ICIMOD

The 2022 Pakistan floods

Assessment of crop losses in Sindh Province using satellite data

AUTHORS

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Summary

Nationally, Pakistan's Sindh Province accounts for 42% of the rice production, 23% of the cotton production, and 31% of the sugarcane production. The 2022 Pakistan floods caused unprecedented damage to agriculture crops, livestock, and infrastructure, including storage facilities with millions of tons of grain, posing the risk of an unprecedented food security crisis in the country.

The floods struck before the harvesting stage of key crops, including cotton, rice, and sugarcane. Using an approach based on satellite imagery, we assessed potential crop production losses for major crops at the subdistrict-level to support the Government of Pakistan's rehabilitation and compensation planning processes in Sindh Province.

According to flood extent mapping using Sentinel-1 satellite images acquired during 22–28 August, flood waters directly inundated about 2.5 million hectares of land (over 18% of Sindh's total area), which resulted in obstructed access and mobility in around three-fourths of the province area. The northwestern districts of Jacobabad, Larkana, Shikarpur, and Kashmore were the worst-affected areas. The satellite data of 3 September shows that the expansion of flood water is continuing through the water coming from the western mountain region of Balochistan and is increasing river discharge at Guddu barrage, resulting in additional flooding in the Indus River.

The total agricultural area of Sindh is about 4.9 million hectares. In summer (*kharif*) season, most of the area is cultivated under three commercial crops: rice, cotton, and sugarcane. The flood inundation is highest in the rice crop zone, which has resulted in an overall estimated loss of 1.9 million tons of rice, or an 80% loss of the expected total rice production in Sindh.

Sugarcane is predominantly grown in the northeastern districts, where flood inundation remained relatively lower. Damage amounted to 10.5 million tons, or a 61% loss of the expected production of sugarcane. Like the sugarcane zone, the cotton zone also received relatively lesser inundation. However, this zone received several exceptionally high daily rainfall spells, which almost completely devastated cotton crops at maturity (with cracked cotton balls). We expect a loss of about 88% of the total expected cotton production (3.1 million bales) as a result of the flood inundation and exceptionally high rainfall in the cotton-growing areas of Sindh.

In economic terms, these three crops faced a direct loss of USD 1.30 billion (rice: USD 543 million, cotton: USD 485 million, sugarcane: USD 273 million). In addition, three key vegetable crops – tomato, onion, and chilli – face losses totalling USD 374 million in the affected districts, with the highest losses in Thatta, Badin, and Mirpur. As per estimates, floods killed 42,273 livestock, including sheep, goats, camels, cows, buffaloes, and donkeys, causing a direct loss of around USD 13 million to livestock in the province.

The economic losses in agriculture are much beyond the estimated direct losses to crop production and livestock. Direct damages and losses to agriculture tools and machinery, infrastructure in farms and rural areas, and trees are likely to compound the economic losses. The indirect costs involved in draining and land rehabilitation, increased cost of transportation resulting from damaged roads and infrastructure, losses in successive crop cycles due to water logging and delays in sowing, and the government's rehabilitation and compensation support are likely to have deeper and long-term impacts on Pakistan's agriculture.

This rapid assessment does not cover other agricultural losses such as loss of agriculture infrastructure and equipment and disruption in agriculture services.

Impact of the 2022 floods on agriculture in Pakistan's Sindh Province

Rainfall (August 2022)

+243%
National average

+590%
Balochistan

+726%
Sindh
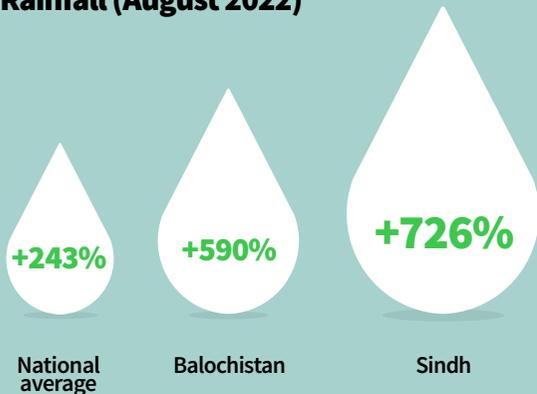
33 million
affected across Pakistan

14.5 million
affected in Sindh Province

Flood intensity across Sindh Province

Indus River

Larkana

Karachi

14 million hectares
land area of Sindh

4.9 million hectares
cropland area
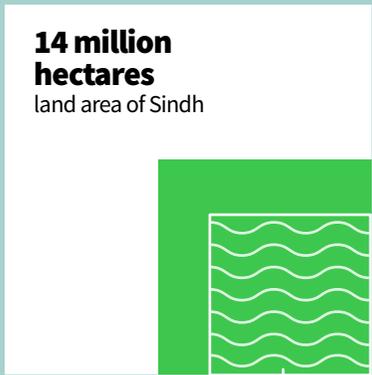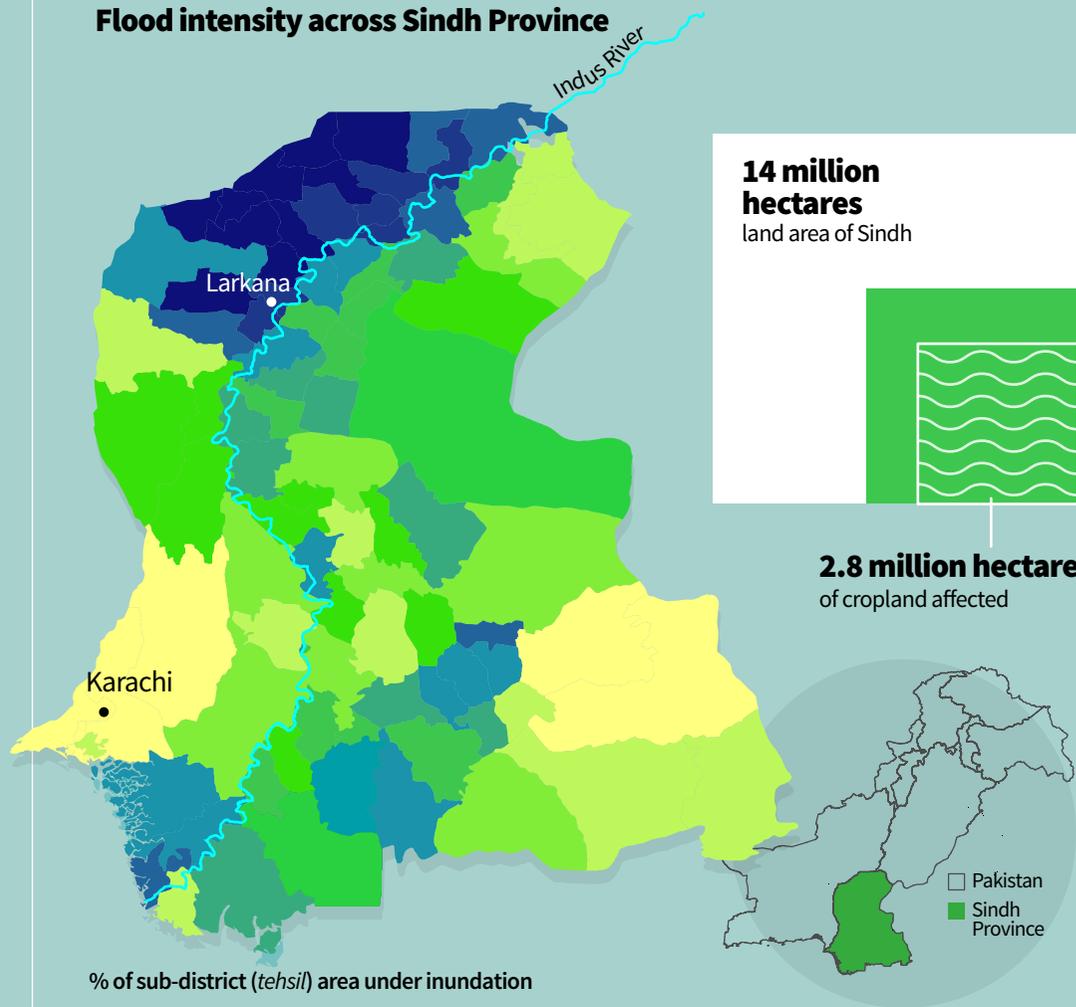
2.8 million hectares
of cropland affected

Pakistan
Sindh Province

% of sub-district (*tehsil*) area under inundation

0–3	8–10	14–16	22–26	35–51
4–7	11–13	17–21	27–34	52–70
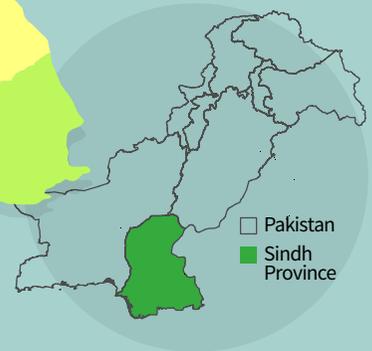
Loss of three major crops in Sindh

	Production loss	Economic loss in USD
Rice	**1.9 million tons**	**543 million**
Cotton	**3.1 million bales**	**485 million**
Sugarcane	**10.5 million tons**	**273 million**

Total agriculture economic loss in Sindh

USD 1.30 billion
rice, cotton, and sugarcane

USD 374 million
tomato, onion, and chilli

USD 13 million
livestock

Key takeaways

The impact of the 2022 floods on Pakistan's rural communities and agriculture has been devastating, resulting in the loss of crops, livestock, and essential infrastructure. The country is now facing an unprecedented food security crisis. Nationally, Pakistan's Sindh Province accounts for 42% of the rice production, 23% of the cotton production, and 31% of the sugarcane production. In our report, we assess potential crop production losses for these crops at the sub-district level using a remote-sensing approach based on satellite imagery. The analyses are designed to support the Government of Pakistan's rehabilitation and compensation planning processes.

- According to flood extent mapping using Sentinel-1 satellite images acquired during 22–28 August, over 18% of Sindh's total area was directly inundated.

- In the summer (*kharif*) season, most of the area in Sindh is cultivated under three commercial crops: rice, cotton, and sugarcane. The flood inundation is highest in the rice crop zone, which has resulted in an overall estimated loss of 1.8 million tons of rice, or an 80% loss of the expected total rice production in Sindh.

- Sugarcane and cotton zones received relatively lesser inundation during the flood. However, both zones received several exceptionally high daily rainfall spells, which almost completely devastated cotton crops at maturity (with cracked cotton balls).

- We expect a loss of about 88% of the total expected cotton production (3.5 million bales) because of the exceptionally high rainfall and inundation in the cotton-growing areas of Sindh. Damage to sugarcane crops amounted to a loss of USD 273 million.

- In economic terms, rice, cotton, and sugarcane together faced a direct loss of USD 1.30 billion (rice: USD 543 million, cotton: USD 485 million, and sugarcane: USD 273 million).

- As per estimates, floods killed 42,174 livestock, causing USD 13 million loss.

- Overall, the province faced a combined loss of USD 1.7 billion in rice, cotton, sugarcane, tomato, onion, chilli, and livestock.

- Economic losses in agriculture are much beyond the estimated direct losses to crop production and livestock.

Other agricultural losses not covered in this rapid assessment of Sindh

Loss of agriculture infrastructure and equipment: farm-to-market roads, telecommunications, electrification, irrigation, solar systems and equipment (tractors, power tillers, thresher, pumping sets, sprayers)

Disruption in agriculture services: animal husbandry, financial services, input distribution, transportation services

Introduction

The South Asian region was forecasted to experience normal to above normal rainfall for June to September 2022. The national average rainfall in Pakistan for August 2022 was excessively above average (+243%), with extremely high rains in Balochistan (+590%) and Sindh (+726%), the wettest ever in August. The Sindh Province has had nearly eight times its average August rainfall (Figure 1). Torrential monsoons in July and August triggered the most severe floods in Pakistan's history, directly affecting 33 million people in Pakistan (Figure 2). Pakistan's National Disaster Management Authority officially declared 66 districts as 'calamity hit' – 31 in Balochistan, 23 in Sindh, 9 in Khyber Paktunkhwa, and 3 in Punjab. Supported by the UN and humanitarian partners, the Government of Pakistan is leading the humanitarian response for people in the affected areas.

The 2022 Pakistan floods caused unprecedented damage to agriculture crops, livestock, and infrastructure, including storage facilities with millions of tons of grain, resulting in an unprecedented food security crisis in the country. The floods struck before the harvesting stage of key crops, including cotton, rice, and sugarcane. Using a satellite data-based remote sensing approach, we assessed potential crop production losses for major crops at the subdistrict-level to support the Government of Pakistan's rehabilitation and compensation planning processes.
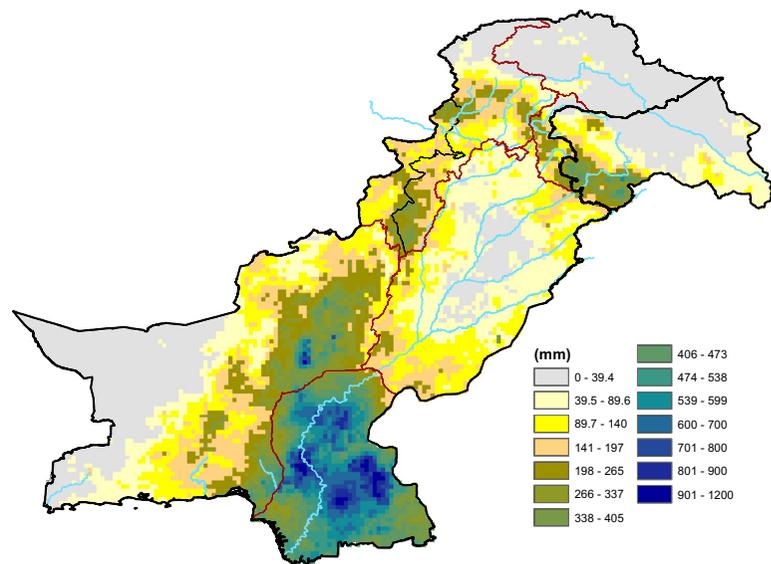

Figure 1: Rainfall observed for August 2022 in Pakistan
Source: GPM IMERG satellite data
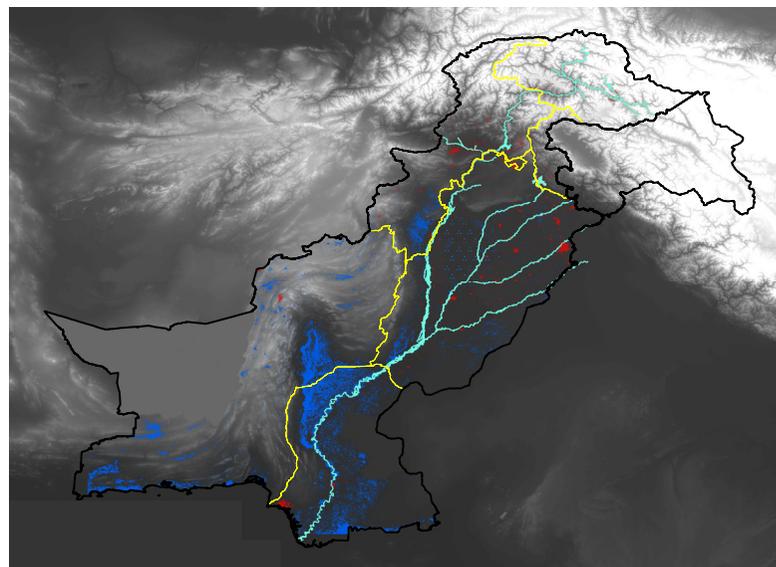
Figure 2: Flood extent in Pakistan on 28 August 2022
Source: Sentinel-1 satellite data

Sindh Province in brief

Sindh's population is estimated to be over 48 million, divided equally between the urban and rural areas. The sectoral shares in the gross provincial product are agriculture 17%, industry 36%, and services 47%. Sindh's share in the national economy is around 25%. The province's total land area is 14.091 million hectares, of which cropped area is 3.9 million hectares. Agriculture is primarily irrigated by the Indus River and mainly involves cereal crops (wheat and rice), industrial crops (sugarcane and cotton), and a small percentage of horticultural crops.

Rainfall patterns in Sindh

The average annual rainfall in Sindh is about 150–180 mm, and most of this rainfall is received from July through September (monsoon season). Since July 2022, several flash floods have occurred in Balochistan, Sindh, and southwest Punjab, inflicting huge losses to human lives and property. On 11 August, Naushahro Feroze District in Sindh received 142 mm of rain in a single day (Figure 3). This exceptional rain spell continued until 25 August, further exacerbating the flooding. In August, Padidan Town in Naushahro Feroze District recorded a monthly total rainfall of 1,228 mm, the highest recorded rainfall for the province (Figure 4).
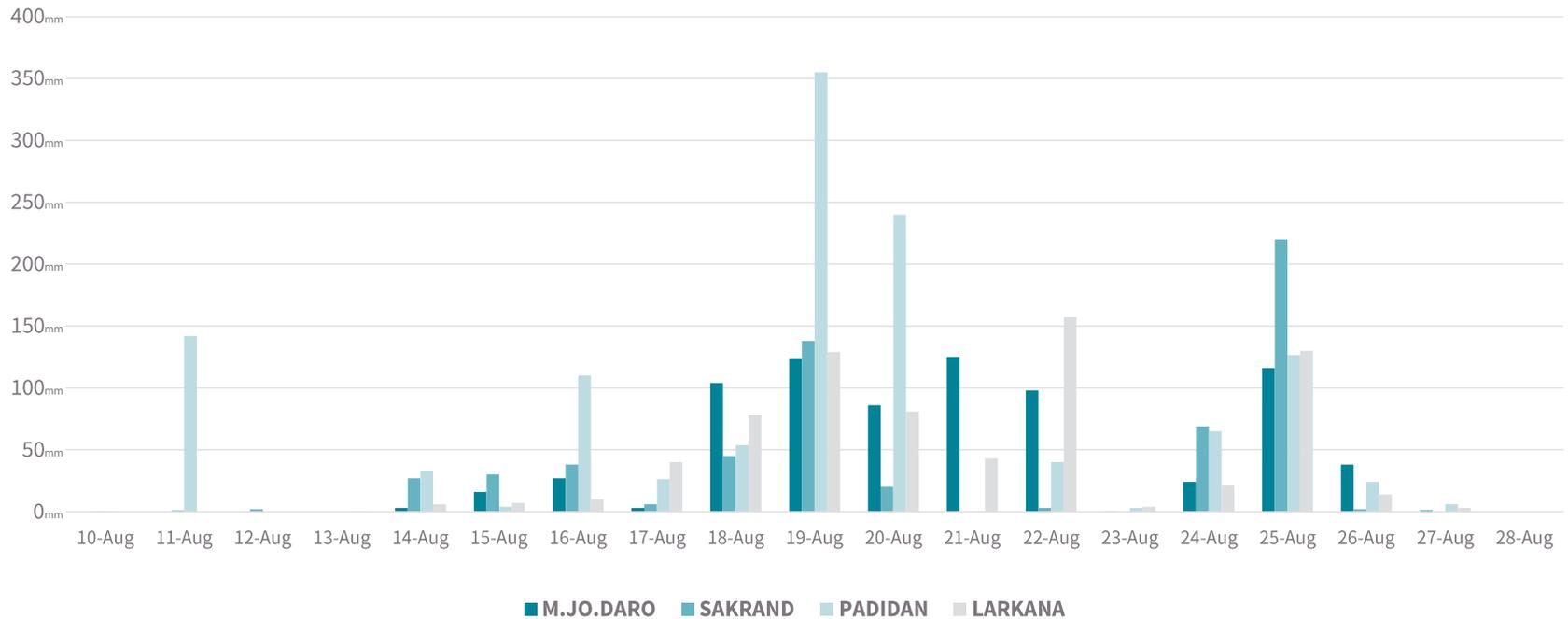
Figure 3: Daily rainfall patterns during August 2022 across the districts of Sindh Province
Source: Pakistan Meteorological Department
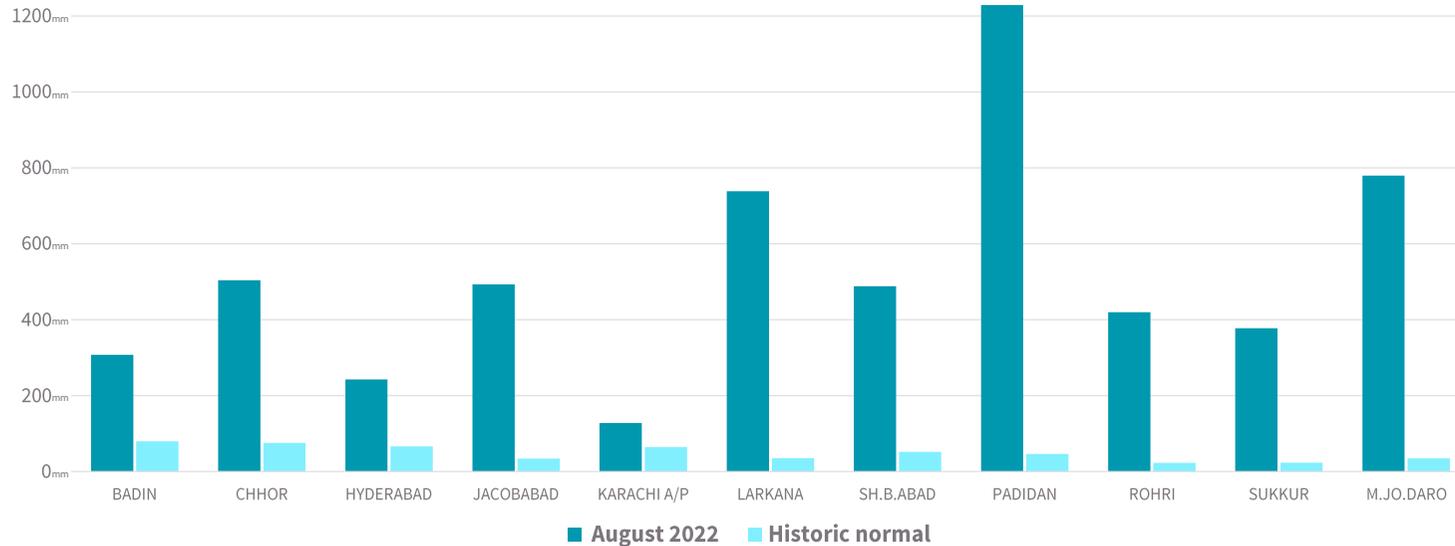
Figure 4: August 2022 rainfall and historical average from selected stations of the Pakistan Meteorological Department in Sindh

Source: Pakistan Meteorological Department

Flood extent in Sindh

Massive floods started in the northwestern region, located below the hill-torrent regions (which are found in arid environments of Pakistan and generally associated with very high run-off water from flash floods), on 11 August and continued expanding until the end of August. On 28 August, flood waters inundated about 2.5 million hectares of land and obstructed access and mobility in three-fourth of the province area (Figures 6 and 7). The northwestern districts of Jacobabad, Larkana, Shikarpur, and Kashmore were the worst-affected areas (Figure 5). These districts received exceptionally high rainfall and were affected by flash floods from the adjacent hill torrents and Balochistan Province. The flood inundated approximately 2.5 million hectares of land, over 18% of Sindh's total area.

Floods inundated almost half or more of the total district area, severely affecting Jacobabad, Larkana, Qambar Shahdad Kot, and Shikarpur districts. Likewise, floods inundated around one-fourth of the district area in Badin, Kashmore, Khairpur, and Sujawal districts.

The satellite data of 3 September shows that the expansion of flood water is continuing through the water coming from western mountain region of Balochistan and increasing river discharge at Guddu barrage, resulting in additional flooding around the Indus River.
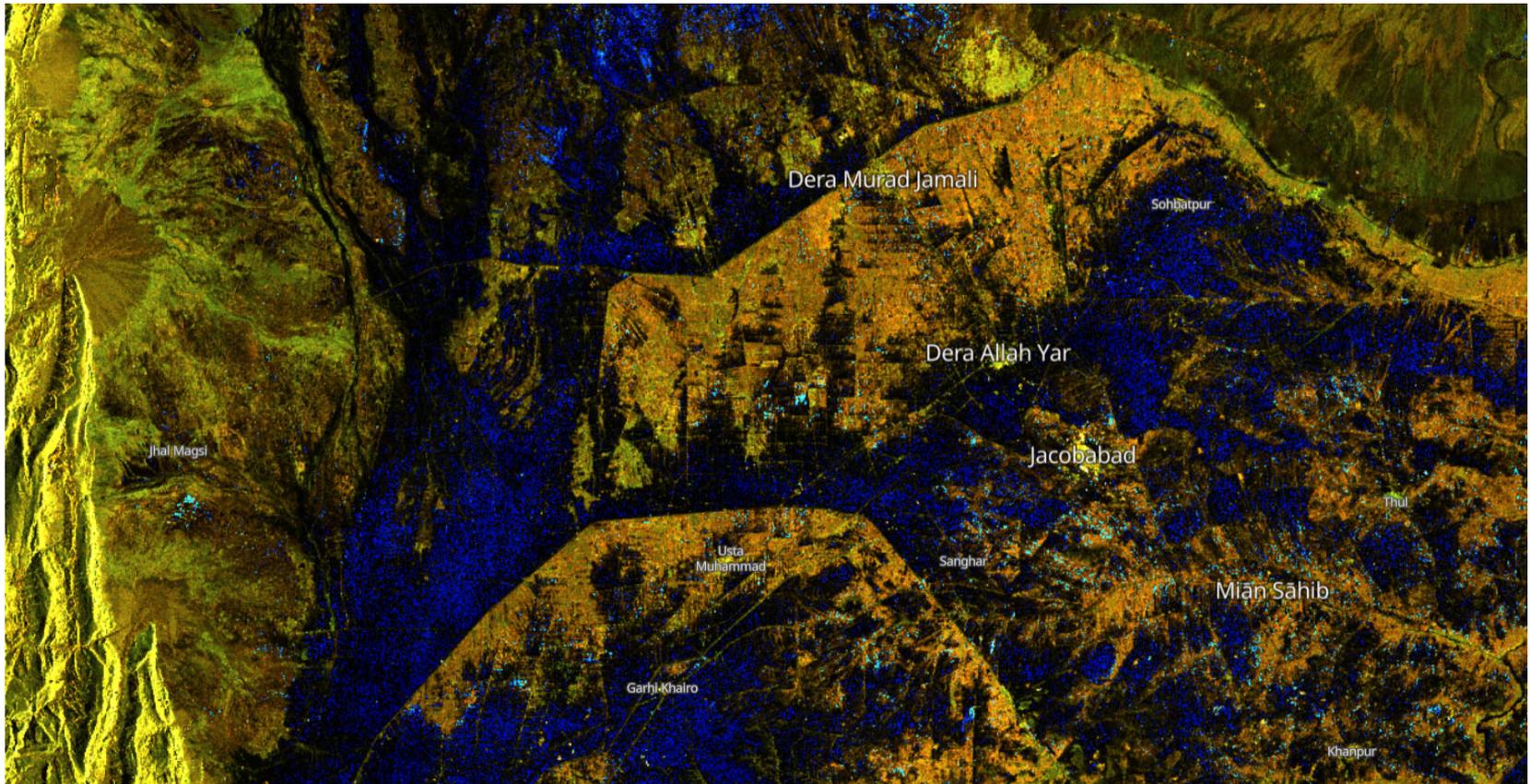
Figure 5: Flood extent patterns in Jacobabad and Dera Murad Jamali on 28 August 2022
     Source: Sentinel-1 SAR satellite imagery

ASSESSMENT METHODS FOR FLOOD INUNDATION

For this assessment, we used Sentinel-1 SAR satellite data, acquired between 22 and 28 August 2022. We employed a combination of machine learning and decision tree rules to identify flood-inundated areas in Pakistan's complex topography. We derived land use and land cover data for the flood damage assessment using remote sensing and population datasets from government census statistics. We also produced detailed flood extent maps and aggregated flood and population intensity maps for the identification of hotspots and visualisation for effective communication.
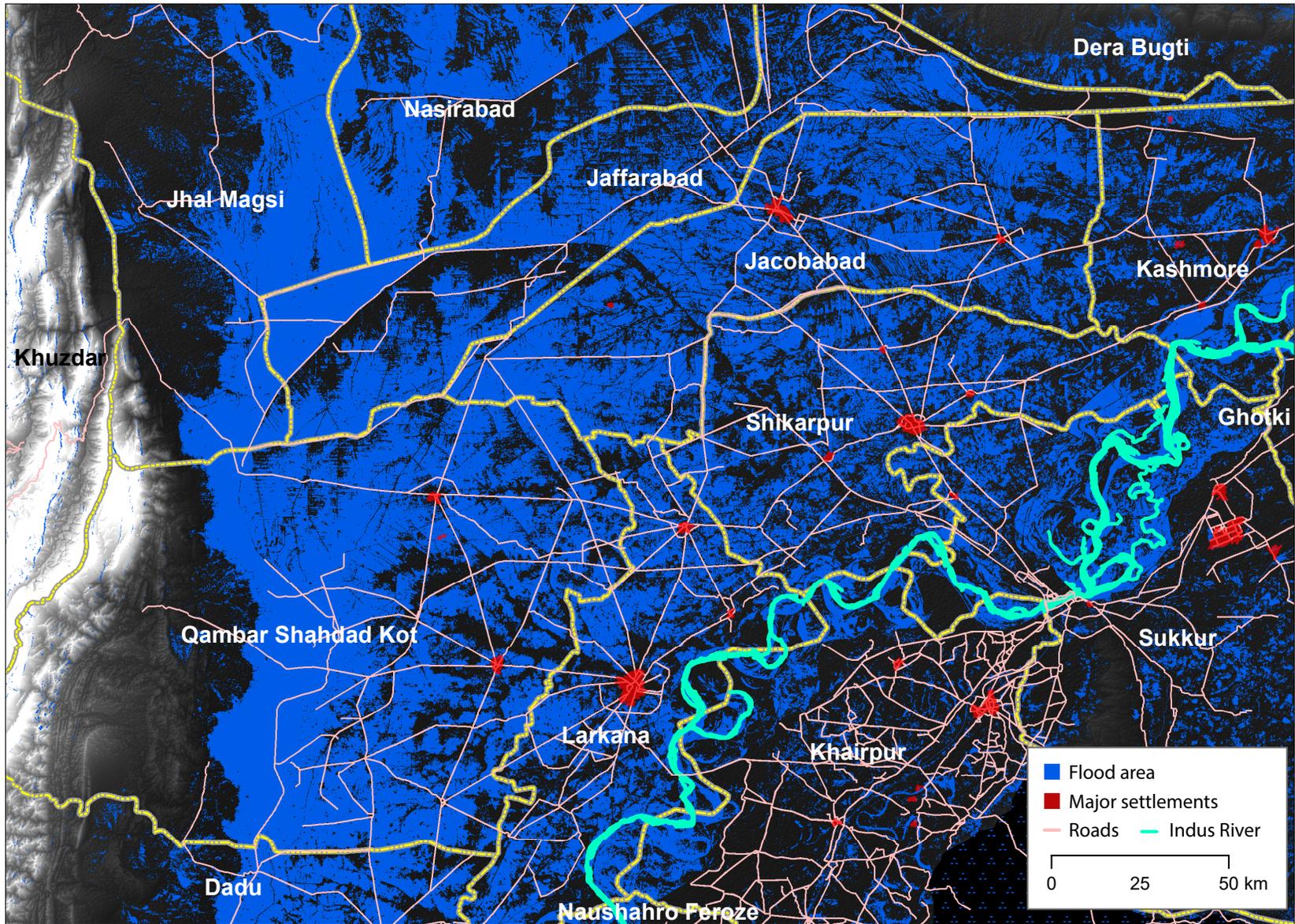
Figure 6: Flood water extent, derived from satellite data, across the largest rice crop zone in Sindh Province (blue indicates water and red indicates major settlements of the district)

Percentage of (tehsil) sub-district area under inundation

0 - 3	11 - 13	22 - 26
4 - 7	14 - 16	27 - 34
8 - 10	17 - 21	35 - 51
		52 - 70

0   100   200 Km

— District boundaries
— Tehsil boundaries
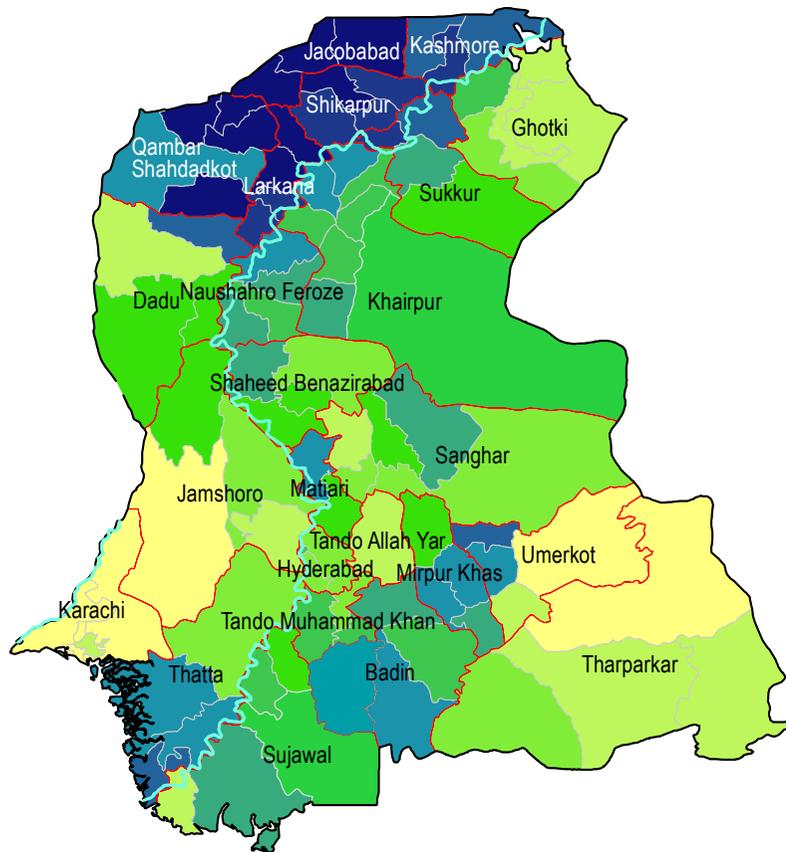
Figure 7: Flood intensity across Sindh Province aggregated at the subdistrict (tehsil) level
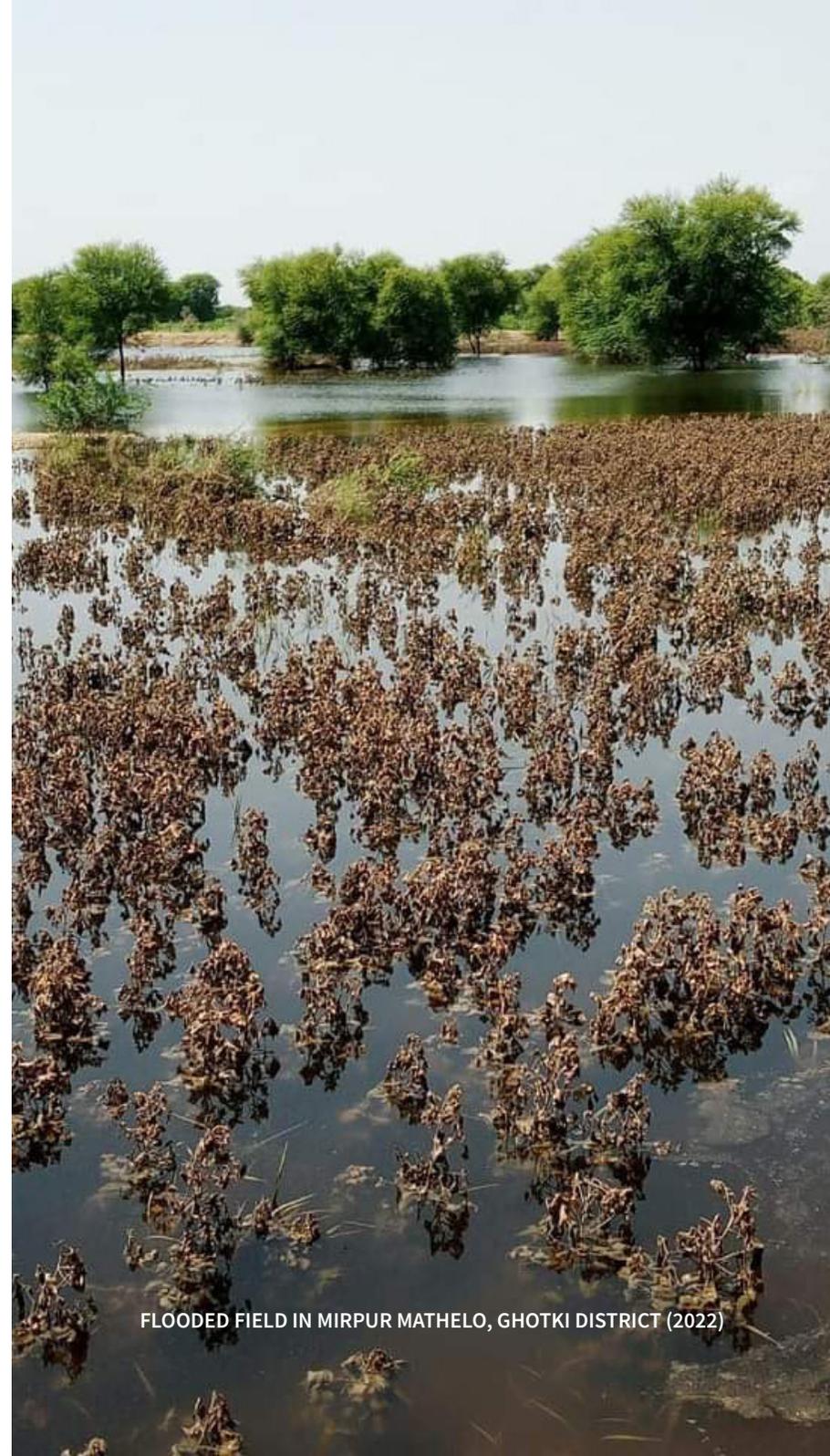
FLOODED FIELD IN MIRPUR MATHELO, GHOTKI DISTRICT (2022)

Agriculture production in Sindh

The total agricultural area is about 4.9 million hectares; food crops and cash crops are grown in 60% and 25% of the total cultivated land, respectively. The major crops in Sindh – rice; sugarcane; cotton; beans; vegetables (tomato, chilli, onion, okra, and cucurbitaceous vegetables); and fruits (mango, banana, and papaya) – are grown during the summer (kharif) season. Three cereal and industrial crops – rice, cotton, and sugarcane – dominate the total cultivated area (Figure 8), while horticultural crops account for only 7%. Nationally, the province accounts for 16% of the wheat production, 42% of the rice production, 23% of the cotton production, and 31% of the sugarcane production.

Rice production (metric tons)

0–500	36385–179868
501–20131	179869–269736
20132–28646	269737–351504
28647–36384	351505–462058

Sugarcane production (metric tons)

0–500	412631–968933
501–45666	968934–1405261
45667–119848	1405262–1971167
119849–412630	1971168–2929661

Cotton production (bales)

0–500	99913–132735
501–27633	132736–221901
27634–42811	221902–419290
42812–99912	419291–698798
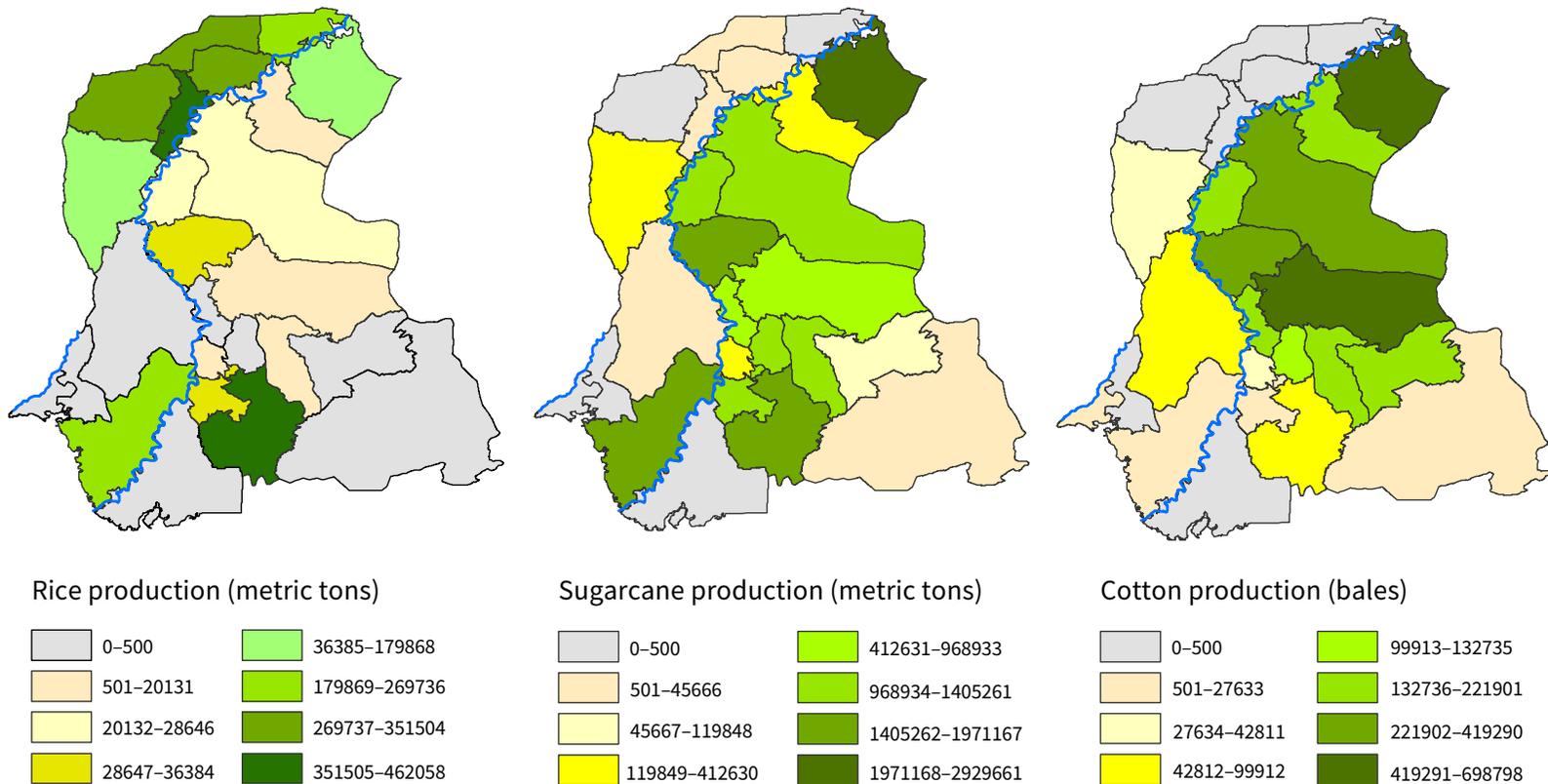
Figure 8: Production of three major crops – rice, sugarcane, and cotton – across the districts in Sindh
Source: Pakistan Bureau of Statistics

STRANDED FLOOD VICTIMS IN FLOODED AREAS (2010)

CROP DAMAGE ASSESSMENT METHOD

We used Sentinel-2 optical satellite data acquired between 25 and 31 August 2022 to assess primary crop conditions. We utilised crop production estimates published by the Pakistan Bureau of Statistics to estimate crop production losses. We also evaluated crop phenology patterns indicating critical crop development phases where greenness rapidly increases from early to the end of August. Based on these observations, we developed a maximum normalised difference vegetation index composite image of 25–31 August for 2021 and 2022 for comparative assessment. We then developed a normalised difference vegetation index difference map to estimate and categorise the comparative losses in greenness over the croplands or cultivated areas. We performed an overlay analysis with the flood inundation maps to further verify the intensity of the damage observed from the vegetation conditions of crop areas (Figure 10). We aggregated the vegetation anomalies at the subdistrict (tehsil) and district levels to further calculate the production losses.

This rapid assessment does not cover other agricultural losses given below:

Loss of agriculture infrastructure and equipment: farm-to-market roads, telecommunications, electrification, irrigation, solar systems and equipment (tractors, power tillers, thresher, pumping sets, sprayers)

Disruption in agriculture services: animal husbandry, financial services, input distribution, transportation services

Production losses of three vital commercial crops

Sindh expected a total of 2.3 million tons of rice production in 2022, mainly from Jacobabad, Larkana, Shikarpur, Qambar Shahdadkot, and the south Badin districts (Figure 8). The floods struck in the middle of the growing season, and the flood damage intensity remained extremely high in the rice crop zone. We estimate an overall loss of 1.8 million tons, or an 80% loss of the expected crop production. Table 1 lists the district-level production losses, and Figure 9 illustrates the subdistrict (tehsil) level damage intensity.

About 18 million tons of sugarcane production was expected, mainly from Sanghar, Khairpur, Ghotki, and Shaheed Benazirabad districts. Based on the flood inundation extent and assessment of vegetation conditions, we estimate a total loss of 10.5 million tons, or a 61% loss of the expected sugarcane production.

The eastern part of Sindh comprises the cotton zone, which underwent less flood inundation than the western districts. Floods inundated about 50% of the cotton zone. However, this zone also received several exceptionally high daily rainfall spells, which further damaged crops nearing maturity. Farmers picked a small amount of early sowing variety of cotton before the heavy rains started. We expect a loss of about 88% of the total expected cotton production (3.5 million bales) resulting from flood inundation and exceptionally high rainfall.

Tehsil level total crop area – August 2022

▢ 58–5000	▢ 78021–87597
▢ 5001–55492	▢ 87598–110635
▢ 55493–69248	▢ 110636–139282
▢ 69249–78020	▢ 139283–192410
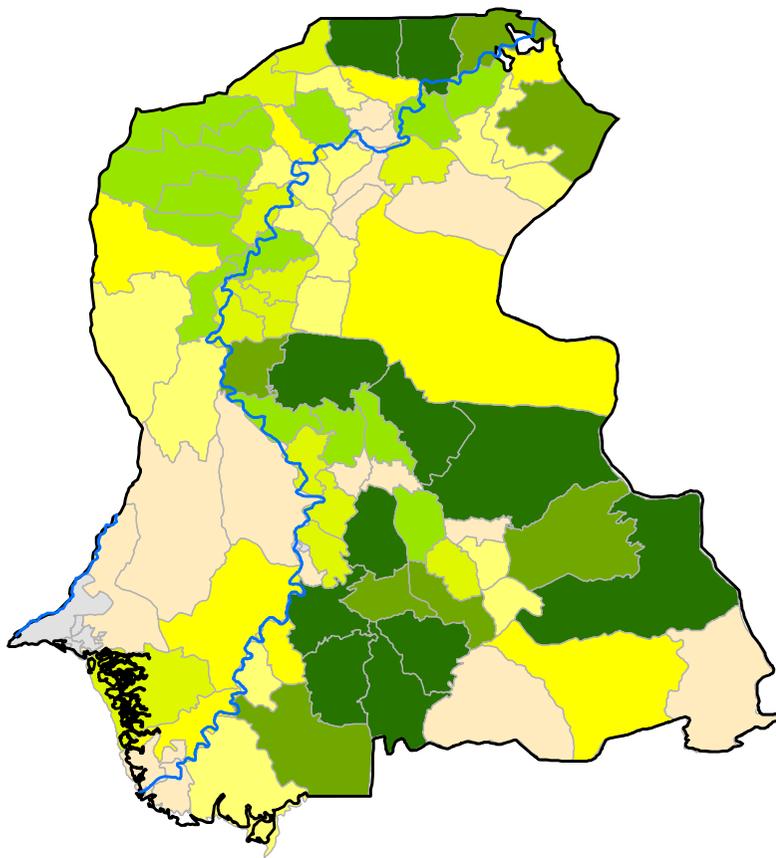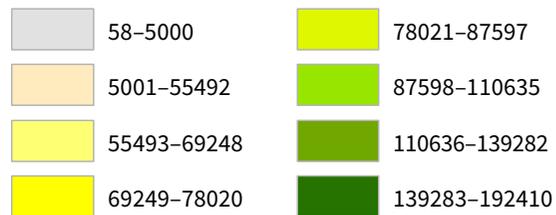
1:5,500,000

Tehsil level total crop area – August 2022

▢ 1–14	▢ 64–78
▢ 15–28	▢ 79–83
▢ 29–47	▢ 84–88
▢ 48–63	▢ 89–96
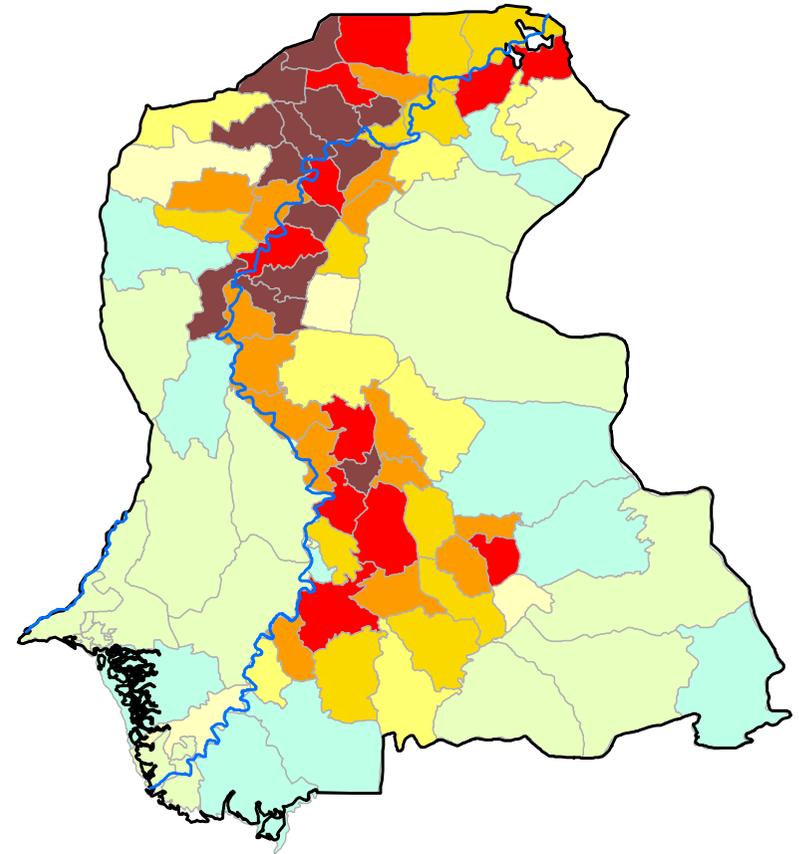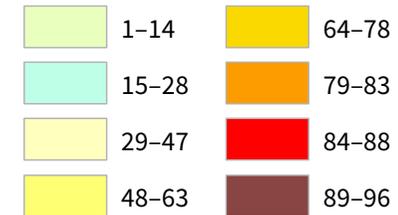
**Figure 9: Crop sown areas and damage intensity across the subdistrict (tehsil) level in Sindh (Source: Sentinel-1 satellite image-based flood extent mapping and Sentinel-2 satellite image-based vegetation conditions assessment)**
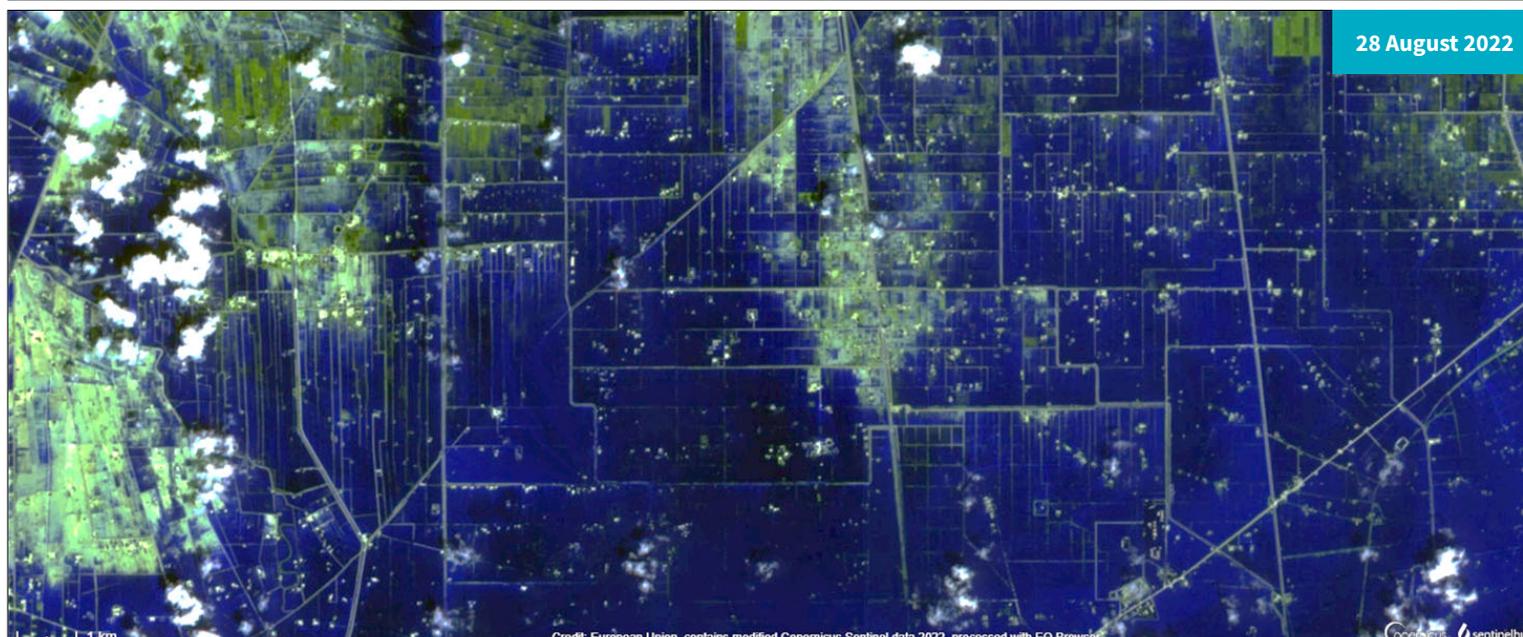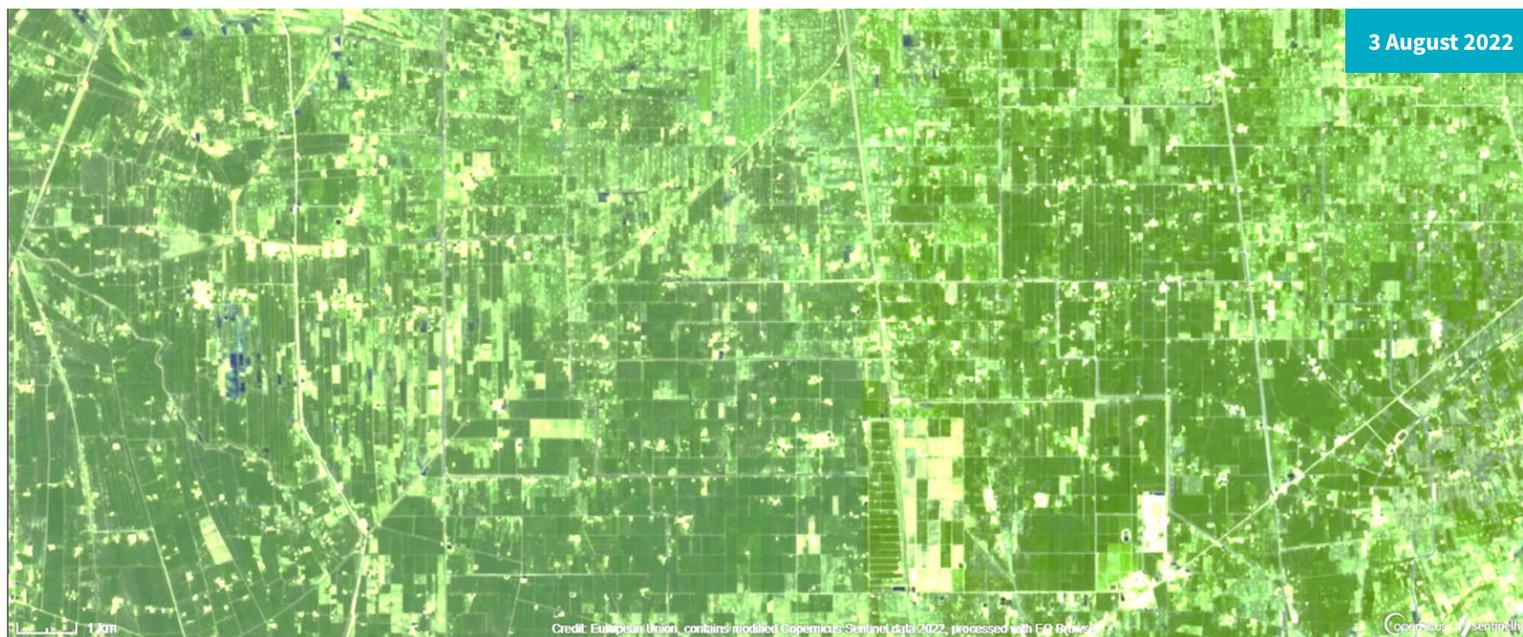
Figure 10: Cropland condition in Larkana District during normal (3 August 2022) and flooded (28 August 2022) periods
　　Source: Sentinel-2 optical satellite imagery

TABLE 1

DISTRICT-LEVEL PRODUCTION LOSSES ESTIMATION

District	Rice production loss (metric tons)	Cotton production loss (bales)	Sugarcane production loss (metric tons)
Badin	320,844	94,432	1,156,688
Dadu	56,547	31,112	100,850
Ghotki	77,620	519,113	1,378,575
Hyderabad	2,321	35,872	231,635
Jacobabad	255,803	nr	3,158
Jamshoro		42,134	1,989
Kambar-Shahdadkot	181,561	nr	
Karachi		nr	
Kashmor	206,507	nr	
Khairpur	6,077	390,125	286,166
Larkana	335,360	nr	31,870
Matiari		199,418	805,470
Mirpurkhas	8,770	196,632	917,677
Naushahro Feroze	24,261	172,345	1,040,376
Sanghar	7,561	634,346	380,237
Shaheed Benazirabad	23,406	301,673	1,298,054
Shikarpur	299,021	nr	18,919
Sujawal		nr	
Sukkur	6,846	144,537	140,323
Tando Muhammad Khan	30,199	13,187	1,166,367
Tando Allahyar		124,321	1,056,866
Thar		873	4,567
Thatta	49,470	16,942	424,746
Umerkot		189,647	42,261
Loss of production	1,892,172	3,106,709	10,486,793
Loss of production (USD)	543,053,386	484,646,532	272,656,608
Price per unit (USD)	287 (per metric ton)	156 (per bale)	26 (per metric ton)
Total production in Sindh Province (2020)	2,374,300	3,523,400	17,233,830
Loss of production (%)	80	88	61

AN AERIAL VIEW OF FLOODED SHAHDADKOT CITY (2022)

Economic losses of three key commercial crops

Sindh is the province most affected by floods in terms of damage and losses to agriculture. We estimate that the major kharif crops – rice, cotton, and sugarcane – lost 80%, 88%, and 61% of their forecasted production, respectively. These three crops faced a direct loss of USD 1.30 billion. Almost all cotton crops in Badin, Mirpur Khas, Khairpur, Sukkur, and Ghotki districts were damaged. Bananas, lemons, onions, chillis, tomatoes, and other kharif vegetables were either wholly damaged or suffered severe losses in most producing districts. Three key vegetable crops – tomato, onion, and chilli – face the loss of USD 374 million in affected districts, with highest losses in Thata, Badin, and Mirpur (Figure 11). As per estimates, floods killed 42,174 livestock, including sheep, goats, camels, cows, buffaloes, and donkeys, causing the direct loss of around USD 13 million to livestock in the province.

Overall, the province faced the loss of USD 1.7 billion in in rice, cotton, sugarcane, tomato, onion, chilli, and livestock. There is a high likelihood of significant nonreported losses to the production of other crops and livestock in the affected districts.

The economic losses in agriculture are much beyond the estimated direct losses to crop production and livestock. Direct damages and losses to agriculture tools and machinery, infrastructure in farms and rural areas, and trees are likely to compound the economic losses further. The indirect costs involved in draining and land rehabilitation, increased cost of transportation resulting from damaged roads and infrastructure, losses in successive crops due to water logging and delays in sowing, and the government's rehabilitation and compensation support are likely to have deeper and long-term impacts on Pakistan's agriculture.
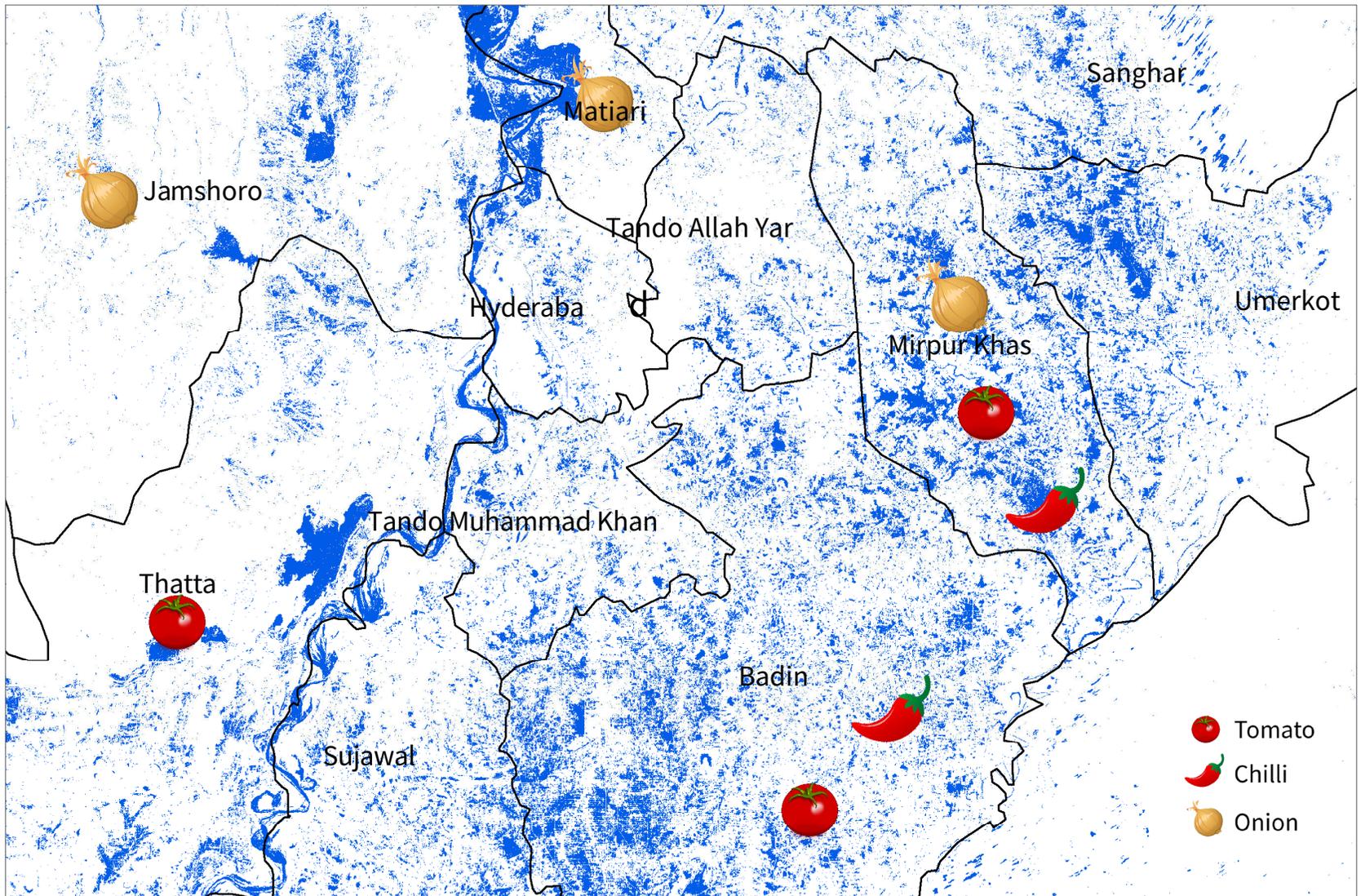
Figure 11: Key vegetable production zones of Sindh and flood extent in the region
Source: Data collection survey on agricultural sector in Sindh Province, Pakistan, JICA, February 2022

Annex: Production of three key vegetables across Sindh

PROVINCE/DISTRICTS	Tomato		Onion		Chilli	
	Area (ha)	Production (metric tons)	Area (ha)	Production (metric tons)	Area (ha)	Production (metric tons)
SINDH	23,395	171,659	56,253	758,638	35,409	81,936
Kashmore	61	434	537	7,566	13	33
Jacobabad	178	1,256	3,507	48,173	-	-
Ghotki	65	476	518	7,089	122	290
Sukkur	189	1,557	235	3,276	93	223
Shikarpur	221	1,429	149	1,947	403	802
Khairpur	134	938	377	5,296	339	759
Larkana	914	5,211	1,220	17,030	92	212
Kamber/Shahddad Kot	280	1,938	159	2,237	-	-
Naushahro Feroze	276	2,135	1,668	22,962	65	164
Dadu	187	1,387	4,234	59,143	815	1,882
Shaheed Benazir Abad	199	1,604	4,380	63,204	314	822
Sanghar	498	2,710	5,012	68,534	1,975	3,373
Matiari	1,298	9,481	7,334	105,715	1,997	3,848
Jamshoro	154	1,249	12,272	167,978	1,964	3,514
Umer Kot	590	4,211	2,721	31,766	5,566	16,480
Mirpurkhas	1,860	12,208	9,530	123,494	5,077	14,843
Tando Allahyar	166	1,248	2,096	29,728	819	1,342
Hyderabad	210	1,627	292	4,125	367	892
Tharparkar	77	421	681	7,262	910	2,764
Badin	3,022	24,222	309	3,777	8,666	17,340
Tando Muhammad Khan	1,163	9,317	1,693	19,243	901	1,962
Thatta	12,217	90,749	2,211	26,536	4,734	9,966
Karachi	150	1,013	64	608	177	425

Production year (2020–2021)

Source: Data collection survey on agricultural sector in Sindh Province, Pakistan, JICA, February 2022

A SMALL VILLAGE IN PANO AQIL, SINDH, REMAINS SURROUNDED BY WATER IN OCTOBER (2010)

About PARC

The Pakistan Agricultural Research Council's (PARC)mandate includes aiding, promoting, and coordinating the research effort across Pakistan; ensuring that research results are disseminated and utilised; and creating a cadre of highly trained human resources to undertake and manage research. PARC also plays an advisory role in the promotion of agricultural enterprises. Other key functions of the organisation include:

- Strategic research on national and provincial priorities and emerging challenges in agriculture
- Exploratory research on new commodities and filling gaps in provincial research agenda
- Collaboration and linkages with international and provincial research systems
- Services to the provincial system in the conservation and supply of germplasm
- Establishing agricultural informatics to support planning and policy processes

About SERVIR

A joint initiative of NASA, USAID, and leading geospatial organisations in Asia, Africa, and Latin America, SERVIR partners with countries in these regions to address critical challenges in climate change, food security, water and related disasters, land use, and air quality. Using satellite data and geospatial technology, SERVIR co-develops innovative solutions through a network of regional hubs to improve resilience and sustainable resource management at local, national and regional scales.

ICIMOD implements the SERVIR Hindu Kush Himalaya (SERVIR-HKH) Initiative – one of five regional hubs of the SERVIR network – in its Regional Member Countries, prioritizing activities in Afghanistan, Bangladesh, Myanmar, Nepal and Pakistan.

About ICIMOD

The International Centre for Integrated Mountain Development (ICIMOD), is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalaya – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalisation and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues. We support regional transboundary programmes through partnership with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.

REGIONAL MEMBER COUNTRIES

AFGHANISTAN   BANGLADESH   BHUTAN   CHINA

INDIA   MYANMAR   NEPAL   PAKISTAN

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