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Assessment of REDD+ Suitable Area for Sustainable Forest Management in Paraguay

Jeongmook Park, Yongkyu Lee, Byeongmin Lim and Jungsoo Lee*
Department of Forest Management, College of Forest and Environmental Sciences, Kangwon National University, Chuncheon 24341, Republic of Korea

Abstract

This study extracted deforestation area and degraded forestland area, which are potential REDD+ (Reducing Emissions from Deforestation and Forest Degradation) project candidate areas in Paraguay using Land Cover Map (LCM) and Tree Cover Map (TCM). The REDD+ project objectives scenarios were set three stages: 'afforestation and economic efficiency scenario', 'local capacity reinforcement scenario', and 'Infrastructure-oriented scenario'. And then, we evaluated the project unit suitable area of the REDD+ project. All scenarios selected the evaluation factors for each scenario in addition to the area ratio factors for deforestation area and degraded forestland area and weighted values were extracted by assigning category scores. As a result of the three scenarios comparison analysis, Concepcion state score was the highest. Within Concepcion state, the Belon district had the highest score, making it appropriate as a project unit REDD+ project candidate area in Paraguay, while the San Carlos district had the lowest score. This study can be used as basic data for selecting REDD+ project candidate area in Paraguay, and it is expected to contribute sufficiently to REDD+ project if additional data or information of social, cultural and economic sectors are secured.

Key Words: REDD+, deforestration area, degraded forestlands, land cover map, tree cover map

Introduction

The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil in 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted to promote sustainable development. This treaty aimed to stabilize the greenhouse gas (GHG) concentrations in the atmosphere (Ministry of Environment 2016). There was, however, no system to guarantee the implementation of measures to reduce GHG emissions. This has caused the effectiveness of the convention to be questioned (Cho 2010).

Therefore, at the third meeting of the Conference of the Parties (COP) in 1997, the Kyoto Protocol that imposed GHG reduction obligations to advanced countries was adopted. The Kyoto Protocol promised legally binding numerical goals for GHG reduction for the first time, and allowed flexibility in fulfilling these obligations, such as emission trading (ET), joint implementation (JI), and clean development mechanism (CDM) (Lee 2016; Oh 2017; Murthy and KV 2018; Park et al. 2018).

The Kyoto Protocol, however, was expected to be ineffective because the United States, a country with the largest GHG emissions (36.1%) worldwide, refused to ratify the protocol, and some other parties showed a passive attitude by not joining the fulfillment or withdrawing from the

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Corresponding author: Jungsoo Lee
Department of Forest Management, College of Forest and Environmental Sciences, Kangwon National University, Chuncheon 24341, Republic of Korea
Tel: 82-33-250-8334, Fax: 82-33-259-5617, E-mail: jslee72@kangwon.ac.kr

protocol, to ensure their economic growth (Sohel MSI et al. 2009; Oh 2017). In addition, because the obligations to reduce GHG emissions were imposed only on some advanced countries, the protocol was severely criticized by several advanced countries due to the increase in GHG emissions produced by the economic growth of developing countries (Choi 2016). With the limitations of the Kyoto Protocol and the termination of its commitment period in 2020, new climate programs are necessary. In this regard, the Paris Agreement, a new model to be applied after 2020, was adopted at COP21 in Paris in 2015 to replace the Kyoto Protocol (Kim 2016; Bel and Teixidó 2020).

The Paris Agreement is an integrated system in which both advanced and developing countries are included. South Korea did not have any obligation concerning GHG emissions under the Kyoto Protocol because it was classified as a developing country. However, it will have GHG reduction obligations under the new system beginning in 2021 (Chung 2017). While the necessity of reducing GHG emissions is increasing for South Korea, the REDD+ program, ratified at COP15 in Copenhagen, is attracting attention as a major GHG-reduction activity by securing potential GHG credits in the forest sector (Seok and Yun 2010).

REDD+ was first proposed in 2005 in response to climate change and to prevent indiscriminate deforestation and forest degradation. REDD+ is a financial mechanism that reduces carbon emissions by restoring and recovering areas subjected to deforestation and degradation and generating credits based on these results (Di Gregorio et al. 2017).

REDD+ includes forest conservation, sustainable forest management, and activities to increase the carbon stocks, in addition to combatting deforestation and forest degradation. Advanced countries are expanding overseas afforestation to secure bioenergy, carbon credits, and wood resources through existing industrial afforestation, emphasizing the importance of REDD+ projects (Park et al. 2018).

The Korea Forest Service established strategies and response plans (2012-2016) for REDD+ and has been aggressively implementing REDD+ projects to secure overseas forest carbon credits and activate overseas cooperation (Bae and Seol 2012; Phua et al. 2014). Currently, most of South Korea's investment in overseas afforestation is concentrated in Southeast Asia, with approximately 80% in countries such as Indonesia, Vietnam, the Philippines, Cambodia, and Myanmar. Among them, Indonesia accounts for 68% of the total investment, indicating that the investment in overseas afforestation is highly dependent on Indonesia (Lee et al. 2013). In addition, 83% of the total demand for wood in South Korea depends on imports. Therefore, projects that are not concentrated in certain areas for securing long-term and stable sources of wood are required (Seo et al. 2015).

South America has the largest forest growing stock (128,944 million m^3) of all the continents, and its annual reduction rate of forests ranks second (0.4%), indicating considerable GHG emissions caused by deforestation and forest degradation (National Institute of Forest Science [NIFOS] 2007). In particular, according to the latest studies, Paraguay has one of the highest deforestation rates worldwide. Due to the rapid deforestation, approximately 90% of forests have been lost in eastern Paraguay (Fleytas 2007).

Therefore, this study considered Paraguay, a country expected secure carbon credits through overseas afforestation, as a candidate area for REDD+ projects based on the selection criteria suitable for the objectives of these projects. Site assessment in the determined scenarios was performed based on the four project objectives classified in the guidelines on the implementation of the Indonesia REDD+ project.

The purpose of this study was to assess the suitability of REDD+ project candidate areas for each scenario in Paraguay using geospatial information and statistical data and to select target sites according to the REDD+ project objectives.

Materials and Methods

Study area

Paraguay is an inland country in the center of South America, adjacent to Brazil, Argentina, and Bolivia. The administrative districts of Paraguay are divided into 18 states including Asuncion, the capital, at the level of Admin Level 1 and into 218 districts at the level of Admin Level 2 (USAID 2010) (Fig. 1).

The total area of Paraguay is 40,675,000 ha, and its total

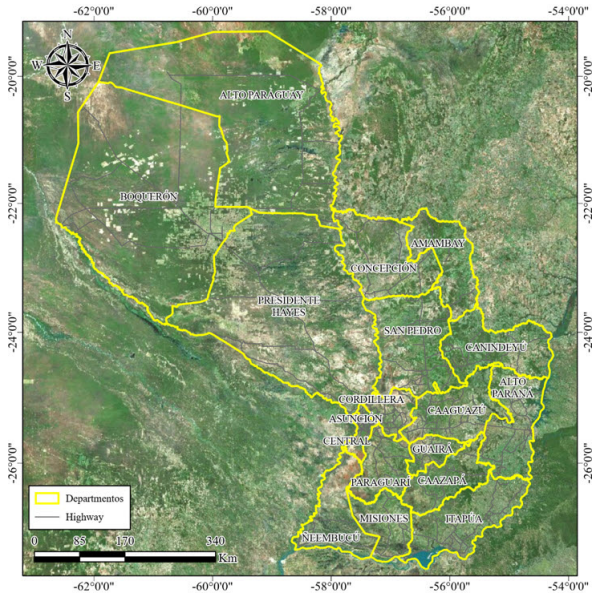


Fig. 1. Location of study area.

forest area is 15,323,000 ha. Therefore, approximately 38% of its total area is composed of forests. The forests consist of naturally regenerated forests (89.2%), virgin forests (10.5%), and artificial forests (0.3%), and most of these are composed of natural forest (FAO 2015).

The forests of Paraguay provide various vital ecological services in addition to their role as carbon reservoirs, and REDD+ can potentially provide benefits by mitigating climate change impacts through actions in Paraguay.

The forests of Paraguay are declining rapidly with their annual reduction rate ranking sixth worldwide. The Zero Deforestation Law, enacted in southeastern Paraguay in 2004, slowed the reduction in forest area by prohibiting deforestation in natural forest areas, but illegal deforestation remains a problem. In addition, deforestation has continued in northwestern Paraguay due to the absence of such legislation (Korea Green Promotion Agency 2013). Accordingly, REDD+ projects in Paraguay can produce a substantial economic effect.

Method

The REDD+ project candidate areas in Paraguay were selected by extracting the deforestation areas and degraded forestlands for each spatial unit of Admin Level 1 based on changes in time series using the Land Cover Map (LCM)

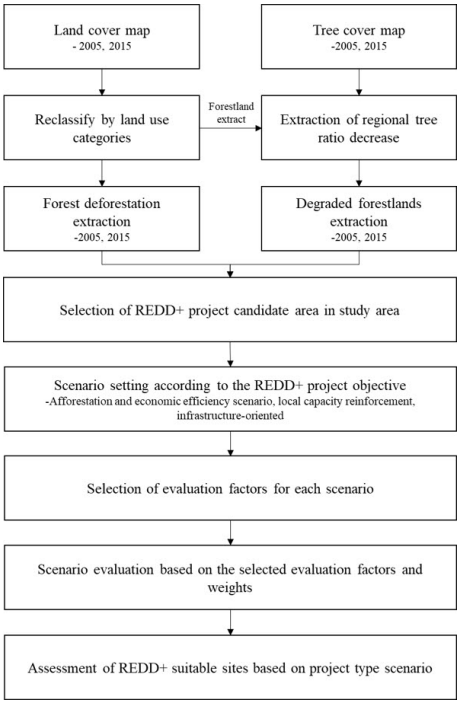


Fig. 2. Study method.

provided by the European Space Agency (ESA) and the Tree Cover Map (TCM) tool provided by the United States Geological Survey (USGS). In addition, for the REDD+ project candidate areas, three REDD+ project objective scenarios were set using the "REDD+ project implementation guidelines" of NIFOS (2013). The scenarios were the "afforestation and economic efficiency scenario" "local capacity reinforcement scenario" and "infrastructure-oriented scenario". The evaluation factors to be considered in each scenario were selected and weighted using the ranking method. Based on the derived results, the sites in Paraguay suitable for each scenario were evaluated (Fig. 2).

Selection of REDD+ project candidate areas

The REDD+ project candidate areas in Paraguay were selected by extracting deforestation areas and degraded forestlands using data from the LCM for 2005 and 2015 (VCS 2007). The time-series unit was set to ten years by referring to the VCS (Verified Carbon Standard), which defined deforestation areas as areas converted from forestlands to other lands for at least three years, and the REDD Cookbook of Japan, which specified that the REDD+

monitoring reference year requires data for 7 to 15 years or more (Japan REDD+ cookbook 2012).

Land use was classified into six categories (forestland, cropland, grassland, wetlands, settlements, and other lands) according to the guidelines (IPCC guidelines 2019) of the Inter-governmental Panel on Climate Change (IPCC). Deforestation areas were extracted by detecting lands that changed from "forestlands" in 2005 to "other lands" in 2015 (Table 1).

National Institute of Forest Science (NIFOS) (2007) used the TCM "crown density" data by defining degraded forestlands as areas where the crown density was maintained at a level between 50% and 80% for the stable development of forest trees and understory vegetation, and set the time-series unit to ten years, as with the LCM. Degraded forestlands were extracted by detecting areas where the crown density of "forestlands" decreased from 50% or more in 2005 to less than 50% in 2015. In this study, the REDD+ project candidate areas were selected by overlapping the deforestation areas and degraded forestlands.

Scenario setting according to the REDD+ project objective

The main objective of REDD+ projects is to reduce the GHG emissions caused by deforestation and forest degradation, withs various subsidiary objectives based on reducing GHGs (NIFOS 2013). Such subsidiary objectives can be divided into "aid-level capacity reinforcement", "environmental service protection", "securing credits" and "research-oriented" (NIFOS 2013).

In this study, three scenarios were set considering the above objectives. The first scenario was the "afforestation and economic efficiency scenario", which first considers economic efficiency when securing carbon credits through overseas afforestation. In particular, this situation aims to maximize profits by planting trees that can generate income.

The second scenario was the "local capacity reinforcement scenario", which intends to create additional income for the local community and sustainable forest protection through forest education. For all areas in Paraguay other than Asuncion, the capital, and the Central State, the development index compared with the MERCOSUR (Mercado Comun del sur) average was less than 75% in 1990 (Hyun 2019). This shows that most areas in Paraguay are underdeveloped and require local capacity reinforcement projects.

The last scenario was the "infrastructure-oriented scenario", which prioritizes infrastructure across all projects. An excellent infrastructure environment reduces project costs and allows the effective supply and demand of the workforce, but Paraguay has very poor infrastructure, ranking 17th out of 18 countries in the 2015 Latin Infrastructure Index (Kwon 2016). Therefore, it is critical to consider infrastructure when performing projects in Paraguay.

Table 1. Land use category guideline of IPCC and Classification of land cover map for category

Classification for IPCC category	Classification of land cover map for category
Forestland	Coniferous, deciduous, evergreen
Cropland	Cropland, irrigated, post-flooding, mosaic cropland
Grassland	Lichens, mosses, sparse vegetation
Wetland	Brackish water, saline water
Settlement	Urban area
Otherland	Permanent snow and ice

Selection of evaluation factors for each scenario

Factors that affect the REDD+ project objectives of each scenario were selected as the evaluation factors. All scenarios included the factor of the area ratio of deforestation areas and degraded forestlands. In addition, for the "afforestation and economic efficiency scenario", the population and the distance to a road were selected because a large population facilitates the supply and demand of manpower and close proximity to a road reduces transportation costs and increases profitability. In addition, it was assumed that eucalyptus, a representative forest tree species in the tropical zone, was planted in the REDD+ projects, and a high annual growth rate was modelled to increase the profitability. In particular, because eucalyptus has a high average annual growth rate (up to 38 m^3/ha) and precipitation has the largest impact on the growth of eucalyptus, the annual precipitation was also selected as an evaluation factor (Sohn and Seok 2002; Stape et al. 2010).

For the "local capacity reinforcement scenario", the proportion of the poor population, distance to a water system, and Gini coefficient, an index for income inequality, were

selected as the evaluation factors. The purpose of local capacity reinforcement was to reduce poverty through income creation and to allow the sustainable management of forests (Angelsen and Kaimowitz 2000). Accordingly, areas that require local capacity reinforcement were determined by selecting the proportion of the poor population to the total population and the Gini coefficient as evaluation factors (Shrestha et al. 2017). In addition, the distance to the transportation infrastructure that was used to generate income was considered for profitability. According to IIRSA (Initiative for the Integration of the Regional Infrastructure of South America), 45% of the wood products exported from Paraguay used waterways (Korea Green Promotion Agency 2013). Therefore, the distance to a water system was selected as an evaluation factor under the assumption that the wood obtained through logging was processed in the local area and exported through marine transportation to generate income.

For the "infrastructure-oriented scenario", areas close to the transportation infrastructure and settlements were considered as project target sites (Lin et al. 2014). Because Paraguay is an inland country, road utilization is the highest, but river transportation is also active using waterways such as the Paraguay River (Korea green promotion agency 2013). In addition, the distances to a road, a water system, and an airport, which is essential for business with countries outside of South America, were selected as evaluation factors considering the use of airports. The distance to a settlement where infrastructure is integrated was also added (Sloan et al. 2012) (Table 2).

The evaluation factors were constructed using geospatial information and statistical data. The data from the statistical office of Paraguay (DGEEC) were used for the population, poor population, and Gini coefficient of each state in Paraguay, and the 2012 geospatial information of DGEEC was used for the road network and water system network. The settlements were extracted from the 2015 LCM, and the monthly precipitation of Paraguay provided by the Feed the Future Initiative (FTF) were combined for the annual precipitation. The Guaraní International Airport and Silvio Pettirossi International Airport, which are international airports, were added to a map using Arcmap 10.1 by acquiring their X and Y coordinate values from Google Earth.

Scenario evaluation based on the selected evaluation factors and weights

Assignment of category scores for each factor: The range of values for each evaluation factor were divided into five groups, as shown in Table 2, and category scores were assigned to each group. Because the necessity of REDD+ projects increases alongside the increase in the area of deforestation areas and degraded forestlands, 100 points were assigned to the areas with the highest scores for factors such as the population, the poor population ratio, Gini coefficient, and annual precipitation, and points were proportionately allocated to other areas. The supply and demand of the workforce became more significant as the population increased, and areas where the proportion of the poor population and the Gini coefficient were high met the

Table 2. Assignment of category scores for each factor

Factor	Category score				
	100	75	50	25	0
Deforestation area and degraded forestland area ratio (%)	81.2-70.7	70.7-51.5	51.5-40.1	40.1-29.3	29.3-3.8
Population(10 thousand)	198.5-25.3	25.3-11.7	11.7-6.0	6.0-1.8	1.8-1.7
Poor population ratio (%)	52.8-44.3	44.3-37.4	37.4-30.3	30.3-21.3	21.3-21.2
Gini coefficient	0.62-0.57	0.57-0.54	0.54-0.53	0.53-0.52	0.52-0.44
Distance to a road (km)	0-0.3	0.3-1.1	1.1-2.6	2.6-5.7	5.7-53.4
Distance to a settlement (km)	0-12.9	12.9-29.8	29.8-58.7	58.7-100.4	100.4-203.8
Distance to a airport (km)	0-145.4	145.4-245.5	245.5-400.7	400.7-591.2	591.2-823.7
Distance to a water system (km)	0-7.1	7.1-19.3	19.3-37.7	37.7-108.8	108.8-259.0
Annual precipitation (1,000 nm)	1.8-1.5	1.5-1.3	1.3-0.9	0.9-0.6	0.6-0.4

objectives of the local capacity reinforcement projects. The annual precipitation has a positive correlation with the annual growth rate of eucalyptus. Conversely, accessibility increased as the distances to a road, settlement, airport, and water system decreased. Therefore, for these factors, 100 points were assigned to the lowest value.

Selection of weighs for each factor: In this study, weights were used to reflect the relative importance of the factors in each scenario. The rankings of the factors were determined by identifying the status of Paraguay and the objectives of each scenario, and weights were selected using rank sum weights. The formula for rank sum weights is as follows (Saeid et al. 2011; Roszkowska 2013) (eqs. 1) (Table 3).

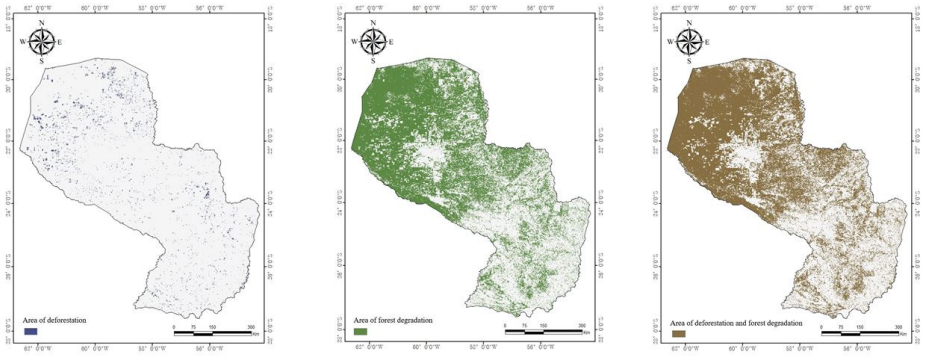
$$W_i = \frac{n - r_i + 1}{\sum (n - r_k + 1)} \quad (1)$$

w_i : Normalized weight for the i-th evaluation criterion
n: Number of evaluation criteria (k=1, 2, n)
r_i : Ranking of the evaluation criterion

Evaluation map creation for each scenario: The scenario evaluation maps were created by overlapping the category scores and weights of the factors in each scenario. Consequently, the scores of each state were calculated, and the state with the highest score was found to be the most suitable for the scenario.

Table 3. Weight of factor for scenario

Scenario	Rank	Factor	Select reason	Weight
Afforestation and economic efficiency scenario	1	Deforestation area and degraded forestland area ratio (%)	Area ratio of deforestation area and degraded forestland area which is REDD+ project area, is the first priority	0.4
	2	Population	When the afforestation and logging are performed, a lot of labor is needed	0.3
	3	Distance to a road	If the distance between afforestation to road is closer, log-skidding cost of transport, etc, forest operation cost decrease	0.2
	4	Annual precipitation	If the annual growth of tree is greater, profitability increase	0.1
local capacity reinforcement scenario	1	Deforestation area and degraded forestland area ratio (%)	Area ratio of deforestation area and degraded forestland area which is REDD+ project area, is the first priority	0.3
	2	Poor population	Income creation of the community for the poor is the first priority	0.3
	3	Gini coefficient	Residents with low social classes's income generation need in areas with high social inequality indexes	0.2
	4	Distance to a water	Residents acquire economic income with export of wood product using water system	0.1
Infrastructure-oriented scenario	1	Deforestation area and degraded forestland area ratio(%)	Area ratio of deforestation area and degraded forestland area which is REDD+ project area, is the first priority	0.33
	2	Distance to a road	Paraguay is an inland country as the highest use of roads among logistics infrastructure.	0.27
	3	Distance to a settlement	Local residents have high accessibility to business sites and excellent infrastructure construction.	0.20
	4	Distance to a water system	Considering the export, transportation and movement of forest resources through riverbed transportation	0.13
	5	Distance to a airport	When the foreign affiliated afforest, it is necessary to use the airport in overseas forestry in Paraguay	0.07



(a) (b) (c)

Fig. 3. Deforestation area and degraded forestlands in Paraguay. deforestation area (a), and degraded forestlands (b), deforestation area and degraded forestlands (c).

Table 4. Assessment factor average value for Paraguay state

Administrative district	Population (10 thousand)	Poor population ratio (%)	Gini coefficient	Annual precipitation (1,000 mm)	Distance to a road (km)	Distance to a water system (km)	Distance to a airport (km)	Distance to a settlement (km)
Alto Paraguay	1.7	37.3	0.57	0.8	6.9	90.8	605.9	63.9
Alto Parana	77.3	29.1	0.53	1.7	0.5	11.6	60.5	12.0
Amambay	15.9	39.8	0.54	1.5	1.1	12.6	325.6	30.2
Asuncion	52.6	24.8	0.51	1.4	0.1	2.9	11.4	0.3
Boqueron	6.0	21.3	0.53	0.6	5.7	115.2	571.7	88.5
Caaguazu	53.5	48.7	0.59	1.6	0.6	17.6	111.4	12.3
Caazapa	18.0	46.5	0.56	1.5	1.0	16.8	156.1	15.8
Canindeyu	21.3	44.2	0.62	1.6	0.9	16.5	166.2	19.1
Central	198.5	41.7	0.48	1.4	1.7	15.2	41.0	6.2
Concepcion	23.7	52.8	0.53	1.4	2.0	15.5	300.3	51.2
Cordillera	29.1	30.5	0.45	1.5	1.0	36.3	67.3	9.3
Guaira	21.6	36.6	0.50	1.6	0.5	20.3	140.6	10.4
Itapua	57.7	41.1	0.61	1.6	1.0	18.8	199.5	14.6
Misiones	12.1	42.7	0.54	1.5	1.9	21.4	219.2	19.6
Neembucu	8.8	40.6	0.46	1.4	2.7	16.9	195.8	24.3
Paraguari	25.2	35.7	0.49	1.5	1.6	28.4	112.2	14.7
Presidente Hayes	11.7	30.3	0.53	1.0	2.8	16.6	249.1	88.7
San Pedro	40.9	51.5	0.52	1.5	1.2	20.3	169.2	13.5

Results and Discussion

Deforestation areas and degraded forestlands

After the extracting deforestation areas (2005-2015) and degraded forestlands (2005-2015), the area ratio of the factors was calculated for each state. It was found that Boqueron, Alto Paraguay, and Presidente Hayes in western Paraguay exhibited high values of 82.4%, 70.9%, and 51.2%, respectively, while eastern Paraguay showed a low average value of approximately 28%. In particular, Asuncion with the largest population exhibited the lowest area ratio (3.6%), followed by Alto Parana (16.0%), and Central (20%) (Fig. 3).

For areas where the area ratio of deforestation areas and degraded forestlands was high, significantly low category scores were expected in the population, the poor population ratio, annual precipitation, distance to a road, distance to an airport, and distance to a settlement.

In addition, Table 4, which represents the average evaluation factor value for each state, shows that the Central had the largest population and Concepcion included the largest poor population. Canindeyu possessed the highest Gini co-

efficient, and Alto Parana experienced the highest annual precipitation. Asuncion, the capital, exhibited the lowest average values for the distances to a road, a water system, an airport, and a settlement.

Evaluation map for the afforestation and economic efficiency scenario

When the evaluation maps were created for each scenario, Concepcion demonstrated the highest score (70.4 points) in the afforestation and economic efficiency scenario, followed by the Amambay (64.9 points) and Cordillera (62.4 points). Conversely, Asuncion showed the lowest score (17.7 points), followed by Paraguari (20.3 points) and Cordillera (29.4 points). While the score of the area ratio of deforestation areas and degraded forestlands was high in western Paraguay, the scores for population, distance to a road, and annual precipitation were high in eastern Paraguay (Fig. 4).

Since 2002, Paraguay has been carrying out large-scale afforestation projects in the eastern Paraguay area to enrich forest resources and contribute to future forests. Currently, the score of forestlands and forest deforestation non-factors is concentrated in the western Paraguay area. As a result, the population and roads are concentrated in the eastern Paraguayan area, so the economic evaluation was high in eastern Paraguay. In particular, Gran Chaco in western Paraguay accounts for about 60% of the land area, but only 2% of the total population, so when REDD+ area evaluation is done, it should be considered first (JAFTA 2002).

Evaluation map for the local capacity reinforcement scenario

In the local capacity reinforcement scenario, Concepcion exhibited the highest score (82.2 points), followed by Alto Paraguay (77.5 points) and Amambay (65.2 points). This result was due to Concepcion receiving 100 points for the poor population ratio and Alto Paraguay receiving 100 points for the Gini coefficient. Conversely, Asuncion showed the lowest score (17.7 points), followed by Paraguari (20.3 points) and Neembucu (29.5 points). Alto Paraguay received a high score in this scenario because the area ratio of deforestation areas and degraded forestlands and the Gini coefficient achieved high scores despite low scores for the poor population ratio and the distance to a water system. Because deforestation areas and degraded forestlands are proportional to the poverty population and Gini coefficient, REDD+ projects should be strengthened in the region, mainly in Conception and Alto Paraguay (Fig. 5).

Especially, Shrestha et al. (2017) suggested that reduction of poverty by flowing credits to poor population in

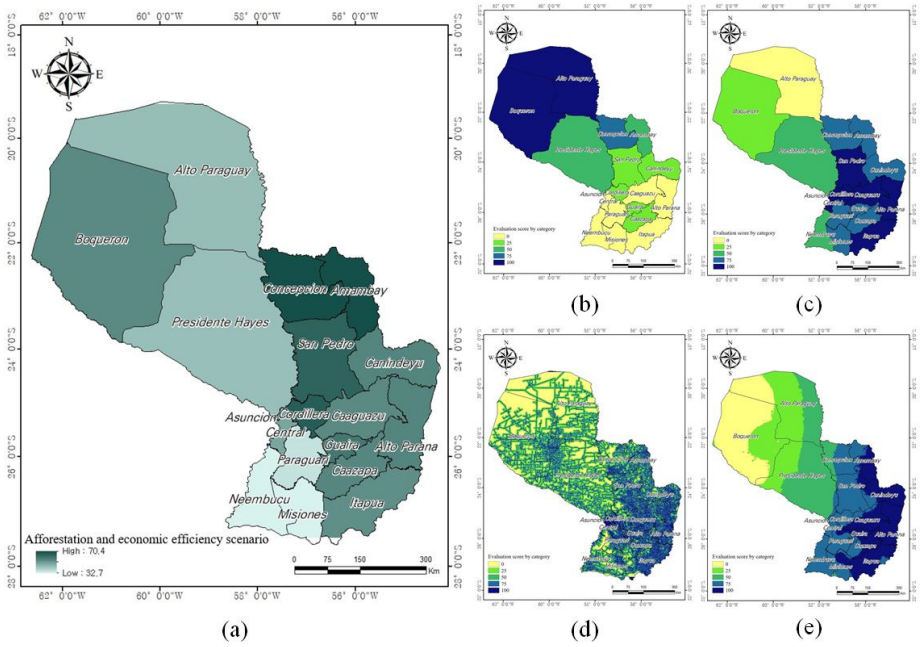


Fig. 4. Afforestation and economic efficiency scenario and factor. Afforestation and economic efficiency scenario map (a), deforestation area and degraded forestlands (b), population (c), distance to a road (d), annual precipitation (e).

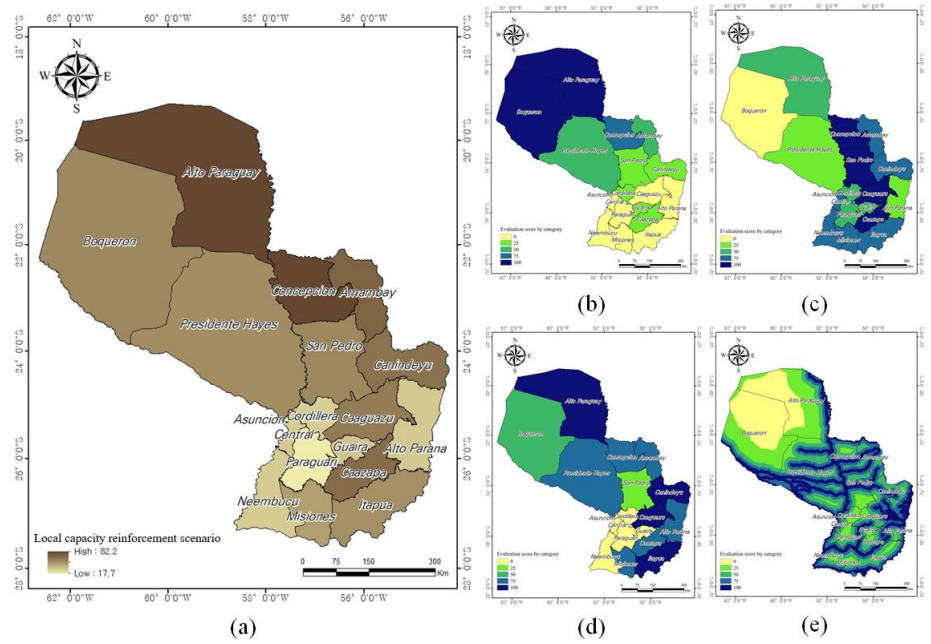


Fig. 5. Local capacity reinforcement scenario and factor. Local capacity reinforcement scenario map (a), deforestation area and degraded forestlands (b), population (c), distance to a road (d), annual precipitation (e).

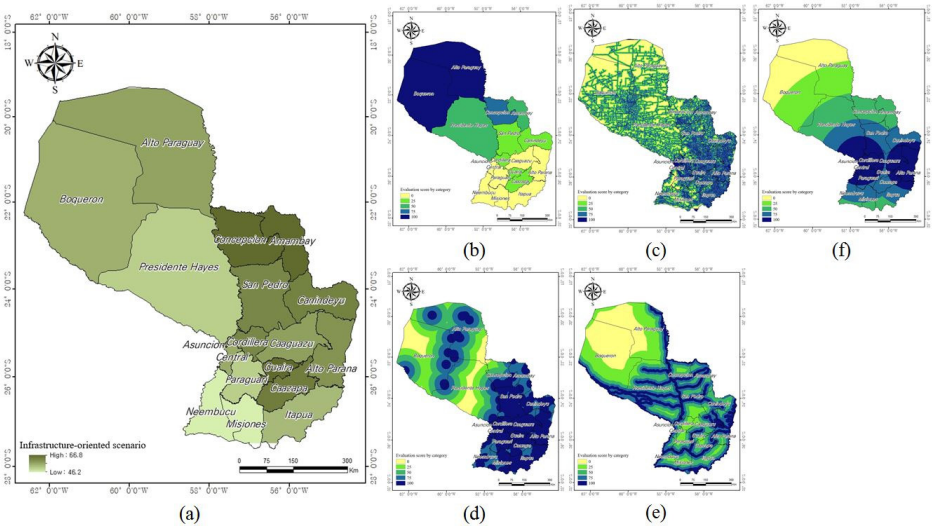


Fig. 6. Infrastructure-oriented scenario and factor. Infrastructure-oriented scenario map (a), deforestation area and degraded forestlands (b), distance to a road (c), distance to a settlement (d), distance to a water system (e), distance to a airport (f).

REDD+ project objective has a great impact on the implementation of the REDD+ project. Therefore if the REDD+ project suggest incentive to poor population for achieve objective of sustainable forest management, is expected that solve the frustration and conserve forestlands pushfully.

Evaluation map for the infrastructure-oriented scenario

In the infrastructure-oriented scenario, Concepcion received the highest score (66.8 points), followed by Asuncion (65.4 points) and Guaira (65.1 points). Concepcion exhibited high scores for all factors, except for the distance to an airport. As for Asuncion, the factors of the distances to a road, a settlement, a water system, and an airport received

high scores, but the score of the area ratio of deforestation areas and degraded forestlands was low (Fig. 6).

Therefore, it is reasonable to select the next district in Conception besides the Asuncion with high infrastructure environment and carry out the REDD+ project. This is similar to the results of the study that the REDD+ project should be carried out by maintaining the forest conservation such as urban forest and living forest in urban area and preempting accessible area for sustainable forest management (Kim 2016; Palomo et al. 2019).

Detailed maps for each scenario

When the three aforementioned scenarios were compared and analyzed, Concepcion exhibited the highest scores. In the afforestation and economic efficiency scenario, Concepcion (70.4 points) was the only area that showed a score higher than 70 points. In the local capacity reinforcement scenario, its score was 82.2 points, which was significantly higher than the second highest score (77.5 points) from Alto Paraguay. In the infrastructure-oriented scenario, the score was for Concepcion was 66.8 points, which was not significantly different from the scores of Asuncion (65.4 points) and Guaira (65.1 points) (Fig. 7).

Based on these results, the Admin Level 1 unit were analyzed. The evaluation determined that Concepcion is suitable as an REDD+ candidate area in Paraguay, and a detailed analysis was conducted for the Admin Level 2 units within Concepcion. The Belon district received high scores of 77.6, 84.1, and 85.7 points in the three scenarios, respectively, but the San Carlos district exhibited low scores in all the three scenarios. Therefore, Paraguay's REDD+ project suitable area should be balanced with three scenarios on Concepcion

Conclusion

In this study, scenarios were compared and analyzed in the Admin Level 1 unit using spatial information for Paraguay. For the Admin Level 1 unit selected as a REDD+ project candidate area, a detailed analysis was conducted in the Admin Level 2 units.

For the Admin Level 1 administrative district, the area ratio of deforestation areas and degraded forestlands was extremely high for the states of Boqueron (82.4%), Alto Paraguay (70.9%), and Presidente Hayes (51.2%) in western Paraguay, but the ratios were relatively low for 15 administrative districts in eastern Paraguay (27.6% on average). This result is because the proportion of forests was high in western Paraguay and most forests in Paraguay had been degraded.

Concepcion was determined to be the most suitable REDD+ project candidate area in Paraguay because it received the highest scores of 70.4, 82.2, and 66.8 points in the afforestation and economic efficiency scenario, local capacity reinforcement scenario, and infrastructure-oriented scenario respectively. Western Paraguay was not selected as a suitable project candidate area for the scenarios because it exhibited low scores for all factors except for the area ratio of deforestation areas and degraded forestlands, which received a high category score. Concepcion received the highest score in eastern Paraguay because it exhibited a category score of 75 points for the area ratio of deforestation areas

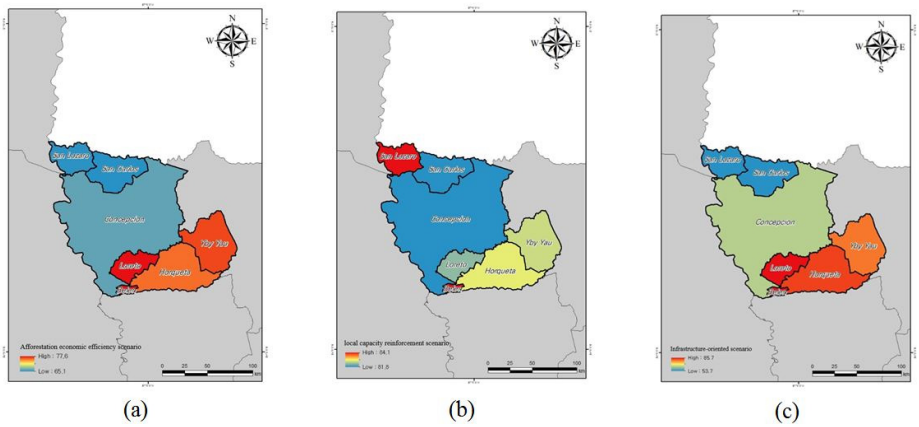


Fig. 7. Detail maps for each scenario. afforestation and economic efficiency scenario (a), local capacity reinforcement scenario (b), infrastructure-oriented scenario (c).

and degraded forestlands, which is the most significant factor. Accordingly, this state acquired the highest score in eastern Paraguay where category scores for most of the factors were high.

Afterwards, a scenario analysis was conducted in the Admin Level 2 units within Concepcion, which were found to be suitable REDD+ project candidate areas.

The Belon district was determined to be a suitable option for all projects because it received scores of 77.6, 84.1, and 85.7 points in the afforestation and economic efficiency, local capacity reinforcement, and infrastructure-oriented scenarios. On the other hand, the San Lazaro district has low scores for afforestation and economic efficiency scenarios and infrastructure-oriented scenarios, but it is suitable for REDD+ project by recording high scores in local capacity reinforcement scenario. Accordingly, it is judged that the San Lazaro district needs forest degradation prevention projects through job creation, improvement of local income, and replacement of demand for fuel wood, rather than the existing infrastructure such as afforestation project. Paraguay has undergone severe deforestation and forest degradation. Therefore, implementing REDD+ projects in Paraguay could significantly contribute to South Korea securing carbon credits in the upcoming new climate system. The Korea Forest Service and the Korea Forestry Promotion Institute have performed pilot afforestation projects in Paraguay since 2013, but research on REDD+ projects in Paraguay has not been actively conducted. Research was limited by the factors that could not be considered due to lack of sociocultural and economic data. The results of this study, however, are expected to be used as basic data for REDD+ projects in Paraguay.

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