Food and Agriculture Organization of the United Nations

A geospatial assessment of the impact of flood in support to the restoration of irrigation schemes in **Malawi**

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Abbreviations and acronyms

AOI	Area of interest
DAPS	Department of Agriculture Planning Service
DEM	Digital elevation model
DoI	Department of Irrigation
ECHO	European Civil Protection and Humanitarian Aid Operations
EPA	extension planning area
ETI	evapotranspiration and interception
FAO	Food and Agriculture Organization of the United Nations
FS–TIP	Food Systems Transformative Integrated Policy
JICA	Japan International Cooperation Agency
JRC	Joint Research Centre
km^2	Square kilometre
ha	Hectare
MASDAP	Malawi spatial data platform
MoA	Ministry of Agriculture
MwAPATA	Malawi agricultural policy advancement and transformation agenda
NPC	National Contingency Plan
NSO	National Statistical Office
SAR	Synthetic aperture radar
SRTM	Shuttle radar topography mission
UN	United Nations
UNSALB	UN second administrative level boundaries
WDI	water deficit index

Executive summary

In early 2022, the southern and central provinces of Malawi were impacted by various extreme events, such as tropical storm Ana in January followed by tropical cyclone Gombe in March. The strong winds and flooding including flash flood events, caused severe damage to crops and irrigation infrastructure. Irrigation infrastructure plays an important role in providing food and livelihood to a large part of the population, as the agriculture sector in Malawi employs 76.36 percent of the total population. On the other hand, extreme weather events are becoming more frequent in Malawi and appraisal of the damage is difficult with limited information. In this context, the Geospatial unit at the Land and Water Division (NSL) of the Food and Agriculture Organization of the United Nations, in close collaboration with the country office and Irrigation Department, provided technical assistance to the Government of Malawi to assess the impact of floods using innovative geospatial technologies in support of the restoration of irrigation schemes. The majority of the large-scale irrigation infrastructure in the country is located in the south of the country, mainly in Chikwawa and Nsanje districts.

To assess the impacts of flood and flash flood on irrigated cropland, earth observation data were extensively used to extract information such as flood extent, flash flood potential, cropland extent, irrigated cropland. According to the results of the assessment, most of the impacted irrigated areas that require technical assistance and perhaps further assessments and interventions, are located in Chikwawa (impacted 15 103 ha) and Nsanje (impacted 12 960 ha) districts. This information can be used to facilitate the revision of priority areas for detailed assessment and intervention.

Several recommendations were made to further enhance the national capacities to assess the impacts of extreme events for policy intervention and management to implement resilient actions. This assessment also highlights the relevance of a national geospatial database and monitoring platform for irrigated land.

1 Introduction

The expansion of irrigated cropland has been one of the key development goals for the acceleration of economic growth during the past three decades in Malawi (NPC, 2021a). The implementation of several flagship irrigated projects to expand command areas in the country has been at the centre of different initiatives within the agriculture sector. The Government of Malawi is planning to expand efforts towards irrigated agriculture as part of the implementation of the Malawi Vision 2063 as well as its first 10-year implementation plan (MIP–10) 2021 – 2030 (NPC, 2021b). Therefore, the role of agriculture under irrigation cannot be more overemphasized in the country's strategic long-term planning as it is critical to catalyze national food security needs, commercialization of agriculture products and indirectly foster promotion of exports.

All in all, irrigated agriculture plays an important role in supplying food and sustaining a large part of the population. However, extreme weather events often pose an important risk to irrigation infrastructure, thereby reducing the intended impacts and requiring regular important investments for rehabilitation.

The agriculture sector in Malawi employs 76.36 percent of the total population and 64 percent of the country's workforce (NPC, 2021b). It accounts for more than 80 percent of national export earnings and contributes 23 percent of GDP (JICA, 2020). Over 51 percent of Malawians are under the age of 18, and household food availability is largely determined by self-production (NSO, 2018; FS–TIP, 2021). However, approximately 76 percent of the farmer population operates on relatively small farm sizes of less than one hectare, with at least 30 percent already virtually landless and struggling to sustain a family on less than half a hectare of land (Muyanga et al., 2020). With a population growth rate of 2.9 percent per year, more strain is being placed on already limited productive resources.

During the last rain season of 2021/22, Tropical Storm Ana passed through southern Malawi in late January 2022, leaving behind devastation and destruction (UN, 2022) and causing massive losses among rural communities along lakeshore areas and riverbanks. The storm caused heavy rainfall, wind gusts and flash flooding in several districts such as Chikwawa, Nsanje, Phalombe, Zomba, Neno and Mulanje and 10 more districts, affecting more than 1 million people. This dire humanitarian situation was compounded by the side effects of COVID-19, an outbreak of wild poliovirus and by the damage inflicted by the Tropical Cyclone Gombe, which made landfall in Mozambique and moved to Malawi by mid-March 2022, also causing additional flooding in Mulanje, Chikwawa, Neno, Phalombe and other nearby districts (ECHO, 2022).

Flash flooding caused by tropical storms is one of the leading causes of crop losses and agricultural infrastructure damage, greatly impacting food security in both developed and developing countries (Brody, Highfield and Blessing, 2015). This type of situation is becoming more common in Malawi, and assessing damage to irrigation infrastructure in the country's southern region is typically difficult due to limited information and difficulties mobilizing timely expertise and resources to identify critical areas for rapid intervention.

In this context, the Geospatial Unit at the Land and Water Division (NSL) of the Food and Agriculture Organization of the United Nations has been actively providing support in collaboration with regional and national partners to assess the impacts of extreme events, natural disasters and conflicts using innovative geospatial technologies.

In the case of Malawi, the main aim of this assessment is to appraise the impacts of flooding on irrigation infrastructures for the period 1 January 2022 to 31 March 2022 by using remote sensing/GIS and field data. A list of common irrigation infrastructures is given in Box A.

The objectives of the assessment are to:

- Assess the flood extent in the impacted areas within the irrigation perimeters;
- Assess the damage to the irrigation perimeters;
- Assess the impacted cropland area within the irrigation perimeters to inform implementation of early recovery plans to be implemented by the Ministry of Agriculture and its partners in the coming months.

2 Methodology

The following methodological steps were implemented to provide results for this geospatial assessment of the impact of floods on the irrigation infrastructure in the specific area of interest (AOI).

2.1 Delineation of area of interest

The AOI was selected based on five-day Visible Infrared Imaging Radiometer Suite (VIIRS) data on flood extent and Ministry of Agriculture (MoA) data on damages to irrigation infrastructures. The AOI selection aimed to prioritise the assessment of areas where floods had mostly impacted cropland land and irrigation infrastructure. The Second Administrative Level Boundaries (SALB) at the district level were used to define the AOI. The extension planning area boundary (EPA) was obtained from the Malawi Spatial Data Platform - MASDAP [1] to extract zonal statistics. The boundary was modified to fit with the SALB [2] district boundary.

2.2 Mapping of flood extent

A flood extent map was prepared using the Sentinel 1 Synthetic Aperture Radar (SAR) data for the period from 1 January 2022 to 31 March 2022. The water-body was extracted after applying the Edge Otsu algorithm to the individual data. Sentinel 2 optical data was used to verify the presence of new water-bodies. Seasonal water bodies (presence of water for more than six months) were removed using the Joint Research Centre (JRC) long-term water body seasonality dataset. The data was further filtered using a slope map derived from the SRTM digital elevation model (DEM) to remove the SAR shadow areas (Kropatsch and Strobl, 1990). This method is unable to detect flash flood impacted areas.

To map potential flash flood locations, a contributing area (flow accumulation) map and a slope map were created using the SRTM DEM (http://www2.jpl.nasa.gov/srtm).

2.3 Mapping of cropland

A 10-metre crop mask was prepared using the monthly composite of Sentinel 1, Sentinel 2 and Planet data for the period from June 2021 to May 2022. Three thousand training points were collected using the Collect Earth Online[3] platform. A random forest machine learning model was setup using the training data to classify the satellite images into crop and non-crop areas.

[1] http://www.masdap.mw
[2] https://www.unsalb.org
[3] https://collect.earth/

2.4 Labelling of irrigated and non-irrigated cropland

Crop phenology based on the Moderate Resolution Imaging Spectroradiometer (MODIS 16-day) Enhanced Vegetation Index (EVI) and the water deficit index (WDI) (Equation 1) were used to label the irrigated and non-irrigated cropland as data on irrigated areas was not available. Three different crop seasons were detected based on the crop phenology information (start and end of season). The Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) V2 and the FAO Water Productivity Open-Access evapotranspiration and interception indicator - WaPOR ETIa (250 m resolution) data were used to determine the water deficit index (WDI) as follows:

$$WDI = \frac{\sum_{SoS-1}^{EoS} P}{\sum_{SoS}^{EoS} ETI} \quad (1)$$

Where, SoS refers to start of season, EoS refers to end of season, P stands for precipitation and ETI is the evapotranspiration and interception.

$WDI \leq 0.99$ was considered as irrigated cropland. Due to the coarser spatial resolution of WDI (250 m), this method does not capture small and isolated irrigated areas of less than six hectares in size.

2.5 Assessment of impacts

The irrigated cropland data and flood extent data were overlaid to delineate the flooded cropland. The EPA, district boundaries and hexagons were used to extract the statistics for the subsequent analysis.

The contributing area and slope map at the hexagonal level for the irrigated areas were used to identify irrigated areas with a high risk of flooding, including flash flooding.

3 Results

3.1 Area of Interest

Figure 1 shows the area of interest with district and EPA boundaries. Twenty three impacted districts in the central and southern provinces were selected. The EPAs are the third level structural units for the governmental extension system. There are 144 EPAs spread across 22 selected districts.

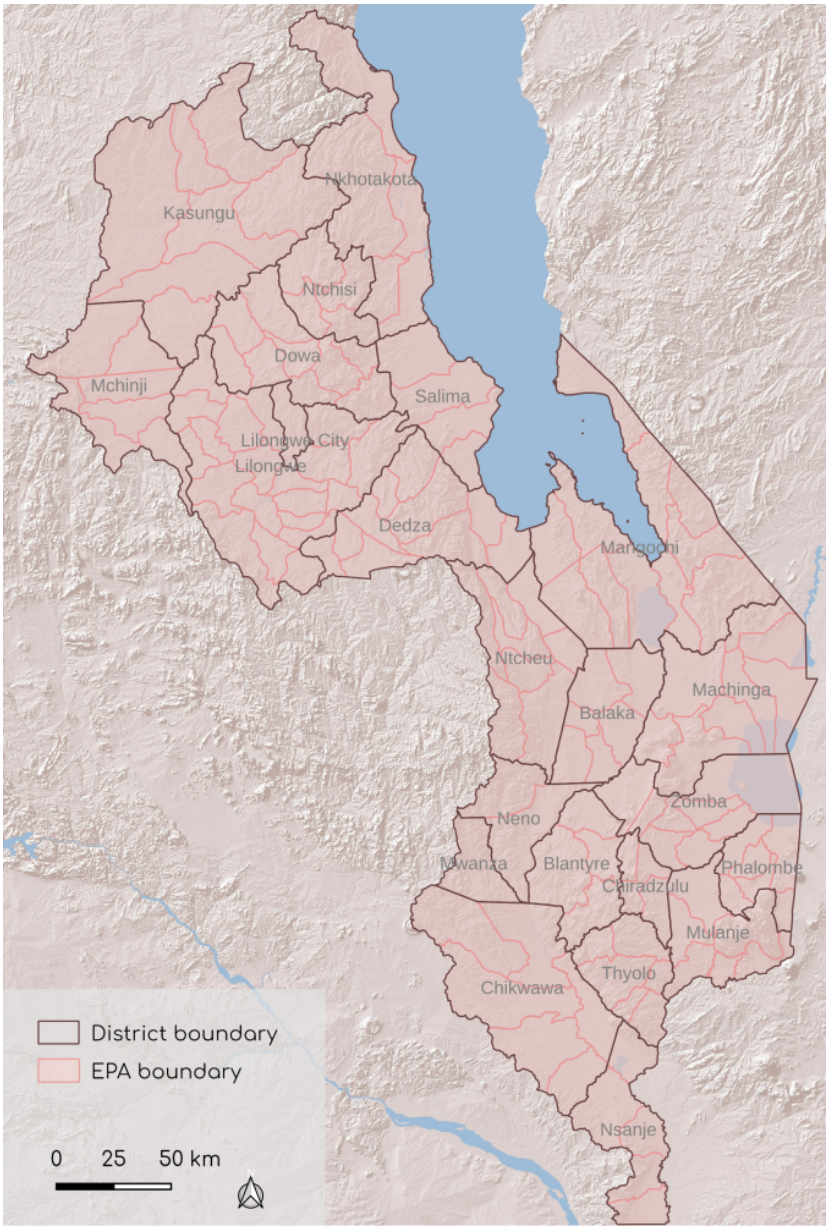


Figure 1: Area of interest

Source: District boundary: UNSALB, EPA boundary: MASDAP (Accessed 2 May 2022). Map conforms to UN (2020)

3.2 Flood extent

Figures 2 and 3 show the inundated areas during the period from 1 January 2022 to 31 March 2022. In terms of the flooded area, Chikwawa was the most impacted district with 37 557 ha of flooded area, followed by Nsanje with 33 558 ha of flooded area. Figure 3 shows the flooded areas by EPAs.

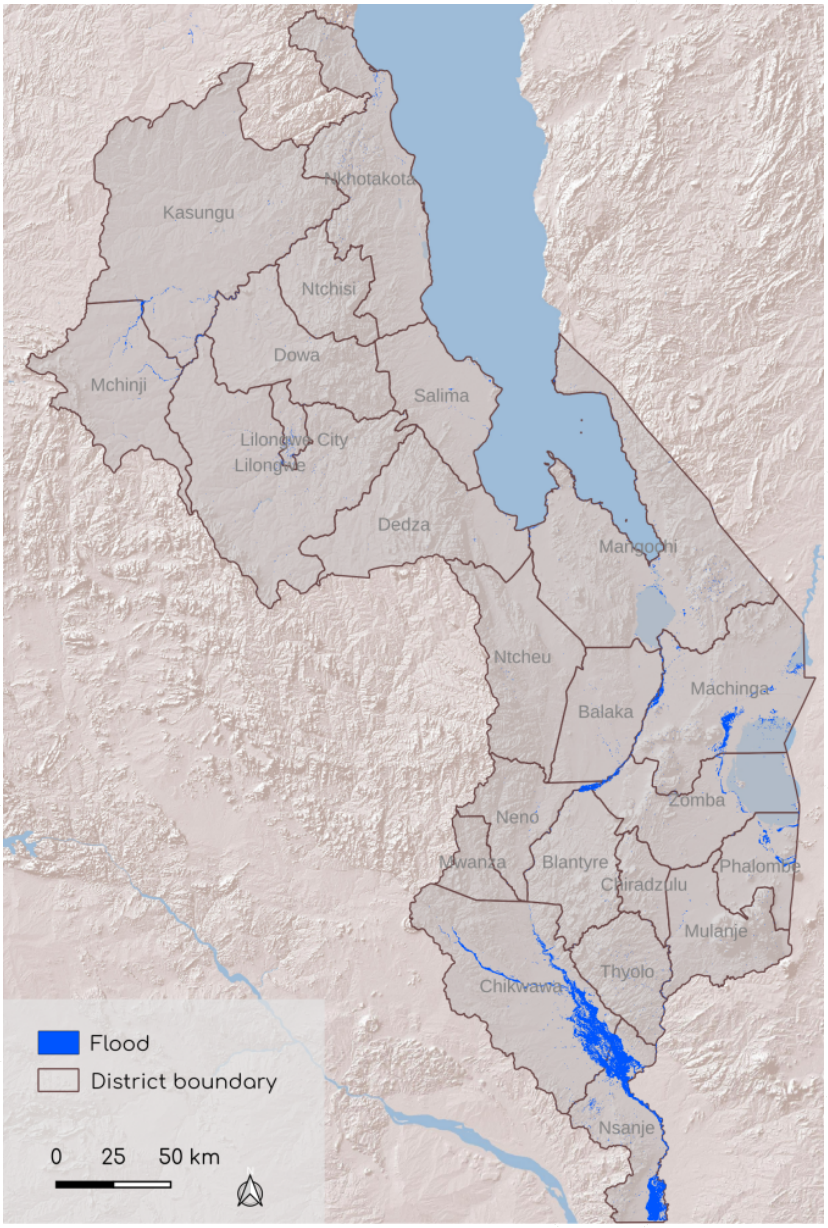


Figure 2: Flooded areas during the period of from 1 January to 31 March 2022 in the selected districts.

Source: District boundary: UNSALB, EPA boundary: MASDAP (Accessed 2 May 2022). Map conforms to UN (2020)

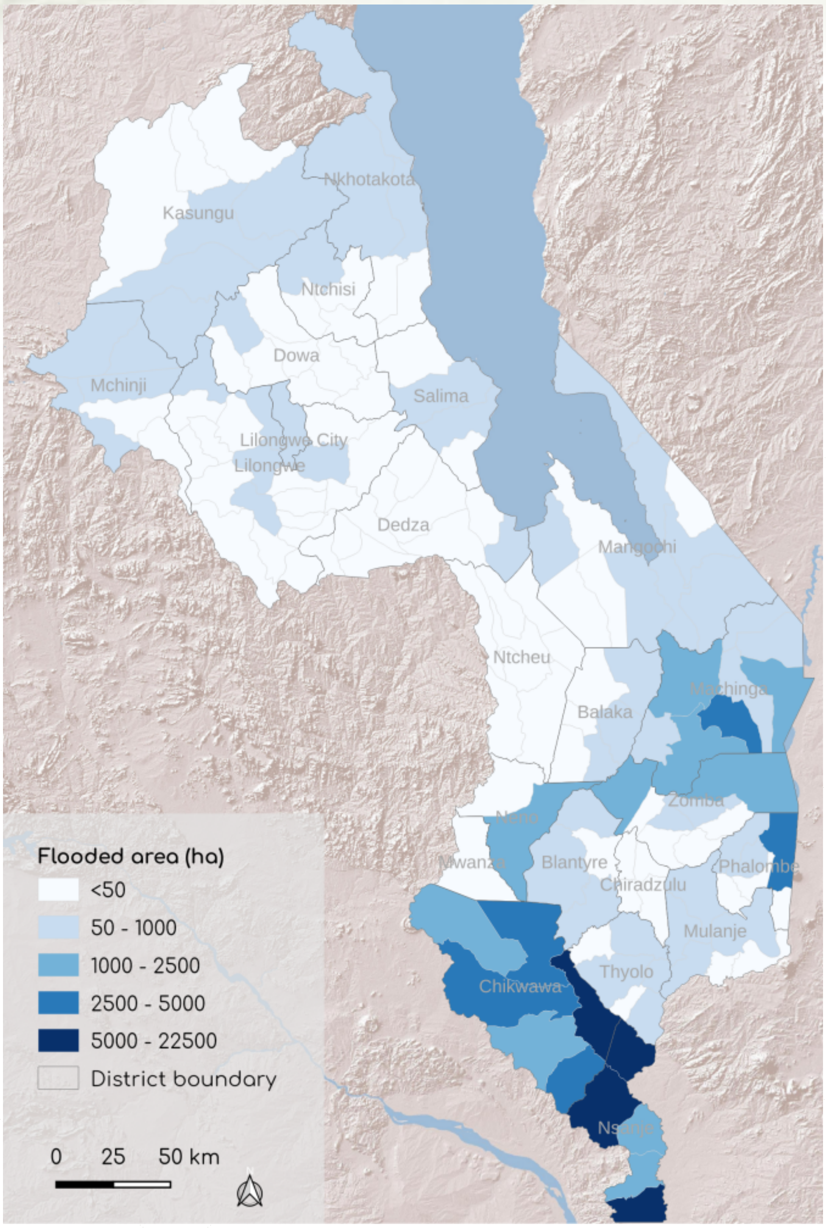


Figure 3: Flooded area by extension planning areas

Source: District boundary: UNSALB, EPA boundary: MASDAP (Accessed 2 May 2022). Map conforms to UN (2020)

3.3 Cropland mask

Figure 4 shows the extent of cropland prepared using Sentinel 2, Sentinel 1 and Norway's International Climate & Forests Initiative (NICFI) planet data for the selected districts. Croplands are almost equally distributed in the area of interest. A high proportion of the cropland area is located in the flat areas in the northern part of the AOI. For example, cropland as a percentage of total land is 66 percent in Mulanje, 64 percent in Mchinji, and around 60 percent in Lilongwe. Details of the cropland area distribution are reported in Table 1 and Annex C/ A-2.

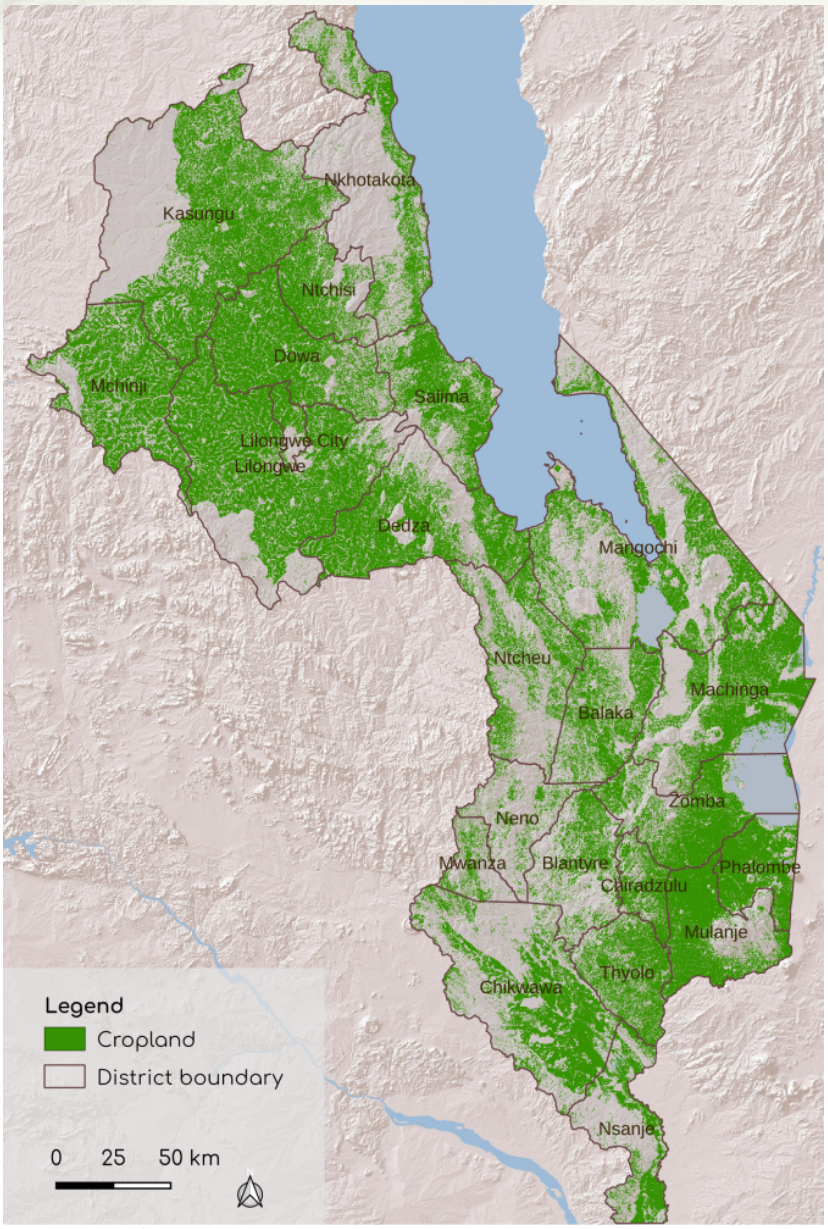


Figure 4: Cropland area in the area of interest in Malawi in 2022

Source: District boundary: UNSALB, EPA boundary: MASDAP (Accessed 2 May 2022). Map conforms to UN (2020)

3.4 Irrigation schemes

Most of the irrigated land is in the southern part of the area of interest, particularly in the flat areas in the districts of Nsanje (21 638 ha, 29.3 percent), Chikwawa (37 345 ha, 18.4 percent) and Thyolo (6 543 ha, 6.1 percent). Figure 5 shows the distribution of irrigated land by extension planning area (EPA). The presence of small isolated irrigated areas of less than six hectares in some of the EPAs was not detected. Figure A-1 presents the location and extent of irrigated cropland in the area of interest. Details of the distribution are reported in Table 1 and Annex C/ A-2.

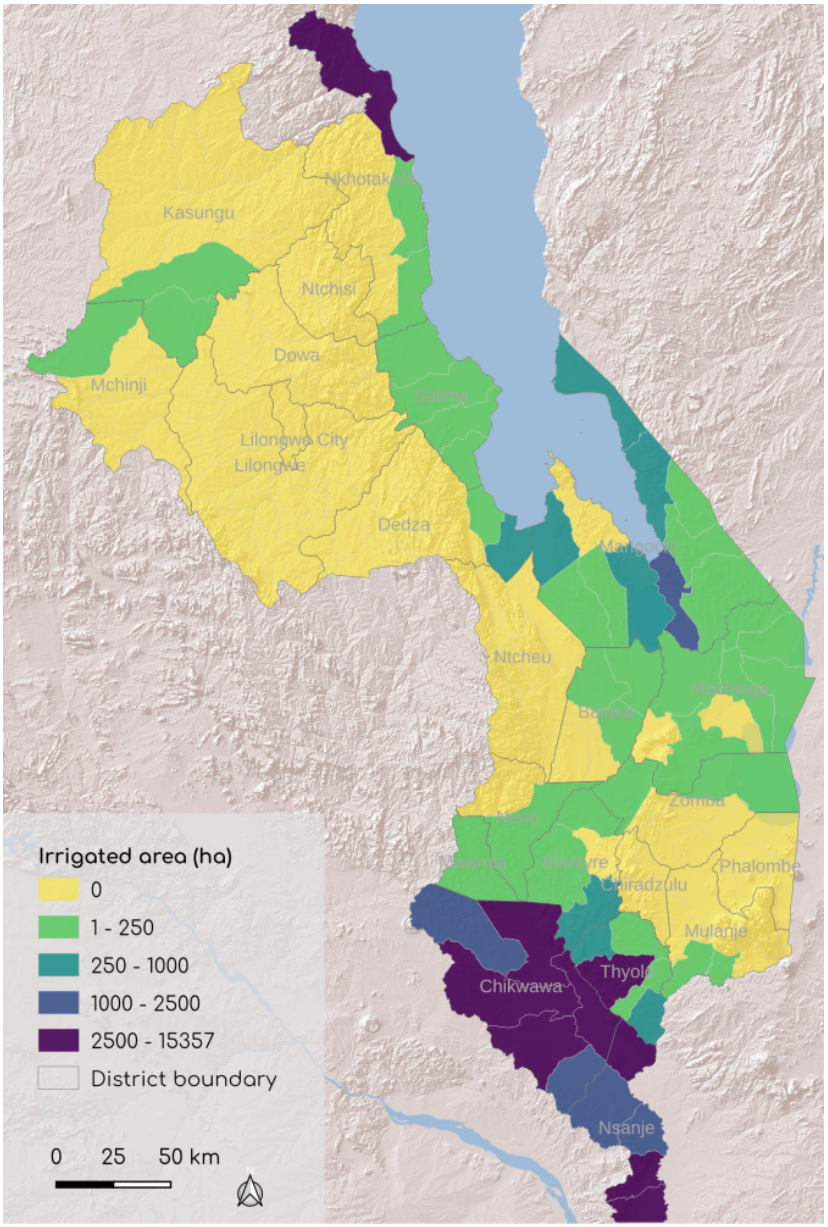


Figure 5: Distribution of irrigated area by extension planning area from Jan to March 2022 (Minimum mapping unit: 6 ha)

Source: District boundary: UNSALB, EPA boundary: MASDAP (Accessed 2 May 2022). Map conforms to UN (2020)

Table 1: Distribution of cropland area, irrigated area, flooded area and impacted irrigated cropland area by districts in Malawi during the period January-March 2022

District	Admin area [ha]	Cropland area [ha]	Irrigated area [ha]	Cropland irrigated [%]	Flooded area [ha]	Impacted irrigated cropland [ha]
Balaka	214 985		238	0	1 395	2
Blantyre	201 814	71 548	931	1	920	25
Chikwawa	490 296	202 802	37 345	18	37 557	15 103
Chiradzulu	75 389	48 787	0	0	56	0
Dedza	355 673	205 578	366	0	204	12
Dowa	299 981	213 797	0	0	237	0
Kasungu	808 469	377 246	61	0	1 535	24
Lilongwe	653 375	401 658	0	0	1 586	0
Machinga	425 796	219 027	208	0	11 771	15
Mangochi	668 915	201 321	4 686	2	2 671	110
Mchinji	315 378	204 632	3	0	1 953	0
Mulanje	210 334	139 431	33	0	505	0
Mwanza	74 854	22 031	6	0	11	0
Neno	157 245	29 444	63	0	1 143	48
Nkhotakota	439 369	111 381	3 846	3	1 292	93
Nsanje	198 178	73 941	21 638	29	33 558	12 960
Ntcheu	311 717	113 368	0	0	118	0
Ntchisi	160 565	88 452	0	0	71	0
Phalombe	134 196	102 585	0	0	3 188	0
Salima	225 784	132 451	256	0	392	3
Thyolo	163 501	107 343	6542	6	1 019	91
Zomba	279 007	123 049	249	0	3 355	28
Total	**6 864 831**	**3 300 463**	**76 479**	**2**	**104 547**	**28 521**

3.5 Assessment of damages to irrigated cropland

The geodesic grid (ISEA3H hexagons - resolution: 14, area: 10.63 km^2) was used to accumulate the statistics and to assess the impacts at the hexagonal level. Figure 6 shows the distribution of flooded areas at the hexagonal levels.Chikwawa and Nsanje are two of the hardest hit districts. The majority of the irrigated croplands are located in the Chikwawa (18 percent), Nsanje (29 percent) and Thyolo (6 percent) districts (Figure 7).

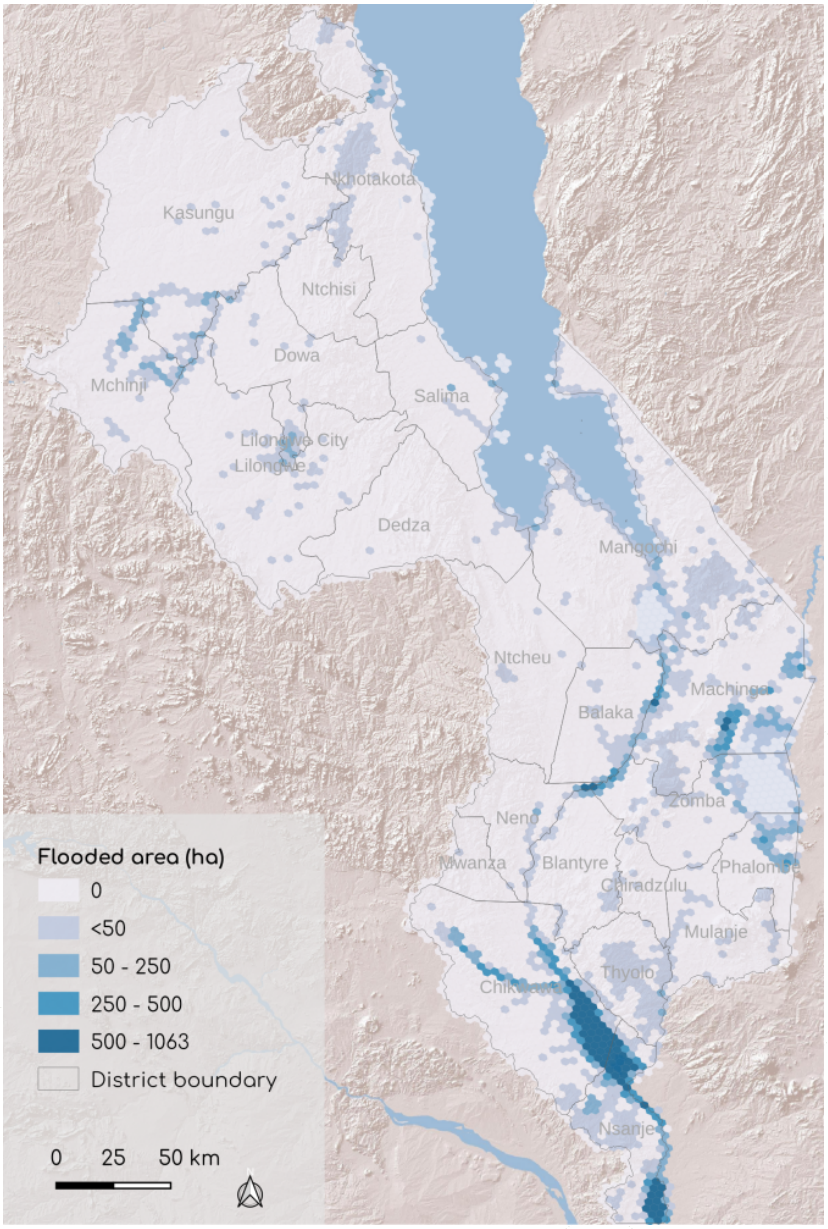


Figure 6: Distribution of flooded area during the period of from 1 January to 31 March 2022

Source: District boundary: UNSALB, EPA boundary: MASDAP (Accessed 2 May 2022). Map conforms to UN (2020)

Therefore, the irrigated cropland and infrastructure are vulnerable to flooding as most of the flooded areas are also located in these districts. An overlay analysis was carried out to identify the location where flood and irrigated cropland coincide. Chikwawa and Nsanje are the most affected districts

in terms of inundated cropland area. Most of the inundated cropland areas are located across the Shire River flood plain in the districts of Chikwawa and Nsanje. The topsoil deposition that was eroded due to inundation may damage critical irrigation infrastructure in these areas.

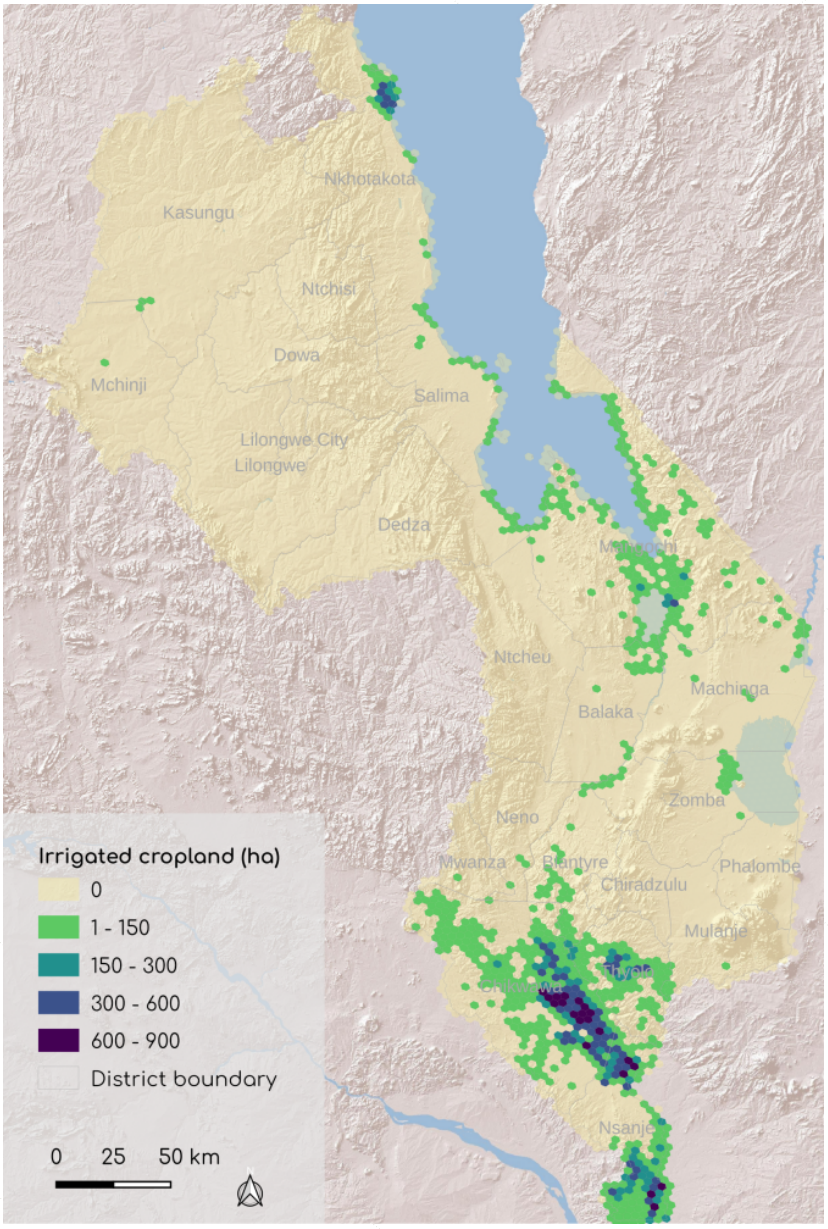


Figure 7: Distribution of irrigated cropland in the selected area of interest in 2022

Source: District boundary: UNSALB, EPA boundary: MASDAP (Accessed 2 May 2022). Map conforms to UN (2020)

3.5.1 Impacted Irrigated cropland

The Southern region is the most affected, as it contains approximately 94 percent irrigated croplands. An important proportion of the areas affected are in Chikwawa and Nsanje districts (Figure 8). The irrigated croplands in the Thyolo district are not located in the floodplain. Hence, they

are not vulnerable to the flash flood inundation. The irrigation infrastructure developed in the highlighted impacted areas can be considered vulnerable to floods. The type of infrastructure was identified using the geographic location and slope profiles of the analyzed areas.

Most of the pivot irrigation systems located in the flat region are also impacted by flood water. However, it was not possible to account for the impacts of flash floods with the information available for the assessment.

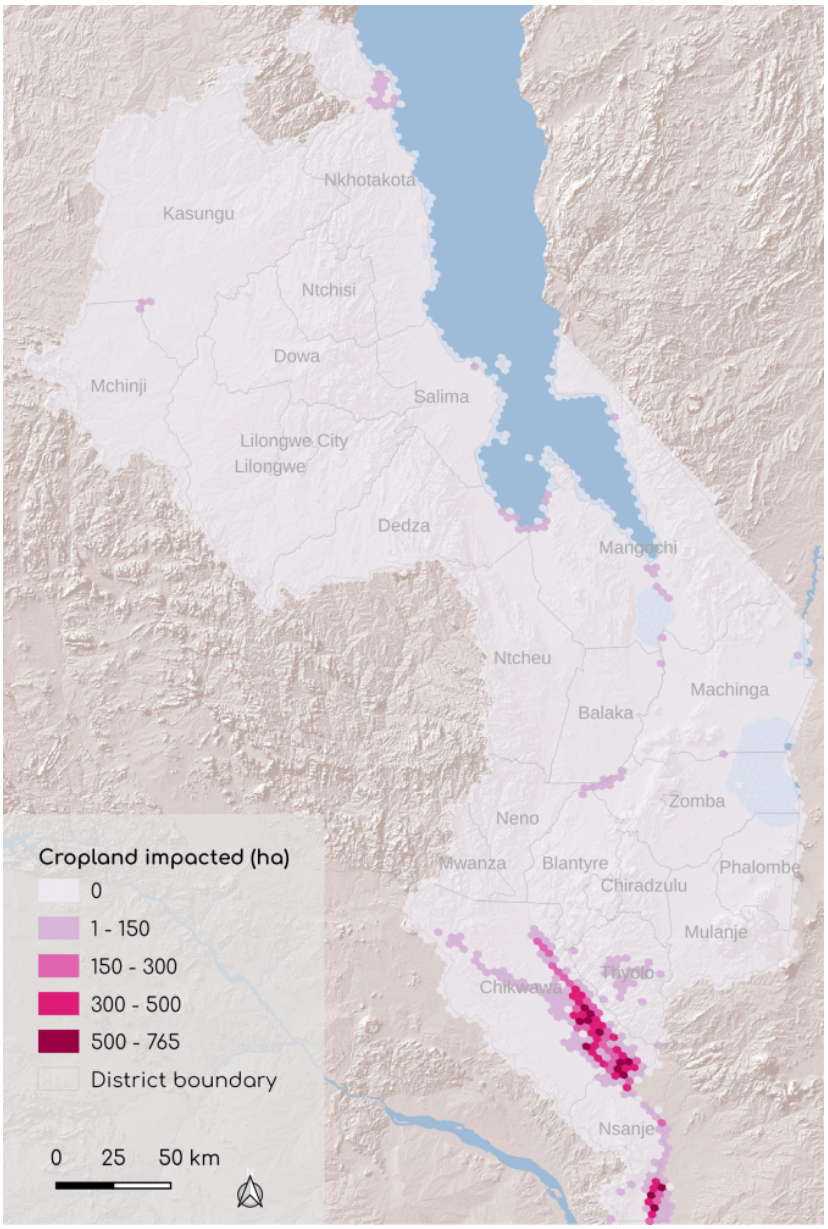


Figure 8: Distribution of flood impacted cropland areas for the period of from January to March 2022

Source: District boundary: UNSALB, EPA boundary: MASDAP (Accessed 2 May 2022). Map conforms to UN (2020)

3.5.2 Impacts of flash flood

The presence of flash floods cannot be directly detected using satellite images. Therefore, contributing area and slope maps were prepared to locate the irrigated cropland areas impacted by the flash flood. The contributing area is the accumulated surface area that contributes run-off to the target locations. A high contributing area with a low slope represents flood prone areas, whereas a high contributing area with a gentle to steep slope is prone to flash floods. The details of which are given in the following sections.

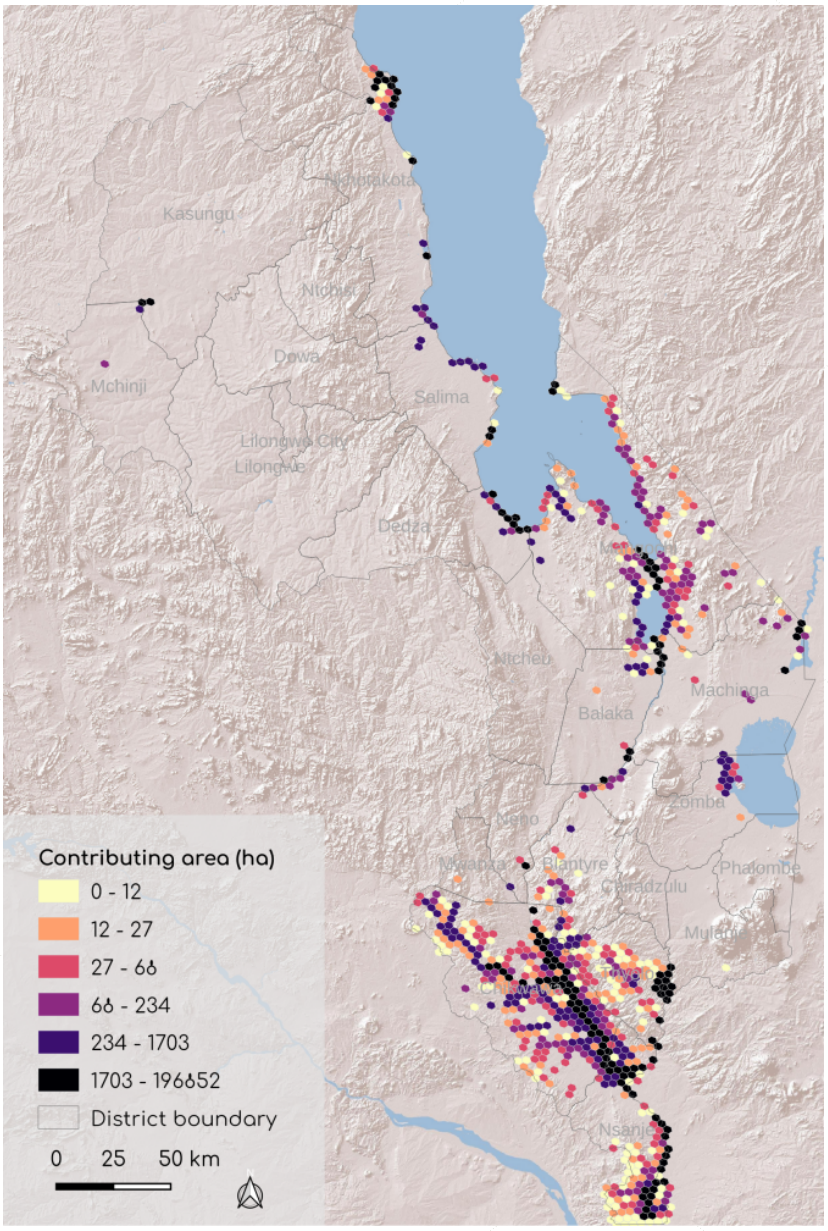


Figure 9: Distribution of contributing area over the irrigated cropland

Source: District boundary: UNSALB, EPA boundary: MASDAP (Accessed 2 May 2022). Map conforms to UN (2020)

Contributing area Figure 9 shows the contributing area over the irrigated cropland. To delineate the presence (potential) of flash floods, this data was further divided into three classes (50 ha-low, 50 to 1000 ha-medium, and > 1000 ha-high). Areas with a low contributing area cannot be considered flooded as they do not receive enough run-off to cause any kind of flooding.

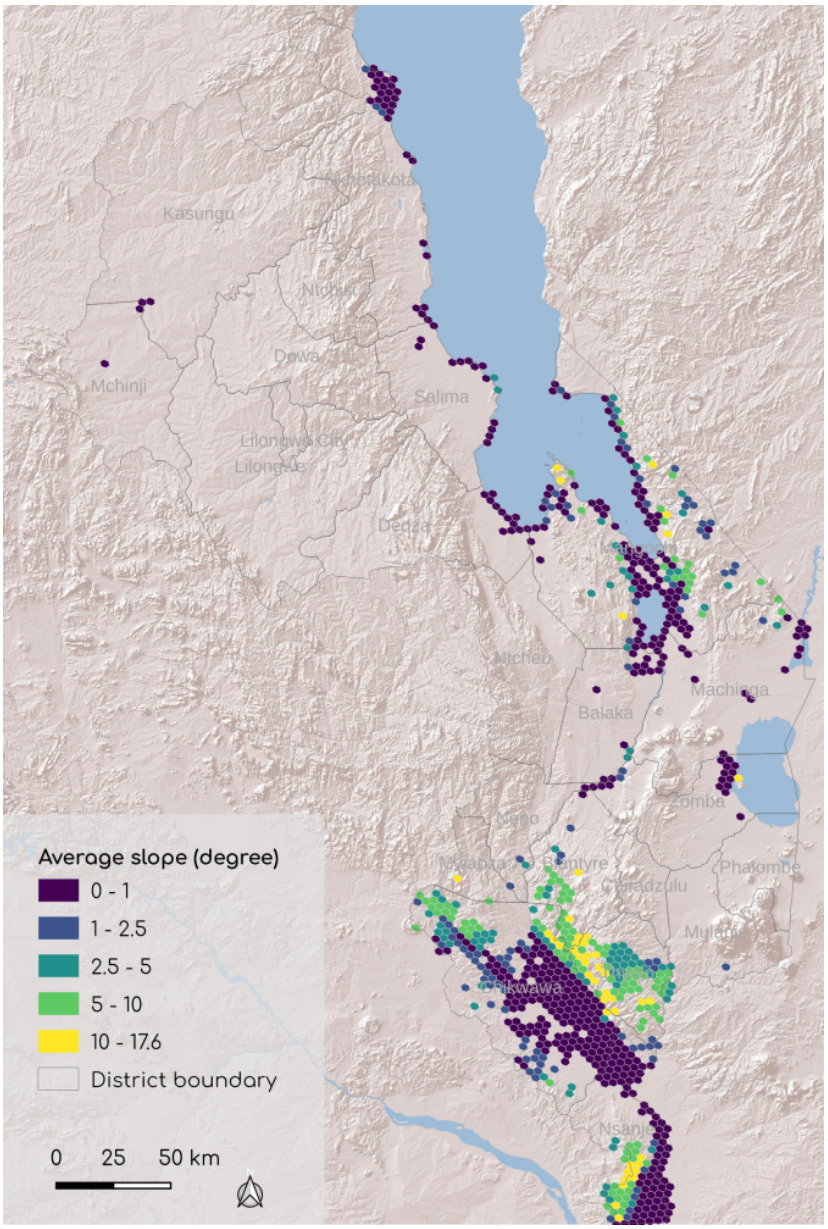


Figure 10: Distribution of average slope over the irrigated cropland

Source: District boundary: UNSALB. Map conforms to UN (2020)

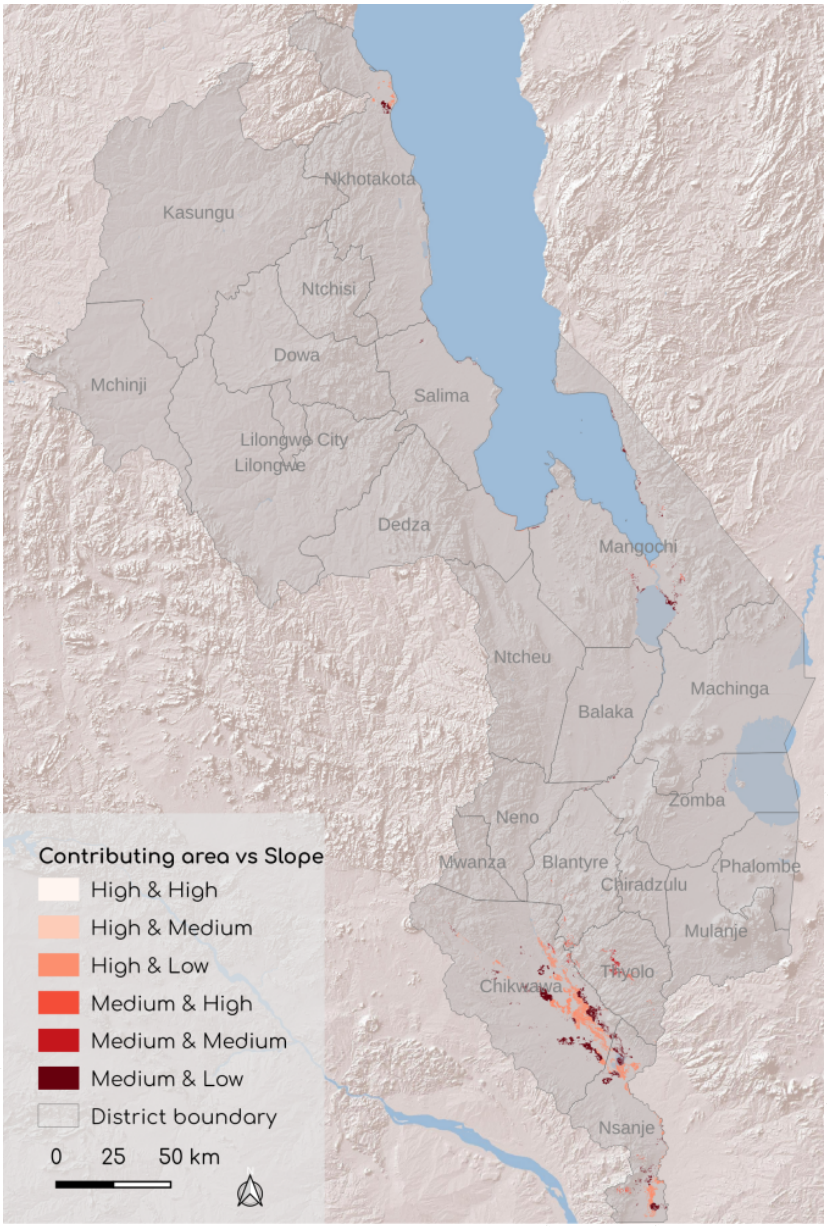
Average slope The slope derived from the SRTM elevation data was averaged at the hexagonal level (Figure 10). To delineate the presence (potential) of flash floods, the map was reclassified into three classes (2 degrees - low; 2 to 5 degrees - medium; > 5 degrees - high). Areas with a flat to low slope decrease the discharge rate of surface run-off. Therefore, flat areas with high contributing

areas can cause flooding. Areas with a gentle to steep slope can increase the discharge rate of surface run-off. Therefore, areas with gentle to steep slopes and a high contributing area can cause severe damage to crops, including topsoil erosion and damage to irrigation infrastructure.

Slope \ Contributing area	Low	Medium	High
Low	-	-	-
Medium	-	Medium	High
High	-	High	Very high

Figure 11: Plausible flash flooding areas as a relation between slope and contributing area

Potential location of flash floods A database of proxy information that indicates potential locations of flash floods in the region was prepared. It combines the contributing area classes (medium and high) and average slope classes into an indicator (Figure 11). Figure 12 presents the combination of medium and high contributing areas with three slope classes. Irrigated cropland in medium to high slope classes can be considered impacted by flash floods. Gravity-fed irrigation systems may be more at risk than other irrigation schemes because of the exposure to overland flow with a high discharge rate. From the database, gravity-fed irrigation systems are prevalent in this area, most of which are in the Thyolo district. Details of the flash flooded area by EPA are provided in Annex C/ A-3.



Source: District boundary: UNSALB. Map conforms to UN (2020)

Figure 12: Combination of contributing area classes (medium and high) and average slope classes

4 Conclusions and recommendations

This geospatial assessment of the impact of 2022 floods on irrigation infrastructure in Malawi provides critical information to inform recovery plans set by the Ministry of Agriculture to facilitate restoration and rapid rehabilitation of the infrastructure affected in the southern region of the country. Since a majority of the large-scale irrigation infrastructure in the country is there, mainly in Chikwawa and Nsanje districts, accurate information is required to inform rapid action and make decision-making processes easier.

The maps provided in this report, supported by remote sensing analysis, can facilitate the revision of priority areas for detailed assessment and intervention. In that case, resources mobilized for recovery can cover rehabilitation of irrigation schemes in the coming months, particularly with the aim of scaling up winter production in the Lower Shire Valley area as well as making more efficient targeting of scarce resources in the areas where more potential can be harnessed.

In the absence of geospatial boundaries for established irrigation schemes, the delineation of the possibly affected areas/infrastructure presented challenges and might compromise the accuracy of the results obtained. In addition, small-scale irrigated areas of less than six hectares in size were not prioritised nor captured by this analysis as location and boundary information obtained from secondary sources did not count with all the required parameters.

Another critical area that requires further discussion is the need to strengthen the technical capacity in GIS and remote sensing in Malawi, particularly for the Departments of Irrigation (DoI) and Agriculture Planning Services (DAPS). This may have the potential to better support planning and agricultural development, as well as to efficiently respond rapidly with the provision of accurate data in the aftermath of flash floods in areas strategic for agriculture production in the country.

Based on this geospatial assessment, some technical recommendations provided by the analysis could be summarized as follows:

- It is important to mobilize efforts from the Department of Irrigation and Department of Agriculture Planning Services (DAPS) to proceed with the delineation of irrigation schemes based on the remote sensing analysis from this assessment;
- Mobilize technical support from FAO and other partners to facilitate the sustainable development of a national geospatial database for irrigation schemes;
- Undertake field data collection to complement the national database with critical information related to farming systems, irrigation infrastructure, crop calendar and rotation, socio-economic and biophysical information;

- Upgrade the remote sensing analysis methodology used by the Department of Irrigation in Malawi, considering the inclusion of land cover, crop type, yield, crop, and water productivity data, among others;
- Support both DAPS, DoI and other line departments within the Ministry of Agriculture in Malawi to improve monitoring of the development of irrigation schemes and related agricultural development with priority indicators (e.g., land resources, soil quality, agricultural inputs, yield, productivity, etc.);
- Assess the vulnerability of agricultural activity and irrigation schemes to natural hazards in areas in which strategic infrastructure is being developed and enhance early warning and information systems for improved productivity;
- Develop innovative geospatial tools (including platforms and applications) to provide access to scheme-specific related information;
- Strengthen the DoI's technical capacity in data management, geographic information systems, remote sensing, and Earth Observation integration for irrigation scheme planning and monitoring.;
- Development of a national geospatial database for irrigation schemes and integration with the National Agriculture Management Information System (NAMIS) under the Ministry of Agriculture (MoA) and the Department of Irrigation;
- Support the development of monitoring systems for irrigation schemes and related agricultural development with priority indicators.

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Appendices

A Boxes

Box 1: Types of irrigation infrastructures

Gravity fed: Gravity fed, meaning gravity irrigation scheme - an irrigation scheme in which water is supplied to the agricultural land with the force of gravity.

Gravity weir diversion permanent: Headworks (e.g., weir) at the source (river or stream) is used to divert the source water towards the agricultural land and water flows by the force of gravity.

Gravity fed with solar pumping: Irrigation water is pumped from the source using a solar pump to a storage reservoir. From storage tanks to agricultural land, water flows by the force of gravity.

River diversion: Headworks (e.g., weir) at the source (river or stream) is used to divert the source water towards the agricultural land and water flows by the force of gravity.

Solar powered submersible pump: A solar-powered irrigation system, that is, water is lifted from the source to a higher elevation using a solar-powered pump - submersible pump is used for pumping groundwater while surface water is pumped using surface pumps.

Sprinkler/gravity:An irrigation scheme that employs both a gravity irrigation system and a sprinkler irrigation system.

Treadle pump: A human-powered suction pump is used to lift water from a shallow source of water to agricultural land.

B Figures

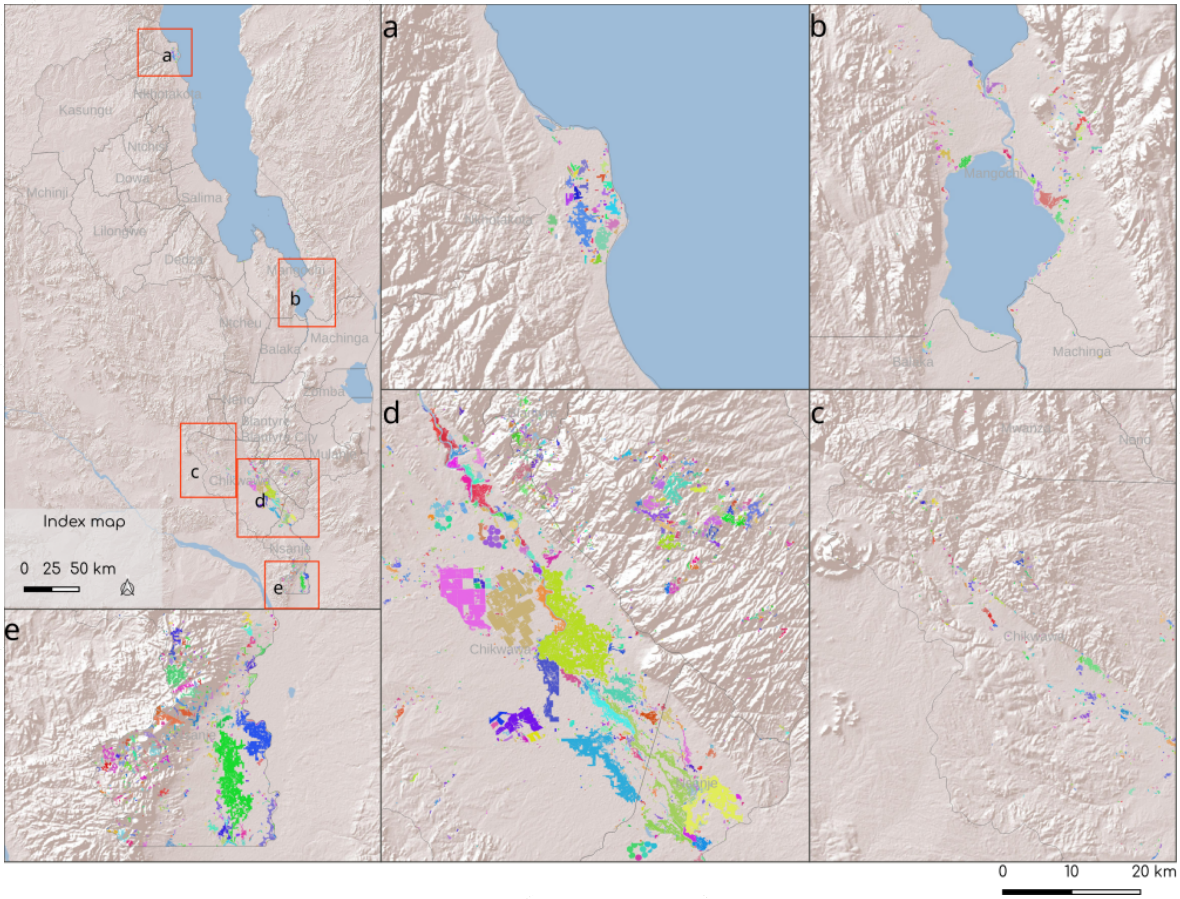

Figure A-1: Distinct irrigation schemes - different colours represent plausible discontinuities between schemes

C Tables

Table A-2: Distribution of cropland area, irrigated area, flooded area, irrigated cropland impacted and percentage of irrigated cropland

District	EPA	Admin area [ha]	Cropland area [ha]	Irrigated area [ha]	Irrigated area [%]	Flooded area [ha]	Irrigated area impacted [ha]
Balaka	Bazale	47 715	24 609	3	0	49	0
	Mgaza	15 836	10 686	0	0	14	0
	Mpilisi	37 683	19 736	41	0.2	295	0
	Phalula	35 963	13 234	0	0	0	0
	Ulongwe	54 507	27 952	195	0.7	459	2
	Utale	23 282	14 364	0	0	577	0
Blantyre	Chipande	30 516	17 516	0	0	17	0
	Kunthembwe	82 208	21 355	168	0.8	131	0
	Lirangwe	38 732	20 412	33	0.2	646	26
	Ntonda	50 359	12 266	731	6	126	0
Chikwawa	Dolo	43 071	25 022	1 522	6.1	3 280	1 232
	Kalambo	102 545	29 120	1 555	5.3	1 025	72
	Livunzu	52 606	33 291	15 357	46.1	22 458	10 439
	Mbewe	118 913	43 963	10 794	24.6	4 788	1 247
	Mikalango	81 902	44 133	3 391	7.7	1 933	549
	Mitole	91 260	27 273	4 725	17.3	4 074	1 564
Chiradzulu	Mbulumbuzi	16 825	7 937	0	0	31	0
	Mombezi	29 776	18 822	0	0	18	0
	Thumbwe	28 789	22 028	0	0	7	0
Dedza	Bembeke	54 010	23 047	0	0	36	0
	Chafumbwa	20 810	15 815	0	0	3	0
	Golomoti	36 865	28 210	293	1	113	11
	Kabwazi	20 539	16 619	0	0	2	0
	Kanyama	67 994	24 793	0	0	7	0
	Kaphuka	19 231	13 687	0	0	1	0
	Linthipe	28 159	23 670	0	0	6	0
	Lobi	33 048	26 872	0	0	11	0

	Mayani	44 700	12 449	0	0	2	0
	Mtakataka	30 317	20 417	73	0.4	25	1
Dowa	Bowe	55 887	45 294	0	0	40	0
	Chibvala	23 170	16 762	0	0	17	0
	Chisepo	35 718	29 565	0	0	21	0
	Madisi	36 587	30 133	0	0	117	0
	Mndolera	29 882	25 386	0	0	2	0
	Mponela	24 977	19 863	0	0	36	0
	Mvera	38 583	18 608	0	0	0	0
	Nachisaka	35 554	19 232	0	0	3	0
	Nalunga	19 623	8 954	0	0	0	0
Kasungu	Chamama	123 054	74 537	0	0	133	0
	Chulu	55 763	36 935	0	0	2	0
	Kaluluma	111 147	64 239	0	0	13	0
	Kasungu Game Reserve	231 279	3 571	0	0	11	0
	Kasungu/Chip	106 859	79 697	0	0	72	0
	Lisasadzi	105 452	62 808	19	0	329	12
	Santhe	74 915	55 460	42	0.1	976	12
Lilongwe	Chilaza	21 052	17 250	0	0	1	0
	Chileka	19 746	15 279	0	0	0	0
	Chimutu	40 143	28 385	0	0	17	0
	Chitekwele	58 630	23 263	0	0	13	0
	Chitsime	18 623	14 436	0	0	34	0
	Demela	30 078	23 187	0	0	0	0
	Dzalanyama forest	93 579	3 405	0	0	47	0
	Kalumba	16 925	14 235	0	0	12	0
	Kambanizithe	26 605	19 800	0	0	20	0
	Mingongo	40 780	31 350	0	0	23	0
	Mitundu	13 137	10 206	0	0	8	0
	Mlomba	17 618	14 413	0	0	2	0
	Mngwangwa	28 340	22 523	0	0	97	0

	Mpenu	36 769	24 133	0	0	53	0
	Nakachoka	23 408	18 310	0	0	29	0
	Nthondo	36 397	29 446	0	0	251	0
	Sinyala	26 847	19 921	0	0	87	0
	Thiwi	28 981	20 501	0	0	212	0
	Ukwe	37 510	30 031	0	0	46	0
Lilongwe	Chingoti	38 210	21 584	0	0	635	0
Machinga	Chikweo	48 751	35 097	113	0.3	485	14
	Malosa	74 054	29 434	2	0	1 720	1
	Mbonechera	83 183	24 707	75	0.3	2 433	1
	Mtubwi	34 824	10 188	0	0	585	0
	Nampeya	62 622	39 485	4	0	1 546	0
	Nanyumbu	47 654	32 488	3	0	898	0
	Nsanama	40 492	27 054	0	0	4 041	0
	Nyambi	34 217	20 575	11	0.1	63	0
Mangochi	Chiripa	68 835	22 151	2	0	27	0
	Katuli	41 205	20 177	47	0.2	23	0
	Lungwena	56 950	13 949	786	5.6	126	1
	Maiwa	44 324	26 239	1 992	7.6	797	59
	Masuku	101 256	36 651	95	0.3	820	0
	Mbwadzulu	60 723	2	0	0	0	0
	Mpilipili	61 819	13 787	420	3	229	6
	Mthilamanja	49 387	9 982	9	0.1	3	0
	Mtiya	50 554	17 068	15	0.1	51	0
	Nankumba	55 993	22 313	319	1.4	262	25
	Nansenga	77 870	19 002	1 000	5.3	333	18
Mchinji	Chiwosya	45 407	31 237	0	0	21	0
	Kalulu	43 516	31 225	0	0	653	0
	Mchinji	44 872	25 133	0	0	60	0
	Mikundi	51 009	38 879	0	0	423	0
	Mkanda	92 764	53 211	4	0	792	0
	Msitu	37 810	24 947	0	0	5	0
	Kamwendo	50 682	48 060	0	0	62	0
	Milonde	25 230	16 372	0	0	19	0

Mulanje	Msikawanjala	28 434	25 140	25	0.1	122	0
	Mulanje	14 035	10 904	9	0.1	14	0
	Mulanje Mountain	58 035	9 011	0	0	127	0
	Thuchila	33 920	29 945	0	0	161	0
Mwanza	Mwanza	74 854	22 031	7	0	12	0
Neno	Lisungwe	95 169	20 410	64	0.3	1 124	48
	Neno	62 077	9 034	0	0	19	0
Nkhotakota	Linga	53 215	25 349	10	0	73	0
	Mwansambo	38 542	12 906	0	0	0	0
	Nkhotakota Game Reserve	181 907	3 288	0	0	557	0
	Nkhunga	116 387	45 779	3 800	8.3	656	94
	Zidyana	49 318	24 060	36	0.2	7	0
Nsanje	Magoti	66 286	14 968	1 954	13.1	5 996	1 335
	Makhanga	36 607	17 701	6 277	35.5	13 526	5 532
	Mpatsa	34 266	9 855	1 300	13.2	1 714	560
	Nyachirenga	31 304	17 937	6 253	34.9	10 045	4 485
	Zunde	29 715	13 481	5 855	43.4	2 277	1 049
Ntcheu	Bilila	24 781	15 775	0	0	17	0
	Kandeu	31 129	7 412	0	0	2	0
	Manjawila	74 437	16 109	0	0	3	0
	Mphepozinayi	26 792	10 698	0	0	1	0
	Njolomole	38 921	11 067	0	0	36	0
	Nsipe	30 582	10 140	0	0	36	0
	Sharpe Valley	36 741	22 647	0	0	8	0
	Tsangano	48 334	19 519	0	0	14	0
Ntchisi	Chikwatula	42 320	13 985	0	0	6	0
	Chiphuka	26 952	22 863	0	0	11	0
	Kalire	30 789	14 278	0	0	0	0
	Malomo	60 505	37 326	0	0	55	0
	Kasonga	19 290	17 123	0	0	274	0

Phalombe	Mpinda	41 703	24 247	0	0	2 679	0
	Naminjiwa	14 201	11 659	0	0	17	0
	Nkhulambe	14 311	12 349	0	0	7	0
	Tamani	27 719	23 224	0	0	211	0
	Waruma	16 971	13 984	0	0	1	0
Salima	Chingulube	77 405	46 743	110	0.2	235	3
	Chopoka	30 121	16 680	8	0.1	9	0
	Khombedza	69 470	43 389	103	0.2	13	0
	Tembwe	48 789	25 640	36	0.1	136	1
Thyolo	Khonjeni	13 372	10 336	248	2.4	204	5
	Masambanjat	11 613	7 562	16	0.2	19	0
	Matapwata	37 688	26 832	214	0.8	125	1
	Nkaombe	22 690	9 898	683	6.9	45	3
	Thekerani	28 053	20 331	295	1.5	317	4
	Thyolo	50 086	32 385	5 086	15.7	310	79
Zomba	Chingale	51 055	24 160	110	0.5	1 632	27
	Dzaone	24 808	17 363	0	0	14	0
	Mpokwa	23 849	18 650	0	0	152	0
	Msondole	101 168	25 629	139	0.5	1 389	1
	NA	36 763	6 674	0	0	38	0
	Ngwelero	24 049	22 621	0	0	22	0
	Thondwe	17 316	7 954	0	0	108	0

Table A-3: Distribution area (in ha) of composition of contributing area and average slope (CA=contributing area, S=Slope)

District	EPA	High CA & Low S	Medium CA & Low S	High CA & Medium S	High CA & High S	Medium CA & Medium S
Balaka	Mpilisi	0	0	36.7	0	0
	Ulongwe	24.9	33.8	0	0	0
Blantyre	Lirangwe	0	32.8	0	0	0
Chikwawa	Dolo	457	1 024.0	0	0	1.8
	Kalambo	504	233.5	16.8	0	41.3
	Livunzu	9 433.7	4 176.6	0	0	173.7
	Mbewe	4 249.6	2 476.1	42.1	0	0
	Mikalango	230.2	1 971.5	0	0	0
	Mitole	2 629.5	843.1	93.3	0	152.1
Dedza	Golomoti	290.7	2.3	0	0	0
	Mtakataka	25.8	47	0	0	0
Kasungu	Lisasadzi	18.9	0	0	0	0
	Santhe	42.3	0	0	0	0
Machinga	Chikweo	66.9	22.4	0	0	4.6
	Malosa	0	2.5	0	0	0
	Mbonechera	18.1	0	0	0	0
	Nampeya	4.3	0	0	0	0
	Nanyumbu	0	3.2	0	0	0
	Nyambi	0	0	0	0	2.1
Mangochi	Katuli	0	8.4	0	0	0
	Lungwena	0	448.6	0	0	0
	Maiwa	203.4	1 238.0	0	0	36.1
	Masuku	0	6.4	0	0	8.2
	Mbwadzulu	0	90.8	0	0	4.4
	Mpilipili	48.7	170.3	0	0	0
	Mtiya	0	0	0	0	0
	Nankumba	55.3	170.1	0	0	0
	Nansenga	226.6	436.7	0	0	86.8
Mchinji	Mkanda	0	3.6	0	0	0
Mulanje	Msikawanjala	0	0	11.3	13.3	0

Neno	Lisungwe	2.8	46.2	7.4	0	0
Nkhotakota	Linga	10.4	0	0	0	0
	Nkhunga	1 166.4	914.4	0	0	0
	Zidyana	25.6	10.8	0	0	0
Nsanje	Magoti	765.6	1 077.0	0	0	2.8
	Makhanga	2 774.5	1 760.9	0	0	0
	Mpatsa	481.3	154	0	0	0
	Nyachirenga	2 350.7	951.2	0	0	0
	Zunde	986.1	842.6	0	0	0
Salima	Chingulube	0	106.3	0	0	0
	Chopoka	0	0	0	0	0
	Khombedza	0	102.9	0	0	0
	Tembwe	12.6	0	0	0	0
Thyolo	Khonjeni	0	0	4.5	191.2	0
	Matapwata	0	0	0	0	41.4
	Nkaombe	0	0	0	0	144.3
	Thekerani	19.4	0	20.7	5	0
	Thyolo	0	0	0	0	1 075.6
Zomba	Chingale	2.6	101.9	0	0	0
	Msondole	0	133.5	0	0	0

A geospatial assessment of the impact of flood in support to the restoration of irrigation schemes in **Malawi**

The southern and central provinces in Malawi are vulnerable to extreme weather events such as floods and droughts. Over 75 percent of the irrigated land in the Southern region of the country is located in Nsanje and Chikwawa districts. In early 2022, the region has been impacted by various extreme events such as tropical Storm Ana in January 2022, followed by Tropical Cyclone Gombe in March 2022. The tropical cyclones and storms caused strong winds and heavy flash flooding event in several districts and urban centres, impacting irrigated land and productive infrastructure.

In this context, the Geospatial Unit at the Land and Water Division (NSL) of the Food and Agriculture Organization of the United Nations provided technical assistance to the Government of Malawi to assess the impacts of 2022 tropical storms and cyclones on irrigated land and infrastructure using innovative geospatial technologies.

In close collaboration with the Department of Irrigation and using remote sensing techniques as well as available national datasets on irrigated land and infrastructure, irrigated land area was characterized. Likewise, inundated irrigated land area was assessed, potential pluvial, fluvial and flash flood impacted areas were analyzed. The results were mapped and provided in tabular format for easy reference of national and district-level authorities. According to the results, most of the impacted irrigated areas, that require technical assistance and perhaps further assessments and interventions, are located in the Chikwawa (15 103 ha) and Nsanje (12 960 ha) districts.

Geospatial technologies offer opportunities in support to sustainable and resilient irrigated land management. Beyond the remote sensing analysis availed, this assessment highlights the relevance of establish a national geospatial database and monitoring platform for irrigated land, infrastructure and schemes management and resilient actions towards increasing frequency of extreme events.

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