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BOOK REVIEW

Developments in earth surface processes: Remote sensing of geomorphology

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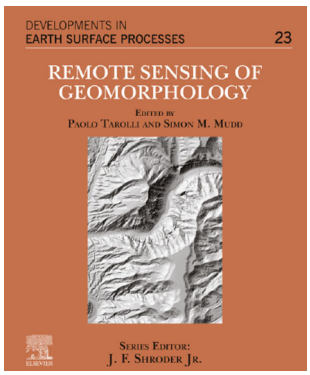

In present context, geomorphology is a multi-faceted and integrative subject which has transgressed the bounds of mere description and understanding of earth surface landforms and processes. Contemporary geomorphology has fundamental interlinkages with, and contributes to, many important areas of earth, environmental and social sciences such as ecology, natural hazards, glaciology, archaeology, planetary sciences, climate change impacts, oil-gas exploration, engineering geology and environmental policy making and management. The geomorphological studies therefore provide vital knowledge and perspectives on the geoscientific and environmental issues which are essential for their complete understanding and comprehensive resolution. Like any other science, geomorphology achieved the unattainable with the aid of ongoing technological advancements. The advent and advances in the geospatial techniques have completely revolutionized the earth science research paradigm, in which geomorphology is included. With the availability of a variety of data at different spatial, temporal, spectral and radiometric resolutions and rapidly evolving image processing techniques, the remote sensing today offers great opportunities and choices like never before for geomorphologists.

Similar to the dynamic surface of our planet, the knowledge, data and techniques for studying them have also been evolving rapidly. Considering this, the current book aims to portray the strengths and utility of advanced remote sensing techniques for various geomorphological studies. Extraction of high-resolution topographic information through various novel remote sensing techniques and its application in resolving the geomorphological problems remains the focus of the book. This book is the 23rd volume in the *Developments in Earth Surface Processes* book series edited by Dr. John F Shroder Jr and published by Elsevier. The book runs into 398 pages and starts with a crisp and suitable foreword from the Series Editor followed

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an introduction by the Volume Editors wherein they briefly recount the contents and highlights of the collection. Further, it is well structured into 12 edited chapters by well-known researchers and academicians.

Chapter 1 reviews the novel technique of structure from motion (SfM) photogrammetry highlighting its procedural details and providing intricate guidelines. The SfM technique provides high-resolution topographic information from overlapping images acquired from different perspectives with standard compact cameras and georeferencing information. The chapter also summarizes the application of SfM in geomorphology at spatio-temporal scale. With a balance between the details of the technique and demonstrating its potential for the geomorphic studies, the chapter has apt information for a novice as well as an expert. Chapter 2 brings forth a very pertinent issue of extracting the high-resolution river bathymetry, discusses the existing methods and gives functional details of the airborne LIDAR topo-bathymetry (ALTB) technique. Authors use their own ALTB survey results to clearly describe the implemental and processing steps, nature of the data obtained and final derivation of the results (hydraulic geometry of the channel, channel morphodynamics, sediment load, etc.). We are told that the topo-bathymetric lidar can now be considered an operational technique to obtain synoptic, 3D high-resolution and high-accuracy surveys of rivers (measurable depth $\sim$5 m and accuracy $<$10 cm). The major highlight being the continuous nature of the topography and bathymetry which makes it suitable for a wide range of geomorphological applications, including erosion/sedimentation mapping with repeat surveys.

Chapter 3 discusses the use of geophysical techniques for the shallow sub-surface geomorphological studies. Here, the fundamental concept of geophysical surveys, basics of the prevalent methods, guidelines for choosing and planning of a geophysical survey for a given task and examples from nine different field sites for deriving the details on structure and fluid dynamics are presented in a very simple yet effective manner. Though nearly all the suitable geophysical methods are explained, the electrical resistivity tomography (ERT) and ground penetrating radar (GPR) techniques are covered in much detail as they seem to be the most used ones. Authors also jot down certain important challenges to be tackled in future, particularly, employing the seismic, induced and spontaneous potential methods, improving the processing abilities to utilize certain (gravimetry and surface nuclear magnetic resonance (SNMR)) geophysical methods and advancing the techniques for much detailed and focused application of these methods.

Precise topographic information is vital for any geomorphic analysis, asserts chapter 4, as it converses upon multiple aspects of topographic data acquisition from satellites. The chapter begins with stating and comparing the methods (LIDAR, RADAR and Optical stereo-imaging) of imaging the Earths topography from Space. Details of all the global and regional Digital Elevation Models (DEMs) are presented and a thorough review followed by a summary on their accuracies and intercomparison are given. Author concludes that the TanDEM-X is in general superior to the other DEMs (Shuttle Radar Topography Mission (SRTM) 1 arcsec, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), and **A**dvanced Land Observing Satellite (ALOS) **W**orld **3D 30** m (AW3D30)) with SRTM and AW3D30 at par to each other and ASTER DEM being the least accurate. However, one study states that in very high-relief terrain, the TanDEM-X dataset may have worse vertical accuracy than both SRTM and AW3D30 datasets. Finally, the chapter delves upon the potentials of improved DEM resolution and future availability of global and regional Digital Terrain Models (DTMs) instead of existing Digital Surface Models (DSMs). Advance in future DEMs would definitely enhance the accuracy of the derived geomorphic metrics though at the cost of more computer space and processing time. Towards the end, we are made aware of the United States' upcoming 'Land surface topography for landslide hazards and water runoff' (LIST) mission which would be conducted using a satellite mounted laser altimeter and plans for much advanced topographic imaging of the Earth than the existing ones.

Chapter 5 focuses primarily on remote sensing of vegetation and various aspects governing it. The beginning justifies the quest that why one should consider remote sensing of vegetation within geomorphological studies, its measurable properties, soil and sub-surface carbon components. Further, basics of passive optical, microwave and LIDAR remote sensing applications to vegetation studies are discussed. The advanced information retrievable from air and space-borne LIDARs (canopy structure, tree height models, tree gaps, individual tree type recognition, aboveground biomass

(AGB), the mass of carbon per unit area stored in aboveground vegetation (ACD), plant area index (PAI) and plant area distribution (PAD)) and associated uncertainties are explained in appreciable details. The remote sensing techniques described so far have the limitation of estimating only the above-ground characteristics of the vegetation; however, the carbon content in the belowground region is almost double or more than that. The authors assert that this gap may be addressed by the potential of airborne electromagnetics (AEM) to assess the belowground organic matter and carbon content. Chapter 6 deals with the application of SfM technology in geoarchaeology. Starting with a befitting summary of the remote sensing, the chapter gives a detailed evolution of the SfM photogrammetric approach in extracting the high-resolution topography (HRT) for various applications including archaeology. Further, the on-ground application of SfM right from collection of data (via UAV) to post-processing and analysis of results are presented in the form of a case study from the Ingram Valley, UK. Authors emphasize that SfM is an efficient tool that overcomes the general limitations of archaeology such as difficulty-associated synoptic interpretation of data, approaching private owners, vegetated areas and inaccessibility of certain locations while conducting ground surveys over large areas. The DTMs ($\sim$0.25–0.10 m) prepared from the SfM data (using UAV) are useful to analyze in detail the topographic features (scaled plans, profiles, and sections) and attributes of terraces systems. Towards the end, we are told that though the SfM technique has great potential for geoarchaeology, especially in estimation of certain important metrics (riser height and slopes) for cultivation terraces and integrated archiving of surface and subsurface data (from excavation trenches), it may produce grossly erroneous results if applied incorrectly.

Chapter 7 presents the basic principle and functioning of the laser scanners with a brief historical background of its development. LiDAR technology has not only revolutionized the landslide, but also other geomorphology related research owing to its fine resolution capabilities. Utilizing this technique, authors systematically used the application of laser scanners in the landslide studies. The authors have come off in explaining the data analysis using LiDAR that has improved landslide mapping and characterization of rock discontinuities. The use of laser scanners in landslide assessment provides a good network of cloud points, which can further be utilized for landslide mapping in field, which is often not possible due to constraints like dense vegetation. Also, the involvement of good LiDAR sensors provides an improved analysis of landslides even in a densely vegetated terrain such as that of the Himalaya. Chapter 8 is centered on the application of terrestrial laser scanning (TLS) in fluvio-geomorphological studies. Studying the detailed morphology of fluvial landforms has been quite challenging. With the introduction of TLS, it is now possible to exhaustively and precisely study the fluvial dynamics at macro (km) to micro (sub-cm to mm to sub-dm) scales. The study highlights certain limitations of TLS data with regard to its 3D data complexity, large volume, less spatial coverage and high-cost, inhibiting the exploitation of its full potential in various applications. The study is a complete guide for deciding upon the choice of TLS or UAV-SfM techniques and TLS sensors for fluvial monitoring. The ways to extend the spatial coverage and reduce shadow effects, intra-survey registration error, and survey duration using TLS sensors are also discussed. A generalized methodology on the processing requirements and operations of 3D point cloud data generated through TLS survey is given. The study emphasizes the preference of 3D point cloud data over 2D Digital Elevation Models (DEMs) in understanding the fluvial morphodynamics, mainly because 3D point cloud processing does not degrade resolution in steep slopes, captures overhanging features, and promotes complex 3D change detection. The ways to reduce uncertainties from different sources for measuring the topographic changes are also specified. Different methods to measure the vertical/horizontal/3D changes in erosion/accretion rates of the river bed or along the bank and the sinuosity of the channel are reviewed. The study concludes with describing the potential applications of TLS or UAV-SfM in assessing the spatial variations in surface grain sizes of braided rivers, bedrock bank erosion and morphology, glacial lake outburst flood induced channel change, etc. The study recommends performing the event-based TLS river surveys along with field monitoring to assess the contribution and impact of floods on fluvial morphodynamics.

Chapter 9 provides the details regarding the application of high-resolution topography for understanding the increased human interference in modifying the earth's surface. It has emphasized mainly on agricultural landscapes and has showed relevance of remote-sensing technologies (e.g., airborne LiDAR) for better understanding of the

interaction between anthropogenic elements, potential erosion, and associated sediment delivery. The authors have introduced various indices and successfully examined the role of terraces on water flow paths and sediment connectivity, induced linkages between runoff and sediment sources and the corresponding sinks in the landscape.

Chapter 10 evaluates the temporal evolution of reservoir bottom gullies from Jijia Hills, Romania using high resolution (0.25 m) historic LiDAR (2012) and recent UAV-generated DEMs (2019). The study first highlights the sequential development of new technologies for geomorphic mapping such as LiDAR, digital photogrammetry, and SfM, which are capable of capturing fine topographic details at high accuracy, and then evaluates their current status in geosciences. These technologies are particularly useful in studying small landforms whose evolution involves gradual processes. The Jijia hills region has long history of construction of large number of small low-height dams which were, after siltation, purposely evacuated causing gully development on the lacustrine bottom. Authors select four out of 489 identified gullies from the region for detailed investigation where UAV surveys were conducted in 2019. Processing of LiDAR and UAV SfM is described in detail with useful suggestions for choice of right parameters. Detailed qualitative as well as quantitative results for each selected gully are presented in a systematic manner with a lucid writing style. Interestingly, separate quantitative assessment of sediment budget for each element for each selected gully such as alluvial fan, bank, bottom, channel, fan, edge, edge bank, head, landslide, etc., is made. Such studies are definitely of great use in understanding the evolution of small landforms and take effective measures to minimize their negative impacts. Nevertheless, technical expertise, small spatial coverage of high-resolution data and cost involve in data acquisition can still be the bottleneck.

The endeavors of the Opentopography.org towards dissemination and maintaining the topographic data have been discussed in the chapter 11. The relevance and importance of the topographic data (especially high-resolution topographic data) for any geomorphic analysis cannot be ignored. In this regard, authors assert that open access of the topographic data expands and enhances its usability for communities beyond academic research (e.g., educators, public agencies, and commercial sector) and applications (e.g., infrastructure, sustainability, and hazards). The OpenTopography thus manages and provides topographic data including archiving, querying, data handling, preprocessing, and differencing via cyberinfrastructure and geoinformatics. Chapter 12 highlights the issue of reproducibility in topographic analysis (also a common problem in the geoscientific research). It discusses all aspects in process of making the topographic research reproducible including, the concept and definition of 'reproducible' and 'replicable', the need for it, hurdles for reproducible topographic analysis and finally the guidelines for the same. Thus, the complications emphasized in this chapter are quite relevant and the guidelines suggested are very practical and useful.

Overall, this collection of articles is a commendable addition to the *Developments in Earth Surface Processes* book series. Main highlights of the book which may secure a place for it in the libraries of the university, research institutes as well as commercial firms include: (i) an apt balance of basics and fundamentals of the ace technologies with elaborate case studies providing in-depth functional details, suggestions and guidelines for their trouble-free implementation; (ii) the book emphatically showcases the application, usability and significance of high-resolution topography in various geomorphological domains; (iii) it suitably covers all the major and significant areas of geomorphology in-vogue through the complied chapters; (iv) the careful inclusion of chapters with thorough reviews and those with dedicated applications, is noteworthy; (v) lastly, the lucid yet effective style of writing followed throughout, together with justified, good quality and exclusive illustrations further enhance the understanding of concepts. In a nutshell, I define this compilation as a fine mix of rich and updated reference source with adequate fundamental details which would benefit a scholar and a seasoned researcher alike.

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