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Flood simulation in parts of Cuttack city using space inputs

Bhagyashree Sahoo[1,2], Santiswarup Sahoo[1,*], Jitunandan Pradhan[1], Bhabani Shankar Sethi[1]

[1]*P. G. Department of Geology, Utkal University, Vani Vihar, Bhubaneswar, India*
[2]*Central Ground Water Board, Central Region, Nagpur, India*

ABSTRACT

In this paper, an attempt has been made to understand flood simulation in parts of Cuttack City using high-resolution Cartosat- 1 stereo orthokit data. A Digital Elevation Model (DEM) was generated with the help of RPCs (Rational Polynomial Coefficient). Flood simulation was done for increasing water level from 0.5m, 1m, and 2m and it was observed that out of 32.165 sq. km of study area (mainly Cuttack city), 13.211 sq. km get inundated with 0.5m increase in water level, 14.366 sq. km get inundated with 1.0m increase in water level, 15.941 sq. km get inundated with 2.0m increase in water level respectively. The result will surely help to create necessary facilities and minimize the damage during flooding for greater service of mankind.

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1. INTRODUCTION

Floods are the natural disaster that impacts almost every part of India every year. Monsoon or otherwise heavy downpours for a shorter period of time causes man-made floods which has become a persistent problem in our country, causing widespread damage to life, property, and communities. The varying degrees of magnitude of flood cause loss of precious lives, increase economic burden, etc. The government uses a huge share of financial resources for rehabilitation activities for the affected people every year. With an aim to keep the people and property safe from flood, scientific methods are now used to delineate flood plains and possible inundated areas. Satellite Remote Sensing data is proven to be a boon for mankind to solve the problem and provides real-time information on flood inundation due to riverine and cyclonic floods, and are used for delineating flood-affected areas.

Information on the flood profile at a reasonably large scale is not available for planning necessary mitigation measures by the concerned State Government. The Ministry of Jal Shakti (MoJS) recent estimate on flood-prone areas in the country is 49.15 mha, out of which Assam, Bihar, Odisha, Uttar Pradesh, and West Bengal are largely affected (PIB, 2022). Surwase et al. (2019) reported that approximately 8 million hectares of land in India is affected by floods annually, among them 4.18% is contributed by Odisha which is 1.672 million hectares. In Odisha, floods are caused due to three main rivers namely Mahandi, Brahmani, and Baitarani which have a common delta as the three rivers meet and create havoc in the state. Being a coastal state, the floods followed by severe cyclones added misery to the people. During the last 25 years (1998–2023), Odisha has faced 17 flood events which has affected several districts in a single period of time (Table No. 23.1 of NDMA Flood Atlas, Govt of India). The major cities of Odisha that were affected by flooding in the years 2003, 2008, 2009, 2011, 2019, 2020, and 2022 are Cuttack, Khurdha, Puri, Jagatsinghpur, Kendrapara, Sambalpur, Angul, and Boudh. The coastal districts like Cuttack where Mahandi is the main river and has nearly a flat slope is more exposed to flooding whenever there is rain.

2. STUDY AREA

The city, Cuttack brings a lot of interest to many researchers as the Mahanadi delta originates near the

*Corresponding author. Email: santiswarup@utkaluniversity.ac.in (SS)

city and another distributary Kathajodi is south of the city (Fig. 1). Both river engulfs the city giving resemblance like an island. The cause of flooding here is due to heavy localized rainfall as well as the discharge of water from the Hirakud dam located 330km upstream. Nowadays Rain pattern has changed and we are also experiencing heavy localized rain causing urban flooding in the city. Population growth and unplanned urban development are one of the reasons but during heavy rain, choking of the narrow drains with solid waste, and frequent water logging problems cause urban flooding in many parts of the city. An unprecedented supercyclone affected this district during 1999 and 2019 and flood in major rivers in the years 1972, 1973, 1975, 1978, 1980, 1982, 1984, 1991, 1999, 2000, 2001, 2003, 2006, 2008, 2011, 2019, 2020 and 2022 causing heavy loss to lives and property (NRSC-ISRO & NDMA, 2023). The city is selected to study flood inundation due to its population, economic importance, and availability of high-resolution data.

The study area due to its proximity to the Mahanadi River, the widespread occurrences of alluvium of the Holocene age characterized the area with the presence of Archean terrain of charnockite, Khondalite suites having laterite capping in the Northwest of the study area. Naraj, where mighty Mahandi bifurcates into two begins forming its classic arcuate delta which is a highly fertile region and reserve of groundwater resources. This gives a unique importance to Cuttack City to study geology in detail (Mahalik et al., 1996). Cuttack City generates lots of interest due to its prominent geographical location and economic viability. Flooding is a concern here in the city and in order to ease the inundation in the city, we are focusing on generating (i) 3D model of the area using CARTOSAT-1 stereo ortho-kit data and (ii) Flood simulation using the Digital Elevation Model (DEM).

3. METHODOLOGY

The present work was carried out around Cuttack City with high-resolution Cartosat-1 stereo ortho-kit data with the help of multiple software. The satellite data with path and row number 579-302 was purchased from the National Remote Sensing Centre to develop three-dimensional model (3D) and prepare the flood simulation map of Cuttack City and its surrounding area. Leica Photogrammetric Suite (LPS) has been used to extract the Digital Elevation Model (DEM) (Fig. 3), ENVI software was used to generate anaglyph (Red & Cyan color, Fig. 4), and Global Mapper is used for extraction of drainage (Fig. 5) and flood simulation of the area (Fig. 6a–c). The flowchart shown below demonstrates the combined methods adopted for the generation of DEM and flood simulation (Fig. 2).

Global Mapper has been used to extract the drainage networks and drainage patterns. The geomorphology of this selected area is studied and flood inundation area has been extracted and the image showing flooded areas have been extracted with a rise of water level in the drainage basin from 0.5m to 2m systematically as shown with different images with inundated parts of this area.

4. RESULTS AND DISCUSSION

4.1. Digital Elevation Model

A high-resolution DEM was generated using Cartosat-1 stereo ortho-kit data for the study area (Fig. 3). For the generation of the DEM, RPC and tie points were used. The generated DEM revealed that the maximum elevation of the studied area is ˜193 m from MSL.

4.2. Drainage Network

The drainage network of the study area, on a regional scale, was extracted from the DEM generated from Cartosat-1 stereo ortho-kit data. The drainage network is marked by a parallel to a radial pattern. All the drainages follow the regional slope i.e. from west to east (Fig. 5). The river Mahanadi flows in the northern part and the river Kathajodi flows in the southern part of the study area.

4.3. Flood Simulation

Flood simulation provides essential information for flood risk management and identifies flood-prone areas and its potential impact. It also delivers information about water depth, flow velocity, flow direction, etc. During extremely intense rainfall, such simulations can be used to facilitate the development of evacuation and flood risk reduction measures. Flood simulation can be used for inland and coastal flooding projects. Simulation of water level rise/ flooding was done using Global Mapper software from the Cartosat-1 DEM. The analysis was done taking two criteria into consideration i.e., water level increase

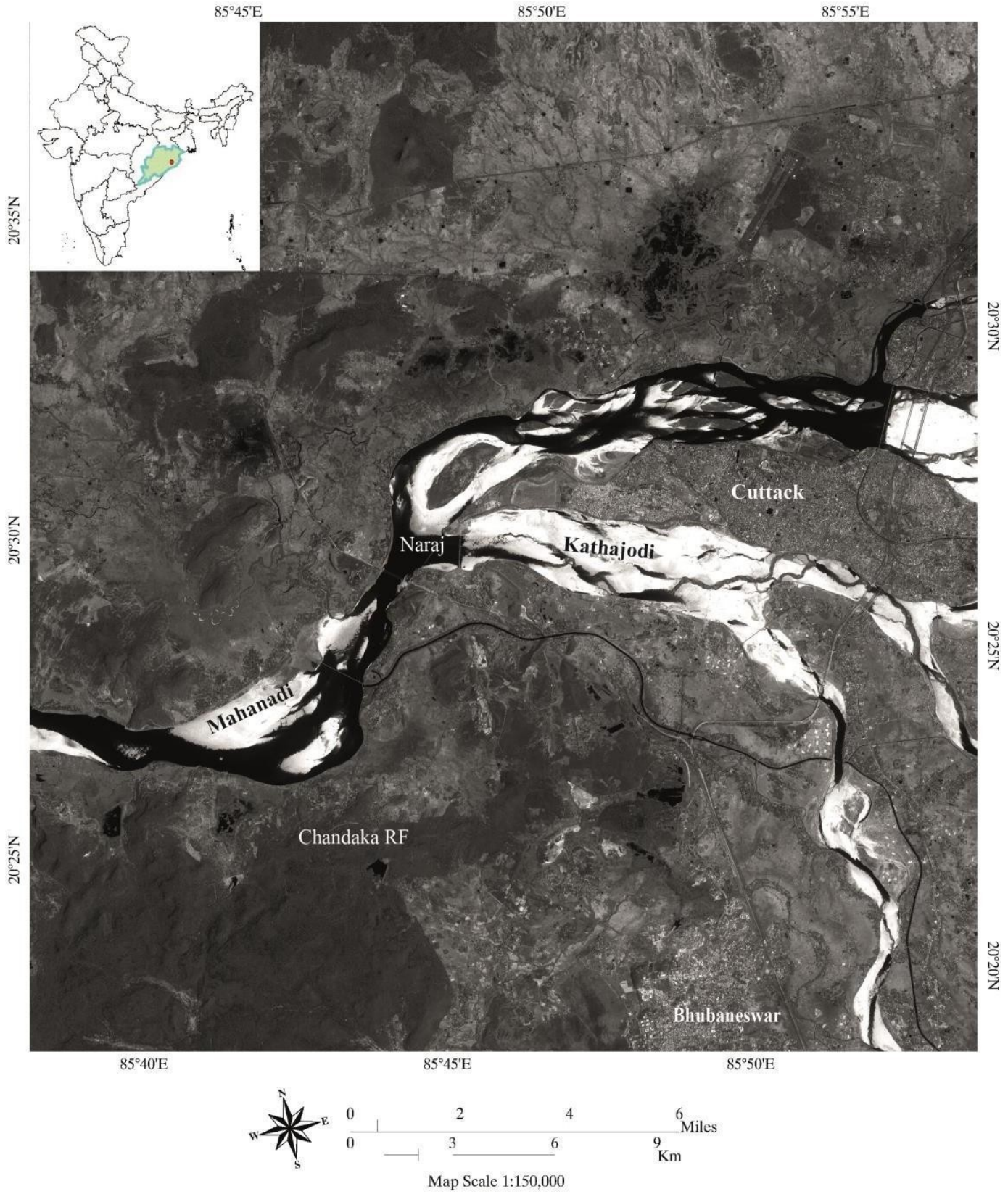

Fig. 1. Cartosat-1 image showing the extent of the study area.

amount and elevation from sea level. Three scenarios are considered to simulate flood for Cuttack City. In the first scenario, the water level amount was kept 0.5m, 1m for the second scenario, and 2m for the

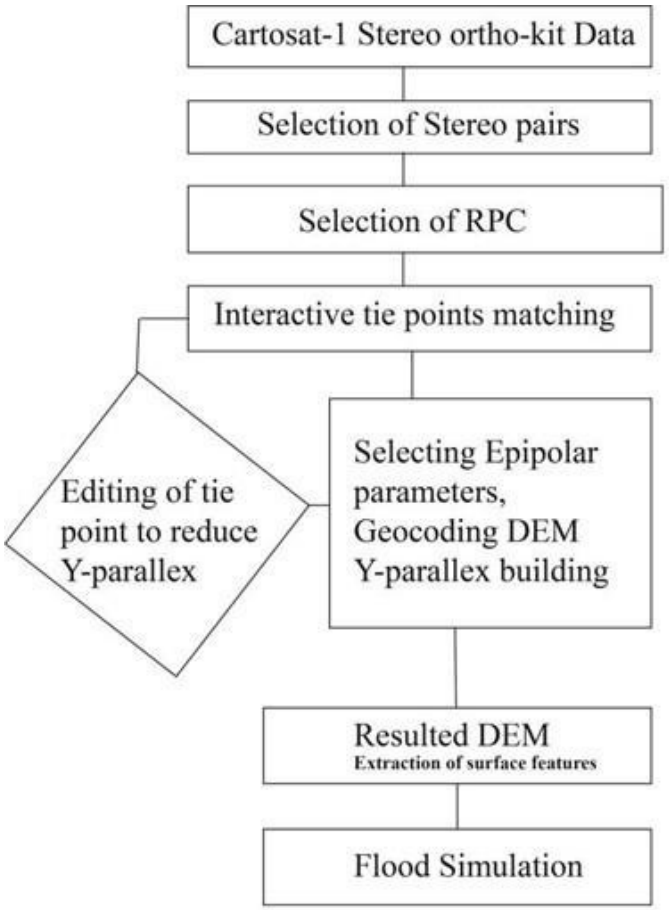

Fig. 2. Flow Chart showing methods of DEM generation using LPS software and flood simulation using Global Mapper software.

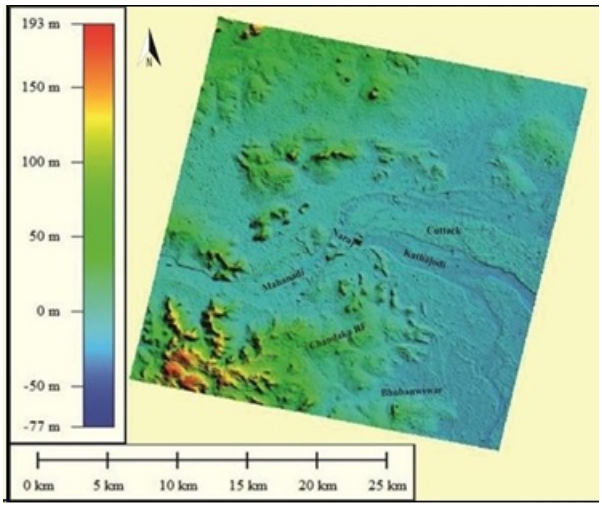

Fig. 3. Digital Elevation Model (DEM) of the study area prepared from Cartosat-1 stereo ortho-kit data.

third one. The changes were analyzed for Cuttack City. Flood inundation from Cartosat-1 stereo ortho-kit data was derived from DEM (Fig. 6a–c). Pink color indicates the portion of the inundation area in the figures. Out of 32.165 sq. km of the study area

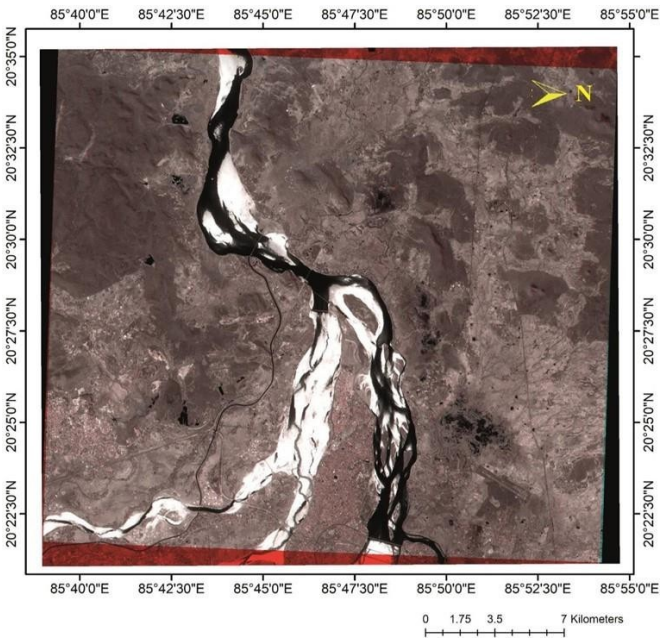

Fig. 4. Anaglyph of the study area prepared from epi-polar images of Cartosat-1 stereo ortho-kit data (Can be viewed in red-cyan glass).

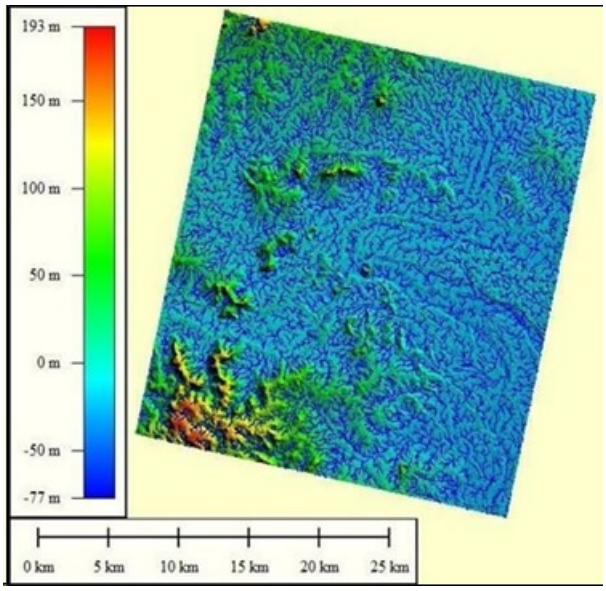

Fig. 5. Drainage network extracted (Blue lines) from Cartosat-1 DEM of the study area.

(mainly Cuttack city), 13.211 sq. km get inundated with 0.5m increase in water level, 14.366 sq. km get inundated with 1.0m increase in water level, 15.941 sq. km get inundated with 2.0m increase in water level.

5. CONCLUSION

Flooding is a common disaster affecting the Asian continent which accounts for 41% of global flooding.

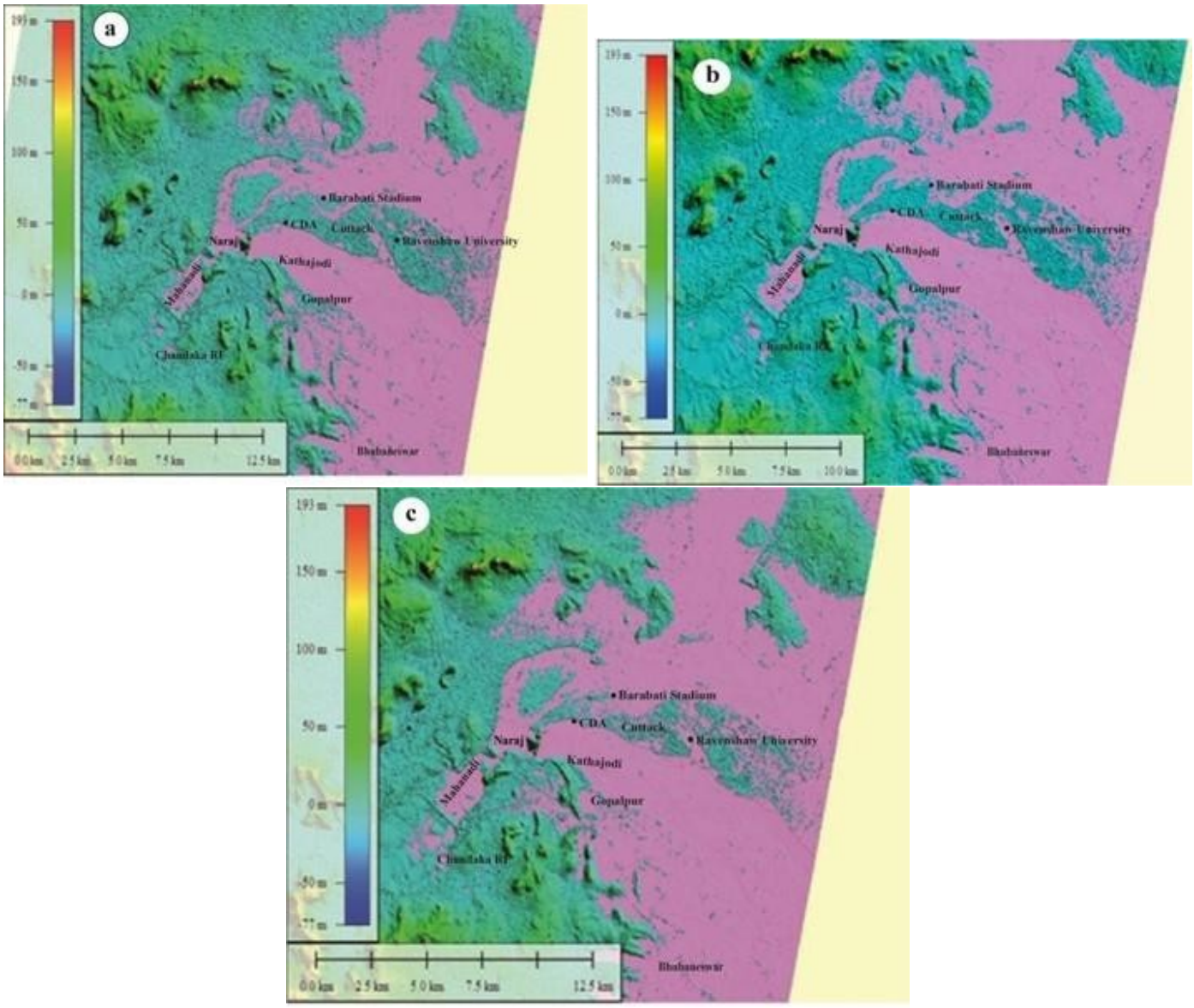

Fig. 6. (**a**) Simulation result for water level Increase amount= 0.5m, (**b**) water level Increase amount=1.0m, (**c**) water level increase amount= 2.0m. Pink color refers to the inundated area in the above images.

Riverine flooding is very frequent in Asian countries India, Bangladesh, Pakistan, Sri Lanka, and Nepal which caught the urgent attention of the media. This research work has generated DEM (relative DEM) for Cuttack City and its surroundings from the stereo data. The generated DEM helped for hydrological applications including the delineation of flood plains, and its implementation for controlling urban flooding. The use of various aspects related to DEM may represent a useful and rapid tool for a preliminary delineation of flooding areas in ungauged basins and in areas where expensive and time-consuming hydrological simulations are not affordable or economically convenient. From this DEM, flood simulation images have been extracted for the area with a rise of water level of 0.5m, 1m, and 2m systematically. It is seen that if any change of water level (i.e. $\geq$0.5m and more) occurs in the existing watershed, then the main city and the peripheral area of the district will be inundated which will cause great damage to mankind, infrastructure set up as well as to society as a whole.

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