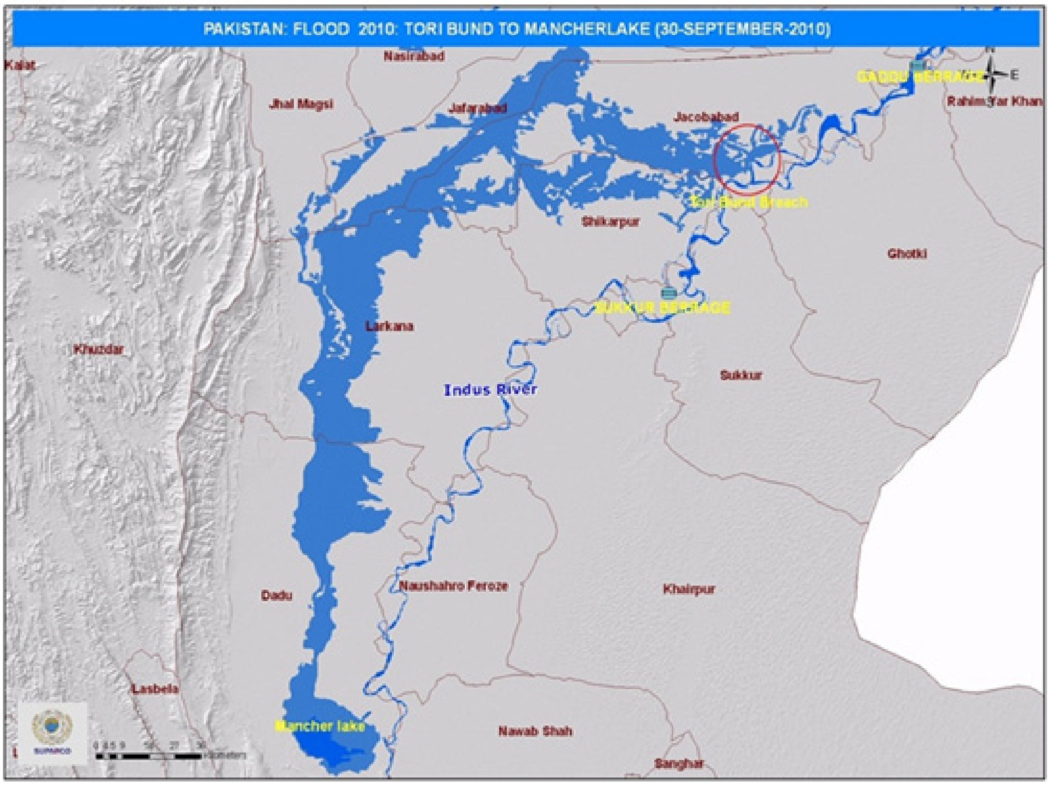
The thematic maps of flooded areas by categories were generated on the request of different user agencies. The pre and post disaster situation analysis was performed using satellite images on themes like agriculture, irrigation, status of breaches in embankment, IDP sites and distribution of funds to the people in the most affected areas etc. The early recovery stage starts with the thematic mapping and flood water recession maps of flood affected areas, generated with the help of satellite imagery. These maps are critical tools for carrying out damage need assessments throughout the affected areas, rehabilitation strategy for of IDPs and reconstruction planning of the damaged infrastructure.

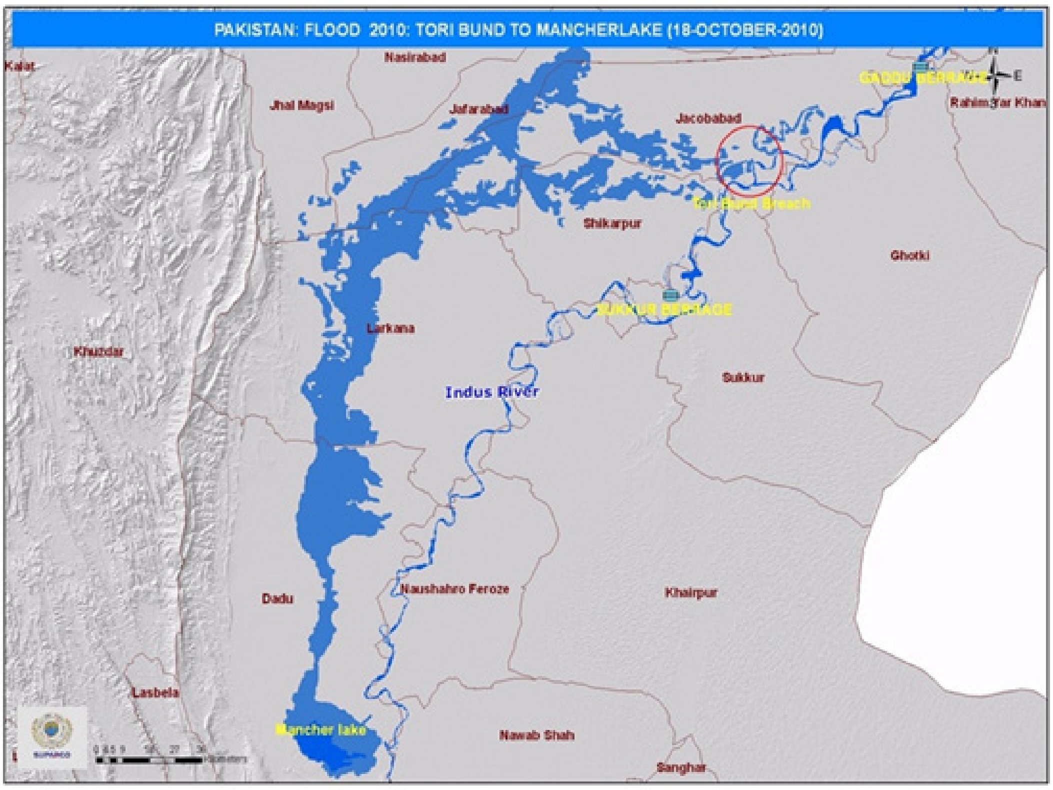


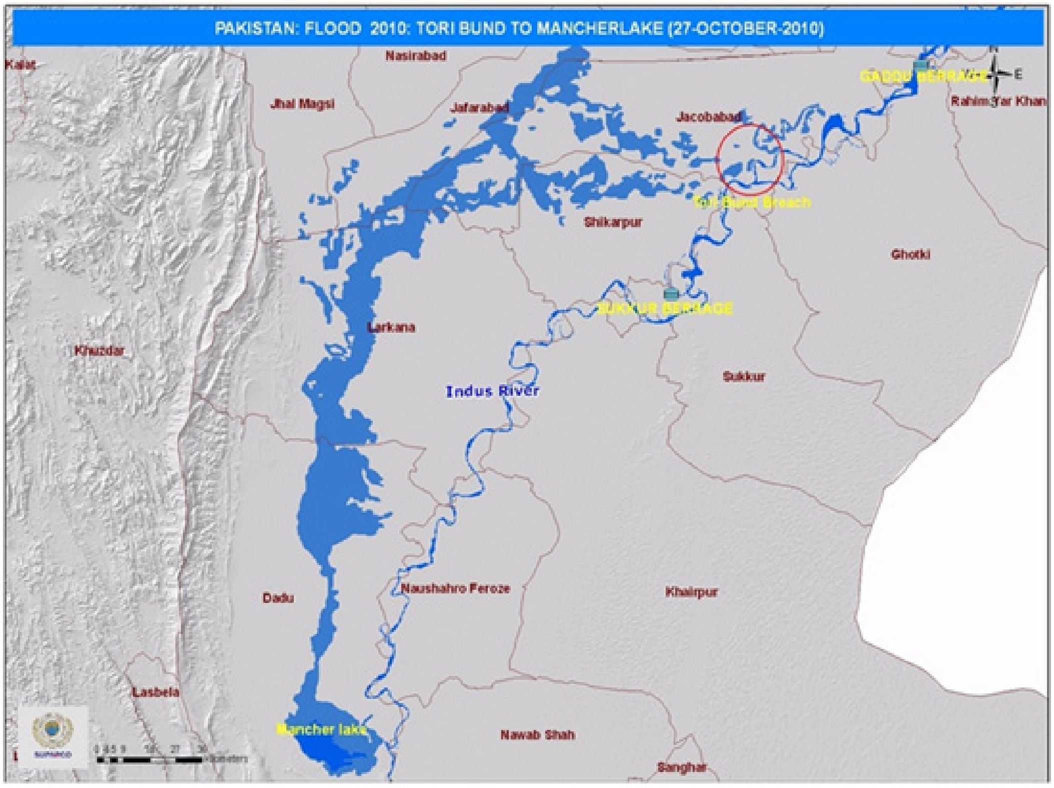
The thematic map reveals the extent of affected agriculture due to flooding

3.4 Time series Analysis






PAKISTAN: FLOOD 2010: TORI BUND TO MANCHERLAKE (18-OCTOBER-2010)
Kalat
Nasirabad
Jhal Magsi
Jafarabad
Jacobabad
Rahim Yar Khan
Shikarpur
Ghotki
Larkana
Khuzdar
Sukkur
Indus River
Dadu
Naushahro Feroze
Khairpur
Lasbela
Nawab Shah
Sanghar


PAKISTAN: FLOOD 2010: TORI BUND TO MANCHERLAKE (27-OCTOBER-2010)
Kalat
Nasirabad
Jhal Magsi
Jafarabad
Jacobabad
Rahim Yar Khan
Shikarpur
Ghotki
Larkana
Khuzdar
Sukkur
Indus River
Dadu
Naushahro Feroze
Khairpur
Lasbela
Nawab Shah
Sanghar

3.5 Support to national and international organizations

In Pakistan, the National Disaster Management Authority (NDMA) is responsible for all activities related to disaster management at national level. Its role is to act as the implementing, coordinating and monitoring body for disaster management as well as provide the necessary technical assistance to the Provincial Governments and the Provincial Authorities for preparing their disaster management plans in accordance with the guidelines laid down by the National Commission. Additionally, they must coordinate a response in the event of any threatening disaster situation. During the floods of 2010 and 2011 SUPARCO provided space based information to the NDMA on a regular basis and also provided the technical support by sending a GIS expert to interpret the images.

The products included:

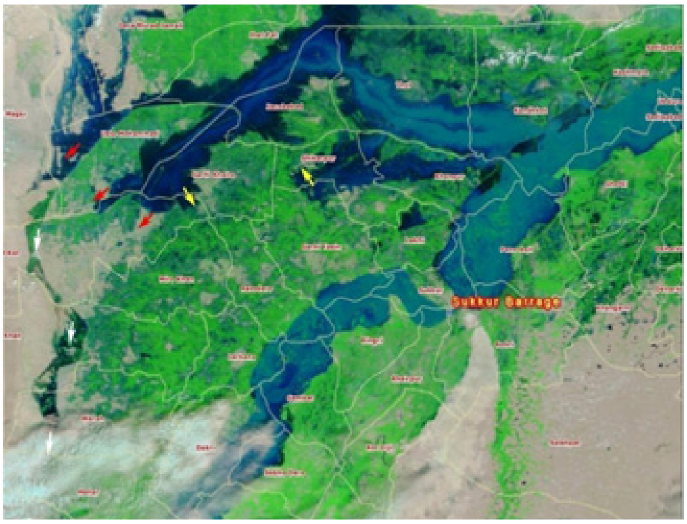
- Cumulative flood extent maps
- Assessment of damages to settlements, housing, roads, and railway lines
- Crop-wise damage
- Projected water flow routes

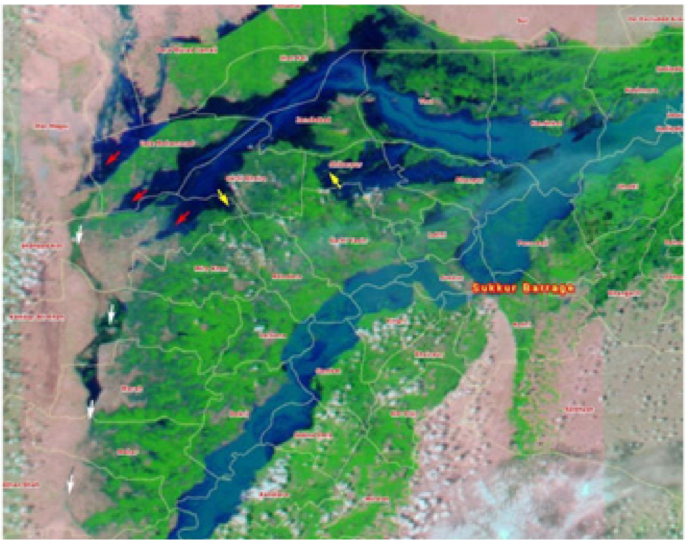
SUPARCO also provided satellite based information products to the following national stakeholder organisations:

- Ministry of Food & Agriculture (MINFA)
- National Database & Registration Authority (NADRA)
- Punjab Information Technology Board (PITB)
- Government of Sindh, Chief Minister's Secretariat
- Advisor to Prime Minister on Water Resources
- Advisor to President on National Reconstruction Bureau

The following international organizations also requested SUPARCO to provide a Detailed Need Analysis (DNA) in order to submit a report to the Government of Pakistan of overall damages caused by floods:

- The World Bank and ADB
- UNESCO
- FAO





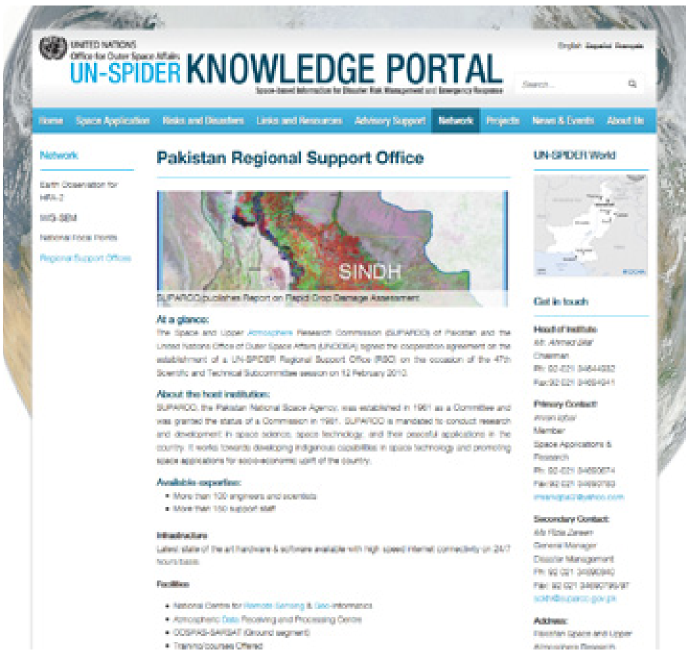
Projected Water Flow Routes on 20 August 2010 (top) and on 21 August 2010 (bottom)

3.6 Narrative Reports - Crop Damage Assessment

SUPARCO in collaboration with the FAO have published the work done during these floods. Three publications on crop damage assessment series 1, 2 & 3 were published in addition to several interim reports.

4. UN-SPIDER support to PAK-RSO

UN-SPIDER worked together with its Regional Support Office, Pakistan's Space and Upper Atmospheric Research Commission (SUPARCO), from the very beginning of the disasters. SUPARCO provided the coordinates of the affected areas for tasking the collection of satellite imagery by various providers. UN-SPIDER was the first to coordinate with SUPARCO and ensure the exchange of information with the major international mechanisms and satellite providers. Subsequently, SUPARCO developed several maps in addition to the ones that were provided by other international mechanisms and organisations. These maps portrayed the extent and damage of the floods. To support the relief operations, they were provided to various national bodies, among them the National Disaster Management Authority and the Ministry of Food and Agriculture. The UN and the various national bodies of Pakistan were not alone in their use of satellite imagery, a number of NGOs such as iMMAP and the Pakistan Youth Organization also used the space based images. In close coordination with SUPARCO, UN-SPIDER supported the activities of the major international mechanisms that were activated: the International Charter Space and Major Disasters, Sentinel Asia, and Services and Applications for Emergency Response (SAFER) and DubaiSat-1 (which is not part of any of these mechanisms), all of which helped collect imagery for the disaster response and made it available through UN-SPIDER for the first time.



SUPARCO profile page on the UN-SPIDER Knowledge Portal

The International Centre for Integrated Mountain Development (ICIMOD) also channeled their rapid mapping support to Pakistan through UN-SPIDER. ICIMOD obtained images through Sentinel Asia and generated a series of maps which were shared with SUPARCO. Especially during the first weeks of the disaster, a steady communication was established where UN-SPIDER and SUPARCO shared information about the situation on the ground and updates about the work of the different international mechanisms on a daily basis. Furthermore, a series of teleconferences were held under the moderation of the US Office of Foreign Disaster Assistance (OFDA). They brought together representatives of the UN Office for Outer Space Affairs (UNOOSA), UN Office for the Coordination of Humanitarian Affairs (OCHA), UN Institute for Training and Research (UNITAR/UNOSAT), German Aerospace Center (DLR), Canadian Space Agency (CSA), US Geological Survey (USGS), ICIMOD, Pacific Disaster Center, Red Cross, University of Georgia, and Hope International University. This was done to ensure better coordination between these institutions, the UN and other organizations delivering and working with satellite imagery and geographical data. A considerable amount of post and pre-disaster optical and radar satellite data was collected and processed and served for relief operations, including COSMO-SkyMed, ALOS PALSAR, RapidEye, SPOT 5, TerraSAR-X, Aqua MODIS, DubaiSat-1, IRS-P6, FORMOSAT-2, WorldView-1, WorldView-2, Landsat-7, and ENVISAT ASAR.

5. The Learning Experience & Exposure

Risk Reduction (protection should go beyond technical and include socio-economic considerations)

In order for Pakistan to ensure its efforts towards improving risk reduction are achieved, major improvements have to be made, through the use of remote sensing and GIS technologies in conjunction with flood management and its inter-relationship to flood hazard assessment and planning. An augmentation of the forecasting systems especially along the Indus River to forecast and assess the likely extent of damage is immediately required. On the other hand, the need to update flood hazard maps in the lower Indus areas, where the flood protection dykes were breached and experienced, intensive inundation is required.

The protection should go beyond the technical fixes, particularly for protection to improve the structure. Historically the communities living along the river basin have been more severely affected by the effects of a disaster than others. This is due to the following factors:

- High exposure
- Limited resources
- High sensitivity
- Low adaptive capacity

Investment in disaster preparedness and response capacities for the safety of vulnerable communities requires better regulation of the riverine and Khadir areas conjointly proper regulatory and enforcement mechanisms should be implemented. Therefore, the growth of the population in the high risk areas can be controlled. The socio-economic considerations should be given utmost importance to reduce the human and socioeconomic impacts of flooding in Pakistan. This will improve the social, economic, and ecological benefits of floods, as well as foster safer human settlements near flood plains. Accomplishing this objective requires building on the country's capacity to deal with floods and watershed management comprehensively.

Ex- Chairman NDMA unveiling Flood Relief and Early Recovery Response Plan 2010

5.1 Early warning (poor people, many of them do not understand weather forecasting or early warning signs)

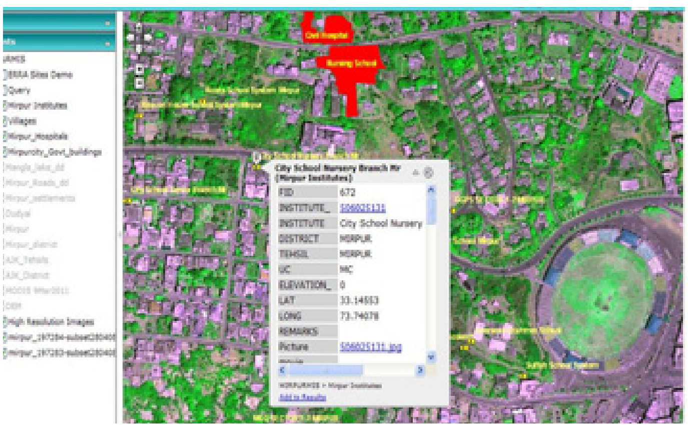
The affected communities lack awareness, sensitization and education regarding localized hazard and flood risk reduction, emergency preparedness and response functions. Education is a particular requirement for populations generally located within the flood plains.

The early warning systems are somewhat in place but the outflows of information have a limited outreach to those who need it most. On the other hand, there is a need for scientific information to be produced in a clear and concise manner, so that the average person is easily able to understand it. The simple satellite maps with a graphic and pictorial representation of ground information, known mostly to locals, could be an interesting addition to Early Warning Systems (EWSs). “The Hyogo Framework for Action: 2005-2015” describes the significance of an EWS; the system should be timely and understandable for the residents and communities in order to take action against the disasters. The need for enhanced Early Warning Systems with sufficient technical capacity is an essential requirement to combat future disasters.

5.2 Vulnerability mapping (Reaching those most in need)

The magnitude of the floods in 2010 was extraordinary, they caused severe damage along the Indus River. Since there had been no flooding in these areas for many years, people had settled in either flood plain or flood prone areas. The population intrusions into these river beds and flood-prone plains were primarily Internally Displaced Persons (IDPs) and the landless farmers. The local government agencies could not foresee such a vulnerability to the flood risk due to the settlement on the flood prone areas. This probably was due to a lack of updated maps with demarcation on the areas which could depict flood hazards.

The vulnerability assessment based on population density and propensity to flood over time, post-2010 flood event, is of immense importance. There is an urgent need to map riverine and flash flood risk areas and develop hazard management maps, especially covering flood prone areas in the Northwest and Southern parts of Pakistan.



Socio-economic mapping: Education Management Info System AJK

In 2009, SUPARCO started mapping educational institutions and hospitals in the northern AJK territory using the latest satellite imagery and developed a GIS database customized to the needs of the Government agencies. This exercise is still ongoing and would cater to identify the vulnerable locations and settlements that could be affected during a disaster. Additionally, such information can be utilized in the form of a planning tool for the development of new infrastructure in least risk areas.

With the help of the national and provincial disaster management authorities, SUPARCO earnestly desires to expand this initiative for the whole country.

5.3 Consideration of Climate Change Adaptation

The risks of extreme weather phenomena are increasing along with global climate change. Pakistan is no exception to the global picture and has encountered an increased frequency and intensity of climate extremes in recent decades. It is believed that the frequent occurrence of extreme weather events could be due to the changing climate.

Despite the fact that region’s contribution to the world’s total greenhouse gasses emission is not very high, it is faced with severe effects of climate change.

At present, the available climate information is often not being optimally utilized. It is of paramount importance that socio-economic policies and projects should take into account the change in climate conditions. Pakistan’s lack of climate adaptability entails a loss of investment and even human lives. Such losses can be avoided by factoring in climate information in to the decision making process.

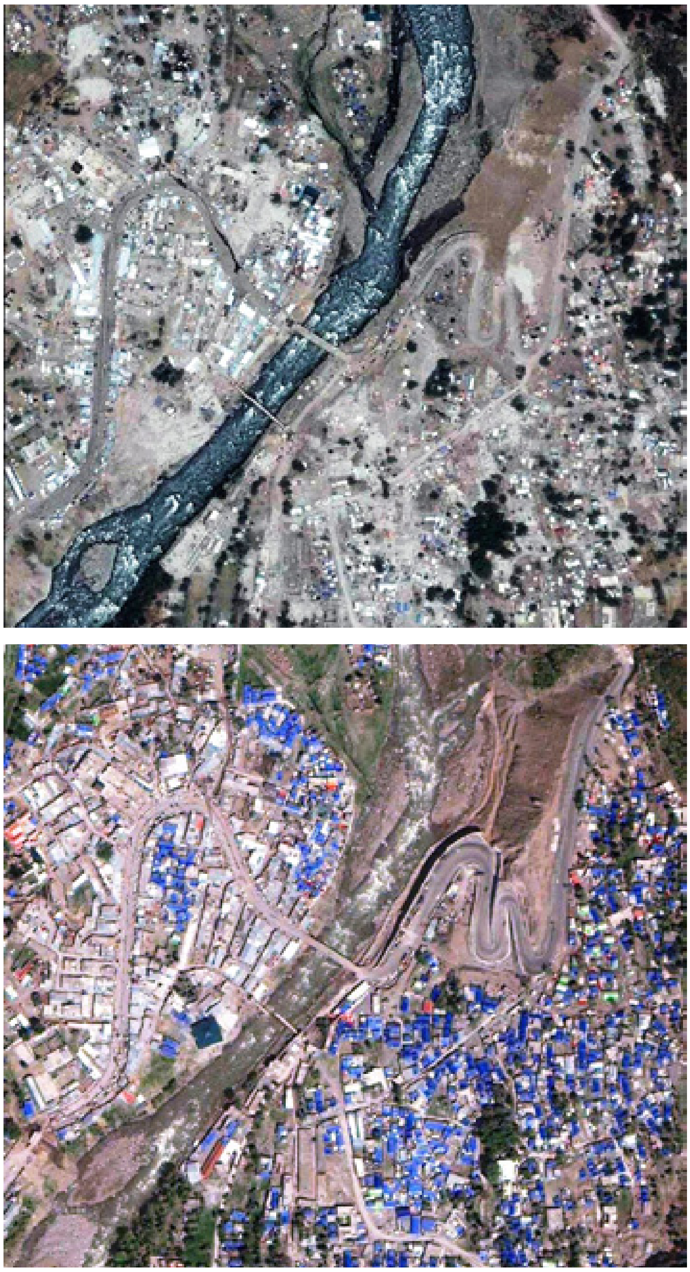
This can be achieved through undertaking activities to promote advocacy programs with the aim to create mass awareness of climate change. Various initiatives may include cooperation in capacity building, the exchange of information on the best practices and sharing the results of research and development for mitigating the effects of climate change.

5.4 Economic impact of disasters and how to reduce them

A major flood can lead to tremendous damage to public property; its disastrous effects are often far reaching, which lead to the suffering of millions of people and most importantly to the loss of human life. In addition to the short-term effects, the crops are not only lost during the year of the flooding but also for the upcoming seasons. According to the Damage and Needs Assessment (DNA) conducted by World Bank and Asian Development Bank, Pakistan had to bear with an estimated loss of more than 10 billion PKR to its national economy, through the direct and indirect consequence of the floods.

The floods did not only wash away the development achievements of the past but also further aggravated the chronic poverty and inequality which exists among the vulnerable segments of society. The disaster and its aftermath are a direct threat to Pakistan's prospects of achieving the Millennium Development Goals (MDGs). It is likely that many years of consistent effort will be required to get back on track.

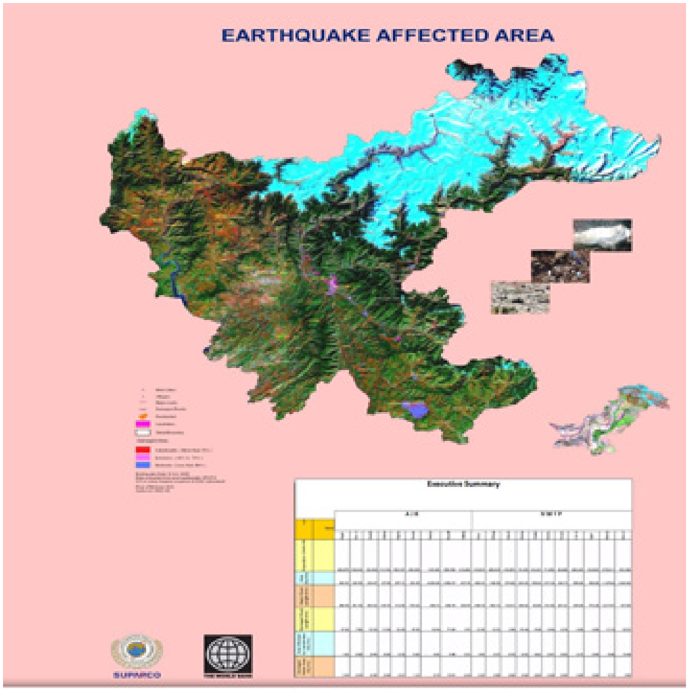
Marooned people: A direct consequence of flooding



Monitoring infrastructure development over time Balakot on 13 June 2006 (top) and on 6 April 2010 (bottom)

It is difficult to devise a strategy which could completely avoid floods and the damages that coincide with it. However, it is possible to minimize the damage of a flood by adopting appropriate measures and modern technologies. An anticipatory monetary investment on better planning & development based on a scientific outlook would definitely be a worthwhile investment. It would save money which would otherwise be spent on the recovery process if another disaster was to strike. The areas of immediate attention are improvement in early warning systems, relocation of settlements to safer places, strengthening of hydraulic structures and the diversion of water to a possible store site. Such improvements would reduce the damage impact of a flood.

Post-disaster, the reconstruction phase normally starts with repair to the damaged infrastructure along with the development planning for new infrastructures. Here the utilization of space based information can be very effective to monitor mega infrastructure development projects. The city of Balakot in the KPK province, which was totally destroyed during the earthquake of 2005, was rebuilt by 2010. The use of satellite images was helpful throughout the reconstruction phase of the new Balakot city.



Damage need assessment

The World Bank and Asian Development Bank together led the Damage Needs Assessment (DNA) at the request of the Government of Pakistan. The multi-sectoral DNA estimated the overall relief, recovery and reconstruction costs associated with the floods. SUPARCO offered help in assessing the extent of the damage and the requirements for rehabilitation and reconstruction of the damaged assets and infrastructure using remote sensing and GIS technologies.

SUPARCO carried out this exercise in close coordination with the Federal and Provincial departments, especially the NDMA. High resolution satellite imagery and other relevant data were used for this purpose. The areas included all the flood affected regions. Maps of the flooded areas were developed under this endeavor; they provided useful information on the extent of the floods and the damage to the infrastructure.

Similarly, after the earthquake of 2005, The World Bank arranged the donors conference on 19 November 2005 to collect the maximum amount of possible donations for the rehabilitation of the Earthquake affected people. The Damage Need Assessment Report incorporated data and analysis carried out by SUPARCO.

5.5 Utilization of satellite communication technology during and post disaster: Tele-education & Tele-medicine

Natural disasters often cause damage to the basic health care facilities, educational institutions and terrestrial communication. In such emergencies, the role of satellite based medical care and education becomes more important.

SUPARCO, having experience in satellite communications initiated a Satellite Communication based Telemedicine pilot project. Two sites were connected through PAKSAT, a communication satellite.

The pilot project helped in determining the ben-

Tele-Medicine at a pilot stage

efits of this technology for the social and health-care sectors during the period of an emergency. It also demonstrated the use of space based technology in educating doctors/paramedical staff in rural areas on the latest medical practices.

The valuable experience gained through the pilot project would be helpful in establishing an operational network based on Pakistan's own Communication Satellite. This would provide an important emergency platform for tele-health care to address the sufferings of the affected population during a natural disaster.

5.6 Identification of an appropriate place for Temporary shelters (Schools etc) and storage sites for relief goods

The sheer scale and breadth of the disaster made bridging the shelter needs an enormous challenge. Around 864,000 households were provided with temporary shelter which was only 50% of the emergency shelter needs. Management and capacity issues presented a serious challenge. The delay in identifying suitable sites had a profound impact on providing rapid assistance to the affected people.

Tent village for internally displaced people

UN Secretary General visits internally displaced people

Pre-disaster identification of the possible temporary shelter sites and storage sites for relief goods can easily be identified by using satellite images in the nearest safe neighborhoods of the affected areas. This information could be effectively utilized by the administration in the case of an emergency. Similarly, the emergency routes can accordingly be mapped using the latest satellite imagery.

5.7 Card distribution of monetary resources through Banks (A programme that directly supports communities and their local organizations)

The Government of Pakistan launched the Watan card, a household level initiative, as the main strategy for providing financial support for the victims of the flood. The eligibility criteria was very simple-any head of a household with a national ID card stating their residence in a flood affected area was considered eligible for registration and would subsequently be issued a Watan card.

Satellite based maps showing the moderate and adversely affected areas were provided by SUPARCO to the concerned agencies. This information helped in the verification process before the cash transfers were made to the deserving households. This was a strikingly modern and innovative approach to help the most affected people by utilizing the available technologies on an immediate and translucent basis.

The experience of the 2010 and 2011 floods confirmed that cash transfers of compensation to disaster hit communities was a successful initiative. The Watan cards model should be replicated in future emergencies. The registration process of such a scheme must ensure that the people who are most vulnerable are targeted, to ensure the protection of those most in need.

Watan Card Recipients in Shaheed Benazir Abad District

A system can be developed quickly by using space-based information to identify the most adversely affected villages and towns while being able to develop a GIS database of the most affected population.

6. Future thrust areas - Application of Earth Observation technologies for national needs

Long term solutions-Beneficial utilization of flood water

One of the experiences of the floods was the realization that water may stagnate in areas where there is not a sufficient gradient. This was the case in the Sanghar, Umarkot and Mirpurkhas districts, where the terrain is flat and the movement of water was further interrupted by man-made barriers such as roads, railway lines and other elevated spatial features. The only possibility to drain the affected areas was to put the water into an existing canal and connect the canal to an existing drainage system. Other methods included putting the water into various old and abandoned natural drainage routes as well as simply using pumps to drain the water. However, the canals were at a higher level than the inundated lands and the water had to be pumped into them. Subsequently, connecting channels were dug to put them into abandoned drainage routes. The process of pumping and excavating connecting channels was an extensive operation which delayed rainwater disposal from these areas.

Based on the above practical experience, SUPARCO carried out a preliminary study on mitigating the effects and beneficial utilization of flood water. The study explored a possible diversion of flood water to some new channels.

Five suitable sites were identified for the flood water diversion on both sides of the Indus River. It would be interesting to analyze how the flood water could be effectively utilized for construction, in an otherwise water depreciated country.

The satellite images along with the Digital Elevation Model (DEM), irrigation network, flood protective embankments, ancient river channels (10,000 to 2,000 BC) were used to identify potential sites for water diversion based on following criteria:

a. Safe conveyance of flood water

b. Gradients support for natural flow

c. Minimum disturbance to surrounding

environment and infrastructure

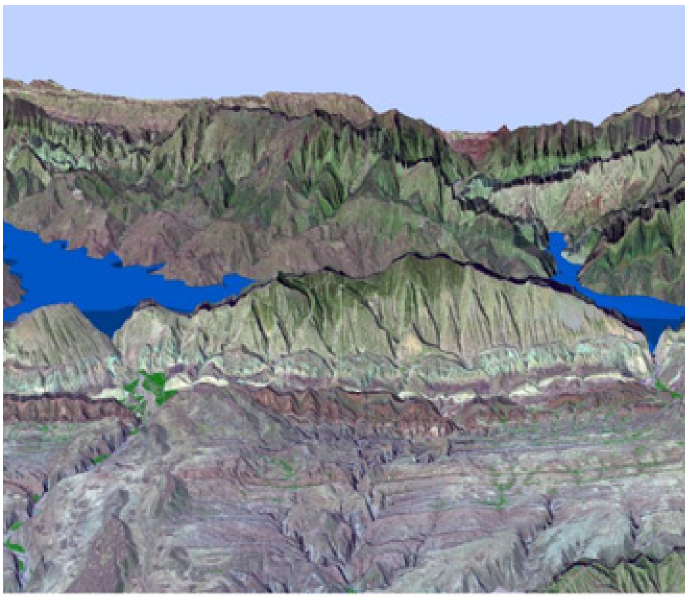
d. Optimum utilization of flood water

e. Economic viability

This is an initial effort by SUPARCO which may lead to establish an operational plan to achieve the objective of storing excessive water which becomes available during monsoon season.

6.1 Identification of possible new Storage sites for excess water

During the four consecutive floods of 2010, 2011, 2012 and 2013 severe hill torrents were observed in the Suleiman Mountainous Range (SMR) in addition to river flooding.



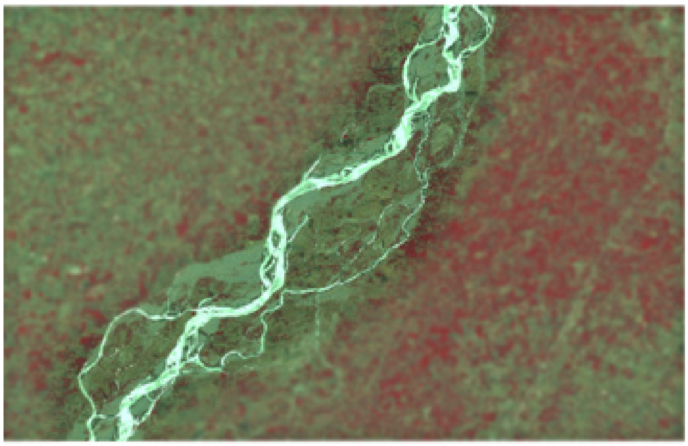
3D prospective view of a proposed dam site, Tunsa, Dera Ghazi Khan

This necessitated taking a comprehensive account of such an occurrence. SUPARCO carried out a preliminarily study for the selection of a Dam/Reservoir site in D.G. Khan to reduce the damages inflicted by hill torrents and to convert this devastating effect into the an opportunity to store water for irrigation purposes.

Satellite remote sensing and GIS technology along with ancillary information were used to carry out a pre-feasibility study for the Dam site selection in the Suleiman Mountainous Range.

Keeping in mind the catchment area drainage pattern, an analysis was carried out using 2.5m satellite imagery and 90m Digital Elevation Model (DEM) to obtain the height information.

Two potential sites have been identified. A detailed study should be undertaken to ensure geological capabilities, behavior of regional topography and the effect of sedimentation.



River on route

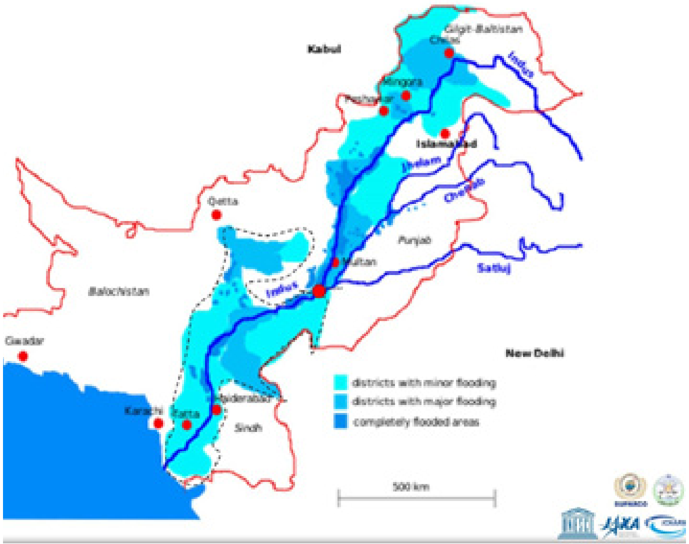
6.2 Study of River morphology & River bank erosion modeling

The 2010 floods also badly damaged the flood protection measures and regulatory systems of the Indus River Basin and increased the chances of floods during the subsequent years of (assumed) normal monsoon rains until those major engineering works have been fully repaired. Soils of inundated areas in the lower Indus Basin remain saturated from the 2010 floods and again suffered flooding in 2011. Moreover, many irrigation canals and water courses managed by farmers remain silted or damaged and incapable of providing the drainage required of the 2011 monsoon rains.

Changes in the morphology of rivers as a consequence of the 2010 floods caused random flow patterns which posed a threat to the population and infrastructure in the region, even in a moderate flood situation.

The exposure to this unprecedented situation envisaged the potential for the establishment of an early warning flood system based upon modeling outcomes. This idea resulted into cooperation between the FAO, University of Southampton, SUPARCO and UNESCO to develop a comprehensive flood monitoring system. This included bank erosion modeling and assessment, and an analysis of the impact of flood and bank erosion on the agriculture in the Indus Pakistan region. The key activities included:

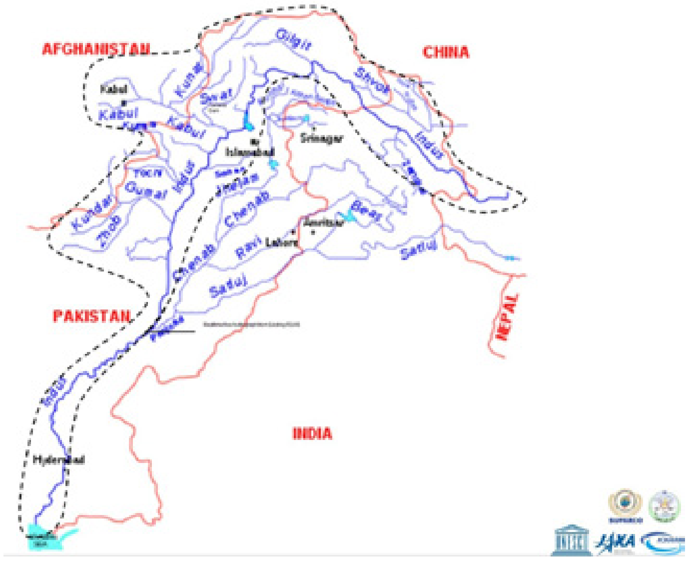
- Mapping of erosion based land loss and the agricultural impact on the River Indus due to 2010& 2011 floods
- Statistical analysis of 20 years of satellite data for a trend analysis of the historical hot spots of erosion
- Conduct field tests of characteristic geotechnical properties of riverbanks to model likely impacts of any given flood event on agricultural land and production as well as high potential for an embankment breech
- Build capacity in user departments for joint production of erosion models based upon flood data and associated reporting/publications.



Proposed flood hazard mapping area

6.3 Indus-IFAS

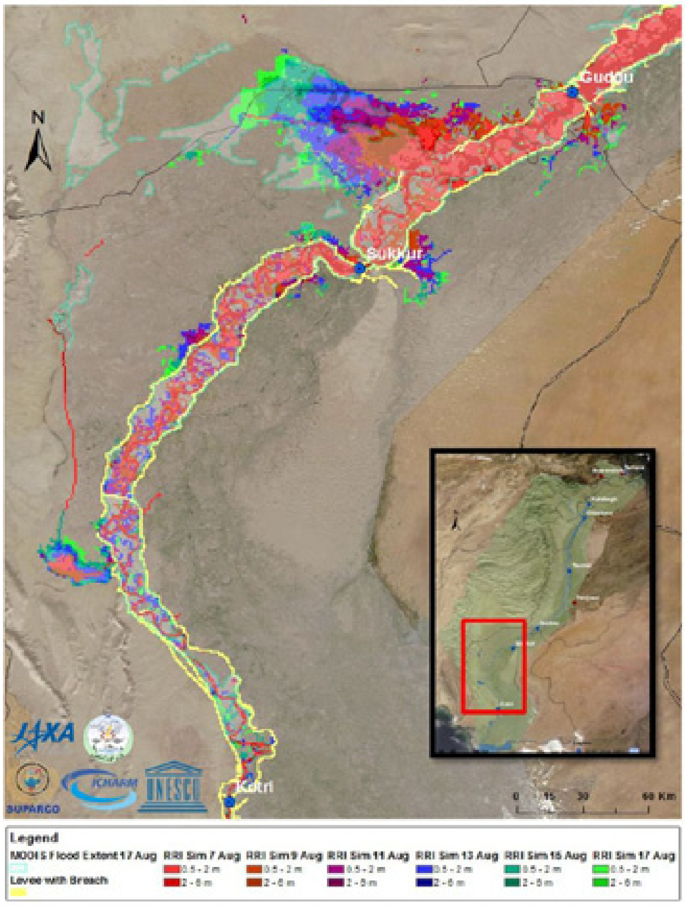
Another exposure due to the consequences of the flood events of 2010 & 2011 is a need for an immediate assessment and upgrade of the flood forecasting systems especially along the Indus River to forecast and assess the likely extent of damage caused by the recent and potential floods. In parallel, there is a need for updating flood hazard maps in the lower Indus areas where historically the flood protection dykes have been breached. These maps will guide recovery and enhance national, provincial and local capacity to disseminate flood warnings, which would reduce potential catastrophic impacts of future inundations. The project will focus on developing an Indus-IFAS as a flood forecasting and early warning system comprising detailed hydrological models of the Upper Indus above Tarbela Dam and Kabul river catchments.



Geographic area (endorsed by dotted lines) to be covered by Indus-IFAS

In order to implement this plan, an integral project for strategic strengthening of flood warning and management capacity of Pakistan under the patronage of UNESCO has been initiated. Pakistan Meteorological Department, SUPARCO, ICHARM would collaborate to develop an Integrated Flood Analysis System (IFAS) called INDUS-IFAS.

The Indus-IFAS is an integrated tool for flood forecasting which incorporates the Rainfall-Runoff (RR) model and Rainfall-Runoff-Inundation (RRI) model for the upper and lower Indus catchment. The integrated model would also implement interfaces to input not only ground-based but satellite-based rainfall data such as Global Satellite Mapping of Precipitation data (GSMap), Numerical Weather Prediction (NWP) model precipitation data, GIS functions to assist flood-run-off models, a default run-off analysis model, and interfaces to display output results. Indus-IFAS can be used as a Decision Support System for a reliable flood forecast, flood monitoring, flood risk and hazard mapping and assisting emergency relief and evacuation activities.



RRI simulated Tori Breach Scenario

The mapping component for the IFAS would utilize images and data acquired during the floods of 2010 & 2011 from satellite based observations systems such as ASTER, Landsat, SPOT and data acquired through UN-SPIDER and other similar initiatives. Using existing and augmented digital terrain maps, inundation mapping (the depth and extent of flooding using terrain models, Indus-IFAS modeled flow and water stage analysis for previous floods) and flood hazard mapping (mapping of various return periods and flood occurrences due to breaching of different protection works) will be carried out for a number rivers. The flood hazard maps will also include possible routes and safe places for evacuation.

Using an RRI Model to simulate a breach scenario at Tori during 2010 floods

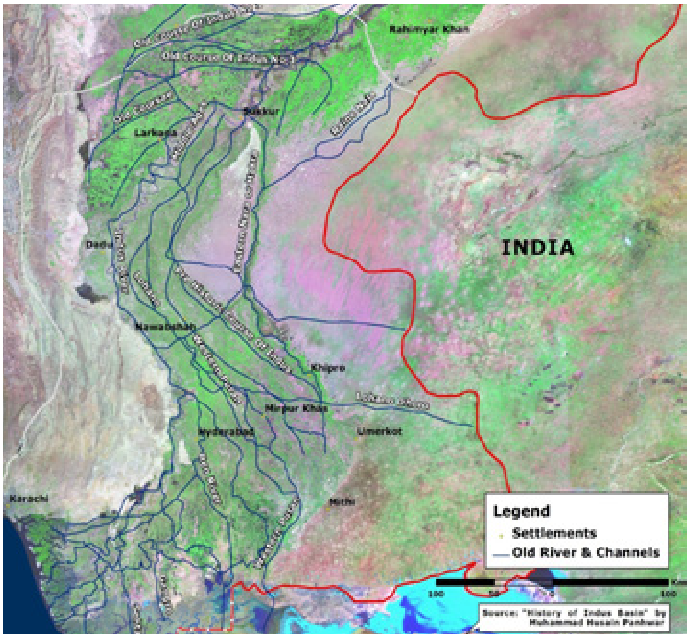
Indus-IFAS coupled with rapid flood mapping techniques can be used to create a complete picture of flood disasters. The integrated RRI model can be used to model flash flooding events and hill torrents that have devastated various parts of the country during the flood events of 2010, 2011 and 2012. The model can allow a generation of inundation maps at very small time steps to allow monitoring of flash floods and the subsequent damage estimation. It can also be used to simulate historic extreme flooding events and generate flood hazard maps for dissemination to increase flood preparedness among local communities and local management authorities.

6.4 Revival/ activation of abandoned natural waterway (Dhoros)

Prior to development of weir controlled irrigation systems in Sindh and the river bunds, River Indus used to meander at its will through various branches. These river branches were curtailed/ blocked after construction of the weir controlled irrigation system and river bunds.

With the development of settlements and an increase in population, these natural drainage routes were encroached upon or blocked for extension of existing towns, construction of villages and agricultural development etc. Parts of different towns were constructed in these natural waterways.

The current rainfall patterns and deluge requires a creation of a comprehensive multi-purpose drainage system by activation of the old drainage routes. The satellite imagery could be very helpful in identifying the abandoned river channels.



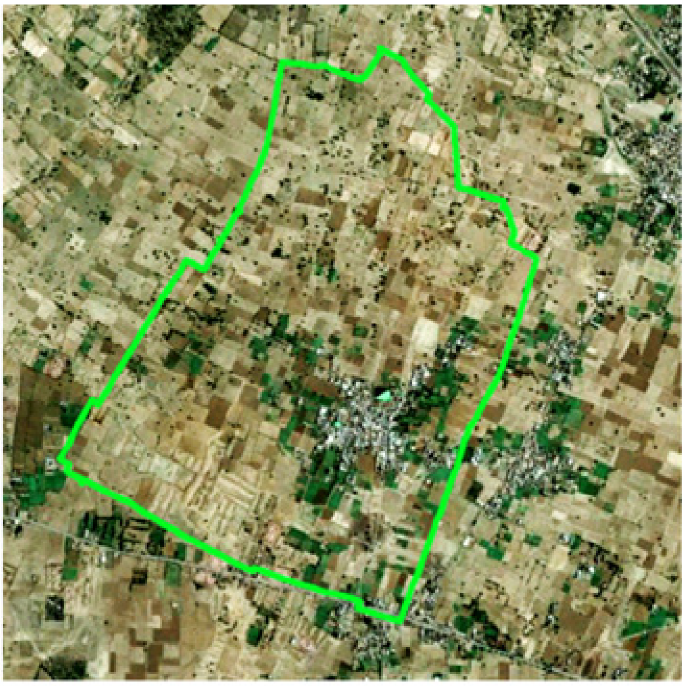
Ancient River Channels in Sindh (10,000 – 2,000 BC)

6.5 Mauza (revenue village) boundary mapping initiative by Punjab Government

Unprecedented flooding in Pakistan affected millions of households and destroyed infrastructure, houses, crops and farmland.

During the rehabilitation and reconstruction phase, the need to develop accurate geo-spatial maps was felt to be necessary to support the disaster response efforts. Most of the critical data at rural level, both flood related and otherwise, is reported with the Mauza (land revenue village) as the unit of analysis, and therefore there is a need to have a mauza-level administrative boundary map which is detailed and accurate.

Masavi Map Mauza Garmala (1920) - Four Masavis stitched to form one complete Mauza



Satellite map Mauta Garmala (2010) - Geo-referencing of Masavis to satellite image

It is necessary to consider the importance of these maps, they pertain an unprecedented significance in the government's operations, including, but not limited to, flood relief and the rehabilitation and reconstruction process.

The Government of Punjab took the initiative and tasked the Punjab Information Technology Board (PITB) to collaborate with SUPARCO and develop the mauza level geo-spatial maps for 18 districts.

The mauza-level geo-spatial maps is an effort towards building a Spatial Data Infrastructure (SDI) in Punjab, which would serve as a key planning tool, particularly in natural hazard characterization and response planning.

6.6 Glaciers monitoring and Climate change adaptation

Space based technologies can be of great help in climate research studies, observations, and forecasting.

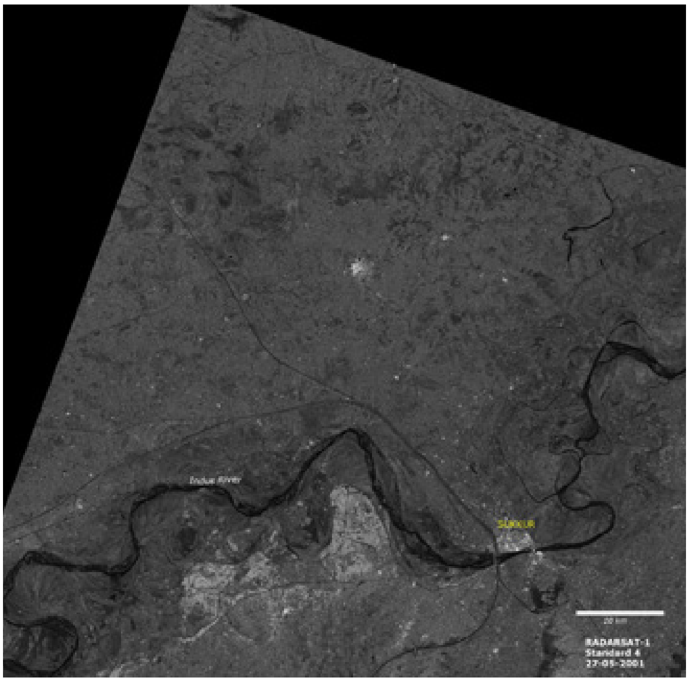
SUPARCO in collaboration with the Institute of Tibetan Plateau (ITP) in China are carrying out research on the melting of glaciers in Himalaya HKH region. In recent decades, most of these glaciers are shrinking at an accelerated rate.

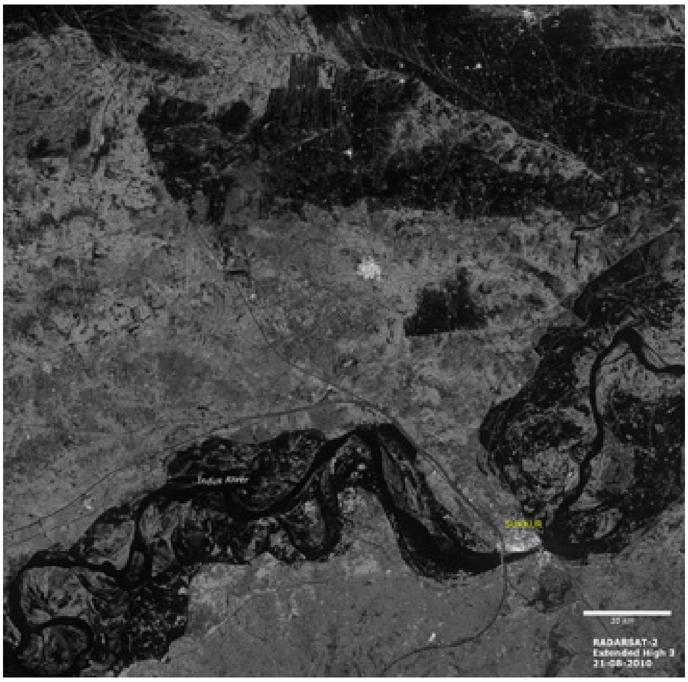
The focus of the study is to observe and monitor Growing Glacial Lakes & Glacial Lake Outburst Floods (GLOFs) in the region, using earth observation technologies.

6.7 SAR Imaging technologies

Synthetic Aperture Radar (SAR) sensors are meant for all type of weather, as well as day & night imaging capabilities. This means that these would complement the limitations of optical satellite operations in adverse weather & daylight conditions.

In the aftermath of floods, the ability of SAR to penetrate clouds is extremely useful. The SAR data can help to optimize response initiatives and to assess the damages.





Synthetic Aperture Radar (SAR) images are very useful during the cloudy season

7. Concluding remarks

Prioritizing Prevention and Preparedness

The scale and complexity of the disasters faced by Pakistan in the past years would have been a challenge to any country. However, a unified response from the Pakistani society as well as the tireless efforts of all the national and international agencies involved had proved vital. Timely assistance from around the world in the form of monetary assistance coupled with a large number of philanthropic activities helped bring Pakistan back to a state of normality. Pakistan has a long way to go in order to improve its disaster prevention and reduction framework. Disaster prevention has to be a priority of the Pakistani Government. It is of paramount importance that the relation between Disaster Risk Reduction and environmental protection be understood. Although the government has made tremendous efforts to reduce the risks and consequences of natural disasters, it is clearly aware that several shortcomings exist, which need to be addressed immediately. More than ever, the government needs to develop an accurate as possible system to improve the Disaster Risk Reduction.

The operational experiences gained during all phases of the disasters needs to be well documented and the lessons learned should be considered while planning preparedness and mitigation measures.

As natural disasters pose a common challenge to mankind, the potential of space based information should be utilized to the fullest extent in disaster reduction efforts. The booklet attempts to provide lessons learned in Pakistan and present an integrated approach of using space technology for disaster risk reduction.

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