Application of GIS in Facility Space Management: A Case Study of ILRI

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Abstract: *Space management is an important part of facilities management. It is a process of determining space requirements, identifying deficiencies, and allocating available space to users in an equitable way, monitoring use, assisting users with space usage problems, and resolving space problems. Managing facilities space involves storing, querying, and updating spatial and non-spatial data related to these facilities. This makes Geographic Information System (GIS) an important tool in management of space. International Livestock Research Institute (ILRI) lacks a system that has data repository of all its facilities integrated in one platform to help in effective and efficient management of space. The facilities department faces many problems, including time spent searching for information on space allocated to facilities, organizing data, difficulties finding accurate location of facilities, duplication of work, and difficulties in adding and updating data. This project demonstrates how GIS can be used in managing space. This was achieved through building of a GIS database which integrated spatial and non-spatial data of facilities in ILRI. Data which was obtained from AutoCAD ArchiCAD and PDF files was geo-referenced, harmonized and used to create spatial entities. Non-spatial data was obtained from Excel and PDF files. GIS analyses were then carried out on the data stored in the geodatabase. These analyses included determination of the main types of facilities that occupy the organizations' space and their areas, paddocks sub-division in the grazing area as well as assessment of spaces allocated to rooms of the buildings that are used as offices in order to determine whether they are utilized well, under-utilized or over-utilized. Potential locations for fire assembly points were also determined. Finally a web map of the underground and surface facilities was built using features stored in the geodatabase.*

Keywords: GIS, Space Management, Spatial, ILRI, Facilities Management.

1. Introduction

Space management is an important part of facilities management. Like facilities management, space management is not only concerned with the amounts of space, but should also address the quality of space. Therefore, interaction with users and other organizational elements involved in facilities management is necessary [1]. Managing facilities space involves storing, querying, and updating spatial data and GIS is a recommendable tool for building a geodatabase. Many facilities departments are using computer aided design (CAD) software for drawings and plotting maps. Recently, however, many are adopting GIS to work with their CAD files [2].

The key functions of GIS use in facilities management are spatial visualization and geodatabase management functions. It has been used extensively for facilities management in the public sector and has great potential for use in the private sector as well. [3] in her review of utility applications of GIS technology notes that GIS fulfills "an ever-increasing demand for information pertaining to the location, condition, and performance of the utilities' infrastructure". GIS has been used to assist in the management of building spaces and facilities in recent years. With powerful capabilities for presenting data in visual formats and analyzing spatial relationships, GIS has gained popularity in both research and practice [4]. An example is the introduction of GIS software into the administration of hospital infrastructure whereby Downey Regional Medical Center in California developed a tool that used GIS to feature both the floor plans and the supporting facilities of the hospital on detailed maps, and to store data associated with hospital activities in a database [4].

In addition, GIS has been used as a spatial data management and decision support system in Space Optimization and Utilization at the National Aeronautics and Space Administration's (NASA) Langley Research Center (LaRC). This was done using ArcGIS software coupled with custom Visual Basic code. Also, a research done by [5] urges that GIS is a very efficient and effective tool and the simplicity of developing GIS interfaces and spatial databases and the low cost of implementing them make the technology applicable to nearly every library as well as any organization for management of space.

ILRI being a research centre would highly benefit from capabilities of GIS in management of the space in its facilities. It has various buildings used for different purposes and activities. A geodatabase containing spatial and non-spatial data for the underground and surface facilities was developed using ArcGIS software. This data was then used to build a web map using open source software, OpenGeo Suite. Spatial analyses were then performed on data stored in the geodatabase for assessment of space used in rooms as well as grazing area. Other analyses performed were determination of potential locations for fire assembly points and paddocking of the grazing area

2. Problem Statement

ILRI has about seventy buildings, of which most have been drawn using AutoCAD or ArchiCAD software, and a number exist in hard copy**.** These drawings have been duplicated due to lack of sharing of data as well as lack of a harmonized data storage location. It is the responsibility of engineering department in the institute to manage facilities.

The data they have is in different formats and in different locations. In some instances, they rely on knowledge of the persons in charge for information.

ILRI is a member of Consultative Group on International Agricultural Research (CGIAR), and it hosts other members within the campus who pay rent on the basis of the amount of space they occupy. At times there are instances when a client would want a justification of the space they occupy in specific buildings. This calls for the facility managers to search their hard copy maps, PDF, Excel files, as well as CAD files where they have stored it which is time consuming and tiresome. Space proportions allocated to major facilities is also not known.

The approach to solving these problems with facilities space management would be through use of GIS to build a geodatabase which has unique advantage of storing database tables, map information, and metadata in a common repository. This would help managers to perform spatial analysis for disaster response, better management, planning and monitoring of facilities.

3. Study Area

ILRI is an international agricultural research institute based in Nairobi (Kenya), and founded in 1994 by the merging of the International Livestock Centre for Africa and the International Laboratory for Research on Animal Diseases. It is a non-profit institution and has its headquarters in Nairobi (Kenya), a principal campus in Addis Ababa (Ethiopia), and offices in West and southern Africa and in South, Southeast and East Asia [6]. It occupies approximately 166 acres of land and is located in Kiambu County, 13 km from Nairobi City's Central Business District (CBD).

ILRI as a member of CGIAR works with partners worldwide to enhance livestock pathways out of poverty, principally in sub-Saharan Africa and Asia. The products of these research partnerships help people in developing countries keep their farm animals alive and productive, increase and sustain their livestock and farm productivity, find profitable markets for their animal products, and reduce their risk to livestock-related diseases [6]. Figure 1 shows the map of the study area.
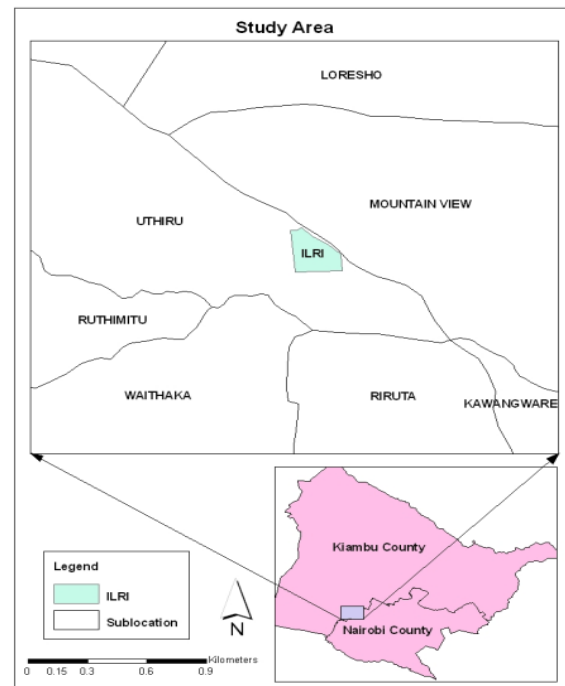

Figure 1: Study area

4. Methodology

Primary data was collected through carrying out a topographical survey using a geodetic GPS. This data was used to generate an AutoCAD drawing showing all the physical features in the institute. Secondary data included AutoCAD and ArchiCAD drawings of floor plans of the buildings as well as PDF and Excel files which had details about the employees and rooms.

Due to duplication of CAD drawings (floor plans), sorting was done in order to identify the updated ones. ArchiCAD drawings were converted to AutoCAD format. This was followed by separating each room from the others in a building by drawing polygons in these AutoCAD drawings that show their layout. This was done for all the buildings, each at a time. All these drawings were then georeferenced using the topographical map and imported to ArcGIS software. ArcCatalog was used to manage and organize various data sets, while ArcMap was used to display, explore, analyze, assign symbols, print, publish, and create maps.

In ArcMap, spatial entities were extracted from the AutoCAD drawings by either importing them to the geodatabase or onscreen digitizing. Floor plans were imported directly since each room was a single entity prepared from CAD data. Non-spatial information was entered in the attribute tables of their respective spatial entities. This yielded to a geodatabase containing data for all the underground and surface facilities in the institute.

GIS spatial analyses were then performed on the data in the geodatabase to demonstrate capabilities of GIS in space management issues. This included determination of the types and sizes of the main facilities in the institute, assessment of whether space allocated to rooms that are used as offices as

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well as the grazing area is well-utilized, under-utilized or over-utilized, sub-division of the paddocks, determination of locations for fire assembly point and creation of a web map. These analyses were performed as explained below.

Grazing area: The institute has allocated approx. 96 acres to grazing area which yields about 1,711,488 lb of forage annually. The animals that roam this area are 50 cattle, 30 sheep and 20 goats. The amount of forage they needed per year was calculated based on their average weight and their daily utilization rate (DUR) which is normally 4%, as shown in Table 1.

Table 1: Forage needed by the animals each year

DUR	No. of animals	Average weight (lb)	No. of days	Total (lb)
0.4	50 cattle	1200	365	876,000
0.4	30 sheep+20 goats	300	365	219,000
			Total	1,095,000

With the amount of forage available to feed the animals known, then the number of paddocks the grazing area should have could be determined. Paddocks number depends on the number of days the animals should graze in each paddock and the maximum rest period (MRP).

Rest period is normally based on pasture growth rate, which varies with season and weather conditions, normally 35 days. Species and class of animal determines the grazing period. Since lactating dairy cows need consistent forage quality, the grazing period for them may be anywhere from 2 to 5 days. However, beef cows, brood ewes, and most other ruminants do not need consistent forage quality, so a grazing period of 3 or more days may suffice [7]. In this case 4 days was adopted since the animals grazed were only for research purposes.

The number of paddocks was then determined using the formula: MRD ÷ number of grazing days + 1 = paddock number. 35 ÷ 4 + 1 = 10 paddocks. With 96 acres available for grazing, then each paddock would have approximately 9.6 acres.

Space utilization in rooms: According to regulation 10 of [8], every room where persons work should have sufficient floor area, height and unoccupied space for purposes of health, safety and welfare. The total volume of the room, when empty, divided by the number of people normally working in it should be at least 14 m^3, and at most 28 m^3. In a typical room, where the ceiling is 2.4 m high, like in ILRI, a floor area of approximately 6 and 12 m^2 would be needed to provide a space of 14 and 28 m^3 respectively. By performing selection by attribute in the geodatabase on the buildings used as offices, rooms with areas below 6 m^2 (over-utilized), 6 m^2 - 12 m^2 (well-utilized), above 12 m^2 (under-utilized) and vacant ones were identified.

Fire assembly points: Fire assembly points are the areas where people can safely be evacuated to incase of fire or an emergency. Assessing the suitability and location of fire assembly points is one of the major functions of fire risk assessment process which was handled in this project. The

areas of the fire assembly points are to be large enough to accommodate the expected maximum occupancy of the building being evacuated (staff, visitors and users). Areas in the open spaces that could hold at least one hundred persons were considered.

Buffer zones of twenty meters from each building were then generated to ensure that the assembly point areas are at a considerable distance from any building, safe from heat and smoke in a fire situation. Other factors considered were accessibility and elevation of the ground since assembly point cannot be on a steep slope. A slope of the area was generated and areas with a slope less than or equal to twenty five degrees were identified.

Web mapping: Web mapping is the process of using maps delivered by GIS. Generally web mapping means a map that you can interact with, zoom in and out, pan around, and change what you are looking at. This is done using a program that runs on a web server that can convert spatial data into a map and understand what the user wants to do next.

Open source software, OpenGeo Suite (Geoserver and Geoexplorer), was used to create a web map of the facilities in the study area. Data which had been stored in the geodatabase as shapefiles was imported to Geoserver and were assigned spatial reference (Arc 1960, UTM zone 37S). This data was then imported to geoexplorer where there are tools provided to allow for interaction with the data and publishing it gave a link which was launched in a web browser as a web map. Figure 2 show the method in this project.
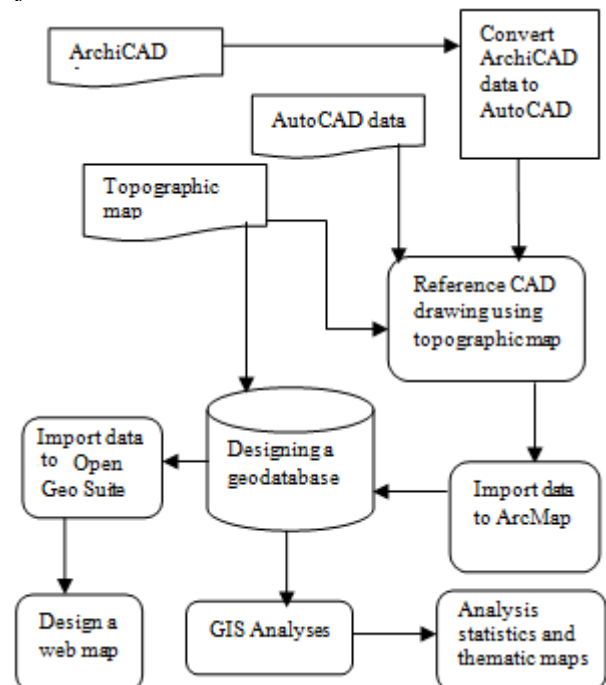

Figure 2: Study design

5. Results

ILRI lies in a 166 acres piece of land. Approximately 96 acres are used as grazing area; 14 acres as wet and bushy

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area; 7 acres as buildings; 12 acres as roads and pavements while open spaces occupy approximately 47 acres. Figure 3 is a pie chart representing the percentages of the space occupied by these facilities.
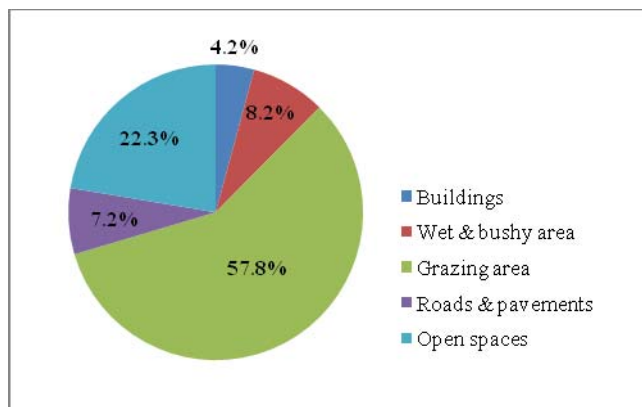

Figure 3: Space used by various facilities

5.1. Geodatabase design

The geodatabase for GIS implementation was designed containing detailed attributes for each feature class. The file geodatabase contained two feature data sets: ground facilities and underground facilities as shown in Figures 4 and 5. Ground facilities were buildings, roads, pavements, trees, sewage ponds, wire fence. Underground facilities were steam pipe, foul water pipe, electricity cable, cold water pipe, horse reel, fire hydrant.

Figure 4 shows the buildings with each building having their room detailed stored in the geodatabase. These details were room number, room use, area, number of occupants, name of occupant and department. They are important as they would help facility managers to better manage these buildings. With this information they are able to know how space has been allocated to various employees and even how much it is. This would also help them make informed decision on rooms that are over-used or under-used. In addition, the managers are made aware of the design of insides of each building and therefore they would be better placed to respond to emergencies.

Figure 5 shows the underground and surface facilities in the institute. These are facilities that help run the daily activities in the institute and they are very important. With knowledge about these facilities and their location as well as their details integrated in one platform, managers would be able to respond to needs that arise more effectively and efficiently.
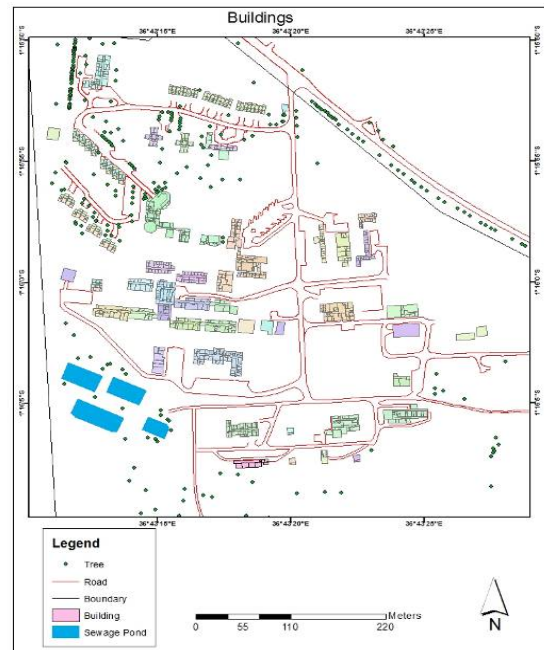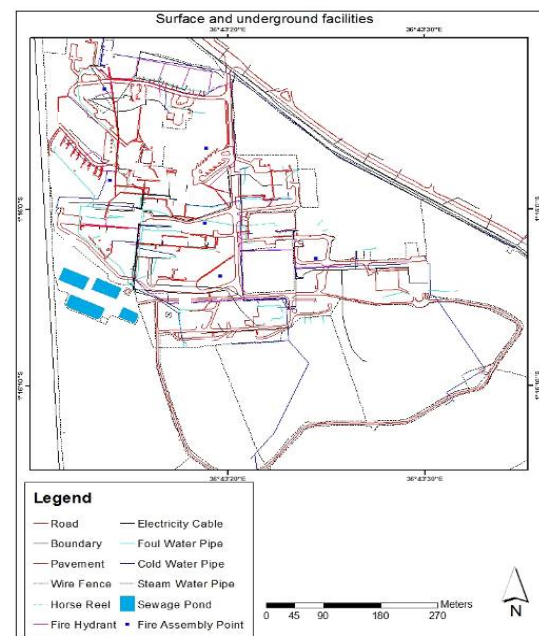

Figure 4: Buildings

Figure 5: Surface and underground facilities

5.2. Grazing Area

The area set aside as grazing area on the ground was divided into 10 paddocks as shown in Figure 6. These paddocks were of different sizes, the largest was 13 acres while the smallest was 5 acres. Also, the paddocks on the lower part did not have a direct access. In order to reach them, the animals have to pass through the paddocks adjacent to the track/road.

From the analysis performed when executing the methodology in Figure 2, and assuming that the size of the grazing area would remain the same, the number of paddocks that could be sub-divided in the area would be 10, with each paddock having approx. 9.6 acres. The existing paddocks were therefore modified to almost equal areas as

shown in Figure 7 and access routes to each paddock were provided. These access routes would help control the movement of animals since each paddock is independent of the others. Rotational grazing also becomes easy with the animals grazing in each paddock within the stipulated days before moving to the other paddock(s).

Further analysis showed that the forage available in the grazing area exceeded what the animals needed by about 616,488 lb (56%). This indicates that the grazing area was under-utilized. It was bigger than the required size by approximately 34 acres. This would therefore imply that the grazing area can be reduced by 34 acres or more animals can be stocked to ensure that this space was optimally utilized.
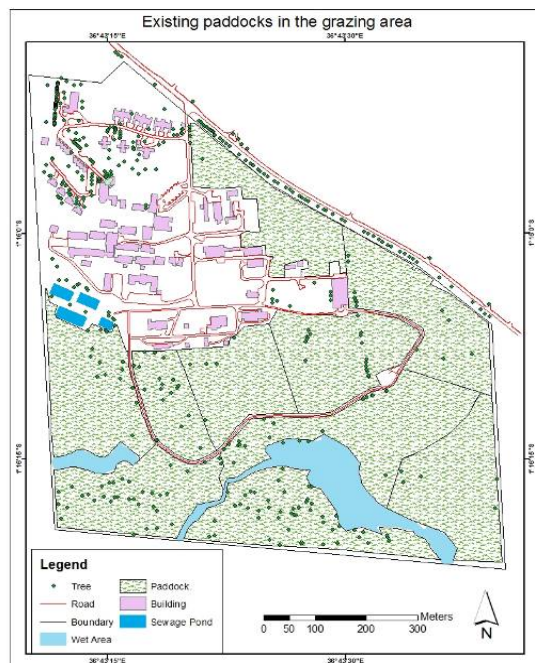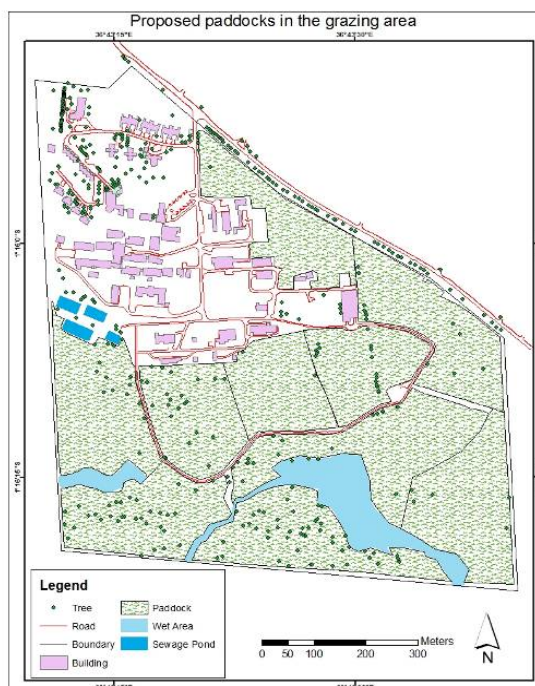

Figure 6: Existing paddocks

Figure 7: Proposed paddocks

5.3. Space utilization in rooms

Buildings which are mainly used as offices were considered in assessing how space has been utilized in the rooms. Figure 8 shows a summary in of these rooms and their areas as well as the vacant rooms in percentages.
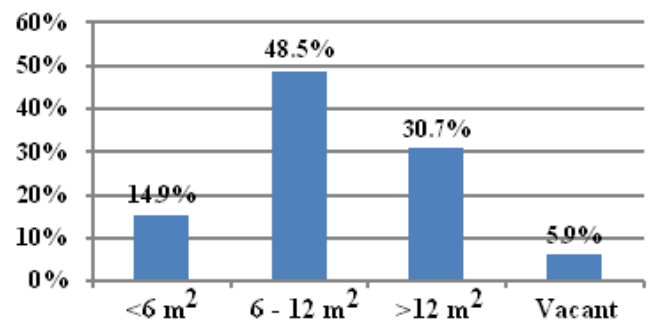

Figure 8: Number of rooms and their respective sizes

It was deduced that most of the rooms had been allocated enough working space for the employees (48.5%). However, the percentage of rooms that had more space than required was high (30.7%). This could imply that these rooms were under-utilized and could be sub-divided, if possible, to accommodate more employees, or employees could be brought on board without sub dividing the rooms. 14.9% were below the allowed working space, hence over-utilized. Vacant rooms were not many and they only constituted 5.9%. These were rooms that were unoccupied.

5.4. Fire assembly points

Figure 9 shows the areas that were found on site identified as fire assembly points while Figure 10 shows the proposed assembly points. Using Figure 9, it was observed that assembly point E could not hold up to one hundred people and the people it was serving could be well served by C and F. In addition to that, it was very closely located to C and hence could be eliminated as shown in the proposed layout.

There was another observation of many buildings closely located to each other in the middle part of the study area. These were laboratories and administration blocks being served by A, C and G, located on the periphery. There were two generators located on the lower side near the sewage ponds and therefore an assembly point could not be situated near them. In addition to that, the slope was beyond twenty five degrees in the potential areas. There was a proposal to add assembly point I to help serve these building better.

An observation was also made about lack of an assembly point where people could access with ease on the lower right side of the area and therefore assembly point D was proposed to serve the purpose. With establishment of D, B could be eliminated and have the people it was serving being served by either D or A. This was because the buildings around point B were animal holding units and had very few people working there.

The uppermost and upper left regions were the residential area and had been assigned assembly points F, G and H. This

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area had the residential houses and hostels where visitors spent when in the institute. Since this area is inhabited during the day and at night, there was a proposal to add assembly point J in order to help secure residents safely in case of fire or any emergency at any time of the day.
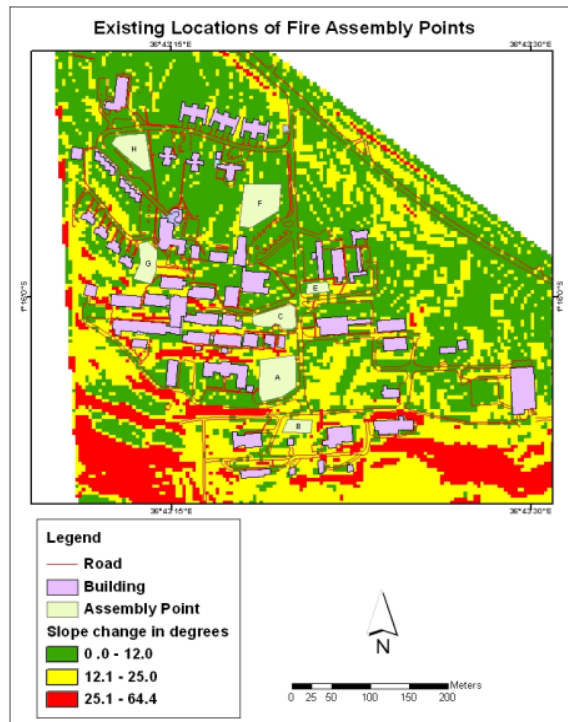

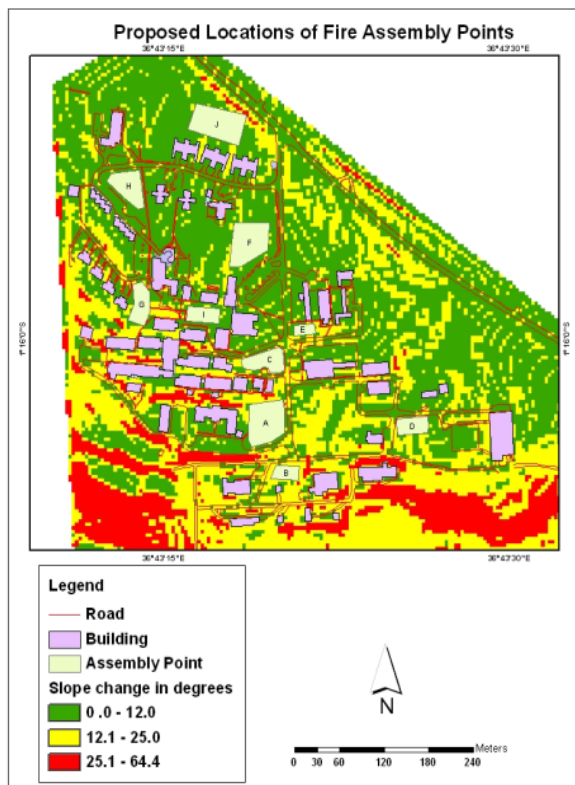
Figure 9: Existing locations of fire assembly points

Figure 10: Proposed locations of fire assembly points

5.5. Web Mapping

Web mapping helps in launching spatial data on the web which allows for better visualization as well as sharing of data over the internet. Figure 11 shows a map of the facilities with open street map from MapQuest used as the base map while Figure 12 shows the same with google earth satellite imagery as the base map. These maps were published in geoexplorer whereby a link to the web was produced and the maps were launched on Mozilla web browser.

The maps had user interface where commands that the user can use to navigate through the map were provided. These were the tools on the upper left corner of the maps which would allow a map user to view spatial entities in a web browser and interact with them through zooming in & out, panning around, selecting the features they want to view on the screen as well as viewing information about spatial features represented.
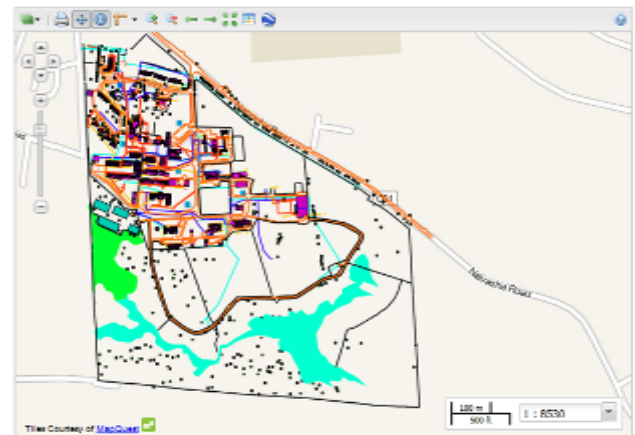

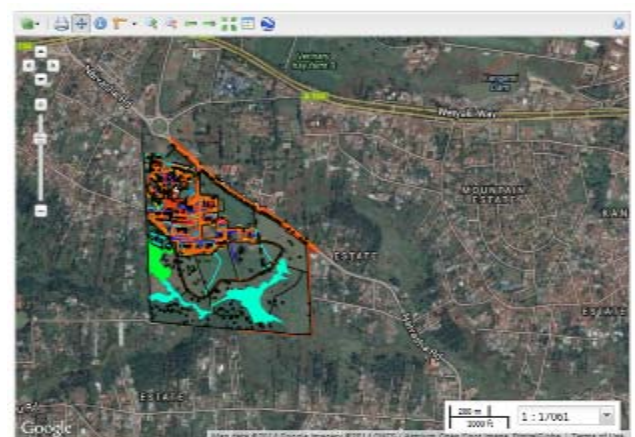**Figure 11:** Web map with open street map as base map

Figure 12: Web map with Google earth satellite imagery as base map

6. Conclusions

The results showed that GIS would be a useful tool in management of space in facilities. It would help in storage, updating, editing, querying, sharing of data in one platform, the very thing that was lacking in ILRI. Data which was used entailed AutoCAD and ArchiCAD drawings, Excel and PDF files. These were used to achieve the objectives of the

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project. A data management system in form of a geodatabase was built for the facilities in the institute using ArcGIS software. The geodatabase contained spatial and non-spatial data for underground and surface facilities. These facilities were buildings, roads, pavements, trees, sewage ponds, wire fence, steam pipe, foul water pipe, electricity cable, cold water pipe, horse reel, fire hydrant.

Analyses were then performed on the data in the geodatabase. The main facilities in the institute were identified as buildings (4.2%), roads & pavements (7.2%), open spaces (22.3%), wet & bushy area (8.2%) and the grazing area (57.8%). Analysis performed on the grazing area showed that it was bigger than what the animals kept needed by approx. 34 acres.

Furthermore, there was a proposal on how paddocking would be done on the grazing area and a proposal for locations of fire assembly points. Results of the analysis performed to assess space use in rooms showed that 14.9% were over-utilized, 48.5% were correctly utilized, 30.7% were under-utilized while 5.9% were vacant.

We recommend the use of a three dimensional (3-D) model for the management of ILRI facilities. 3-D visual if modeled and animated for ILRI facilities can enable facilities managers to effectively visualize, plan, analyze, and design spatial data. A 3-D virtual tour of ILRI can enable users to view a facility from multiple viewpoints and walk around or fly through digitally. In addition, users can use the 3-D visual for analysis of evacuation routes or crime patterns in the institute [9]. This would provide the best visual interpretation for planners and decision makers.

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Author Profile

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