Title: Prioritizing areas suitable for implementing REDD+ project activities: Seima Biodiversity Conservation Areas, Cambodia

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Prioritizing areas suitable for implementing REDD+ project activities Seima Biodiversity Conservation Areas, Cambodia

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Abstract

This paper uses multi-criteria evaluation (MCE) approach in IDRISI to identify areas most suitable for the implementation of REDD+ project activities in Seima Biodiversity Conservation Area (BCA) in Mondulkiri province, Cambodia. Prior to this MCE analysis, this paper also utilizes ArcGIS software to create the study area map for Seima BCA using data downloaded from the Digital Chart of the World produced by the Environmental Systems Research Institute, Inc. (ESRI). The criteria applied to conduct the MCE analysis are the specifications for REDD+ project within protected areas. Based on the analysis, approximately 7,508 hectares or 4 percent of the total study area are considered to be the most suitable sites for REDD+ project implementation. The aggregation and analysis framework described for this particular REDD+ project may be used for other type of REDD+ project.

1. Introduction

Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+) represent a form of environmental governance that transcends multiple structures of decision-making and organizations, assembles actors with diverse interests, and translates into numerous implementation procedures. Despite its importance in the design and implementation of national REDD+ schemes, the nature of the global REDD+

architecture is yet to be universally institutionalized. To deal with these uncertainties, REDD+ participating countries adopt flexible mechanisms and implement the schemes in three overlapping phases. Countries start by preparing a national REDD+ strategy through inclusive multi-stakeholder consultations, start building capacity in monitoring, reporting and verification, and begin demonstration activities. The focus of the second phase is to implement policies and measures to reduce emissions as set out in the national REDD+ strategy. In the final phase, countries are compensated for the reduced emissions and enhanced carbon stocks relative to the established reference levels (Streck, Gomez-Echeverri et al. 2009).

Sources of funding vary depending on the phase of the project. For example, while voluntary financial contributions from the World Bank's Forest Carbon Partnership Facility, the UN-REDD Programme, or bilateral initiatives are the main funding source for phase 1. The main sources of funds for phase 2 REDD+ national strategy implementation come from bilateral and multilateral sources and Conference of the Parties mandated fund-based finance. These funds may generally be spent on national capacity building and readiness, broad policies to address the drivers of deforestation and forest degradation, and project performance (Streck, Gomez-Echeverri et al. 2009). REDD+ demonstration activities are nationally realized through four implementation options, such as (i) reduced emissions agricultural policy, (ii) community forest management, (iii) payment for environmental services, and (iv) protected areas combined with integrated community development programs (Angelsen 2009).

As of April 2011, there are five REDD+ projects in Cambodia, two of which are being implemented. The first REDD+ project in Cambodia, the Oddar Meanchey REDD+ project, is developed and currently being implemented under the community forest management option. The second REDD+ project, the Seima BCA REDD+ project, has been proposed to be implemented through protected areas combined with integrated community development programs. Seima BCA covers 298,250 hectares in Mondulkiri Province in eastern Cambodia. The site provides habitats for more than 40 species on the International Conservation Union's Red List, including at least four critically endangered bird species. Seima BCA provides an ideal site for developing a REDD+ project because forests in this area have been under intense pressure from commercial and illegal logging, forest fire, economic land concessions and encroachment. 3 percent of Seima CBA's forests have been lost each year from 2002 – 2006, based on remote sensing analyses conducted by the Forestry Administration. Project sites also include large tracts of healthy closed-canopy forests, as well as degraded forests suitable for restoration

2. Research objectives

Although Seima BCA has been selected as the site for the implementation of REDD+ project, project developers and relevant government institutions are still locating areas within the BCA to develop and implement REDD+ project activities. Therefore, the main purpose of this project paper is to contribute to this decision making process using a set of aggregation and analysis approaches in ArcGIS and IDRISI Taiga to identify and prioritize suitable areas within the CBA for REDD+ project activities to be implemented (Eastman

2009; Ormsby, Napoleon et al. 2010). To achieve this objective, the paper needs to address the following complementary objectives:

1. Locating and reviewing landuse history and socio-economic conditions within Seima BCA
2. Identifying the required criteria for site selection for protected areas REDD+ project
3. Understanding the constraints and factors influencing the degree of suitability for project areas
4. Prioritizing the importance of each factor for the analysis

In terms of GIS application, there are two main objectives:

1. Create a map of project sites using ArcGIS tools such as overlay, select by location, and symbology.
2. Perform a MCE analysis of the data to locate the most suitable sites for project implementation using IDRISI's tools such as surface, edit/assign, fuzzy, and area.

3. Rationale/Literature Review

More than 102,000 protected areas (PAs) cover 12.2 percent of the Earth's land area and provide benefits such as protecting biodiversity and cultural values, and ecosystem services, including carbon storage. PAs support around 1.1 billion people providing them with food, fuel, fresh water, fiber, shelter and genetic resources. PAs also store around 15 percent of the terrestrial carbon stock and cover 13.5 percent of the world's forests (Schmitt, Burgess et al. 2009). Keeping forested PAs intact is an essential part of the effort to retain forest carbon. While biodiversity conservation is the primary objective of most PAs, their management has increasingly focused on relationships with local people.

Increasing recognition that it was neither politically feasible nor ethically justifiable to exclude people with limited resource access from parks and reserves without providing them with alternative means of livelihood led to a new generation of projects that reached outside PA boundaries to focus on the welfare of local people by promoting social and economic development, referred to as integrated conservation and development projects (Wells and Brandon 1992).

Previously classified as the production forest area with logging concession granted to Sampling International in the mid 1990s, Seima BCA was established in 2002 when the Royal Government of Cambodia suspended all the logging operation in the kingdom (Forestry Administration 2011). The Forestry Administration of the Ministry of Agriculture Forestry and Fisheries in partnership with the Wildlife Conservation Society (WCS) manages the BCA. This partnership aims to establish an effective management of the BCA, to conserve the biodiversity values, and to protect the livelihoods of local people depending on the BCA (Pearson, Petrova et al. 2008). Technically, Seima BCA is still classified as production forest not protection forest. And, based on Cambodian Forestry Law, production forest can be commercially exploited and converted into other land use. After three years of lobbying, WCS gain additional legal support from the government, and thus Seima BCA was designated as a Protection Forest under the Council of Ministers' sub-decree dated August 7, 2009. This is the highest level of political support that enables Seima BCA to be selected for REDD+ project development and implementation. This REDD+ project aims to expand and improve law enforcement activities, to register existing communities land claim, and to provide incentive for communities to protect forests (Evans 2010). Globally, REDD+ project activities are being implemented on a plot-by-plot basis, implying that plots or areas within identified project site that are most suitable will be prioritized. In regards to the selection of suitable sites for Protected Areas REDD+ project activities in Seima BCA, the criteria are as follow:

1. Project Boundary

   Seima BCA covers almost 300,000 hectares of land, but for the current REDD+ project only two third of the area will be considered for project activities implementation.

2. Landuse Type

   Since REDD+ project in Seima BCA aims to conserve existing forests, areas that will be considered for the project need to be forested land. In the context of REDD+ project, forest land is defined as areas where trees are taller than 5 meters with more than 40 percent of crown cover (UN-REDD Programme 2009).

3. Carbon Stratification

   Carbon stratification refers to the distribution of carbon in the vertical. It is often used in reference to oceanic carbon or soil carbon to explain the distribution of carbon with depth. Using the Intergovernmental Panel on Climate Change's three tiers of carbon measurement (Gibbs, Brown et al. 2007), areas within Seima BCA are classified as having high, medium or low carbon stratification based on the amount (tons of CO_2 equivalent) of carbon measured at plot sites. Areas identified as having high carbon stratification are more suitable than medium and low respectively.

4. Distance Between Villages

In order to implement REDD+ project activities, a considerable amount of human labor is required. And as part of the requirements for REDD+ project to help improve socio-economic status of local communities who are depending on incomes generated from forests, areas with higher concentration of population is more suitable than areas that are not (UN-REDD Programme 2009).

5. Soil Fertility

   REDD+ is still in its infancy, and it is still a very risky business investment. In addition, 80 percent of the Cambodian populations are associated with the agricultural sector. Therefore, there is a chance that the government might withdraw their commitment to REDD+ and convert some, if not all, of the areas within the Seima BCA to agricultural expansion projects. Therefore, REDD+ project should target areas where soil fertility is low.

6. Slopes

   Areas within Seima BCA vary considerably in terms of elevation. Because relatively low slopes are the most cost effective for the development and implementation of REDD+ project activities, those areas with a slope less than 15 percent are considered more suitable than those equal to or greater than 15 percent.

4. Data

There are two sets of data used in this project. The first set contains shapefiles retrieved from the Digital Chart of the World produced by ESRI, while the second set are raster images provided by WCS through Clark Labs' director – professor Ronald Eastman. The first set is used to locate and highlight Seima BCA location in the context of Cambodia, whereas the data in the second set are used for the suitability analysis using various modules in IDRISI Taiga. Table 1 summarized the data used in this project. It highlighted the title of the data, its format, source, date created and the organization that created and/ or maintains it.

Table 1. Data sets used for suitability analysis in the project

Title	Format	Source	Date created	Organization
First Data Set				
Cambodia International Boundary, de jure	Vector Polygon	ESRI	1993	ESRI
Seima BCA Boundary	Vector Polygon	ESRI	1993	ESRI
Road layer	Vector Line	ESRI	1993	ESRI
Second Data Set				
DEM of Seima	Raster (30 X 30m)	WCS	2008	WCS
Carbon stratification	Raster (30 X 30m)	WCS	2008	WCS
Soil Fertility	Raster (30 X 30m)	WCS	2008	WCS
Distribution of Villages	Raster (30 X 30m)	WCS	2008	WCS
Landuse Type	Raster (30 X 30m)	WCS	2008	WCS
Selected Sites within Seima BCA	Raster (30 X 30m)	WCS	2008	WCS

5. Methods

The process of analysis was conducted in two separate procedures. In the first or pre-processing stage, both sets of data were checked for consistency in regards to projected coordinate systems, datums, accuracy and precision, and unit of display. Then all layers and images were re-projected using WGS1984 UTM Zone 48N for Cambodia. The overall accuracy of the WCS's data according to Clark Labs is 95 percent; however this information was not reported for the ESRI's data. The unit of display for WCS's data is in meters, while it is in miles for ESRI's. In the second or analysis stage, there were two sets of analysis. The first analysis was simply a combination of overlaying and then symbologizing of the three shapefiles from ESRI to create the map of the study area within the boundary of Cambodia. Figure 1 illustrates the location of Seima BCA in Cambodia.

The second phase of the analysis was a suitability analysis using MCE module in IDRISI to locate areas where REDD+ project activities should be implemented within Seima BCA. We started the analysis by producing necessary images from available data to create images (Boolean and non-Boolean) using different modules in DRISI. For example, Surface was used to generate a slope image from the DEM data. In addition, Edit/ Assign were used to create a Boolean image of forested and non-forested area within Seima BCA from landuse data. Next, we decided which of the criteria required for site selection in REDD+ project are constraints and which are factors influencing the suitability of the areas. In terms of definitions, constraints are those Boolean criteria that constrain or limit our analysis to particular geographic regions. No matter which method is eventually used to aggregate criteria, constraints are always Boolean images. On the other hands, factors are criteria that define some degree of suitability for all geographic regions. They define areas or alternatives in terms of a continuous measure of suitability. Individual factor scores may either enhance (with high scores) or detract from (with low scores) the overall suitability of an alternative. The degree to which this happens depends upon the aggregation method used. Factors can be standardized in a number of ways depending upon the individual criteria and the form of aggregation eventually used (Eastman 2009).

Based on the description on each of the criteria in Section 3 Rationale/ Literature Review, it was decided that project boundary and land use types should be considered as constraints. As a result, the factors influencing decision on suitable site selection are carbon stratification, distance between villages, soil fertility, and slopes. In order to use fuzzy factors with the multi-criteria evaluation, these factors were standardized to a byte-level range on a continuous scale from 0 to 255. While most factors can be automatically rescaled using some mathematical function, rescaling categorical data requires giving an informed rating to each category based on previous knowledge. Since carbon stratification and soil fertility were represented in categorical data, Edit/Assign was used to give each category a suitability value. On the continuous 0-255 scale, we gave a suitability rating of 255 to high carbon stratification, 150 to medium, and 50 to low. For soil fertility, we gave a suitability rating of 255 to high fertility, 150 to medium, and 50 to low. Standardization was necessary to transform the disparate measurement units of factor images into comparable suitability values. However, criteria identified as constraints were converted to Boolean images and remained un-standardized because they were simply used as masks in the later step of the weighted linear combination. During standardization in Fuzzy, different standardization functions were used for the different factor images. Table 2 summarized the standardization functions used for each factor map.

1. Distance to village - measures of relative distance from the town center, an important determinant of socio-economic development for forest dependent communities, was rescaled to a range of suitability where the greatest cost distance has the lowest suitability score (0) and the least cost distance has the highest suitability score (255). A simple linear distance decay function was chosen for this criterion. To rescale the cost distant factor, we chose the monotonically decreasing linear function and used minimum (0) and maximum (76,208) distance values found in our cost distance image as the control points at the end of the linear curve.
2. Slopes – as mentioned in the previous section, slopes below 15 percent are the most effective for project implementation. However, the lowest slopes are the best and any slope above 15 percent is equally unsuitable. Thus, we decided to use a monotonically decreasing Sigmodial function to rescale the data to the 0-255 range.
3. Carbon stratification – areas that are most suitable for the implementation of project activities should be in areas where carbon stratification is classified as high, and least suitable where the distribution of carbon is low. Thus, we decided to rescale carbon stratification using the monotonically increasing linear function.
4. Soil fertility – in contrast to carbon stratification factor, project developers are encouraged to implement the activities where soil fertility is low. This implies that areas where soil fertility is high are least suitable in comparison to areas where soil fertility is low. Therefore, monotonically decreasing linear function was chosen to rescale soil fertility.

Table 2. Factor map and its standardization function

No	***Factor image***	***Standardization function***
1	*Distribution of villages*	*Linear – monotonically decreasing*
2	*Slopes*	*Sigmoidal – monotonically decreasing*
3	*Carbon stratification*	*Linear – monotonically increasing*
4	*Soil fertility*	*Linear – monotonically decreasing*

We then assigned to each factor its factor weight or tradeoff weight. This weight indicated a factor's importance relative to all other factors and they control how factors will tradeoff or compensate for each other. The degree to which one factor can compensate for another is determined by its factor or tradeoff weight. In IDRISI, there are different methods to assign weight to factor images (Eastman 2009). However, since there are only four factors in this project, we decided to assign weight to each factor as shown in Table 3. The weighting decision was done based on information discussed in Section 3 Rationale/ Literature Review. Images produced from this procedure are attached in Figure 2. The final step in this analysis was putting all these information into the MCE module in IDRISI to derive the suitability map indicating areas more or less suitable for REDD+ project activities to be implemented in selected project sites within Seima BCA. Areas that are most suitable were then calculated in hectares. A macro-modeler illustrating the steps in this analysis is attached in Figure 3.

Table 3: Weight for each factor image

No	***Factor image***	***Weight***
1	*Carbon stratification*	*0.4*
2	*Distribution of villages*	*0.3*
3	*Slopes*	*0.2*
4	*Soil fertility*	*0.1*

6. Results & Discussion

According to the suitability map attached in Figure 4, areas that are the most suitable for REDD+ project activities to be implemented account for 7,508 hectares or 4 percent of the entire project areas. In addition, approximately 22,034 hectares or 11 percent of the study site is in the middle of the suitability range. There were two approaches that we could have used to locate these sites that meet the requirements specified above – Boolean analysis and multi-criteria evaluation analysis. This project decided to conduct the analysis and aggregation using MCE technique mainly because Boolean standardization and aggregation severely limit analysis and constrain resultant land allocation choices. Another limitation of the simple Boolean approach is that all factors have equal importance in the final suitability map. This is not likely the case, some criteria are more important than others. For example, the possibility of the government to convert the Seima BCA into an agricultural expansion project is extremely low at this point; therefore, this factor should not be equally weighted as others. And as been the case for this project, all factors were weighted with a weighted linear average where weights were assigned to govern the degree to which a factor can compensate for another factor based on its relative importance. Basically this weighting technique allowed us to place our analysis exactly halfway between the AND and OR operations.

It is essential to acknowledge that there were limitations in this exercise in terms of data availability, time constraint, and capability in IDRISI applications. In terms of data limitation, despite the fact that Clark Labs had been instrumental in providing the data set necessary to conduct this MCE analysis, the analysis itself would have been more representational of the complexity involved in sites selection for REDD+ project activities if we had access to other spatial information such as household income, different deforestation threats, projected land use scenario. The second constraint is mutually tied to the first because more data would have been incorporated into the analysis, should we had more time. Finally, there are other modules in IDRISI that could have been useful in extending this analysis. Because our competency in using this software package is rather limited to introductory level, we therefore encourage a more advanced analysis of this problem in later research.

7. Conclusions

The immediate benefit of this project is its contribution to the decision making process of the REDD+ project developers in regards to selecting sites most suitable based on the requirements for REDD+ project within protected areas. This is also another case to demonstrate the relevance and importance of GIS software such as IDRISI and ArcGIS in complex global environmental projects. It should be acknowledged that criteria required for the development and implementation of REDD+ project vary depending on the option that the project is proposed to be realized on the ground. However, as this case study has demonstrated, not only is the application of the MCE approach in IDRISI appropriate. It is also accommodating to the various criteria used to determine suitable sites for REDD+ project activities.

8. Bibliography

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9. Figures

Figure 1. Location of Seima Biodiversity Conservation Area, Cambodia

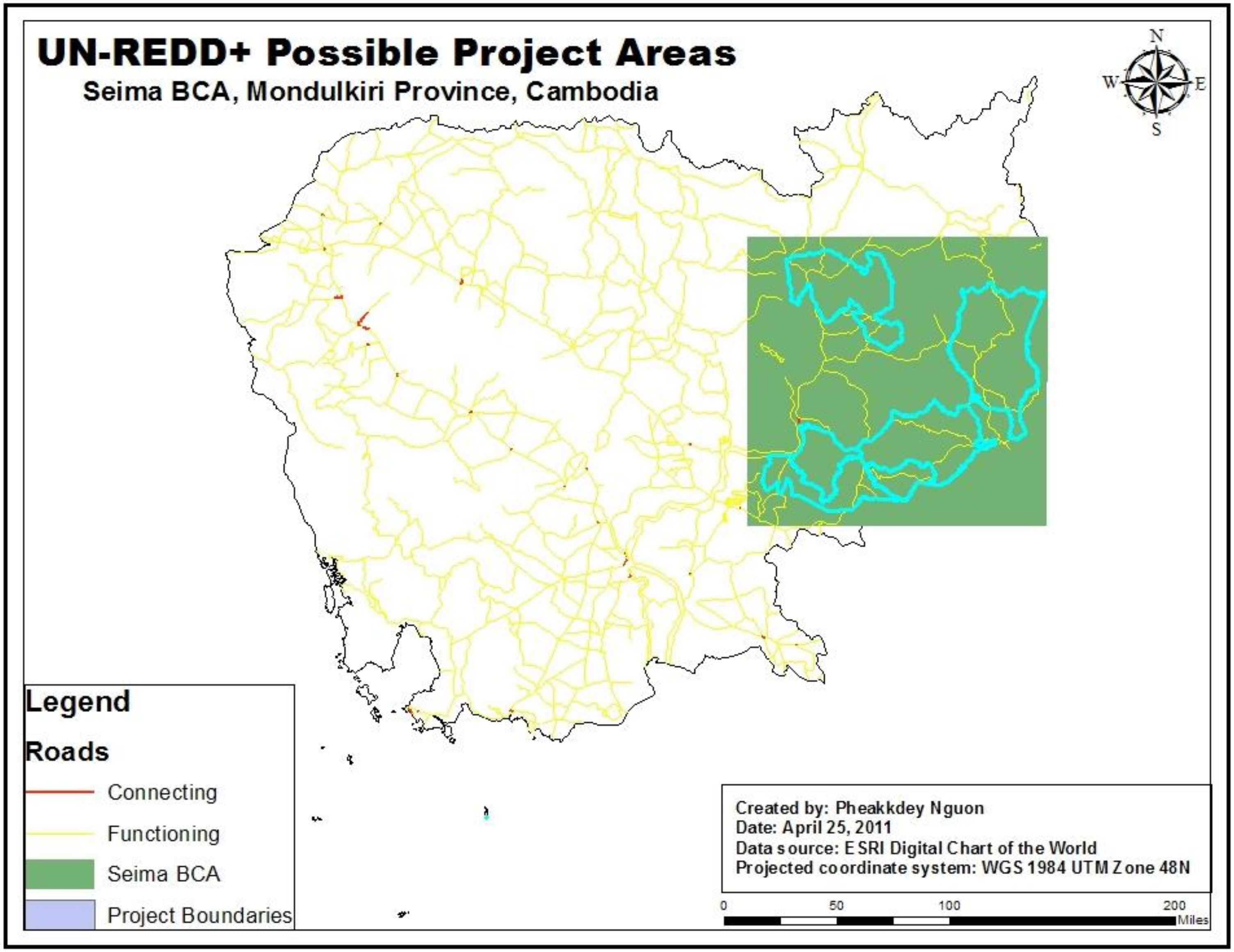
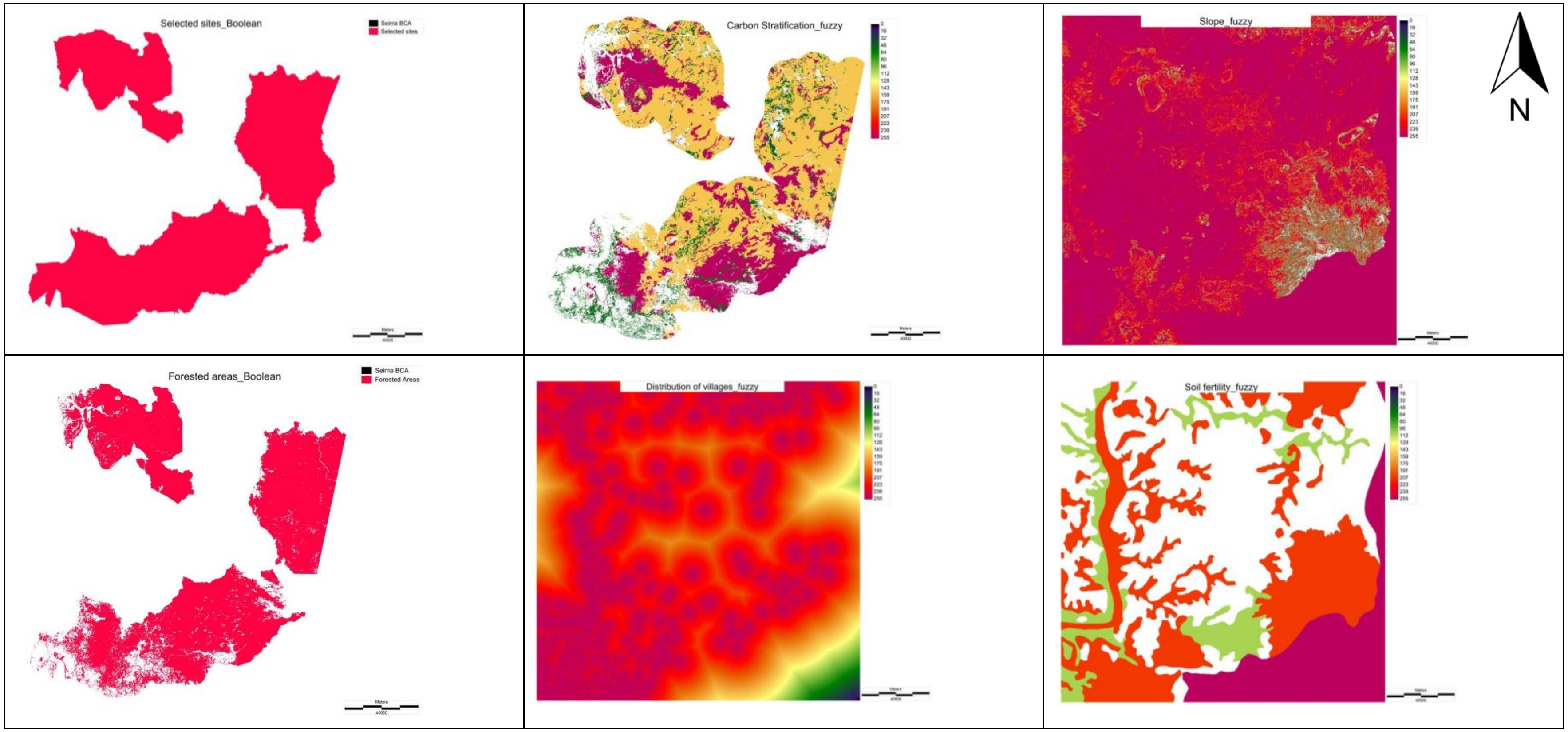


Figure 2. Constraint and Factor Images



Created by: Pheakkdey Nguon

Date: April 25, 2011

Data source: Wildlife Conservation Society

Projected coordinate system: WGS1984 UTM Zone 48N

Figure 3. Macro-modeler describing the MCE analysis process

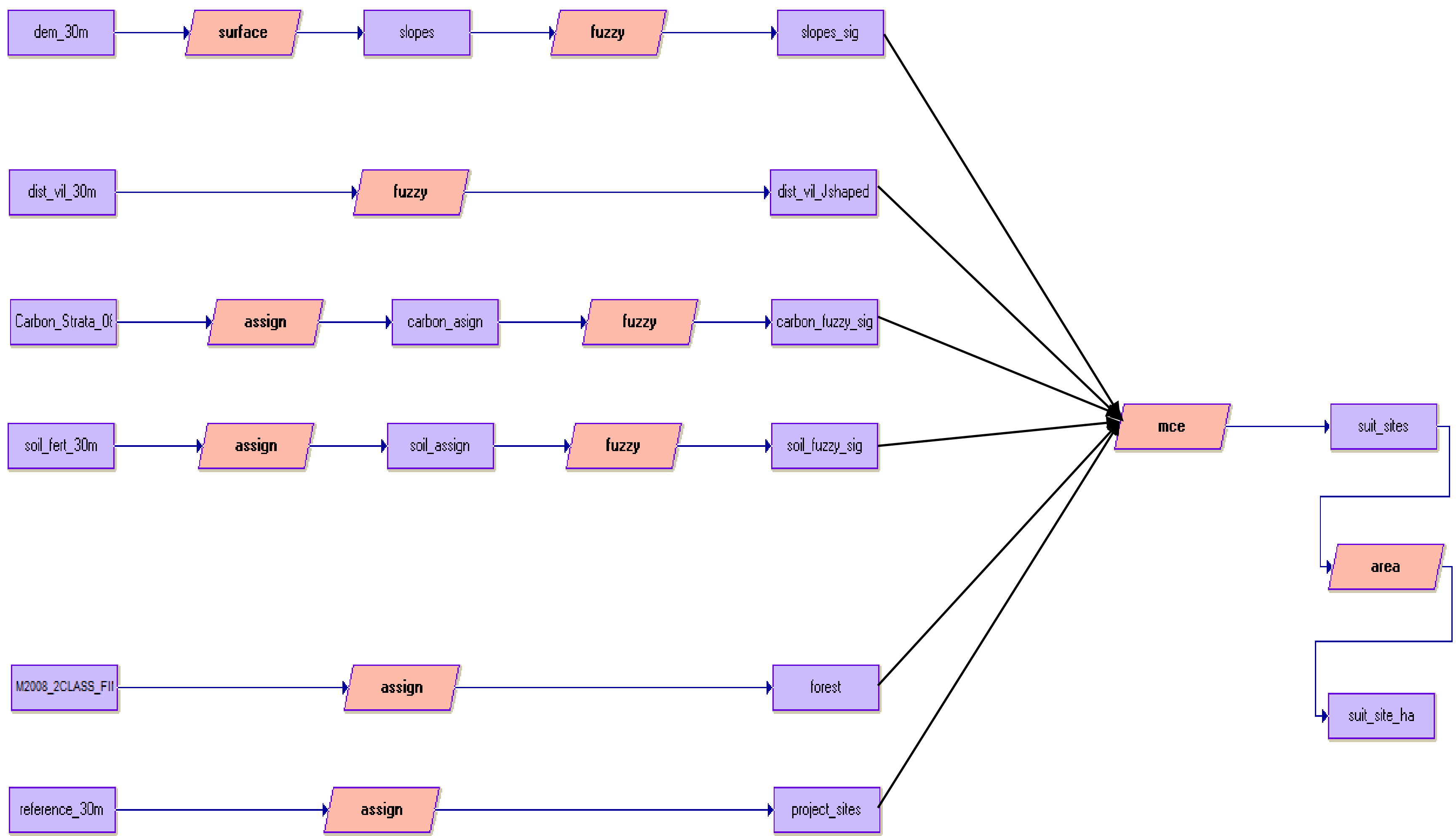


Figure 4. Areas suitable for REDD+ project implementation