LAWN MONITORING AT GOLF COURSE USING INTEGRATION OF GIS, REMOTE SENSING AND GNSS TECHNOLOGIES

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ABSTRACT: To monitor the damages to lawn of large golf courses needs lots of labors. In this study, Satellite Remote Sensing, UAV and GNSS technology are applied for lawn monitoring to improve lawn management efficiently. Identifying patches of dead lawn caused by water shortage and stress due to foot and cart traffic can lead to maintenance cost cutting through efficient fertilizer and/or pesticide spraying. With the method for automating dead lawn identification developed, treatment through water and fertilizer/pesticide application is optimized. It is possible to develop a system for lawn management with dramatic cost reduction compared with the traditional management system. The areas where lawn damage occurred at the golf course were detected by calculating NDVI (Normalized Difference Vegetation Index) using high resolution satellite image firstly. An Unmanned Aerial Vehicle (UAV) or drone was used to acquire images in more detail to supplement the satellite images. Moreover, trajectories of golfers were collected by carrying GNSS logger at the test site. The golf course was divided into grids and treading stress index was calculated in each grid using trajectory data from GNSS.
The method developed for lawn monitoring using remotely sensed data integrated with GNSS data is a unique approach and very effective. This method can be promoted and improved further because there are still limited application cases. This is also the first research and trial to analyze the movements of golfers from GNSS loggers for work control and treading stress determination on lawn. New space data utilization can be developed for data integration to solve the issues in this project.

1. INTRODUCTION

In Japan, several mountains cover 60% of the national land. Yamaguchi Prefecture, which is located in the western part of Japan, has 67% of its area covered by mountains, with around 800 sites identified as disaster-prone areas. Many observations, including satellite data, have been made to monitor these areas during normal time but disasters do not always occur.

Satellite image usually observes wide area. Once disaster like landslide occurs in mountainous area, only small parts of the satellite image are used for analyzing disaster damage. These satellite images include large portion of unaffected areas that are not usually used. This study explores using these satellite images acquired for disaster monitoring in other non-disaster purposes, thus serving dual purposes. This is advantageous since it optimizes the usage of the satellite images. If facilities like parks, campsites, golf courses in mountainous areas are observed by imaging satellites, it is possible to detect the occurrence of landslide through time series analysis of archived images. Additionally, these can be used for updating the maps that will aid in rescue operations in times of disaster occurrence.

Many golf courses are reflected in satellite images that are taken in mountainous areas for disaster monitoring. There are 38 golf courses in Yamaguchi Prefecture, and huge amounts of money are spent for its maintenance. This study investigates the possibility of the satellite image usages for monitoring the condition of the lawn in golf courses.

A golf course is a vast site and detecting unhealthy lawns only by monitoring the ground by green keepers is labor intensive (Robert et al., 1987, Dimock et al., 2004). The purpose of the study is to improve the efficiency of lawn management by easing and expediting lawn management work in golf course using remote sensing technology. Lawn maintenance is usually performed based on the experience and intuition of ground keepers. It is said that there are 32,471 golf courses in 209 countries, and Japan ranks third in the world in terms of number of golf courses, with 3,169 courses, 45,684 holes and 2,227 facilities (The E&A, 2020). So, the method proposed in this research has the potential to be used in many different places.

2. REMOTE SENSING DATA ANALYSIS

2.1 Study Site

In this study, Ube Country Club 72 in Ube City, Yamaguchi Prefecture is a test site as shown in Figure 1. Yamaguchi Prefecture is the westernmost tip of main island in the Japanese archipelago, and this golf club is the largest golf course in western Japan with 72 holes on four courses on a vast site, occupying 3.4 square kilometers. This study focuses on one of the courses with 18 holes.

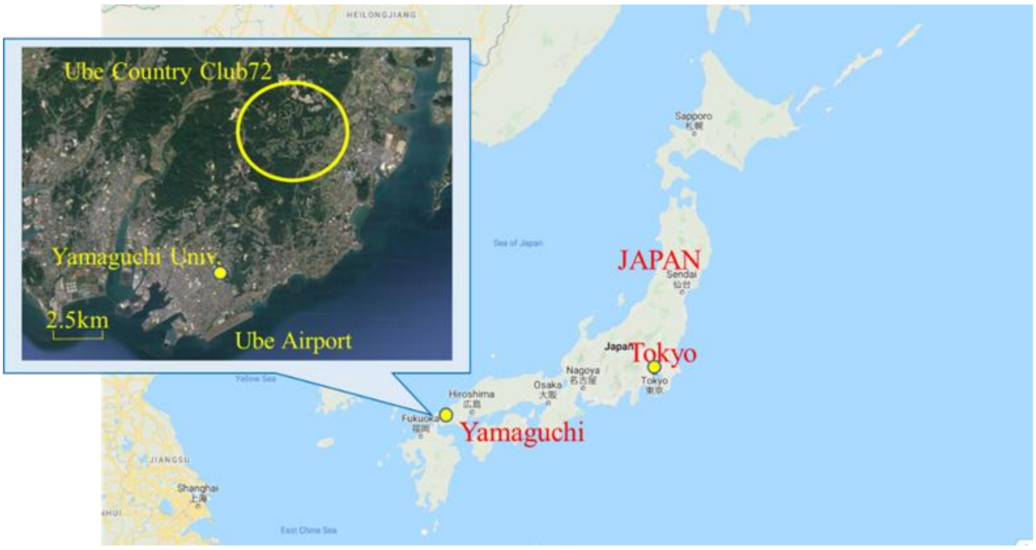

Figure 1. Location of the study site

2.2 Collected Data

In this study, data are acquired from satellite, drone and GNSS survey. The satellite images are obtained from Landsat-8, Sentinel-2 and Pleiades. In case of drone, data acquisition is performed using optical camera Parrot Sequoia installed in the fixed-wing drone eBee Classic of SenseFly Inc. Table 1 shows an overview of the acquired data.

Table 1. Overview of the acquired data

Platform	Observation Date	Specification
Landsat 8 (from USGS)	(Seasonal data) Spring: 16th May 2019, Summer: 4th Aug. 2019, Autumn: 14th Oct. 2019, Winter:10th Dec. 2019	Resolution: 30m
	(Time series data) 1st Aug. 2018, 5th Aug. 2017, 2nd Aug. 2016, 9th Aug. 2015	
Sentinel-2 (from USGS)	(Seasonal data) Spring: 7th May 2019, Summer: 10th Aug. 2019, Autumn: 14th Oct. 2019, Winter:10th Dec. 2019	Resolution: 10m
	(Time series data) 1st Aug. 2018, 5th Aug. 2017, 2nd Aug. 2016	
Pleiades	(Seasonal data) Spring: 7th May 2014, Summer: 20th Jul. 2018, Autumn: 16th Oct. 2015, Winter:16th Nov. 2016	Resolution: 2.8m
eBee (Sequoia)	03rd Dec. 2019, 28th Jan. 2020	Resolution: 5cm

2.3 Landsat Data

Landsat is an earth observation satellite launched by the National Aeronautics and Space Administration (NASA) from 1972, and currently in operation (Michael A. W, 2019). The resolution is 30 m. This low-resolution image is used to analyze lawn vegetation. After downloading the seasonal Landsat images of 2019, the NDVI (Normalized Difference Vegetation Index) are calculated to characterize their vegetation. NDVI is calculated by (Band4-Band3)/(Band4+Band3), as commonly used, Band-3 is Red, and Band-4 is NIR (Near Infrared). Seasonal changes in vegetation are analyzed by taking NDVI differences. In addition, the condition of lawn changes is analyzed by examining the NDVI secular change. Here, the possibility of lawn management in satellite images with low resolution is examined. Figure 2 shows Landsat images. The left side of the figure is an enlargement of RGB image at the course, and the right is a false color image of the entire course using Landsat.

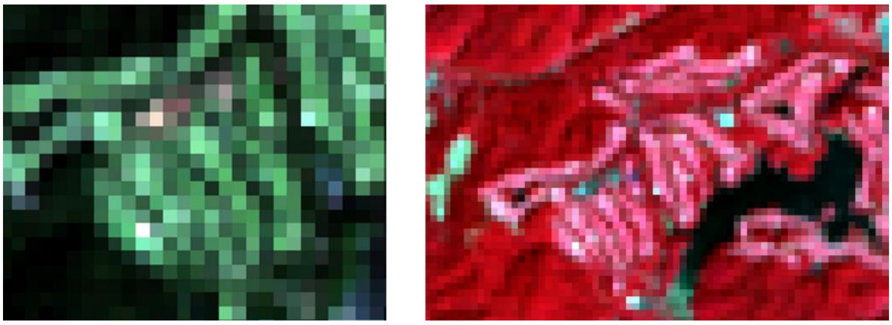

Figure 2. Landsat images/ Left: Zoomed in image of the course (RGB; B2, B3, B4), Right: Whole image of the course (False Color: B5, B4, B3)

Figure 3 shows the results of NDVI for each season using Landsat 8. The upper images show the results of NDVI for each season, and the lower images show changes in NDVI due to the change of seasons. From spring to summer, there is little change in vegetation, and from summer to autumn, the vegetation in the surrounding forests are decreasing, but there is little change in lawn vegetation on golf courses.

From autumn to winter, vegetation other than the lawn on the golf course are clearly reduced, but the lawn on the golf course shows little change in vegetation. From winter to spring, it is found that vegetation increased in many places including golf courses.

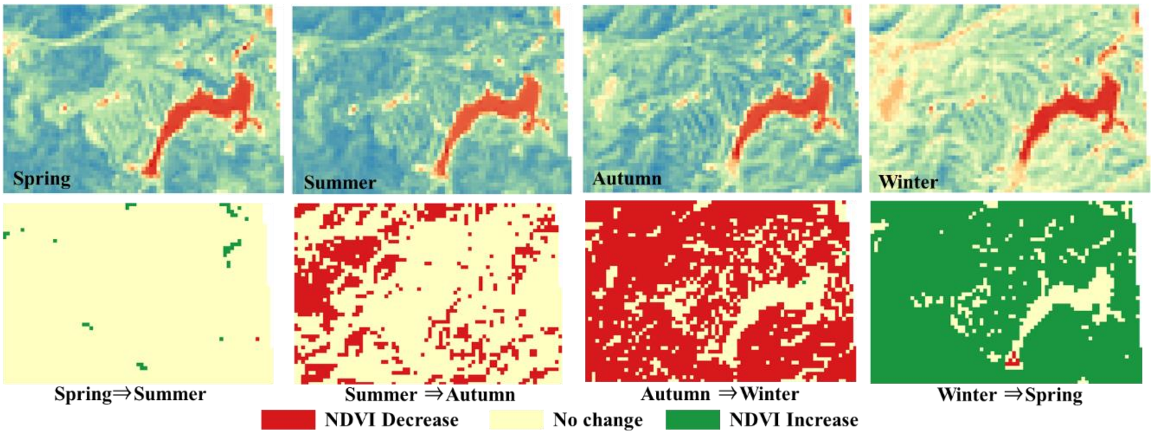

Figure 3. Landsat NDVI seasonal comparison

The upper part of Figure 4 shows NDVI calculated from LANDSAT images taken during the summer season from 2015 to 2019, and part of the results obtained by taking the difference over time for each NDVI are shown in the lower part of Figure 4. Red indicates decrease, light yellow shows no change and green indicates increase in NDVI.

According to the lower part of Figure 4, the result shows that NDVI decreased as indicated by red. There was little change in vegetation between 2015 and 2016, but the value of NDVI changed significantly on the lawn of the golf course from 2016 to 2019.

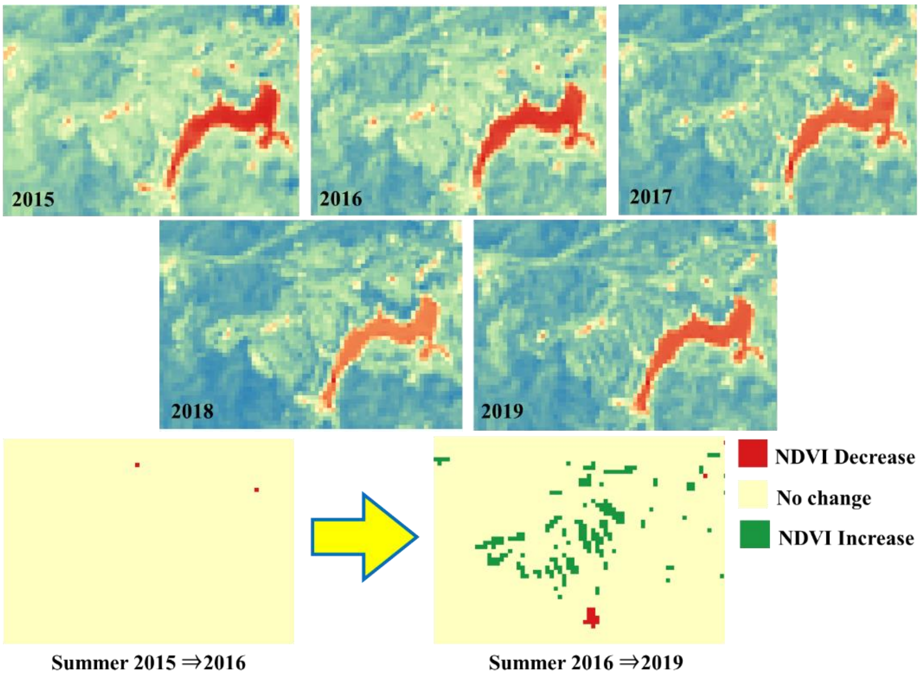

Figure 4. Landsat NDVI seasonal comparison

2.4 Sentinel-2 Data

Sentinel-2 is an earth observation mission as a part of the Copernicus program launched by European Space Agency (ESA) (Zoltan Szantoi,2019). It conducts surface observations to support projects such as forest monitoring, land cover change detection, and natural disaster countermeasures. It acquires multispectral data over 13 bands, and in this case, band 4 (Red) and band 8 (NIR) are used in the calculation of NDVI. The lawn vegetation is analyzed using this medium resolution satellite image with a resolution of 10 m. Figure 5 shows an image of the Sentinel-2 in the study area. The left figure is an RGB image in which the course is enlarged, and the right figure is a false color composite of the image of the entire course.

The same data processing used in Landsat is applied to analyze seasonal and time differential changes of vegetation in satellite images at medium resolution.

Figure 5. Sentinel-2 Image / Left: Zoomed in image of the course (RGB: B04, B03, B02), Right: Whole image of the course (False Color: B08, B04, B03)

The result of seasonal NDVI using Sentinel-2 taken in 2019 are shown in the upper images of Figure 6 and the results of seasonal vegetation change are shown in the lower parts.

The summer images regarding to Sentinel-2 for the study area in 2019 had many clouds, only images with less cloud cover are used for the analysis. It affects the values of NDVI due to this limitation. There is little change in vegetation from spring to summer and summer to autumn, but the red part in the dotted oval at the lower left of the figure is not due to the decrease in vegetation, but to the effect of clouds.

From autumn to winter, the vegetation around the golf course lawn has been slightly affected, but the lawn and surrounding vegetation have been reduced. From winter to spring, the vegetation of the trees surrounding the golf course have not changed much, but vegetation has increased in many places including the lawn.

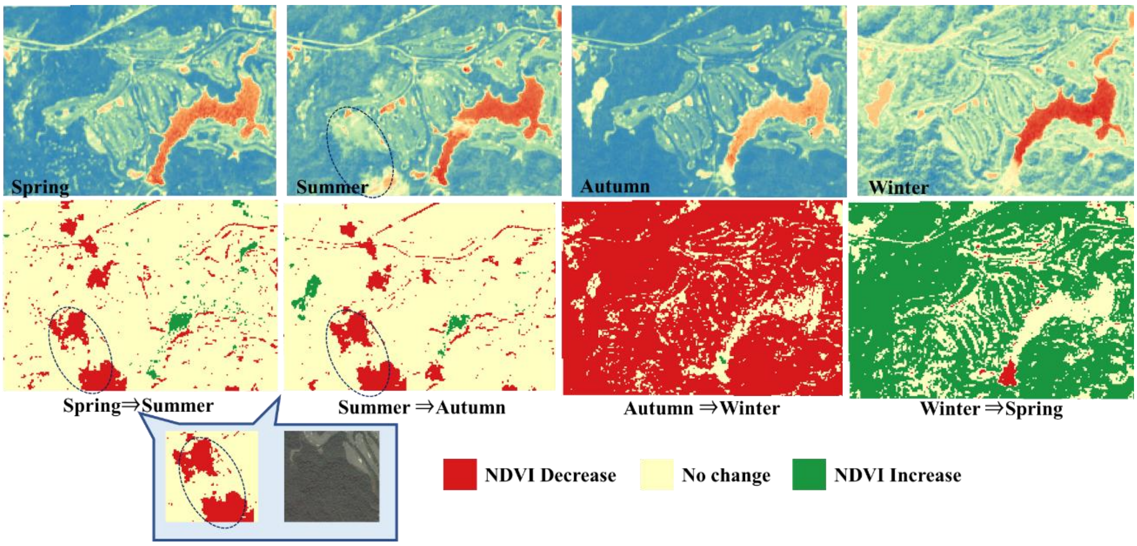

Figure 6. Sentinel-2 NDVI Seasonal Comparison

Figure 7 shows the time-series changes in NDVI of Sentinel-2 in the summer season. Most of the images are covered with clouds and only the images shown are useful. The results of the analysis showed that the NDVI on the lawn vegetation on the golf course becomes clearly higher from 2016 to 2019, the same result is obtained in the NDVI analysis from Landsat.

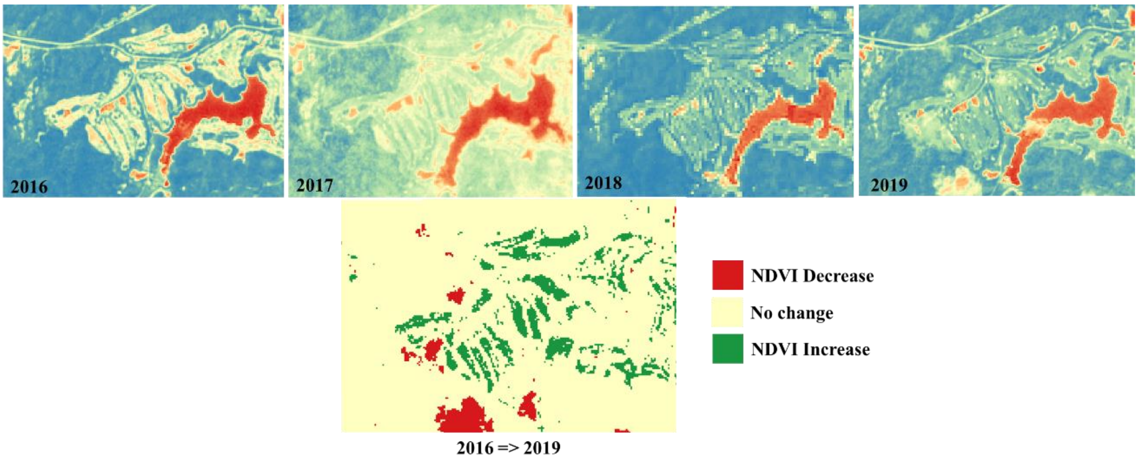

Figure 7. Sentinel-2 NDVI Timeseries Comparison

2.5 Pleiades Data

Pleiades is an earth observing satellite operated by the French Space Agency (CNES). It is equipped with a visible / infrared light multispectral sensor with common wavelengths of three visible bands and one near infrared band, and a panchromatic sensor for high-resolution imaging. Multispectral resolution is 2.8m (M. Alain, 2012). NDVI analysis is performed using this high-resolution satellite image.

The relationship between NDVI and the trajectories of the golfers who are equipped with GNSS loggers are examined by overlaying them on the image of Pleiades. By displaying the value of NDVI with the trajectories, the relationship between the trajectories and NDVI is analyzed. Figure 8 shows an image of the Pleiades in the study area. The left figure is an RGB image in which the course is enlarged, and the right figure is a false color composite of the image of the entire course using Pleiades image.

Figure 8. Pleiades Image/ Left: Zoom in image of the course (RGB: B04, B03, B02),

Right: Whole image of the course (False Color: B05, B04, B03)

Figure 9 shows the seasonal NDVI results for Pleiades. Compared to Landsat or Sentinel-2, the study area can be discriminated in detail. For example, the differences between greens, fairways, and courses can be identified. As a result, this makes it possible to relatively evaluate the difference in the degree of lawn activity for each course.

There are some difficulties in analyzing the seasonal differences by overlaying the images. This depends on the satellite mode of acquisition e.g. descending or ascending. But it is clearly identified the seasonal NDVI changes using Pleiades satellite imageries.

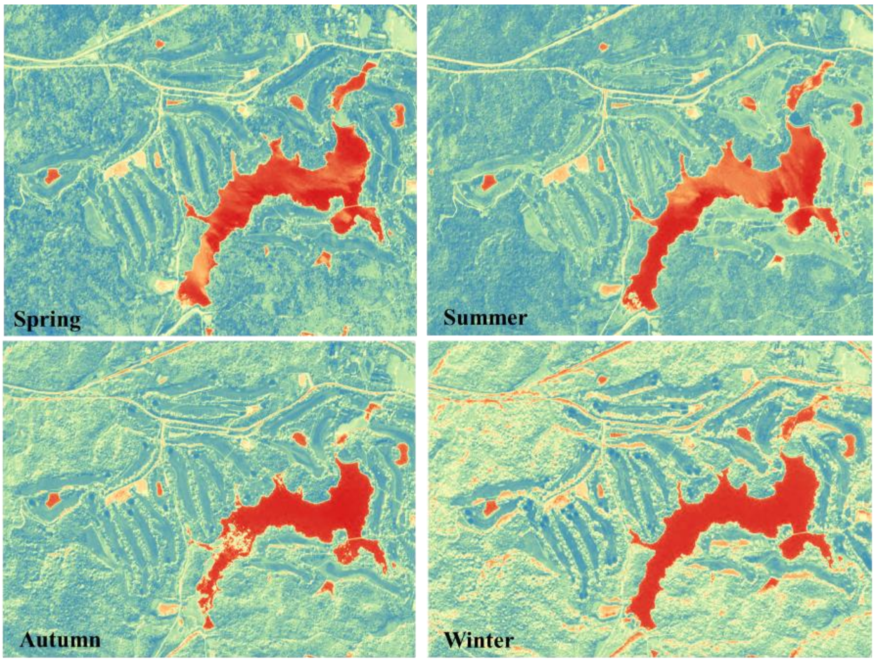

Figure 9. Pleiades NDVI Seasonal Comparison

2.6 Drone

Since the NDVI values change depending on the influence of shadows and micro topography for analyzing the vegetation, the golf course is observed not only with optical satellites but also with fixed-wing drones.

In this study, SenseFLY's eBee-Classic fixed-wing drone with Parrot Sequoia + multispectral camera with about 5cm resolution is used, which is capable to detect small objects as small as 10cm. The specifications of the drone and onboard camera are shown in Table 2. As a result, the detection of abnormalities such as a hole dug during play by a player, dying of a turf, withered lawn, a puddle, and digging of a course by a wild boar (this is a problem that has been declared in this test site) are examined.

Table 2. Specification of Drone and Camera

Drone (SenseFLY)	eBee Classic	Wingspan: 96cm (37.8in), Weight: 0.69kg (1.52lb), Cruise speed: 40-90 km/h, Wind resistance: up to 45 km/h 
Camera (Parrot)	Sequoir	4 spectral cameras 1.2 Mpx, 10 bits Global shutter, RGB camera 16 Mpx, 72g, 39.6x47x18.5mm

Figure 10 shows an image of the drone in the target area. In this study, 8 courses out of 18 courses of the targeted golf course are photographed by drone. The upper parts of the figure are an RGB images of a part of the course, and the lower parts of the figure are false images of the entire 8 courses.

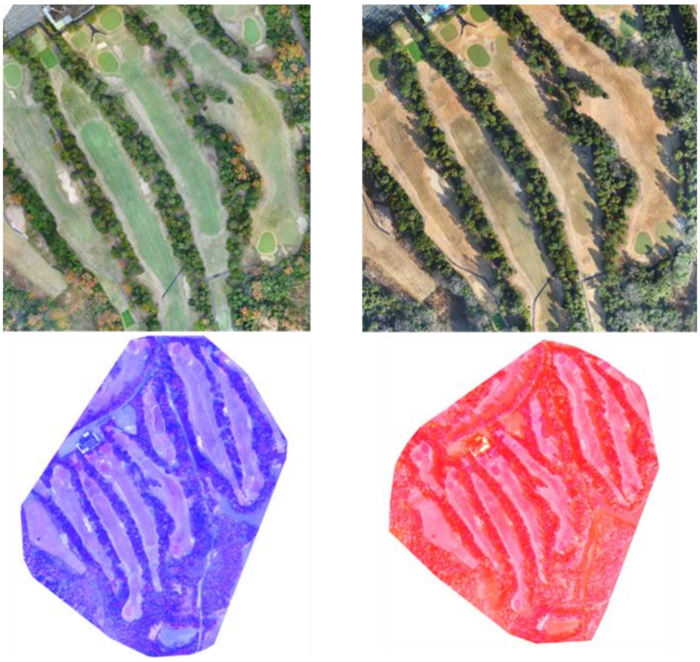

Figure 10. Drone Image/ Upper: Zoomed in image of the course (RGB: B03, B02, B01), Left: 3rd Dec. 2019, Right: 28th Jan. 2020, Lower: Whole image of the course (False Color: B04, B03, B02), Left: 3rd Dec. 2019, Right: 28th Jan. 2020

Figure 11 shows an example of a detailed drone image. In this way, it is possible to grasp the state of lawn and locate where many of the small holes are and areas that are withering. Drone can obtain detailed data of a particular place when it is needed, instead of imaging the whole vast site.

Figure 11. Example of detailed drone image.

3. GNSS Data analysis

The GNSS technology is used for two applications: The first is for GCPs (Ground Control Points) establishment for use in georeferencing and overlaying the satellite images and UAV acquired images. The other is to trace the trajectory of the golfer and use it to verify the lawn treading stress.

3.1 GCP for overlaying images

To measure GCP, high-precision positioning is performed using U-Blox C00-F9P multi band GNSS receiver. The coordinates of the GCPs are computed by post processing the data using the data from one of the CORS (Continuous Operating Reference Station) of the Geographical Survey Institute at Yamaguchi, Ube.

3.2 Golfer’s trajectory

The trajectory of the golfer's movement is observed and used to verify the effect of tread pressure on the lawn using GPS logger “I got U”. The GPS logger is worn on the player's arm and waist as shown in Figure 12. The golfer's trajectory is observed at one point per second. Figure 13 shows the observed trajectory.

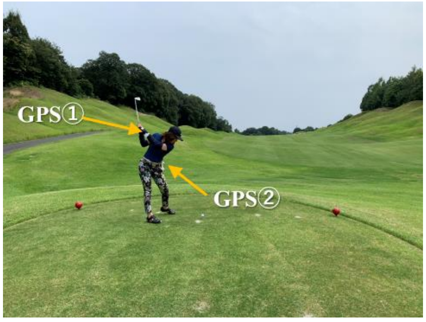

Figure 12. Player with GPS Logger.

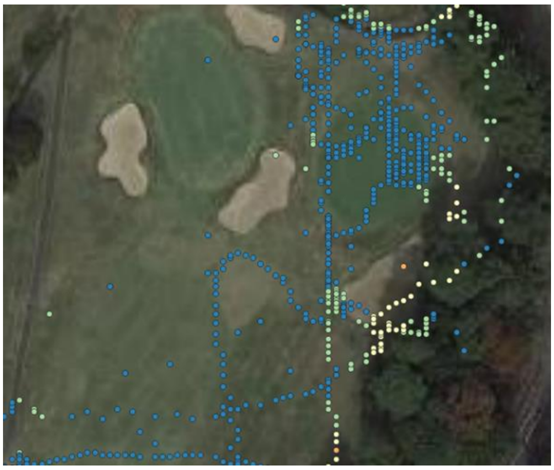
Figure 13. Player with GPS Logger.

3.3 Creating a golfers’ trajectory grid

A golfer's trajectory is thinned out by one point every 30 seconds, a 10m x 10m grid is created, and the number of people who stepped on the grid is measured. Figure 14 shows the number of trajectories on 10m grid at a part of the test site. The darker the color the greater the number of trajectories. Where more golfers step in, it is likely that many people would step on the lawn and damage it.

Figure 14. Player with GPS Logger.

4. Conclusion

In this study, we investigated the use of satellite data acquired for the purpose of disaster monitoring for other non-disaster application. In particular, the study focused on utilizing satellite images for lawn monitoring of golf course.

The golf course is normally a vast site and costs a great deal of money to maintain. In addition, the course maintenance is monitored by experienced green keepers and labor intensive.

The lawn condition of golf courses was analyzed using various satellite images such as Landsat 8, Sentinel-2 and Pleiades. Landsat-8 is effective for analyzing the aging of the lawn, although its intensive resolution is low. Since Sentinel-2 is effective in analyzing aging and seasonal changes, it can be used for lawn management in each season.

Pleiades being a high-resolution satellite image can be used to analyze changes in vegetation for each course even in the same season, so that the lawn status can be inferred in more detail. The UAV or drone can obtain localized images and is very effective for locating lawn damage due to its very high resolution. The GNSS data not only helps to georeference the images acquired by the Drone, but also collects the trajectory data of the player. By overlaying the trajectories of the players on the image, the grid having more trajectories identifies areas with possible lawn damage.

The combination of space data and in-situ measurements facilitates the efficient maintenance of the golf course by providing a general information of the lawn condition from satellite images up to detailed identification of lawn damages from UAV and GNSS logger. Archived satellite images acquired for disaster monitoring is re-purposed for other non-disaster application i.e. golf course maintenance, thus optimizing their use. Other applications can also be explored in various fields. If the cost of data is reduced by dual use during disasters and during normal times, it can be used in various fields.

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