MAPPING COCONUT TREES AND ITS PRODUCTION OF VIRGIN COCONUT OIL WITHIN BUTUAN CITY, PHILIPPINES USING SENTINEL-2 DATA

James Ian L. Jancinal[1], Jeremy B. Corvera1[2], Arturo G. Cauba Jr.*[3]
[1]Geodetic Engineer, DENR Regional Office XIII
Ambago, Butuan City 8600, Philippines
Email: jamesian.jancinal2@gmail.com

[2]GIS Specialist II, DAR Regional Office XIII
Libertad, Butuan City 8600, Philippines
Email: jeremycorvera11@gmail.com

[3]Faculty member, Caraga State University
Ampayon, Butuan City 8600, Philippines
Email: agcauba@carsu.edu.ph

KEY WORDS: Maximum Likelihood Classification, Normalized Difference Vegetation Index, VCO Production

ABSTRACT: The coconut tree (Cocos nucifera) is also known as the “tree of life” because of its multiple uses of its products to humans. Caraga region has a large extent of coconut industry and Butuan City is one of the producers of coconut products within the region. This study aims to accurately map coconut plantations in Butuan City, Agusan del Norte, Philippines using Sentinel-2 data. The Maximum Likelihood Classification (MLC) was used to classify the image using the combination of 4 spectral bands, Normalized Difference Vegetation Index (NDVI), and Synthetic Aperture Radar Digital Elevation Model (SAR-DEM) that resulted an average overall accuracy of 91.55%. A total of 8,965 ha. coconut trees were detected using MLC and the estimated annual production of Virgin Coconut Oil (VCO) of bearing coconut trees in the city was 3380.03 metric tons. the annual estimated VCO was only based on the total harvested nuts by bearing coconut trees.The application of the MLC technique on Sentinel-2 satellite imagery successfully mapped coconut plantations and trees in Butuan City with high accuracy. This information can be invaluable for the sustainable management and development of the coconut industry in the region, while also contributing to the overall understanding of agricultural resources and economic potential in Butuan City.

1. INTRODUCTION

1.1 Background of the Study

The coconut tree (Cocos nucifera) is also known as the "Tree of Life" because of its multiple uses of its natural products to human needs, especially in the development of medicines and industrial products. People who lived in traditional coconut growing areas used coconut food and non-food products in some way in their daily life, which include coconut water, kernel, oil, meat, leaves, shell, coconut toddy, coir pith, and wood-based products [1].

Coconut trees can grow by 30-50 centimeters in their height annually and can be 20-22 meters tall within their first 40 years of growth, having an 8-9 meters diameter of the canopy [2]. Coconut trees are planted ideally in a square system with a spacing of 7.5 m x 7.5 m with 177 palm trees per hectare, however, several coconut growing areas of the country adopt 7.5 to 10 meters spacing [3]. Coconut can produce its first matured fruit after 5-6 years from planting and continue to produced fruits throughout the year. The amount of coconut fruit produced will vary depending on the weather season at a certain time of the year [2]. The productivity life span of a coconut tree is 50-70 years, depending on the variety of the tree [4]. Coconut fruits are considered to be matured fruits and can be harvested after 11-12 months from pollination. Harvesting matured fruits can be achieved every 2-3 months interval having 1-2 harvestable bunches of each tree that is considered practical and more economical [3][4]. From the 19th century until the mid-twentieth century, when several competing crops entered the market for edible oil, the coconut was the foundation of vegetable oil production for importation by emerging industrial economies [5]. The coconut trees are abundant in countries within the tropical region between 23-degrees north and south of the equator, and it is also a native plant in coastal countries [2][5]. Among more than 93 countries around the world that cultivates coconut trees, the Philippines is one of the top 3 producers of coconut products together with India and Indonesia [3].

Virgin Coconut Oil (VCO) is a high-value coconut product having an excellent potential to increase coconut farm incomes by five to eight-fold compared to conventional copra production because of its rising global demand [6]. The VCO is rich in vitamins, mineral, and antioxidants because it is extracted from a fresh coconut kernel without using any

chemical processes which has earned the title as the "Mother of all Oils" [3]. The pharmacological properties of VCO, including anti-inflammatory, analgesic, antipyretic, antioxidant, anti-stress, and antimicrobial properties, have been investigated in several studies [7]. Recently, a study in the Philippines states that VCO can be an adjunct therapy to the suspected Covid-19 patient to prevent their symptoms become severe [8]. The technology of the current time has been the biggest contributor as a platform for the development of research and projects. Remote Sensing is a process that used a satellite or aircraft that has a sensor to capture images on the Earth's surface from a certain amount of distance above the ground. The imagery produced by the remote sensing process has several applications in mapping a certain project [9]. The field of Remote Sensing, together with the Geographical Information Systems (GIS), is expanding rapidly, and their methods are continuously applied to new fields of application [10].

The European Commission's Copernicus program designed a constellation of Sentinels to produce a plentiful amount of data and imagery of the Earth's surface. This constellation of satellites has the advantage of monitoring the way how to manage the environment and understand the effects of climate change on the planet [11]. The Copernicus Sentinel-2 mission is made up of two similar satellites orbiting in the same orbit. Each satellite is equipped with an advance wide swath high-resolution multispectral imager with 13 spectral bands that provides a new perspective on land and vegetation [12]. The goal of Sentinel-2 is to support in monitoring the variability of land surface conditions and the changes of the Earth's surface [13]. The availability of satellite images through remote sensing technology and the use of GIS methods help in the management and monitoring of the land condition of the Earth's surface. Thus, this study is relevant to the management and monitoring of the coconut farmlands in Butuan City and to boost the economic development of the coconut industry in the city.

1.2 Study Area

The study is Butuan City which is located in the Caraga Region of the Philippines which is a tropical country (Figure 1). It has a total land area of 81,662 hectares and consists of 86 barangays, which is approximately 4.1% of the total land area of the Caraga Region. The city has a total population of 337,063 people according to the 2015 census. The city is the Caraga region's commercial, agricultural, and administrative center and was considered as the strategic trading hub of Northern Mindanao based on the location of its major roads connecting to other main cities. The city is composed of agricultural areas (397.23 km²), forestland (268 km²), grass/shrub/pasture land (61.14 km²), and other uses (90.242 km²) [14]. Philippine Coconut Authority in the Caraga Region indicates that the region has a total land area of 272,093 hectares fully planted with coconut trees covering 1,311 barangays, where some of the barangays are in Butuan City [15].

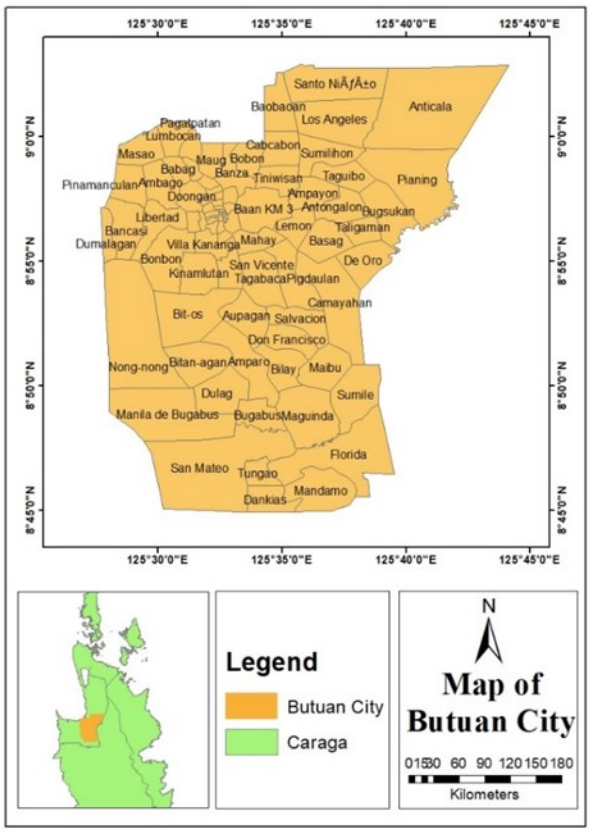


Figure 1. Map of Butuan City

2. MATERIALS AND METHODS

The methodological flowchart of the study as shown in Figure 2 consists of five (5) major activities namely, Data Collection, Image Preparation of Sentinel-2B, Collection of Regions of Interest (ROIs) for Training and Validation Accuracy, Image Classification and Accuracy Assessment using Maximum Likelihood Classification (MLC), and VCO Estimation using PCA-Region 13 Data. The following methods including their specific activities are discussed in the sub-sections.

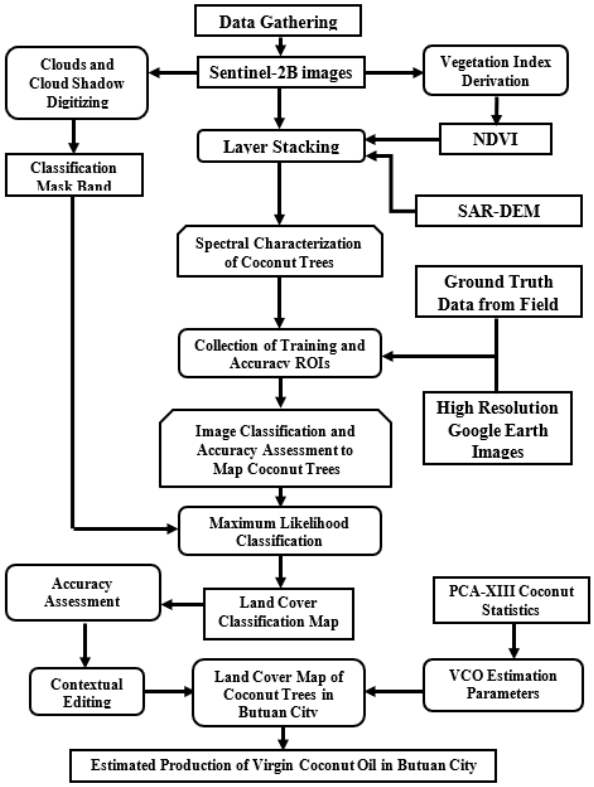


Figure 2. Methodology flowchart

2.1 Data Collection

The Sentinel-2B level 2A images were downloaded from European Space Agency's Copernicus Programme. An additional of two supplemental images were downloaded to fill out the masked area of clouds and cloud shadows that were present in the base image.

Collection of ground truth data is essential to classify the coconut trees and other land cover classifications found in Butuan City. The collection of ground truth data on certain features on the ground allow remote sensing data to be calibrated as well as aid in the interpretation and analysis of what is being sensed [16]. The high-resolution Google Earth images was used to validate the location of coconut trees and other land cover classes in the Sentinel 2B image in creating Region of Interests (ROIs) for training and accuracy samples. A total of fifty sample points of coconut trees were collected from the field survey using hand-held GPS instrument. The data collected was used as validation points for accuracy assessment.

2.2. Sentinel-2B Pre-processing

In the Sentinel-2B images, clouds and cloud shadows were observed. The significant presence of clouds and shadows in the images, which obscure the land surface, contains missing information for classifying land covers [17]. The clouds and cloud shadows in the images were manually removed by digitizing them in a true-color (RGB combination) appearance.

The digitized image of clouds and shadows and the Butuan City boundary shapefile was used to generate the project area classification mask band. These shapefiles have undergone Band Math (B1*B2) to generate a classification mask band [18]. Two classification mask bands between the upper and lower part of Butuan City image were generated.

To increase the number of bands and to boost the classification of the images, two sets of data namely, Normalized Difference Vegetation Index (NDVI) and Synthetic Aperture Radar – Digital Elevation Model (SAR-DEM) of Butuan

City in GeoTIFF format were added to layer stacked with the 10-m resolution multispectral bands of Sentinel-2B images. The NDVI was derived from Red and Near Infrared band of the image while SAR-DEM was requested from the Caraga Center for Geo-Informatics. Furthermore, the land cover classes present in Butuan City were visually interpreted from the pre-processed images [19, 20]. Shown in Table 1 are the land cover types being considered in the Sentinel-2B image.

Table 1. Land cover classes considered

CLASSES	**DESCRIPTION**
1. Barren	Exposed mountain areas, barren lands, or croplands without any vegetation and unpaved roads
2. Built-ups	Residential, commercial, roads, industrial buildings/areas, and other man-made features
3. Coconuts	Tracts of lands covered by Coconut Trees
4. Forest	Densely vegetated areas, especially of the vegetation type filled with trees and other kinds of vegetation found in forested areas.
5. Grassland	Areas dominated by croplands, grasses, and other less dense vegetation.
6. Shrubs	Includes tress that can be seen in built-up areas, along the roads, and tress mixed with shrubs. Also, sparse vegetation.
7. Water	Lakes, reservoirs, rivers, streams, and other bodies of water.

2.3 Collection of Regions of Interest (ROIs)

After identifying the various land cover types, the area of each land cover class in the layer stacked Sentinel-2B image was manually determined using ENVI 5.1 software. The acquisition of training samples was done using polygon ROI-type. Google Earth application was used to assess image classification [20]. Regions of interest with a minimum of 50 pixels per land cover class were used as training samples. Tables 2 and 3 show the number of pixels per land cover class.

Table 2. Number of pixels collected per land cover class (Upper Image/ North Portion of Butuan City)

Land Cover Class	Number of Pixels
1.)Barren	816
2.) Built-ups	468
3.) Coconut	92
4.) Forest	239
5.) Grassland	69
6.) Shrubs	55
7.) Water	915

Table 3. Number of pixels collected per land cover class (Lower Image/ South Portion of Butuan City)

Land Cover Class	Number of Pixels
1.)Barren	2511
2.) Built-ups	1944
3.) Coconut	378
4.) Forest	1907
5.) Grassland	431
6.) Shrubs	426
7.) Water	2864

Accuracy samples were collected using a point ROI-type in ENVI 5.1. A manual sampling procedure was used to acquire accuracy ROI which deals with spectral, spatial, and textural signatures for each land cover class. A minimum of 50 pixels per land cover class was utilized for accuracy assessment with the help of high-resolution Google Earth images [18]. Tables 4 and 5 show the number of pixels per land cover class in both the upper and lower part of Butuan City.

Table 4. Number of pixels collected for accuracy ROIs (Upper Image/ North Portion of Butuan City)

Land Cover Class	Number of Pixels
1. Barren	84
2. Built-ups	77
3. Coconuts	65
4. Forest	101
5. Grassland	58
6. Shrubs	53
7. Water	93

Table 5. Number of pixels collected for accuracy ROIs (Lower Image/ South Portion of Butuan City)

Land Cover Class	Number of Pixels
1. Barren	140
2. Built-ups	124
3. Coconuts	122
4. Forest	121
5. Grassland	122
6. Shrubs	124
7. Water	120

2.4 Image Classification and Accuracy Assessment

The layer stacked Sentinel-2B image containing 4 multispectral bands, NDVI, and SAR-DEM was used for image classification using Maximum Likelihood Classifier (MLC). The MLC is a statistically based parametric classifier, which assumes that the spectral signatures of land cover classes are normally distributed. To classify an unknown pixel, this classifier calculates the variance and covariance of the class spectral signatures [21, 20]. The one file layer stacked image together with the collected training ROIs in the previous activity was used as input in the classification. Before classifying the land cover class of the image, the classification masked band masked out the clouds and cloud shadows present in the image [18]. The generated classified image was then subject to accuracy assessment using the collected accuracy ROIs to check the accuracy of the land cover classification. A class confusion matrix containing the Overall Accuracy (OA), Producer's Accuracy (PA), User's Accuracy (UA), and Kappa Coefficient was used as basis to determine the accuracy of the generated land cover class [18, 20].

The classified base images and their supplement images were loaded to ArcMap 10.4 to be refined and optimized through contextual editing. The misclassified pixels were corrected according to the land cover class they belong to improve accuracy and to have a better resource map to be used for estimating the production of virgin coconut oil [18, 19].

2.5 Estimation of VCO Production

The refined land cover class image of Sentinel-2B shows the distribution and location of the detected coconut trees in Butuan City. The classified image provides several important information including the total area that was covered by each land cover class. The total area covered by coconut trees was used to estimate the total coconut trees in Butuan City with the supporting information from Philippine Coconut Authority (PCA) Region 13. Tables 6 and 7 and figures 3 and 4 provide certain information for estimating the VCO production.

Table 6. The ratio of coconut trees per hectare in Butuan City

Number of Coconut Trees per hectare in Butuan City	
Total Coconut Trees	Area (Ha)
100	1

Table 7. Number of Coconuts per volume of VCO

Equivalent Number of Nuts per VCO (L)	
VCO (L)	Nuts (No.)
1	10

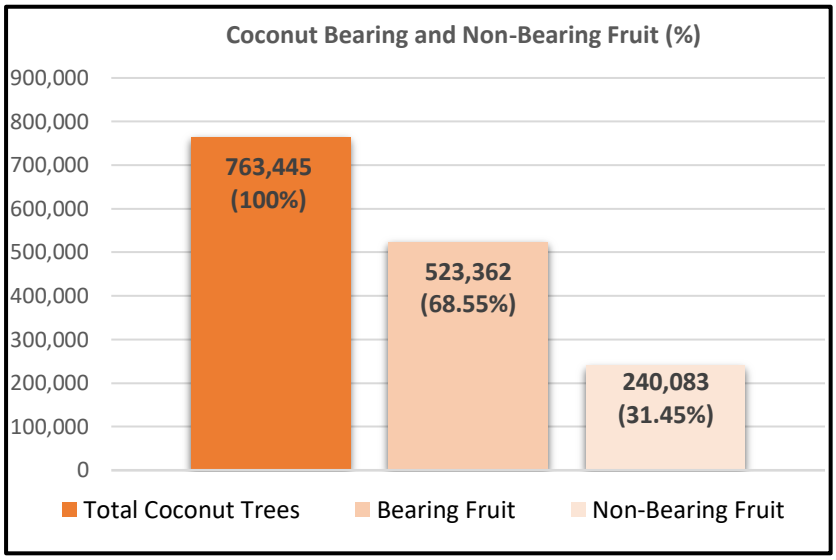


Figure 3. Coconut Bearing and Non-Bearing Fruit in Butuan City

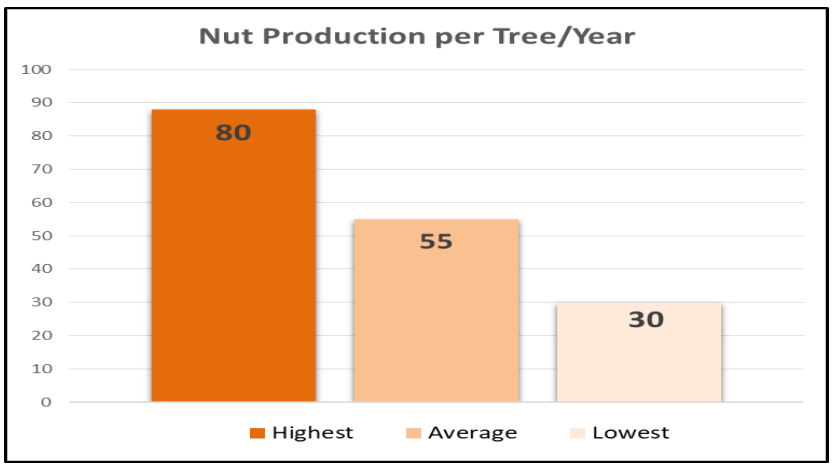


Figure 4. Coconut production per tree per year in Butuan City (2019)

The total area of coconut trees was determined based on the total area of the classified coconut trees in the land cover map. The total area of coconut trees was multiplied by the ratio of coconut trees per hectare to calculate the total number of coconut trees. The percentage of coconut-bearing and non-bearing fruit was used to get the approximate number of the fruit-bearing coconuts. Nut production was based on the annual average of coconut fruit per tree and was then multiplied by the number of fruit-bearing coconuts to get the total nut production. The total nut production was then multiplied to the ratio of the number of nuts per liter of VCO on calculating the volume of production of Virgin Coconut Oil in Butuan City.

Number of Bearing CT = X * Area of CT * Number of CT per hectare — Equation 1

Nut harvested = Number of CT * average harvested CF per tree annually — Equation 2

Estimated VCO (MT) = Total CF * VCO extracted (L) per Nut — Equation 3

Where,
CT = Coconut Tree,
CF = Coconut Fruit,
VCO = Virgin Coconut Oil,
X = Percentage of Bearing Fruit

3. RESULTS AND DISCUSSION

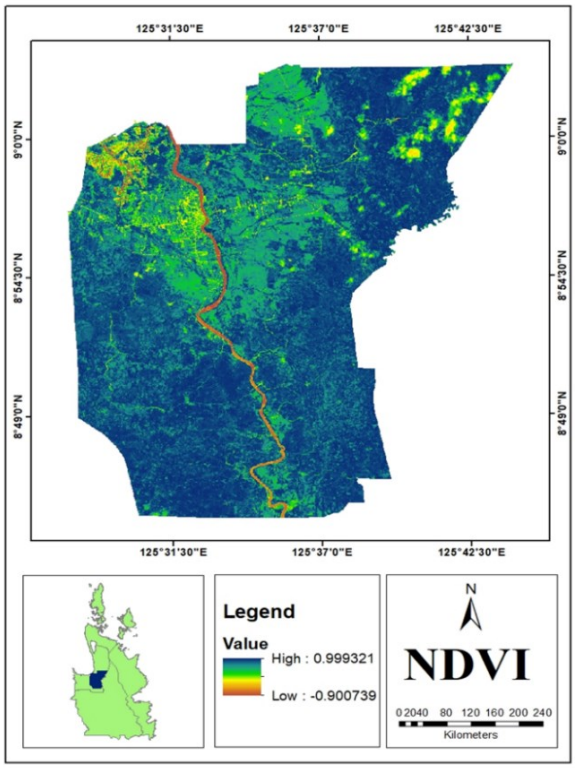


Figure 5. NDVI Map of Butuan City

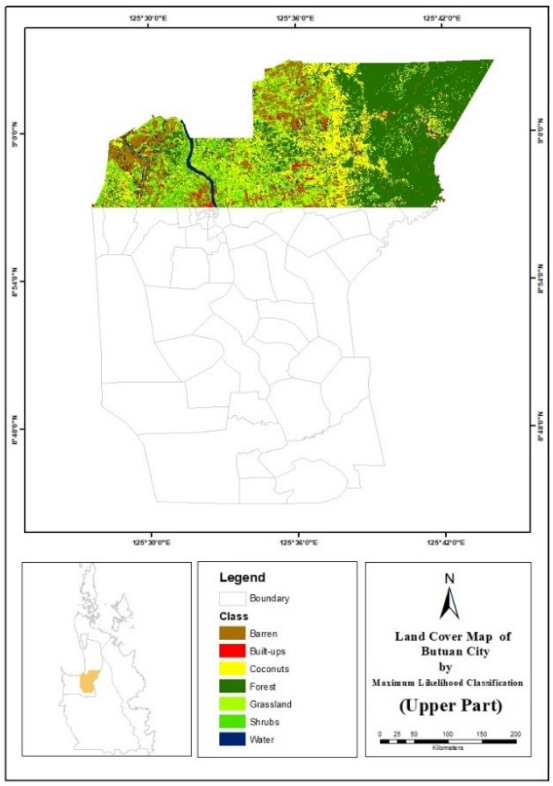


Figure 6. Land Cover Map of the Northern Part of Butuan City

3.1 Normalized Difference Vegetation Index (NDVI)

Figure 5 shows the NDVI of Butuan City. The value ranges from – 0.900739 to 0.999321 indicated from Red to Blue. The highest values are found in dense vegetation, while the lowest values represent water bodies.

3.2 Land Cover Classification and Accuracy Assessment Result

Figure 6 shows the land cover map of the upper image portion of Butuan City together with the distribution of coconut trees. The image map shows the distribution of coconut plantations/trees within the northern part of Butuan City. Table 8 shows the accuracy assessment, which has an OA of 92.84% while its PA and UA are 86.15% and 87.50%, respectively. Figure 7 shows the land cover map of the lower image portion of Butuan City together with the distribution of coconut trees. The image map shows the distribution of coconut plantations/trees within the southern part of Butuan City. Table 9 shows the accuracy assessment, which has an OA of 90.26% while its PA and UA are 85.25% and 91.23%, respectively. The overall accuracy of the land cover map passed the standard overall accuracy of 85% which is considered as a method for classifying coconut trees/ plantations.

Table 8. Accuracy Assessment Result (Upper Image)

LAND COVER TYPES	ACCURACY/GROUND TRUTH ASSESSMENT PIXELS									
	Barren	Built-ups	Coconuts	Forest	Grassland	Shrub	Water	Total	CE (%)	UA (%)
Barren	84	0	0	0	1	0	5	90	6.67	93.33
Built-ups	0	77	0	0	0	0	0	77	0.00	100
Coconuts	0	0	56	1	2	5	0	64	12.50	87.50
Forest	0	0	5	100	0	0	0	105	4.76	95.24
Grassland	0	0	3	0	52	12	0	67	22.39	77.61
Shrubs	0	0	1	0	3	36	0	40	10.00	90.00
Water	0	0	0	0	0	0	88	88	0.00	100
Total	84	77	65	101	58	53	93			
OE (%)	0.00	0.00	13.85	0.99	10.34	32.08	5.38			
PA (%)	100	100	86.15	99.01	89.66	67.92	94.62			
Overall Accuracy = (493/531) = 92.84%										

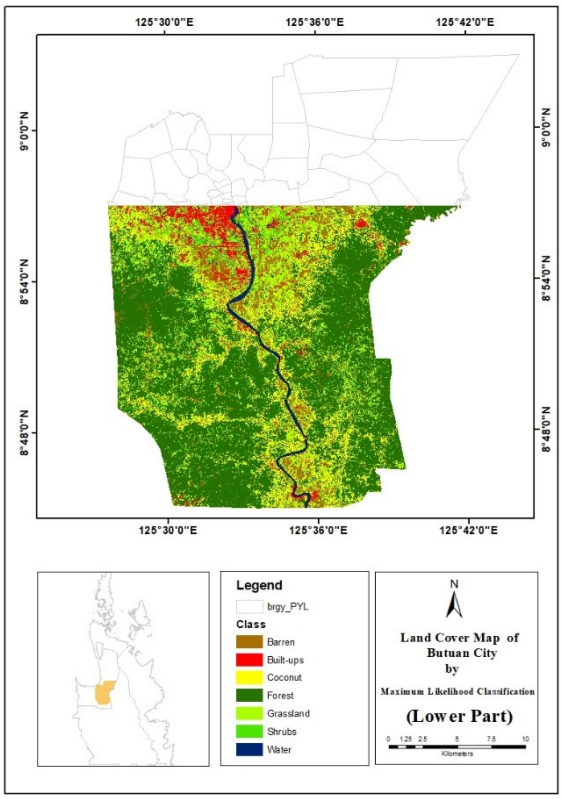


Figure 7. Land Cover Map of the Southern Part of Butuan City

Table 9. Accuracy Assessment Result (Lower Image)

LAND COVER TYPES	ACCURACY/GROUND TRUTH ASSESSMENT PIXELS									
	Barren	Built-ups	Coconuts	Forest	Grassland	Shrub	Water	Total	CE (%)	UA (%)
Barren	136	14	2	0	0	0	3	155	12.26	87.74
Built-ups	4	110	0	0	0	0	5	119	7.56	92.44
Coconuts	0	0	104	1	6	1	2	114	8.77	91.23
Forest	0	0	10	120	0	0	1	131	8.40	91.60
Grassland	0	0	5	0	112	24	0	141	20.57	79.43
Shrubs	0	0	1	0	4	97	0	102	4.90	95.10
Water	0	0	0	0	0	2	109	111	1.80	98.20
Total	140	124	122	121	122	124	120			
OE (%)	2.86	11.29	14.75	0.83	8.20	21.77	9.17			
PA (%)	97.14	88.71	85.25	99.17	91.80	78.23	90.83			
Overall Accuracy = (788/873) = 90.26%										

Figure 8 shows the land cover map of the entire Butuan City using MLC. The map shows the distribution of the different land classes considered in Butuan City. The UA, PA, and OA for the whole portion of Butuan City are 89.37%, 85.7%, and 91.55%, respectively.

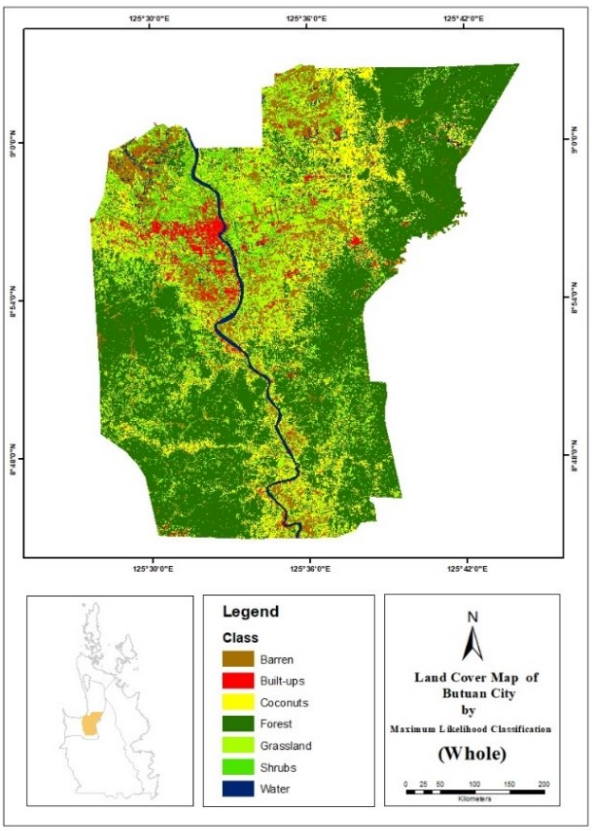


Figure 8. Land Cover Map of the Entire Butuan City

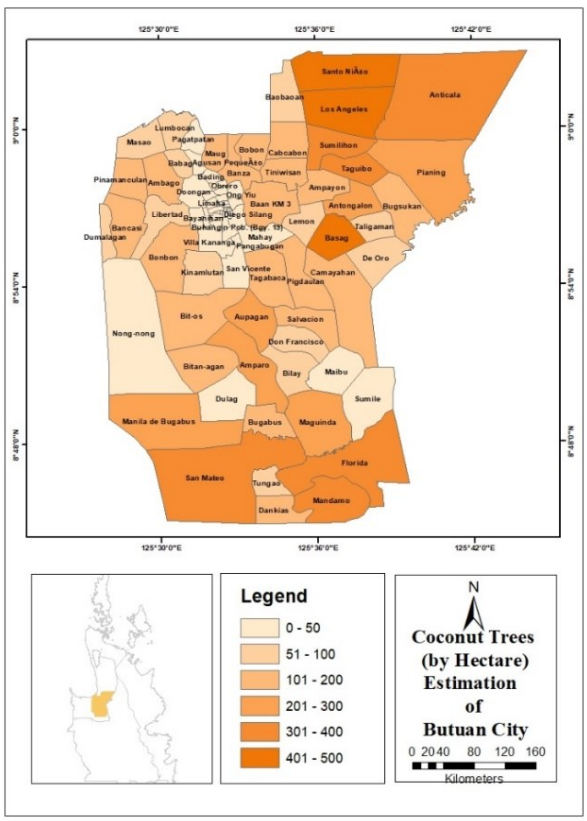
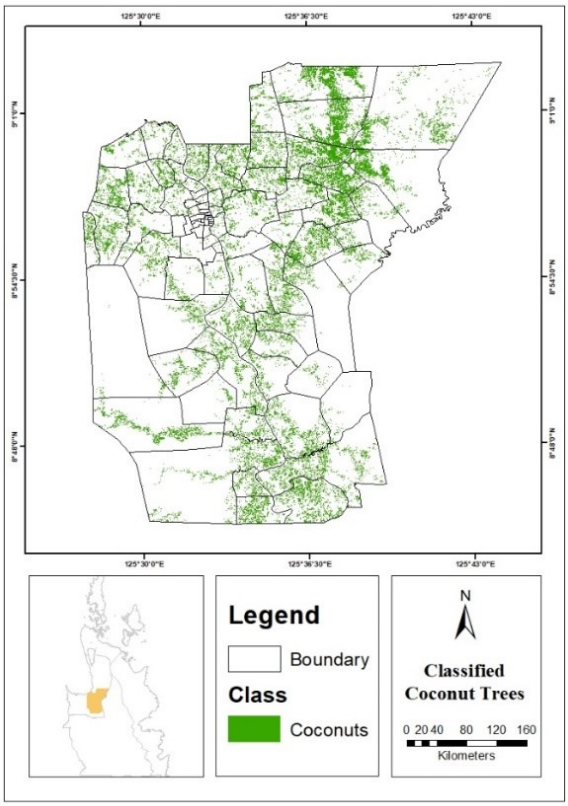


Figure 9. Estimation of Coconut Trees (in ha) in Butuan City (2021)



3.3 Assessment of the Coconut Areas Based on the Classified Land Cover Map of Butuan City

In figure 9, the map shows a specified range of area of coconut trees per barangay in Butuan City. It indicates that Barangay Basag (431 ha), Los Angeles (482 ha), and Santo Nino (423 ha) have the largest area of coconut trees while the Barangays situated near or within the city proper have the lowest area of coconut trees. Also, the total area of coconut trees in Butuan City is 8,965 ha. Figure 10 shows the distribution of the classified coconut trees in Butuan City. Most of the coconut plantations/ trees are located in the upper center part and lower center part of the city.

3.4 Estimation of VCO Production in Butuan City

The total area of coconut trees in Butuan City is 8,965 ha. Using the data from Table 6 and Figure 3, the total number of bearing coconut trees was 614,551. Using the data from Figure 4, the total nut harvested was 33,800,305 nuts. Using the data from Table 7, the estimated annual volume of VCO products is 338,030.5 L. The calculated volume of VCO was only based on the total nuts produced by the coconut trees in Butuan City and did not consider any other potential coconut products from the calculated total number of harvested nuts.

Number of Bearing CT = (68.55%) * 8962 ha * 100 tree/ ha
Number of Bearing CT = 614,551 trees
Nut Harvested = 614,551 trees * 55 nuts/tree
Nut Harvested = 33,800,305 nuts
Estimated Annual VCO (MT) = 33,800,305 nuts * (1L/10 nuts)
Estimated Annual VCO (MT) = 338,030.5 L

4. CONCLUSIONS AND RECOMMENDATIONS

The main objective of this study was to map coconut plantations/ trees in Butuan City, Agusan del Norte, Philippines using the satellite images of Sentinel-2 and to estimate the potential production of VCO based on the land cover map of Butuan City and the supporting coconut statistic data from Philippine Coconut Authority Region 13, Philippines. The study utilized MLC to detect spectral signatures of each considered land cover class. The results of coconut classification in the lower and upper image portion of Butuan City have modest accuracies in both User's and Producer's Accuracy while both of their Overall Accuracy reach above 90% which had passed the accuracy standard of 85% that makes it considerable in mapping coconut trees in Butuan City. The largest barangay, which has the largest area of coconut trees are Basag, Los Angeles, and Santo Nino, while those barangays near or situated in the city proper have the lowest coconut areas. The estimated annual production of VCO products was 338,030.5 L.

Based on the results, Sentinel-2 images can be used for mapping and monitoring coconut trees and the estimation of VCO production in Butuan City through RS and GIS techniques. However, the separability ROI must be improved to lessen the misclassification of the land cover map. Lastly, in estimating the VCO product, other potential coconut products from harvested coconuts and the minimum area of coconut plantations must be considered to have a better estimation of VCO production.

5. REFERENCES

[1] M. DebMandal and S. Mandal, "Coconut (Cocos nucifera L.: Arecaceae): In health promotion and disease prevention," *Asian Pac. J. Trop. Med.*, vol. 4, no. 3, pp. 241–247, 2011, doi: 10.1016/S1995-7645(11)60078-3.

[2] V. Hocher, J. L. Verdeil, and B. Malaurie, "Cocos nucifera coconut.," *Biotechnol. fruit nut Crop.*, no. April, pp. 90–112, 2009, doi: 10.1079/9780851996622.0090.

[3] "Model Profile for 1 . 0 ha Coconut Cultivation."
[4] S. S. Magat, "Understanding right , the productivity (yield) of coconut from the Philippines ' Research and Field Experience : A knowledge tool for industry development and management (A research notes)," p. 9, 2015.
[5] S. Adkins, M. Foale, and H. Harries, "Growth and production of coconut Perspectives in Coconut Production Glossary Bibliography Biographical Sketches," *Encycl. Life Support Syst.*, 2010.
[6] D. D. Bawalan and K. R. Chapman, "Virgin Coconut oil production manual for micro- and village-scale processing," *FAC Reg. Off. Asia Pacific Bangkok*, pp. 0–80, 2006.
[7] G. G. Dumancas *et al.*, *Health benefits of virgin coconut oil*, no. March. 2016.
[8] "Coconut and COVID-19: Philippines DOST-led study reveals virgin coconut oil reduce symptoms in suspected patients." [Online]. Available: https://www.nutraingredients-asia.com/Article/2021/01/27/Coconut-and-COVID-19-Philippines-DOST-led-study-reveals-virgin-coconut-oil-reduce-symptoms-in-suspected-patients. [Accessed: 18-Apr-2021].
[9] E. Dyring, "Principles of Remote Sensing.," *Ambio*, vol. 11, no. 3, pp. 57–69, 1973, doi: 10.1111/j.1745-7939.1987.tb01104.x.
[10] U. Mårtensson, "Introduction to Remote Sensing and Geographical Information Systems," *Dep. Phys. Geogr. Ecosyst. Sci.*, p. 55, 2011.
[11] "ESA - Introducing Sentinel-2." [Online]. Available: http://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-2/Introducing_Sentinel-2. [Accessed: 18-Apr-2021].
[12] "ESA - Sentinel-2." [Online]. Available: http://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-2. [Accessed: 18-Apr-2021].
[13] "Sentinel-2 - Missions - Sentinel Online - Sentinel." [Online]. Available: https://sentinel.esa.int/web/sentinel/missions/sentinel-2. [Accessed: 18-Apr-2021].
[14] "About Butuan | Butuan." [Online]. Available: https://www.butuan.gov.ph/cgbgov/page/about-butuan. [Accessed: 17-Apr-2021].
[15] "PCA seeks increased domestic use of coco products in Caraga | Philippine News Agency." [Online]. Available: https://www.pna.gov.ph/articles/1113340. [Accessed: 17-Apr-2021].
[16] "Ground truth - GIS Wiki | The GIS Encyclopedia." [Online]. Available: http://wiki.gis.com/wiki/index.php/Ground_truth. [Accessed: 17-Jun-2021].
[17] X. Zhu and E. H. Helmer, "An automatic method for screening clouds and cloud shadows in optical satellite image time series in cloudy regions," *Remote Sens. Environ.*, vol. 214, pp. 135–153, Sep. 2018, doi: 10.1016/j.rse.2018.05.024.
[18] M. M. Bermoy and J. C. Casinginan, "Exercise No . 2 : Land Use Land Cover Classification using Landsat 8 OLI Image," no. 2.
[19] T. M. Framework and L. C. Mapping, "Figure 1 The Methodological Framework of the Land Cover Mapping using Sentinel 2 images.," no. 2, pp. 1–23.
[20] J. R. Santillan, M. M. Santillan, and R. Francisco, "USING REMOTE SENSING TO MAP THE DISTRIBUTION OF SAGO PALMS IN NORTHEASTERN MINDANAO , PHILIPPINES : RESULTS BASED ON LANDSAT ETM + IMAGE ANALYSIS (a .) (b .)." In Proceedings of the 33rd Asian Conference on Remote Sensing, ACRS 2012 – Aiming Smart Space Sensing, November 26-30, 2012, Ambassador City Jomtien Hotel, Pattaya, Thailand.
[21] S. Liang, J. Cheng, and J. Zhang, "Maximum likelihood classification of soil remote sensing image based on deep learning," *Earth Sci. Res. J.*, vol. 24, no. 3, pp. 348–356, Sep. 2020, doi: 10.15446/esrj.v24n3.89750.