Response to the Comments of Reviewer No. 1

We sincerely acknowledge the reviewer for her/his time spent reviewing this manuscript. The manuscript has been improved after addressing the reviewer's comments. The following contains our response to each comment. Each response contains a reply and reports the changes in the manuscript. In this document, we refer to the manuscript that was revised by the reviewer as the ***original*** manuscript, and the manuscript that contains the modifications, based on the reviewer's comments, is referred as the ***updated*** manuscript.

Comment:

"Line 40 in Page 2

"However" is a bit strange from the context of the paragraph. Please correct it."

Reply:

As suggested by the reviewer, we have rephrased the sentence.

Change in manuscript:

Line 40:

were delimited with chalk, and makeshift shelters were built with wooden sticks and plastic sheets (See Figures 1e and 1f). It is worth mentioning that the government declared the Morro Solar as an intangible area in 1977 and a historical monument in 1986. The police, in coordination with the local authorities, removed the inhabitants that participated in the invasions in April 14 and April 28 in Morro Solar and Lomo de Corvina, respectively, and the makeshift shelters were removed several days later.

Comment:

"Figure 1(c)-(i), -(ii), (d)-(i), -(ii) and Figure 3

Please add north arrows in each figure."

Reply:

As suggested by the reviewer, we include the north arrows in the referred figures.

Change in manuscript:

Figure 1:

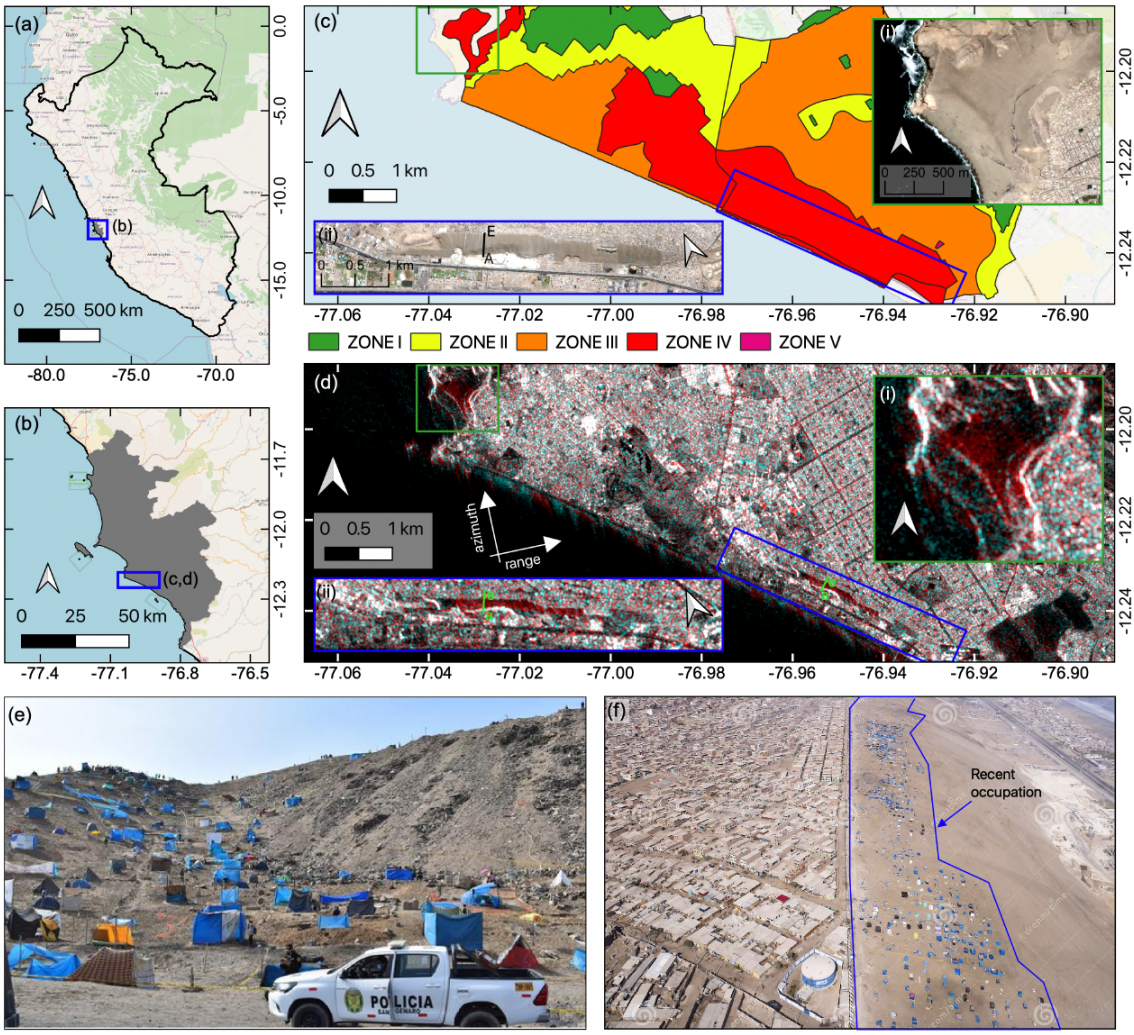

Figure 1. Location of the study area. (a) Location of Metropolitan Lima (blue rectangle) within Peru. (b) Location of the study area (blue rectangle) within Metropolitan Lima, which is partly located in the districts of Chorrillos and Villa el Salvador. (c) Seismic microzonation of the study area. The green rectangle denotes the location of inset (i), the Morro Solar. The blue rectangle denotes the location of the inset (ii), the Lomo de Corvina. (d) Color composite of SAR backscattering intensity images. Red band: image recorded on April 14, 2021; Green and blue band: image recorded on December 03, 2020. (e) Photograph of the squatter settlement in Morro Solar recorded by Gestion (2021). (f) Photograph of the squatter settlement in Lomo de Corvina (modified from Inga (2021)).

Figure 3:

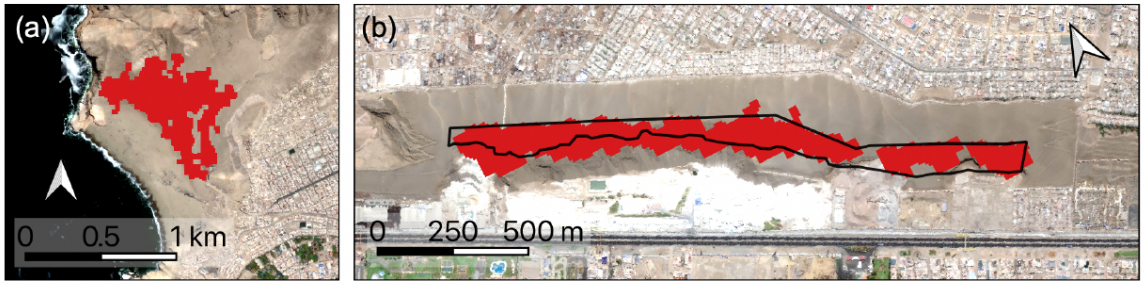

Figure 3. Sentinel-1 SAR-based map of the recent informal settlement in Morro Solar (a), and Lomo de Corvina (b).

Comment:

"Figure 3 in Page 4

Considering the spatial resolution of Sentinel-1 images as shown in Fig. 1, Pixel size of the extraction results in Fig. 3 seems much larger than the original resolution. Furthermore, there are no misdetection in outer area of the target area. If the author performed further analysis other than thresholding, please describe it."

Reply:

The reviewer is right, performed further analysis to reduce the effect of the speckle noise in SAR images. We apologize for missing such details. The further processing is explained as follow: After the thresholding (Figure R1a), the morphological operators "opening" and "closing" with a kernel-size of 5x5 pixels were applied (https://docs.opencv.org/master/d3/dbe/tutorial_opening_closing_hats.html), see Figure R1b. Then, we identified the pixel clusters, where a cluster is a set of neighbor pixels, and two pixels are neighbor if they share a common side (Figure R1c). finally, clusters consistent of less than 200 pixels were filtered out. Note that a pixel has an area of about 100m2, which is less than the average area of informal buildings in Lima; furthermore, the number of people that participate in such informal occupations is in the order of thousands. Therefore, we consider that a threshold size of 200 pixels to filter out small clusters is a reasonable choice. Note also that the final results (Fig R1d) include additional clusters that are easy to discriminate because some (the three small clusters on the left) are located in the sea and some are located in existing urban areas (the two small clusters on the right).

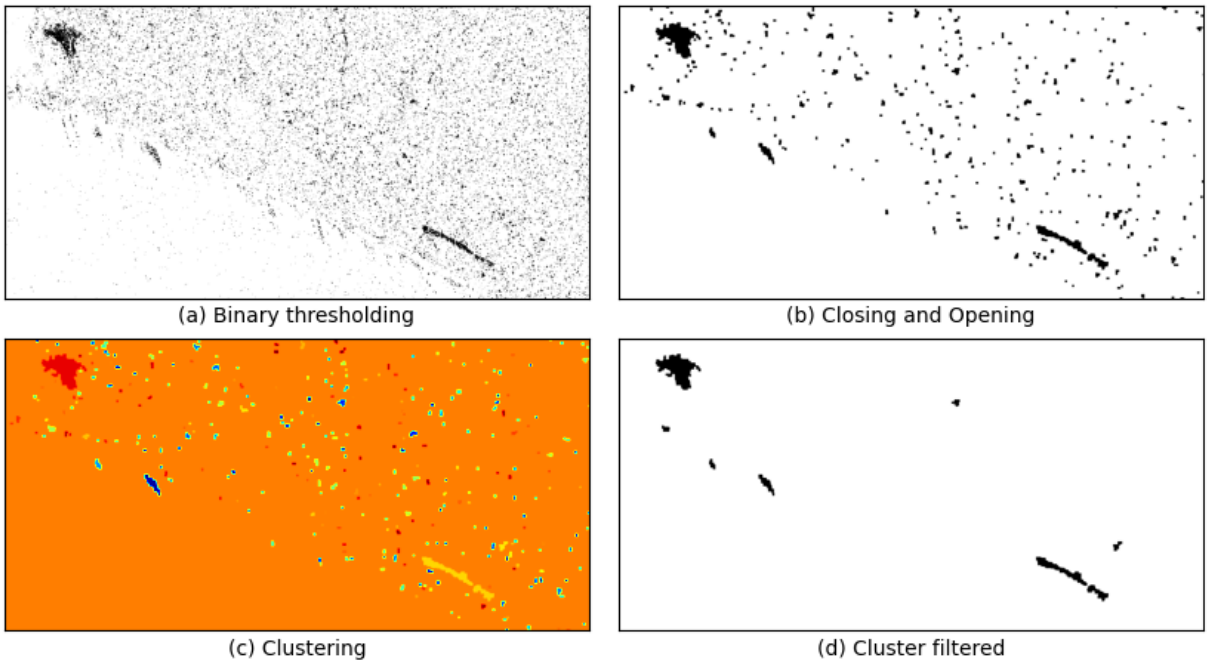

Figure R1. (a) Binary thresholding. (b) Closing and opening operators with kernel-size 5x5. (c) Clustering. (d) Clusters of less than 200 pixels are filtered.
In the updated manuscript, we decided to apply the morphologic operators (opening and closing) with a kernel size of 3x3 (instead of 5x5) to improve the final resolution:

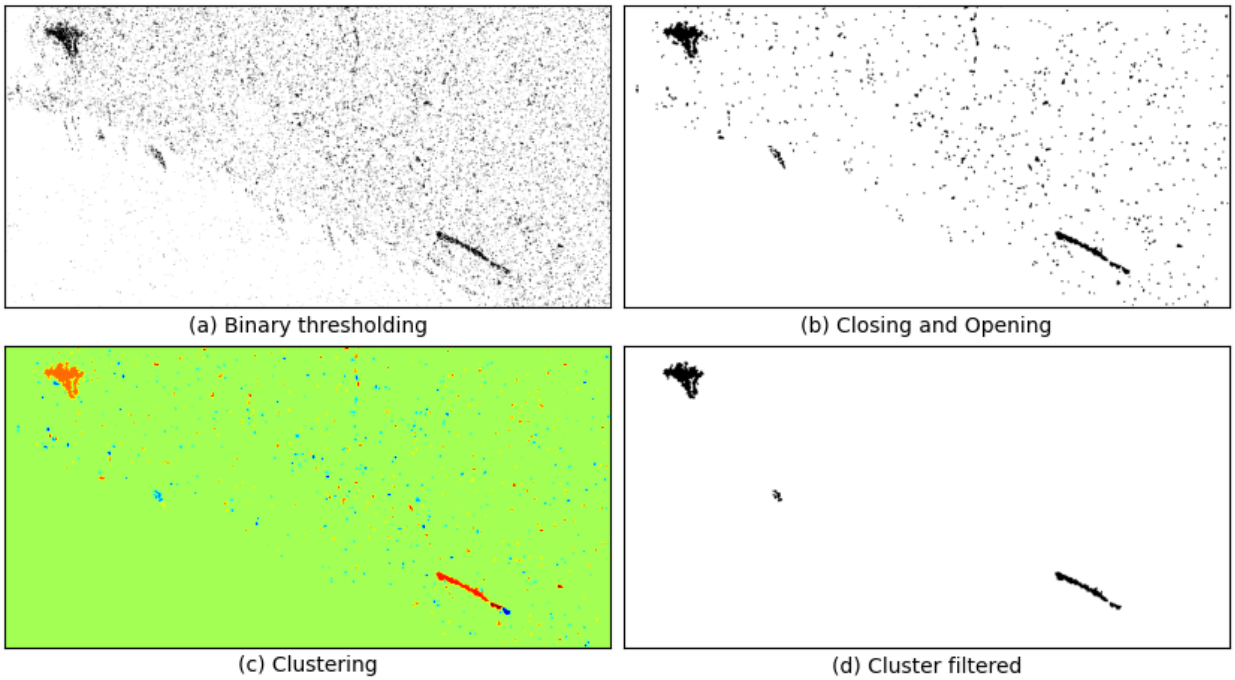

Figure R2. (a) Binary thresholding. (b) Closing and opening operators with kernel-size 5x5. (c) Clustering. (d) Clusters of less than 200 pixels are filtered.

Change in manuscript:

Line 94:

the backscatter intensity recorded on April 14, 2021, is greater than the threshold, it is assumed that the area is occupied. After thresholding, the morphological operators *closing* and *opening* were applied using a kernel size of 3×3. Then, pixel-clusters were identified and those with size lower than 200 pixels were filtered out. Figure 3 depicts the extent of the invaded areas in Morro Solar and Lomo de Corvina. The black polygon shown in Figure 3b denotes the extension of the occupied area estimated from visual inspection of images recorded by an unmanned aerial vehicle (UAV). Our results from SAR images identified 84% of the area identified by visual inspection. Furthermore, only 67% of the area identified from SAR images is contained within the black polygon. We believe that the main reason of the discrepancies between the information from SAR images and visual inspection lies in the complex geometric distortions in the SAR images.

Figure 3:

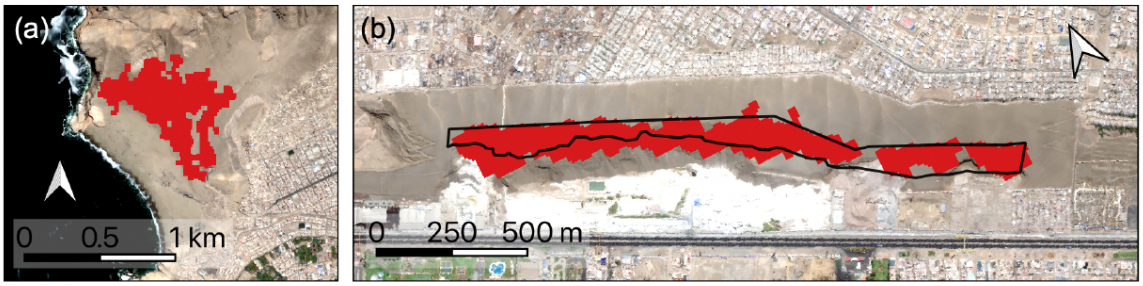

Figure 3. Sentinel-1 SAR-based map of the recent informal settlement in Morro Solar (a), and Lomo de Corvina (b).

Comment:

"Line 83-84 in Page 5

The author described "the occupied area in Lomo de Corvina is underestimated" without any evidence. Underestimation must be judged from comparison with other investigation such as field survey or previous studies. Please show some evidence for the underestimation."

Reply:

The reviewer is right, the referred statement was based on the typical geometric distortions of SAR images in areas with significant slope as we expected to be the case of the Lomo de Corvina. However, recent evidence published in the internet proved that it is not the case.

The geometric distortions that occur in Lomo de Corvina area is referred as foreshortening/layover. Such distortions are well-known effects in SAR images (See, for instance, section *2.1.4 Geometric Properties of SAR data* of the book *The SAR Handbook:* https://servirglobal.net/Global/Articles/Article/2674/sar-handbook-comprehensive-methodologies-for-forest-monitoring-and-biomass-estimation). Figure R3 shows Lomo de Corvina recorded from both an optical sensor and a microwave sensor. Grid lines are drawn for better visualization of the geometric distortions. The bare land, which was recently occupied, seems smaller in the SAR image that that from the optical image. Because the Lomo de Corvina area was shrunk in the SAR images, we stated our results might be underestimated.

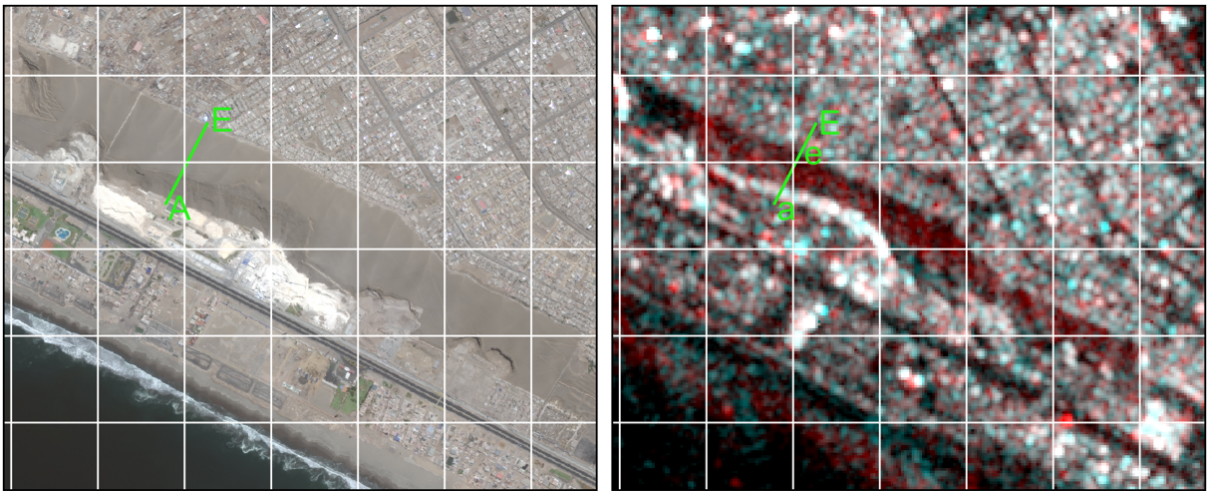

Figure R3. Lomo de Corvina recorded from an optical sensor (left), and from a microwave sensor (right).

However, videos recorded from a UAV at the occupied areas in Lomo de Corvina were recently published in the internet:

- https://www.dreamstime.com/lima-peru-zone-known-as-lomo-de-corvina-people-illegal-invasion-land-poor-people-illegal-land-dealer-lima-lima-peru-april-video217521408
- https://www.dreamstime.com/lima-peru-zone-known-as-lomo-de-corvina-people-illegal-invasion-land-poor-people-illegal-land-dealer-lima-lima-peru-april-video217520606
- https://www.dreamstime.com/lima-peru-zone-known-as-lomo-de-corvina-people-illegal-invasion-land-poor-people-illegal-land-dealer-lima-lima-peru-april-video217520563
- https://www.dreamstime.com/lima-peru-zone-known-as-lomo-de-corvina-people-illegal-invasion-land-poor-people-illegal-land-dealer-lima-lima-peru-april-video217520465
- https://www.dreamstime.com/lima-peru-zone-known-as-lomo-de-corvina-people-illegal-invasion-land-poor-people-illegal-land-dealer-lima-lima-peru-april-video217520257
- https://www.dreamstime.com/lima-peru-zone-known-as-lomo-de-corvina-people-illegal-invasion-land-poor-people-illegal-land-dealer-lima-lima-peru-april-video217518049
- https://www.dreamstime.com/lima-peru-zone-known-as-lomo-de-corvina-people-illegal-invasion-land-poor-people-illegal-land-dealer-lima-lima-peru-april-video217517546
- https://www.dreamstime.com/lima-peru-zone-known-as-lomo-de-corvina-people-illegal-invasion-land-poor-people-illegal-land-dealer-lima-lima-peru-april-video217516965
- https://www.dreamstime.com/lima-peru-zone-known-as-lomo-de-corvina-people-illegal-invasion-land-poor-people-illegal-land-dealer-lima-lima-peru-april-video217516619
- https://www.dreamstime.com/lima-peru-zone-known-as-lomo-de-corvina-people-illegal-invasion-land-poor-people-illegal-land-dealer-lima-lima-peru-april-video217515700
- https://www.dreamstime.com/lima-peru-april-th-aerial-media-over-pan-american-highway-one-most-important-america-crossing-south-to-north-video217513019
- https://www.dreamstime.com/lima-peru-zone-known-as-lomo-de-corvina-people-illegal-invasion-land-poor-people-illegal-land-dealer-lima-lima-peru-april-video217512728

Figure R4 shows an image of the northwest side of the occupied area, which is limited by a white wall. A simplified idealization of a cross-section in Lomo de Corvina hill is depicted in Figure R5. The location of the cross-section is depicted in Figure R4 as the segment $\overline{AE}$. The cross-section is simplified as four segments $\overline{AB}$, $\overline{BC}$, $\overline{CD}$, and $\overline{DE}$. We assume that the range direction is parallel to the vertical plane that contains the cross-section to illustrate the geometric distortions in the SAR image. The *slant range* denotes the direction from which the microwave energy travels from the satellite to the ground. The microwave images are presented in *ground-range* format. Note that because the points A and C share about the same distance to the satellite, both segments $\overline{AB}$and $\overline{CB}$ occupy the same geographic position in the ground-range (see $\overline{ab}$ and $\overline{cb}$). In the ground-range the cross-section is located along the segment $\overline{AE'}$ in the optical image; on the other hand, the cross-section is located along the segment $\overline{ae}$ in the microwave image. It is observed that the length of $\overline{AE'}$ is larger than the length of $\overline{ae}$, which is the reason we stated our results might be underestimated. However, the reviewer is right mentioning that our assumption is not conclusive. Note that the length of $\overline{DE'}$, the segment that contains the occupied area, is slightly larger than the length of $\overline{de}$.

Figure R4. Occupied area in Lomo de Corvina (Source: internet)

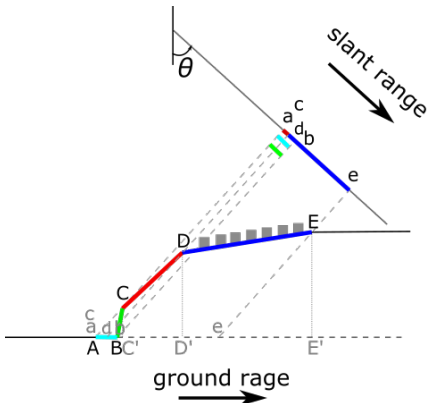

Figure R5. Simplified scheme of the cross-section of the Lomo de Corvina hill. It is assumed that the cross section and the range direction lie on the same vertical plane. Due to the oblique observation of SAR images, surface slopes lead to geometric distortions.

Regarding a comparison of our results and field surveys, by georeferencing some images extracted from the videos, and with the aid of a high-resolution optical images, we manually draw the extent of the occupied areas at the Lomo de Corvina (See Figure R6a). Then we shifted the polygon to fit the occupied area in the SAR image, we use as reference the boundary between the existing urban area and the recently occupied area (See Figure R6b).

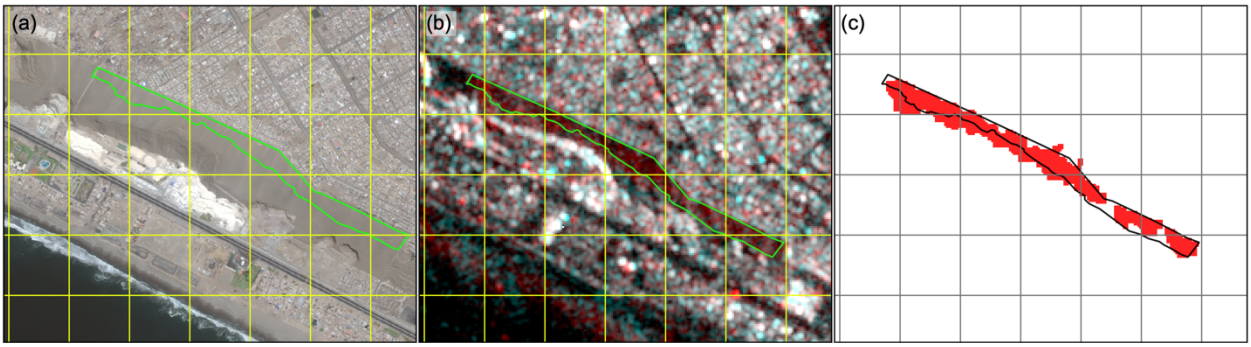

Figure R6. Extent of the occupied area in Lomo de Corvina

Figure R6c shows the estimated occupied areas from SAR imagery and that from visual inspection (VI). 84% of VI-based area were identified in the SAR-based results; on the other hand, 67% of the SAR-based results belong to the VI-based area.

Change in manuscript:

Line 71:

color composite of backscattered intensity recorded on different dates. The red band denotes an image recorded on December 03, 2020, and the green and blue band denote the image recorded on April 14, 2021. Note from inset (ii) in Figure 1c and 1d that the Lomo de Corvina area in the SAR image looks smaller than that from the optical image. Such geometric distortions are because of the oblique observation geometry of SAR images. Figure 2a depicts a scheme of the elevation profile corresponding to the line $\overline{AE}$ depicted in the inset (ii) of Figure 1. The profile is simplified by four segments, $\overline{AB}$, $\overline{BC}$, $\overline{CD}$, and $\overline{DE}$. In order to illustrate the geometric distortions in the SAR images, it is assumed that the range direction is parallel to the vertical plane that contains the profile. The slant range denotes the direction from which the microwave energy travels from the satellite to the ground. The microwave images are presented in ground-range format. Note that because the points A and C share about the same distance to the satellite, both segments $\overline{AB}$ and $\overline{CB}$ occupy the same geographic position in the ground-range ($\overline{ab}$ and $\overline{cb}$) of the SAR image. In the optical image, the profile scheme is located over the line $\overline{AE}$ (Figure 1c); on the other hand, the profile is located along the segment $\overline{ae}$ in the SAR image, which is significantly smaller. However, the segment that contains the informal settlement in the optical image, $\overline{DE}$, is only slightly larger than the length of $\overline{de}$. Note also there is a shift between $\overline{DE}$ and $\overline{de}$.

Figure 2:

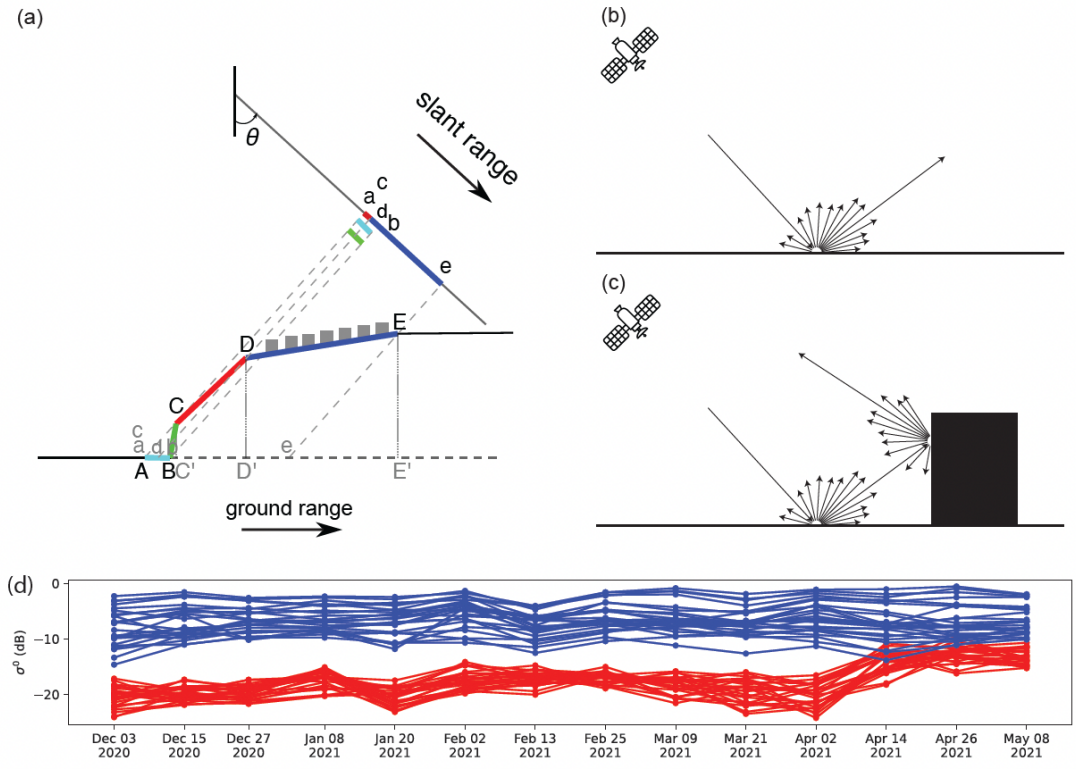

Figure 2. (a) Simplified scheme of the elevation profile at the line $\overline{AE}$ in Figure 1c, inset (ii). (b) Diagram of the radar pulse, I_a, backscattered from the ground. (c) Diagram of the radar pulses backscattered from the ground, I_a, and the makeshift shelter, I_b. (d) Red lines: SAR backscattering intensity time series at some representative points of the recently invaded land in Morro Solar. The sudden increment from April 14 denotes the change of the backscatter mechanism from the mechanism shown in 2(b) to that shown in 2(c); Blue lines: SAR backscattering intensity time series at some points of an old informal settlement located close to the recently invaded land.

Line 97:

thresholding, the morphological operators *closing* and *opening* were applied using a kernel size of 3×3. Then, pixel-clusters were identified and those with size lower than 200 pixels were filtered out. Figure 3 depicts the extent of the invaded areas in Morro Solar and Lomo de Corvina. The black polygon shown in Figure 3b denotes the extension of the occupied area estimated from visual inspection of images recorded by an unmanned aerial vehicle (UAV). Our results from SAR images identified 84% of the area identified by visual inspection. Furthermore, only 67% of the area identified from SAR images is contained within the black polygon. We believe that the main reason of the discrepancies between the information from SAR images and visual inspection lies in the complex geometric distortions in the SAR images.