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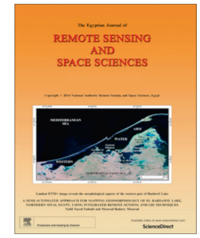

RESEARCH PAPER

# Spatiotemporal Land Use Land Cover change analysis and erosion risk mapping of Azad Jammu and Kashmir, Pakistan

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**Abstract** Land Use Land Cover (LULC) change analysis assists decision makers to ensure sustainable development and to understand the dynamics of our changing environment. During the past 15 years the study area has undergone many LULC changes due to rapid urban growth, poorly planned infrastructural development and a devastating earthquake event. This study was proposed to detect LULC changes and to investigate the major factors that have caused these changes. Steep topography, shallow soils and monsoonal climatic conditions tend to accelerate soil erosion that causes heavy sedimentation downstream. Therefore, erosion risk mapping was performed to prioritize the vulnerable areas for conservation efforts. For LULC change detection and analysis temporal Landsat satellite data captured by Thematic Mapper (TM) were employed. Maximum Likelihood (MLH) supervised classification algorithm was applied to classify the study area, whereas, Post Classification Comparison (PCC) approach was adopted to analyze the LULC changes. Soil erosion risk map was generated using four erosion controlling factors including rainfall, topography, soil erodibility and LULC. Results revealed that over a period of 11 years, a decrease has taken place in forest and low vegetation cover at a change rate of −02.70% and −02.60% respectively. On the other hand, built up and bare soil have increased at a rate of 01.00% and 04.20% respectively. The resultant erosion risk map shows that 59% of the area lies under low risk zone whereas 24%, 5% and 12% of the total area fall in medium, high and very high risk categories respectively.


## 1. Introduction

Land Use (LU) and Land Cover (LC) are two fundamentals describing the terrestrial environment in connection with both natural processes and anthropogenic activities (Jansen and di Gregorio, 2002; Bender et al., 2005; Mendoza et al., 2010,

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2011). The integrated term Land Use Land Cover (LULC) includes both categories of LU and LC and analysis of changes is of prime importance to understand many social, economical and environmental problems (Pelorosso et al., 2008). In recent years, LULC change analysis has emerged as an important research question, because LULC change has been identified as a key factor which stands responsible for environmental modification worldwide (Xiao et al., 2006). Though it is possible to monitor LULC changes by involving traditional surveys and inventories but Satellite Remote Sensing (SRS) apart from being advantageous in terms of cost and time saving for regional scale also provides large scale data on LULC changes with information about their geographic distribution (Yuan et al., 2005). Geographic Information Systems (GIS) and Remote Sensing (RS) have proved to be useful tools for assessing the spatiotemporal dynamics of LULC (Hathout, 2002; Herold et al., 2003; Lambin et al., 2003; Serra et al., 2008). Information about change is necessary for updating LULC maps and the management of natural resources. It is very important to have continual, historical and precise information on LULC changes of the earth's surface for any kind of sustainable development program in which LULC serves as one of the major input criteria (Mei and Qing, 1999; El-Kawy et al., 2010). Especially such information obtained (using LULC change detection) can be useful for planning rehabilitation in the Muzaffarabad district and also the surrounding regions which experienced a major earthquake in October 2005 (Kamp et al., 2008; Owen et al., 2008).

These regions are located on mountainous terrains which form a part of the catchment region for Jehlum–Neelum River in Azad Jammu and Kashmir (AJK). The area has monsoonal climate, where hilly topography, deforestation on steep slopes, soil disturbance through vegetation removal and terracing all contribute significantly to water controlled soil erosion. Water erosion is responsible for serious social and economic consequences (Akgun and Turk, 2010; Butt et al., 2011). It has strong environmental impacts on water resources and their conservation (Eroglu et al., 2009; Butt et al., 2011). Mitigation and conservation measures are required to lessen the on-site and off-site effects of soil erosion and only focused utilization of resources on priority action areas can ensure the success of conservation projects (Nigel and Rughooputh, 2010). The available limited resources for conservation can be allocated to the erosion susceptible areas by highlighting them through mapping, monitoring and prioritizing (Fei et al., 2010). Erosion risk mapping of the area can enable the decision makers to prioritize the susceptible areas for conservation measures in accordance with their level of vulnerability. The key objectives of the current study are to assess and analyze the LULC changes and to prepare a soil erosion risk map through weighted overlay of influencing factors such as vegetation, rainfall, slope, aspect, LULC and soil types. We also identified the potential risk areas showing levels of vulnerability to soil erosion. The main objective of this study is to provide LULC change and soil erosion susceptibility to decision makers for better managing the natural resources and manmade assets and to prioritize the erosion vulnerable areas for focused and well planned conservation measures.

## 2. Materials and methods

### 2.1. Study area

The State of Azad Jammu and Kashmir (AJK) forms a part of the northeastern fringe of Pakistan, with its situation in the Himalayan mountainous region and encircling an area of 13,297 km$^2$ (AJK P&D, 2008). The study area, which constitutes one of the two sub divisions of Muzaffarabad district, is located between 73°29′–73°48′ E longitude and 34°7′–34°27′ N latitude and extends over 740 km$^2$. It is bounded by Naseerabad, Hattian and Dhirkot (subdivisions of AJK) from north, east and southwards respectively with its western border covered by district Abbottabad of Khyber Pakhtun–Khwa (KPK) province (Fig. 1). The tract, having its situation in northwestern Himalayas is mainly hilly with rugged topography featuring gentle to steep slopes, deep ravines, undulating ridges and furrows. At average Muzaffarabad received around 1400 mm of rainfall annually during last 10 years, most of which occurred during monsoon season from late June to early September (Fig. 2). The mean minimum temperature for the month of January and mean maximum temperature for the month of June are 2.65 °C and 36.75 °C (Fig. 3) respectively. The study area includes both urban as well as rural components. The city of Muzaffarabad and its surrounding areas have been experiencing a significant change in LULC. The ever growing human population which numbered 0.317 million in 1998 grew to 0.419 million in 2009 (AJK P&D, 2011) and triggered many changes in LULC.

In the study area, exposed lithostratigraphic units range from Precambrian to Quaternary in age and mainly consist of sedimentary rocks. Existing geological formations are Hazara, Abbottabad, and Murree formations. The Hazara formation is late Precambrian in age and uppermost member of this formation is composed of yellowish to brownish, thin bedded, gypsiferous limestone interbedded with shales, marls and phyllites. Abbottabad formation is early Cambrian in age and this formation consists of cherty dolomite, limestone, quartzite and siltstone. The Murree formation is early to middle Miocene in age and it consists of alternating series of shales and sandstone of predominately buff color. Gray, green and purple facies are also found commonly (Hashmi et al., 2002). The area has different soil types that have been derived from parent material of different origins and parent material plays an important role in determining characteristic of these soils. Soils of residual and colluvial slopes have originated from shales, schists, granite, dolomites, sandstone, mudstone and clays. These soils occur on mountain ridges that have gently sloping to very steep surfaces which are partially modified by terracing. The soils of piedmont alluvium are mostly derived from the shales, schists, sandstone and other local rock materials brought by torrents. These soils occur on gently to moderately sloping surfaces that are transformed into almost flat terraces. They are moderately deep to deep and have coarser fragments. The soils formed in river alluviums are comprised of materials transported by the Jhelum River and its tributaries from wide variety of rocks occurring in the catchments of these channels. Major forest types of the area include subtropical evergreen dry broad-leaved forests, subtropical chir pine forests and temperate broad leaved and coniferous forests (Ahmad et al., 2006).