INTEGRATING GIS WITH LANDUSE DECISION-MAKING: THE CASE OF CENTRAL MINDANAO UNIVERSITY, PHILIPPINES

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ABSTRACT: As a state university, the Central Mindanao University (CMU) is confronted with a myriad of issues pertaining to the utilization of its land resources in the university's 100 years of existence. These issues stem from its strategic location and productive land, which entice informal settlers to encroach the land. In response, the university invests in formulating its comprehensive landuse plan. With the application of GIS, lands are delineated and classified to optimize its uses considering biophysical setting, social condition and climate and natural hazards. Land utilization also ensures that the university is able to perform its four-fold functions, i.e. instruction, research, extension and production. The process is an avenue to generate information on the current landuses and issues to provide direction on the path of progress that the university will take. Considering student population growth rate, the campus will be increased by 179%; the agricultural landuses will be re-classified considering the slope gradients suitable for crop, livestock and agroforestry production while the 50% slope land are allocated for forest protection. Informal settlers now occupying 50% and 9.5% of the total land area within the agriculture and forest land uses, respectively, will be developed into social enterprise. The delineated flood and other disaster-prone areas are planned for infrastructure and vegetative engineering measures. Thus, the GIS-generated maps have become the tool for decision-making to optimize the allocation and use of CMU land.

INTRODUCTION

Geographic Information System (GIS) is increasingly an important tool in data and spatial analysis for various purposes such as research, planning and modeling. This is because GIS has the power to integrate data from various sources which generate decision-making especially in urban planning (Han and Kim, 1989). Yeh (1999) claims that mapping is a "powerful visualization tool in GIS" that could also explore spatial analysis of the distribution of socioeconomic and environmental data. In fact, GIS is applied in landuse planning (Holden, 2000; Trung, *et al*, 2006; Dushaj, *et al*, 2009). In the case of the Philippines, GIS has been applied in Local Government Units for their landuse plans (e.g. Cruz, 2004). Given this, it is noteworthy to apply GIS as a tool in the crafting of landuse development plan in an academic institution. This study explores the use of GIS in the

The then Mindanao Agricultural College established in 1952 has now evolved into the Central Mindanao University (CMU) - a leading state university in the southern part of the Philippines. CMU is in existence for over 100 years, offering baccalaureate and graduate degrees with prime specialization in agriculture and allied sciences such as forestry, veterinary medicine, engineering and environmental science. CMU obtained its legal claim over its 3,401 hectares through Presidential Proclamation No. 476 dated January 16, 1958 as public land. During the land registration proceedings that commenced in 1961, a total of 321 hectares were segregated from CMU's land reservation and to the legitimate claimants. The remaining 3,080.82 hectares were adjudicated and titled in the name of CMU on January 25, 1975.

Like any other public land and land reservations, CMU is not spared from land conflicts with landless farmers by virtue of the Comprehensive Agrarian Reform Program Law (CARP) as well as other informal settlers who establish their residence and livelihood through farming. In addition, CMU is also confronted with issues on the increasing number of student population and curricular programs to operationalize its vision of "a leading ASEAN University ... for total development of people for a globally sustainable environment and humane society." CMU likewise commits itself to other mandates for research, extension, development and income generation.

With enormous responsibilities as well as the multi-dimensional issues on the utilization and management of the land, the CMU administration under the leadership of University President Dr. Maria Luisa R. Soliven has initiated the formulation of its 25-year Land Use and Development Plan (LUDeP) as blueprint and roadmap of its vision for progress. Moreover, the LUDeP becomes a legally binding commitment of CMU to address the various issues of landuse while upholding its main responsibility in the fields of instruction, research, extension and production for income generation. Along this vein, the LUDeP outlined the three (3) development strategies, which includes (1) improvement and expansion of university's infrastructures and facilities, (2) enhancement of university's income generation, and (3) management, protection, and control of CMU's land resources from informal settlers through RDE (research, development and extension), social enterprise, and PPP (public private partnership) approaches.

In all these LUDeP efforts, GIS is applied as a crucial tool in addressing landuse concerns. GIS-generated maps provide the spatial context of specific strategies to respond to specific concerns per identified and delineated land use zones. With the above development strategies, this study aims to provide relevant data and information applying the GIS tools. Specifically, it aims to:

1) delineate the major landuse zones within the CMU landholding;
2) generate thematic maps and data as bases for landuse decision-making; and
3) draw out management implications of the GIS-generated maps and data for the CMU landuse plan.

METHODOLOGY

Study Site

Central Mindanao University (CMU) lies between 125°03'03.51" E longitude and 7°51'34.27" N latitude. CMU is situated in the central part of the southern Philippine island, which is Mindanao. It has a total land area of 3,080.82 hectares with different noticeable land use/land cover such as natural forest, plantation forest, residential, and agricultural land. The area has a mean elevation of 312 meters above sea level (masl). The general climate of the area falls under Type III based on the Modified Corona classification of PAGASA (Philippine Atmospheric, Geophysical and Astronomical Services Administration). Type III climate is characterized as having a seasonal variability that is not very well pronounced, with dry season from November to April and wet during the remaining months of the year.

Land use Mapping

GIS and GPS technologies were both utilized in this study. In 2008, a land use map was developed but recent developments have made important changes to it. To generate an updated and a more comprehensive land use map, field and GPS surveys were undertaken. The surveys were not only aimed at validating the accuracy of the old map but also to delineate various land uses that are not reflected on the said map. Editing and validation are important since the determination of accurate size and location of land use zones is an important consideration in the crafting of development plans. Google Earth Engine was also used to update road and river GIS datasets.

GPS, survey and Google earth generated data comprised the primary inputs in the GIS analysis. From CAD survey data, a polygon feature of CMU boundary was developed using ArcMap version 10.2.2 (with institutional license). The CAD data was acquired from the University Planning and Development Office (UPDO). Using the 2008 land use map as a baseline, an updated map was generated by editing the boundaries of polygon features. Edits were made based on the most recent GPS survey data provided by the University Income Generation Program (UIGP) Office. A detailed current land use map and its corresponding were finally generated using ArcMap.

The generation of development (future) maps proved to be a more tedious work. With the existing map as the baseline, projections relative to student population, dormitories, expansion of colleges, projected land use allocations and other information were translated into spatial data. Part of the activities was the agreement between university officials about future land use allocations. Those projections were all factored-in in order to develop the development maps and its database. A simplified GIS analysis workflow is shown in Figure 1.

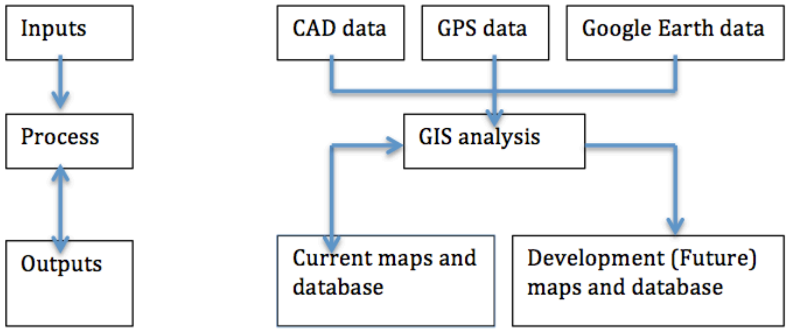

Figure 1. Flow Chart of the GIS Analysis

RESULTS AND DISCUSSION

The university's landholding of 3,080.82 hectares is the focus of the comprehensive landuse planning. Using mapping, delineation and field validation, the data are integrated through GIS to spatially locate the 51 types of land uses as shown in Figure 2. These types of landuses are broadly categorized into three (3) land use zones, i.e. academic campus land use; forest/upland land use; and the agriculture/lowland land use (see Table 1).

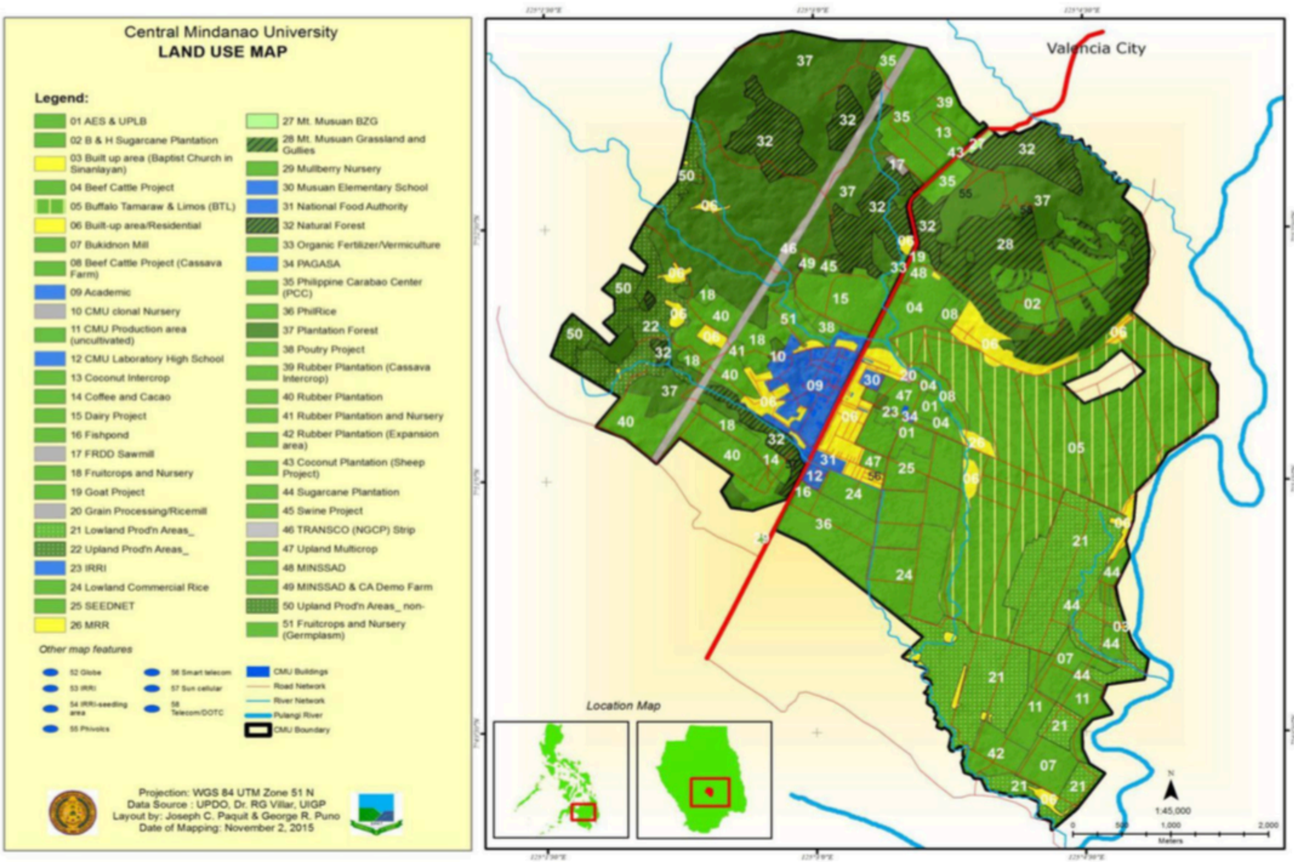

Figure 2 . Landuses within the CMU landholding

Table 1 shows that the actual academic campus of CMU only covers 5% of the total area. This indicates that prime agricultural and forest lands have to be appropriately used to allocate lands for future uses. The active use of these lands will reduce further encroachment and other landuse management problems. These data are, therefore, important input for CMU's roadmap towards progress in the next 25 years.

Table 1. Area per land use zone

Land Use Zone	Area (ha)	Percent (%)
Academic Campus Land Use Zone	146.65	4.76
Forest/Upland Use Zone	1, 210.40	39.28
Agriculture/Lowland Use Zone	1, 723.77	55.95
Total	3, 080. 82	100

GIS tool spatially locate the three landuse categories. Figure 3 shows that these landuse categories are contiguous, except for patches of forestlands in the agricultura/lowland use zone. However, built-up areas, specifically residences of both CMU employees and informal settlers, are spread in the three landuse zones.

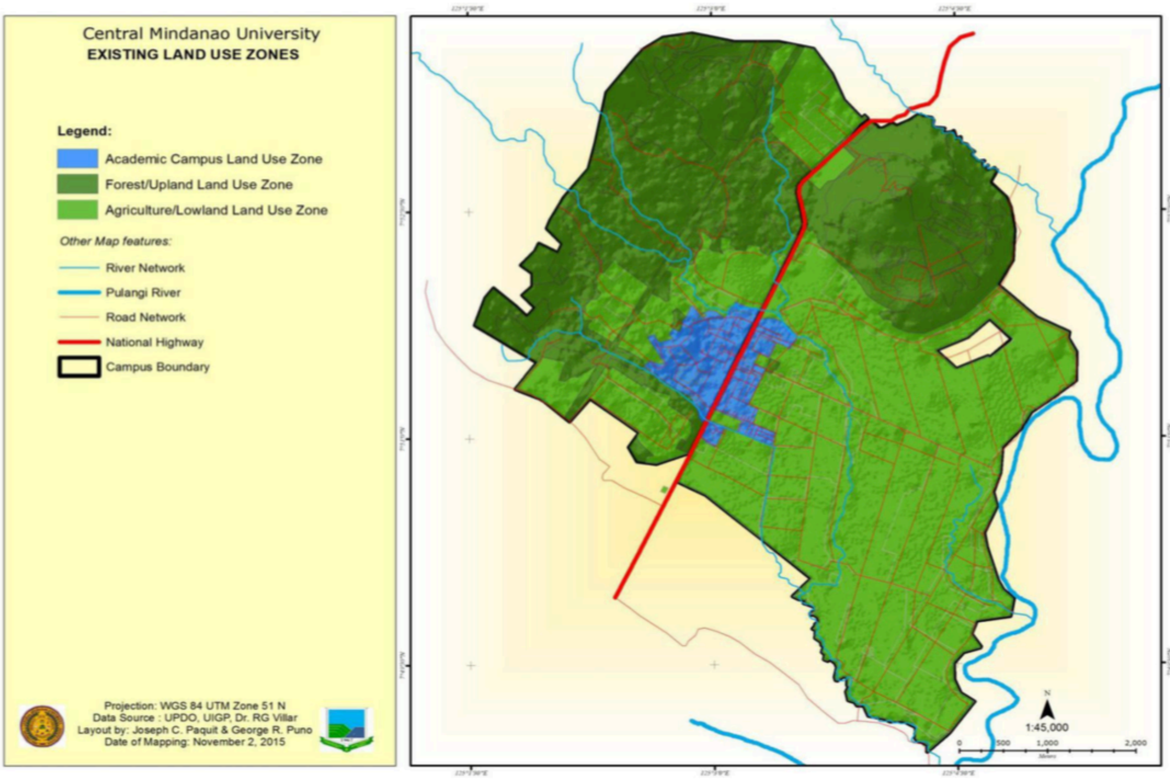

Figure 3. Landuse zone categories

The above GIS-generated data provided relevant information, specifically pertaining to land allocation to cater to the functions and responsibilities of CMU as a state university, i.e. instruction, research, extension and production. In the case of production, CMU has to enhance and sustain its income generation programs to lessen its dependency on government funding. These data on hectarage per landuse zone becomes the basis for detailed use considering the location, topography, vegetation cover, disaster-prone areas as well as socio-cultural setting.

Each of the landuse zone category are further detailed into specific landuses reflecting the current use as well as the land and vegetation cover. Overlaying the above information is the extent of land area with different management control, i.e. university controlled; lands that are now utilized by informal settlers for residence and livelihood; and under the public-private partnership (PPP) mechanism and government agencies (GA). In the latter's case, CMU lands are leased to government agencies such as Philippine Rice Research Institute (PhilRice), the National Food Authority, the Department of Education (DepEd), among others. The data on hectarage covered under specific management control are shown on Table 2.

Table 2. CMU land-use zones and management control

Land-Use Zone	Management Control (in hectares)			Sub-Total	Percent
	University Controlled	Informal Settlers	Under PPP & GA		
Academic Campus	137.67 (93.87 %)	4.98 (3.4%)	4.00 (2.73%)	146.65	4.76
Forest/ Upland	964.92 (79.72%)	115.52 (9.54%)	130.06 (10.74%)	1,210.40	39.28
Agriculture/ lowland	632.03 (36.67%)	862.21 (50.02%)	229.53 (13.31%)	1,723.77	55.95
Total	1,734.62 (56.30%)	982.61 (31.89%)	363.59 (11.81%)	3,080.82	100

Using GIS as a tool, the different categories of management control are spatially located on the map as shown in Figure 4.

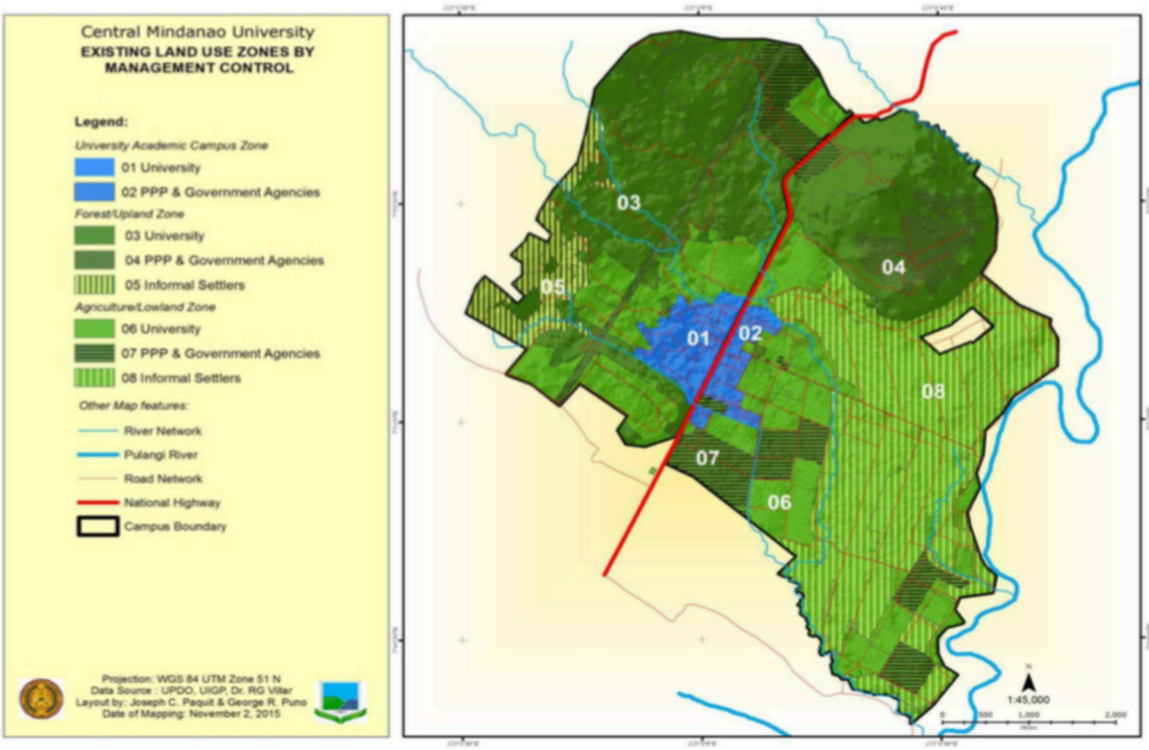

Figure 4. Management control of landuse zones

Data generated indicate an alarming presence of informal settlers occupying 32% of the total land area of CMU, particularly in the agriculture and lowland landuse zones. This situation is similarly experienced in other state universities in the Philippines. State universities occupy lands that are declared as public lands, which become prone for encroachment of informal settlers. Without a fair and comprehensive strategy, this situation will compete with the university's demand of land to realize its functions of instruction, research, extension and production.

The GIS-generated maps and data became the basis for strategies and interventions as captured in the formulated comprehensive landuse and development plan (LuDeP) for CMU. For the purpose of this report, emphasis is given on landuse decision-making on the development plan for campus, forest and agricultural/lowland landuse zones.

Considering student population growth rate, the campus will be increased by 179% based on its current area. Thus, the campus area has to expand to accommodate infrastructures for academic buildings, research and laboratory facilities, dormitories and sports and recreation facilities. Green spaces and parking lots are also identified. In addition, new housing sites will be located for the increasing demand of housing units of university employees. However, the expansion of built-up areas has to consider climate and natural hazards such as flooding (Figure 5) and volcanic eruption (Figure 6). This is because CMU is within a major river network, which caused flooding during heavy rainfall, and the university landmark, which is the majestic Mt. Kalayo (fire) or Mt. Musuan Peak that reportedly erupted in 1886 and experienced seismic movement in 1976.

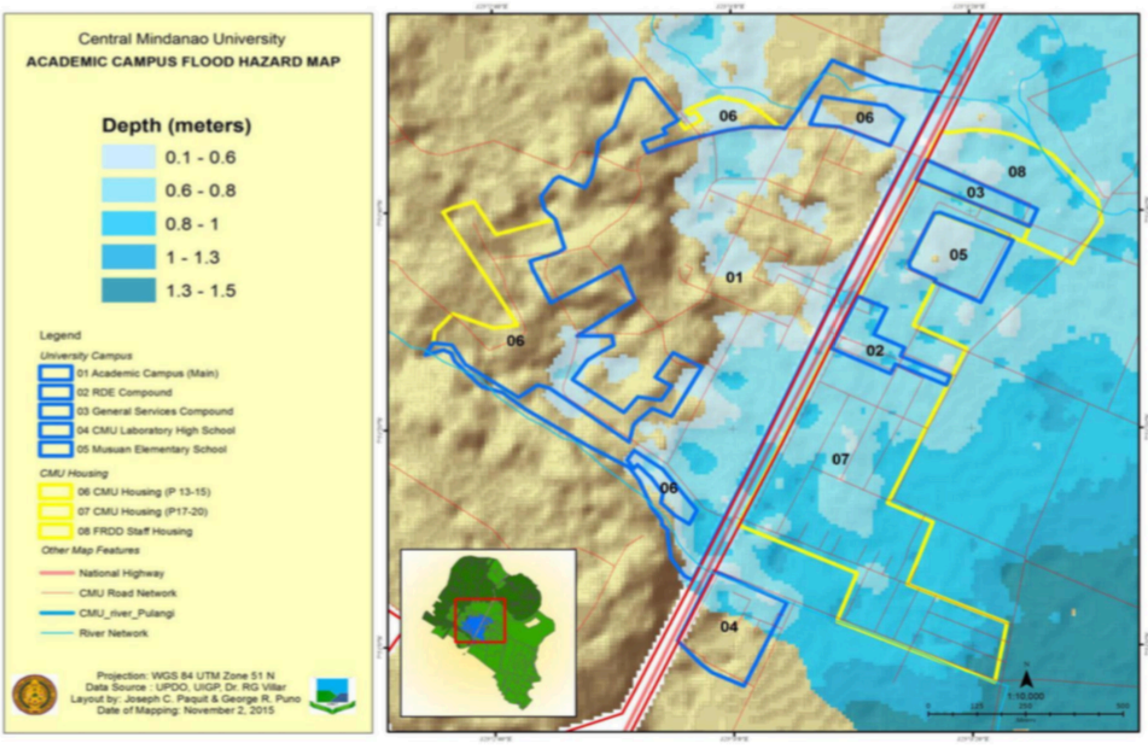

Figure 5. Flood hazard map of CMU

Overlaying the GIS-generated thematic maps also produce decisions to optimize the use of land in the agricultural landuse zone. For instance, the existing agricultural landuses are re-classified considering the slope categories as to its suitability for crop, livestock and agroforestry production while land under 50% slope are allocated for forest protection. Degraded forests lands are also identified for rehabilitation and natural regeneration through planting of appropriate tree species and land cover. Whilst, riverbanks for bamboo planting to stabilize slope and reduce runoff and erosion. Additionally, the delineated flood and other disaster-prone areas are planned for infrastructure and vegetative engineering measures.

Informal settlers now occupying 50% and 9.5% of the total land area within the agriculture and forest land use zones, respectively, have to be dealt with in the landuse plan. These areas, which are legally still under the management of CMU, are to be integrated into the social enterprise program of the university. Although this could be controversial and critical concern of the administration, GIS-generated maps and data provide the spatial context on the socio-economic and political dimensions that management will be confronted with.

All the proposed management strategies and interventions are reflected in the GIS-generated maps. These maps reflect the proposed development plans per landuse zone, which overlay different thematic maps and data sources on existing biophysical and socio-cultural settings within the CMU landholding of 3080 hectares.

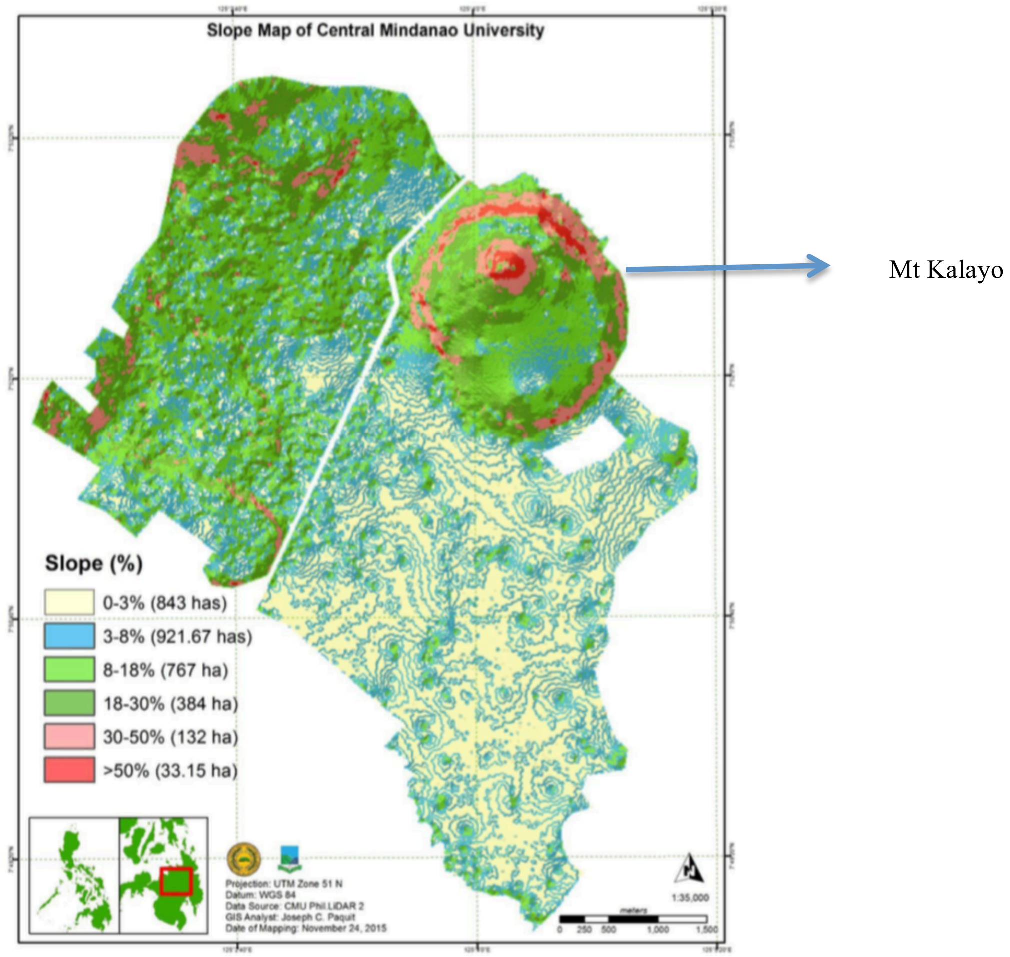

Figure 6. Slope map of CMU

SUMMARY AND CONCLUSIONS

As a prime state university, CMU upholds its vision and functions in the fields of instruction, research, extension and production or income generation. The delineated 3,080.82 hectares of land under the management of CMU have to accommodate the competing demands to perform its functions while simultaneously addressing concerns on climate and natural hazards and the presence of informal settlers. The application of GIS is a very helpful tool to generate data and produce maps that spatially locate the landuse zones. The GIS-generated data and maps provide relevant information that feed into decision-making on the best use per landuse zone. These decisions include the expansion of campus; the relocation of buildings and housing sites; re-classification of lands based on slope categories; rehabilitation of degraded areas; appropriate crop, livestock and agroforestry production; and the integration of informal settlers in the social enterprise program of the university. These decisions were drawn out through the overlay of the different thematic maps generated such as land cover, landuse, slope and flood hazard maps.

RECOMMENDATIONS

GIS is a powerful tool to generate relevant data and information that are crucial in decision-making. In the case of landuse decision-making, the following can be recommended:

1) integrate soil classification in the slope categories map for better analysis on appropriate agricultural and forest land uses;
2) overlay data on the location of built-up areas, specifically residential structures, for monitoring on the extent of encroachment;
3) use GIS-generated maps to create scenarios for 5, 15 and 25 years to reflect changes and locate the major

investments in the landuses over the 25-year period of the LuDeP; and
4) enhance maps through the use of remote sensing technologies.

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LITERATURE CITED

Cruz, RB. 2004. Developing a landuse information system for local government: The case of Naga City, Philippines. MS Thesis. International Institute for Geo-Information Science and Earth Observation. Enschede, The Netherlands. Retrieved September 13, 2016 from https://www.itc.nl/library/Papers_2004/msc/upla/cruz.PDF.

Dushaj, L, I. Salillari , V. Suljoti , M. Cenameri, and F. Sallaku . 2009. Application on GIC for land use planning: A case study in central part of Albania. Research Journal of Agricultural Science, Vol. 41 (2). Retrieved September 1, 2016 from http://www.rjas.ro/download/paper_version.paper_file.a7f3acc8f17bf8b1.3234322e706466.pdf.

Han S Y, Kim T J 1989. Can expert systems help with planning? Journal of the American Planning Association Vol. 55, pp. 296–308.

Holden, M. 2000. GIS in land use planning: Lessons from critical theory and the Gulf Islands. Journal of Planning Education and Research Vol. 19 Issue 3, pp 287-296. Retrieved September 13, 2016 from http://www.jpe.sagepub.com.

Trung, N.H., L.Q.Tri, M.E.F.v. Mensvoort, and A. Bregt. 2006. Comparing Land-Use Planning Approaches in the Coastal Mekong Delta of Vietnam, *In* C. T. Hoanh, et al., eds. Environment and Livelihoods in Tropical Coastal Zones: Managing Agriculture-Fishery- Aquaculture Conflicts. CABI Publishing, UK.

Yeh, AGO. 1999. Urban planning and GIS. Retrieved on September 11. 2016 from http:// www.masters.dgtu.donetsk.ua.