Long term change of land use in Ishigaki Island, Japan

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Abstract. The differences in land resource use methods depend largely on climate change, the natural situation of the area and society. Until now, there has been much research on climate change and the impact of economic globalization on land use in the region, but land use hasn’t been discussed as a regional strategy. In this research, the land use map was reconstructed while paying attention to the historical changes of Ishigaki Island in Japan. Tourism is the main industry in the island. However, coral reefs, which are important as tourism resources, have been threatened by red soil runoff from farmland and development sites. Red soil runoff became worse in the pineapple boom that has occurred since the 1950s. After that, the “Red soil prevention law of Okinawa Prefecture” was enacted in 1994, and the red soil runoff was suppressed. Based on these social changes, we reconstructed the land use maps in 1921 (before pineapple boom), 1966 (the pineapple boom) and 2004 (after Red Earth Ordinance). As a result, it was found that the cultivated area of pineapple is expanding and reducing with the pineapple boom.

1. Introduction

Land resources are indispensable for human life and are the relationship between nature and human society. Resources have regional characteristics, and the use of land resources depends heavily on local natural characteristics and human society [1]. Especially on small islands where the economy is supported by tourism, agriculture and fisheries industries that feature nature, they are susceptible to the effects of climate change and socio-economic changes. Moreover, although it is indispensable for local people, agriculture and tourism using nature can be a cause of environmental problems. To date, there have been many papers describing the impact of globalization and climate change, such as overconsumption and greenhouse gases, on local land use. However, there has been little discussion about land use as a regional strategy. Therefore, land use that is affected by socio-economic changes needs to be considered while considering historical changes.

As a historical background, Ishigaki Island had a pineapple boom since 1956. Until then, he worked to increase the production of sugar cane as a cash crop [2]. This pineapple boom represents the period when canned pineapple was expanded to the economy that canned pineapple was made a “Nansei Islands commodity” by the Japanese government and was subject to a protection policy. Pineapple production in Okinawa started in 1956 [3]. Around this time, the red soil problem, in which rivers and seas were contaminated by the outflow of red soil, became apparent. There are two peaks in the pineapple boom, with the first peak in 1967. The second peak was in 1980. After that, the production of Pineapple decreased, and the ordinance was enacted in 1995, changing to agriculture that emphasizes nature conservation [4]. The land use map used in this study was 1921 before the Pineapple boom, 1966, which
is the development period just before the Pineapple boom Peak, and 2004, the nature conservation period after the Pineapple boom. As mentioned above, the socio-economic situation of Ishigaki Island, particularly related to agriculture, has changed significantly over the past 100 years, and land use has also changed significantly. However, there are no studies that quantitatively examine the changes. The purpose of this paper is to reconstruct the land use map based on geographical parameters such as soil pH and slope. Furthermore, quantitative land use changes will be examined while paying attention to long-term changes from the created land use maps.

2. Methods

2.1. The study area

Ishigaki Island, the subject of this study, is part of the Yaeyama Islands at the southwest end of the Japanese archipelago. Ishigaki Island is located at about 24 degrees north latitude and about 124 degrees east longitude. The climate is subtropical. The average annual temperature is 24.6 degrees and precipitation is 2100 mm. It is warm and rainy, but the variation in rainfall varies depending on the season. A typhoon approaches from May to October [5]. Total area is 222.24 sq km, farmland area is 31%, forest and wilderness account for 42% [5, 6]. Population is 49686 in 2019 [7]. The economy is supported by tourism and agriculture. For agriculture, sugarcane accounts for 40% of cultivated land. Sightseeing feature natural scenery and scenery such as the sea and traditional streets.

2.2. Data analysis

In this study, ArcGIS 10.5 was used to analyze the 1921, 1966, and 2004 land use maps [8]. In the analysis, we used the DEM (digital elevation model) data with a spatial resolution of 50m and the digital soil map [9]. Land use data was classified into bare land, forest, paddy field, pineapple, sugar cane, urban and water. Water was the sea, river, dam, pond. At this time, in 1921 and 1966, the field was cultivated land that could not be classified as sugar cane or pineapple. Furthermore, I first categorized Fields by pH using digital soil maps [10]. I analyzed the relationship between sugarcane and slope calculated from pineapple's Dem, and the relationship between pineapple and pH, using the 2004 land use map. At this time, The minimum is 0 degrees and the maximum is 38.05 degrees. The slope with the decimal part rounded down is represented as slope0 to slope38. From this analysis, it was confirmed whether pineapple was cultivated on sloped land with higher acidity than sugar cane and good drainage.

![Flowchart of land use map creation procedure](image)

**Figure 1.** 1966 land use map creation procedure
As for 1921, the cultivated crops at that time were estimated from the village history [11]. For 1966, I first added together from a low pH location. However, the field whose pH was unknown was Sugar cane, pH soil less than 1966 pineapple cultivation area was classified as Pineapple. The pH soil exceeding the cultivation area was classified as Sugar cane. The pH soil just including the cultivation area was further classified using slope. We added Fields in descending order of Slope. Slope soil less than the cultivation area was classified as Pineapple. Sugar and Pineapple were used as slope soils that were larger than the cultivation area. Pineapple has a cultivation cycle of 5 years [12]. The planting area from 1962 to 1966 was added to obtain the pineapple cultivation area in 1966.

3. Results

3.1. Relationship between sugar cane, pineapple and slope, pineapple and pH

Fig. 2 shows the ratio of the sugar cane and pineapple slope areas to the sugar cane and pineapple cultivation areas. Sugarcane and Pineapple existed between slope0 and slope21. Sugarcane has an area peak of 26% at slope1, and pineapple has an area peak of 18% at slope2. Moreover, the ratio of the area of pineapple to the soil area of each pineapple and each pH is shown in FIG. When the pH was 5.9, the maximum value was 68%, the proportion of the pH 5.9 millimeter pH area was 23%, and the proportion of the pH area larger than pH 5.9 was 3%.

![Figure 2. Pineapple field on slope](image)

![Figure 3. Relationship between sugar cane, pineapple and slope](image)
Figure 4. Rate of pineapple area at each pH to total pineapple area in 2004

3.2. 1921 land use map

A map of land use in 1921 is shown in Figure 5. Yaeyama, where Ishigaki Island is located, introduced pineapple from Taiwan in 1930. In addition, sugar cane was not yet cultivated in 1921, but this time all fields except pineapple were classified as sugar cane. So all the fields in 1966 were sugar cane. In the direction of Kabira, Sakieda and Nakasuji, there is a description that pineapple was settled by Dutch ship in 1866, but at this time, only some Taiwanese people cultivated pineapple for self-consumed [2]. Therefore, the cultivation area was small and was not included in this analysis.

Figure 5. Land use map in 1921
3.3. 1966 land use map
A map of land use in 1966 is shown in Figure 6. As a result of dividing the field by pH, the area up to pH 5.8 was calculated to be 31% of the cultivated area in 1966, and the area up to pH 5.9 was calculated to be 132% of the cultivated area in 1966. From this result, the area of pH 5.9 was added for each slope. When the area of Slope2 or more was added to pineapple, it was 94% of the cultivated area in 1966, and when the area of Slope1 or more was added to pineapple, it was 118% of the cultivated area in 1966.

![Figure 6. Land use map in 1966](image)

4. Discussion
Pineapple was cultivated in a place with a large slope and high soil pH (Figure 3.4) Because pineapple prefers acid soils and well drained slopes, the location was suitable for pineapple [7]. There was a mountain at the center of the island, Pineapple was cultivated on the slope, and Sugar cane was cultivated on the coast. This can be said to use the typical topography of a small island with steep topography and flat coastal land (Figure 7).

The land use from 1921 to 1966 was changed from Bare land to Pineapple. (Figure 5, Figure 6) As a percentage, Bare land decreased from 30% to 11% between 1921 and 1966. On the other hand, Pineapple increased from 0% to 13%. Including Sugar and pineapple, it was 16%. This change seems to be related to the spread of Urban where people live. The land has changed from Bare land to new cultivated land, centering on the newly created part of Urban. This is due to the pineapple boom, suggesting that the production of pineapple and development for expanding the cultivation area took place actively. In addition, Sugar cane increased from 13% to 16% and 19% when Sugar and Pineapple were included. there are few places where Pineapple is greatly eroded compared to places where Sugar cane has already been cultivated. This means that the place where Sugar cane was already planted was not replaced by Pineapple during the pineapple boom. This seems to have resulted in compartmentalization between Sugar cane and Pineapple.
Figure 7. Land use map in 2004

Land use from 1966 to 2004 can be seen where the place where Pineapple was grown has changed to Sugar cane (Figure 6, Figure 7) As a percentage, between 1966 and 2004, Pineapple decreased from 13% to 16% including Sugar and Pineapple. Meanwhile, Sugar cane increased from 19% to 22%, including Sugar and Pineapple, 16%. It can be said that with the end of the pineapple boom, sugar cane cultivated land has been replaced by sugar cane. It is suggested that Sugar cane has been cultivated stably over the long term. In addition, much of Bare land in 1966 has been converted to Glass land. The percentage of Grassland increased from 0% to 17%. In Okinawa, where Ishigaki Island is located, warmland pasture was introduced in the 1970s, and in Yaeyama Islands, breeding cattle management became active as the pasture expanded [13]. It was thought that the pasture land was also introduced in Ishigaki Island, and Bare land in 1966 changed to pasturelands. In 2004, there was a place where sugar cane was cultivated in a place where the soil pH was relatively high at 5.9, though the soil pH was considered suitable for cultivation of pineapple. This is thought to be largely due to the slope that affects drainage. Therefore, this time, analysis with a 50m mesh DEM suggests that there is room for improvement.
5. Conclusion
In Ishigaki Island, there was an expansion of pineapple cultivation on Bare land where Sugar cane could not be cultivated during the 1966 pineapple boom. In 2004, after the pineapple boom, the pineapple cultivation area was reduced along with the end of the pineapple boom, and the pasture was expanded on bare land. This is the expansion of cultivated land and changes in cultivated crops accompanying socio-economic changes.

It is expected that discussion will spread as a regional strategy for small island that are susceptible to climate change.

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