



An Appropriate Guideline for Participatory GIS: A Result from the Experience of Joint Management of Protected Area Project in Thailand

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Abstract

This study aims to examine the effectiveness of the Participatory Geographic Information System (PGIS) process as implemented through the Joint Management of Protected Areas (JoMPA) project. This article analyzes the process of local land use planning using PGIS through demarcation of special use zones. This was demonstrated to be a crucial process in the implementation of conservation projects. Implementation of PGIS involves several operational steps, brought together in this study using the method of action research. It is based on collaborative participation by stakeholders in the local area, leading all stakeholders to effective co-management of resources.

The means of PGIS is also discussed here as a set of key tools, comprising geo-information acquisition and analysis tools. They are used mainly as participatory and interactive tools for communication and decision-making in collaborative planning or public meetings. The results of this implementation indicated that villagers could clearly understand the boundaries of land use areas, and the community regulations to facilitate practical co-management of land use by all local stakeholders. In addition, this study evaluates intensities of participation in 3 dimensions: facilitation, mediation and empowerment. This integrated approach including participatory local land use planning with PGIS is useful to identify problems in protected areas and also to develop strategies and solutions in partnership with local communities and external stakeholders, that together lead to a co-management approach for protected areas.

Keywords: Participatory GIS; local land use planning; co-management

Introduction

The developmental and operational project of Joint Management of Protected Area (JoMPA) was established to address problems in the protected area at Doi Phu Kha National Park, Nan Province, Thailand (Figure 1). This project was supported by DANIDA from 2006 to 2009 and extended until 2011. It was jointly implemented by Doi Phu Kha National Park, Raks Thai Foundation, and the Mekong Environment and Resource Institute (MERI). The objective of this project was conservation of biodiversity and ecosystems within the protected areas, through shared responsibilities for sustainable management among authorities and local people, including members of the target and neighboring communities, park authorities, forest agencies, local government officials, local authorities and all other stakeholders.

From the conservation perspective, several problems were found in the study area, as a designated protected area:

1) Encroachment was observed in many sites within the park, caused by various reasons such as abandoned farmland, shifting cultivation, illegal logging backed by outside investors or influential persons;

2) Illegal hunting of wild animals, including wild boar, deer, birds, porcupine and pangolin. Although the local communities were established in this area long before establishment of the park, their hunting activities are prohibited by law.

3) There was no clear information on designation of community lands, which had led to conflicts over land use between local communities and the park authority.

4) The poor relationship between local communities and the park authority prevented adequate discussion and resolution of many misunderstandings. The villagers fear arrest by park staff for various kinds of charges. In some areas, they have even used violence against the park authority to prevent enforcement of laws perceived as unjust [1].

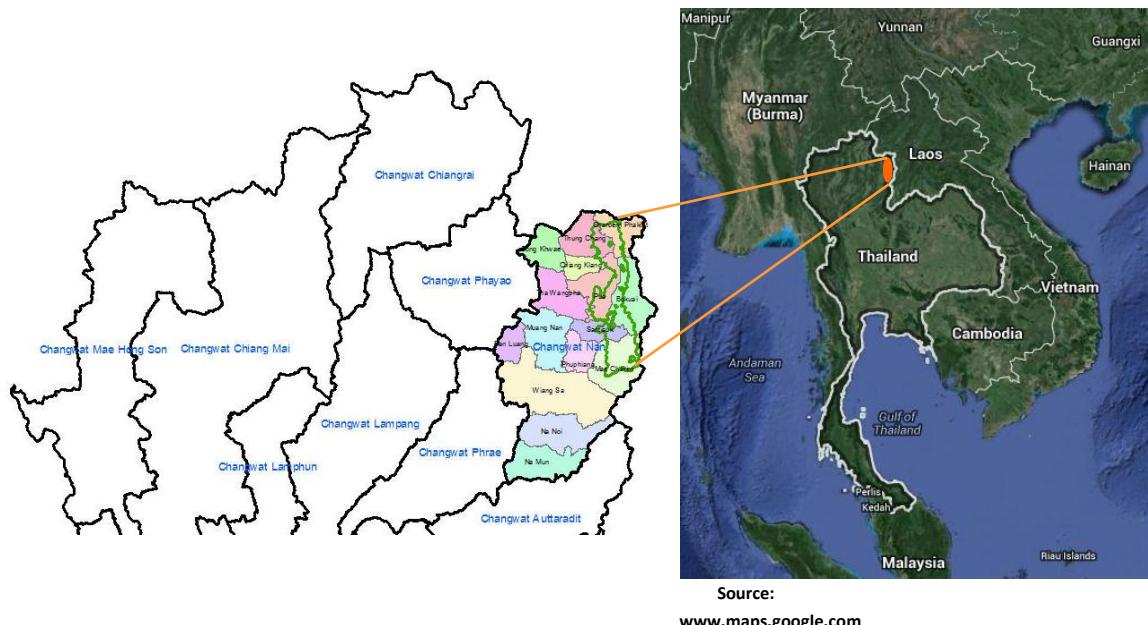


Figure 1 Location of Doi Phu Kha National Park, Thailand

In fact, the socio-economic tensions within this protected highland area have been complicated by various influences such as conservation policy by a remote centralized government, high population growth rates among hill tribe communities, introduction of commercial agriculture, improvement of infrastructure, low quality of health, and poverty. The resulting land use conflicts among farmers and forestry agencies and also between neighbouring hill tribe communities have emerged as critical social problems. Moreover, climate change seems to be impacting this local environment. For example, increasing annual rainfall and intense rainfall in short periods have caused more frequent landslides and reduced the stability of community livelihoods.

To address these problems, this project employed the method of joint management by participatory local land use planning with spatial allocation or demarcation of special use zones. The process of special use zone demarcation was one of the important operations implemented through Participatory GIS (PGIS). The process uses a participatory approach for collection, management, analysis, and display of spatial information. A key element in the JoMPA Project was the integration of geographic information on communities, which explained their physical and land use conditions through spatial technologies such as mapping, Geographic Information Systems (GIS), Remote Sensing and Global Positioning System (GPS).

As the growing number of PGIS projects in developing countries clearly suggest, local people are fully capable of using Geo-spatial Information Management Tools (GIMTs) to record and express data about their land and resources. They are also able to 'work on their maps', and use them effectively to express their opinions in the discussion about sustainable resource use. GIMTs encourage participation of local people. It is shown that sophisticated technology can empower marginalized groups

by providing them with some leverage in their dealings with government agencies and private companies that are making plans for exploiting natural resources in their environs [2].

However, as actual situations may differ widely, guidelines for PGIS are necessary to apply in accordance with the local settings. Accordingly, in this article, the author presents a general guideline for PGIS which was summarized as a result from the experience of JoMPA Project. The details of the study area and process of application were already described in previous articles [3]. Expected roles for PGIS in the near future were also discussed, focusing on issues related to climatic change. Through those analyses, a general process, key tools and evaluation criteria for PGIS are explained in this article.

Process of Local Land Use Planning with PGIS

The PGIS framework is derived from integration of Participatory Research Methods (PRM) with Geographic Information Systems (GIS). Both have been recognized independently over the past 20 years for their contributions to planning for sustainable development [4]. Beginning in the late 1980s, GIS underwent great changes in the 1990s with the diffusion of modern spatial information technologies including low-cost GPS, remote sensing imagery and analysis software, open access to data via the internet and the steadily decreasing cost of computer hardware [5].

PGIS may be simply described as the process of participatory creation and mapping, based on interpretation of data by communities and resource owners. Thus, PGIS serves as a tool to integrate local knowledge and stakeholders perspectives in the GIS [6]. Therefore PGIS also combines the process of Participatory Learning and Action (PLA) methods with Geographic Information Technology and Systems (GIT&S). PGIS practice, therefore, is based on using geo-spatial information management tools [7].

In particular, PGIS is typically used for identification of control over, and access to resources, and the usage in spatial or resource data of owner knowledge [8]. Moreover it is also used for conservation or protection of traditional knowledge from outside forces or authorities. They can be used to display Indigenous Spatial Knowledge (ISK), and support the process of spatial learning, discussion, negotiation, information exchange, analysis, advocacy, and decision making within the community and external stakeholders.

However, ISK is often misunderstood and inadequately communicated in a reliable and provable manner. ISK is often criticized as inaccurate, imprecise, or non-scientific. We can to some extent bring more rigour and reliability into ISK using geo-coordinate systems (geo-referencing), which corrects ISK data using spatial data properties in GIS processes. Consequently, communities can define and clearly communicate information about their area in a manner that is accepted by external parties. The geo-referencing process of ISK serves to some extent to redress the balance between the insider's knowledge and presentation of the problem in question, and the authority or economic force of external influencers [9].

For implementation in the JoMPA project, the process for demarcation of special use zones would be effective in dealing with the problem of unclear information on boundaries and land use areas for local communities within a protected area. PGIS is employed for land use classification i.e. residential areas, agricultural areas (permanent, rotated or abandoned areas), conservation forest, multipurpose forest, or cemetery forest. This is an important process which contributes to successful negotiation on land use by local communities through the process of participatory land use planning.

To accomplish this goal, it is important to arrange a negotiation stage where agreements on land use systems and regulations of local communities are accepted by all stakeholders

including the committee and all community members, representatives of neighbouring communities, local government authorities, forestry agencies, park authorities, local government officials, and other local stakeholders (e.g. consulting committees of the national park). This method assures active involvement of local people and stakeholders in co-management of forest and land resources, based on spatial data provided by tools such as GIMTs. This process can strengthen local communities and lead to the establishment of local organizations for forest and land use management.

Demarcation of special use zones is one of the most important processes, and is supported by PGIS with local land use planning processes. This process represents collaborative participation by stakeholders in the local area, and is based on understanding of the local knowledge of hill tribe people, such as land use patterns, socio-economy, systems of traditions, culture and belief, which are reflected in their relationship with the land.

The implementation of PGIS includes several steps which all affect the efficiency of the land use planning process. In practice creating a shared understanding among all stakeholders is not easy, and it is necessary to have tools which facilitate understanding from different perspectives. Such tools contribute to participation of all stakeholders in problem-solving [10].

Figure 2 shows the operational steps in the process of special use zone demarcation. The first step is obtaining community information. The collected basic data on the community includes sketch maps and interviews as well as prepared GIMTs comprising both high and low technology based maps such as digital topographic maps, satellite imagery, digital ortho-aerial photos, low-cost GPS, digital GIS database (e.g. showing contour lines, streams, political boundaries, roads, etc.) and GIS software. The detailed properties of these tools are explained in the next section.

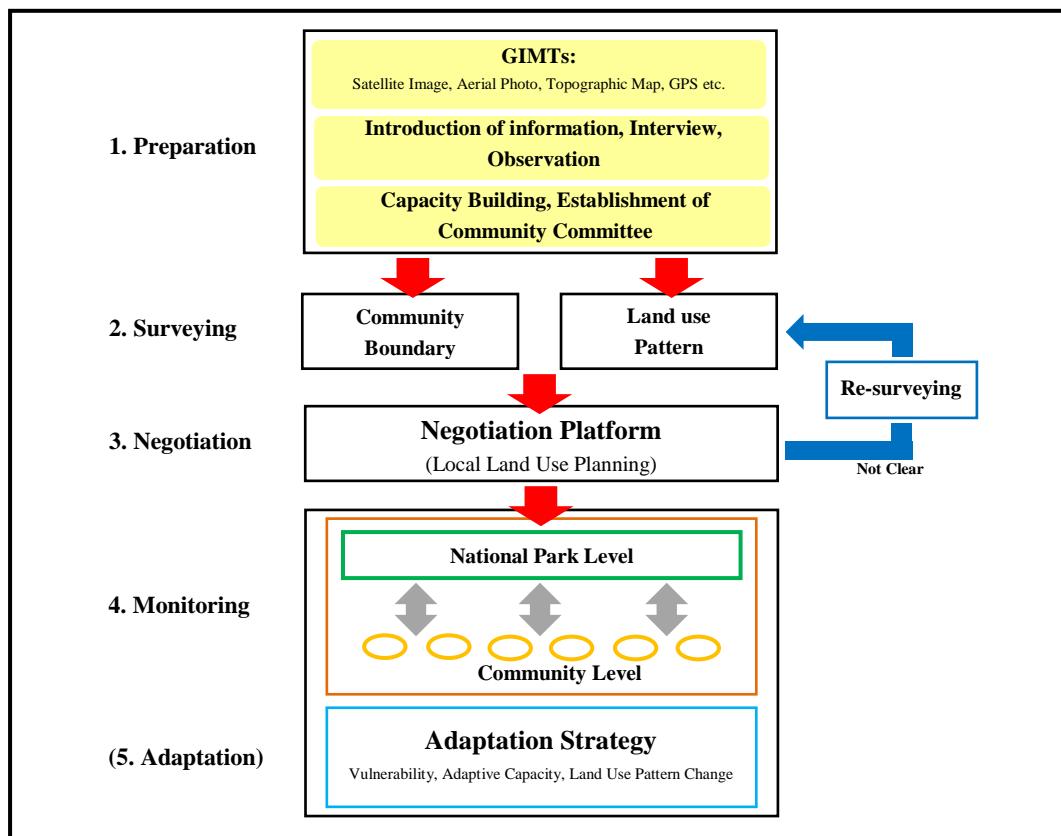


Figure 2 Operational process of special use zone demarcation with PGIS

This process is also essential to improve human capacity in geographic technology and knowledge for both national park officials and community representatives. Moreover, it facilitates establishment or reorganization of community committees while the representatives of communities are responsible for planning, controlling and monitoring their land use and resource management and following related regulations. This step involves community members, community committees and outside researchers (Figure 3).

Step 2 comprises a field survey conducted to establish community boundaries and the current land use system (Figure 4). GIMTs are utilized, as in Step 1, for the field surveys, in which all stakeholders participate together e.g. committees of communities, representatives of neighbouring communities, park authorities, local government officials, and outside researchers. As a result of this process, communities can

clearly recognize the community boundaries and the limits of their own land use areas, as well as understand the purpose of community regulations concerning limitations on land use within their territory.

Step 3 is the negotiation platform (Figure 5). This process provides all stakeholders with geographic data in the form GIMTs, helping them to share the same information by using sketch maps, GIS current land use maps and 3D models to give actual information collected from field surveys. It allows all stakeholders to reach an agreement and acceptance on community boundaries, land use systems and regulations. Meanwhile, it will suggest the direction of land use planning for sustainable livelihood development and ecosystem conservation.

Step 4 is the participatory monitoring system on land use areas and regulations. This process takes place at community and park levels, on which the system of monitoring functions

interactively to control, protect and conserve their accepted land use areas. Therefore, explicit guidelines of efficient monitoring systems are provided to encourage collaboration between park authorities and local communities. GIMTs also support this monitoring system to provide the same information for both levels as shown in Figure 6.

The final step (Step 5) is one of the outputs from the local land use planning process. This operation provides a framework for dialogue between local people and other stakeholders for land use planning supported by PGIS. This process enables the local community to promote analysis of direction in order to adapt them-

selves to create sustainable livelihoods and address issues of environmental and socio-economic change, as well as climate change impacts (Figure 7).

As a result of this process, villagers quickly acquire an understanding of the boundaries of their land use areas, as well as the community rules governing land use in their territory. In some cases, communities are more willing to change their activities, land use patterns, and will work with the park officials in joint management of resources, if they are given greater opportunities for alternative livelihoods.



Figure 3 Step 1- Preparation

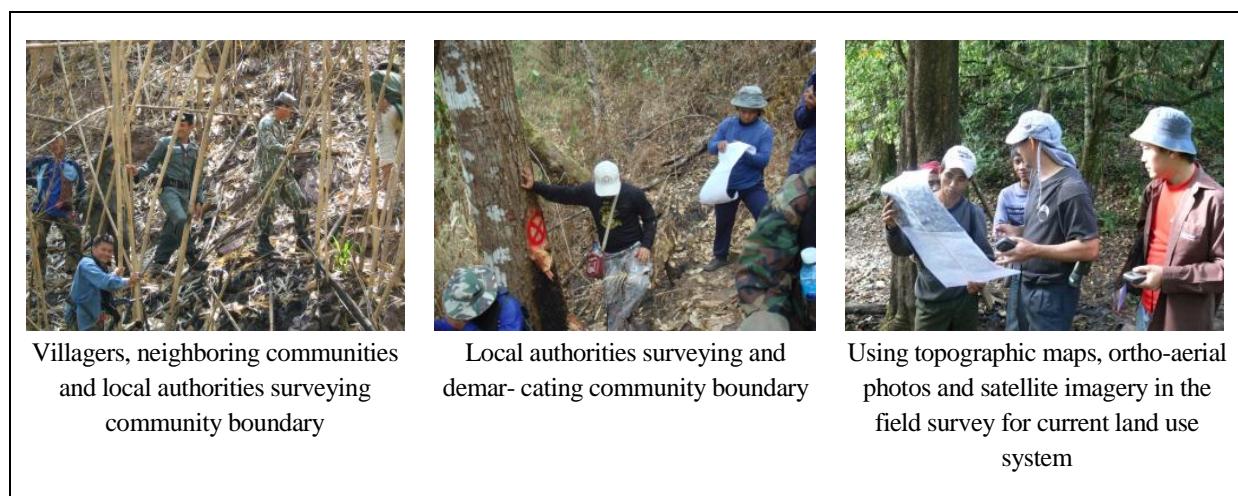


Figure 4 Step 2 - The land survey

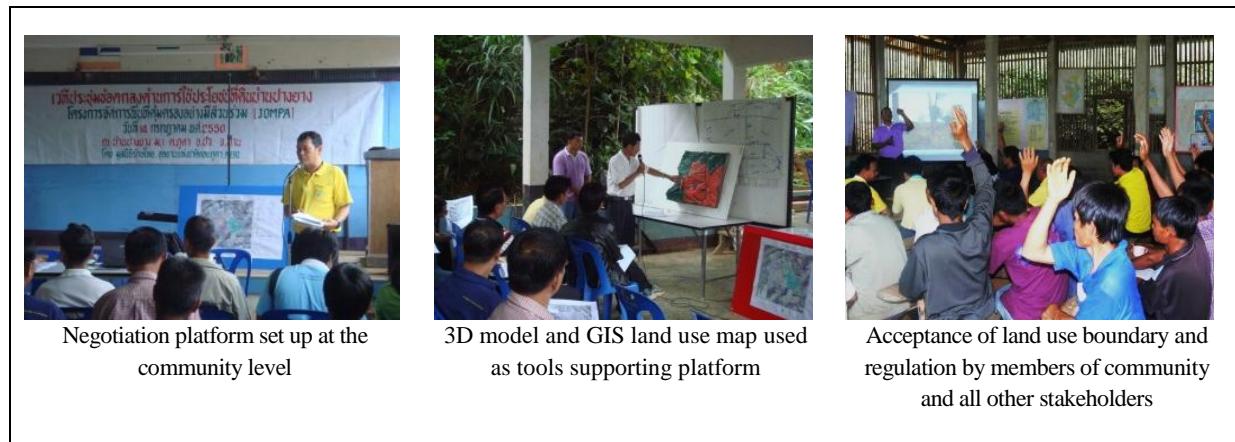


Figure 5 Step 3 - The negotiation platform



Figure 6 Step 4 - Participatory monitoring system supported by GIMTs



Figure 7 Step 5 - Outputs of local land use planning through adaptation strategy

Outputs of Special Use Zone Demarcation Process

Demarcation of special use zones in the JoMPA project was undertaken in 14 target communities, predominantly Lua and Hmong ethnic groups. Data collection was key to the

demarcation process; data collected on social and cultural conditions, economic conditions, and community attitudes and actions showed that some of the communities were better prepared than others to accept the project. One important factor was geographic information

which explains the physical and land use conditions and challenges facing hill tribe communities. The geographic data generated helped villagers and park staff understand the spatial information as maps and 3D-models, understand the boundaries of their territories, and assist stakeholders to work towards co-management agreement between the community and the park staff on the land use territory and zone-specific regulations.

Information on land use patterns were found to be influenced by culture and tradition of hill tribe communities as shown in Table 1.

Recent land use patterns within the target communities may be classified into 3 groups: subsistence, semi-commercial and commercial agriculture. This study also assesses the outcomes of implementing the process of special use zone demarcation as reflected by successful improvement of livelihoods at several levels. Three representative communities were selected, based on their agricultural land use patterns: High level-Huai Win, Middle level-Pang Yang, Low level-Manepluek 1 [3].

Table 1 Summary of land use types for 14 target communities

Land use type	Area (Rai)	%
1. Residence	954	0.48
2. Agricultural Area	105,493	53.27
2.1 Permanent area i.e. terrace paddy fields, fruit trees, vegetables	16,629	8.04
2.2 Rotated area (Rai Lao) which was left 1-8 years i.e. upland rice, corn fields	52,746	26.64
2.3 Abandoned area (Rai Rang) which was left abandoned for 1-7 years	36,118	18.24
3. Forest Area	91,585	46.25
3.1 Ceremonial forest or cemetery	1,197	0.60
3.2 Conservation forest	23,414	11.82
3.3 Multipurpose forest	52,683	26.60
3.4 Revival forest by community	14,291	7.22
Total	198,032	100.00

Source: Author's calculation from GIS database, surveyed by fieldwork in 2008 (1 rai = 0.16 ha)

Huai Win represents a typical land use pattern for subsistence cultivation by groups of Lua including Puedoo, Huai Pood and Kho Kuang. This simple system is dominated by cultivation of upland rice in the *Rai Lao* areas within this community. Upland rice is the main subsistence crop but only one crop per year can be cultivated. This system is characterized by long-fallow cultivation, the use of household labour and minimal investment in cash inputs. As cultivation is typically a community effort, there is an efficient demarcation processes, with clear land use boundaries and regulations that are strictly followed by all members of the community.

Pang Yang represents the semi-commercial cultivation groups of Lua including, Pa Bong, Nongnan, Huai Loy, Huai Kuang, Namkwang and Sawang. The residents have changed their agricultural patterns from subsistence cultivation to a more commercial-oriented system, with a small marketable surplus sold in local markets. This community is representative of many communities in Phu Kha National Park, which have shifted to adopt more complex agricultural patterns for economic reasons. The regulations on land use for communal resource management have been clearly created, but it is often not possible to enforce them in some areas where there is an overlap between subsistence and commer-

cial crops. Consequently, the regulations on land use for this community are more detailed than for Huai Win due to the more complex pattern of land usage.

Maneepluek 1 is representative of the fully commercial agricultural groups of Hmong including Kiw Nam and Pang Kob. Short-term vegetables are the main cash crops, and economic factors are the most important influence on their cultivating decisions; this strategy has generated significant improvement in economic status for the community. Because of the economic incentive from cash crops and the variety of social relations of members in the community, the regulations on land use management are the most detailed. However, it is difficult to enforce the regulations, and there are cases of violation every year.

The observations of this study raise several issues and paradoxes. The communities that are more efficient in land use management and protect local wisdom and biodiversity remain in poverty. On the other hand, communities which are less efficient in land use management have higher levels of income since they have turned to commercial agricultural practices, degrading biodiversity and the fragile highland ecosystem. How, then, to encourage communities which are conducting more commercial-oriented cultivation to improve the efficiency of their land use management? Secondly, for subsistence-based communities, how to enhance livelihoods while maintaining their efficient land use management systems?

Key Tools for Participatory GIS

The PGIS approach employs GIS to empower community-level resource use management. Information and communication systems are key to participatory decision-making, which is based on an effort to ensure that all parties have equal access to information [11]. The use of GIMTs for the operational process is important for stakeholders to support the process of spatial learning, discussion, negotiation, information sharing, analysis, ad-

vocacy and decision making as a partnership.

Geo-information acquisition and analysis tools are used mainly as participatory, interactive, communication and decision-making tools in collaborative planning or public meeting. These tools may be employed for Participatory Spatial Planning (PSP) in countermap, to explicitly display the needs and requirements of groups that are typically excluded from scientific surveys because they are socially and institutionally marginalized [12].

1) Participatory Sketch Map

The sketch map is a fundamental geo-spatial information management tool- it is a participatory method which is easy to create, though not to scale, and does not have map coordinates. It contributes as an initial tool to explore and learn about the spatial perception or mental maps of local people concerning their land and resources. Sketch maps also help understanding and explaining the indigenous spatial knowledge (ISK) of local people. In the case of the JoMPA project, the participatory sketch map method was adopted in the initial operation, supporting collection of basic data on the community related to their ISK, such as past and present land use patterns, current situation of land/resource use, and natural hazards (Figure 8)

2) Topographic Map

Topographic Map of 1:50,000 is the base map for Thailand, covering the entire country. It is provided by The Royal Thai Survey Department (RTSD) in both paper and digital formats. The map provides important spatial data such as contour lines, main roads, rivers and streams, locations of communities, all of which are georeferenced by both geographic and grid coordinates. However, the data on this map should be updated by field surveys prior to use to ensure local features are correctly detailed. Topographic maps are vital for field surveys to illustrate the shape and elevation of the topography so that we

can easily draw or transpose boundary lines and other relevant data from the real world to the

map (Figure 9). Finally, they serve as the basis for building a 3D model on the community scale.



Figure 8 Participatory sketching map

3) Low-cost GPS

The Global Positioning System (GPS) is one of the high-technology GIMTs tools. There are several types i.e. handheld, base station and navigation GPS. In the JoMPA Project, handheld GPS was adopted because of its affordability and ease of use. However, GPS users should have the knowledge about coordinates and utilization on a map. It, therefore, is necessary to provide training on use of GPS use and map coordinates for those involved, both the park authorities and respective communities. Low-cost GPS provides the location coordinates, facilitates collection of point and line data, and represents the location of important landmarks and community boundary from field survey (Figure 10). It facilitates data transformation from real world to maps, which makes its data reliable because it is expressed as scientific knowledge. This data can be handled by GIS software which enables integration with other geo-spatial data software in order to generate a supporting map for the next participatory process.

4) Ortho-aerial photography

Ortho-aerial photography differs from conventional aerial photography, and is available from Thailand's Land Development Department (LDD). It is the outcome of an LDD project in 2002 covering the whole country by aerial photography at a scale of 1:4,000. The images

are produced using ortho-rectification processing by photogrammetric methods. Ortho-aerial photos have the same map properties, with a high accuracy of location. When conducting surveys in the field, it is very useful for geo-referencing of location and details can be easily seen, thanks to its high resolution (Figure 11). However, its use is limited since it has not been updated since 2002.



Figure 9 Understanding the shape of the land with elevation through comparing topographic map and 3D model



Figure 10 Field surveying community boundary using low-cost GPS

5) Satellite Imagery

Satellite imagery is classified as raster data, and is recorded by sensors on orbiting satellites. This type of color composite data allows detailed classification of land cover, not only by residential, forest, agricultural area or water bodies, but also by the type of agriculture (e.g. upland rice, corn, and abandoned fields). The JoMPA project used a SPOT 5 image covering the Doi Phu Kha National Park area, acquired in April 2010 and distributed by the Geo-informatics and Space Technology Development Agency (GISTDA) in Thailand (Figure 12). This data is useful for field surveys of current land use patterns in local communities, and can distinguish forest area from abandoned fields or rotated crop areas. However, the processing of this satellite imagery is a specialist task.



Figure 11 Ortho-aerial photo representing community boundary after surveying with GPS

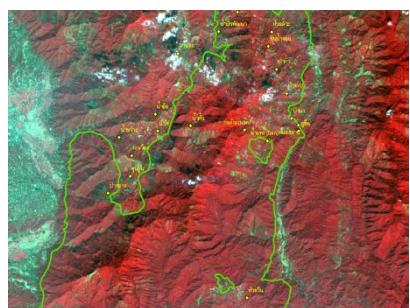


Figure 12 Satellite Image covering the Park area for land use/land cover assessment

6) 3D Models

The 3D elevation model is an efficient representative tool to support communication and negotiation. It is an accurate and precise tool in spatial dimension, illustrating position, direction, distance, and elevation because it is built with

1:10,000 maps which are enlarged from 1:50,000 topographic maps, or on the scale of community level. Its shape and elevation are generated using contour lines from the topographic map, at 20-metre intervals. The information from the survey process is represented on the 3D model using different colors to represent each land use category, and also includes other data such as community boundaries, main roads, streams, and important landmarks. These are labelled using local place names with which local people are familiar. The 3D model should be constructed by villagers themselves as a process of collaborative learning, pooling their collective local knowledge. The 3D model is an important tool to visualize and simplify understanding of land use conditions. Therefore, it is an important tool for communication and information sharing (Figure 13).

7) GIS Software

The JoMPA Project adopted a commercial GIS software (ArcGIS version 9.1 by ESRI Thailand) in order to manage geo-spatial data and generate GIS maps. It is efficient GIS software and is used widely in Thailand. However, it is too expensive to employ for small development projects or local organizations. However, alternative GIS software is becoming increasingly available as freeware (e.g. Quantum GIS, Map Window GIS, GRASS GIS, and Google Earth) with similar functionality to commercial software. Freeware GIS software are thus well-suited for PGIS implementation by local organizations.

With training of local people in operation, GIS software can be readily used for PGIS implementation. However, in cases where hill tribe people are unable to do so, the system would be operated by outside mentors. GIS software is used for geo-spatial data management both at the park and community levels. This process can make ISK more reliable as it is corrected with spatial data properties through the GIS process, especially the geo-referencing process. Further-

more, it supports generation of land use and other thematic maps which contribute to the negotiation platform for land use planning (Figure 14).



Figure 13 3D Model for participatory discussion by all stakeholders



Figure 14 GIS Map of land use pattern generated by GIS Software to support the negotiation platform

Evaluation of PGIS by Participation Level

In the JoMPA project, implementation of PGIS was represented by special use zone demarcation in the local land use planning process, which combined a participatory approach and Geographic Information Technology and System (GIT&S). The intensity of participation is critical to balancing the interests of communities against those of external stakeholders [13].

This study classifies the intensities of participation into 3 levels as shown in Table 2. At the first level, PGIS facilitates collection of information and construction of geo-referenced spatial data (*e.g.* land marks, contour lines, roads, streams, political boundaries, park boundaries), supported by GIMTs such as sketch maps, topographic maps, satellite imagery, ortho-photos,

low-cost GPS and GIS software. In this process, these geo-spatial data are managed by GIS software including the elicitation of ISK from local people.

This level also facilitates capacity building through training of park authority officers and local people in new skills such as geographic technology (*e.g.* map reading, map coordinates, use of GPS and creation of 3D models). This enhanced capacity and knowledge helps the operation of joint management. Outputs from this process improve the reliability of geo-spatial databases, especially community boundary and land use pattern, through the georeferencing process and collaboration on field surveys.

The second level- the negotiation platform- is created at the community level, to facilitate information sharing, negotiation and mediation. To address the lack of clear information on community land use, which may lead to conflicts between local communities and the park authority, this process can mediate the conflict by collaborative agreement on clear information regarding land use patterns as well as explicit guidelines for a participatory monitoring system managed together by local communities and the park authority.

GIMTs, including 3D models, GIS land use maps and sketch maps, are all used as spatial tools for communication among stakeholders. They can also be used to visualize ISK. These spatial tools help external stakeholders to interpret and understand the mental map and ISK of local people in respect for their land management (*e.g.* traditional agricultural patterns with rotational cultivation, conservation forests and multipurpose community forest areas, traditional community boundaries). This process, therefore, leads to the process of spatial learning, information sharing, discussion, negotiation, analysis, advocacy, mediation, and decision making among local communities and external parties.

Moreover, because the negotiation platform is usually attended by representatives of local government and organizations with expertise in related areas, the process can introduce practical suggestions for improving the efficiency of the productive system, e.g. by suggesting alternative livelihoods.

The third and final level provides a framework for dialogue on local land use spatial planning for the local community, involving issues such as the community's capacity to adapt to environmental impacts such as climate change, as well as sustainable livelihoods for the community. Likewise, empowerment of local com-

munities can lead to the establishment of a local-level organization for managing the community's forests and land use. GIMTs, such as hazard risk maps, analytical GIS maps, 3D models and GIS land use pattern maps, can all support this process, identifying specific local risks and vulnerabilities. GIMTs also support decision-making on initiating actions upon the land with strategy for adaption to changing situations: for instance, planning irrigation systems, analyzing suitable areas for cropping, assessing vulnerability and adaptive capacity to disaster impacts.

Table 2 Intensities of participation in PGIS processes

Participation Levels	GIMTs	Functions	Outcomes
Facilitation on collection and construction of spatial geo-referenced database	Sketch map Topographic map Satellite Imagery Ortho-photo Low-cost GPS GIS software	<ul style="list-style-type: none"> - Generating highland spatial geo-referenced database managed by GIS software - Storing and displaying data at national park and community levels - Collecting ISK of local people - Supporting field survey on both community boundary and land use pattern/territory 	<ul style="list-style-type: none"> - Explicit information of community boundary, land use pattern to build reliable spatial database through geo-referencing process - Collaborative operation of field surveying
Mediation and Negotiation to reach collaborative agreement with spatial communication tools	3D model GIS land use map Sketch map	<ul style="list-style-type: none"> - Supporting negotiation platform at local community level - Sharing information and understanding between local people and outsiders - Reaching collaborative agreement with decision-making of all stakeholders through learning, discussion, advocacy to share spatial perception and information - Consultation or suggestion about alternative livelihoods for local communities - Construction of participatory monitoring systems on land use by the park and local community 	<ul style="list-style-type: none"> - Collaborative agreements on community boundary, land use territory and their regulations - Reducing conflicts from misunderstanding on land use information between local people and park authority - Building conservation system of natural resources through co-management approach
Empowerment by local land use planning	Hazard risk map Analytical GIS map 3D Model GIS land use pattern map	<ul style="list-style-type: none"> - Providing dialogue framework for adaptation of community to all changing situations - Analyzing land use spatial planning based on the balance between sustainable livelihood and natural resource management under environmental changes to initiating actions on the land - Assessing vulnerability or risk of environmental and possible climatic changes - Raising awareness of their land use impacts on highland ecosystem 	<ul style="list-style-type: none"> - Awareness of conservation-oriented approach to sustainable livelihood - Appropriate guidelines of land use conversion - Adaptation strategies with real practices on the land through analysis of environmental change impacts

This level promotes appropriate guidelines for land use change based on balancing the need for sustainable livelihoods with natural resource management under environmental changes. The integrated process of PGIS in local land use

planning therefore leads to realistic, workable solutions that respect the principles of sustainable development and conserve both livelihoods and biodiversity in highland protected areas through a co-management approach.

Concluding Remarks

Demarcation of special use zones is an important process in participatory land use planning for local communities. The four main steps in the process of demarcation include preparation, field surveying, negotiation and monitoring/adaptation. PGIS supports each of these steps. As well as providing accurate spatial data, GIMTs such as 3D models, GIS land use maps and sketch maps can serve as powerful communication tools to share information among stakeholders. These spatial tools help external stakeholders to understand geographical conditions as well as ISK of local people who have traditionally managed their land.

As PGIS reliably displays both geographical conditions and indigenous knowledge in terms of local resources, it offers a platform for discussion and negotiation among stakeholders to achieve efficient co-management of forest and land resources. This process also promotes analysis of local community needs from different perspectives, to attain a balance between sustainable livelihoods under changing environmental and socio-economic contexts, as well as increased frequency and intensity of natural hazards brought about by climate change.

The implementation of PGIS is evaluated by the intensity of participation level in three dimensions: facilitation, mediation and empowerment. At the first level, PGIS facilitates collection of information to construct geo-referenced databases by GIMTs with elicitation of ISK. At the second level, a negotiation platform is created within the community, promoting mediation among all stakeholders. At the final level, empowerment of local people strengthens the community, leading to the possibility of establishing community-based organizations for managing forests and land use, as well as to conduct vulnerability analysis to assist the community in adapting to social and environmental change.

The integrated approach including participatory local land use planning with PGIS is

useful to identify problems in the protected area and to develop strategies and solutions in partnership among local communities and external stakeholders. These efforts can contribute significantly to enhance the agricultural systems of local communities to support their adaptation to the changing environment.

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