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Measurements of Vegetation Distribution Using Various Local Remote Sensing Techniques

MEASUREMENTS OF VEGETATION DISTRIBUTION USING VARIOUS LOCAL REMOTE SENSING TECHNIQUES

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ABSTRACT

One of the difficult issues in river management in Japan is the treatment of overgrown vegetation developed especially on flood plain, because the vegetation zone sometimes yields natural environment good for birds or small creatures, which makes it difficult to clear the vegetation for improving the flood flow efficiency. However, it is evident that leaving the overgrowth of vegetation untouched might cause flooding due to the increase of flow resistance by the trees; therefore, it is required to establish an appropriate vegetation management scheme. In order to estimate the effects of vegetation with a reasonable accuracy by using a numerical simulation model, detailed information on vegetation such as vegetation distribution, density and height of trees, type of vegetation are necessary. In the present study, four types of local remote sensing techniques are used for measuring a river reach downstream of the Ichikawa River, where vegetation zone has developed on the floodplain and compare the accuracy and features of the methods.

Keywords: local remote sensing, lidar, vegetation, helicopter, stereoscopic measurement

1. INTRODUCTION

The use of local remote sensing techniques has become a promising way for measuring various aspects of river basin, such as vegetation development, riverbed variation, and flood flow, which are difficult to obtain from satellite images. The advantageous feature of local remote sensing techniques is it high density of measurement. A representative local remote sensing method is the use of airborne lidar sensors (ex. Adams and Chandler, 2002, Andersen et al. 2002, and Holmgren and Persson, 2004). This sensor has been also used for measuring individual trees or vegetation distributions for management of river basin (Brandtberg et al., 2003, Hodgson et al. 2003, Holmgren and Persson, 2004, Leckie et al. 2004, and Raber et al. 2002). The other methods of local remote sensing include the ground laser profiler and imaging techniques. As one of the imaging methods, the authors have proposed the use of video image taken from a riverbank to obtain flood surface flow (Fujita, et al. 1998, Fujita, et al. 2007b). Another method for river flow measurement uses a helicopter installing a high-density video camera (Fujita, et al. 2007a). In the present study, four types of local remote sensing techniques are applied for the measurement of vegetation area developed in the lower river reach of the Ichikawa River in Japan. The techniques used are 1) measurement using laser profiler(Lidar) from an airplane 2) stereoscopic surface measurement using high resolution video camera from a helicopter 3) measurement using ground laser profiler and 4) stereoscopic measurement using a digital camera from ground level. The first two methods cover four kilometres of the river reach, while the other two methods concentrated on the two local vegetation zones for the ground truth of the first two methods.

2. MEASUREMENT LOCATION

The general target area is the lower reach of the Ichikawa River, one of a class B Rivers in Hyogo Prefecture and the measurement area of airborne lidar this time is indicated as a rectangle in Figure 1. The drainage area of the Ichikawa River is 506km^2 and the length of the main river is 78km. The bed slope of the upstream area is about 1/100, 1/150-1/300 in the middle area, 1/400 in the downstream area and 1/5000 near the river mouth. Figure 2 shows the aerial photograph of the target area of airborne lidar measurement. As shown in Figure 2, there develops large single bars in the middle of the region, where vegetation zone has developed significantly which might be caused by the flow control at the upstream dams. Since there inhabits a number of birds in this region, this area is considered as a sanctuary for birds. However, it is also true that the vegetation zone becomes a source of significant drag forces once a flood occurs. In addition, a number of weirs have been build to decrease the energy slope and to intake water for rice field. Another feature of the area is that the width of the river decreases in the downstream end section, which can cause the lower efficiency for floods. In the present study, we conducted measurement paying more attention to a local vegetated area shown in Figure 2 as a rectangle.

Figure 1 Basin of Ichikawa River

Figure 2 Area for airborne lidar (2007.10.29)

3. AIRBORNE LIDAR MEASUREMENT

Airborne lidar measurements were conducted in 2006 and 2007 for the same area about 2.7km in the flow direction. The apparatus installed on Cessna 207 is ALTM3100DC produced by Optech co. This lidar apparatus is capable to emit 0.1 million laser shots per second. The criterion for the proper measurement density is at least one point in one meter square. In the measurement of 2006, 3,815,487 point data are obtained, while in 2007 the number of data becomes 10,684,113. In the 2007 measurement, the mean error of altitude was 0.099m and its standard deviation was 0.110m. Figure 3 compares the difference of relative height of objects calculated by the subtraction of the digital elevation model (DEM) from the digital surface model (DSM) within a local area indicated in Figure 2. Since the measurement season is not the same, it is not easy to simply compare the respective data; however, the distribution of vegetation area is made clear and the 2007 measurement provides a taller vegetation zone. This can be due to the leaf drop in spring season in 2006.

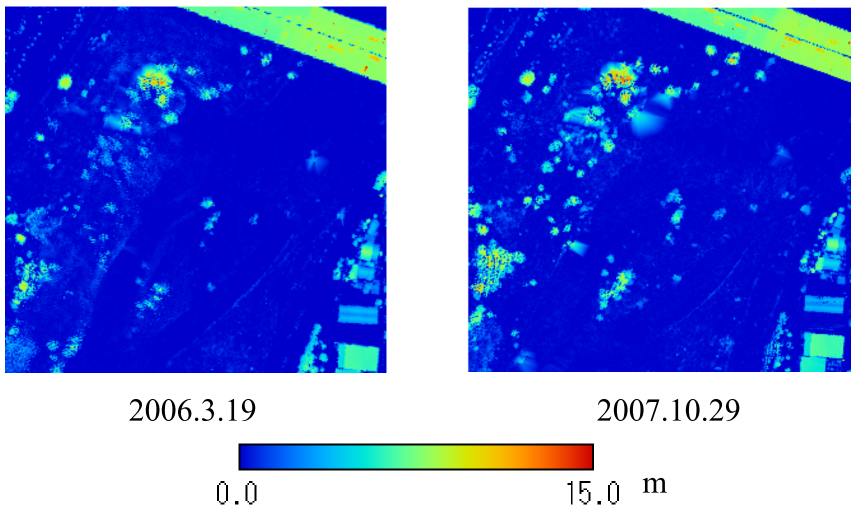


Figure 3 DSM minus DEM（area is 300m by 300m）

4. GROUND LIDAR MEASUREMENT

The ground lidar measurement is conducted on Nov. 17, 2007 by using Scan Station of Leica co. The maximum shooting distance is about 300m and about 4000 laser shots per second are possible with this instrument. In the actual measurement, the ground lidar is set at three locations covering the target local area. By combining the three dimensional data from the three angles, the flood plain model including vegetation area is established as shown in Figure 4(b). The number of data was 6,127,849 in total. The three measurement locations are indicated as white circle in the figure. Figure 4(a) presents the airborne lidar data for the same area. The overall agreement between the two measurements is favorable; however, as we had to set the ground lidar near the ground, laser shots cannot penetrate behind objects such as vegetation zone or riverbank, which results in the erroneous altitude in such area as is clearly seen in Figure 4(b). In order to compare the data more precisely, altitude data along the black arrow line is provided in Figure 5. It is clearly seen that the airborne lidar data in 2006 and 2007 provide little difference between each DSM except for the vegetated area, which confirms the reliability of the method. Also from the comparison with the ground lidar data of 2007, we can find the difference is relatively small in most of the zone (x=100~300m)

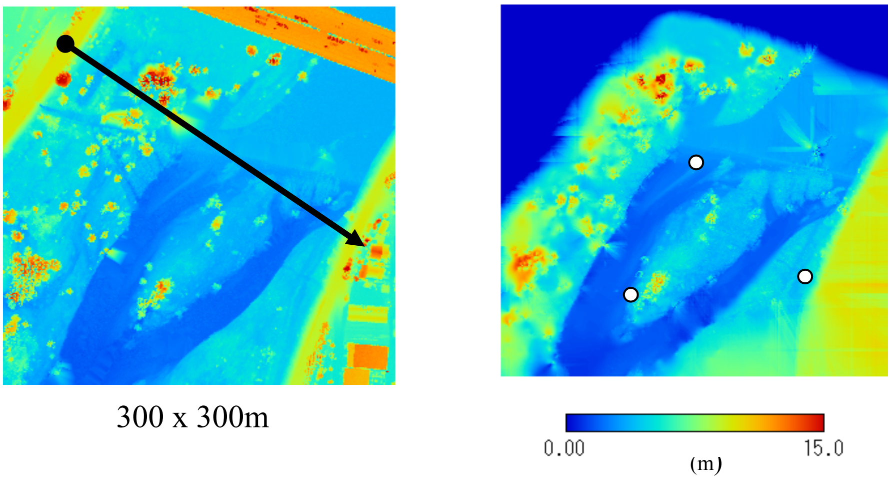


Figure 4 Comparison of laser measurements (left: aerial, right: ground)

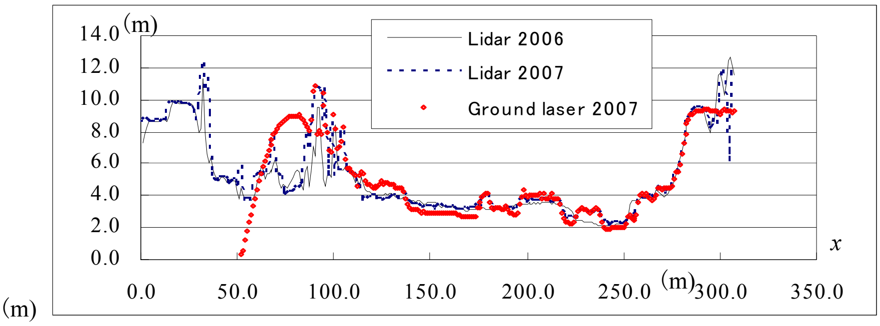


Figure 5 Comparison of measurements by aerial and ground lasers: DSMs along the black line arrow in Figure 4(a)

including the gravel bed (x=150~300m) and vegetated (x=90~150m) zones, although there still remains some disagreement on the order of 0.5m even in the lower channel section. The reason for this disagreement can be due to the differences of the laser beam direction and the measurement density, because the ground lidar yields laser spots about ten times more than that of airborne lidar.

The advantageous aspect of the ground lidar is its ability of extremely high density measurement as presented in Figure 6. It can be easily seen that leaves and stems can be resolved using this instrument. In order to verify the performance of the ground lidar, altitude data within four level bands are picked up for the same area as Figure 4 and indicated in Figure 7. It can be noted that the number of data, mostly corresponding to each of the vegetation, increases with lowering the slicing level and finally the level reaches the ground level as shown in Figure 4(d). The important point to mention here is that it becomes

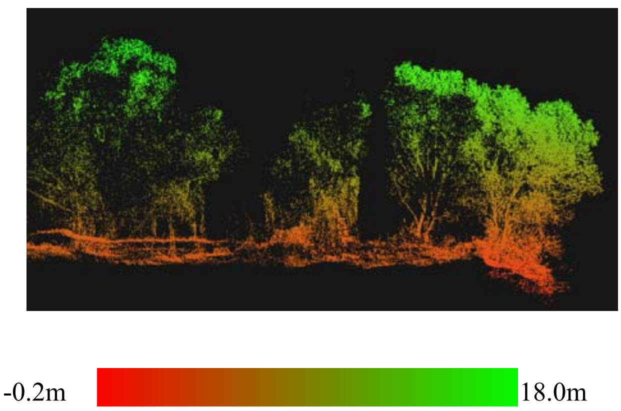
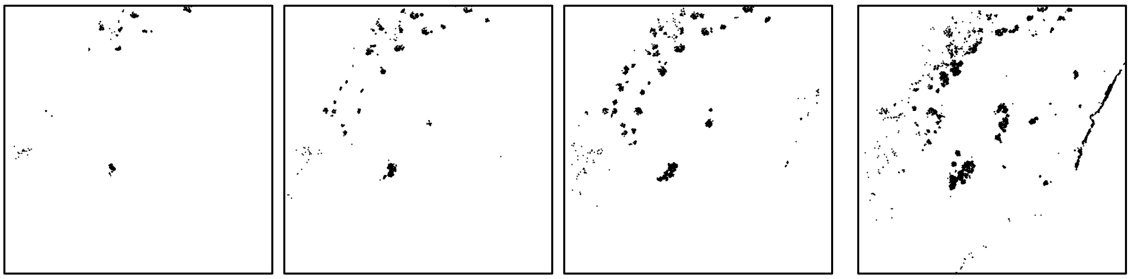


Figure 6 Ground laser data for trees

possible to extract the vertical distribution of vegetation data as well as the number of trees using a ground lidar, which is difficult to obtain from airborne lidar data. This kind of data is of great significance for evaluating the resistance of vegetation at arbitrary water level in the flood flow simulation.



(a) 12.5-13.0m (b) 11.0-11.5m (c) 9.5-10.0m (d) 6.5-7.0m

Figure 7 Vegetation distributions at several level bands

5. STEREOSCOPIC MEASUREMENT WITH DIGITAL CAMERA

The stereoscopic measurement using a digital camera is conducted on the same day as the ground lidar measurement, Nov. 17, 2007. In this measurement, we prepared a 2 meter slider attachable to two tripods as shown in Figure 8 and compared the effect of camera spacing and height. The digital camera we used is Nikon D70, which has a spatial resolution of 3008 by 2000 pixels. An example of an image pair for stereoscopic measurement is shown in Figure 9, shooting the low weir in the center of the image. We used the image analysis software, Erdas Imagine, produced by Leica Geosystems Geospatial Imaging co. We set fourteen mark points in the target field in order to establish a relationship between camera and physical coordinates.

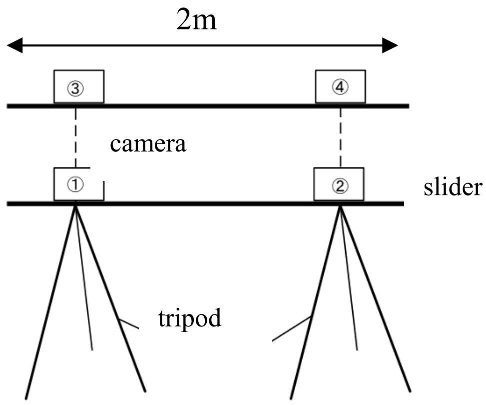
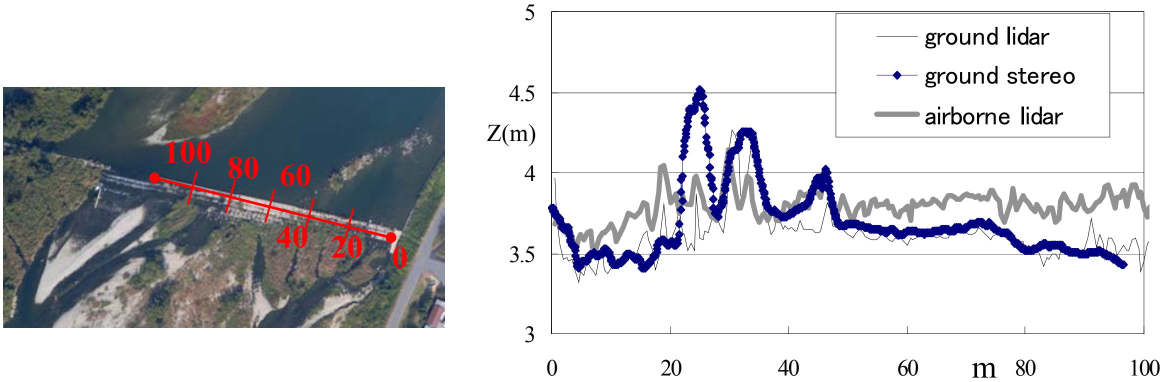


Fig 8 Camera setting

(a) left angle (b) right angle

Figure 9 Images for stereoscopic measurements of a weir



(a) Coordinate along weir (b) Weir height distribution

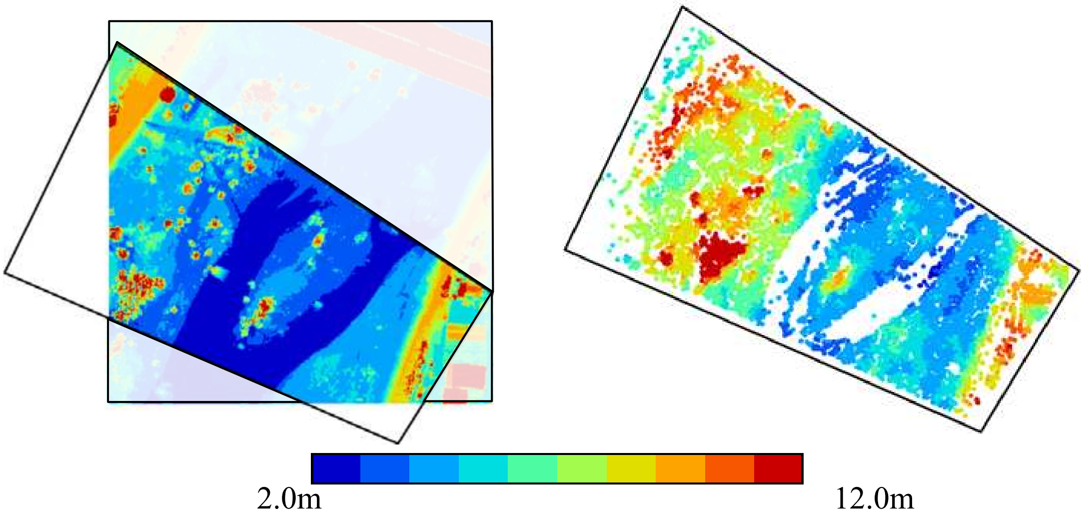
Figure 10 Comparison of imaging method and two lidar methods

Figure 10 compares the measurement results by the three methods: airborne lidar, ground lidar and ground stereo imaging methods. In the ground stereo imaging method, we found that the pair of camera setting of number one and four in Figure 8 yields a better result than the other combinations. Considering the measurement density of data, we can assume that the ground lidar provides the most reliable altitude data in this case. From this assumption, the stereo imaging method yields a surprisingly favorable result within a range of about one hundred meters from the camera location. For example, lowering of the weir in the center of the river is reproduced. On the other hand, airborne lidar fails to provide transverse altitude distribution of the weir. The difference is about 20 cm on the average. The reason for this difference can be attributed to the error in the measurement when targeting a local spot such as a weir in the present case. However, further examination is necessary for this discrepancy. The shortcoming of the ground stereo method is its difficulty to find a place from which an image can cover a large area including vegetation zone. In order to achieve this requirement, a relatively high camera location such as from a tower is required, which is not feasible in the actual situation. Therefore, the stereo imaging method should be used to measure a relatively local area paying attention to transverse variation of river bed or water surface in the application to river engineering problems.

6. STEREOSCOPIC MEASUREMENT FROM A HELICOPTER

The final local remote sensing technique we applied is the stereoscopic measurement from a helicopter. The measurement is conducted on October 31, 2007, which is almost the same timing considering the slow growth rate of vegetation. A high-density video camera, with a resolution of 1440 by 1080 pixels, is installed on the helicopter, whose flying altitude is 305m and speed of 96.2km/s. Although the helicopter took a root much longer than the airborne lidar measurement, we compared the measurement data of the common target area. In the image analysis of stereo images, we applied the same software as used in the ground stereo imaging case.

Figure 11 presents a result of the aerial stereo imaging method by comparing it with airborne lidar result. The image pair having a time difference of three seconds, about 85.7 m in the air, is used for the stereoscopic measurement. The ground control points (GCPs) that connect the camera and the physical coordinates are picked up from the raw airborne lidar data and the corresponding image coordinates. The number of data obtained is 8574, which is



(a) Airborne lidar (b) Aerial stereo

Figure 11 Comparison of the DSM by airborne lidar and stereoscopic measurement from a helicopter

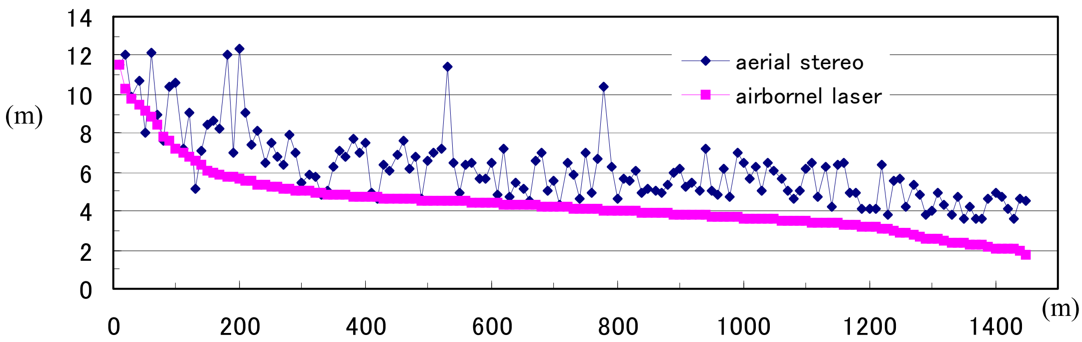


Figure 12 Comparison of aerial stereo imaging data and airborne lidar data

much less than the lidar data. Despite somewhat difference of the absolute altitude, the general distribution of vegetation area obtained by aerial imaging method agrees well with lidar data. For quantitative comparison, altitudes at almost the same point obtained by the two methods are compared by sorting the data by airborne lidar. It is apparent that aerial stereo imaging method overestimated the altitude. The average difference is about 1.8m and the standard deviation is about 1.2m in the present case. However, the general trend of the altitude variation agrees fairly well with the lidar data as can be observed in Figure 12.

In order to compare more specifically, two local areas, one with the area of totally vegetated (area 1, 30 by 30m) and the other with isolated vegetation (area 2, 20 by 20m) are compared in Figure 13. The respective location is indicated in Figure 13(a). In the case of area 2, there grows a tree with a height of more than ten meters within the area. While the airborne lidar captures this tree successfully as shown in Figure 13(b), aerial stereo imaging's result underestimates the value significantly as indicated in Figure 13(c). The tree in the center of the area is captured as a slight increase of altitude distribution. However, ground level information is obtained fairly well as shown in Figure 14(a), which is a similar plot of Figure 12.

Figure 13(e) is the results of the fully vegetated area, area 1. The airborne lidar data

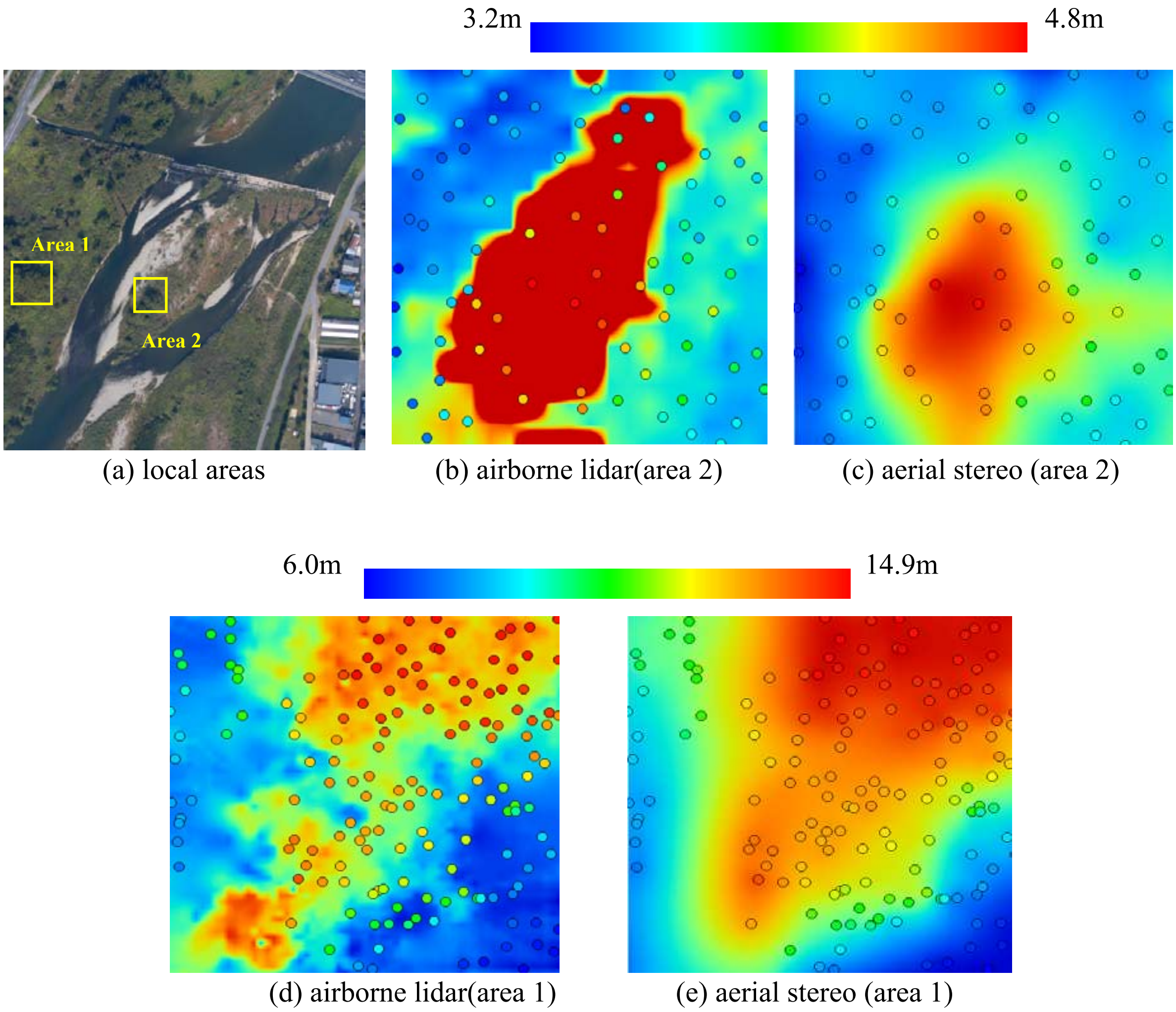
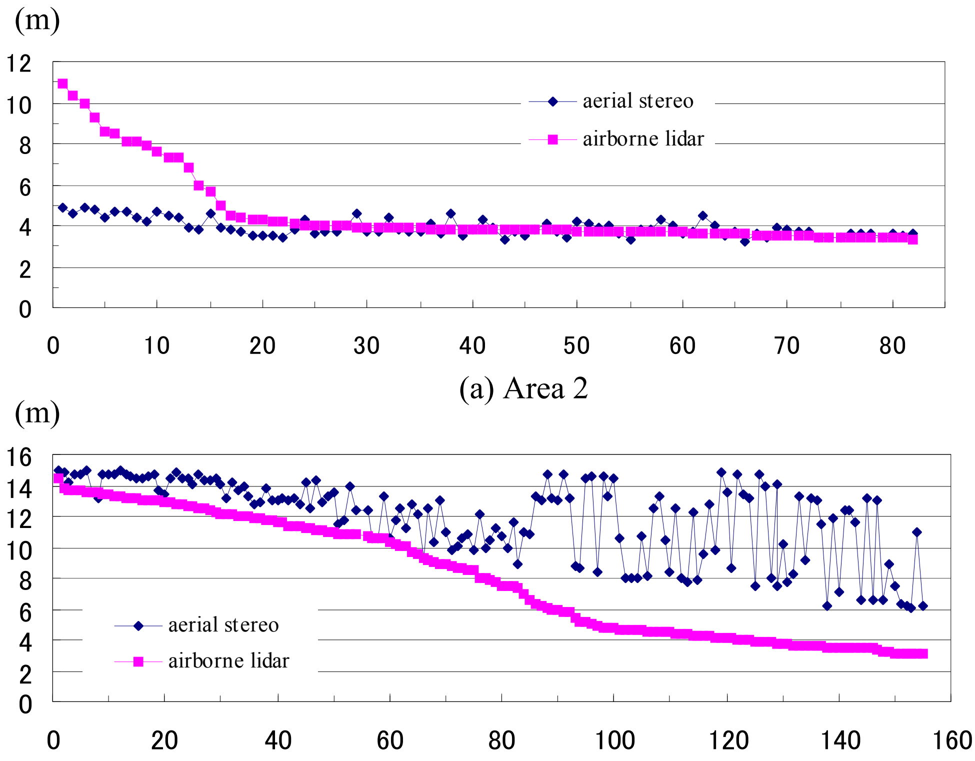


Figure 13 Comparison of local altitude distribution: area 1 is 30m by 30m, area 2 is 20m by 20m; color of circle in lidar data is that of aerial stereo data

provides a patch-like pattern, while the stereo imaging data shows a relatively smooth variation. The patch-like pattern in Figure 13(d) is generated due to the fact that some of the laser beams penetrate into the vegetation and reach the ground level. Figure 14(b) provides the comparison of the two methods. The above figures suggest that the height of vegetation zone can be favourably captured by a stereo imaging method as long as the vegetated area has a spatial distribution.

7. CONCLUSIONS

We have conducted four types of local remote sensing techniques to the same vegetated area of the Ichikawa River almost at the same time and evaluated the performances of .each method by comparing the altitude data. Since the number of obtained data is totally different between the laser measurements and stereo image measurements, it is not easy to make a reasonable comparison. The advantage of the laser measurements is their extremely high density of data points; however, the cost of measurement is also very high and thus it is difficult to conduct the measurements frequently. On the other hand, although the imaging techniques yield much less data than the laser measurements, the measurement data provides comparable results if we know the characteristics of the imaging data from a practical point of view. The imaging methods are economically advantageous over the laser methods as well.



(a) Area 2

(b) Area 1

Figure 14 Comparison of DSM data; sorted for airborne lidar data

However, since the imaging techniques are indirect measurement their results can be influenced by various factors such as lens aberration, error in mapping relation, viewing angle, and the reliability of height and speed data of a helicopter, etc. Therefore, further examination of the stereo imaging methods are required.

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