

GIS-Based Inventory of Irrigation Networks Using LiDAR Derived Datasets in Licab, Nueva Ecija

A. M. P. Alberto¹, G. N. Ramos², G. B. Damian³

^{1,2}Institute of Climate Change and Environmental Management, Central Luzon State University (CLSU), Science City of Muñoz, Nueva Ecija 3120, Philippines

³Institute for Climate Change and Environmental Management, Central Luzon State University, Muñoz, Nueva Ecija, 3120
(¹melindapaz@gmail.com, ²gloramos151@gmail.com, ³virysse10@gmail.com)

Abstract-In 2002, the registered farms for agriculture use in Central Luzon has a total of 341.5 thousand, covering 552.1 thousand hectares. The region's total agricultural land area comprised 25.6 percent of the region's total land area including the 4th class municipality of Licab in Nueva Ecija. Agriculture has remained the prime industry of the municipality. Agricultural lands of Licab is devoted to various agricultural activities cover about tens of thousands hectares out of the total provincial area of 550,718 hectares. Rice is still the prime crop of agricultural development and programs. Palay production in the town is boosted by a large network of irrigation facilities and other appurtenant structure.

Irrigation networks are important in distributing water resources to areas in which rainfall is not enough to sustain agriculture. A detailed inventory of irrigated crop acreage is not available at the level of resolution needed to accurately estimate water use or to project future water demands in many areas of the country. With the lack of studies about irrigation feature extraction, which range from wide canals to small ditches, this study aims to present a method of extracting these features from LiDAR-derived digital terrain models (DTMs) using Geographic Information Systems (GIS) tools such as Whitebox Geospatial Analysis Tools (Whitebox GAT) and ArcGIS. High-resolution LiDAR DTMs with 1-meter horizontal and 0.25-meter vertical accuracies were processed to generate the gully depth map. This study also provides a detailed digital map and summary of irrigated areas for 2013 within the municipal boundary of Licab. The irrigated areas were delineated using LiDAR data and orthoimagery that were then field verified between March and May 2015. The irrigation structure delineated have a total length of 89.25 km and a total length of 42.23 km stream which can also be a source of irrigation water.

Keywords- *Geographic Information System, LiDAR, Whitebox GAT, DTM, Delineation*

I. INTRODUCTION

Remote sensing provides fast and efficient monitoring which include indirect access to certain places. Through day by day advancement, it has enabled many activities thought impossible to be conducted. Remote Sensing is an effective

tool to monitor irrigated lands for several decades over a variety of climatic conditions and locations.

Nowadays, the availability of high-resolution digital terrain model (DTMs) is derived through the advancement of remote sensing such as airborne LiDAR (Light Detection and Ranging) technology that has permitted significant advances in different field of science, including analysis and mapping (Booth et al., 2009; Tarolli et al., 2012). DTMs are a topographic informative layer useful for the automatic definition of the drainage paths. These terrain models offer an unprecedented capability to interpret surface morphology and the related geomorphic and hydrological processes [Tarolli et al., 2009; Trevisani et al., 2012]. Accordingly, also research in channel network analysis greatly benefits from the availability of HR-DTMs [Cavalli and Tarolli, 2011] which favor the application and development of several techniques for the identification of channel heads and the extraction of channel networks.

Irrigation systems consist of man-made structures responsible for supplying water in agricultural areas to increase yield and maintain a stable temperature of crops (Rapinel et al., 2013). Irrigation plays an important role in the improvement of farm production and in the effectiveness of other inputs. Irrigation water is applied to supply the essential moisture needed by crops and to maintain a favorable water balance in the crop root zone. Irrigation was an essential means for increasing the production of agricultural crops in Central Luzon where the Municipality of Licab is included. As the earth's population continues to increase and the demand for food, fuel, and fiber rises, continued agricultural intensification will require at least a 50 percent increase in water resources, especially in arid and semi-arid regions (SIWI).

II. OBJECTIVES

The main objective of the study was to map the irrigation networks in the municipality of Licab, Nueva Ecija as of 2013 (date when the LiDAR data was acquired). Specifically it aims to:

1. Determine the total length of the irrigation networks in the municipality of Licab, Nueva Ecija, and

2. Determine the irrigated land area based on the land cover of Licab, Nueva Ecija as of 2013.

III. METHODOLOGY

A. Location and Study Area

The municipality of Licab in Nueva Ecija is a fourth class municipality with a population of 26,187 according to the 2010 census. The municipality has a total land area of 54.71 km² which is covered by different land cover classifications. Agriculture has remained the prime industry of the municipality where agricultural lands devoted to various agricultural activities cover about tens of thousands hectares out of the total provincial area of 550,718 hectares. Figure 1 shows the map of Nueva Ecija showing the location of the municipality of Licab.

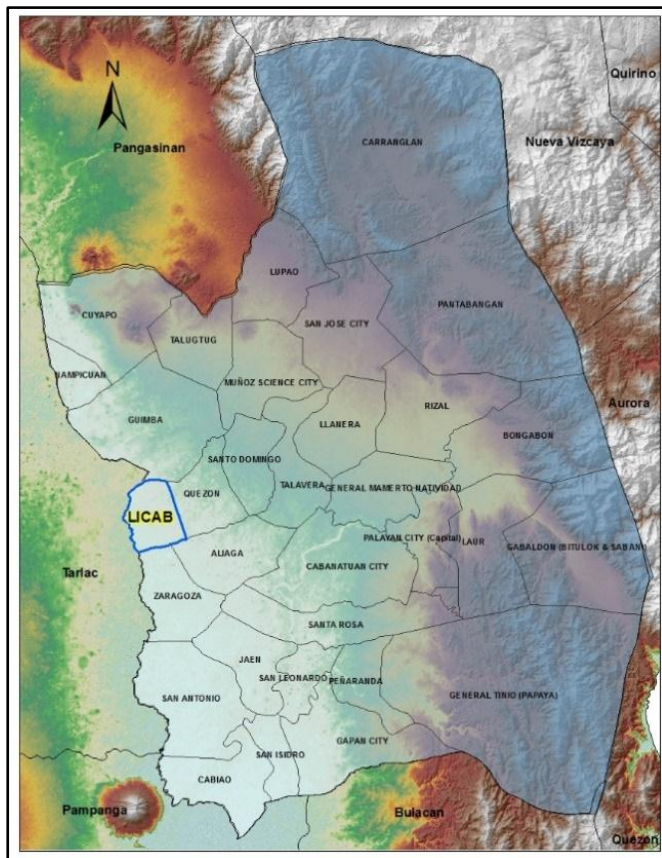


Figure 1. Map of Nueva Ecija showing the location of Licab

B. Datasets and Software used

The LiDAR derived Digital Terrain Model (DTM) with 1-meter resolution (acquired by the Disaster Risk Exposure and Assessment for Mitigation – Data Acquisition Component (DREAM-DAC) of the University of the Philippines Diliman) was processed using various filters with the use of the ArcGIS software. The Digital Terrain Model (Figure 2) have the Mean Sea Level as vertical datum and were delivered in ESRI GRID format with Universal Transverse Mercator (UTM) Zone 51 North projection and the World Geodetic System (WGS) 1984 as horizontal reference. Using the extracted control points collected through field validation, calibration value was identified using statistical computations to assess the quality of data and obtain the value for the vertical adjustment of the DTM.

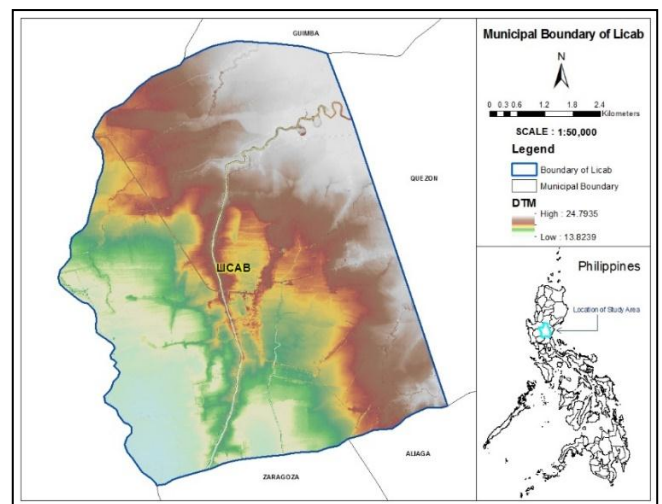


Figure 2. Available LiDAR DTM of Licab, Nueva Ecija

C. Irrigation networks extraction

The extraction of irrigation networks have undergone different process and used different software (Figure 3). The processed DTM was used in the generation of gully depth map (Figure 3) using the Whitebox GAT software. The values of the depth were indicated in the created .dep file from the MGD tool which means that the higher the value, the deeper it is. Irrigation networks (Figure 5) were digitized using ArcGIS environment with the use of the generated map gully depth as a guide. The extracted irrigation networks were undergone quality checking and field validation.

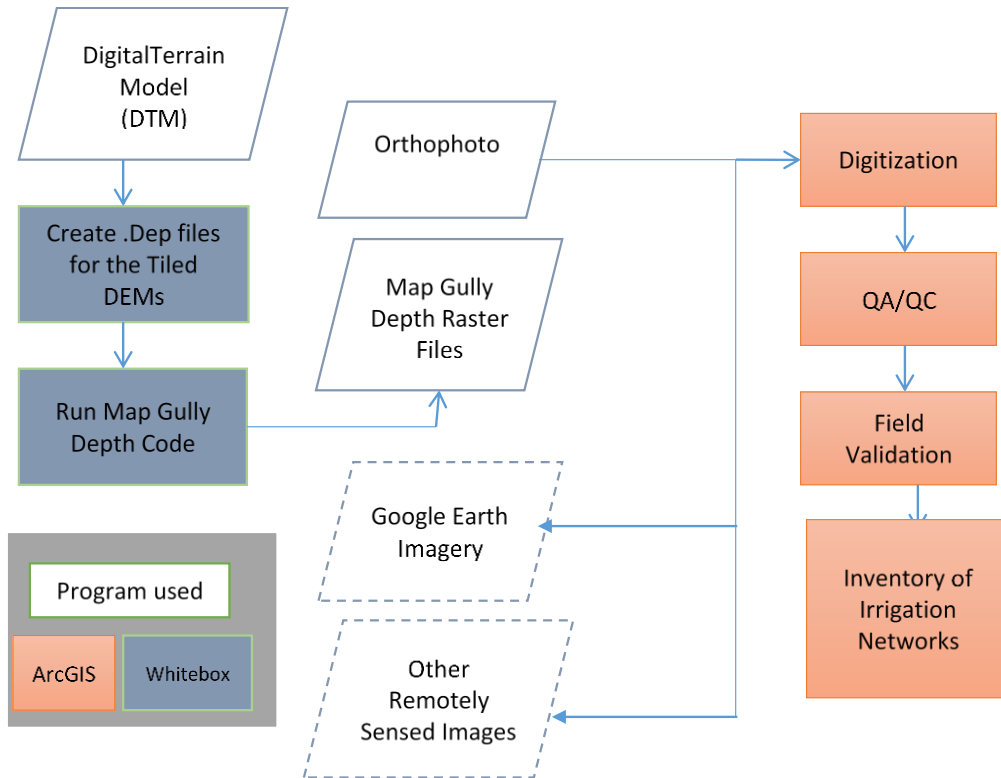


Figure 3. The Conceptual Framework of Irrigation networks extraction

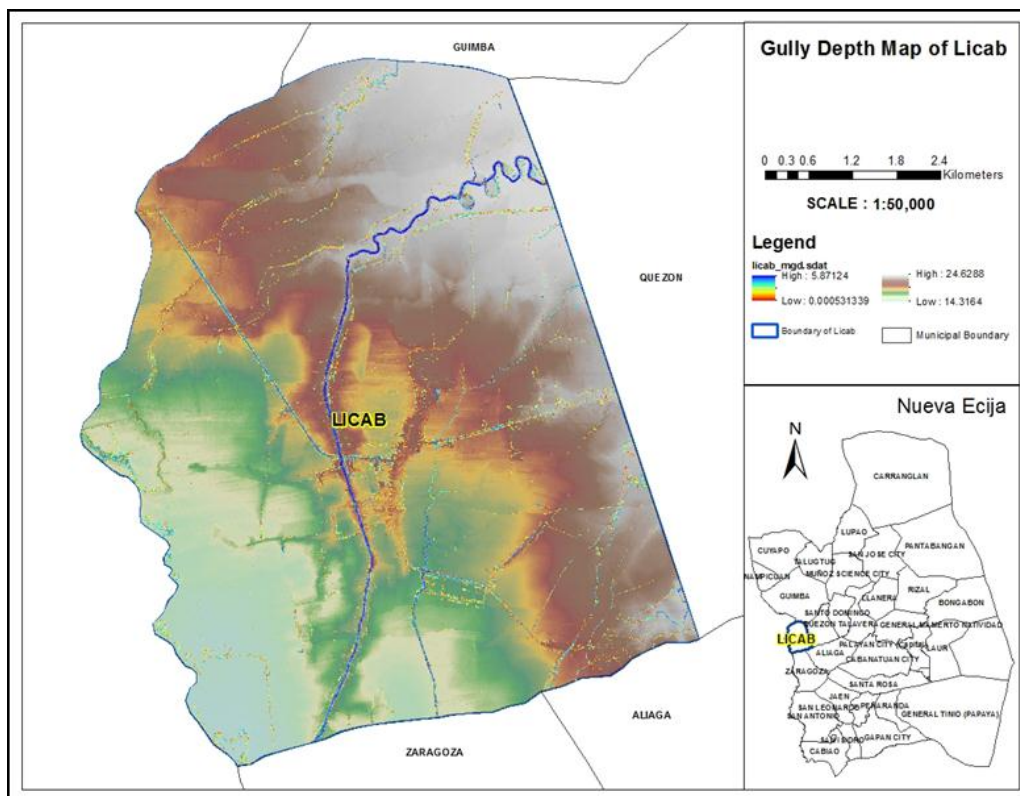


Figure 4. Generated Map Gully Depth of Licab, Nueva Ecija

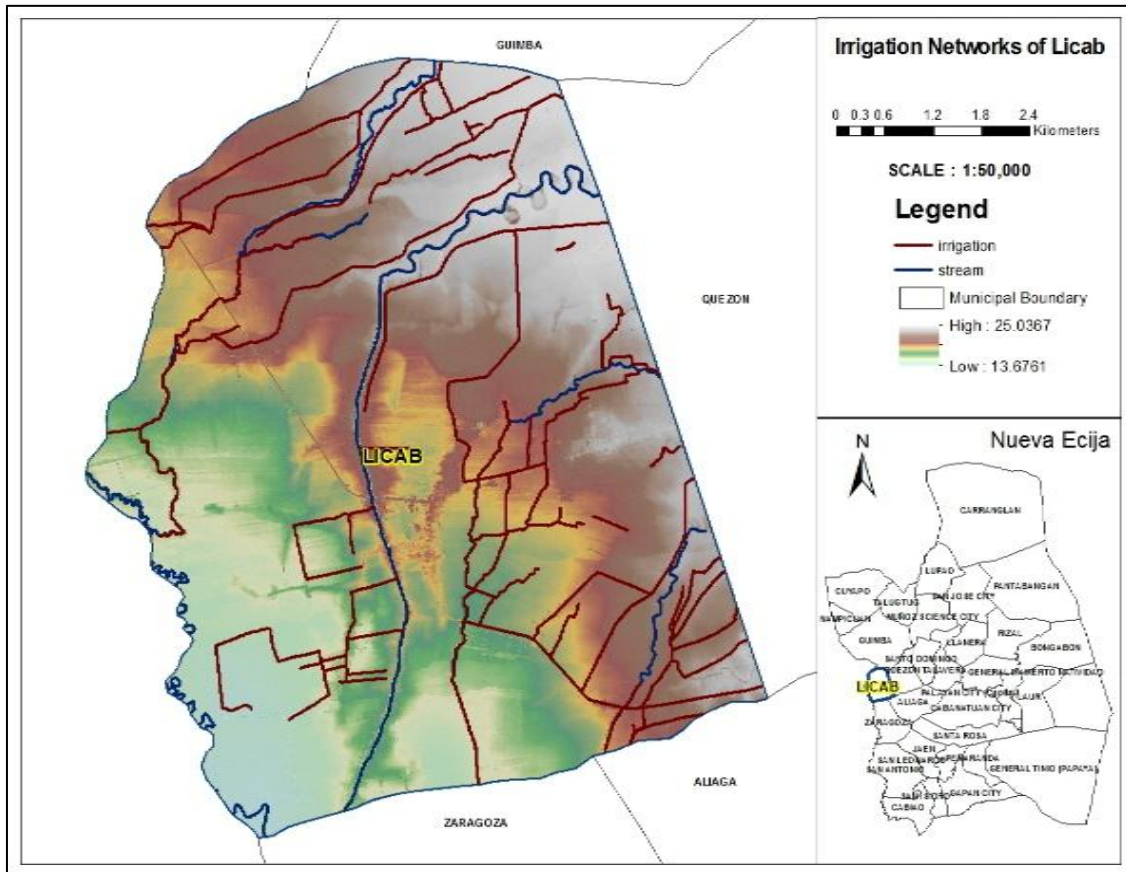


Figure 5. Digitized irrigation networks guided by the generated Map Gully depth

D. Irrigated Land Area Identification

The land cover of Licab was produced through shapefiles from Philippine Agricultural Resources Mapping (PARMAP) component of Central Luzon State University – Philippine Light Detection and Ranging 2 (CLSU Phil-LIDAR 2). The LiDAR data and Orthophoto were processed using different software to generate different point cloud derivatives for the extraction of agricultural land cover map. The BLAST2DEM software was used to generate Digital Terrain Model (DTM) and Digital Surface Model (DSM), LASgrid software was used to generate building layer, Intensity and Number of returns, Envi software was used to produce derivatives such as RGB and GRVI, and the ArcGIS on the other hand was used to generate normalized DSM (nDSM), Curvature, Road layer, Water Layer, training points and validation points (Alberto et.al, 2016). All derivatives (Figure 6) were loaded in Ecognition developer for Object Based Image Analysis using Support Vector Machine (SVM). The support vector machine is a supervised learning method that generates input-output

mapping functions from a set of labeled training data (Wang, 2005). Using spatial analysis, the extracted land cover classification project were loaded in ArcGIS to determine the different land covers areas, crop type, primary water source, and type of irrigation system.

E. Field Validation

Validation was done to determine the accuracy of the extracted irrigation networks. Points for validation were generated using the random sampling method called Weighted Disproportionate Stratified Systematic Random Sampling (WDSSRS) where twenty (20) points were created. Also, accuracy assessment was done to determine the accuracy of the generated outputs.

For the land cover of Licab, field validation was also done in order to attain the ground true features of the municipality and to identify the accuracy of the produced map. Figure 7 shows the sample validation points used in validating the different land cover class of Licab, Nueva Ecija.

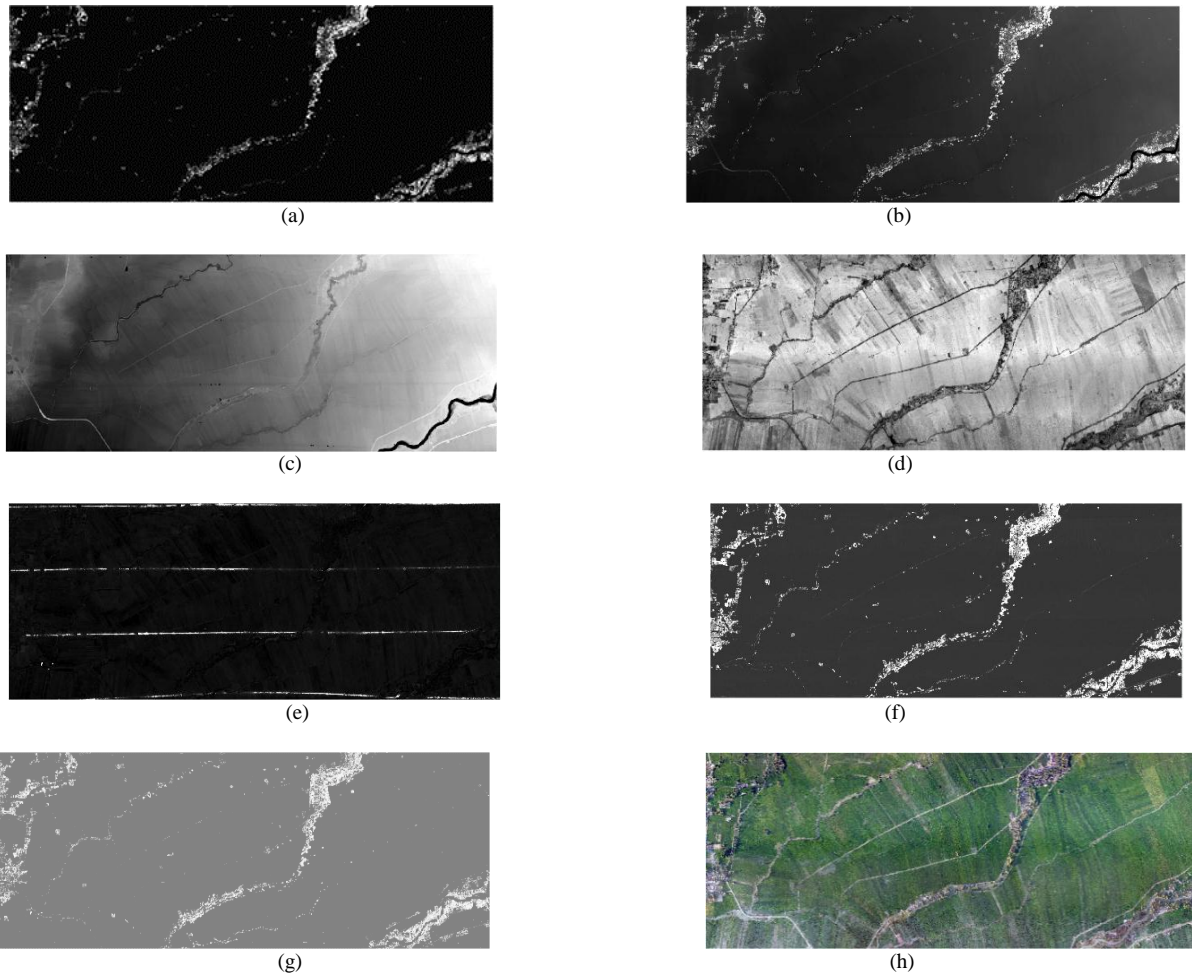


Figure 6. Different derivatives used to generate land cover classification map (a) CHM, (b) DSM, (c) DTM, (d) GRVI, (e) Intensity, (f) nDSM, (g) numret and (h) rgb



Figure 7. The sample validation points used in validating different land cover class of Licab, Nueva Ecija

IV. RESULTS AND DISCUSSION

A. Inventory of Irrigation Networks

Based from the map generated, the delineated irrigation structure and stream network has a total length of 89.25 km and 42.23 km, respectively. With the availability of high resolution LiDAR data, the extraction of different water structures is possible. The accuracy of the delineated irrigation networks was 95% or 19 of 20 points were correct with respect to the ground truth.

B. Land Cover Classification Map of Licab, Nueva Ecija

From the total area of 54.71 sq.km., the municipality has a total of 9 land cover classes namely; Bareland, Built up, Fallow, Grassland, Mango, Non Agricultural Trees, Rice, Road and Water. The average accuracy and kappa coefficient of the produced map were 97.66 % and 94.41%, respectively. The generated Land Cover Classification Map or Agricultural Map of Licab, Nueva Ecija is shown in Figure 8. Using spatial analysis, the extracted land cover classification was loaded in ArcGIS to determine the total area of each classification which is shown in Table 1.

In remote sensing, the precise definition of what is considered to be irrigated lands are areas that receive full or partial application of water by artificial means to offset periods of precipitation shortfalls during the crops growing period (Ozdogan et. Al., 2010). In this study, total irrigated land area was identified using identifying factors such as rice, vegetable and fallow. From the total area per classification, Figure 9 presents the total irrigated land area of 49.43 square kilometers.

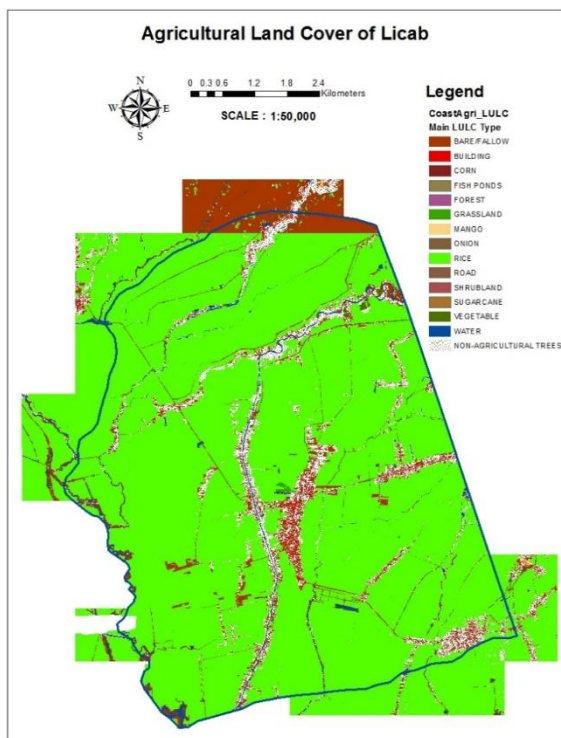


Figure 8. Land Cover Classification Map (Agricultural Map) of Licab, Nueva Ecija

TABLE I. LAND COVER CLASSIFICATION OF LICAB, NUEVA ECIA

Land Cover Classification	Land Area (km ²)
Water	0.738
Fallow	2.843
Building	0.601
Road	0.356
Grassland	0.033
Mango	0.001
Vegetable	0.041
Rice	46.549
Trees	3.544
Total land area	54.71

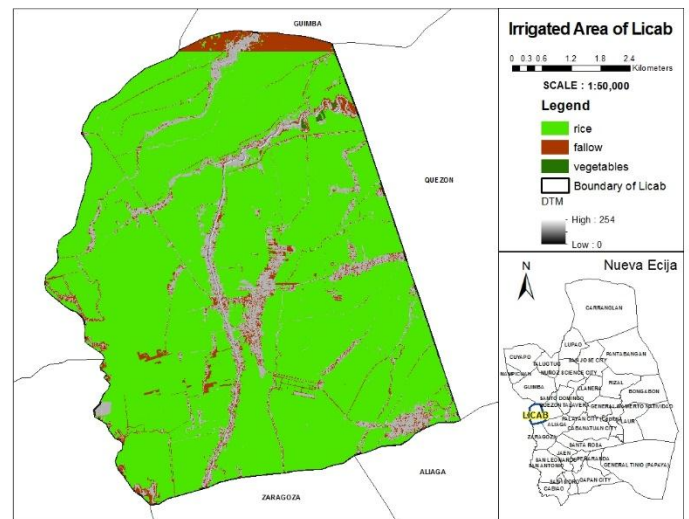


Figure 9. Irrigated area (Agricultural Map) of Licab, Nueva Ecija

V. CONCLUSIONS

The main purpose of this study was to determine the total length of irrigation networks in Licab, Nueva Ecija, Philippines using LiDAR DTM. The study found out that most of the detected and extracted irrigation networks in the municipality of Licab, Nueva Ecija are concrete irrigation canals. The total length of the irrigation networks is 89.25 km while the total length of stream is 42.23 km.

Remote Sensing offer tremendous advantages for irrigated area mapping problems at various temporal and spatial scales. With the availability of high-resolution satellite imagery, the use of remote sensing data has become very important for the assessment and estimation of crop hectarage and irrigated area in the municipality of Licab, Nueva Ecija. Since Licab is mostly covered by rice class, mapping of irrigation networks is very important to determine the possible irrigation development and planning that should be done.

Map shows different informations with specific uses. In this study, service area of a certain irrigation network can easily be located. With the area of land covers identified and with the elevation data that can be seen in the LiDAR DTM, the

irrigation water that should be supplied in the whole area can possibly be computed.

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