UCL INSTITUTE FOR RISK AND DISASTER REDUCTION

LANDSLIDE SUSCEPTIBILITY MODELLING USING GEOSPATIAL TECHNIQUES: A CASE STUDY OF COX'S BAZAR MUNICIPALITY, BANGLADESH

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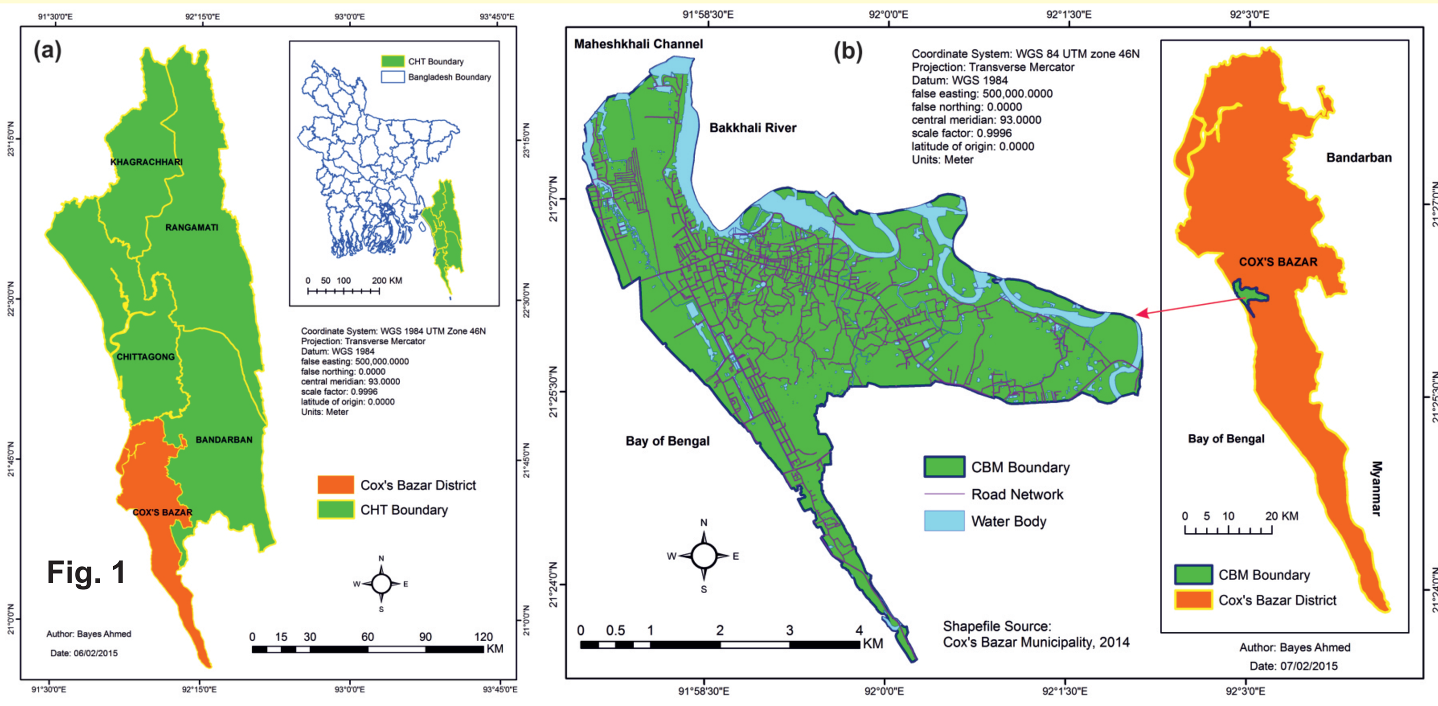
1. Background

Landslide hazards are a common threat for the people living in the hilly slopes of Cox's Bazar Municipality (CBM), Bangladesh. Every year during the monsoon period, landslide hazards are continuing to cause human casualties, injuries, and property damage. This is happening because of the increase of urban population, indiscriminate hill cutting, inappropriate agricultural practice, unplanned city planning, development of unauthorized settlements in dangerous steep slopes, and lack of institutional capabilities to reduce the community vulnerability. At this drawback, the main objective of this article is to prepare the landslide susceptibility maps to help reducing the risks of landslide disasters in CBM.

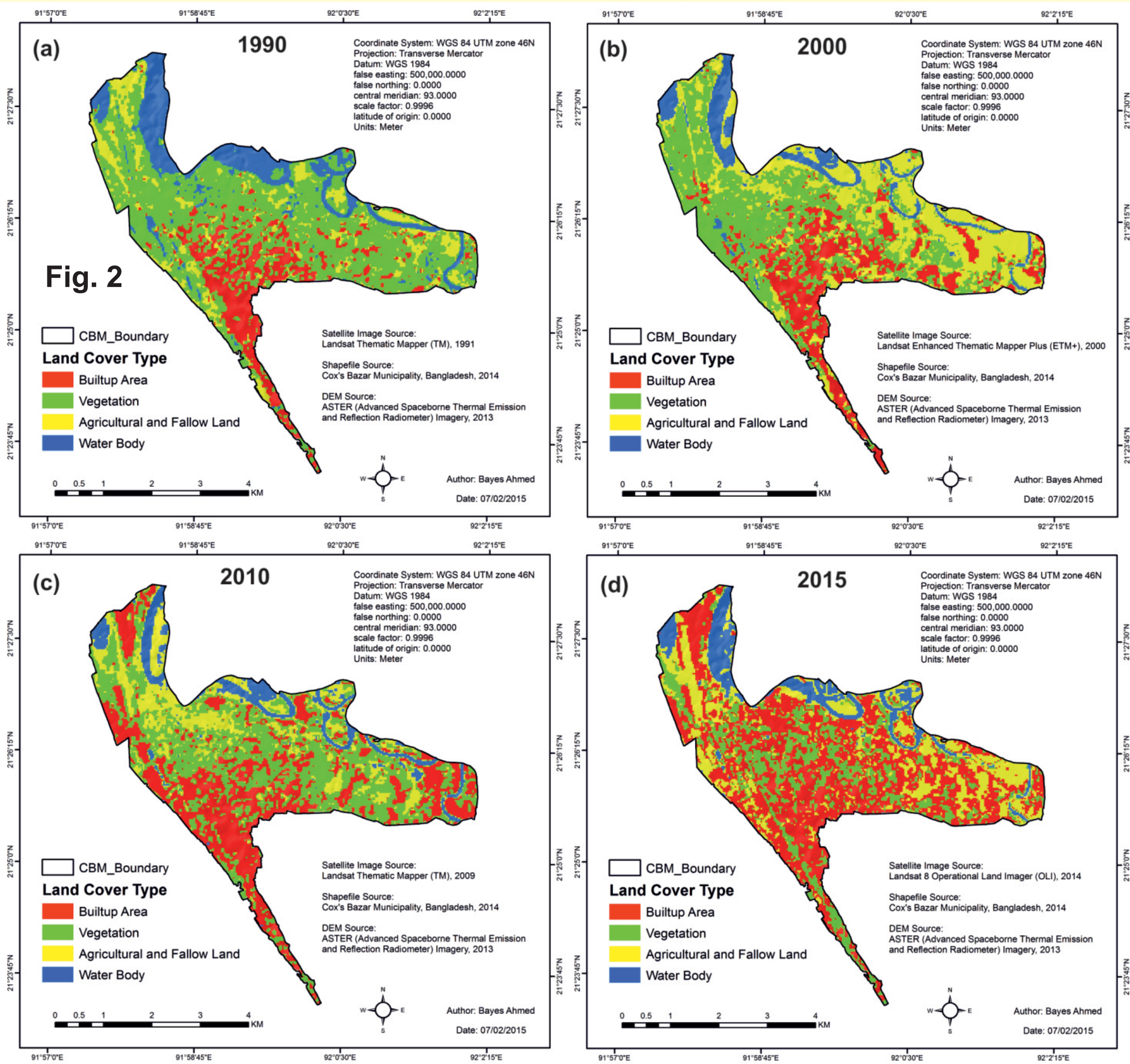
2. Study Area Profile

CBM is located in Cox's Bazar District (CBD) that is one of the five districts of the Chittagong Hill Tracts (CHT) region (Fig. 1a). The study area, CBM, is approximately situated within 22° 23′ 30″ and 22° 27′ 30″ north latitude and between 91° 58′ and 92° 2′ east longitude (Fig. 1b).It is bounded on the west by the Bay of Bengal, on the north-east by *Bakkhali* River, and on the north by *Moheshkhali* Channel (Fig. 1b). The population of CBM increased fourfold in the past two decades (1991-2011), which is now about 1,67,477. The urban built-up area of CBM increased by three-fold (Fig. 2) from 1990-2015.



3. Methodology

For preparing the landslide susceptibility maps, a landslide inventory map with 74 historical locations and 12 factor maps are produced (Figs. 3-14). Two weight-based qualitative (WLC, and AHP), and two data-driven statistical (logistic regression, and multiple linear regression) techniques were chosen. Artificial Hierarchy Process (AHP) involves pair-wise comparison of factor maps.Each factor map is assigned with a weight (9-point scale) against other factor to construct pair-wise comparison matrix. The Weighted Linear Combination (WLC) is a simple additive weighting method. In WLC, a weight is assigned to each factor. The weights are assigned based on expert opinion surveying and field work experience. In Logistic Regression (LR) model, the dependent variable can have only two values: 1 (landslides exist) and 0 (landslides do not exist). LR can produce surface interface using the probability. It can be described as follow:

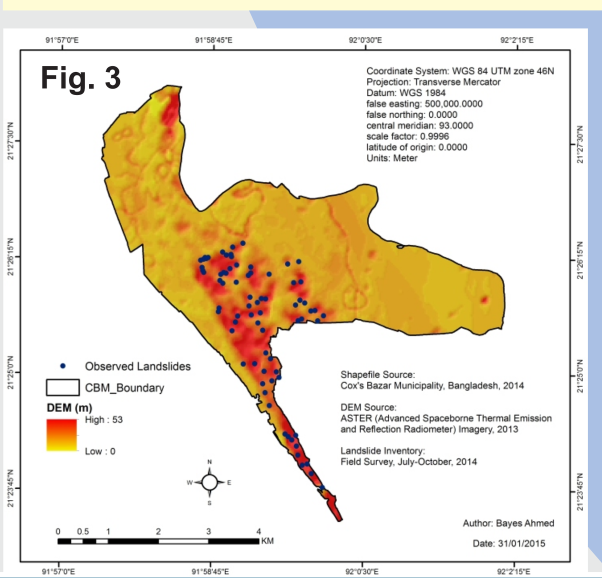


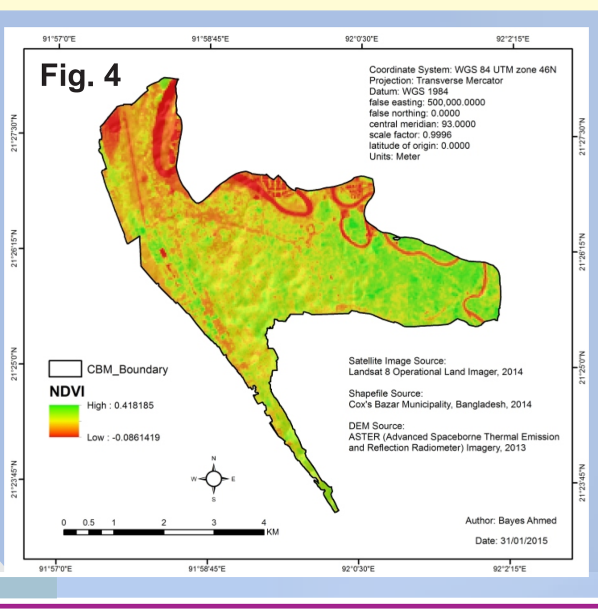
$$Y = Logit(p) = ln(p/(1-p)) = C_0 + C_1X_1 + C_2X_2 + \ldots\ldots + C_nX_n$$

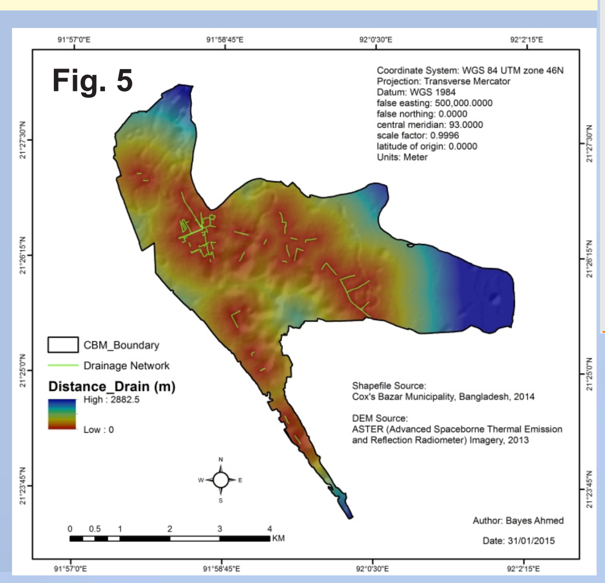
Where p = the probability that the dependent variable (*Y*) is 1, p/(1-p) = the likelihood ratio, C_0 = the intercept; and C_1, C_2, ..., C_n = coefficients, which measure the contribution of independent factors (X_1, X_2, ..., X_n) to the variations in *Y*.

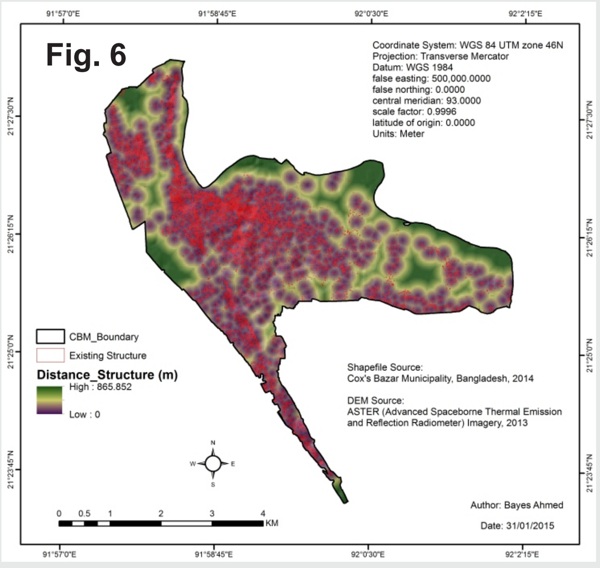
Multiple Logistic Regression (MLR) model considers multiple explanatory variables. In MLR, the landslide occurrence is expressed as a continuous variable (Ohlmacher and Davis 2003). The MLR model for the log odds is:

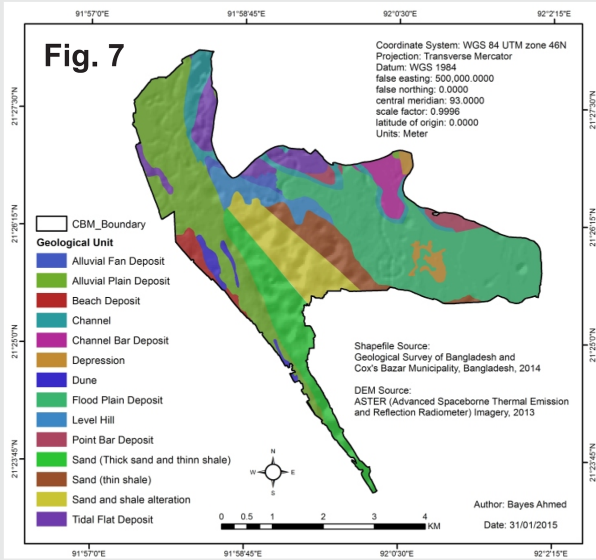
$$logit[P(Y = 1)] = \alpha + \beta_1x_1 + \beta_2x_2 + \ldots\ldots + \beta_kx_k$$

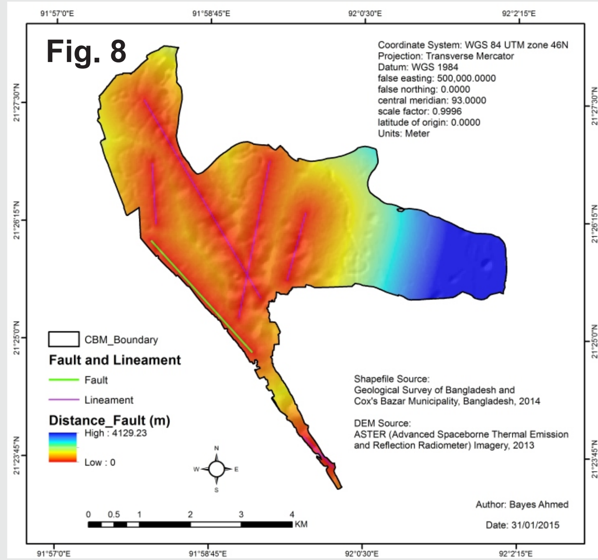


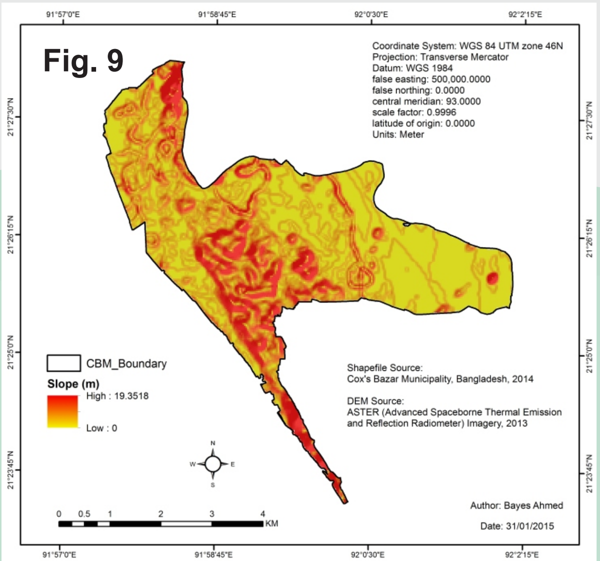


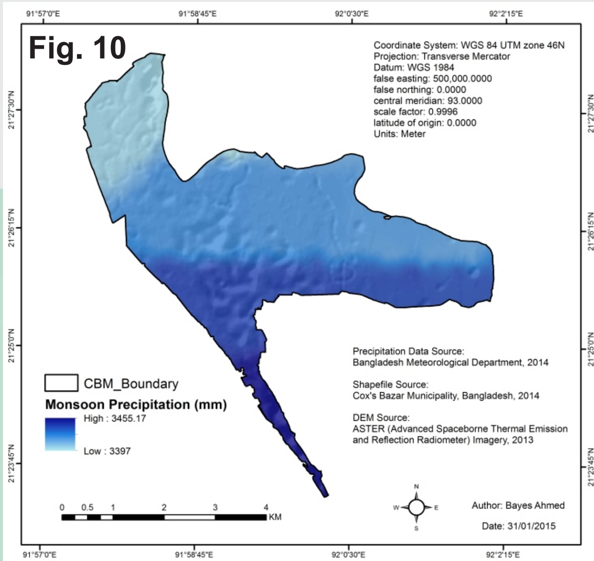


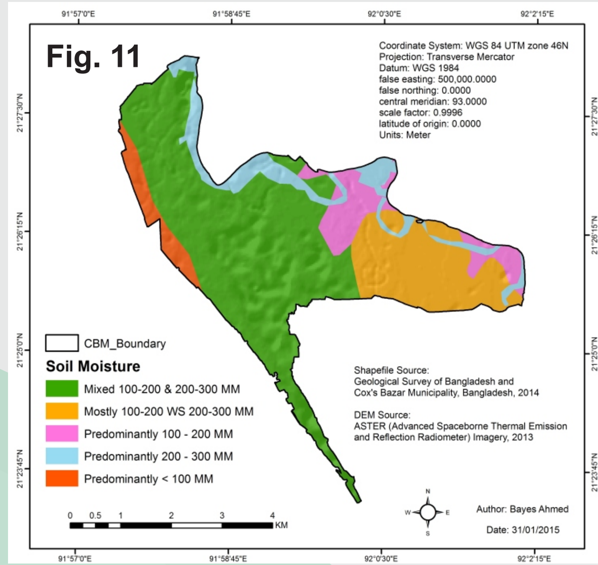


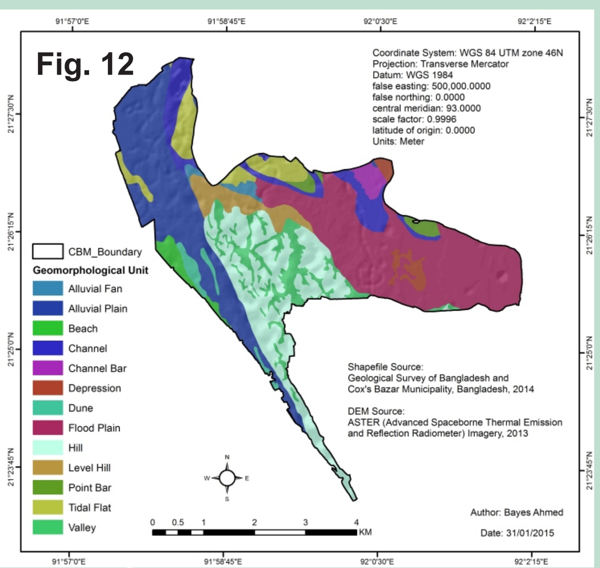


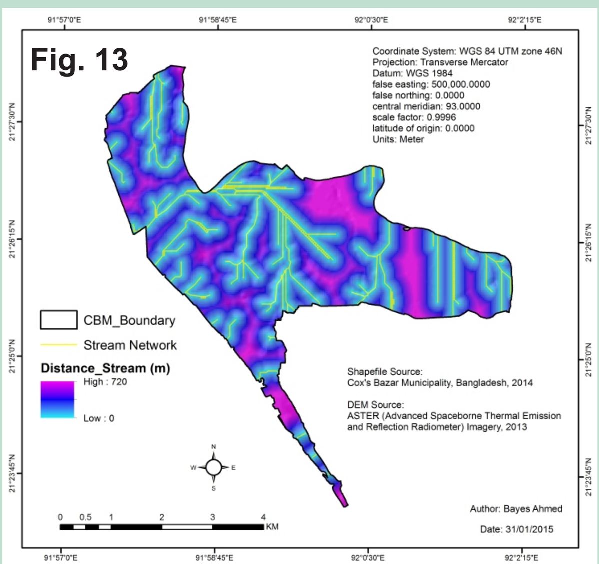


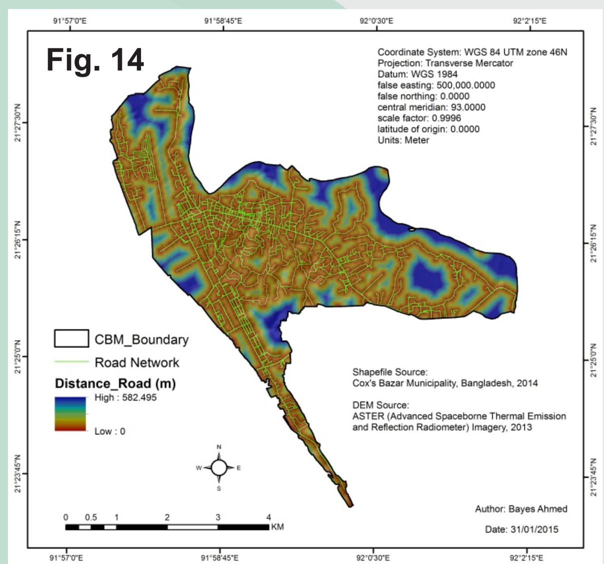










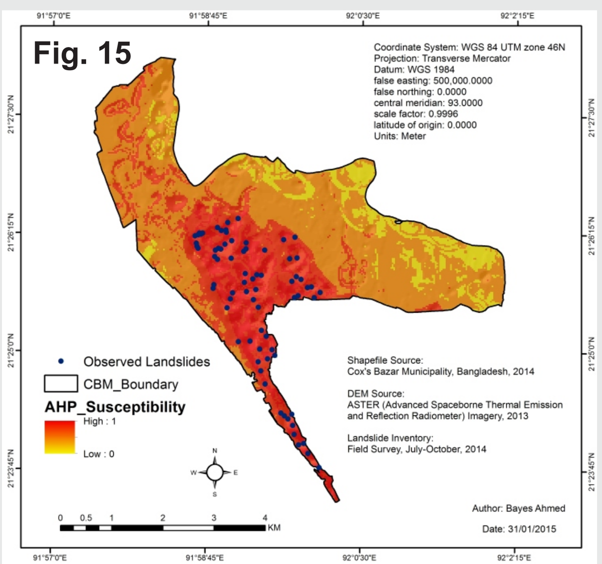


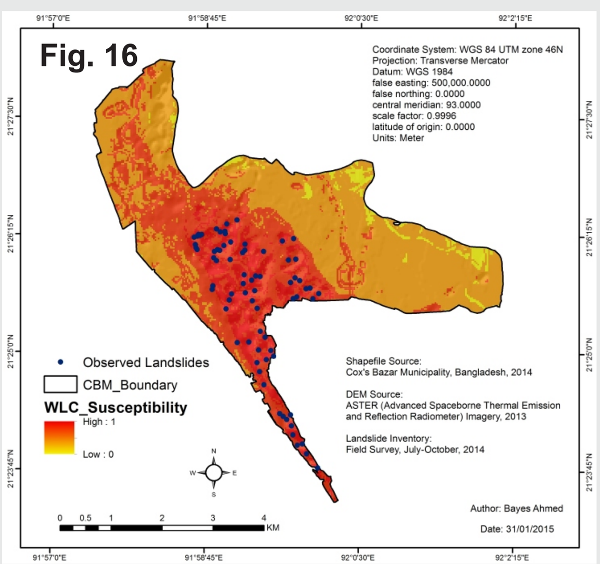
4. Results and Discussion

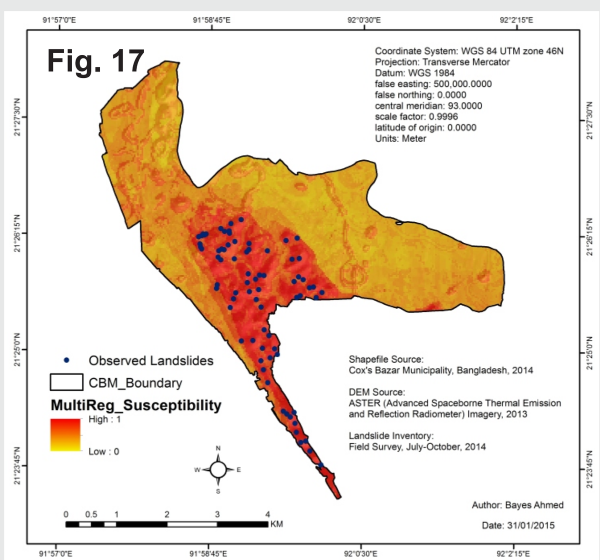
For LR analysis, the Boolean landslide inventory map is considered as dependent variable, while thefactors maps as independent variables. The regression equation is found as follows: logit(landslides) = -144.8048 - 0.284121*SR - 0.756613*DR - 0.529084*FA + 0.486189*GE + 1.776796*GM - 0.030485*LC + 17.448088*NV - 1.465677*PR + 0.159403*RO + 0.287524*SL + 17.452729*SM + 0.306172*ST.

The MLR equation is found: landslides = -0.0098 + 0.0003*SR - 0.0004*DR- 0.0003*FA + 0.0002*GL + 0.0031*GM- 0.0005*LC + 0.0012*NV + 0.0012*PR- 0.0003*RO + 0.0017*SL - 0.0001*SM + 0.0005*ST.

The landslide susceptibility maps (LSM) prepared from AHP, WCL, and MLR methods are depicted in figures 15-17.







To determine the statistical reliability of the results, the Area Under the Relative Operating Characteristic (ROC) Curve (AUC), or simply AUC method is employed. The AUC is a good indicator to evaluate the performance of a model qualitatively and it is being widely used for LSM validation. AUC values <= 0.5 indicate no improvement, between 0.7 and 0.9 indicate reasonable agreement, and AUC >= 0.9 represents ideal situation. Fig. 18 shows the calculated AUC values (using equal interval, thresholds of 25% and 10% stratified random samples) for LSM, indicating the accuracy of the models implemented. AUC values of AHP, WLC, LR and MLR are found as 0.889, 0.859, 0.749 and 0.904, respectively, indicating acceptable level of performance. It can be concluded that only MLR generated LSM is found ideal in terms of the model validation results.

The current trend of hazard mapping is associated with computer assisted GIS and RS techniques. This kind of inductive technique neglects the views and vulnerability of the people living at landslide risks. Therefore, the urban planners and researchers should focus more on incorporating local, cultural and indigenous knowledge through community based participatory hazard mapping.

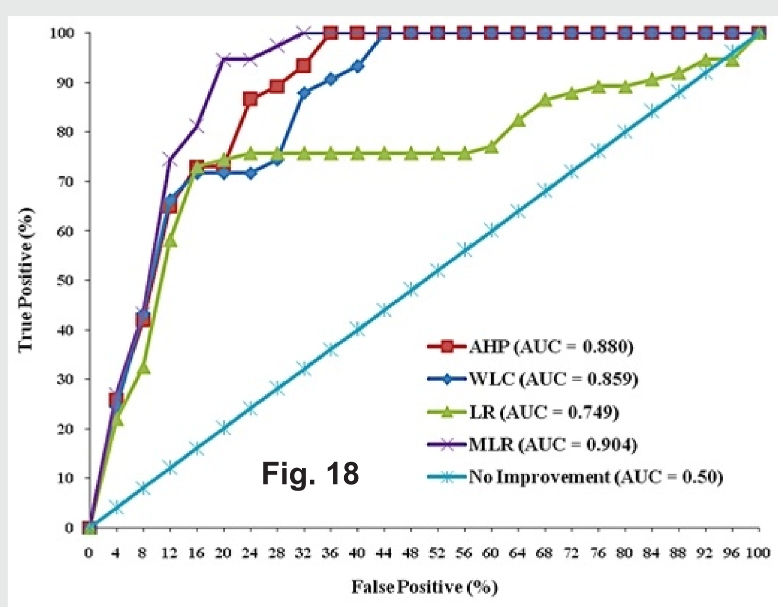


Fig. 18

2015 Unidata Users Workshop. Data-Driven Geoscience: Applications, Opportunities, Trends, and Challenges.
Date: 22-25 June 2015. Location: Boulder, Colorado, USA

ACKNOWLEDGEMENTS