ASSESSMENT OF LAND COVER CHANGE (2001-2021) USING REMOTE SENSING WITHIN AND AROUND MINALUNGAO NATIONAL PARK IN NUEVA ECIJA, PHILIPPINES

TUMBAGA, J. R. A.

Center for Environmental Research, Nueva Ecija University of Science and Technology, Cabanatuan City, Nueva Ecija 3100, Philippines
(e-mail: janramel.tumbaga@neust.edu.ph)

(Received 15th Mar 2023; accepted 1st Jun 2023)

Abstract. This study determines the land cover change within and around Minalungao National Park in Nueva Ecija, Philippines. Landsat images (Landsat 7 Enhanced Thematic Mapper Plus – ETM+ and Landsat 8) with different time intervals (2001, 2014, 2021) were used in the analysis. The Semi-Automatic Classification Plugin in Quantum Geographic Information System (QGIS) using the minimum distance classification algorithm was employed for the classification. The results establish four classifications of land cover: inland water, closed forest, open forest, and open/barren land. Accuracy assessments and kappa coefficients were accepted considerably. The result presented a dynamic land cover gain and loss related with different community activities. Both positive and negative activities affecting land cover were noted. Positive activities are related to forest restoration, ecotourism programs, and reports of tree-cutting activities. Moreover, negative activities are directly related with tree-cutting and livestock grazing. An alternative state of the protected area is also modelled based on land cover change around the protected area. This can be used to determine the most likely land cover status of Minalungao National Park if not established as a protected area.
Keywords: *protected area, Geographic Information System, management, alternative state*

Introduction

Protected areas (PA) are mainstream as natural solutions to various global challenges such as climate change, land degradation, food and water security, and human health and well-being. It helps in the attainment of the Sustainable Development Goals (SDG), particularly SDGs 14 and 15, which are “life below water” and “life below land”, respectively (Dudley et al., 2017). A PA in the Philippine context is one of the policy areas under the Comprehensive Land Use Plan, regarded as a life support system, an example that is included in the National Integrated Protected Areas System (NIPAS). PAs provide habitat for different species, mean an economic engine to local people, and ensure a healthy community. However, despite their importance, PAs are still threatened because of population pressure and demand for natural resources (Secretariat of the Convention on Biological Diversity, 2008).

To control potential problems within PAs, the establishment of legal and managerial regime is an example that restricts land cover changes, thereby conserving biodiversity (Rodríguez-Rodríguez et al., 2019), which is the primary goal of PAs. However, the establishment of protected areas in the country is an extensive process that requires a suitability assessment before its legislative enactment as iterated in the Expanded National Integrated Protected Areas System Act of 2018 – e-NIPAS. A decline in the recommendation of PA establishment results in its disestablishment, thereby threatening the initial components of the NIPAS.

The harmonization of the Protected Area Management Plan and Comprehensive Land Use Plan (CLUP) of local governments is emphasized in the e-NIPAS. The

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

Housing and Land Use Regulatory Board of the country emphasizes that CLUP requires thematic maps such as the land cover map needed for ecosystem planning. Since land is an indispensable natural resource, land cover is constantly changing because of social and ecological reasons (Hailu et al., 2020). An evident land cover change highlights the need to address land degradation problems (Vasconcelos et al., 2002). The need for both good data and understanding of the causes of change (Lambin et al., 2001) must be highlighted. At present, accurate and updated land cover information is needed (Szantoi et al., 2020) to support policymakers.

The integration of remote sensing is an important approach to determine the land cover of a landscape. The Minalungao National Park (MNP), a PA in the province of Nueva Ecija, Philippines, is one of the PAs that presents established land cover information for conservation approaches. Due to the unavailability of land cover information, especially land cover changes, this study provided a systematic analysis for its integration into the PA Management Plan of MNP.

Review of literature

Protected areas and the protected landscape

The International Union for the Conservation of Nature (IUCN) (2008) defines a protected area (PA) as a "clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values." Also, the National Integrated Protected Areas System (NIPAS) Act of 1992 (Phl) defines protected area as "identified portions of land and/or water set aside by reason of their unique physical and biological diversity and protected against destructive human exploitation." Regardless of definition, the framework points to the sustainability of natural resources protected against unsound human activities.

Protected areas have different management approaches concerning their classification. The IUCN has six (6) categories, namely: (Ia) strict nature reserve, (Ib) wilderness area, (II) national park, (III) natural monument or feature, (IV) habitat/species management area, (V) protected landscape/seascape, and (VI) protected area with sustainable use of natural resources (Worboys, 2015). In contrast, the Philippines has eight (8) categories, namely: (I) strict nature reserve, (II) natural park, (III) natural monument, (IV) wildlife sanctuary, (V) protected landscapes and seascapes, (VI) resource reserve, (VII) natural biotic areas, and (VIII) other categories established by law, conventions or international agreements which the Philippine government is a signatory. Among these differences in categories, protected landscape is an interest that is attributed to the study area (i.e., Minalungao National Park). From its name as a "national park", it is categorized as a "protected landscape", thereby, confusion in the international arena is evident.

In the Philippines, national parks are not named as a category; it falls under the last category of the NIPAS which is "other categories established by law." The MNP was enacted under Republic Act 5100 in 1967, thus, included in the category. However, in 1999 MNP was categorized by the Community Environment and Natural Resources Office of Cabanatuan City as a "protected landscape" after conducting assessment. To clarify this mixed-up of ideas, the following descriptions and definitions are presented.

A national park in the NIPAS context refers to the "lands of the public domain classified as such in the constitution which include all areas under the NIPAS, primarily designated for the conservation of native plants and animals, their associated habitats

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

and cultural diversity". However, the IUCN describes the category of national parks as "large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities". This is different when categorized into a protected landscape "where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic values and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values" (Dudley, 2008). This is also equivalent to the NIPAS context that promotes the harmonious interaction of man and land while providing opportunities for public enjoyment through recreation and tourism.

Irrespective of the name associated with MNP, the need to perceive it as a protected landscape must be emphasized and not as a national park. Its primary objective is "to protect and sustain important landscapes and the associated nature conservation and other values created by interactions with humans through traditional management practices" (Dudley, 2008). The classifications are being used to adopt specific management options; however, despite the differences, the purpose of protected areas is for biodiversity conservation (Worboys et al., 2015).

Environmental problems within and around the protected area

The protected area's primary goal concerns biodiversity conservation; however, the goals of PA are now broadening that encompasses the provision of ecosystem services (i.e., provisioning, regulating, cultural, supporting) (Xu et al., 2016). Despite the benefits obtained from PAs, threats are still underway, leading to a decrease in the quality of services received from nature. According to the Convention on Biological Diversity (CBD) (2014, as cited by Mathur et al., 2015), threats in protected areas are "any human activity or related process that has a negative impact on key biodiversity features, ecological processes or cultural assets within a protected area." Also, threats are classified into direct (human activities or processes within the protected area that causes degradation) and indirect (arises outside) threats (*Table 1*).

Some of the underlying causes of these threats are attributed to the following factors such as (1) human population growth, (2) higher consumption of materials, (3) inadequate economic systems, (4) insufficient legal and political systems, (5) a breakdown or dysfunction of social, cultural, or political relations, (6) values and attitudes incompatible with conservation goals, (7) inappropriate governance and management, (8) lack of information, knowledge, and education, including the inadequate recognition of relevant knowledge systems, (9) lack of technical and human capacity, and (10) low levels of human resources for protected area management (Worboys et al., 2006, as cited by Mathur et al., 2015).

Some of the environmental problems such as illegal hunting, pollution, and cleanliness have been documented in national parks in Greece (Andrea et al., 2014). These problems have been identified by visitors as well as inhabitants of the protected area. Also, land cover changes in protected areas are attributed to human activities (land use) (Foley et al., 2005) such as livestock grazing, mining, on-site pollution, and unsustainable tourism (*Table 1*). The land use and land cover are known as the global modifying phenomenon that occurs in a spatiotemporal level, for example decline in forestland, shrubland, grassland, and wetland, but expansion in cultivated land and settlement areas (Wubie, et

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

al., 2016). However, despite these environmental threats, protected areas are still considered successful in maintaining natural ecosystems (Lopoukhine et al., 2012).

Table 1. *Examples of direct and indirect threats to protected areas*

Direct threats	Indirect threats
1. On-site pollution, impacts of chemicals 2. On-site impoundment/diversion of streams and rivers, groundwater withdrawal 3. Excessive livestock grazing 4. Mining 5. Infrastructure and industrial development within the protected area 6. Unsustainable tourism 7. Excessive resource extraction; overharvesting including poaching, hunting, fishing, fodder and fuel-wood extraction, logging (legal and illegal) 8. War and civil strife 9. Inadequate or incompetent technical and protected area management actions, processes, and resources 10. Invasive species of plants and animals 11. On-site cataclysmic natural events (such as fire, flood, earthquakes, volcanic activity)	1. Off-site pollution 2. Off-site damming of streams and rivers, diversion of water, groundwater withdrawals 3. Inappropriate land use and sea use 4. Climate change

Source: Worboys et al. (2006), as cited by Mathur et al. (2015)

Land cover and land cover change in protected areas

Land cover and land use are different cases. A land cover is the "observed (bio)physical cover on the earth's surface" (Di Gregorio and Jansen, 2005) "and is a synthesis of the many processes taking place on the land" (Di Gregorio, 2016). Moreover, land use is "characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it". For example, a sandy beach is a land cover and being a recreation area is its land-use (Food and Agriculture Organization, n.d.).

Many classification schemes are utilized by mappers/planners in land use/cover mapping. For example, the U.S. Geological Survey's (USGS) Land-Use/Land-Cover Classification System for use with Remote Sensor Data (Anderson et al., 1976, as cited by Jensen, 2015) is a resource-oriented land-cover classification system as compared to the American Planning Association (APA) Land-Based Classification Standard that focused on people or activity land-use classification systems. The former has nine (9) categories: urban or built-up land, agricultural land, rangeland, forest land, water, wetland, barren land, tundra, and perennial snow or ice (Jensen, 2015). In addition, the National Land Cover Dataset (NLCD) 2006 Classification Scheme adapted the Anderson Land Classification System, which has the following classes: water, developed, barren, forest, shrubland, herbaceous, planted/cultivated, and wetlands (Jensen, 2015). In the Philippines, the National Land Cover Map from the National Mapping and Resource Information Authority (NAMRIA) uses 14 classes (Santos, 2014, as cited by Estomata, 2018) and 12 classes in 2010 and 2015, respectively. This was aggregated into six major Intergovernmental Panel on Climate Change (IPCC) classes (2003) which are: forestland, grassland, cropland, otherland, settlements, and wetlands (Estomata, 2018) (*Table 2*).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

Table 2. *Land cover classification categories*

IPCC	NAMRIA 2010	NAMRIA 2015
Forest	Closed forest	Closed forest
	Open forest	Open forest
	Mangrove forest	Mangrove forest
	Shrubs	
	Fallow	Shrubs
	Wooded grassland	
Grassland	Grassland	Grassland
Cropland	Annual crop	Annual crop
	Perennial crop	Perennial crop
Otherland	Barren land	Barren land
Settlements	Built-up area	Built-up area
Wetlands	Marshland/Swamp	Marshland/Swamp
	Fishpond	Fishpond
	Inland water	Inland water

The assessment and monitoring of land cover are essential elements in natural resources management, environmental protection, food security, humanitarian programs, and core data monitoring and modeling (Food and Agriculture Organization, 2016). For example, using Landsat imagery, the land-cover change within and surrounding a biodiversity hotspot in Southern Africa was measured. Agricultural lands and human settlements increase, especially directly bordering the protected area. Also, varied woody vegetation was observed associated with deforestation activities (Bailey et al., 2015). Land cover change was also documented in two protected areas in Guinea-Bissau in West Africa for more than 40 years (1956 and 1998). Evidence of mangrove, palm grove, and dry forest/wooded savanna degradation was documented in one of the protected areas – Cacheu Natural Park. However, this is not the case on the other, where there is only a localized decrease in mangroves, but an increase in the extent of grassland savanna (Vasconcelos et al., 2002). In the Philippine context, with a total of 198 protected areas (4.68 million ha) from 2000-2012, the average rate of forest cover loss is 2.59% compared to the entire country, which is 2.69%. However, a higher rate of forest cover loss (1.4 times) is found around the 2-km buffer zone (Apan et al., 2017).

Watersheds – where most forested protected areas are located – are also an interest in the Philippines concerning land cover change. Estoque et al. (2018) conducted a study in La Mesa Watershed using Landsat data that revealed a net forest cover loss of 259 ha between 1988 and 2002, but a net forest cover gain of 557 ha between 2002 and 2016. The increase in forest cover is a result of forest restoration activities. On the other hand, Mialhe et al. (2015) combined remote sensing techniques and participatory land-use maps to understand land cover changes in the area. This provides accurate baseline information for capturing land changes and reporting their causes and consequences.

Materials and methods

Study area

Minalungao National Park (MNP) is located in the Municipality of General Tinio and City of Gapan, Nueva Ecija, Philippines (*Fig. 1*). It is located 15°17’N to 15°20’N

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

latitude and 121°07' to 121°10'E longitude with an area of 2,018 ha by virtue of Republic Act (RA) 5100 – the Act that established MNP in 1967 – and 1,997.23 ha as the "initial" component for RA 7586 or the National Integrated Protected Areas System Act of 1992. The MNP was also categorized as a protected landscape in 1999 by the Community Environment and Natural Resources Office in Cabanatuan City. Currently, the managers of MNP are continuously working for it to be declared and included as an "established" protected area under RA 11038 or also known as the Expanded National Integrated Protected Areas System (e-NIPAS) Act of 2018.

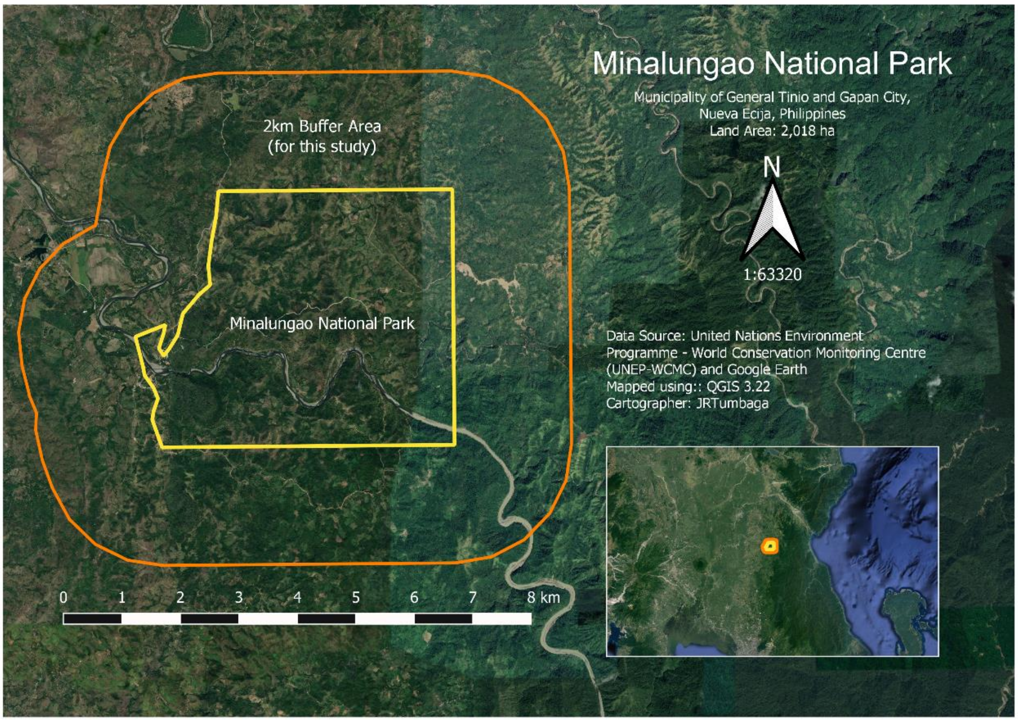


Figure 1. *Map of Minalungao National Park and 2 km buffer area (for this study)*

The topographic pattern of the protected area is rolling to mountainous with an elevation range from 60-247 m above sea level (masl). It also has steep slopes, particularly cliff-like river side mountainous areas and rugged terrain. Also, MNP is characterized with an annam loam gravelly phase soil (reddish-brown surface soil, coarse granular and friable, gravelly loam), moderate permeable and moderately well-drained soil, and a low-moderate susceptibility to landslide (91%). The protected area has two distinct seasons: (a) dry from November to April and (b) wet during the rest of the year. It also has the Sumacbao River as its main tributary that catches water from the nearby mountain ranges in General Tinio. The MNP is a unique ecotourism destination in the Province of Nueva Ecija, highlighting its karst forest, caves, rock formations, and pristine river. However, it is still threatened by human activities such as *kaingin* (slash and burn), charcoal making, and illegal logging, affecting its land cover.

Land cover classification

The Semi-Automatic Classification Plugin (SCP) in QGIS software, using minimum distance supervised classification technique, assists in the classification (*Fig. 2*) of land

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

cover types within and around (2 km buffer area) Minalungao National Park (MNP) (*Fig. 1*). The Landsat (i.e., Landsat 7 ETM+ and Landsat 8) satellite images with a spatial resolution of 30 × 30 m having *no cloud cover* were selected (*Table 3*). Three (3) land cover classifications were produced in different years: 2001 (using Landsat 7 ETM+), 2014, and 2021 (using Landsat 8).

To validate the land cover classifications, an accuracy assessment was performed. A full report of the (a) area-based error matrix, (b) user's accuracy, (c) producer's accuracy, (d) overall accuracy, and (e) Kappa statistic were determined.

Table 3. *Dates and Scene ID number of Landsat 7 ETM+ and Landsat 8 images used*

Year	Day and month	Path/Row	Product ID
2001	26 November	116/049	LE07_L1TP_116049_20011126_20170202_01_T1
2014	07 February	116/049	LC08_L1TP_116049_20140207_20170426_01_T1
2021	26 February	116/049	LC08_L1TP_116049_20210226_20210226_01_RT

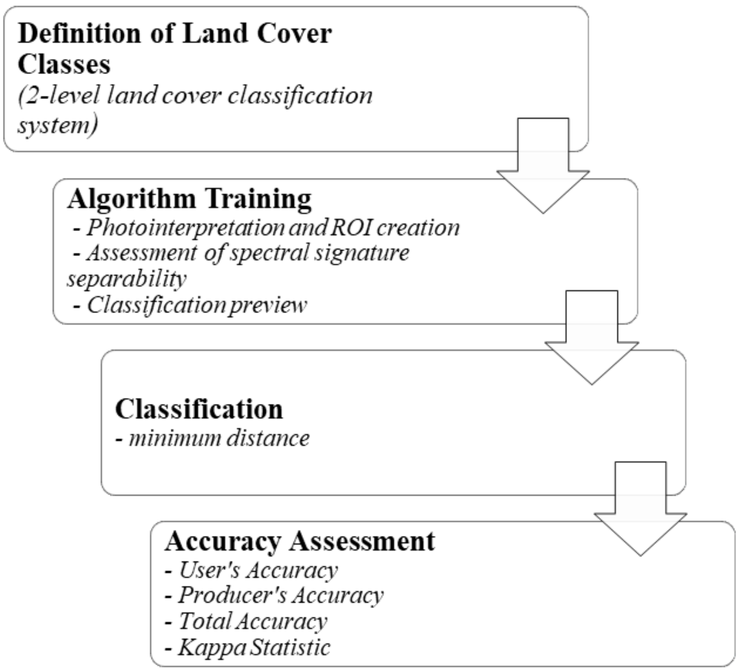


Figure 2. *Workflow for land cover classification (modified from Congedo, 2020)*

Stratified random sampling was used to select random points that was photo interpreted to calculate the error of classification. In this study, the percentage area of each class (*Pci*) was divided by 100 to get the required mapped area proportion of class *i* (*Wi*). The set sample points (*N*) were divided by the total number of classes (*c*) for equal distribution. Thus, the weighted distribution (*Nwi*) and mean sample (*Nmi*) were obtained (*Eqs. 1–4*). The equations were used to obtain samples based on the classification report (*Appendix 2*).

Mapped area proportion of class *i:*

$$Wi = \frac{Pci}{100} \quad \text{(Eq.1)}$$

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

Equal distribution:

$$Ni = \frac{N}{c} \quad \text{(Eq.2)}$$

Weighted distribution:

$$Nwi = N \times Wi \quad \text{(Eq.3)}$$

Mean sample:

$$Nmi = \frac{(Ni + N \times Wi)}{2} \quad \text{(Eq.4)}$$

From the previous approaches, the land cover was classified into three macro classes, namely: (1) wetlands, (2) forestland, and (3) otherlands (IPCC, 2003, as cited by Estomata, 2018). This was further classified into sub-classes, namely: (1) inland water, (2) closed forest, (3) open forest, and (4) open/barren land. The latter classifications were used in the analysis. The other classifications such as grassland, cropland, and settlements were not considered; instead, these were included as open/barren. This is in relation to the photointerpretation made before the classification (*Appendix 1, Table A1*). From the operational description of land cover classes, inland water consists of the major river (i.e., Sumacbao River), creeks, and small ponds. Closed forest refers to densely populated tree cover (>40%), while open forest refers to sparse-moderate tree cover (at least 10% and <40%) (Food and Agriculture Organization, 2000). Open/barren includes land that is tilled for agriculture, cleared forest areas, sand and exposed rocks, roads, settlements, and grassland (*Appendix 1, Table A2*).

The produced land cover classifications were compared to the 2016 MNP-PAMP (*subject for ground validation*), where there are three macro classes (other woodedland, otherland, and inland water) and five subclasses (shrubs, wooded grassland, cultivated annual crop, natural grassland, inland water) in vector format. From these classifications, a direct comparison was made from this study to establish similarities (*Table 4*). Despite that this classification is only applicable within the MNP, this was also applied in the 2 km buffer area. This land cover classification was presented to the Protected Area Superintendent, where no objections were raised.

Table 4. *Land cover classification difference between this study and from the 2016 MNP-PAMP*

Macro classes	Classified land cover	
	NAMRIA	**PA management plan**
Wetlands	Inland water	Inland water
Forestland	Closed forest Open forest	Shrubs Wooded grassland
Otherland	Open/barren	Cultivated, annual crop Natural grassland

Related activities on land cover change

A key informant interview with the Protected Area Superintendent was facilitated to identify related human activities on land cover change. The key informant is selected

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

considering the broad experience within and around the MNP. The informant is currently the head officer of the Department of Environment and Natural Resources – Community Environment and Natural Resources Office (DENR-CENRO) in Cabanatuan City, Nueva Ecija. The produced land cover classification is shown and explained to the informant. The informant was asked to state thoughts on why such changes happened in the area. An unstructured interview was used to elicit the response of the informant.

Alternative state computation

The rate of land cover change produced around the MNP was used to compute the hypothetical alternative state within MNP for 2021 (*Eqs. 5–7*). The alternative state is produced to present land cover scenarios within the park without protection measures (Peh et al., 2013). Moreover, the current land cover of MNP shows protection measures. The state for a positive increase in land cover of closed forest through time was not estimated, since the current state already showed an improvement in closed forest cover. This may affect other natural ecosystems such as grassland (i.e., open/barren). Forestland and inland water were highlighted in the analysis. Adjustments were also made in open/barren land to fit the total land area of MNP.

Land cover around MNP:

$$Rate\ of\ Change\ (\%) = \frac{[Area\ (ha)\ 2014 - Area\ (ha) 2021]}{Area\ (ha) 2014} \times 100 \qquad \text{(Eq.5)}$$

Land cover within MNP:

$$Added\ Area = \frac{Baseline\ Area \times Rate\ of\ Change}{100} \qquad \text{(Eq.6)}$$

$$\boldsymbol{Alternative\ Area} = Baseline\ Area\ (Land\ Cover\ 2014) + Added\ Area\ (-/+) \qquad \text{(Eq.7)}$$

Results

Land cover classification

The Minalungao National Park (MNP) has an area of 2,018 ha; however, using the shapefile obtained from UNEP-WCMC (2021), the extracted raster data only yields an area of 2,004.39 ha. Thus, the area of analysis has a lesser extent of 3.61 ha. The data was cross-referenced from the data used in the 2016 MNP Protected Area Management Plan (MNP-PAMP). Given that MNP is on the course for its establishment as a protected area (PA), this area was still used for the land cover analysis and will be subjected to further validation. Also, the established 2 km buffer around the MNP has an area of 4,928.04 ha.

A higher value of overall accuracy and kappa statistic (*Table 5*) was noted within the PA than the buffer area from the land cover classification. However, both land cover classifications were acceptable. Thus, the researcher able to validates the land cover map for interpretation. An overall accuracy of 70-100% and a kappa coefficient of 0.70-1.00 were considered in this study.

Land cover changes within MNP

The land cover classification within MNP is observed in different time intervals: 2001, 2014, and 2021 (*Fig. 3*). Moreover, land cover changes can be observed in

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

Table 6. The forest cover of MNP as a protected landscape is considered the key interest in this study. From the total area percentage of different classes, it shows that closed forest has the largest area in 2001 (39.14%) and 2021 (40.14%), while open forest has the largest area in 2014 (38.61%). The large area of open/barren land is also noted in 2001 (31.46%), where it follows closed forest. However, there was a continuous decrease in its extent over the 20 years. Inland water which the Sumacbao River primarily represents, has the least area.

Table 5. *Land cover classification overall accuracy (%) and kappa statistic*

	Within MNP			**Around MNP**		
	2001	**2014**	**2021**	**2001**	**2014**	**2021**
Overall accuracy	85.24	86.53	86.18	86.30	81.08	80.87
Kappa statistic	0.7816	0.8005	0.7922	0.7734	0.7178	0.7025

Table 6. *Total area coverage, percentage, and net change between the years 2001, 2014, and 2021 for the classified land cover categories* ***within*** *the MNP*

Class	**Area (2001)**		**Area (2014)**		**Area (2021)**		**2001-2014**	**2014-2021**	**2001-2021**
	ha	**%**	**ha**	**%**	**ha**	**%**	**Net area change (ha)**	**Net area change (ha)**	**Net area change (ha)**
Inland water	49.50	2.47	45.45	2.27	54.00	2.69	**-4.05**	**+ 8.55**	**+ 4.50**
Closed forest	784.44	39.14	601.47	30.01	804.51	40.14	**-182.97**	**+ 203.04**	**+ 20.07**
Open forest	539.91	26.94	773.82	38.61	733.59	36.30	**+ 233.91**	**-40.23**	**+ 193.68**
Open/barren	630.54	31.46	583.65	29.12	412.29	20.57	**-46.89**	**-171.36**	**-218.25**
Total	2,004.39		2,004.39		2,004.39				

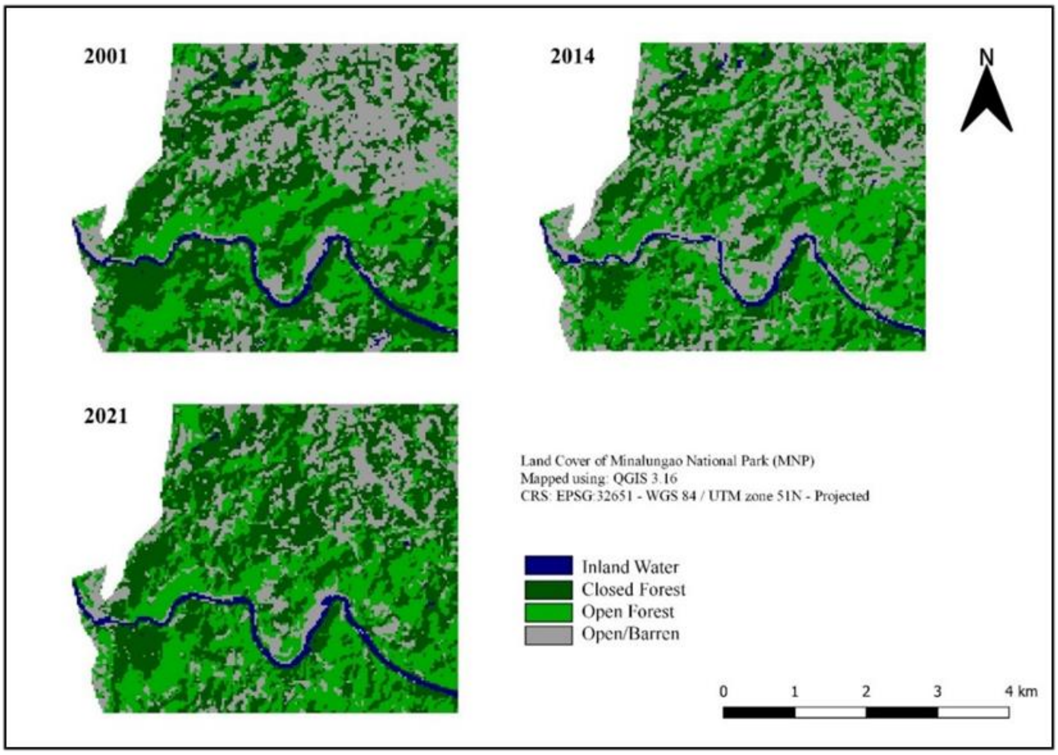


Figure 3. *Land cover classification of MNP for 2001, 2014, and 2021*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

Despite the decrease of closed forest between 2001 and 2014, its area increased in 2021. It has a total gain of 20.07 ha from 2001 to 2021. On the other hand, open forest with a sparse to moderate tree cover increased from 2001 to 2014, but it decreased in 2021. However, it still gains 193.68 ha from 2001 to 2021. The open/barren area shows a constant decrease from 2001 to 2021, where it loses 218.25 ha. Inland water, on the other hand, has only increased 4.5 ha from 2001 to 2021. Also, the area of narrow creeks was not significantly measured considering the large pixel size of the processed satellite image, including the tree cover effect in the landscape.

Land cover changes around MNP

The land cover classification around MNP is observed in different time intervals: 2001, 2014, and 2021 (*Fig. 4*). Also, its land cover change can be observed in *Table 7*. The land in this area is privatized and not protected; thereby, an extreme land cover change is observed. The open forest has the largest area in 2001 (52.83%) and 2021 (48.58%), while closed forest has the largest area in 2014 (35.42%), though it did not significantly increase from 2001 to 2014. Also, open/barren land greatly increased from 2001 (11.64%) to 2014 (31.29%). This is probably related to the significant decline of open forest in 2014 (32.44%). The closed forest also declines greatly in 2021 (19.08%). This is in relation to the increase of open forest in the same period. Moreover, inland water only constitutes a small part of the landscape.

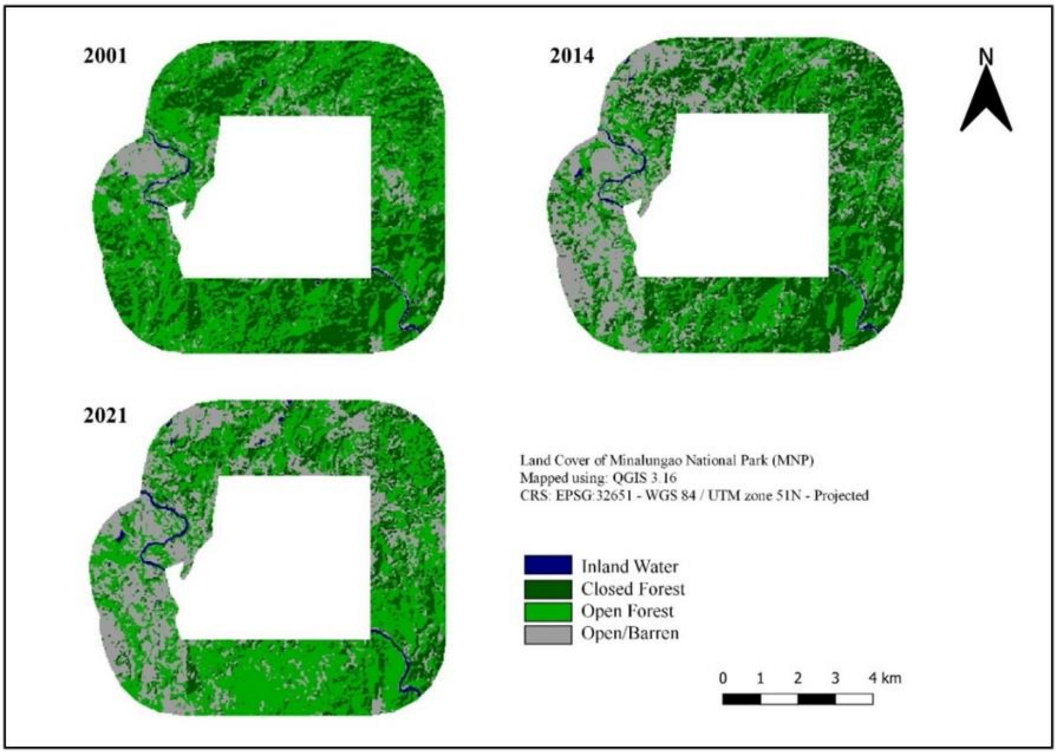


Figure 4. *Land cover classification around MNP for 2001, 2014, and 2021*

For the span of 20 years, open forest especially closed forest, declines in extent with a total loss of 209.16 ha and 773.01 ha. However, a significant total gain is evident in open/barren land with 964.89 ha. Inland water also increased by 17.28 ha.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

Table 7. *Total area coverage, percentage, and net change between the years 2001, 2014, and 2021 for the classified land cover categories* ***around*** *the MNP (2 km buffer)*

Class	Area (2001)		Area (2014)		Area (2021)		2001-2014	2014-2021	2001-2021
	ha	%	ha	%	ha	%	Net area change (ha)	Net area change (ha)	Net area change (ha)
Inland water	37.44	0.76	42.03	0.85	54.72	1.11	**+ 4.59**	**+ 12.69**	**+ 17.28**
Closed forest	1,713.42	34.77	1,745.73	35.42	940.41	19.08	**+ 32.31**	**-805.32**	**-773.01**
Open forest	2,603.34	52.83	1,598.49	32.44	2,394.18	48.58	**-1,004.85**	**+ 795.69**	**-209.16**
Open/barren	573.84	11.64	1,541.79	31.29	1,538.73	31.22	**+ 967.95**	**-3.06**	**+ 964.89**
Total	4,928.04		4,928.04		4,928.04				

Alternative state within MNP

From the land cover change produced around MNP, rates were attributed to the 2014 land cover to create an alternative state (*Table 8*) within MNP. A significant decrease in closed forest is related to an increase in open forest. If tree cutting activities continue, the area of open forest will possibly be converted into an open/barren land. This is particularly true if no protection activities will be enforced within the MNP. This trend is observed in *Table 7* (2001-2014 open forest).

This alternative state can be used in future nature valuation studies where policymakers can compare the value obtained from ecosystem types (i.e., closed forest, open/barren) in a protected state. From this scenario, policymakers can weigh the benefits of a landscape that is protected because of a managerial regime or in a non-protected state where communities can alter the landscape because of their rights to manage their lands.

Table 8. *Alternative land cover within MNP following the trend around MNP for 2021*

Class	Baseline area (2014)		Rate	Current area (2021)		Alternative area (2021)	
	ha	%		ha	%	ha	%
Inland water	45.45	2.27	**↑30.19%**	54.00	2.69	**59.17**	**2.95**
Closed forest	601.47	30.01	**↓46.13%**	804.51	40.14	**324.04**	**16.16**
Open forest	773.82	38.61	**↑49.78%**	733.59	36.30	**1,159.02**	**57.82**
Open/barren	583.65	29.12	**=(adjusted)**	412.29	20.57	***462.16**	**23.06**
Total	2,004.39			2,004.39		2,004.39	

Note: *excess hectares in the computation were adjusted to open/barren

Discussion

Causes of land cover change within MNP

The decrease in the area of closed forest from 2001 to 2014 is attributed to the tree cutting activities of the local people. Because of this activity, closed forest was gradually converted to open forest. The cut trees were used to produce charcoal which is sold to add income to the local people. However, this decrease was addressed, and forest cover were restored up to 2021. The principal activity that caused this increase is due to the early initiative of the national government to implement the National Greening Program (NGP) from 2011-2016 based on Executive Order No. 26, s. 2011.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

Also, this is strengthened with the implementation of the Enhanced National Greening Program (E-NGP), to be implemented from 2016-2028 under the Executive Order No. 193, s. 2015. From this activity, a substantial decrease in open/barren land has been noted.

With the E-NGP in place, community members were engaged to participate, which caused the decline in tree-cutting activities. Also, local people actively participate in the MNP ecotourism activities. For example, it was specified that engaging in bamboo rafting as an ecotourism activity is easier to earn income than cutting trees. However, there are still cutting activities observed within the park. This unsound human practice affects the integrity and functioning (Gross et al., 2013) of the MNP. The ecotourism promotes other livelihood activities such as selling items and souvenirs, cottage operation, and serves as a tourist guide.

The protection of the park, which is strengthened by monitoring illegal activities, also encouraged the restoration of closed forest. This includes the reporting of tree-cutting activities; considering that people are already aware that tree-cutting is prohibited and recognized to penalties and legal actions. The Protected Area Management Board (PAMB) members immediately report any illegal activities that happen inside the park. Local people know that there are people who monitor the park, which limits them to cut trees. Accordingly, restoration efforts are expected to be more effective if livestock grazing activities are prevented. During the wet season, it was reported that due to the abundance of grass within the park, livestock is released to forage. This practice is still being addressed with the help of the local government unit. Field officers and managers are having difficulties removing this livestock. They are relying on legal actions filed against the persons involved.

On the other hand, the minimal increase in inland water has been attributed to the open/barren land along the Sumacbao River. Due to the lower capacity of the soil to hold water, the water runs off into the river, which causes inundation. However, inland water in the analysis is not great because the satellite images were obtained during the dry season. The saturation of creeks and small ponds within the park play a minimal contribution to its increase.

Causes of land cover change around MNP

The established buffer area in this study does not correspond with the proposed buffer area in the 2016 MNP PAMP, which is 50 m. Because of this small land area, the researcher intently uses a 2 km buffer to determine changes in the landscape, threatening MNP. The researcher analyzes the 2 km buffer area to produce an alternative state if ever MNP will be disestablished as a component of the NIPAS. The establishment of a buffer area is the same as proclaiming a protected area. Thus, an additional area must be added to the MNP for its establishment. However, most of the parcels of land around the MNP are already titled to private owners based on Proclamation No. 605, s. 1959. Thereby, it was suggested to border the area with fences instead of increasing its size. Financial concerns will again be an issue for its establishment.

The significant decrease in open forest from 2001 to 2014 was due to its conversion into open/barren land. This is particularly evident in the western part of the landscape, where tree cutting and agricultural activities are practiced. Settlements are also starting to occupy this area which adds up to the pressure. The significant decrease of closed forest from 2014 to 2021 has been attributed to granting cutting permits to private

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

landowners. The peripheral area of the MNP was reforested before with *Gmelina arborea* and had been benefited by the landowners through the selling of cut trees. It is expected that tree cover will gradually decrease around the MNP because of this legal issuance of cutting permits along the privatized land areas.

Also, the gradual increase in inland water is attributed to the creation of artificial ponds and irrigation for agricultural areas. The inundation of water to the river system because of increased open/barren land also contributes. Pressures such as agricultural activities could become a threat to the protected area if expansion is not managed.

Issues on land cover classification

In this study, a dynamic land cover transition for the different time intervals (2001, 2014, 2021) between the two areas (i.e., within and around) was analyzed for land cover classification. The intervals presented were doubled in the first scenario (2001-2014) and singled in the second scenario (2014-2021). This was facilitated to use typical satellite images and prevented choosing Landsat 7 ETM+ because of the presence of gap lines due to the failure of its Scan Line Corrector (SLC). There are techniques to remove and fill these gaps, however, the researcher was encouraged to move away from this issue to simplify the classification. Also, considering the refinement of the different classes, this was not applied because it changes (subjectively observed) the classification of the selected region of interest (ROI). Though, the accuracy assessment is acceptable among the land cover classifications made across the different maps.

The land cover classes are not complete based on the IPCC (2003) categories: inland water, forestland, grassland, cropland, otherland, and settlements. Only three major classifications were adopted in the analysis. Considering the season (i.e., dry season), the selection of ROIs using different band combinations made the researcher include grassland, cropland, and settlements under the open/barren classification. This means that open/barren land does not only represent denuded lands. Also, settlements within and around the protected area are scattered; thus, having a small area to be considered. If settlements are selected, this will lead to possible confusion in the algorithm that was used (i.e., minimum distance). Although other classification algorithms in the QGIS were simulated: maximum likelihood and spectral angle mapping, the minimum distance is still selected because of its analogous representation to the satellite image. The result is still significant, considering that forest cover is the fundamental interest within and around the protected area.

Expanding the analysis of land cover scenario in a protected area

The land cover classification of a protected area should not be limited as well within its boundaries. From this study, a well-defined surrounding area (2 km buffer) is used to identify a possible alternative state of the protected area if disestablished. This is used to identify threats that will reduce the quality state of the protected area. These threats include tree cutting, agricultural activities, livestock grazing, and settlement expansion. These pressures are also found in the study of Bailey et al. (2015), where human activities (agricultural activities and deforestation) around the protected area threaten its ecological integrity. On the contrary, the current state of MNP is similar to the study of Estoque et al. (2018) in La Mesa Watershed, where forest cover loss was observed in the early years, however, forest cover gain was observed in the latter years as a result of forest restoration activities – related with the E-NGP implemented by the DENR.

Future of land cover in a protected area

The increased area of closed forest within MNP is a sustainable effort for the PAMB members that oversee the management of the park. However, due to the pandemic caused by Corona Virus Disease (COVID-2019), ecotourism activities and the influx of people are limited, which could cause pressure on local people to go back to cutting trees (J. Aberin, personal communication, April 7, 2021) to earn additional profits. Since ecotourism plays a crucial role in preventing tree cutting activities, livelihood options must be prioritized at this present time to limit the pressures posed to the park. An incompetent technical and protected area management scheme is also attributed to resource extraction activities (Mathur et al., 2015). If PAMB aims for the sustainability of the current status of the park, management options must be presented and weighed for the benefit of the local people, including the environment.

Protective management schemes such as restoration efforts (native tree planting activities), mainstreaming ecotourism, and monitoring illegal activities improve forest cover. However, lands that are alienable and disposable or private lands are subjected to pressures such as tree-cutting activities causing forest cover loss. Human pressures toward the environment cannot be prevented because of the rights given to them. The NIPAS has been an important strategy to control the continuous degradation of forest cover in the country. Thus, disestablishment of its initial components intensifies unsound human activities, causing ecological repercussions. This study points out the need to sustain protective management strategies, especially among protected areas in the country. Modeling possible scenarios as indicated in this study can help policymakers, including the managers, weigh actions, especially in the decision-making process.

Conclusion

Four (4) land cover types based on NAMRIA's classification were established in this study: inland water, closed forest, open forest, and open/barren land. The classifications based on the three time intervals (2001, 2014, and 2021) within and around MNP were considerably accepted based on the overall accuracy assessment and kappa coefficient. Additionally, the land cover changes within and around MNP showed a varying pattern. The land cover changes within MNP showed an interesting improvement in closed forest cover from 2001 to 2021. This is because of the decrease in closed forest in 2014 but improves in 2021. On the contrary, closed forest cover declines around MNP from 2001 to 2021. From this point, the improvement of closed forest within the MNP is due to restoration activities (i.e., NGP), ecotourism program, and careful monitoring of illegal activities. On the other hand, the drastic decline of closed forest around MNP are brought by the issuance of tree cutting permits to privatized land owners as well as land conversion activities (e.g., settlements and agriculture). Lastly, the produced alternative state for MNP for 2021 showed a decline in closed forest cover in line with an increase in open forest cover. This illustrates that with no protection scheme, closed forest in protected areas will continue to dwindle.

The land cover classification produced for Minalungao National Park is the first step in mainstreaming remotely sensed data backed up by pertinent information from the implementing agency as a monitoring strategy to review restoration efforts. Thus, it is recommended to continue land cover monitoring by following a specific interval, which may complement the PAMP implementation. Information derived from remotely sensed data can be relayed to the local government units involved in its protection. This will also strengthen their Comprehensive Land Use Plan (CLUP) in harmony with PAMP as indicated in the e-NIPAS. However, to increase the accuracy of the classifications, additional refinements can be employed. Also, a standard procedure in developing land cover classification must be established for the PA managers, including the technical staff. High-resolution satellite images can now be used as well to baseline the current land cover within and around the park. With this, it will lead to higher accuracy and could define otherland cover classes.

REFERENCES

[1] Andrea, V., Tampakis, S., Tsantopoulos, G., Manolas, E. (2014): Environmental problems in protected areas: stakeholders' views with regard to two neighboring National Parks in Greece. – Management of Environmental Quality: An International Journal 25: 723-737.

[2] Apan, A., Suarez, L. A., Maraseni, T., Castillo, J. A. (2017): The rate, extent and spatial predictors of forest loss (2000–2012) in the terrestrial protected areas of the Philippines. – Applied Geography 81: 32-42.

[3] Bailey, K. M., McCleery, R. A., Binford, M. W., Zweig, C. (2015): Land-cover change within and around protected areas in a biodiversity hotspot. – Journal of Land Use Science 1-22.

[4] Congedo, L. (2020): Semi-automatic classification plugin documentation. – DOI: http://dx.doi.org/10.13140/RG.2.2.25480.65286/1.

[5] Di Gregorio, A. (2016): Land Cover Classification System: Classification Concepts Software Version (3). – Food and Agriculture Organization of the United Nations, Rome.

[6] Di Gregorio, A., Jansen, L. J. M. (2005): Land Cover Classification System Classification Concepts and User Manual Software Version (2). – Food and Agriculture Organization of the United Nations, Rome.

[7] Dudley, N. (ed.) (2008): Guidelines for Applying Protected Area Management Categories. – International Union for the Conservation of Nature, Gland.

[8] Dudley, N., Ali, N., MacKinnon, K. (2017): Protected areas helping to meet the Sustainable Development Goals. Sustainable Development Goals: Links to the IUCN World Commission on Protected Areas – International Union for the Conservation of Nature, Gland.

[9] Estomata, M. T. L. (2018): Forest Cover and Change Classification Using ALOS PALSAR Mosaic Data and Decision Tree Classifiers – Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Quezon City, Philippines.

[10] Estoque, R. C., Murayama, Y., Lasco, R. D., Myint, S. W., Pulhin, F. B., Wang, C., Ooba, M., Hijioka, Y. (2018): Changes in the landscape pattern of the La Mesa Watershed - The last ecological frontier of Metro Manila, Philippines. – Forest Ecology and Management 430: 280-290.

[11] Foley, J. A., Defries, F., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., Daily, G. C., Gibbs, H. K., Helkowski, J. H., Holloway, T., Howard, E. A., Kucharik, C. J., Monfreda, C., Patz, J. A., Prentice, C., Ramankutty, N., Snyder, P. K. (2005): Global consequences of land use. – Science 309(5734): 570-574.

[12] Food and Agriculture Organization of the United Nations (n.d.): Classification Concepts. – Food and Agriculture Organization, Rome.

[13] Food and Agriculture Organization of the United Nations (2000): The Forest Resources Assessment Programme. – United Nations, Geneva.

[14] Food and Agriculture Organization of the United Nations (2016): Land Cover Classification System. – Food and Agriculture Organization, Rome.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

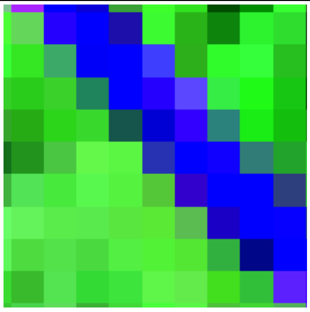
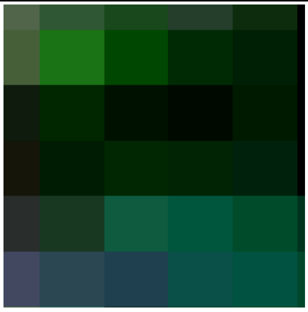
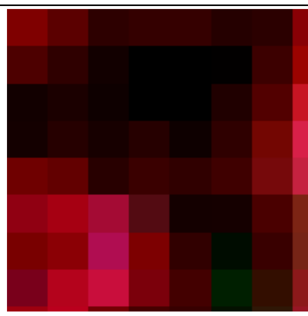
[15] Gross, D., Dubois, G., Pekel, J-F., Mayaux, P., Holmgren, M., Prins, H. H. T., Rondinini, C., Boitani, L. (2013): Monitoring land cover changes in African protected areas in the 21st century. – Ecological Informatics 14: 31-37.
[16] Hailu, A., Mammo, S., Kidane, M. (2020): Dynamics of land use, land cover change trend and its drivers in Jimma Geneti District, Western Ethiopia – Land Use Policy 99: 105011.
[17] International Union for the Conservation of Nature (2008): Protected Areas. – https://www.iucn.org/theme/protected-areas/about.
[18] Jensen, J. R. (2015): Introductory Digital Image Processing: A Remote Sensing Perspective. 4th Ed. – Pearson Series in Geographic Information Science, Illinois.
[19] Lambin et al. (2001): The causes of land-use and land-cover change: moving beyond the myths. – Global Environmental Change 11: 261-269.
[20] Lopoukhine, N., Crawhall, N., Dudley, N., Figgis, P., Karibuhoye, C., Laffoley, D., Miranda Londoño, J., MacKinnon, K., Sandwith, T. (2012): Protected areas: providing natural solutions to 21st century challenges. – Surveys and Perspectives Integrating Environment and Society 5: 117-131.
[21] Mathur, V. B., Onial, M., Mauvais, G. (2015): Managing Threats. – In: Worboys, G. L., Lockwood, M., Kothari, A., Feary, S., Pulsford, I. (eds.) Protected Area Governance and Management. ANU Press, Canberra.
[22] Mialhe, F., Gunnell, Y., Ignacio, J. A. F., Delbart, N., Ogania, J. L., Henry, S. (2015): Monitoring land-use change by combining participatory land-use maps with standard remote sensing techniques: showcase from a remote forest catchment on Mindanao, Philippines. – International Journal of Applied Earth Observation and Geoinformation 36: 69-82.
[23] Peh, K. S.-H., Thapa, I., Basnyat, M., Balmford, A., Bhattarai, G. P., Bradbury, R. B., Brown, C., Butchart, S. H. M., Dhakal, M., Gurung, H., Hughes, F. M. R., Mulligan, M., Pandeya, B., Stattersfield, A. J., Thomas, D. H. L., Walpole, M., Merriman, J. C. (2016): Synergies between biodiversity conservation and ecosystem service provision: lessons on integrated ecosystem service valuation from a Himalayan protected area, Nepal. – Ecosystem Services 22: 359-369.
[24] Rodríguez-Rodríguez, D., Martínez-Vega, J., Echavarría, P. (2019): A twenty-year GIS-based assessment of environmental sustainability of land use changes in and around protected areas of a fast developing country: Spain. – International Journal of Applied Earth Observation and Geoinformation 74: 169-179.
[25] Secretariat of the Convention on Biological Diversity (2008): Protected Areas in Today's World: Their Values and Benefits for the Welfare of the Planet. – Secretariat of the Convention on Biological Diversity, Montreal.
[26] Szantoi, Z., Geller, G. N., Tsendbazar, N. E., See, L., Griffiths, P., Fritz, S., Gong, P., Herold, M., Mora, B., Obregón, A. (2020): Addressing the need for improved land cover map products for policy support. – Environmental Science and Policy 112: 28-35.
[27] Vasconcelos, M. J. P., Mussá Biai, J. C., Araújo, A., Diniz, M. A. (2002): Land cover change in two protected areas of Guinea-Bissau (1956-1998). – Applied Geography 22: 139-156.
[28] Worboys, G. L. (2015): Concept, Purpose and Challenges. – In: Worboys, G. L., Lockwood, M., Kothari, A., Feary, S., Pulsford, I. (eds.) Protected Area Governance and Management. ANU Press, Canberra.
[29] Worboys, G. L., Lockwood, M., Kothari, A., Feary, S. Pulsford, I. (2015): Protected Area Governance and Management. – ANU Press, Canberra.
[30] Wubie, M. A., Assen, M., Nicolau, M. D. (2016): Patterns, causes and consequences of land use/cover dynamics in the Gumara watershed of lake Tana basin, Northwestern Ethiopia. – Environmental Systems Research 5(8): 1-12.
[31] Xu, W., Xiao, Y., Zhang, J., Ouyang, Z. (2016): Strengthening protected areas for biodiversity and ecosystem services in China. – Proceedings of the National Academy of Sciences of the United States of America PNAS 114: 1601-1606.

APPENDIX

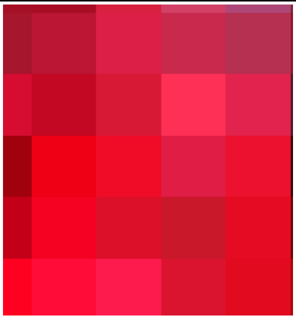
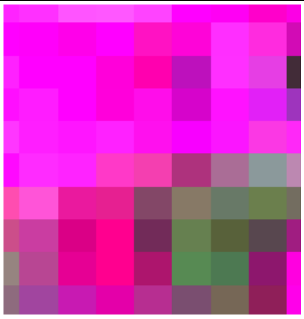
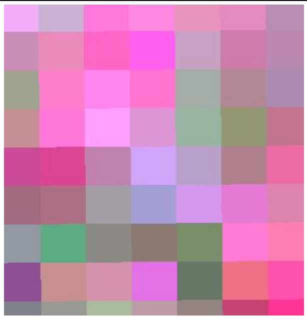
Appendix 1

Photointerpretation used in land cover classification and examples of land cover classes

Table A1. *Photointerpretation used in land cover classification*

Classification	Aerial image (Bing Virtual Earth)	Spectral band combination (in SCP)
Wetland		
Inland water		 6-4-1
Forestland		
Closed forest		 6-4-2
		 4-3-2
Open forest		 6-4-2

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

		 4-3-2
Otherland		
Open/barren		 6-4-2
Grassland*		 6-4-2
Cropland*		 6-4-2
Settlements*		 6-4-2

*Not classified separately, instead, included under otherland (open/barren)

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

Table A2. *Examples of land cover classes identified using Bing Virtual Earth*

Inland water	
	
Closed forest	
	
Open forest	

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

			
Open/barren			
			

Appendix 2

Classification report for sample computation in accuracy assessment (adjustment in mean no. of samples were made to produce 200 points)

Table A3. *Stratified random samples* ***within MNP for 2001***

Land Cover Class	Pixel Sum	Area m2	Percentage	Wi
1	550	495000	2.469579273	0.02469579
2	8716	7844400	39.13609627	0.39136096
3	5999	5399100	26.93637466	0.26936375
4	7006	6305400	31.4579498	0.3145795
Total	**22271**	**20043900**	**100**	
# of class		**4**		
Sample		**200**		

Land Cover Class	Weighted	Equal	Mean	Sample
1	4.939158547	50	27.46957927	28
2	78.27219254	50	64.13609627	64
3	53.87274932	50	51.93637466	52
4	62.9158996	50	56.4579498	56
Total	200	200	**200**	**200**

APPLIED ECOLOGY AND ENVIRONMENTAL RESEARCH 21(4):3591-3613.
http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613

Table A4. *Stratified random samples* ***within MNP for 2014***

Land Cover Class	Pixel Sum	Area m2	Percentage	Wi
1	505	454500	2.267522787	0.02267523
2	6683	6014700	30.00763325	0.30007633
3	8598	7738200	38.60625926	0.38606259
4	6485	5836500	29.11858471	0.29118585
Total	**22271**	**20043900**	**100**	
# of class		**4**		
Sample		**200**		
Land Cover Class	**Weighted**	**Equal**	**Mean**	**Sample**
1	4.535045575	50	27.26752279	27
2	60.01526649	50	55.00763325	55
3	77.21251852	50	63.60625926	64
4	58.23716941	50	54.11858471	54
Total	200	200	**200**	**200**

Table A5. *Stratified random samples* ***within MNP for 2021***

Land Cover Class	Pixel Sum	Area m2	Percentage	Wi
1	600	540000	2.69408648	0.02694086
2	8939	8045100	40.13739841	0.40137398
3	8151	7335900	36.59916483	0.36599165
4	4581	4122900	20.56935028	0.2056935
Total	**22271**	**20043900**	**100**	
# of class		**4**		
Sample		**200**		
Land Cover Class	**Weighted**	**Equal**	**Mean**	**Sample**
1	5.38817296	50	27.69408648	28
2	80.27479682	50	65.13739841	65
3	73.19832967	50	61.59916483	62
4	41.13870055	50	45.56935028	46
Total	200	200	**200**	**200**

Table A6. *Stratified random samples* ***around MNP for 2001***

Land Cover Class	Pixel Sum	Area m2	Percentage	Wi
1	416	374400	0.759734093	0.00759734
2	19038	17134200	34.76879246	0.34768792
3	28926	26033400	52.82708744	0.52827087
4	6376	5738400	11.644386	0.11644386
Total	**54756**	**49280400**	**100**	
# of class		**4**		
Sample		**200**		
Land Cover Class	**Weighted**	**Equal**	**Mean**	**Sample**
1	1.519468186	50	25.75973409	26
2	69.53758492	50	59.76879246	60
3	105.6541749	50	77.82708744	78
4	23.28877201	50	36.644386	37
Total	200	200	**200**	**200**

Table A7. *Stratified random samples* ***around MNP for 2014***

Land Cover Class	Pixel Sum	Area m2	Percentage	Wi
1	467	420300	0.852874571	0.00852875
2	19397	17457300	35.42442837	0.35424428
3	17761	15984900	32.43662795	0.32436628
4	17131	15417900	31.28606911	0.31286069
Total	**54756**	**49280400**	**100**	
# of class		**4**		
Sample		**200**		
Land Cover Class	**Weighted**	**Equal**	**Mean**	**Sample**
1	1.705749142	50	25.85287457	26
2	70.84885675	50	60.42442837	60
3	64.8732559	50	57.43662795	57
4	62.57213821	50	56.28606911	56
Total	200	200	**200**	**200**

Table A8. *Stratified random samples* ***around MNP for 2021***

Land Cover Class	Pixel Sum	Area m2	Percentage	Wi
1	608	547200	1.110380598	0.01110381
2	10449	9404100	19.08284024	0.1908284
3	26602	23941800	48.58280371	0.48582804
4	17097	15387300	31.22397545	0.31223975
Total	**54756**	**49280400**	**100**	
# of class		**4**		
Sample		**200**		
Land Cover Class	**Weighted**	**Equal**	**Mean**	**Sample**
1	2.220761195	50	26.1103806	26
2	38.16568047	50	44.08284024	44
3	97.16560742	50	73.58280371	74
4	62.44795091	50	56.22397545	56
Total	200	200	**200**	**200**

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2104_35913613