The Development of Web-Based GIS Application for Agroforestry Carbon Sequestration Offset Project in Thailand

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Abstract
Advances of agroforestry are known to provide rural people much potential in both struggling out their poverty and mitigating of farm damaged caused by uncontrollable weathers. Changing of cultivation systems from single annually plant cultivation to multi-specie cultivation with various trees and perennial woody plants included can reduce the severities of climate change by capturing more atmospheric carbon dioxide and converting into woody and soiled biomasses. Canopy difference works better in hedging the areas from erratic and extreme climates. Beyond traditional timber and non-timber products, cultivations with agroforestry system also provide farmers a new valuable product which is tradable in certain markets; the carbon. The carbon, a kind of greenhouse causing gas trapped in biomass form, can be counted and amounts of it can be possibly traded at present. This paper describes the efforts of an intensive Web-Based GIS applications for agroforestry carbon sequestration offset project in Thailand.

1. Introduction

Geographic Information Systems (GIS) are tools for acquiring, managing, analyzing, and presenting spatially related information (Coors, 1998). GIS convert diverse data into easy- to-read and easy-to-access maps and information. In addition, the advantages of the World Wide Web are numerous, the two primary being time independence and spatial independence (Mohler and Duff, 1999). GIS architectures have traditionally focused on a static environment in which users sit at workstations to perform spatial analysis. Emerging technologies such as the Internet, wireless communication and mobile computing devices are changing the way GIS is being used by moving GIS from the desktop into field user's hands (Tripathi and Bauchkar, 2005).Distributing data over the Internet is more efficient than transmitting data through disks. Both Internet and GIS changed the processes of accessing, sharing, disseminating and analyzing data. Technology to share GIS data, such as Web-Based GIS, Open GIS and Distributed GIS on the Internet is rapidly progressing (Honda, 2003). According to IPCC Fourth Assessment Reports and other documents (Moutinho and Schwartzman, 2005, Metz et al., 2007, Parry et al., 2007 and Solomon et al., 2007), growths and deteriorates of tropical forests can be significantly influent the climate changes in term of greenhouse gas absorption and emission, respectively. The tropical forests provide many natural resources which are continuously destructed by rural people and can be alleviated by proper agroforestry adoptions (Smith and Scherr, 2003, Angelsen and Kaimowitz, 2004 and Montagnini and Nair, 2004). The agroforestry principal is based on the use of farmed trees in combination with indigenous trees in order to provide a variety of potential incomes from both timber and non-timber products (Michon and de Foresta, 1996, Leakey and Simons, 1998 and Simons and Leakey, 2004). In addition to the traditional products mentioned above, the agroforestry also has the important roles in maintaining ecosystem varieties (Jose, 2009) and climate mitigation through carbon sequestration (Sharrow and Ismail, 2004, Kirby and Potvin, 2007 and Nair et al., 2009). Moreover, the carbon itself becomes a commodity trading item in financial markets under either regulatory or voluntary condition. Therefore, the agroforestry has much potential in climate-severity mitigating and provide

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additional income stream to the farmers. The objective of this research is to use of new innovation methods, infrastructure and geospatial tools and technologies that form a carbon measurement, reporting and verification system, we believe, help reduce costs associated with developing terrestrial carbon mitigation projects and reporting carbon stocks and stock changes to carbon markets.

2. Methodology

This research illustrates international collaboration in efforts to develop the agroforestry carbon sequestration offset project in Thailand and to develop a new protocol for "Biotic Carbon Sequestration in Agroforestry System in Inpang Community Network Northeast Thailand". This project works by cooperation among researchers from Faculty of Science, Mahasarakham University, Thailand, National Resource Council of Thailand (NRCT), Thailand, Department of Forestry, Michigan State University, USA and farmer groups in the Inpang Community Network, Thailand. Figure 1 show the study location in this study. In this research we have developed Web-Based GIS carbon sequestration system by collaborative team of researchers working called Carbon2Markets (Carbon2Markets.org) Lead by Prof. Dr. David L Scole, MSU, USA. The Carbon2Markets is comprised of five integrated components (Figure 2); 1) Relational Database Management System (RDBMS), 2) Spatial data engine, 3) Map server 4) Google Map API extension and 5) Web server. The five components are integrated through custom engineered APIs and scripts. This Carbon2Markets is platform independent and able to be accessed through the World Wide Web. The five components are described in detail below (David et al., 2009):

2.1Relational Database Management System (RDBMS)

The Carbon2Markets stores all data using Microsoft SQL server. Data include maps in vector format, satellite imagery in raster format and tabular data associated with the maps, satellite images and even data of higher dimension which includes time.

2.2 Spatial Data Engine

This component provides spatial indexes for the RDBMS optimized to store and query data related to objects in geographic space, including points, lines, polygons and satellite images. The spatial data engine also adds functionality to support spatial data types (to be able to send queries related to geo-spatial location attributes), enabling the ability for the Web-Based GIS to generate queries that have a spatial component (e.g. find all the line segments that intersect a given point or set of points or a given line segment) in a timely fashion.

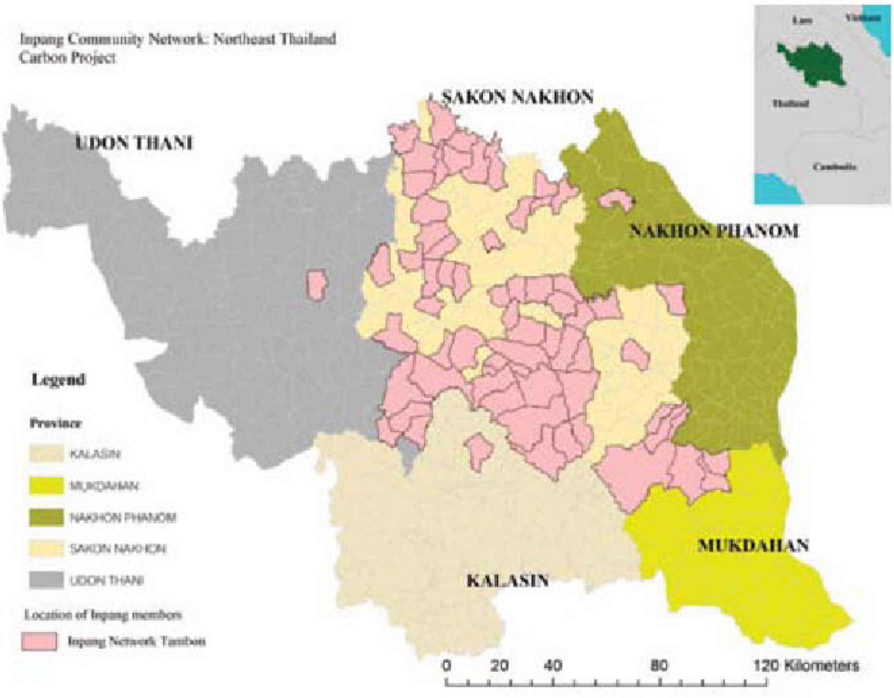

Figure 1: The study area of Inpang member's locations by sub-district in five provinces in northeast Thailand

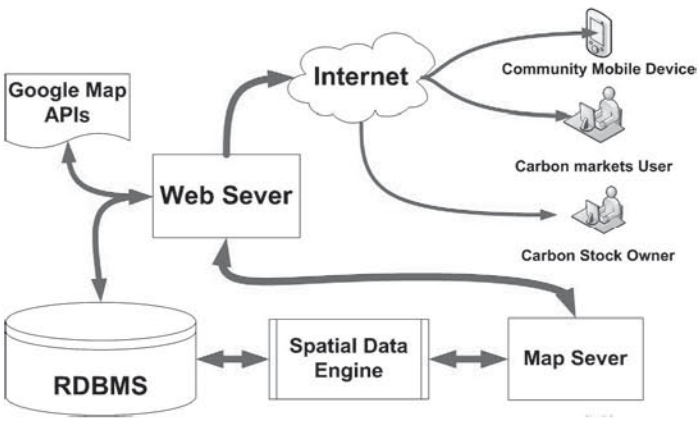

Figure 2: The Carbon2Markets component

2.3 Map Server

The map server component is a customized software environment that provides the elements necessary to build spatially enabled internet applications (web services) that have the ability to respond to spatial queries by creating customized maps on the fly. It also provides the ability to display satellite imagery and derived products. The map server is a set of programs that sit inactive in a computer waiting for requests to build maps or send information related to the maps. When a request is sent to the map server, it uses the parameters sent in the request to build its own request to the Spatial Data Engine and when the Spatial Data Engine returns the information, it builds a map and/or a string with the response. That response is sent to the web server where it is integrated with other elements. The map server in Carbon2Markets will be capable of generating responses in the most common web services protocols (KML, WMS, WFS, REST and SOAP). They all will be delivered in APIs built on JavaScript.

2.4 Google Maps APIs

The Carbon2Markets uses the Google Map interface as a common, ubiquitous user-friendly portal to render project data using Web-Based GIS. Its "look and feel" is very popular and most people know how to navigate its maps. It provides multiple geographic background layers, however our extension of the API allows for use of additional geospatial data sets and the ability to display current acquisitions of high-resolution data in support of project verification as a substitute of the Google Maps imagery. The ability to display maps that include satellite imagery becomes very important in remote areas where Google Maps has only imagery with low resolution. The interaction with Google Maps and the Map Server is executed through the customized JavaScript Extensions of the Google Maps API mentioned above. JavaScript provides an excellent medium for this systems because is a language that provides lightweight applications, since the code runs inside the browser immediately.

2.5 Web Server

The web server component uses the Hypertext Transfer Protocol (HTTP) to portray project information and data in tabular and Web-Based GIS formats over the World Wide Web. This is the component that puts the information coming from the Map Server, the RDBMS and the Spatial Data Engine together in a simple format that can be read with a simple web browser (e.g. Internet Explorer, Firefox, etc.) and does not demand high computer or network power. The Carbon2Markets functions as an on-line application with a suite of tools for developing and managing carbon mitigation offset projects. The system includes data storage and data back-up functionality; it provides data integration services of field-based biometry and Remote Sensing analysis for carbon stock and carbon projection calculations; and it also provides monitoring, reporting and verification services.

2.6 Data Storage and Data Back□Up

Carbon mitigation offset protocols and methods specify data required for generating reliable estimates of carbon capture and carbon emissions avoidance. These data include project boundary areas, spatial and temporal land use and land cover change information, ownership, land management data, sample plot biometry, etc. The Carbon2Markets stores all project data (tabular, GIS, GPS, and Satellite Remote Sensing data) with multiple redundant back-ups for data safety and security.

Figure 3: Carbon2markets of teak project in Thailand

Figure 4: Property plot details of the Carbon2Markets

Figure 5: Property tree level details of the Carbon2Markets

2.7 Data Integration for Carbon Calculation

The Carbon2Markets tools are being developed to integrate the field based biometry measurements at plot and inventory levels with assessments of biomass and carbon from new remote sensing analysis techniques and use allometric and spatially explicit carbon booking models to derive carbon stock. Ex ante projections of carbon sequestration in agroforestry offset projects can be reported using growth and yield models.

2.8 Monitoring, Reporting and Verification Services

The carbon sequestration system uses web-services, including advance web-base GIS, to provide quantification of carbon stocks, monitoring for permanence, reporting and verification services. The carbon sequestration system can accommodate high-resolution satellite data (e.g. IKONOS, QuickBird) and ingest annual or bi-annual updated of field level inventories. These enable monitoring and verification services. The carbon sequestration system can generate on demand project reports that include required protocol modules (project boundary, land use history, eligibility, leakage assessments, permanence commitment, baseline carbon, ex ante projections, monitoring updates, etc.). The carbon sequestration system provides verification services through the on-line system by allowing verifiers to interrogate all data used in quantifying project level carbon stocks and projecting sequestration rates. These data include field level and individual tree level biometry data, allometric equations developed especially for teak in Thailand (Petmark and Sahunalu, 1980) used to estimate biomass and carbon, calibration and validation data used for the remote sensing analysis, and documentation on enrollment, tenure and permanence commitments. The Carbon2Markets (Figure 3 to Figure 5) provides services to both carbon offset providers or managers and carbon offset buyers or the markets. Carbon offset providers or managers may include aggregators, local community organization, or individual land owners. Examples of carbon offset buyers or the markets include the Chicago Climate Exchange, climate investment funds, or direct investments on offsets from corporations and industries.

3. Results and Conclusion

In this research project has established the pilot project area sites and developed web-based GIS (carbon2markets.org) for implementing agroforestry carbon offset projects and for developing the protocols for the markets. Our early efforts as part of this project to complete work in Thailand with small-holder teak areas serves as the simplest agroforestry carbon offset system. In addition to greater awareness and understanding about climate changes, climate mitigation effects of carbon sequestration, and worth of obtained biomass, the project participants also achieve in Inpang carbon offset establishing in the areas. These enrolled participants consist of 98 Thai farmers, 114 smallholders, and teak agroforestry farms in Carbon2Market system. The project included 44 teak area owned by Inpang members, and 54 additional areas owned by non-Inpang farmers (10 in Uttaradit province, 20 in Nakhon Sawan Province, and 24 in Nong Bua Lumphu province). The average sizes of the teak area are less than 3 hectares. The total area enrolled in Carbon2Markets is 283.27 hectares (170 permanent plots and 13,021 teak trees tagged, DBH, and height recorded). By using an allometric equation the baseline carbon stock of total enrolled area (44,801 tons CO_2 equivalent) was successfully calculated (2009).

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