TEN-YEAR COMPARATIVE ANALYSIS OF INFRASTRUCTURE GROWTH OF STATE UNIVERSITIES AND COLLEGES IN CARAGA REGION, PHILIPPINES USING REMOTE SENSING AND GIS

Michelle V. Japitana[1,2*], Alger B. Etorma[2*], and Lavin Orcullo[2]
[1]Caraga Center for Geoinformatics, Caraga State University, Butuan City, 8600, Philippines,
Email: mvjapitana@carsu.edu.ph
[2]Department of Geodetic Engineering, Caraga State University, Butuan City, 8600, Philippines,
Email: alger.etorma@carsu.edu.ph, lavinmurillo@carsu.edu.ph

KEY WORDS: higher education infrastructure, academic facilities, physical assets

ABSTRACT: The state universities and colleges (SUCs) infrastructure growth signify improving its core functions like academic, research, extension, administration, and allied services. This study aims to analyze the infrastructure growth of SUCs in Caraga within ten (10) years by calculating the area, the number of buildings, and the length of roads using Remote Sensing (RS) and Geographic Information System (GIS). This study employed remote sensing techniques to assess the spatial and temporal changes of land cover (LC) in the study area and applied GIS calculations to estimate the infrastructure growth rate (IGR). This study showed that the university with the lowest IGR in building area is Surigao State College of Technology (SSCT), with an IGR value of 15.76%. In contrast, Agusan del Sur College of Agriculture and Technology (ASSCAT) has the highest IGR value of 71.78% for building area among the four (4) SUCs in Caraga. According to the number of buildings, Caraga State University (CSU) has the lowest IGR with an IGR value of 8.42%. In comparison, the Surigao del Sur State University garnered the highest IGR of 54.29%. In terms of road length, SSCT has the lowest IGR value of 58.09%, while ASSCAT yielded a superior IGR value of 200.13%. Further, based on the LC change detection within the study sites, CSU has the lowest change in vegetation with 15.93%, in contrast to the SSCT's 69.02% vegetation change rate. Based on these results, baseline comparison data was established to understand the infrastructure growth rates of SUCs in the region. It can provide insights to assess if social development is adequate and responsive to the region's needs. Particularly, the approach demonstrated in this study is highly beneficial for policymakers as they need to monitor regional and national scale infrastructure development in the education sector.

1. INTRODUCTION

The higher education institutions compete in terms of physical and intellectual assets to attract students globally (Aithal & Aithal, 2019). For determining the development of any academic institution, infrastructure is one of the factors to consider (Ershova & Posokhov, 2016). Nkosi et al., (2020) cited the emphasis of Ochuba (2001) works on the need to provide satisfactory and excellent structures and safety facilities that can motivate learning among students. As pointed out by Education 4.0 has become the trend in the education sector in response to the Fourth Industrial Revolution, in which among the crucial considerations for emerging countries like the Philippines, is the great demand for enhanced infrastructures and facilities. According to Pangandaman et al., (2019), the edge in educational facility empower learners, facilitators, and the system of education and that an Education 4.0 facility is that which allows the use of advance technologies including robotics, Internet of Things, digitalization, automatization, and teleconferencing etc. to be able to produce workers who can be competent to work in the modern world. On top of these still-to-be-harnessed requirements for Education 4.0, the COVID-19 Pandemic caused a significant decrease in budget appropriations on capital outlay for State Universities and Colleges (SUCs) based on the National Expenditure Program 2022 of the Philippines (Mordeno, 2021). Thus, it is essential to know how State Universities and Colleges (SUCs) were given priorities and budget allocation for infrastructure expansion and facility improvements for the past years to gain insights on the impacts of the budget cuts it is experiencing at present.

Building footprints is an essential parameter for different applications such as urban planning, environmental planning, and disaster management (Pandey et al., 2021), and its delineation from remote sensing imagery, according to Wei & Ji, (2021), is a primary task in mapping and geographic information system (GIS). The SUCs infrastructures consist of classrooms, administration buildings, campus gymnasiums, faculty and staff offices, canteens, roads, bridges, etc. Analyzing infrastructure growth should be done in various ways, including calculating the area and number of buildings and determining the length of roads through advanced software toolsets (Rahman et al., 2011). Remote Sensing could acquire multi-sensor and multi-temporal satellite images and archived them in Google Earth. These images could be used as input in RS or GIS software to perform image pre-processing, image classification, accuracy assessment, change detection analysis, and to create land cover maps (Gamshadzaei & Rahimzadegan, 2017; Japitana et al., 2019; Magusara & Japitana, 2015; Marvin et al., 2016). Land cover characterization and monitoring are crucial steps that permit detection of land change at the scale of most human activity (Giri et al., 2013). With the application of Remote Sensing (RS) and Geographic Information System (GIS), spatial and temporal changes of land cover within SUCs campus areas to initially assess infrastructure development and further employ straightforward digitization of Google Earth images to determine building and infrastructure footprints and then compute Infrastructure Growth Rate (IGR) using the formula adopted from De Almeida et al., (2005). Hence, this paper attempts to employ remote sensing and GIS technologies to estimate the infrastructure growth rates of academic institutions to provide baseline data and insights on the budget share for the education sector in the Build, Build, Build Program of the government.

2. METHODOLOGY

2.1 The Study Area

The study covers the main campuses of the SUCs within Caraga Region namely, Agusan del Sur State College of Agriculture and Technology (ASSCAT) of Bunawan, Agusan del Sur, Caraga State University (CSU) of Butuan City, Surigao del Sur State University (SDSSU) of Tandag, Surigao del Sur, and Surigao State College of Technology (SSCT) of Surigao City. Figure 1 shows the location of SUCs in Caraga Region, Philippines.

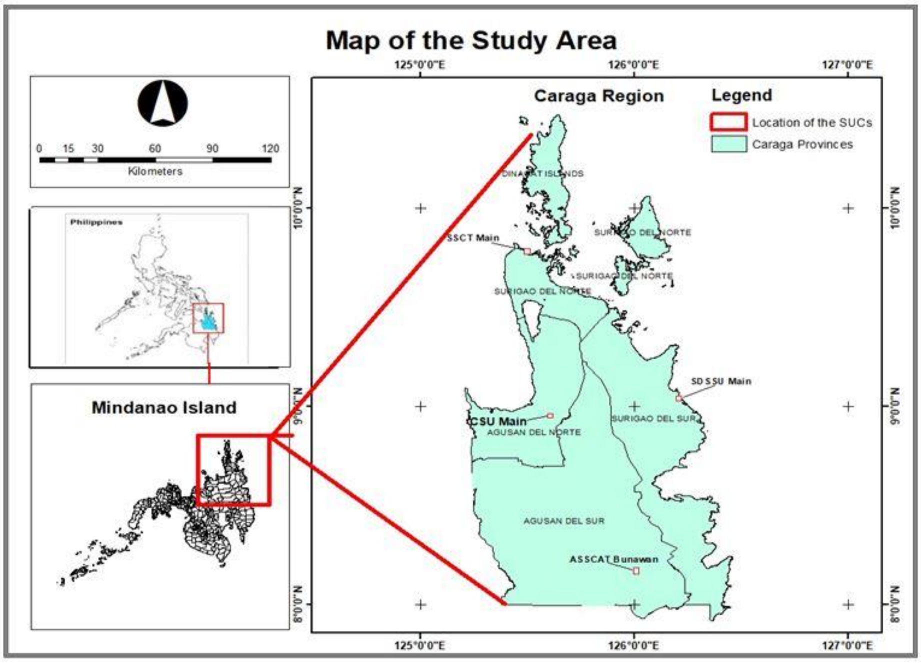

Figure 1. The Location of the SUCs within the Study Area.

2.2 Materials and Method

This study utilized Google Earth images to extract infrastructure features and building footprints. All SUCs considered in this study are covered in one scene of Landsat image; hence, only two (2) Landsat images acquired in 2010 and 2020 were downloaded and were used as input images to generate land cover maps for each SUC. Figure 2 shows the general flow of procedures undertaken in this study.

The infrastructure footprints in each SUC were delineated by digitizing the features from the Google Earth images. Digitized features (buildings and roads) were then loaded in QGIS to calculate areas and lengths. On the other hand, the Landsat images were enhanced prior to land cover classification using Maximum Likelihood Classifier in ENVI 4.3 software. In the same image processing software, accuracy assessments and change detection analysis were employed. The accuracy of the classified images has been assessed based on the training ROI input to the Confusion Matrix tool (M. Sreelekha, 2019). The vegetation cover change detection is done using ENVI 4.3 software using the change detection statistics tool by comparing the classified pixel of the initial state to the final state (Magusara & Japitana, 2015; Shalaby & Tateishi, 2007).

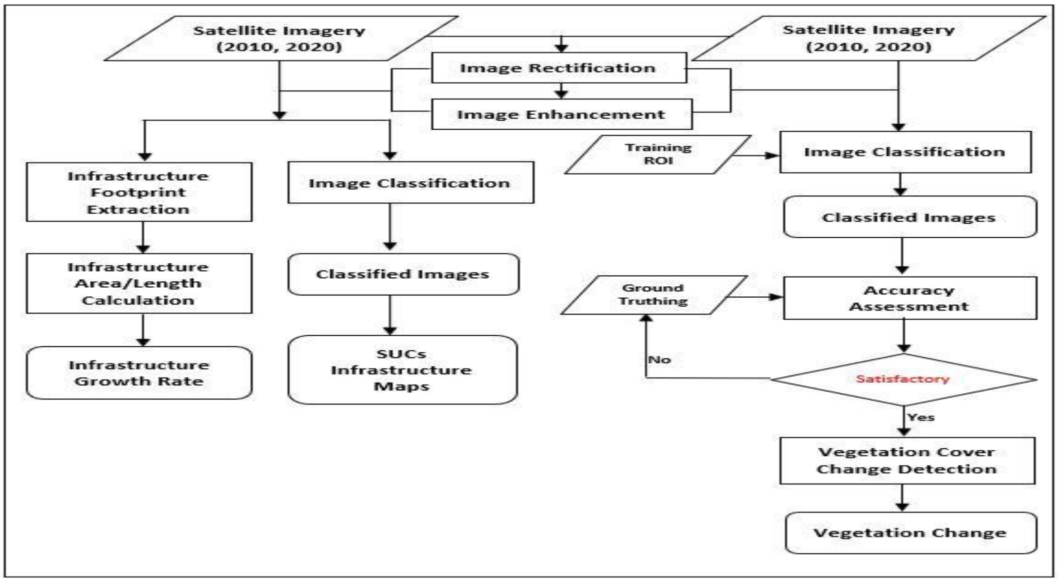

Figure 2. Methodological Flowchart

2.3 Infrastructure Growth Rate (IGR) Computation

The statistical model of IGR specifies the difference of infrastructure growth in a different period given by the formula from De Almeida et al., (2005):

$$IGR = \frac{Measurement_{2020} - Measurement_{2010}}{Measurement_{2010}} \; x\; 100\% \qquad \text{Equation 1}$$

3. RESULTS AND DISCUSSION

3.1 Vegetation Cover Classification and Change Detection Results

3.1.1 Vegetation Cover Classification

The 2010 and 2020 vegetation cover maps for the study sites have been generated using ENVI 4.3 software, and the results are shown in Figure 3 to Figure 6. Through the confusion matrix tool of the software, the generated vegetation cover of CSU Main Campus obtained an overall accuracy of 99.21% and 98.50% for 2010 and 2020 classified images, respectively. The vegetation cover maps for ASSCAT Bunawan Campus yielded accuracies of 99.99% and 99.81%, respectively. While SDSSU Main Campus garnered overall accuracies of 99.82% and 99.94%; and SSCT Main Campus with 99.21% and 99.81%, respectively.

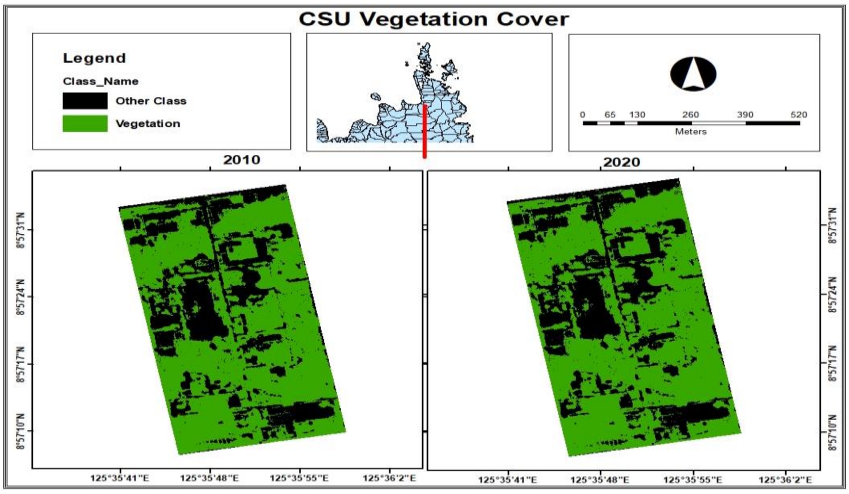

Figure 3. CSU Vegetation Cover

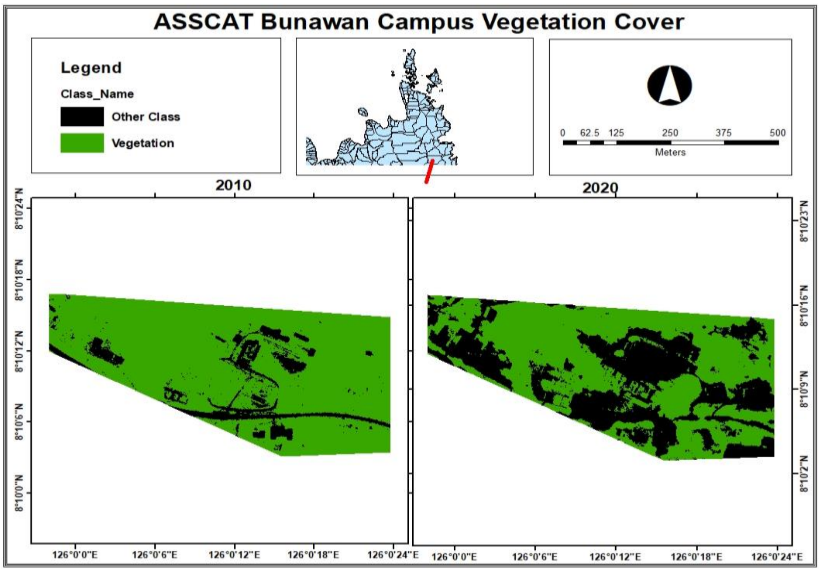

Figure 4. ASSCAT Vegetation Cover

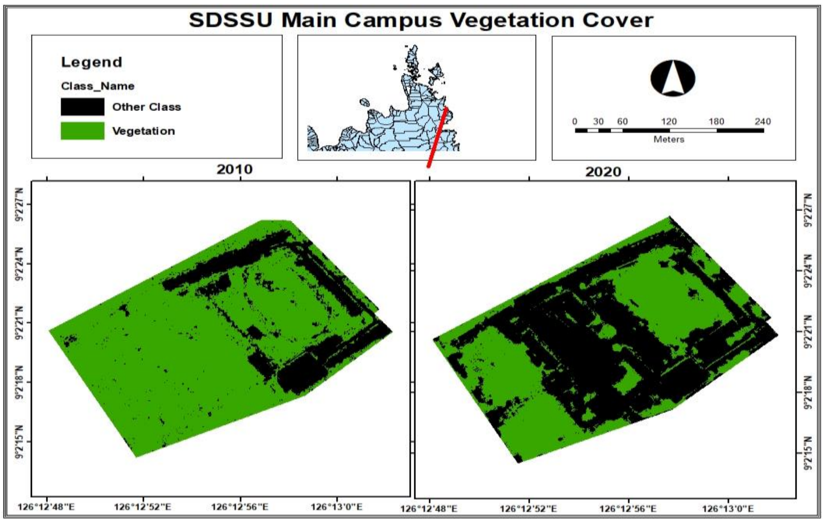

Figure 5. SDSSU Vegetation Cover

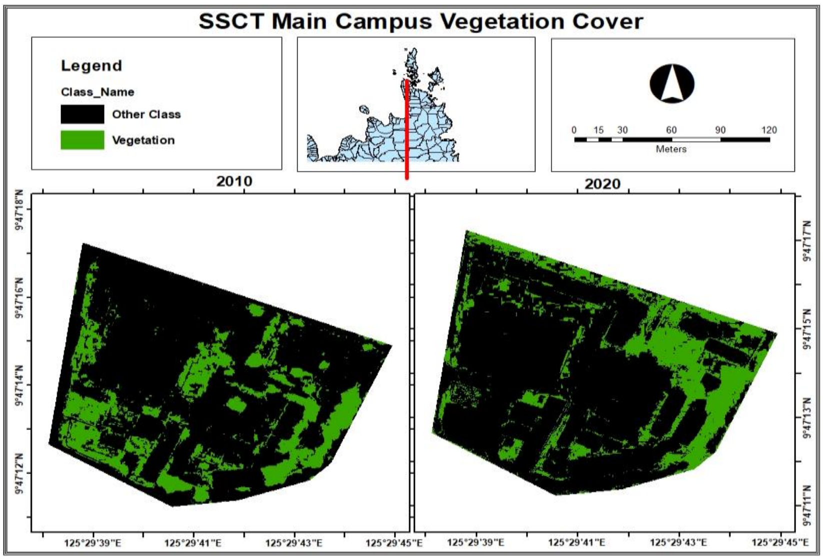

Figure 6. SSCT Vegetation Cover

3.1.2 Change Detection Analysis

Table 1. The vegetation change detection results of the main campuses of Caraga Region SUCs.

CHANGE CLASSIFICATION	ASSCAT (%)	CSU (%)	SDSSU (%)	SSCT (%)
Changed Vegetation	31.88	15.93	52.94	69.02
Unchanged Vegetation	68.12	84.07	47.06	30.98

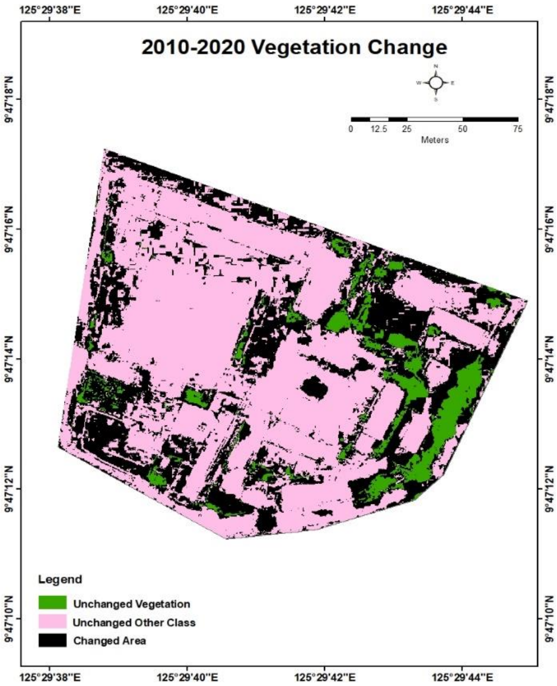

Figure 7. SSCT Main Campus

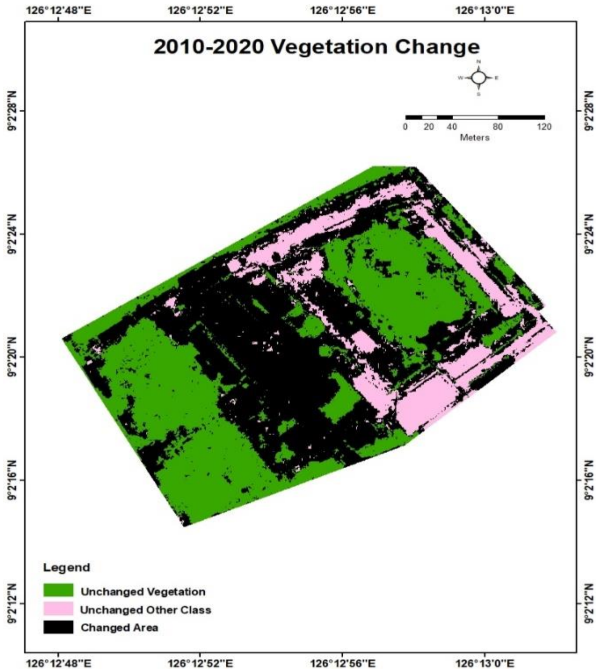

Figure 8. SDSSU Main Campus

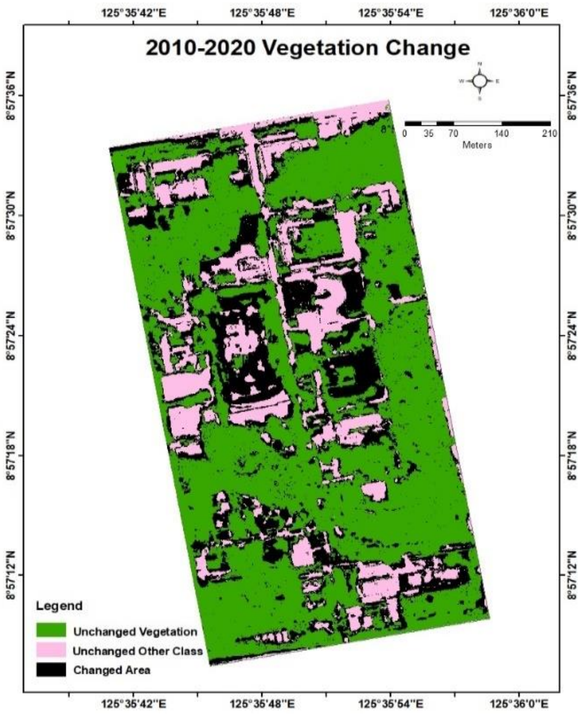

Figure 9. CSU Main Campus

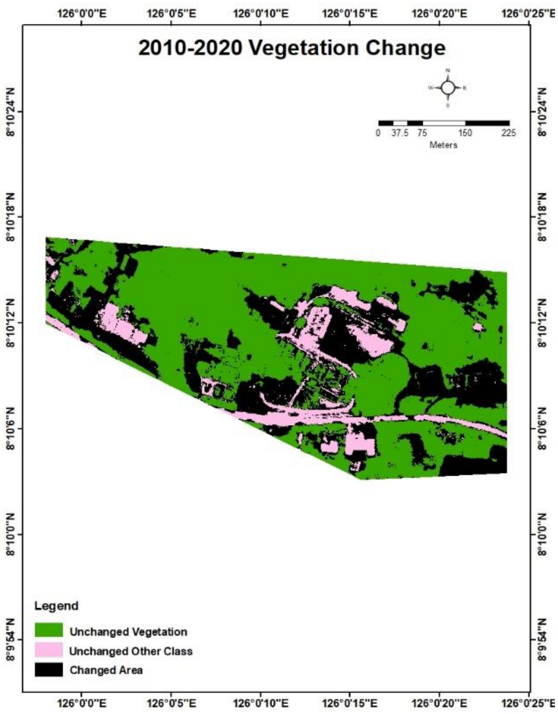

Figure 10. ASSCAT Main Campus

Figure 7 to Figure 10 shows the vegetation cover changes of SUCs from the year 2010-2020, while Table 1 summarizes the percent distribution of changed and unchanged vegetation cover in the universities. The SSCT Main Campus has the greatest change in vegetation with 69.02% CSU Main Campus has the lowest change in vegetation with only 15.93%. Conversely, the CSU campus has the highest unchanged vegetation cover of 84.07%, followed by the ASSCAT with 68.12% remaining vegetation cover.

3.2 Infrastructure Thematic Maps of SUCs

3.2.1 Caraga State University Main Campus

Based on the maps generated in this study, it can be observed that there is significant infrastructure development within the CSU Main Campus (Figure 11). The campus had a total building area of 23,698.97 square meters in 2010 and was increased to 34,368.99 square meters in 2020. These areas correspond to sixty-nine (69) total number of buildings in 2010 and seventy-two (72) in 2020. The paved roads in the CSU campus increased from 671.24 meters (2010) to a 2011.40-meter total length in 2020 as shown in Table 2.

Table 2. Measurements of CSU Main Campus Infrastructures

Year	**Total Number of Buildings**	**Total Building Area (m^2)**	**Total Length of Roads (m)**
2010	69	23698.97	671.24
2020	72	34368.99	2011.40

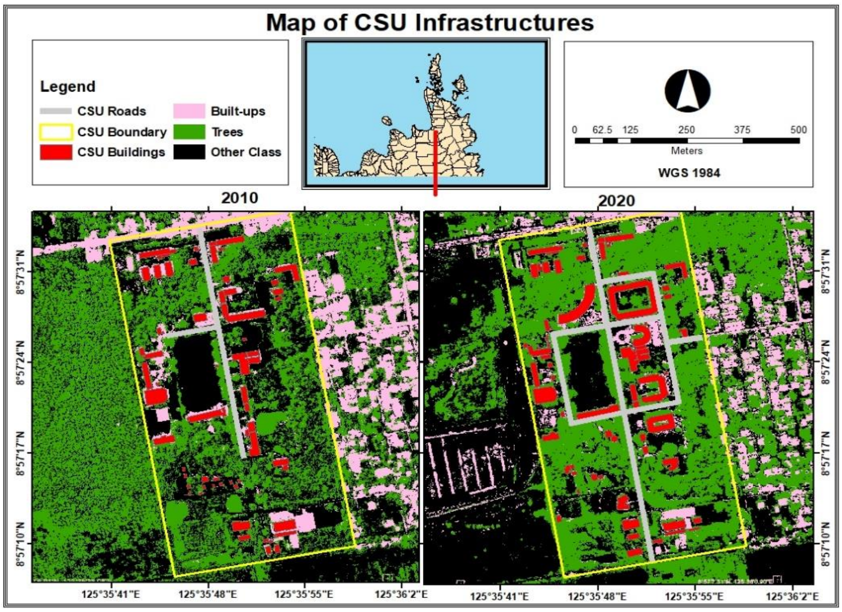

Figure 11. Map of CSU Infrastructures

3.2.2 Agusan del Sur State College of Agriculture and Technology Bunawan Campus

Figure 12 shows the infrastructure development of ASSCAT Bunawan Campus. As shown in Table 3, the campus had a total building area of 12,424.89 square meters in 2010 and was increased to 21,343.14 square meters in 2020. In terms of the number of buildings, there are thirty-seven (37) total number of buildings in the campus in 2010 and increased to fifty-seven (57) in 2020. Results showed that road development in the campus significantly increased from 594.98 meters in 2010 to a 1,785.69-meter total length of the roads in 2020.

Table 3. Measurements of ASSCAT Bunawan Campus Infrastructures

Year	**Total Number of Buildings**	**Total Building Area (m^2)**	**Total Length of Roads (m)**
2010	37	12424.89	594.98
2020	57	21343.14	1785.69

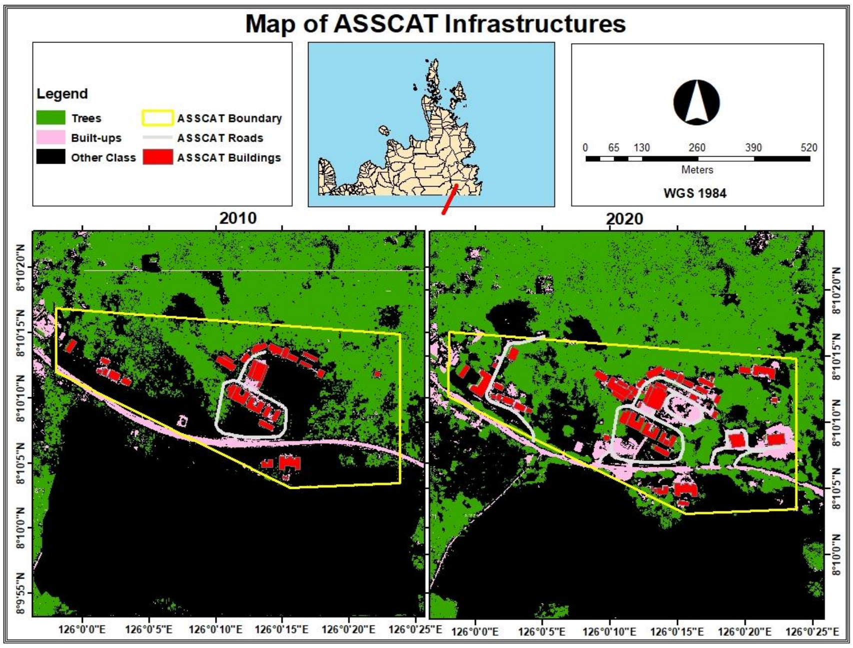

Figure 12. Map of ASSCAT Infrastructures

3.2.3 Surigao del Sur State University Main Campus

At the SDSSU Main Campus, the mapping results as shown in Figure 13 and Table 4 presents that the campus had a total building area of 8,446.69 square meters in 2010 and almost tripled in 2020 with a total area of 17,174.67 square meters. The total number of buildings mapped in the campus is fourteen (14) for 2010 and bloated to fifty (50) buildings in 2020. The total road lengths also increased from 483.58 meters in 2010 to 1371.18 meters in 2020.

Table 4. Measurements of SDSSU Main Campus Infrastructures

Year	Total Number of Buildings	Total Building Area (m^2)	Total Length of Roads (m)
2010	14	8446.69	483.58
2020	50	17174.67	1371.18

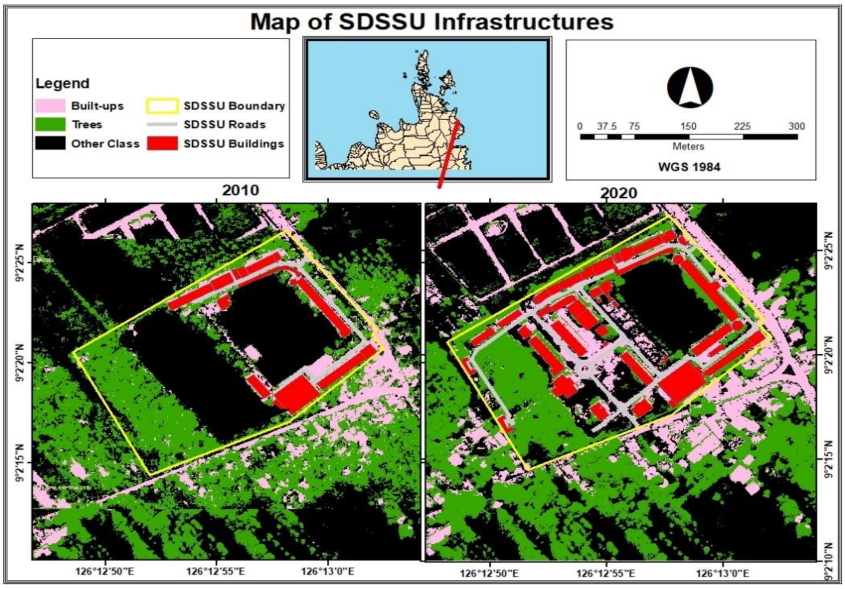

Figure 13. Map of SDSSU Infrastructures

3.2.4 Surigao State College of Technology Main Campus

The ten-year infrastructures development comparison for SSCT Main Campus showed that there is also an increase in terms of the number of buildings and total building areas only, as shown in Table 5 and Figure 14. The campus has a total building area of 14,121.92 square meters in 2010 and 16,524.93 square meters in 2020. This building area increase can be associated to the increase in the number of buildings in the campus with thirty-two (32) from 2010 to thirty-six (36) in 2020. While for the road development in the campus, there is a very slight increase of 0.3 meters within 10 years.

Table 5. Measurements of SSCT Main Campus Infrastructures

Year	Total Number of Buildings	Total Building Area (m^2)	Total Length of Roads (m)
2010	32	14121.92	527.61
2020	36	16524.93	527.95

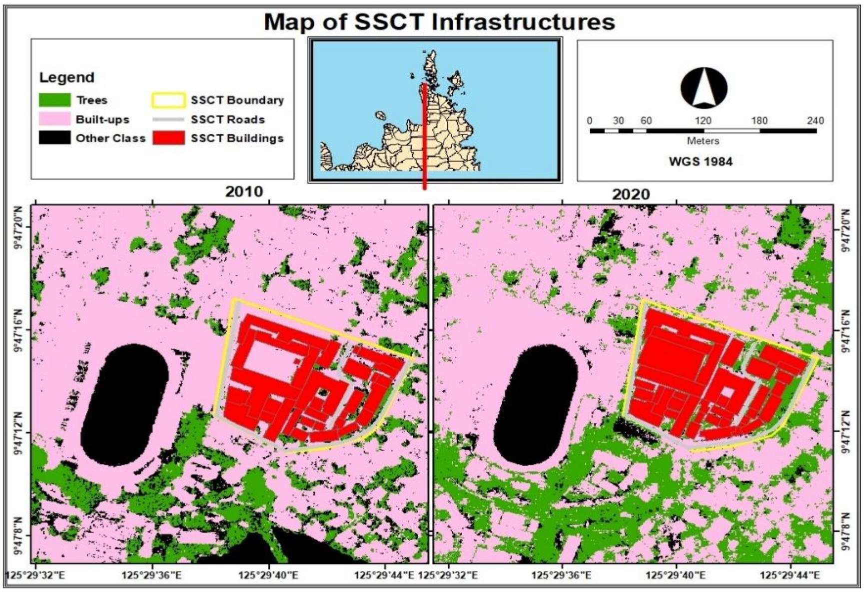

Figure 14. Map of SSCT Infrastructures

3.3 SUCs Infrastructure Growth Rate

The ten-year comparison of the infrastructure development among the Caraga Region's SUCs showed that the university with the lowest IGR in terms of building area is Surigao State College of Technology (SSCT), with an IGR value of 15.76%. The low IGR value, however, may be attributed to the limited land area of the campus, which may have limited the SUC to expand their physical assets. The university may have expanded vertically in the last three years to spend its total capital outlay budget of approximately ₱478 Million based on the General Appropriations Act (GAA) 2017-2020. In contrast, Agusan del Sur College of Agriculture and Technology (ASSCAT) has the highest IGR value of 71.78% for building area among the four (4) SUCs in Caraga. Based on the GAA 2017-2020, ASSCAT garnered a total of ₱249 Million appropriations for capital outlay. In terms of the number of buildings, Caraga State University (CSU) has the lowest IGR with an IGR value of 8.42%. In comparison, the Surigao del Sur State University garnered the highest IGR of 54.29% with a total GAA funding from 2017-2020 of approximately ₱558 Million. The GAA data showed that it is only in recent years that the Caraga State University attained significant budget shares from the national government. Though CSU has a very low IGR value in terms of the number of buildings, the university yielded approximately ₱981 Million, the highest budget share among the Caraga Regions' SUCs from 2017 to 2020. The contrasting IGR value and the budget allocation for infrastructure development of CSU indicate that the campus has recently implemented big-ticket infrastructure projects. In terms of road length, SSCT has the lowest IGR value of 58.09%, which again can be attributed to the limited land area owned by the university while ASSCAT yielded a superior IGR value of 200.13% (as shown in Table 6).

Table 6. SUCs Infrastructure Growth Rate

SUCs	IGR (Building Area)	IGR (Number of Buildings)	IGR (Road Length)
CSU	28.99%	8.42%	144.58%
ASSCAT	71.78%	54.05%	200.13%
SDSSU	49.14%	54.29%	96.88%
SSCT	15.76%	31.58%	58.09%

4. CONCLUSION

The coupled remote sensing and GIS mapping techniques employed in this study, though very simple, proved to help generate baseline data necessary for infrastructure development monitoring for the higher education sector. Based on the land cover change detection analysis conducted within the study sites, CSU has the lowest change in vegetation with 15.93%, in contrast to the SSCT's 69.02% vegetation change rate. Regarding infrastructure development, the university with the lowest IGR in terms of building area is Surigao State College of Technology (SSCT), with an IGR value of 15.76%. In contrast, Agusan del Sur College of Agriculture and Technology (ASSCAT) has the highest IGR value of 71.78% for building area among the four (4) SUCs in Caraga. According to the number of buildings, Caraga State University (CSU) has the lowest IGR with an IGR value of 8.42%, while the Surigao del Sur State University garnered the highest IGR of 54.29%. While for the road development, SSCT has the lowest IGR value of 58.09%, and ASSCAT yielded a remarkable IGR value of 200.13%.

The findings of this study presented baseline comparison data that can aid in understanding the infrastructure growth rates of SUCs in the Caraga Region. Moreover, it can further provide insights to decision makers to assess if social development is adequate and responsive to the region's needs. The baseline characterization on the infrastructure development of these universities will also aid administrators to formulate strategies for providing physical facilities that are responsive to the emerging demands of transitioning into digital universities, as well as to match the requirements of Education 4.0.

5. REFERENCES

Aithal, P. S., & Aithal, S. (2019). Building World-Class Universities: Some Insights & Predictions. *International Journal of Management, Technology, and Social Sciences*. https://doi.org/10.47992/ijmts.2581.6012.0067

De Almeida, C. M., Vieira Monteiro, A. M., Câmara, G., Soares-Filho, B. S., Coutinho Cerqueira, G., Lopes Pennachin, C., & Batty, M. (2005). GIS and remote sensing as tools for the simulation of urban land-use change. *International Journal of Remote Sensing*, *26*(4). https://doi.org/10.1080/01431160512331316865

Ershova, I., & Posokhov, A. (2016). Comparative Analyze of Infrastructure in Developed Countries. *Procedia Economics and Finance*, *39*. https://doi.org/10.1016/s2212-5671(16)30258-1

Gamshadzaei, M. H., & Rahimzadegan, M. (2017). Stable and accurate methods for identification of water bodies from Landsat series imagery using meta-heuristic algorithms. *Journal of Applied Remote Sensing*, *11*(4). https://doi.org/10.1117/1.JRS.11.045005

Giri, C., Pengra, B., Long, J., & Loveland, T. R. (2013). Next generation of global land cover characterization, mapping, and monitoring. *International Journal of Applied Earth Observation and Geoinformation*, *25*(1). https://doi.org/10.1016/j.jag.2013.03.005

Japitana, M. V., Demetillo, A. T., Burce, M. E. C., & Taboada, E. B. (2019). Catchment characterization to support water monitoring and management decisions using remote sensing. *Sustainable Environment Research*, *1*(1). https://doi.org/10.1186/s42834-019-0008-5

M. Sreelekha. (2019). Accuracy Assessment of Supervised and Unsupervised Classification using NOAA Data in Andhra Pradesh Region. *International Journal of Engineering Research And*, *V8*(12). https://doi.org/10.17577/IJERTV8IS120065

Magusara, A. J. T., & Japitana, M. V. (2015). Change detection of forest areas using Object-Based Image Analysis (OBIA): The case of carrascal, Surigao del Sur, Philippines. *ACRS 2015 - 36th Asian Conference on Remote Sensing: Fostering Resilient Growth in Asia, Proceedings*, 3001–3010.

Marvin, D. C., Koh, L. P., Lynam, A. J., Wich, S., Davies, A. B., Krishnamurthy, R., Stokes, E., Starkey, R., & Asner, G. P. (2016). Integrating technologies for scalable ecology and conservation. In *Global Ecology and Conservation*. https://doi.org/10.1016/j.gecco.2016.07.002

Mordeno, M. H. (2021). *2022 budgets for state universities in Mindanao reduced*. MindaNews. https://www.mindanews.com/top-stories/2021/09/2022-budgets-for-state-universities-in-mindanao-reduced/

Nkosi, T., Aboginije, A., Mashwama, N., & Thwala, W. (2020). Harnessing fourth industrial revolution(4IR) for improving poor universities infrastructure in developing countries-A review. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, *0*(March).

Ochuba, V. O. (2001). Strategies for improving the quality of education in Nigerian universities. *Current Issues in Educational Management in Nigeria. NAEAP Publication*, 413–423.

Pandey, G., Sharma, V. K., Chaudhary, P., Chowdary, V. M., & Udayraj. (2021). Integration of Texture and Spectral Response with AI Techniques for Buildings Footprint Identification Using High-Resolution Satellite Images. *Journal of the Indian Society of Remote Sensing*, *49*(6). https://doi.org/10.1007/s12524-021-01322-9

Pangandaman, H. K., Ali, N. D., Lambayong, Hope, J. C., & Ergas, M. L. G. (2019). Philippine Higher Education Vis-À-Vis Education 4.0: A Scoping Review. *International Journal of Advanced Research and Publications*, *3*(3).

Rahman, A., Aggarwal, S. P., Netzband, M., & Fazal, S. (2011). Monitoring Urban Sprawl Using Remote Sensing and GIS Techniques of a Fast Growing Urban Centre, India. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *4*(1). https://doi.org/10.1109/JSTARS.2010.2084072

Shalaby, A., & Tateishi, R. (2007). Remote sensing and GIS for mapping and monitoring land cover and land-use changes in the Northwestern coastal zone of Egypt. *Applied Geography*, *27*(1). https://doi.org/10.1016/j.apgeog.2006.09.004

Wei, S., & Ji, S. (2021). Graph Convolutional Networks for the Automated Production of Building Vector Maps From Aerial Images. *IEEE Transactions on Geoscience and Remote Sensing*. https://doi.org/10.1109/TGRS.2021.3060770