

USING ALOS SATELLITE IMAGES TO DEVELOP EFFICIENT MEASURES AGAINST VECTOR-BORNE DISEASES – REGIONAL DIFFERENCES IN OUTBREAK RISK OF SCHISTOSOMIASIS IN CHINA

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1. INTRODUCTION

Climate changes on a global scale, particularly global warming, and other natural, social and economic changes in the environment, can have a significant effect on the outbreak of infectious diseases. The emergence and re-emergence of infectious diseases has been detected in unexpected regions, and increases in the number of cases reported and expansion of regional distribution is expected in the near future. Prompt and accurate understanding of rapidly changing environments is important in order to establish a monitoring system, and the use of satellite images that allow the compilation of data encompassing the entire surface of the globe, along with location information that also possesses high observation frequency, is essential. Image resolution and scale, data dates, seasons, and photography cycles were selected according to the target diseases or areas. In this study, we have attempted to develop effective risk analysis methodologies that implement type classification of infested foci for schistosomiasis japonica in China using GIS, GPS, and remote sensing (RS) [1].

The surveys that we have undertaken to date, using ALOS images provided by JAXA, cover parasitic diseases, vector mosquitoes for diseases such as malaria, dengue fever, etc, the redback spider, and emerging and re-emerging infectious diseases in Japan and overseas. The diseases and research details are as follows:

- 1) In relation to schistosomiasis [2- 4]:
 - a) Monitoring systems for *Oncomelania nosophora* habitats in the Kofu Basin, Yamanashi Prefecture
 - b) Water level changes in East Dongting Lake in Hunan Province, China and changes in *O. hupensis* habitats, and forecasts for environmental contamination through rodenticides, etc.

- c) Water level changes in the schistosomiasis japonica-infested foci in Anhui Province, China, the shape of *O. hupensis* shells, and risk forecasts,
 - d) Creation of *O. quadrasi* habitat distribution maps for schistosomiasis japonica-infested foci in the Philippines on islands, such as Bohol, Leyte, Luzon and Mindoro, and epidemiological surveys.
 - e) Creation of schistosomiasis mekongi-infested foci distribution maps of marshlands in the Mekong River basin and trend forecasts, in particular, the creation of maps to clarify the regional differences in egg positive rate of several parasites in southern Laos and epidemiological surveys.
- 2) In relation to ecological research into *Aedes albopictus* [5-6]:
 - a) Studies into the relationship between NDVI values and the growing distribution of *A. albopictus* in the Tohoku Region due to environmental warming
 - b) Creation of *A. albopictus* distribution maps for the Aizu Basin, Fukushima Prefecture
 - c) Explanation of inter-species competition between *A. albopictus* and *Ochlerotatus japonicus* in the Yamagata Basin by using NDVI
 - 3) The use of false color images to forecast the runaway expansion of redback spider habitats in the areas surrounding Osaka and Hyogo Prefectures [7-9]
 - 4) In relation to malaria vector mosquito surveys:
 - a) Reproduction of the environment of Hikone-shi in Shiga Prefecture, where the last patients were recorded in order to analyze *Anopheles* mosquito habitats in Japan and forecasts for future vector mosquito habitation
 - b) Studies on the relationship between the malaria infection rate in the Indochina Peninsula and NDVI of NOAA images [10]

2. OBJECTIVE OF THIS REPORT

Among the serious diseases reported worldwide, communicable diseases other than the big three (AIDS, TB, and malaria), which have infected >100 million patients, are referred to as Neglected Tropical Diseases (NTDs). More than 200 million patients worldwide are infected with schistosomiasis, a parasitic NTD. The most common infections in East Asia and South East Asia are schistosomiasis japonica and schistosomiasis mekongi. With schistosomiasis japonica, the eggs expelled from the final hosts, such humans, cattle, or dogs, hatch into miracidium that swim in water. These miracidium enter the intermediate snail hosts, *Oncomelania* spp., where they develop into cercaria, which consequently swim out into paddy fields and marshlands, where percutaneous infection of the final host they encounter by chance occurs. Within this life history, the natural environment such as the water, soil and topography that constitutes the habitat for the intermediate host, the water in which the parasite lives, and the temperature and humidity around the snail and parasite all have a significant effect on the incidence of disease. Control measures, environmental warming on a continental scale, human intervention in the environment, and movement of people are also factors that influence the distribution and incidence status of this disease [11]. Species and shapes of intermediate hosts differ depending on conditions such as topography and water levels, etc. in habitat sites. Furthermore, there are differences in snail susceptibility to *Schistosoma japonicum*, and morphological and experimental studies of the snail are essential, as the shape of the snail's shell can provide some explanation for this, to some extent.

Referencing Japan's schistosomiasis eradication history, we are working in cooperation with researchers from China on a review of methods to establish an accurate understanding of snail habitation status and the movement of patients. Using regional classification through local surveys and ALOS images together with confirmation through laboratory experiments, we must establish new methods to enable rapid response to disease detection.

3. RESEARCH METHODS

3-1 Data and materials

a) There is difficulty in obtaining detailed distribution data for schistosomiasis japonica in China. Consequently, we conducted Internet searches for the names of infested counties and villages across China where schistosomiasis was present between 2006 and 2008 and for the names of counties in which tree planting (disease prevention forestation) had been planned as a snail control measure, and these were designated as infestation foci or snail habitats.

b) For digital regional map data, we purchased land use, river systems, and climatic data in China (Resources and Environment 1-km Resolution Grid Data Sets (1:4,000,000): Beijing GeoTechway Co. Ltd., China.

c) Coordinate data of infested foci was purchased from CBS, Co. Ltd. Tokyo, Japan.

d) For local GPS data, data from a digital camera (Caplio 500SE; RICOH Co. Ltd, Tokyo, Japan) was converted to Excel and applied to GIS.

e) ERDAS Imagine was used for image analysis, while GIS software used was ArcView 9.3.

f) The satellite images used were mainly ALOS/AVNIR-2 and JERS-1 images. In particular, the ALOS images, provided by JAXA were of the Yangtze River basin, showing seasonal differences between 2007 and 2009, and including low water and high water periods in the region.

g) The habitat environment temperatures, temperature tolerance thresholds, developmental zero points and threshold temperatures for hibernation for the intermediate host *O. hupensis* in China, and temperature tolerance thresholds and developmental zero point for the snail from the Yangtze River basin were taken [12-14].

3-2 Research methods

Intermediate snail host collection, topographical classification, analysis of texture, color and chemical composition of soil, and analysis of chemical oxygen demand (COD) and calcium content in water were conducted during habitat surveys. Under laboratory conditions, the collected snails were cultured on soil samples collected from their corresponding habitats. Differences in shell shape, egg production, and incubation numbers according to soil were compared and the ecological characteristics of the snails were clarified.

In relation to infested foci and disease prevention forestation project areas, we created distribution maps by superimposing the water system distribution maps for the Yangtze and Yellow Rivers, etc. that were created during this study over land use maps, with particular emphasis on paddy field distribution and isothermal maps for January.

Experimental comparisons of susceptibility to *S. japonicum* in snails collected in the Anhui and Hunan Provinces, etc. using the Yamanashi strain of *Schistosoma* have been made.

From an epidemiological perspective, the infested foci of this disease as it exists in China can be classified into 3 types: mountain/hill type, fluvial/lake type and waterway type, and control measures differ according to these categories. Based on field surveys, environmental aspects of snail habitat, such as topography, land use, and fluvial channels, were deciphered with false color images of Landsat, SPOT, Jers-1 and ALOS, and habitats were classified into 3 types. ALOS images of the Yangtze River basin of Anhui Province, in particular, made it possible to determine differences in land use depending on seasonal changes in water levels, namely bare land, grassland, forest, etc.

We attempted to clarify the risk areas after taking into account the susceptibility of intermediate snail hosts to the parasite and preventative measures that have been implemented, in addition to environmental warming, water management and land use.

With regard to the habitation threshold of the intermediate snail host, since the temperature of 0°C is considered the northern limit for schistosomiasis japonica, isothermal lines showing monthly mean temperatures for January of 0°C, -1°C, and -2°C were drawn onto river system maps and paddy field distribution maps using 1-km mesh climate values. Each of these show the boundaries of areas currently at 0°C, areas that will remain at 0°C when the temperature increases by 1°C, and areas that will remain at 0°C when the temperature increases by 2°C. We compared the boundaries of this map with the movement zones accompanying the movement of snails due to irrigation of the Yellow River basin using water from the Yangtze River (South-to-North Water Diversion Project) in order to clarify the limiting factor [15, 16].

4. RESULTS AND CONSIDERATIONS

When the infested foci from 2006 to 2008 were marked on a river systems map for the Yangtze River basin and the Yellow River basin (Fig. 1), it is clear that they are distributed within the Yangtze River basin in Yunnan, Sichuan, Hunan, Hubei, Jiangxi, and Anhui Provinces.

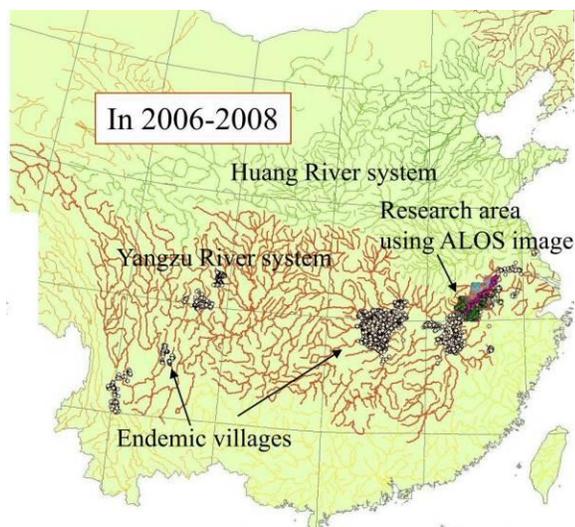


Fig. 1 Geographical distribution of schistosomiasis japonica infested foci in China in 2006-2008

The exception is Jiangsu Province. Although in 1995, infested foci were also distributed in Guangxi, Guangdong, and Fujian Provinces, infested foci are currently limited to the above 6 provinces; furthermore, it is clear that the infested foci in even these provinces are limited to an area ranging only a short distance from the Yangtze River [17, 18]. This distance can easily be calculated using GIS.

It is possible to distinguish fluvial floodplains, back marshes that form braided streams mountainous/hilly areas, as well as river systems and river catchment areas in infested foci in Anhui Province, by conducting geographical classification by using high-resolution ALOS false images. ALOS imaging also allows estimation of land

use, such as in urbanized areas, paddy fields, cotton fields, and other fields, feeding status of livestock and poultry, and soil characteristics such as texture and type.

Low-lying fluvial flood plains are classified as “fluvial type.” Grasslands spread out during low-water level periods, and the land is used as pasturage for water buffalo and cattle and for poultry breeding (Fig.2). The density of the intermediate snail host in these areas is high and infestation is severe. The calcium content of the soil exceeds 1000 ppm. The longitudinal length of snail shells here exceeds 10 mm and growth is fast. The folds in the shells are deep and the snail is considered highly susceptible to the parasite.

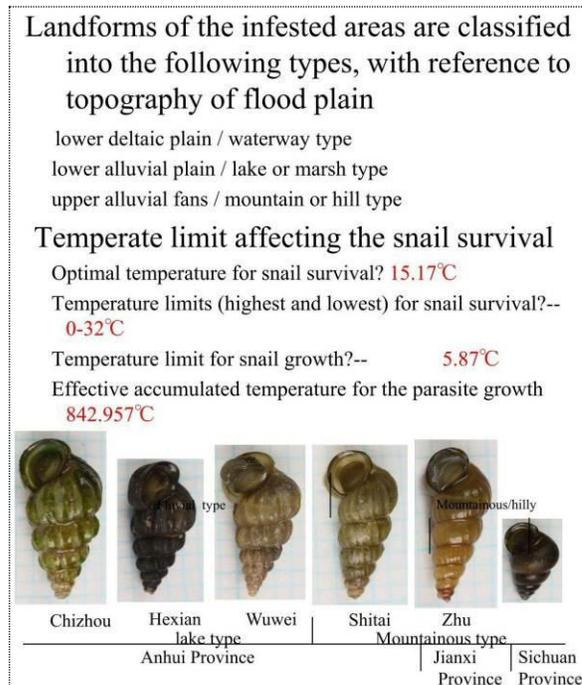


Fig. 2 Regional differences of size, shape and infectivity of Schistosoma japonicum intermediate snail host in China

In areas further inland, there are back marshes of a partially waterway-type terrain -- these are the floodplains of the Yangtze tributaries. This land is cultivated as paddy fields. The soil calcium content here is 200–600 ppm. Shell size is 8–10 mm. Although the shell longitudinal length is small, its width is broad and the folds in the shells are well developed.

Small low flood plains isolated from the Yangtze River or located in upland areas and hills upstream of fluvial areas that flow into the Yangtze River are classified as “mountainous/hilly type”. There are many cases where the calcium content of the soil is low, being <200 ppm. Shell length and width is small, and the shell is smooth, resembling an *O. nosophora* in Japan. Although the susceptibility of the snail that inhabits these areas is

considered low, they can be cultured with ease even on the soil in Japan.

Concerning the infested foci in Anhui Province, false color images were combined, and after deciphering topography and vegetation, the terrain was classified into “hilly type,” “waterway type,” and “fluvial type,” and were mapped (Fig.3). It is clear that there are many infested settlements distributed in areas along the Yangtze River. There are hill type infested foci in between the parallel rows of mountains characteristic of aqueous rock. According to tourist maps, there are limestone caves within these mountains, and snail habitat was assumed to be located in areas with high calcium content.

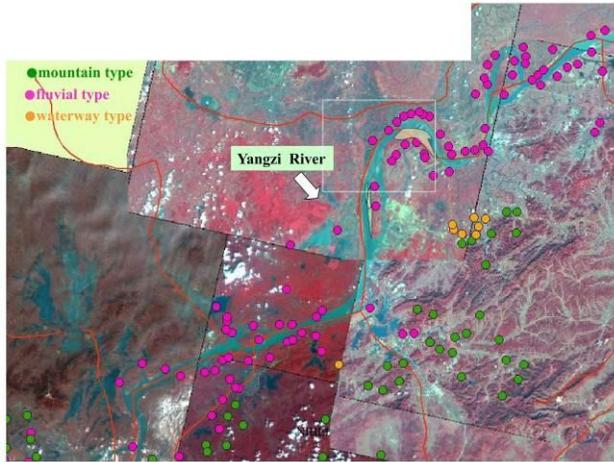


Fig. 3 Analysis of epidemiological types of schistosomiasis japonica infested villages in Anhui Province using ALOS images

Figure 4 shows infested foci in an area in the northern Anhui Province, where the Yangtze River meanders, derived from 8 ALOS images from different periods between October 16, 2006 and May 26, 2009. Areas with high NDVI and high moisture content such as fluvial areas and marshlands can be discerned. Based on images from low and high water periods in particular, it is possible to estimate snail habitation status in areas that are consistently land, even on marshland, which forms reed beds that are comparatively dry and provide habitat for large snails, and in contrast, areas that are dry only during the short low water periods, during which they turn into grasslands where vast populations of snails breed. This enables the consideration of optimum countermeasure methods such as the identification of lands suitable for disease prevention forestation, prohibition of utilization as pasturage in particular areas, and the mechanization of agriculture, etc.

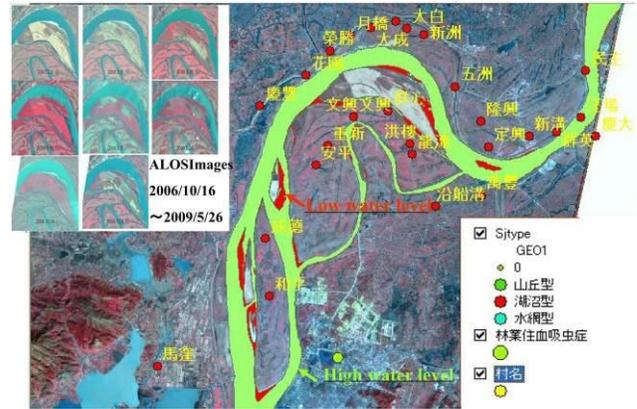


Fig. 4 Survey and analysis for changes of water level of the Yanzi River, epidemiological types and control measures of schistosomiasis japonica infested area using ALOS images

Figure 5 shows the isothermal lines for January mean temperature of 0°C drawn onto Figure 1. Although these isothermal lines represent the limits of current distribution of infested foci in the inland areas of Sichuan Province, eastwards of Hubei Province, it is apparent that these same lines do not represent such limits.

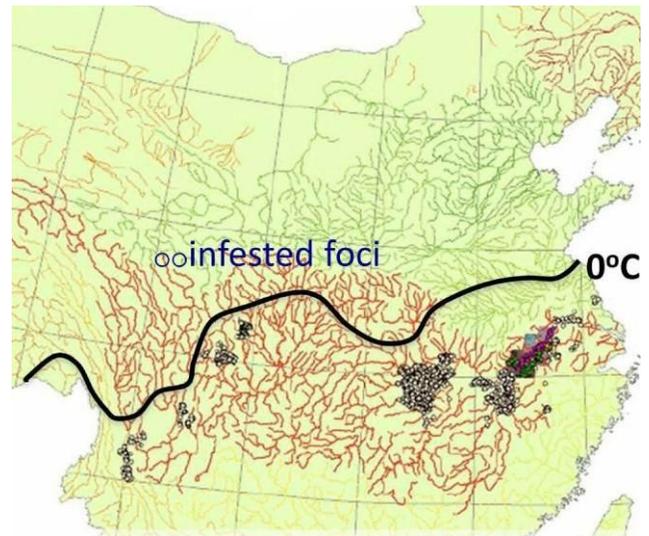


Fig. 5 The isothermal line for January mean temperature of 0°C displayed with schistosomiasis japonica infested villages and the rivers of Yantze and Huang

Figure 6 shows a paddy field distribution map in China, created from land use mesh data, over which isothermal lines for January mean temperatures of 0°C, -1°C and -2°C have been drawn. The fields are located to the south, where mean temperatures are mainly 0°C, and in the coastal areas, the fields are distributed not only in the

Yangtze River basin, but also in the Yellow River basin. However, there are no infested foci. At present, there are no paddy fields in the areas between the 0°C and -2°C isothermal lines. In the absence of temperature increases and the northwards migration of lands cultivated for paddy fields, it is appropriate to surmise that there will be no expansion of waterway-type infested foci. However, there is the possibility of expansion in fluvial-type terrain. Snail breeding experiments in China have already confirmed that snails are able to inhabit fluvial basins in the currently non-habitat areas. Although habitat expansion will differ according to regional conditions, human influence may be greater than that of environmental warming.

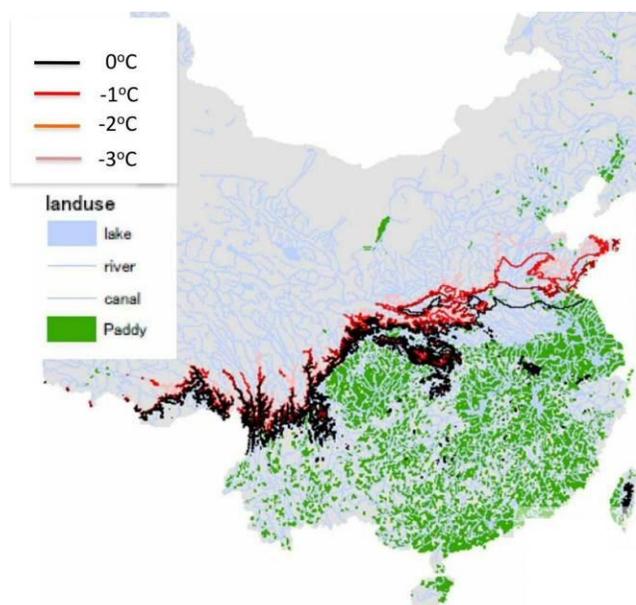


Fig. 6 The isothermal lines for January mean temperature of 0°C, -1°C, -2°C and -3°C overlaid on the landuse map

Figure 6 shows a paddy field distribution map in China, created from land use mesh data, over which isothermal lines for January mean temperatures of 0°C, -1°C and -2°C have been drawn. The fields are located to the south, where mean temperatures are mainly 0°C, and in the coastal areas, the fields are distributed not only in the Yangtze River basin, but also in the Yellow River basin. However, there are no infested foci. At present, there are no paddy fields in the areas between the 0°C and -2°C isothermal lines. In the absence of temperature increases and the northwards migration of lands cultivated for paddy fields, it is appropriate to surmise that there will be no expansion of waterway-type infested foci. However, there is the possibility of expansion in fluvial-type terrain. Snail breeding experiments in China have already confirmed that snails are able to inhabit fluvial basins in the currently non-habitat areas. Although habitat expansion will differ according to regional conditions, human influence may be greater than that of environmental warming.

Where expansion of infested foci of this disease is forecast due to environmental changes, the RS/GIS technologies demonstrated here would be useful in the implementation of monitoring methods and extermination measures.

5. CONCLUSION

Utilizing the fruits of research we have conducted to date, we were able to use ALOS images from different periods to undertake geographical region classification for schistosomiasis japonica in China, with focus on the Anhui Province. For China, we were able to study schistosomiasis japonica risk areas through the high resolution of ALOS images. The opportune research grant awarded by the Ministry of Education, Culture, Sports, Science and Technology enabled us to carry out this research into schistosomiasis in the Anhui Province. For the future, we also hope to commence studies on *O. robertsoni* in the Sichuan Province and eventually create individual village-based infested foci distribution maps for the whole of China and achieve an understanding of the status of schistosomiasis, and furthermore, to estimate topographical classifications and chemical composition of soil, etc. and to study future trends.

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