Epidemiological analysis of infectious diseases and the establishment of a surveillance system through remote sensing using ALOS images

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Abstract

This report pertains to the disease surveillance system for schistosomiasis japonica, a larval habitat analysis of vector mosquitoes, and biting case analysis of imported venomous spider. In order to fully grasp the resurgence of infectious diseases and the distribution of their vector animals, detailed habitation analyses are conducted, and spatial information compiled through GPS and satellite images. GIS is used to map these data, and the regional differences and environmental characteristics of distribution are analyzed. The ideal conditions for habitats of medical important animals were clarified and the significant areas subsequently identified through environmental analysis of the distribution area using ALOS AVNIR-2 images and the vegetation index NDVI. We are currently attempting to estimate new habitat establishment and future distribution for wide area by generalizing the characteristics of a limited research area. Furthermore, this technique is a prompt and accurate way to grasp and monitor rapidly changing environmental conditions.

Keywords**:** ALOS AVNIR-2, surveillance system, vector-borne disease, schistosomiasis japonica, redback spider.

1. INTRODUCTION

Remote sensing using satellite images that allow a wide-ranging, accurate and prompt grasp of environmental conditions is an effective tool for understanding conditions and monitoring vector, prevention and changes regarding sudden outbreaks of emerging/re-emerging infectious diseases or endemic diseases caused by environmental change through global warming and the movement of people or physical distribution. Through our long-term survey of the distribution and habitat of intermediate hosts, the study of ideal environmental conditions using ground data, and research using satellite image data in relation to parasitic or viral diseases with intermediate hosts or vectors, we have shown that remote sensing is applicable. We are currently studying the vector mosquitoes for diseases such as dengue fever, West Nile Fever, etc, and the redback spider (an imported venomous animal) using ALOS data, as well as studying the possibilities concerning the utilization of such data.

2. RESULTS

2.1.1Application to schistosomiasis japonica in Japan

At present, the number of people afflicted by this parasitic disease worldwide has reached 20 million. In Japan, for the past 700 years, this disease has been known as the “Endemic Disease” in the Kofu Basin, Yamanashi Prefecture and many other areas of western and southern Japan. Although Yamanashi Pref. had hitherto been the largest endemic area in Japan in which this disease was prevalent, the incidence of this disease ceased and the parasite from snails and definitive host ceased to be detected following extermination measures, and Japan became the only country in the world to be declared free of infection. However, since the intermediate snail hosts are still present, the re-emergence of schistosomiasis japonica from changes in habitat due to environmental change through global warming and the movement of infected animals and people from other regions in the world in which schistosomiasis japonica is still prevalent, is a cause for concern among parasitologists and persons who have previously received treatment for this disease. However, the budget allowance from the local government has been discontinued and the establishment of an accurate and simple low-cost surveillance system has become increasingly important. As the development of such a surveillance system may be useful for monitoring in regions other than Japan in which epidemiological information regarding schistosomiasis is insufficient, we are currently examining possibilities using GIS/RS.

In order to determine the snail habitat, and in particular high density habitat as surveillance locations, a GIS analysis was conducted using the results from two habitation surveys, one conducted when the post-war eradication measures were implemented (1967-1968) and the other conducted immediately after the declaration of eradication (1996-2003). Areas that were clearly identified as being suitable habitat were then examined using the data from three ALOS images taken in April, May and August 2007.

First, a habitat survey of *Oncomelania nosophora*, intermediate host of schistosomiasis japonica in Japan was conducted in relation to the spring periods for both 1967 and 1968. The results were recorded on a 1:50,000 scale topographical map published by the Geographical Survey Institute, with results color coded to show snail habitation density in irrigation These two maps were then digitally overlain and merged to produce a density distribution map of *O. nosophora* for 1967 and 1968 [1]

In addition, using previous data for reference, snail numbers for each habitat site were calculated to produce the density specific distribution map for the entire Yamanashi Pref.. Based on these figures, a 200m buffer zone was drawn onto the map to prepare the accidental epidemics of schistosomiasis japonica, and an iso-density map was created. From these maps it was possible to ascertain areas with high habitation and low habitation density. Meanwhile, after the declaration of eradication regarding *O. nosophora* in Japan, 120 paddy field sites were selected as fixed points for a five-year survey conducted from 1996 to 2000, and a habitation survey of *O. nosophora* was conducted at the water inlets of each fixed point. The outlines of the paddy fields at these fixed points and the coordinates for the water inlets were determined using GPS and then digitalized through GIS [2]

Of the results obtained through these surveys, Fig. 1 shows total collected snail number for the five-year period color coded into density specific groups. High density habitation areas are shown in red. The areas of high habitation density are concentrated with many located in the alluvial areas on the west side of the south/ north flowing rivers.

The difference between habitation density for two periods show on Fig. 1; Green indicates areas of increased density in recent years and red indicates areas that had high habitation density in the past but are currently more clear. White indicates areas of no change. Habitat in the central areas of the basin has disappeared. Current habitat is limited to areas located within the range of past habitat, and the areas of high density coincide with past areas of high density.

To follow, possible *O. nosophora* habitation areas were determined from aerial photographs, and these areas were shown as risk areas (Fig.2). When the iso-density map for 1967-1968 was superimposed, the high density habitation areas became ever clearer.

When this map is compared to paddy field areas shown from NDIV data of ALOS images for April and August 2007, it developed that we should do survey in the paddy field areas in the risk area (Fig. 3).

2.1.2 Schistosomiasis in China

The main areas of habitat for the intermediate snail hosts in China are in the low marshlands of the Chiangjiang (Yangtze) river basin, in the riverbanks, the sandbanks, the back marshes and lakes. China is currently developing its hydroelectric generation with the construction of the Three Gorges Dam. The world's parasitologists have been keeping a close eye on the construction of this dam to see how it will affect the transmission and dissemination of schistosomiasis japonica. Some have said that the construction of the Three Gorges Dam would cause Lake Dongting to dry up and disappear. In fact, as shown here in the ALOS image taken on January 31, 2007, the water of Lake Dongting has dried up and the surface area of the lake is restricted. The only communities are inside the embankment. In the surrounding area of the communities, distribution of intermediate snail hosts is limited to the paddy field irrigation ditches. The changes in water level of this lake was significant even before the construction of the dam, reaching 17-20m, and the grasslands growing in the dry lake bed have become a huge habitat, creating opportunities for infection [3, 4], at present the snail habitation area has spread to 39,150,000ha, equivalent to 52% of China's total snail habitation area. Furthermore, the wild field mouse population has increased dramatically. Subsequently, as clearly shown in the image taken on September 18, 2007 water discharge from the dam and heavy rainfall in the tributary areas caused the water level in the lake to rise. The mice escaped to the neighboring dwellings, and it seems that a large number of mice were killed and then thrown into the lake. Although these field mice are schistosomiasis resistant and considered to have no effect on the epidemics of schistosomiasis, it will still be necessary to monitor their future movements. Incidentally, the human population in this area is 3,360,000 of which some 205,000 are said to be schistosomiasis patients. Another 50,000 cattle are also said to be infected.

In this way, although the construction of the dam itself poses no problem concerning schistosomiasis infection in the communities around Lake Dongting, it is causing the expanded risk area on the lake bed to spread. We reason that the ALOS image used in this case can be used to calculate increase in snail habitat area (Fig. 4) estimate the volume of water in the lake and the degree of environmental contamination from the accumulation of chemical pollutants such as agricultural chemicals, pesticides and rodenticides, etc.

ALOS images for Feb. 2, 2007 shows the area around Tongling, Anhui Province, further downstream along the Chiangjiang (Yangtze) River from Lake Dongting. Along the sandbanks on the left hand side of the Chiangjiang waterside land is being used as pasturage for schistosomiasis infected water buffalo. Intermediate snail hosts abound in the undulating terrain, from high points on the embankment and low points in old river channels, etc, and also inhabit marshland areas and ponds. The snails here are river type snails easily subjected to flooding and are large, with shell length greater than 1cm with pronounced folds, and have a high rate of infection. The community is located on a natural embankment and livelihoods are earned through rice and vegetable cropping, and chicken farming. Poultry is free range and wild birds are free to fly in and out, which means the poultry is also exposed to the dangers of avian influenza. As the principal final host was water buffalo, all water buffalo were destroyed and the mechanization of agriculture was promoted, and a drop in the schistosomiasis infection rate is anticipated. As a map for the area could not be obtained, the ALOS image was used in place of a map and for environmental analysis.

The marshlands around the mountain village toward the interior of Tongling, is categorized as so-called mountainous type habitat, and like the Kofu Basin in Yamanashi Prefecture, consists of alluvial terrain and valley paddy fields. Snails are small at less than 8mm in total length as in Kofu. Eradication measures were implemented and there are currently no schistosomiasis patients. Although infected snails are said to have been eradicated, snails still inhabit the fields and paddy fields. ALOS images were also used in relation to these regions in order to study the origins and habitat of this snail, and the status of infectious diseases. The use of ALOS to decipher the habitat of these lake, river and mountainous type snail may enable the forecasting of schistosomiasis infection in China.

2.2 Application to mosquito-borne diseases

On a different subject, in order to monitor emerging and re-emerging infectious diseases, we are studying population density and mosquito fauna in the urbanized areas frequented by migratory birds. At this time we surveyed the mosquitoes in N City near Osaka as an urban district case study. The result of a survey of mosquitoes in drainage system is shown here. N City is divided into 10 districts. In each district all the rainwater inlets were mapped for 10% of the towns/streets. Proportion of water catchments with water was also studied and mapped using GIS. The proportion was low in upland areas and hills relatively and high in low lying housing areas. The mosquito count was high in low lying areas and the *Culex* mosquito was the prevalent species in this city. When deciphering these conditions using ALOS images, plateaus with an elevation greater than 5–10m were interspersed with irregularly shaped small red areas, which were studied to see if plateaus could be deciphered from their color tone and distribution status, which in turn may enable the estimation of mosquito numbers and species.

2.3. Application for estimating the habitat of imported venomous spiders

Since the redback spider, *Latrodectus hasseltii* was discovered in the Osaka Bay area, Osaka Prefecture Japan in 1996, we have followed its spreading distribution using GIS [5]. Dissemination is significant and the redback spider has currently spread to the majority of municipalities in Osaka Prefecture. This spider spread to new locations via building materials or via vehicles transportation.

In order to follow the dissemination to other prefectures, we focused our search on developed land in the suburb of cities in Osaka Pref. and found spiders carried to these locations during the development process. We are currently confirming their establishment in these areas. We hope to continue our analyses on the new infested areas with redback spider by satellite images and field survey.

3. DISCUSSION AND CONCLUSIONS

Although the pathogene of infectious diseases and their vector animals cannot be monitored directly with ALOS images, the deciphering of ALOS images to ascertain habitat through ground surface studies, land usage in regions where disease is prevalent, topographical characteristics and water utilization characteristics, is an accurate and effective method of grasping and forecasting the conditions within a changing wide-ranging environment. In particular, use in conjunction with GPS can lead to a greater understanding during times of disaster or of long-standing diseases, and will contribute to policy maker for disease countermeasures. In addition, using NDVI, we have begun analyses of malaria risk areas in the Solomon Islands that are inaccessible due to limited transportation, marshland and the risk of disease. It is great advantage for monitoring and control of vector snail and insect transmitted diseases, even in the venomous spider.

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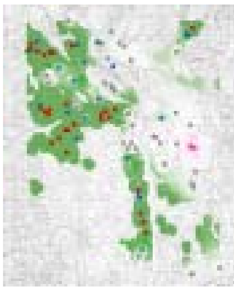

Figure 1. Total number of snails collected at each monitoring site from 1996-2000 and the difference between habitation density for two periods between 1967-68 and 1996-2000

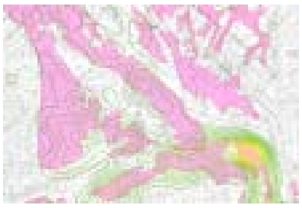

Figure 2. Risk area of schistosomiasis japonica and iso-density map of O.nosophora in 1967-68

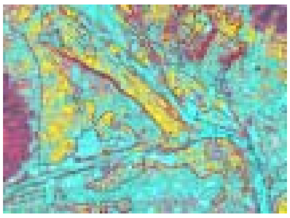

Figure 3. Survey sites in the paddy field areas shown from NDIV data of ALOS images for April and August 2007

Figure 4. Change of the intermediate snail habitat area calculated using by ALOS images taken on January and September 2007