TALLYING IMPERVIOUS AREA IN AGRICULTURAL LAND BY COMBINING HIGH-RESOLUTION SATELLITE IMAGERY AND LIDAR DATA

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ABSTRACT: The shift in the use of agriculture land area had been undergone for recent years. In Taiwan, there are many cases where the agriculture area is not being cultivated but it is used for different purpose. In this study, we call this area as the impervious area. Impervious area evolves many kinds of purposes such as housing, factory, warehouse, graveyard, etc. The loss of farmland could further lead to the threat of national food production shortage and also soil pollution. For this reason, a periodical assessment to record the change of total farmland area is important to be carried out. The task could be laborious since Taiwan has an immense agriculture land area. An approach was proposed by utilizing the integration of Pleiades high-resolution satellite imagery and LiDAR data. The pan-sharpened Pleiades image was processed by using Normalized Digital Vegetation Index (NDVI) algorithm. The height information derived from LiDAR data was processed to produce the Normalized Digital Surface Model (nDSM). The candidate impervious area was selected by setting a NDVI threshold and a nDSM threshold. A pixel-based unsupervised classification would be carried out to this smaller extent of Pleiades. As the result, the time required for processing the images to delineate the impervious area could be reduced.

1. INTRODUCTION

The increasingly growing global population, which results in demand of a higher and varied food supply (World Economic Forum, 2011), requires about 70% increase in food production to meet its demand (FAO, 2009). The need in food production has resulted in the need for agricultural lands. Not only maintaining the food security, agriculture land would also keep the environment sustainability. The growth in agriculture would also trigger the economic opportunity to raise up. Taiwan acknowledged agriculture as its national key industry when the other business and industry were not significantly evolved during 1940. As a subtropical island, Taiwan has a rich soil and dedicated farmers (NL EVD International, 2013). But recently, agriculture is no longer a major support of nation's development (Ranis, 2007). Furthermore, science and new technology have been high-evolved resulting in the shift of land-use. Agriculture area has been built to accommodate the industrial propose or public facilities.

In contrast to the fact that agriculture plays an important role, the total agriculture area is decreasing every year (National Development Council, 2016). The 2016's Taiwan Statistical Data Book shows that the total agriculture land had been decreased by about 50 percent in 60 years since 1950's. In 2015, it was recorded that Taiwan has about more than 800,000 ha agriculture land (National Development Council, 2016). In the other hand, only about 89 percent of the total agriculture area was cultivated with crops. The government has updated the agriculture policies in order to maintain the agriculture land use. Nevertheless, people still use the agriculture land for purposes such as housing, industry, irrigation, warehouse, highway, etc. Those are some examples of what so-called the impervious area. In addition, the impervious area is generally the agriculture land which is no longer being cultivated with crops and vegetation since people build some features above it. The impervious area lessens the way for the water to get absorbed into the ground.

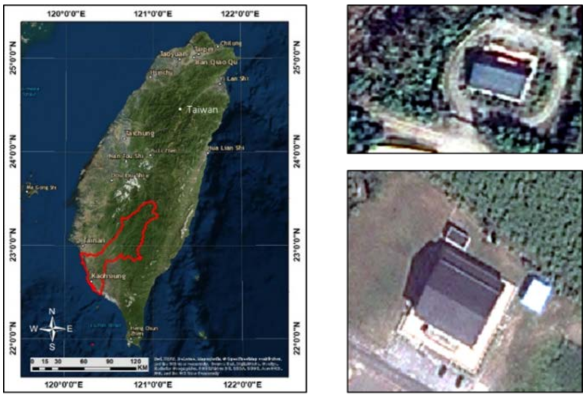
It becomes a laborious task to carry out the agriculture land monitoring considering the size of whole Taiwan. In order to keep up with the most recent land-cover, remote sensing approach is one of the solutions (Reis, 2008). This paper utilized the high-resolution satellite images, Pleiades, and LiDAR data. Pleiades image provides a panchromatic and multi-spectral band with a 0.5 m and 2 m resolution, respectively. In recent years, several studies (Johnson *et al*, 2013; Sousa *et al*, 2015) have proved that the use of the high-resolution satellite imagery would give a good distinction of various features in the images with high accuracy. In this method, the satellite image was responsible for the spectral characteristic aspect in detecting the impervious area. The other indicator to distinct the impervious area with its surrounding was the height information provided by LiDAR data. LIDAR is useful not only that it can provide accurate positions over a large area but also it is fast in obtaining the data. LiDAR data used in this study are Digital Elevation Model (DEM) and Digital Surface Model (DSM) with 1-m resolution. The Normalized Digital Surface

Model or so-called nDSM, were computed by the difference of DSM and DEM. A method was devised using the Pleiades and nDSM to tally the impervious area inside the agriculture land.

2. DATA & METHODS

2.1 Study Area

The study area is a region in Kaohsiung City, southwestern county of Taiwan. The study site is a rural area with roads, rivers, and housings. Unlike the urban housing design which is typically dense and neatly built following the direction of the road, the buildings in the rural area are sparse and scattered. The distance between each building tends to be more spacious. Commonly, they would have their yard layered by asphalt or pavement to become a parking area or just to mark their land ownership, as shown in Figure 1b.



(a) (b)

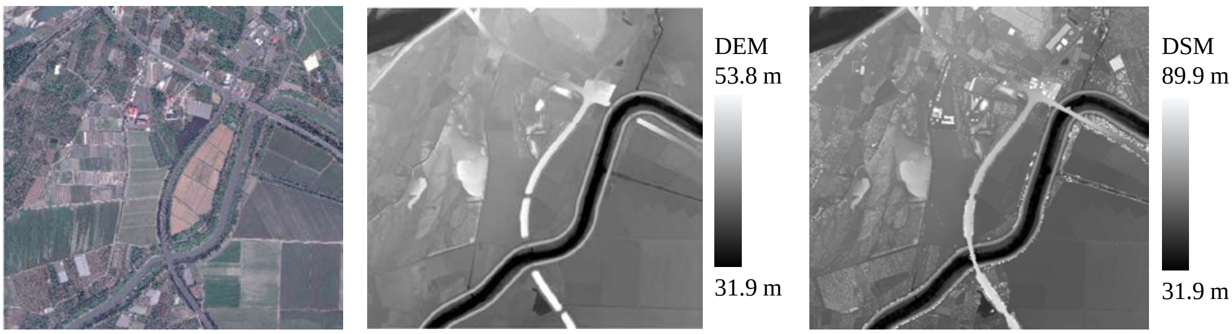
Figure 1. Study area (a) Kaohsiung city; (b) Example of paved ground surrounding the house from Pleiades image

2.2 Datasets

2.2.1 High-Resolution Satellite Imagery: A subset of Pleiades image was utilized in this study, acquired in 12 November 2016. Pleiades satellite image has one panchromatic (PAN) band and four spectral bands, blue, green, red, and near-infrared (NIR). As a high-resolution satellite image, Pleiades has 0.5 m resolution for its PAN and 2 m resolution for its multispectral band. The multi-spectral bands had been pan-sharpened using the panchromatic band to become 0.5 m resolution.

Pleiades constellation consists of 1A and 1B twin satellites which phased 180º apart and were launched in 2011 and 2012 respectively. Since the impervious area tends to not rapidly change within a short interval of time, this image acquisition difference could be neglected in this study.

2.2.2 LiDAR Data: The LiDAR-derived DEM and DSM data, with 1 m resolution, were utilized to create nDSM that represents the height of the objects located above the ground surface. The features visualized in nDSM could be from naturals such as tree and vegetation, or man-made features such as building and road.



(a) (b) (c)

Figure 2. Datasets (a) Pleiades pan-sharpened RGB image; (b) DEM; (c) DSM

2.3 Method

The impervious area needed to be extracted was located inside the agriculture area, thus the size would be quite small compared to its surrounding area. The main characteristics we could rely on was that the agriculture area should be covered by trees or vegetation. In contrary, the impervious area would have a harder surface material and they have no vegetation above.

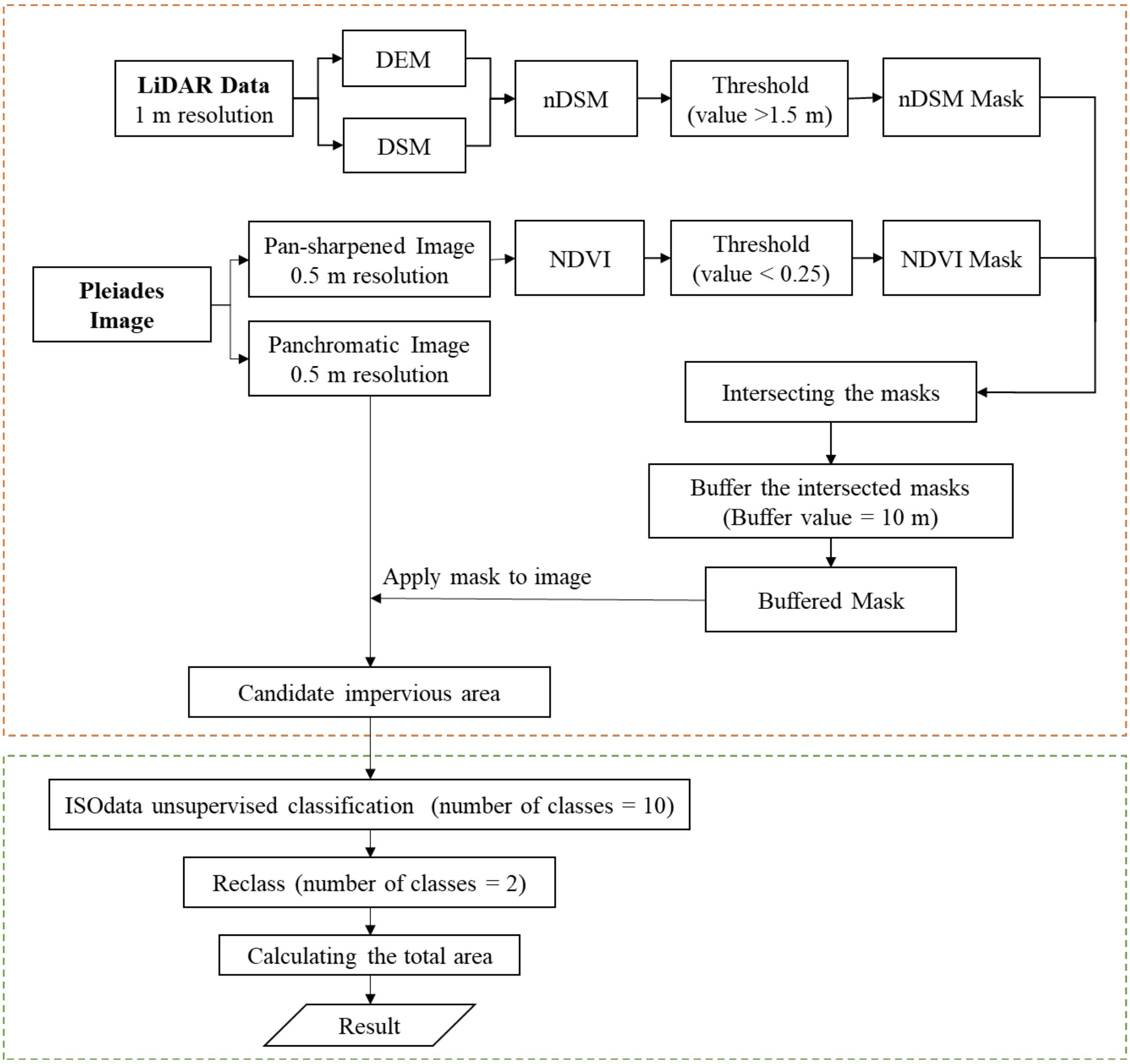


Figure 3. Flowchart

The method proposed composed of two major steps as shown in Figure 3. The first step has the goal of detecting the area with the highest possibility of impervious surface. We could then call this as candidate impervious area. The second step is to process the candidate impervious area using ISOdata unsupervised classification.

In the first step of the method, the candidate impervious area was identified by Normalized Difference Vegetation Index (NDVI) value and further filtered by nDSM value. The following formula shows the NDVI algorithm developed by Rouse *et al.* (1973), our study utilized the NIR and Red band of Pleiades pan-sharpened image.

$$\mathrm{NDVI} = \frac{\mathrm{NIR-Red}}{\mathrm{NIR+Red}} \quad (1)$$

After applying this algorithm, the pixel value of images would vary between -1 and +1 where lower value represents less vegetated area. A NDVI threshold of 0.25 was implemented as it effectively enclosed all impervious areas and a less-vegetated areas in our study area.

A small region of our study area is illustrated in Figure 4 as an example. Figure 4a shows the NDVI map, where the NDVI value in this region is ranged between -0.3 and +1, denoted as gray tones. Figure 4b shows a mask created with NDVI value less than 0.25. Figure 4b shows that after applying the threshold value, the remaining area contained some bare ground surface.

In order to further remove the bare ground area, height parameter was added to highlight the candidate impervious area by setting a height threshold to the nDSM. The height difference between the surface and the ground height (Beumier *et al*, 2016) or so-called nDSM is utilized, as shown in the following formula.

$$nDSM = DSM - DEM \quad (2)$$

An nDSM threshold value of 1.5 m was implemented. The nDSM pixels with values greater than this threshold were regarded as the impervious area as they tended to be man-made features and they are higher than its surroundings. Figure 5a shows the nDSM map of the study area. Figure 5b shows the mask with nDSM values greater than 1.5 m. The bare ground area, as shown in Figure 4b, was filtered out in nDSM mask.

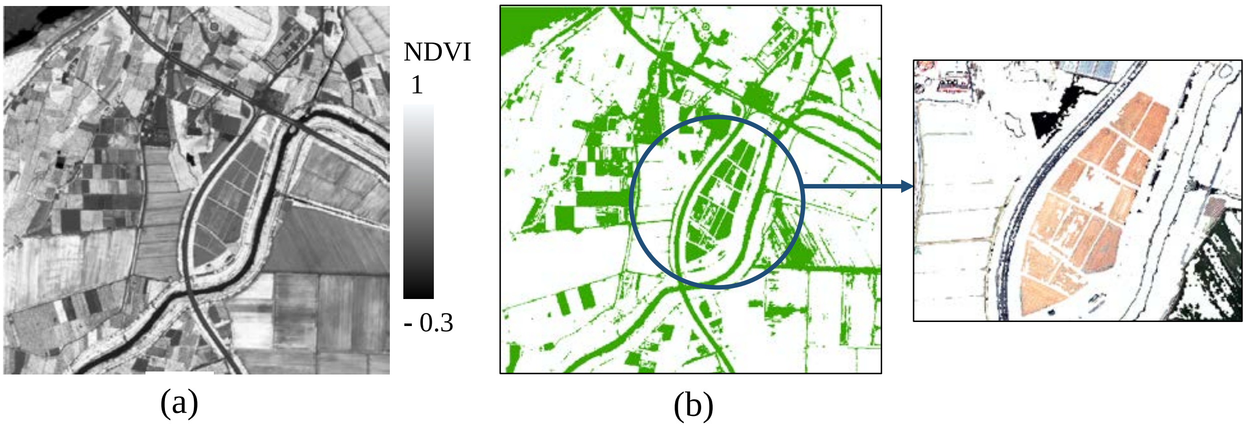


Figure 4. (a) NDVI result; (b) NDVI mask, containing the bare ground

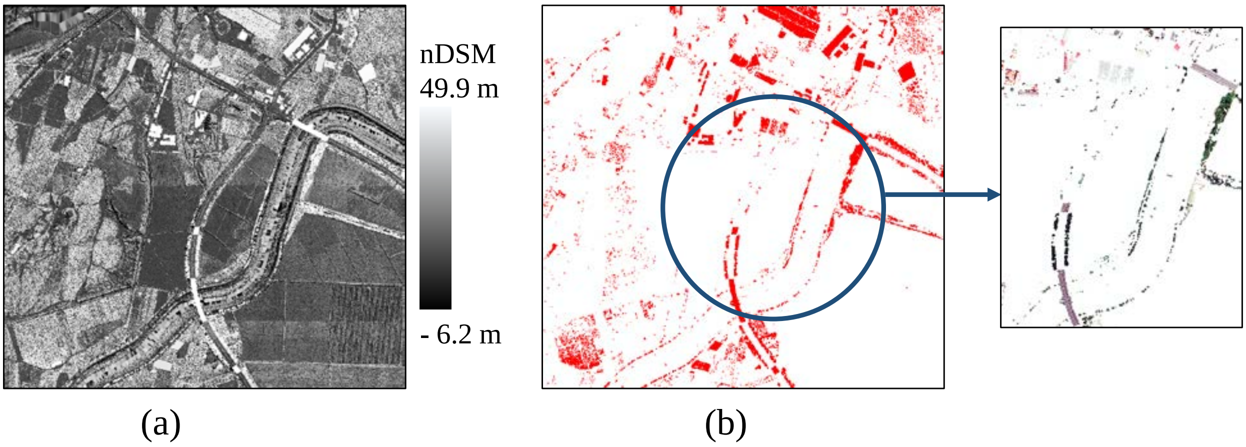


Figure 5. (a) nDSM result; (b) nDSM mask, the bare ground is filtered out

The candidate impervious area would be the area which meets the NDVI and nDSM thresholds. Therefore, a mask was created by intersecting the NDVI and nDSM masks. Because Pleiades image and the LiDAR data were obtained in different time, a buffering value of 10 m was applied to the intersected mask to mitigate this issue.

As shown in Figure 6, the buffered-mask was applied to the Pleiades PAN images and this area regarded as the candidate impervious area. Finally, we carried out the pixel-based ISOdata unsupervised classification on the masked PAN Pleiades images and tally the total area of impervious area.

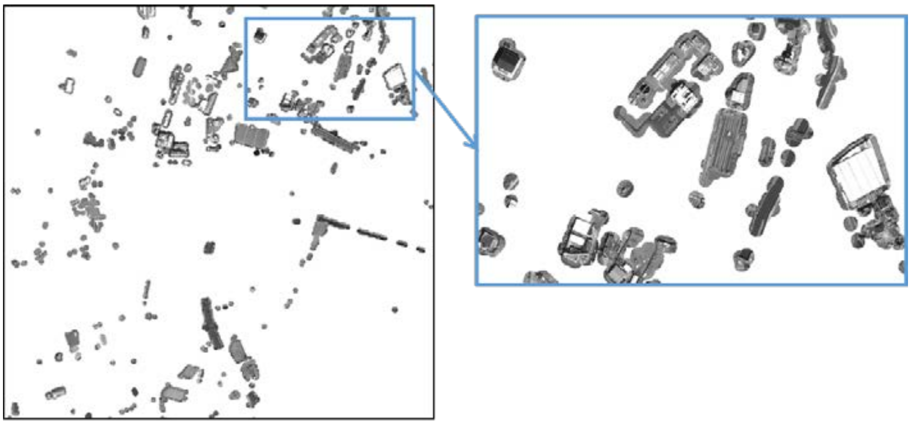


Figure 6. The candidate impervious area from Pleiades PAN image

3. RESULT AND DISCUSSION

Figure 7 shows the masks for NDVI, nDSM, and the candidate impervious area. As we can see that the total amount of the data we need to process has decreased significantly.

We had compared the result of ISOdata usupervised classification utilizing the PAN image and Pan-sharpened image. The result of using PAN image in the classification procedure showed an obvious line of boundary for the impervious area. Therefore, we chose the PAN image to perform the unsupervised classification.

We perform the ISOdata unsupervised classification in order to extract the impervious area. Initially, we got 10 classes from this classification process. The result from this procedure was stored in raster format. Furthermore, we converted to become a vector data. We further carried out a manual reclassing procedure guided by Pleiades pansharpened image.

Figure 9 shows the examples of impervious area found by our proposed method. The outer line of the boundary was clearly defined. In Figure 9a, the building was consisted of two different polygon as they are separated by the color tone, dark roof and light pavement. The factory roof as shown in Figure 9b has light-toned color, thus it defined as a big single polygon. We found the same case as shown in Figure 9c. For Figure 9d, a circle-shaped well, has been detected inside a farmland.

We carried out an area calculation for the whole impervious area. As the result, we found that there was a 6.895 ha impervious area from the total 327.635 ha of our study area.

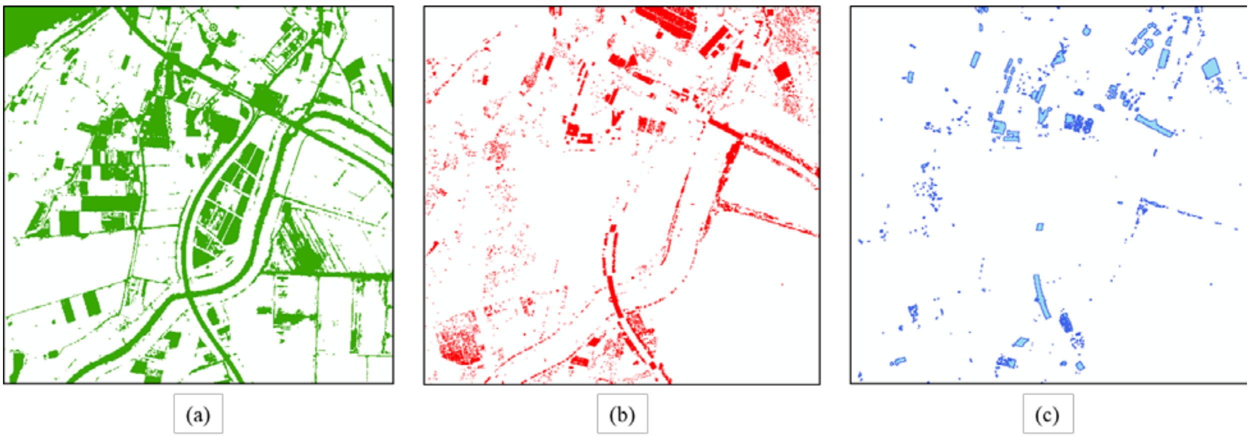


Figure 7. (a) NDVI mask; (b) nDSM mask; and (c) Buffered-mask of the intersected NDVI and nDSM masks; for the whole study area

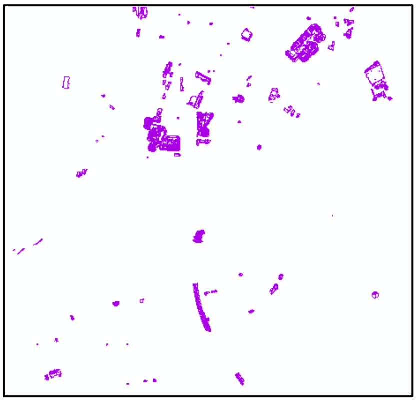


Figure 8. The impervious area of study area

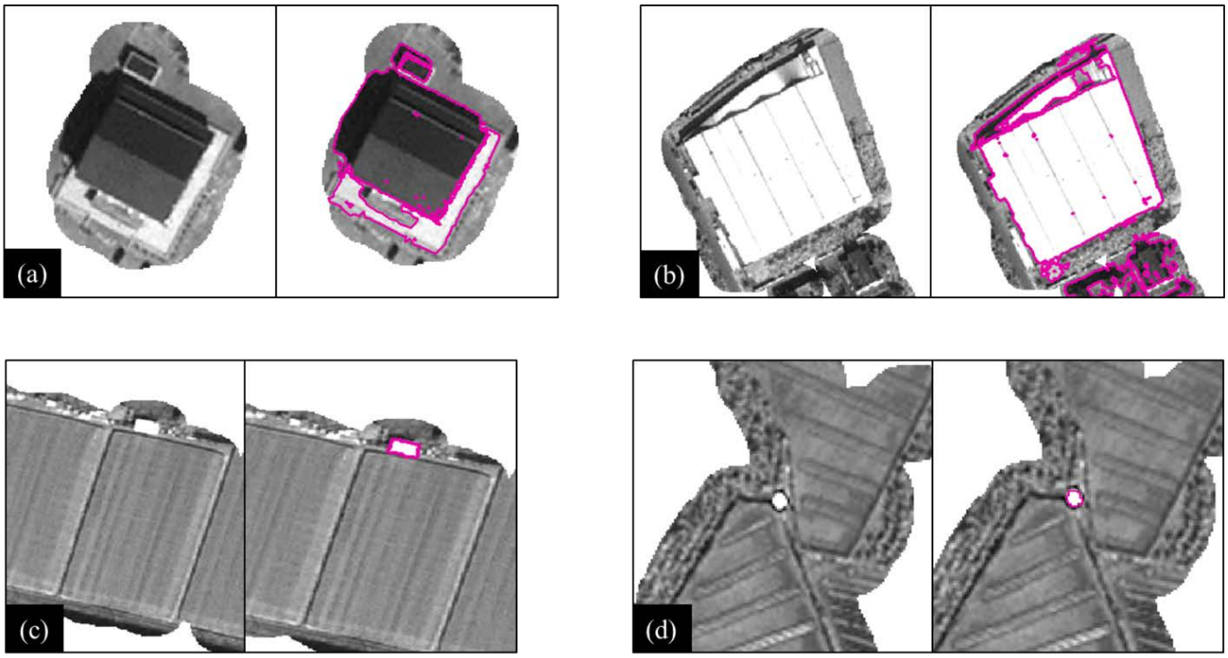


Figure 9. Some impervious area detected in the study area

4. CONCLUSION

Tallying the impervious area in the agriculture land is one of an important task to carry out, especially for the decision maker to make any plan regarding the land-use management. Detecting impervious area using high-resolution satellite imagery can provide us a clear boundary line of the feature. That kind of boundary line could be produced whenever the impervious area, for example, the building, have the high different color-tone with its surrounding pixels.

The proposed method could handle the challenge of the total data size by narrowing down the total area needed to be proceed. Detecting the impervious area by integrating the Pleiades high-resolution satellite imagery and LiDAR data has been proven to increase the efficiency of the processing time. The total impervious area of the study area was 6.895 ha.

The accuracy of the result could be more increased by adding the cadastral or land-use information. Those data would provide us the exact scope of the agriculture area of a county or city. Thus, if we combined it with the current datasets, it would be more powerful.

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