3. Multi-spatial and Temporal Data Integration for Understanding Agricultural Activity and Vulnerability:
A case study of rural farmer's villages

Megumi Yamashita
Survey College of Kinki, Osaka, Japan

Abstract

This chapter describes field investigations and geo-spatial/temporal analysis of livelihood at the village level, with a particular focus on agricultural activities, using a multi-disciplinary approach. As a basic analysis, the integration of all data collected so far has been carried out to understand the situation at the level of the household or village, in terms of adaptation and capacity to cope with a risk caused by an unexpected ecological or social shock.

3.1. Introduction

This research sought to clarify the relationships between social-ecological vulnerability and human activities from a multi-disciplinary point of view using geo-spatial information in combination with social and economic analyses. To this end, it was necessary to collect geo-spatial and temporal data relevant to people's livelihood and the environment in which they live.

We collected crop and field data by conducting field investigations, aerial photographs and satellite images, and integrated and analyzed the data to understand agricultural activity and its vulnerability to risks.

The study area covered sites A, B and C, located in Sinazongwe district, Southern province.

3.2. Data collection and analyses

3.2.1. Obtained and collected data list

Table 3-1 shows a list of all geo-spatial data we have obtained and collected so far. Since FY2007, we have carried out a field investigation to document the boundaries of all crop fields of all households in five villages. We also obtained aerial photographs taken around our study area in 1970, 1980 and 1991 by the Survey Department of Zambia. Additionally, we obtained satellite images obtained by optical sensors with middle-high resolution to identify seasonal changes in the pattern of land use / land cover and the effects of natural vegetation and cultivated land from 1972_3 to the present. These satellite images cover our study area (including Site A, B and C). Data were processed to have the same map coordinates using the universal transverse mercator (UTM) system (Zone35 South, WGS84) map projection.

Pre-processing and analysis were conducted in FY2010, for the data obtained and collected mainly after 2006.

Table 3-1. Geo-spatial data for our study site area

Aerial photos/ crop allocation data	Satellite images						
	Satellite/Sensor		Resolution (m)	Obs. Date	Season	Remarks	Geometric correction
1970 Aerial photos	Landsat	MSS	80	1972/11/23	From dry to rainy		
	Landsat	MSS	80	1973/3/11	Rainy		
1980 Aerial photos	Landsat	TM	30	1986/11/17	From dry to rainy		
	Landsat	TM	30	1987/2/21	Rainy		
1990 Aerial hotos	Landsat	TM	30	1990/3/1	Rainy		
	Landsat	TM	30	1995/1/26	Rainy		
	Landsat	ETM	30/15	2001/8/30	Dry		
	Landsat	ETM	30/15	2001/10/1	End of Dry		
	Landsat	ETM	30/15	2001/12/20	Rainy		OK
	Terra	ASTER	20	2002/2/6	Rainy		OK
	Landsat	ETM	30/15	2002/2/22	Rainy		
	Landsat	ETM	30/15	2002/5/13	Harvesting		
	Landsat	ETM	30/15	2002/8/17	Dry		
	Landsat	ETM	30/15	2002/10/20	End of dry		
	Landsat	ETM	30/15	2002/11/21	From dry to rainy		
	Terra	ASTER	20	2002/11/21	From dry to rainy		OK
	Terra	ASTER	20	2003/4/30	End of Rainy	Cloud coverage 10%	OK
	Terra	ASTER	20	2003/6/1	After Harvest		OK
	Terra	ASTER	20	2003/7/3	Dry		OK
	Terra	ASTER	20	2003/11/24	From dry to rainy		OK
	Terra	ASTER	20	2004/1/11	Rainy	Cloud coverage 10%	OK
	Terra	ASTER	20	2004/7/21	Dry		OK
	Terra	ASTER	20	2004/8/22	Dry		OK
	ALOS	PRISM	2.5	2006/7/19	Dry	Covering siteA only	OK
	ALOS	AVNIR-2	10	2006/9/3	Dry		OK
Rainy crop data 2007/8	ALOS	AVNIR-2	10	2007/9/6	Dry		OK
	ALOS	AVNIR-2	10	2007/10/22	End of dry		OK
	ALOS	AVNIR-2	10	2008/4/23	Harvest	Cloud coverage 10%	OK
Dry crop data 2008	ALOS	AVNIR-2	10	2008/6/8	End of harvest		OK
	ALOS	AVNIR-2	10	2008/9/8	Dry		OK
Rainy crop data 2008/09	ALOS	PRISM	2.5	2008/10/24	End of dry	DEM / covering siteB and C	OK
	ALOS	AVNIR-2	10	2008/10/24	End of dry		OK
	ALOS	AVNIR-2	10	2009/3/11	End of rainy	Cloud coverage 10%	
	ALOS	AVNIR-2	10	2009/4/26	Harvest		OK
Dry crop data 2009	ALOS	AVNIR-2	10	2009/9/11	Dry		OK

3.2.2. Crop allocation map

Field investigations for crop allocation mapping were carried out for more than 220 households in the villages of ASn, ASm (Site A), BKa, BCh (Site B) and CSa (Site C) in two rainy seasons of 2007_08 and 2008_09 and two dry seasons of 2008 and 2009.

To generate the crop allocation map, we used a portable global positioning system (GPS) to measure boundaries at a sub-field level that recognized different crops at Sites A, B and C. In addition, we conducted interviews with all households to obtain information about field names, topography, soil type, crops, cultivated varieties and types of fertilizer, to understand households' coping strategies related to climate variations. The boundaries of crop fields and attributes such as the names of crops and their owners were converted to the general geographic information system (GIS) data format with a Shape file (.shp).

Furthermore, we determined whether each crop field had been damaged by a natural disaster, such as drought or flood, and which crops were replanted after damage.

3.2.3. Generation of Digital Elevation Model

To generate a Digital Elevation Model (DEM) and ortho aerial photo images of the large scale of our study area, we used aerial photos taken in 1991 with a scale of approximately 1 : 30,000. However, because an area around site C was not completely covered, we also used a stereo pair of ALOS/PRISM images taken on 2008/10/24 from nadir, forward and backward views.

We processed the stereo pairs of both aerial photos and ALOS/PRISM images. We used XYZ coordinates of UTM (Zone35 South, WGS84) read from Google Earth as the ground control points (GCPs) for extra orientation. Figure 3-1 shows the Digital Elevation Model (DEM) around our study sites. The grid size of the DEM was 5 m.

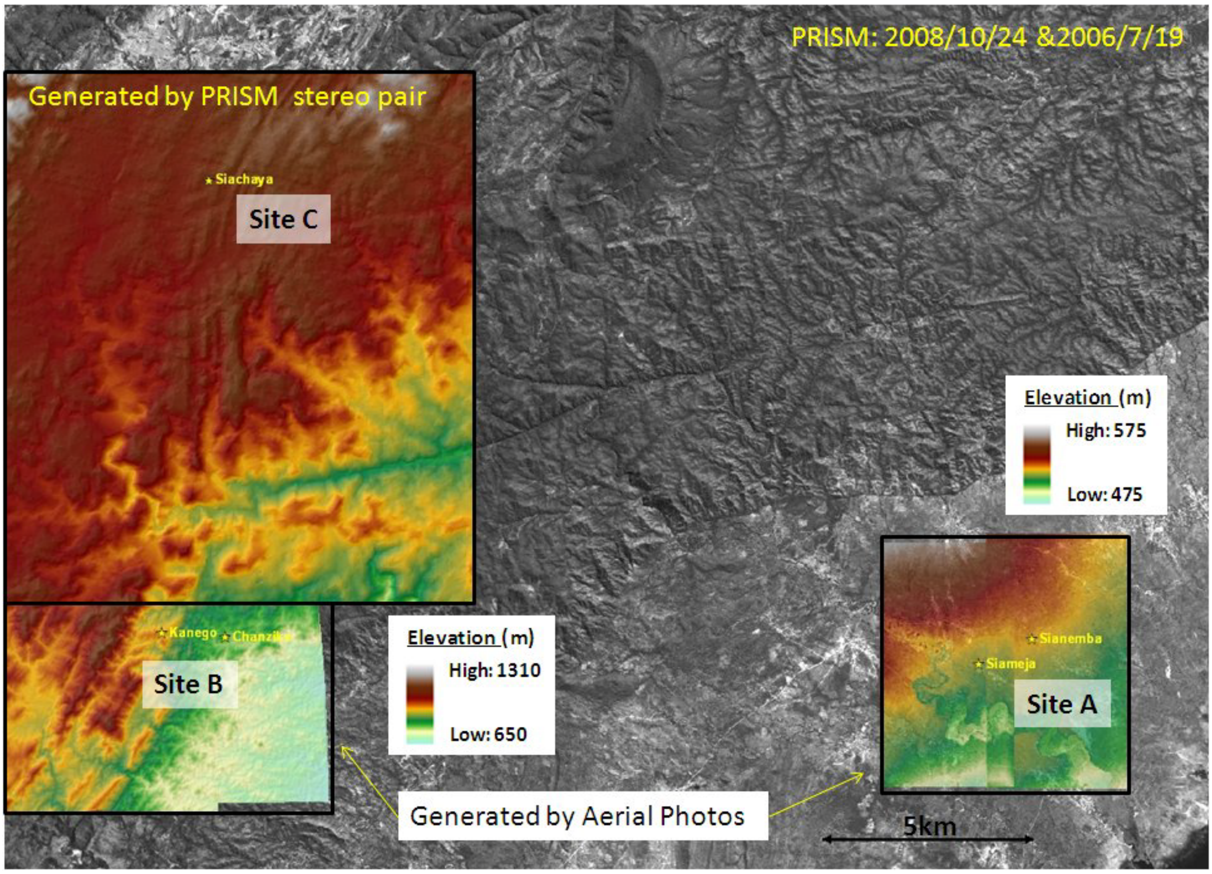

Figure 3-1. DEM generated by aerial photos and ALOS/PRISM stereo pair

3.2.4. Geometric correction for satellite images

Multi-spectral satellite images are useful for recognizing seasonal land surface conditions. In FY2010, we processed the geometric correction for all ALOS/AVNIR-2 images. The AVNIR-2 sensor has four spectral bands of visible Blue (band1), Green (band2), Red (band3) and Near Infrared (band4). Here, we used the same map coordinates from Google Earth as the ground control points (GCPs) for geometric correction. The location accuracies of the geometric corrections for all images were less than one pixel (10 m).

Figure 3-2 shows the results after geometric correction of ALOS/AVNIR-2 false color images taken on 2008/9/8, 10/24, 2009/9/11 in the end of dry season and 2009/4/26 at the end of the rainy season. These images are different visually between the ends of the dry and rainy seasons.

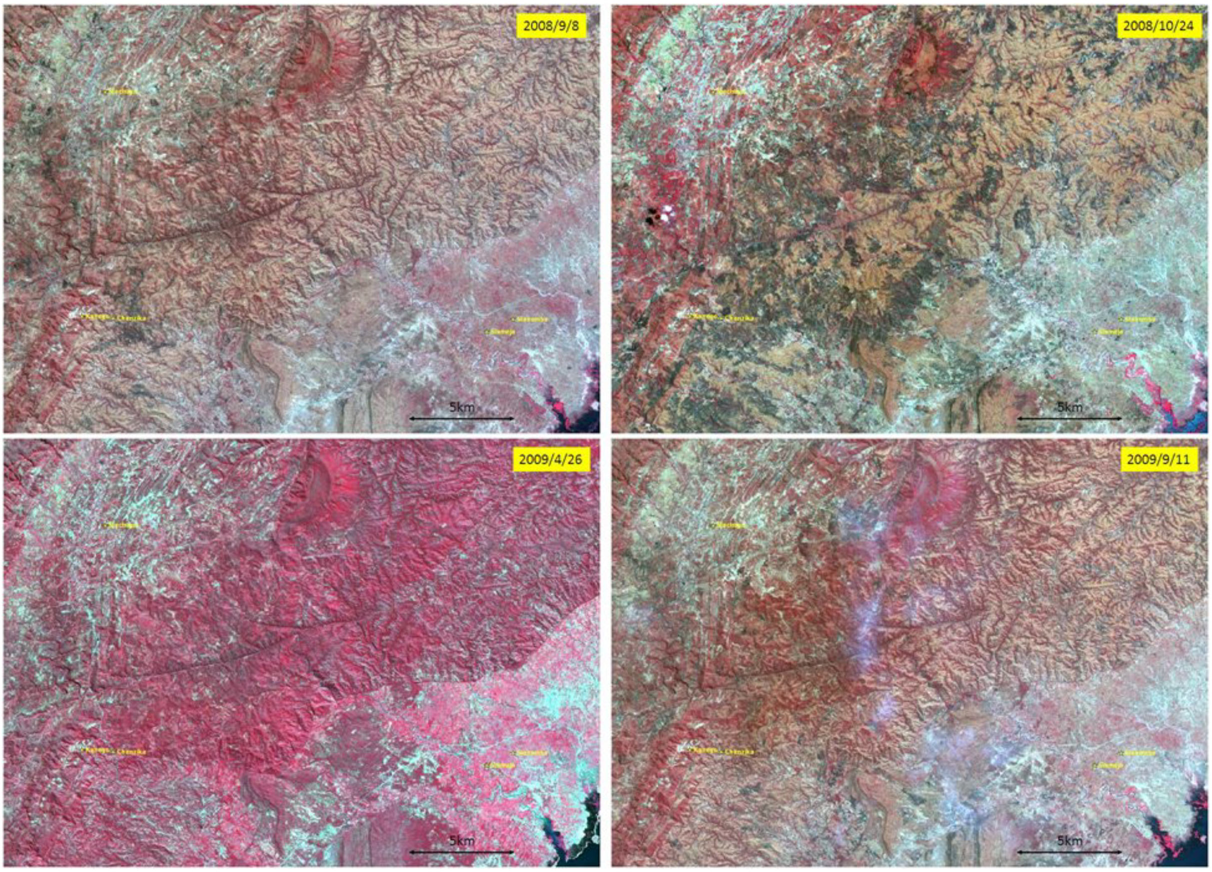

Figure 3-2. Samples of geometric corrected ALOS/AVNIR-2 false color images (RGB:b432)

3.2.5. Additional data

We also collected location data for all of the households we examined, and other facilities such as schools, churches, watering points, water pumps and markets/shops, using portable GPS. Data regarding the main roads and streets commonly used in these areas were also measured with GPS and entered by visual interpretation on the aerial photographs and the ALOS/PRISM ortho images.

Figure 3-3 illustrates the distribution of the households and other commonly used facilities. These kinds of location data can be used to analyze the relationship between the locations of households and crop fields and accessibility to facilities and natural resources. The accessibility of facilities in BKa and BCh (site B), which were established in the 1990's, is more difficult than access at other sites. However, the forest resource has been largely retained in site B, providing an advantage over some other areas. Therefore, some of households in site B have another livelihoods such carpenter, plank and so on.

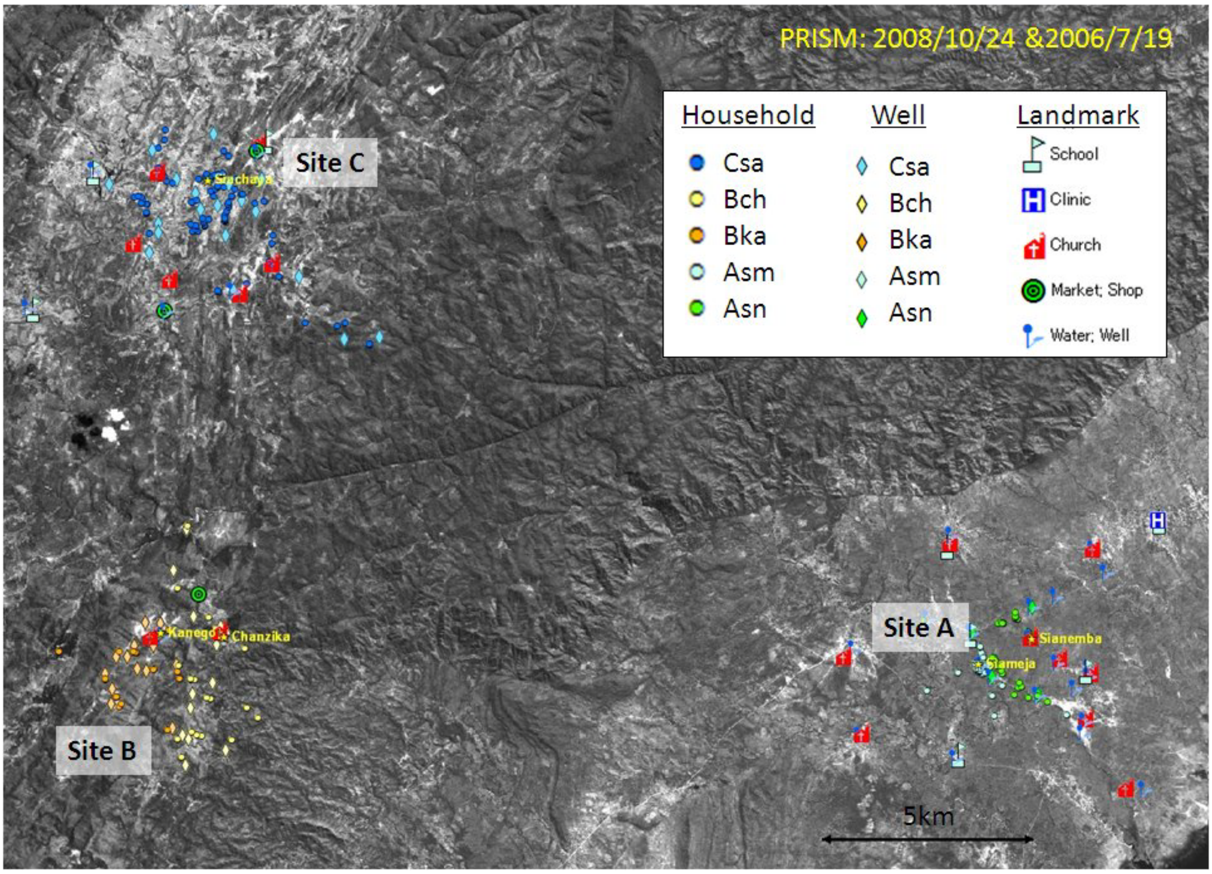

Figure 3-3. The locations of the examined households and commonly used facilities

3.3. Results and discussion

3.3.1. Rainy crop area from 2007_08 to 2008_09

The characteristics of the crop field location were different at each study site. At site C, almost all of the crop fields were distributed along the mountain ridges and the gentle slope of the hill. The crop fields at site B were distributed around very steep hillsides. The terrain at site A is basically flat, and the soil is more fertile than that at sites B and C.

Figure 3-4 shows the crop allocation map at site A during two rainy seasons of 2007_08 and 2008_09. The ALOS/PRISM image is shown in the background. The areas shown in green indicate the overlapped fields of both rainy seasons in 2007_08 and 2008_09.

Figure 3-5 shows a graph of the total crop field area in five villages during two rainy seasons of 2007/2008 and 2008_09. Total crop area in the 2008_09 rainy season appeared to decrease compared to the rainy season of 2007_08. More than 67% of rainy season crop fields in 2008_09 overlapped with the crop fields of the 2007_08 rainy season.

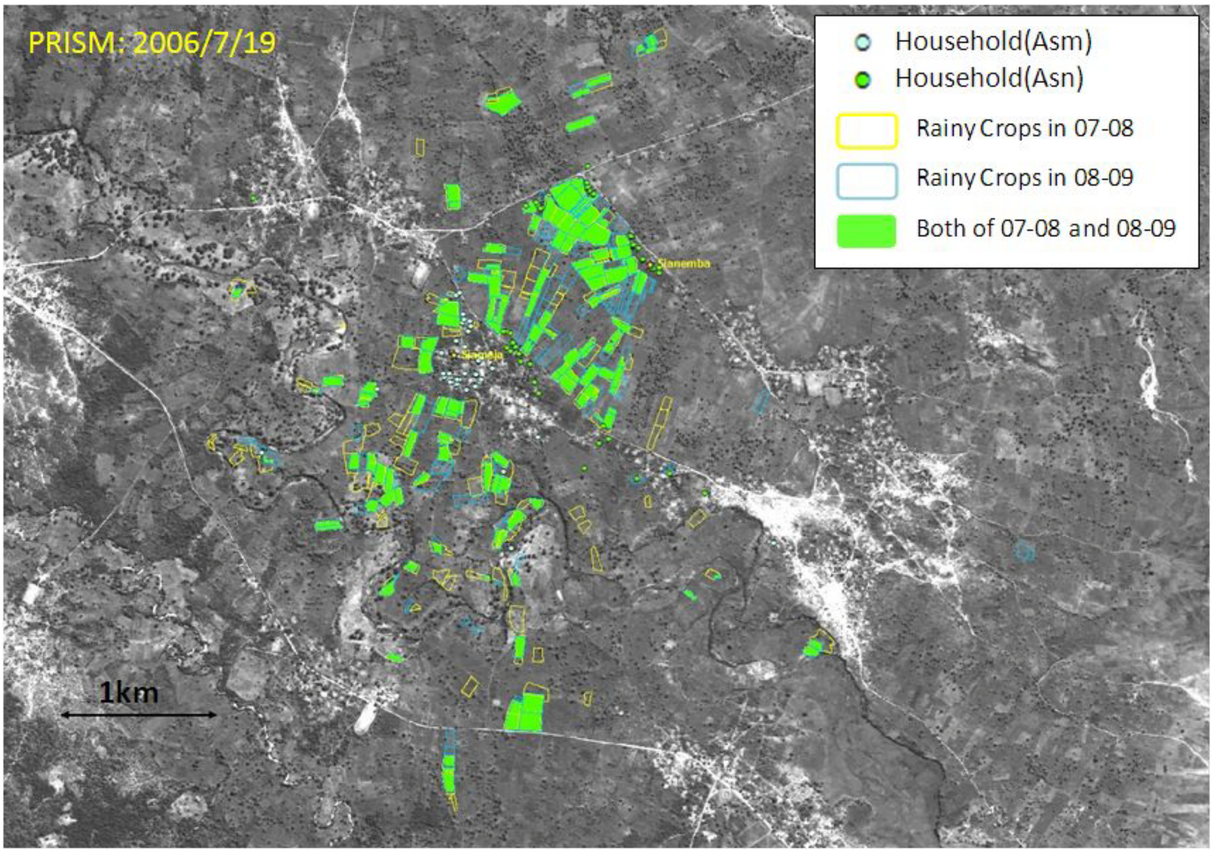

Figure 3-4. Crop field distribution at site A during two rainy seasons of 2007_08 and 2008_09

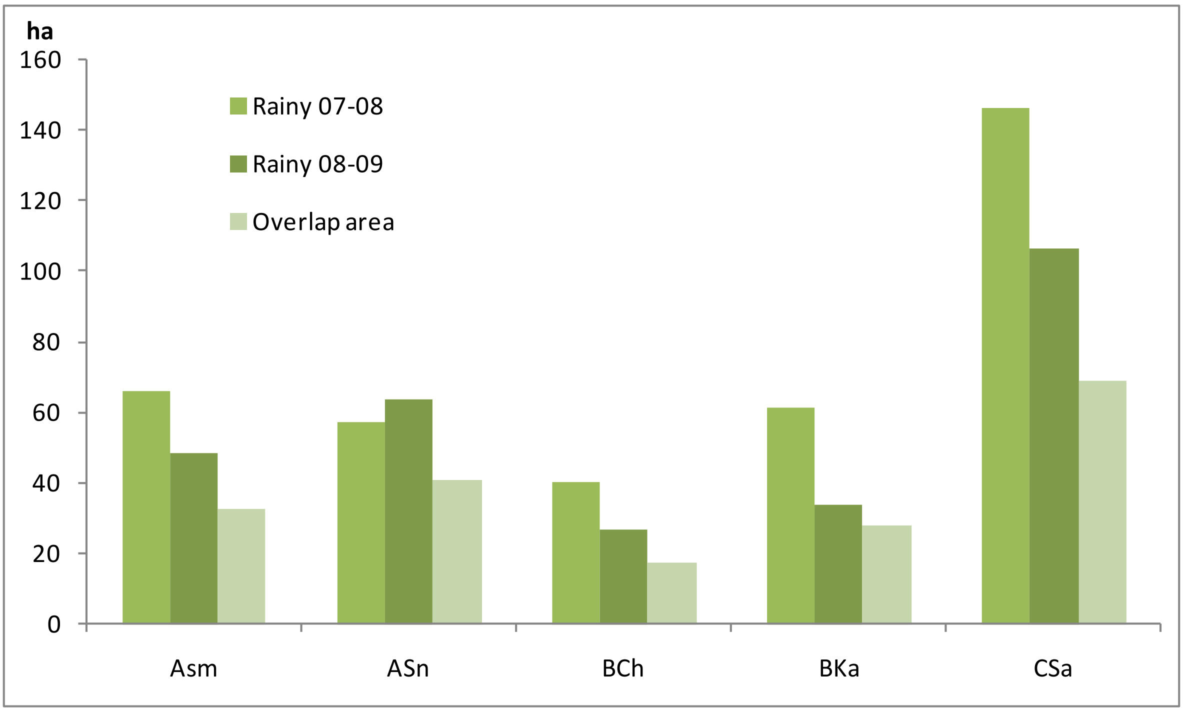

Figure 3-5. Total crop field area during two rainy seasons of 2007_08 and 2008_09

3.3.2. Topographical features of agricultural land use

To examine the topographical conditions of each households' crop fields, the slope was calculated from the DEM and classified into seven classes: Flat (0-1, units: degree), very gently sloping (1-3), gently sloping (3-8), sloping (8-15), steep (25-40), very steep (more than 40), in accord with the Handbook for soil survey (Japanese Society of Pedology, 1978). The mountain ridges and small valleys or thalwegs were detected with the method of water flow accumulation (Jackson and Domingue, 1988).

Figure 3-6 shows the results of slope classification. It is easy to recognize the flat, gently sloping and steep areas at each site.

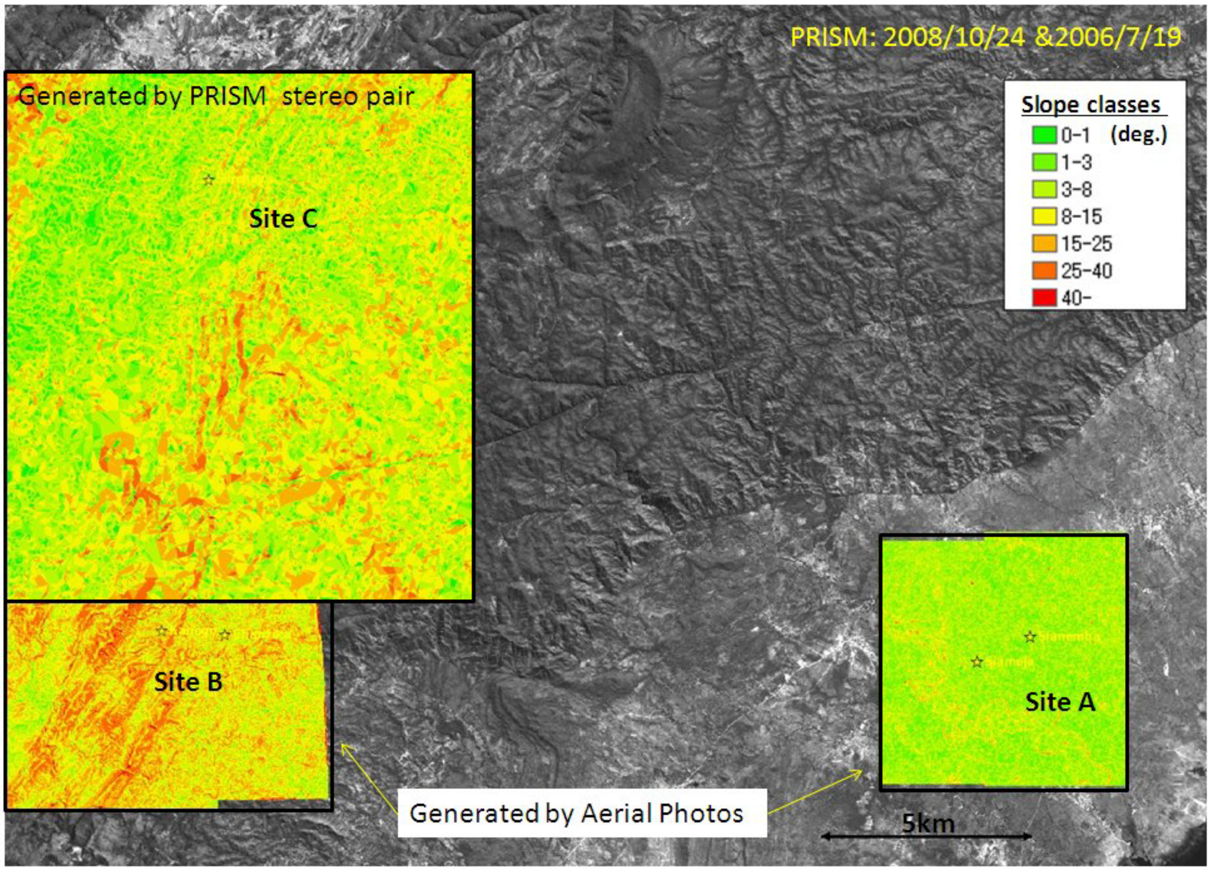

Figure 3-6. Slope classification

Figure 3-7 shows the topographic features of mountain ridges and valleys / thalwegs and the crop field distributions at site B as an example. At site B, all crop fields were located in topographical areas featuring mountain ridges, hill sides and valleys / thalwegs. We analyzed the areas of seven slope classes, mountain ridges and valleys / thalwegs for each crop field. Therefore, we were able to determine the topographical situation of the crop fields of each household in assessing *ex ante* adaptation for ecological risks such as drought and heavy rain. Adaptation at the household level is discussed in Chapter 4.

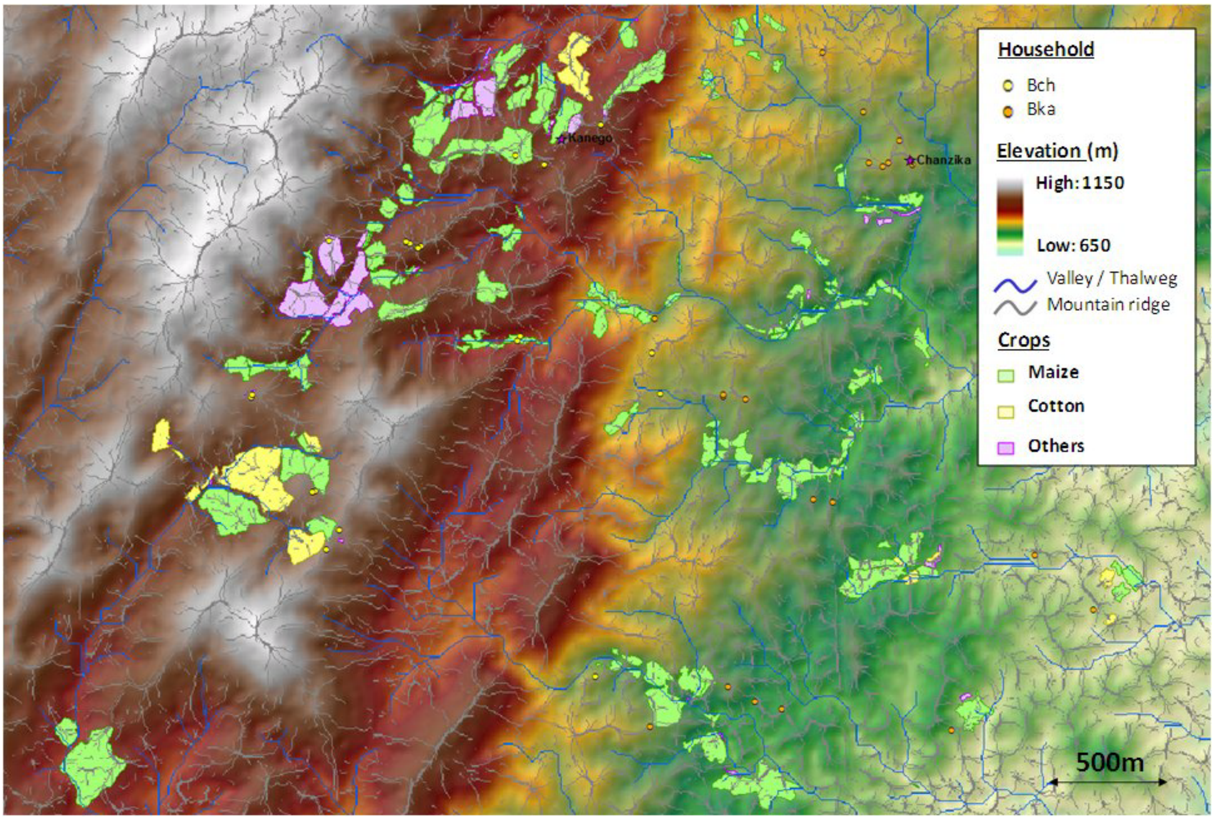

Figure 3-7. Topographic structures and crop fields in part of site B

3.3.3. Seasonal land use / cover characteristics

According to the crop calendar constructed from Miyazaki's interviews about periods of land preparing, planting weeding and harvesting at three sites, the land preparation involved clearing and burning rainy crop fields, performed from September until the beginning of November. In addition, many pictures were taken in the various seasons at three study sites. Figure 3-8 shows samples of the pictures taken on 2007/9/13 in the dry season at Bka.

Figure 3-8. Samples of pictures taken on 2007/9/13 in BKa (by Miyazaki)

Comparing field data with the geo-corrected ALOS/AVNIR-2 images shown in Figure 3-2 allows the characteristics of land use / land cover in each season to be understood. In Figure 3-2, the false color images taken on 2008/9/8 and 10/24 show the charcoal color. These areas show the land cover situation after the burning. In addition, smoke and haze can be seen in the image taken on 2009/9/11. The image taken on 2009/4/26 appears redder than other images on the whole, and the areas around our study sites reveal brightness at that location. The brightness areas on this image show the crop fields after harvesting. These findings suggest that it might be possible to automatically distinguish between cropland and natural vegetation fields using these seasonal characteristics.

3.4. Predicted results in FY2011

We plan to collect and analyze various types of multi- spatial and temporal data in FY2011.

First, the classification of land cover/use in rainy and dry seasons around three study sites will be carried out using ALOS/AVNIR-2 images, crop calendar and field pictures as ground truth data. Second, spatial analysis of the land cover/use and topographical features will be performed. We will then examine the potential risks and ecological shocks at the level of villages or study sites.

References

Japanese Society of Pedology. 1978. “Handbook for soil survey” (Dojou chousa handbook, in Japanese). Tokyo: Hakuyusha.

Jenson, S.K., Domingue, J.O. 1988. Extracting topographic structure from digital elevation data for geographic information system analysis. Photogrammetric Engineering & Remote Sensing. 54, 1593-1600.

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