ABSTRACT

Rice is the major agricultural land use in the world which feeds about 50 percent of its population. This thesis demonstrated an approach to map the change in the spatial extent of rice cultivation using the Remote Sensing (RS) and Geographical Information System (GIS) techniques. The temporal and spatial pattern of change in rice fields from 1995 to 2011 in the Paro valley, Bhutan was analysed with relevant ancillary data to discover some of its major causes (drivers). The conservation of the natural environment is one of the four pillars of Bhutan's development philosophy – Gross National Happiness (GNH); and the 71 percent of the country which is forested provides a habitat for some of the world's endangered species of flora and fauna. Since early 2000, urbanization in Bhutan has expanded rapidly, with this posing a potential threat to both environmental conservation and the supply of agricultural land which is the main source of livelihood for almost 60 percent of the population.

Because information, especially at a local scale, on the change in rice cultivation is not available in Bhutan, this project utilised satellite imagery to derive estimates of rice cultivation in the Paro valley over 16 years. The project employed three broad areas of geospatial science; viz. i) satellite image pre-processing, ii) Land use land cover (LULC) change mapping and iii) spatial analysis to discover some of the causes behind the change in rice fields. Level-2 processed Landsat-5 Thematic Mapper (TM) images of September 1995, August 2005 and August 2011 (summer growing season) were used. Other suitable imagery (satellite or airborne) were not available especially in 1995. Pre-processing and data preparation steps covered verification of geometric registration of images, cloud masking, principal component analysis (PCA), normalized difference vegetation index (NDVI), and extraction of relative heights from the major rivers using a Digital Elevation Model (DEM) from the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) sensor on board Advanced Land Observation Satellite (ALOS). Supervised and unsupervised classifications were performed on five data sets: i) PC1-NDVI-DEM, ii) PC1-PC2-NDVI-DEM, iii) PC1-PC2-NDVI-Relative DEM, iv) PC1-PC2-NDVI-DEM-Relative DEM and v) the original Landsat-5 TM image. Accuracies of ten different LULC classification were compared on a pixel-by-pixel basis with the field cadastral survey data of 2011 which also recorded LU. All geospatial analyses were carried out in ERDAS Imagine 2018 and ArcGIS version 10.6.

Contrary to the findings from the previous literature, none of the composite data of using PCAs, NDVI and or DEM yielded better accuracy than classifications from the original image.

Supervised classification of the original TM image produced the highest accuracy. Hence, the maximum likelihood classifier was used for supervised classification of the 1995 and 2005 TM images. Classification accuracies for rice and other crops from the 2011 TM image were 81.4% and 66.6% respectively, with very high confidences. After applying the same methodology of image classification to earlier dates, a trend of change in LULC from 1995 to 2011 was determined. Despite relatively low accuracy (≈70%) for the post-classification change detection, the rice showed an increase in total area of about 500 hectares. This result for the change in rice field was analysed with available ancillary data to explain the possible causes of the increase in the Paro valley. It was found that substantial increase in rice from 1995 to 2011 correlated to the population increase and economic development that occurred during the study period. The coarser spatial resolution of the Landsat imagery and small plot size of rice field created mixed spectral and thus degraded the classification accuracy. Landsat imagery does not seem be suitable for this type of study in similar terrain.