Part 1 Questions & Answers Session A

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email Mark Trigg (M.Trigg@leeds.ac.uk) or Mark Bernhofen (mark.bernhofen@smithschool.ox.ac.uk) or Luckson Katsi (katsi@unhcr.org) and Ruby Paterson (rubymaepaterson@hotmail.co.uk)

Question 1: Does the difference observed due to geological setting (pluvial/fluvial etc.) of the predictions make for a flood effect?
Answer 1: Yes, geological/topographical setting makes a difference to the flood experienced. For example areas with underlying granite rock, which allows less infiltration of rainfall, usually results in more runoff and faster flooding. These landscape characteristics are included in the flood models, so the hazard maps take this into account.

Question 2: What is the resolution of the flood rasters?
Answer 2: The flood data we use has a horizontal resolution of roughly 90 m at the equator.

Question 3: How do you add the Google map in the XYZ file?
Answer 3: If you don't have the Google satellite imagery in the XYZ tab you can follow these instructions to incorporate them:
https://mapscaping.com/adding-basemaps-in-qgis/.

Question 4: Where did you get the flood map from?
Answer 4: We use flood hazard maps from Fathom Global (https://www.fathom.global/). You can get these directly from Fathom for research purposes. We have also included the flood data we used in the exercise in the linked repository: https://zenodo.org/records/11203929.
There are also other global flood models available, for example the JRC global flood maps -> https://data.jrc.ec.europa.eu/dataset/jrc-floods-floodmapgl_rp50y-tif.
Although this is at a coarser resolution, so may not be as suitable at the camp scale.

Question 5: How exactly were the pluvial and fluvial maps combined?
Answer 5: These were combined by merging the two rasters (fluvial and pluvial) and retaining the maximum flood depth (fluvial or pluvial) for each cell. In the paper this analysis is based on, we calculate fluvial and pluvial risk separately. (https://iopscience.iop.org/article/10.1088/1748-9326/acd8d0)

Question 6: QGIS is to be run on local systems, but if we run on clouds for a larger analysis, could we rely upon GEE, especially using this package with the Pro version of Google Colab?
Answer 6: Yes, this methodology can be duplicated in most geospatial analysis systems, but the exact steps needed will be specific to the software you use.

Question 7: The best free MSS product is S2, if not with SAR. On GEE, it is now Sentinel-2 harmonized. Could the earlier MSS products' resolution effectively be manipulated in a certain manner other than resampling on Cloud?
Answer 7: S2 is used for monitoring floods, although suffers from cloud obstruction. In this session we are using flood maps produced by a global flood model (not observed flooding maps from S2).

Question 8: To clarify, the flood count is binary, right? It doesn't include depth information?
Answer 8: Yes, in Exercise 1 of the hands-on exercise we are only interested in calculating exposure so we use binary flood counts. Flood depths are incorporated in Exercise 2.

Question 9: Is there also a workshop on how to create the preloaded/precreated files or data for when you are starting from scratch?
Answer 9: A lot of the data we use are outputs of previous studies. For example the flood maps we used were produced by Fathom Global. The paper describing how these maps is this one:
https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2015WR016954.
The footprint data we use is from Google Open Buildings (https://sites.research.google/open-buildings/) or OpenStreetMap (https://www.openstreetmap.org/#map=6/54.910/-3.432).
The camp outlines and information we created as part of the original paper (https://iopscience.iop.org/article/10.1088/1748-9326/acd8d0). Unfortunately, there

isn't currently a workshop showing how to produce these from scratch. But essentially we used camp point locations from UNHCR and satellite imagery from Google and Planet Labs (https://www.planet.com/) to manually delineate these camps.

Question 10: How can I calculate a flood map? What data do I need?
Answer 10: We use global flood model maps for this exercise, but you can generate flood maps for your location using your own flood model, provided you have the required data and expertise to build the model. We have built our own models for camps using global datasets such as topography data (FABDEM), land use data (ESA WorldCover), and global rainfall data (ERA5). We have used the HecRas 2D software to build local flood models with these datasets. However, this session is focused on flood risk assessment rather than flood hazard modeling.

Note you can also use observed flooding (we use modeled flooding in this training). For observed flood detection see: SAR for Detecting and Monitoring Floods, Sea Ice, and Subsidence from Groundwater Extraction: https://appliedsciences.nasa.gov/get-involved/training/english/arset-sar-detecting-and-monitoring-floods-sea-ice-and-subsidence.

Question 11: The OSM and the building footprint layers do not line up exactly (i.e., there are many more buildings in OSM than the footprint layer). How are these datasets calculated (I assume ML from EO data) and how reliable/timely are building footprint shapefiles?
Answer 11: Indeed, the footprint datasets do not perfectly overlap because of the different approaches for calculating them. OpenStreetMap data is primarily community-mapped, but is beginning to incorporate ML approaches into mapping. The Google data is entirely ML based using EO data. So these different approaches contribute to some of the differences. Another reason for the differences is the temporal aspect of these datasets – OpenStreetMap data are updated on a continuous (but irregular) basis. Google Open Building data has different iterations at different snapshots in time. For this tutorial we use Google Open Buildings v2 2022 (it has since been updated to v3 2023). So the two datasets may also be different as they show the footprints at different snapshots in time. We explored the effect that the use of different building footprint datasets had on flood risk estimates in our paper (https://iopscience.iop.org/article/10.1088/1748-9326/acd8d0) and found the effect

was less than 5% in all but one camp. In any case it is important to use multiple different exposure datasets to capture this uncertainty.

Question 12: In order to achieve the footprints of the settlements and camps, we need a better object recognition model, otherwise, it would take hours to generate vectors. Kindly shed light on that. Is the Segment Anything Model (SAM) by Meta too much to run for this cause?
Answer 12: The building footprint data that we use in this exercise are already generated. Either through community mapping initiatives (OpenStreetMap) or using AI algorithms on EO data (Google Open Buildings). Because these vector datasets already exist, we don't need to account for computation time for generating the vectors. It would be interesting to explore how to use Meta's SAM model in this context. Perhaps something to explore for a single refugee camp and then see how it could scale!

Question 13: How do you make per style for each layer?
Answer 13: This documentation shows how you can change the style for raster layers: https://docs.qgis.org/3.34/en/docs/training_manual/rasters/changing_symbology.html.

Question 14: Are hazard maps used in an anticipatory fashion to guide building/site footprints for newer camps?
Answer 14: Yes, during site suitability assessment. Government together with traditional leadership, just allocate land then from there UNHCR constitutes a Multi-Functional Team (MFT) to do a quick site assessment, which involves an analysis of flood historical patterns (if available). As part of the MFT assessment, the site assessment form has (red lines are alerts flagging critical issues rendering the site unsuitable for development and orange lines are alerts flagging that heavy mitigation activities will be required to enable the development of the site). But the challenge still remains (see response to Q18) and data is not always available.

Question 15: What kind of data would you use (instead of Fathom Global V2) if you want to assess flood risk related to cyclone rain events?
Answer 15: Good question. This is not my area of expertise, but to give a high-level answer, you would want to integrate some information on tropical cyclones (such as track information) with information on rainfall/flood potential. I link a paper that explores how some of the same flood data we used in our exercise was used in the context of

forecasting cyclone flood risk in Mozambique.
https://www.sciencedirect.com/science/article/pii/S2212420920313133#fig5

Question 16: The floods are seasonal right? Then one of the solutions can be to move the inhabitants seasonally away from the floodplains and then return back during dry periods?
Answer 16: Yes, they are seasonal. However, several challenges with seasonal relocation of refugees:

- Relocation to some places is not that easy, logistically.
- Temporary/seasonal land is not easy to get (hosting communities also use the same land, either as pasture lands or agriculture – making land availability a challenge).
- Setting up a relocation camp, where refugees can be moved seasonally (requires resources).
- Refugees themselves might refuse to be relocated – they have newly created homes and do not want to be moved away from their livelihoods, family, and neighbors in the camps.

Question 17: How can the vulnerability of people in camps or houses be quantified and also added to the map and table?
Answer 17: In order to add vulnerability to the process, we would need to understand how people may be physically vulnerable to specific water depths and velocities. You can find an example of these risk categories for people in the Australian Rainfall Runoff guidance here: http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/ Section 7.2.3. Note that to use this you will need to know the velocity of flood water and global flood models do not currently provide this parameter (only flood depth). If you build your own local flood model, you will have both flood depth and velocity and can apply these risk categories to understand vulnerability. Also many of these methods (particularly structures) are specific to wealthy countries and are not directly relevant to refugee camps where vulnerability is very different.

Question 18: As the data is now becoming available for flooding in locations (whether or not a camp is already located there), would it be feasible for these assessments to be created ahead of time and given to UNHCR and in the hands of governments/local camp managers?

Answer 18: Yes, this is certainly possible now, although the decision making process is quite complex and it will require extensive discussion with the host government and hosting community leaders. It is possible but not practically easy to get a suitable piece of land/location/s. They sometimes don't provide an alternative location. Even if there is evidence of historical flooding trends, no other better options are provided. Securing land is pretty difficult. It involves different negotiation processes including clan leaders. Pressured by the urgent need to relocate refugees from the border, unsuitable land will end up being utilized as a refuge site with the hope that flood mitigation, site improvements, etc. will be undertaken. However, there are often limited resources to undertake site improvement. The challenge of moving refugee camps once they are established is huge. Oftentimes refugees are settled and do not want to be moved from homes they have created.

Question 19: What other factors besides flood depth can be considered to assess flood risk?

Answer 19: Commonly flood velocity is also used to assess risk, although most global models do not provide this (yet). Local flood modeling using packages such as HecRas will provide depth and velocity but will take expertise to build and run.

Question 20: Is there any way to get ready-made better spatial resolution flood raster layers?

Answer 20: The resolution of the global flood maps is improving all the time - mainly driven by improvements in the underlying EO data used to build the models. For example the Fathom v2 model we use in this training is 90 m resolution, based on the MERIT DEM topography. The Fathom v3 just released uses a 30 m FABDEM DEM and this provides a higher resolution flood map. Some countries have better national DEMs, for example 5 m or 1 m datasets, which means you can produce better flood maps with these. However, these national maps are only available in a few countries and very few of those countries with refugees have their own national flood maps.

Question 21: Are these types of analyses done for refugee camps often? Or is this something that is often overlooked?

Answer 21: Yes, for all new camps/settlements, a site suitability assessment is done. The challenge is even if the site is not suitable, oftentimes we are faced with limited suitable site choices and data availability (refer also to Q18 response).

Part 1 Questions & Answers Session B

Please type your questions in the Question Box. We will try our best to get to all your questions. If we don't, feel free to email Mark Trigg (M.Trigg@leeds.ac.uk) or Mark Bernhofen (mark.bernhofen@smithschool.ox.ac.uk)

Question 1: What is the quickest and most effective way to provide sanitation to camps? How are fecal coliform counts in water kept down in these camps? Are key sanitation infrastructure installations located at certain elevations?
Answer 1: With respect to sanitation in camps and flooding, flood water can fill pit latrines, for example, and result in contaminated flood water in the camps which can cause a significant health impact – so this is an added risk factor during floods. Some sanitation facilities are designed with elevated bases to avoid this problem, but it does cost more and it is not always a perfect solution as high groundwater tables during floods can also flood the pits.

Question 2: Are there best practices for infrastructure planning for refugee camps available?
Answer 2: Yes there are – covered by Ruby in section 3 of the talk – however, none of them explicitly cover flood risk assessment.

The following books/docs offer guidance:

- UNHCR Master Plan for Camp Management
- The Sphere Handbook
- Refugee Operations and Environmental Management Key Principles for Decision Making
- Practical guidance on surface water management & drainage for field practitioners
- Engineering in Emergencies
- UNHCR Emergency Handbook- Site Planning for Camps

Question 3: What are your thoughts on "duration/time" as a separate component playing a role in flood risk assessment?
Answer 3: Duration of flooding is also an important factor when assessing flood risk, but this is usually more complex to undertake, as you need fully dynamic flood models of the whole flood event. Currently this is not available through global flood models – they are static maximum flood extent maps. You can derive an understanding of duration through a local bespoke flood model. Larger rivers tend to result in longer duration floods and smaller steeper river systems lead to shorter – but flashier floods. Long duration flooding causes long term problems in terms of coping with the constant flood waters, while flash floods are especially dangerous because of how fast they develop.

Question 4: What countries have space-borne LiDAR available?
Answer 4: You can use online resources such as OpenTopography (https://portal.opentopography.org/datasets) to find countries/regions where there is aircraft flown LiDAR data available. In general there is a bias towards aircraft flown LiDAR data availability to countries in the global North. Spaceborne lidar (ICESAT and GEDI for example) can also be used, but these are generally used to validate or correct global elevation datasets, as they do not provide a full global cover yet, but this may change in the future.

Question 5: Can we load Open Street Map in place of a Google map?
Answer 5: Yes, you could load whatever basemap you find most useful. We chose to show Google satellite imagery so we could see what the refugee camp looked like in the background.

Question 6: How can we generate the flood map data? How can we access it? What is the time span of the data?
Answer 6: We use flood hazard maps from Fathom Global (https://www.fathom.global/). You can get these directly from Fathom for research purposes. We have also included the flood data we used in the exercise in the linked repository: https://zenodo.org/records/11203929.
There are also other global flood models available, for example the JRC global flood maps -> https://data.jrc.ec.europa.eu/dataset/jrc-floods-floodmapgl_rp50y-tif, although this is at a coarser resolution, so may not be as suitable at the camp scale.

The flood maps we use are based on the historical distribution of rainfall and river flow, so they don't give us a look at future changes in risk. We use the 1 in 100 year return period flood map, or a flood with an annual probability of occurrence of 1%.

Question 7: Do you have the same dataset for the other refugee camps/sites in Ethiopia?
Answer 7: The data folder provided (https://zenodo.org/records/11203929) contains detailed information on a subset of camps. You can find the complete dataset for all 24 camps in the repository linked to the original paper we published (https://zenodo.org/records/7962039).

Question 8: Is the flood map from Fathom Global paid data?
Answer 8: They are a commercial data provider that provides their flood data for free for research purposes. You can reach out to them to get access to their flood data by contacting them through their website (https://www.fathom.global). There are also other, completely open global flood datasets available such as from the JRC https://data.jrc.ec.europa.eu/dataset/jrc-floods-floodmapgl_rp50y-tif or through WRI Aqueduct https://www.wri.org/data/aqueduct-floods-hazard-maps. However, many of these flood maps only show flooding on major rivers, which may not always be appropriate for the context of refugee camps as many of these are exposed to the flooding of smaller rivers. These are some important things to consider when you are conducting a flood risk assessment in these contexts.

Question 9: I may have missed it during the presentation, when the at-risk individuals are calculated, how is the likelihood of rain in that specific camp setting considered? And future climate impacts on the flooding?
Answer 9: We use modeled flood hazard maps with associated probabilities. These likelihoods are calculated based on statistical analysis of rainfall/river-flow data. In the exercise, we use the 100-year flood map or the 1% annual probability flood map, so it is representative of an extreme flood. The flood hazard maps we use in the exercise use only historical distributions of rainfall/river flow to generate the flood maps. However, there are now a number of flood datasets that consider how flood hazards might change in the future due to climate change. It would be easy to replicate the analysis in the exercise to include these forward-looking flood maps.

Question 10: If the government sites a camp in a hazardous zone, are they then liable for the lives of refugees during flood events?
Answer 10: Can't answer this question, this is a legal question, but can comment that UNHCR works alongside governments to site camps, they support governments, but ultimately, government is responsible to decide on the location.

Question 11: Can the training be taken into the context of assessing landscape management (Refugee + Environment = One Health) in refugee camp setups?
Answer 11: Yes, good flood management includes landscape management as part of the mitigation options, and nature-based solutions are increasingly used in this context due to the environmental/health benefits.

Question 12: The UN makes available points with coordinates datasets of the refugee camps. Was the data that was used which included boundaries of camps digitized manually? Or is it a global dataset?
Answer 12: They were digitized manually. We had the coordinates for the 24 camps and had to check for accuracy. We then used satellite imagery to try to identify the area of the camp. Some, but not all, camp boundaries exist in Open Street Map.

Question 13: What methods can be used to quantify and map social vulnerability at a fine scale within the camp?
Answer 13: The UNHCR includes in their reports the demographics of the camps. You can use this information to evaluate the risk of groups in the camp, but we still have this information aggregated at the camp level, rather than spatially mapped across the camp. We could use more on-the-ground information, although collecting this brings data privacy and collection cost implications.

Question 14: Why use QGIS and not ArcGIS?
Answer 14: QGIS is open software with no need for a license. You can do the same FRA process in most geospatial software including ArcGIS (which requires a license).

Question 15: Can those flood models that were used for the exercise be considered flood inundation maps (combining both river and flash floods)?
Answer 15: The flood data included both river and flooding data. The maps were combined. The paper provides more information on the risk.

Question 16: As the data is more commonly available for larger rivers and not smaller streams, is there a way to do similar modeling based on elevation changes on land instead of historical flooding data?
Answer 16: Yes, possibly. Elevation data could provide susceptibility information. The Height above nearest drainage method is an example of this approach. However, other data would be beneficial and numerical modeling of water flow remains the most reliable method of identifying flood risk - if you have the data and time to build the models.

Question 17: What satellite was used for the flood model with the 90m resolution? And can we use Sentinel data to derive more precise flood extent results?
Answer 17: The 90m resolution is related to the underlying digital elevation model (corrected SRTM) used in the flood model. Yes, Sentinel can provide observed flood maps at ~10m resolution, but this is not the same as probability-based flood maps, as these may not have been observed by Sentinel in its brief life (e.g., 1 in 100 year event happens approximately once in 100 years).