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Analysis of Sensor Imaging and Field-Validation for Monitoring, Evaluation and Control Future Flood Prone Areas along River Niger and Benue Confluence Ecology, Lokoja, Nigeria

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Abstract
The study area often suffered from flood for the last two year resulting to ecological damages including farmlands, infrastructures, property damage, loss of life and degradation of land-cover. Flood prone areas assessment is conducted using sensor data from space-borne optical sensors with cross-validation by ground-truthing the study area along the two major rivers that converge at Lokoja, otherwise called river-confluence. Maximum likelihood classification (MLC) and ISO-clustering unsupervised classification method of Arcmap-10.1 using NigeriaSat-1 data is applied to the regimes of up-stream and down-stream of River Niger and River Benue respectively. Based on ground truthing of the study areas, classification of inundated areas closely connected with actual flood prone area was developed. The results of the classifications of flood prone areas were displayed on satellite imagery, of which the percentage differences of change detected from variations of 16 class of land-use (LU) and land-cover (LC) using optical sensor shows that wetland flood plain comprising of runoffs-routes and lowland areas recorded the highest of 14.42% using MLC and 16.02% using ISO-DATA. In the final analysis, the classification accuracy conducted shows that the ecology of flood prone areas can be adequately classified using MLC (54.89%) and ISO-clustering unsupervised classification (45.11%). In the same vein, the result of regression function shows high correlation coefficient of 0.6242 (62%) and high strength in their relationship of which the potential flood runoff-route did correlate with the state of the location of the study area. It is anticipated that remote-sensing data integrated from optical sensors could be used to supplement up-stream, down-stream and runoffs-route to monitor, evaluate and detect floods prone areas. It is therefore significant that government and relevant agencies adopts these findings to help in the monitoring, evaluating and control of future ecological disasters.
Keywords:Analysis, lokoja,river niger, river benue, confluence, monitor, evaluate, control, ecology, flood, spatial, temporal

1.0 Introduction

Floods are usually caused by excessive runoff from rainfall amount, particularly in the sub-Sahara of West Africa. In other words floods are sometimes described according to their structural distribution and occurrence. According to Brown et al. (2011), flooding may occur as an overflow of water from river, in which the water overflow its usual bank or boundaries, or it may occur due to an accumulation of rainwater (Adler et al. 2003). Floods can also occur in rivers when the flow rate exceeds the capacity of the river channel, particularly at the bends, often cause damage to homes and the environment (Kuenzer et al 2013). According to Huang et al. (2014), in the medieval period people have lived and worked by rivers because the land adjoining water bank is usually flat, fertile and provide easy travel, and access to commerce and industry. Some floods develop slowly, while others such as flash floods (Huang et al.2014), can develop in just a few minutes and without visible signs of rain. Additionally, floods can be local, impacting a neighborhood or community, or very large, affecting entire river basins. Asante et al. (2007) states that remotely sensed data provides potential for flood monitoring, of recent, remote sensing applications (Hong et al. 2004) have been shown to characterize the hydrologic processes (Schumann et al. 2009) at varying spatial and temporal footprints over sparsely gauged river basins (Brakenridge et al. 2006). Remote sensing data integration from multiple sensors (e.g., optical and microwave) have been used within a hydrologic framework for flood monitoring and prediction in river basins (Hirpa et al. 2013) in southern Africa (Zhang et al. 2013). Multispectral remotely sensed estimates provide timely and cost-effective hydrologic (Khan et al. 2012) monitoring in the flood prone basins, irrespective of the geophysical barriers. Floods can be said to be one of the most hydro-meteorological events that have devastating impacts on human and the environment of man. Lokoja is one of the towns with a large number of people physically exposed to floods, which occur normally due to storm systems during the wet/rainy season from April to October. Floods particularly hit Lokoja environment while torrents tend to affect the lowland and some hilly areas of Adankolo and Ganaja the southern and western areas. The study areas are one such case where river flooding has been a very significant problem to socioeconomics.

1.1 Background of the Study Area

Lokoja is the capital of Kogi State with an area of 3180 km² and a population of 195,261 at the 2006 census. However, the population of Lokoja town is 60,579 according to 2006 census. It is bounded by the Kotonkarfe area council in the north and east upstream from the capital until the border with Kabba/Bunu area council, and includes the city of Lokoja. Lokoja is located at 7.80236 [latitude in decimal degrees], 6.743 [longitude in decimal degrees].

Figure 1. The map of Nigeria indicating the Study Area

1.2 Statement of Research Problem

There are several procedures of assessing the contributions of sensor imaging and field validation to avert future flood particularly within the perimeter of the confluence areas, which could produce appreciable variant results capable of misleading flood specialists. As a result of this, satellite sensor imaging data set from various platform mechanisms, field validation and geo-statistical information system is necessary to provide a standard guideline for interpretability.

1.3 Aim and Objectives

The aim of the study is to analyse sensor imaging contribution and field-validation for monitoring, evaluating and control future flood occurrences along river Niger and Benue confluence spots, Lokoja, Nigeria. To achieve the above aim of the study, the specific objectives were as follows:

1) To analyse the spatial and temporal distributions of flood prone areas
2) To map the potential floods prone runoffs-routes in the study areas.
3) To evaluate variations in the floods pattern and trend.
4) To examine the future occurrences of floods on the environment
5) To attempt to develop a risk map of flood endemic areas.

2.0 Flood studies

Floods impact more people globally than many other type of natural disaster (World Disasters Report, 2003) and they usually return every year in flood-prone regions. It has been established by experience that the most effective means to reduce the property damage and loss of life caused by floods is the development of flood warning systems (Negri et al., 2004). According Huffman et al. (2007) large scale flood warning has been constrained by the difficulty of measuring the primary causative factor due largely to insufficient ground monitoring networks, long delay in data transmission and absence of data sharing protocols among many geopolitically trans-boundary basins (Werner et al. 2006). In addition, Hossain and Lettenmaier (2006) explained that in-situ gauging stations are often washed away by the very floods they are designed to monitor, making reconstruction of gauges a common post-flood activity around the world. De Groeve (2010) did recommend the use of space-borne sensors inherently estimate precipitation across international basin boundaries and cannot be destroyed by flooding.

2.1. Multispectral remote sensing Data for Flood studies

Hong et al. (2007) explains that Advanced photogrammetric and pattern recognition methods for remote sensing data processing can provide reliable information that may help to detect and monitor the progression of floods at high spatial resolution (Robert et al.2012) with reasonable accuracy (Horritt et al. 2007). Such data, after certain processing are capable of providing timely information on flood extents with global coverage and frequent observations. Turk and Miller (2005) often experiment MODIS instruments on the NASA's Aqua and Terra satellites together to provide near global observations of the Earth surface in daylight conditions twice each day with a spatial resolution between 250 m and 1000 m. MODIS instruments has proven to be the best practicable choice for rapid response for large scale flood events because of the high temporal resolution of Aqua and Terra (Jensen, 2005).

2.2. Radar Remote Sensing for Flood Monitoring

According to Blasco et al. (1992), that remote sensing satellite radar imagery has proved invaluable in mapping flood prone. However, flood prone maps derived from Synthetic Aperture Radar (SAR) sensors have been used to validate hydraulic models (Su et al. 2008). However, the Advanced Synthetic Aperture Radar (ASAR) instrument aboard ENVISAT (Gstaiger et al. 2012) with a spatial resolution of (150–1000 m) has been utilized for high resolution flood inundation mapping (Di Baldassarre et al. 2009). The ASAR sensor is a C-Band sensor that can operate in different modes of varying spatial and temporal resolution. The underlying principle behind ASAR flood detection technique is that the backscattering of the incident radar beam by water surfaces is distinguishable than the backscatter of other objects that is observed by the sensor (Bartsch et al. 2008). There are well established radar image processing techniques used for change detection and flood mapping, some detailed comparisons are provided by (Matgen *et al.* 2011).

3.0 Methodology

The methodology of research is principally by acquisition of data, ground truthing and field validation, statistical approach and image classification.

3.1 Acquisition of Data

NigeriaSAT-1 satellite imagery of 2011 from National Space Research Development Agency (NASRDA), Housing population census from the National Population Commission (NPC, 2006) and land-use data acquired from Kogi state ministry of land and Housing to assist in the identification and interpretation of features of the study areas.

3.2 Ground truthing and field validation of Remote Sensing Data

The training site for selected flood plain and runoffs-route is created based on the in-situ assessment of the site carried out during the fieldwork and ground truthing exercise. The result of the ground truthing was also used as training sites for supervised classification of the satellite images. Having demarcated the study area, the flood plains, flood-route and flood-runoffs were identified on the scene.

3.3 Image Classification Procedure (Raster)

First and foremost signature file is created, hence the data is ready for supervised classification however, Maximum likelihood classification (MLC) was carried out on the 2011 NigeriaSAT-1 imagery. Secondly, ISO-clustering unsupervised classification is also adopted for the same study areas using the Image Classification module of Arcmap-10.1 GIS. Furthermore, accuracy of the flood runoff-route can be determined by creating line of sight from an observer query points to target query points.

4.0 Results

4.1 Spatial Distribution

Figure 2 shows the distribution pattern of land-use (LU) and land-cover (LC) in the study area. The Figure 2 identified the following LULC parameters: water body (12.23%), bare ground (3.46%), dense vegetation (6.34%), rock-out crop (5.63%), forest reserve (4.05%), low vegetation canopy (5.23%), savannah grasses (5.08%), cluster river weed (1.76%), rural built-up (4.90%), farmland (12.31%), medium vegetation (3.70%), isolated settlement (4.07%), cultivated land (3.39%), wetland flood plain (14.42%), urban built-up (10.06%) and plain sand island (3.37%) of which wetland flood plain dominate frequency activities. This work buttress those of Ohkura, et al. (1989), that use satellite map to survey and shows classification of flood-inundated areas which indicates the relationships between micro-geomorphological elements and the conditions of flood inundation.

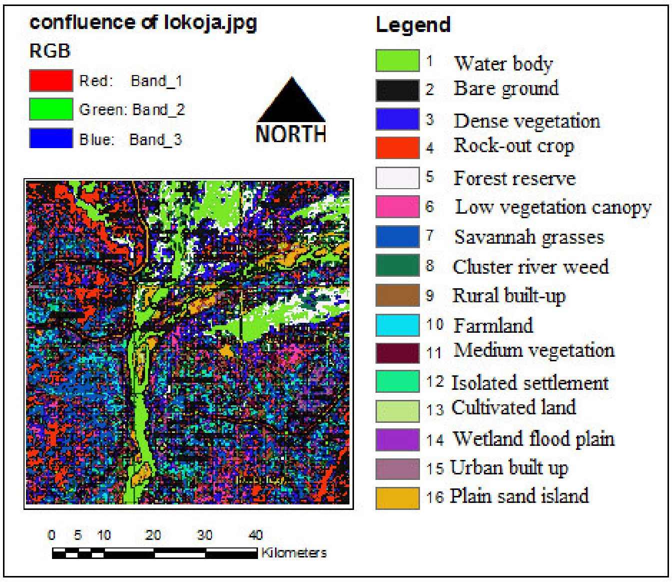

Figure 2. The distribution pattern of flood plain ecology using MLC

Figure 3 using ISO-data identified the following LULC parameters: water body (14.11%), bare ground (2.42%), dense vegetation (6.14%), rock-out crop (3.33%), forest reserve (4.69%), low vegetation canopy (6.22%), savannah grasses (9.72%), cluster river weed (0.24%), rural built-up (2.50%), farmland (12.34%), medium vegetation (2.04%), isolated settlement (3.28%), cultivated land (5.34%), wetland flood plain (16.02%), urban built-up (10.41%) and plain sand island (1.20%). MDC method classifies wetland flood plain as the most pronounced frequency activities in the study areas. This work supports those of Chenghu and Jiancheng (2000) that adopts Flood Monitoring Using Multi-Temporal AVHRR and RADASAT Imagery.

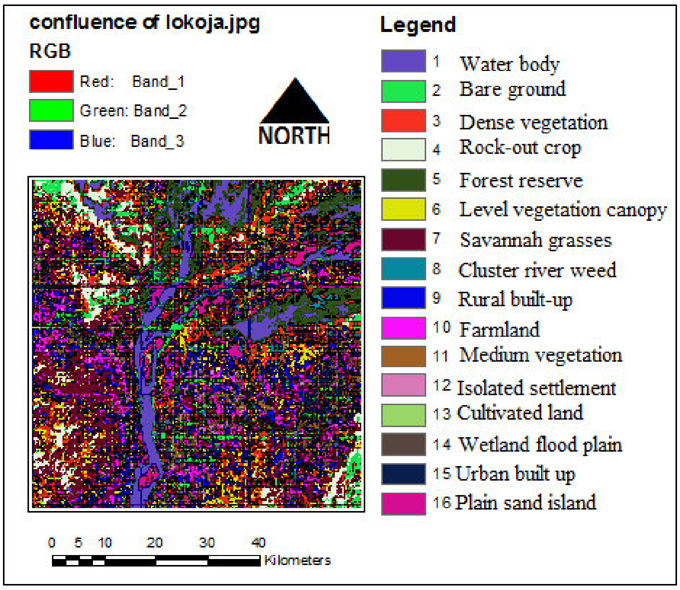

Figure 3. The distribution pattern of flood plain ecology using ISO-data

4.2 Temporal Distribution

Figure 4 shows the two principal rivers that conceptualized the meeting point called river confluence ecology on the satellite imagery. The Figure 4 further identified the flowing pattern and direction of the two rivers i.e. River Niger and River Benue, of which the center of gravity of the confluence is identified by creating circle map.

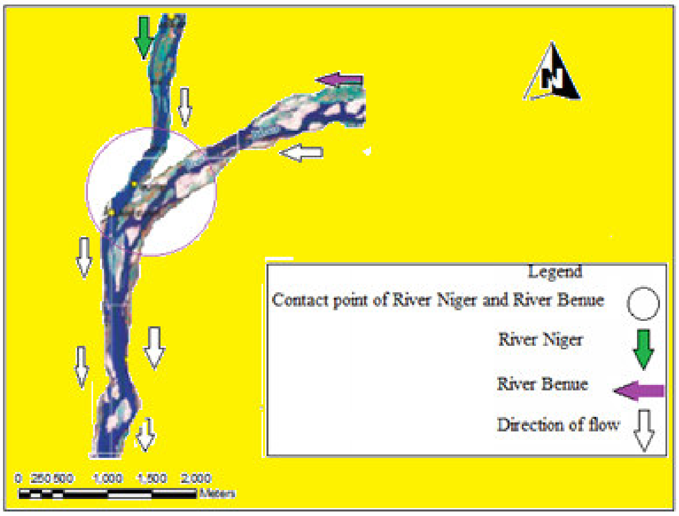

Figure 4. Schematic layout of River Niger and River Benue on NigeriaSat-1 imagery

Figure 5 shows the direction of flow of river Niger and river Benue using image classifier and paint creative tool of Arcmap-10.1 to map the pattern of the two principal rivers. The Figure 4 further identified that the two flowing rivers accelerate toward the southern part of Nigeria. The developed point of meet shows that the first and second margin of River Niger currently stood as 5-degree to 38-degree respectively, making it 33-degrees span width at the upper stream. River Benue has its first and second margin as 45-degree to 85-degree respectively, making it 40-degrees span width at the upper stream.

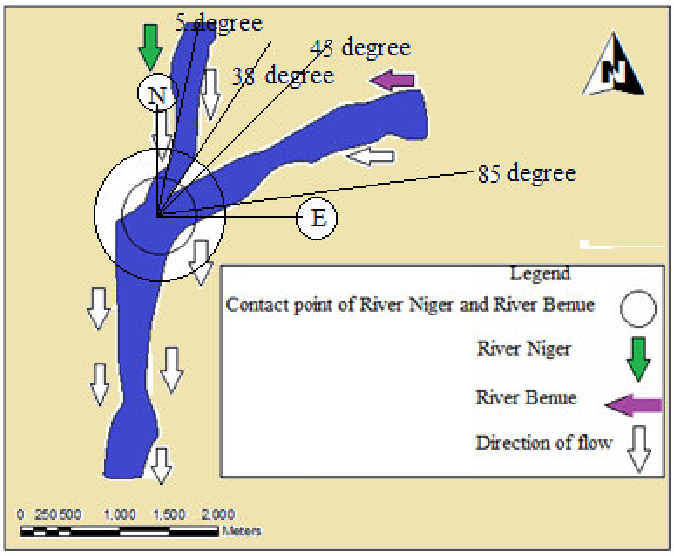

Figure 5. Schematic layout of the river Convergence pattern and trend

Figure 6 shows the pattern of flood runoffs designated as “flood wider runoff (red)” found along the course of the river margin and into hinterland. While the flood narrow runoffs also designated as “flood narrow runoffs (green)” spotted after the wider one. The Figure 6 indicates three specific flood plain areas designated as “flood plains (white)” located at upper stream region of river Niger, lower stream region of river Benue and the lower stream region of river Niger.

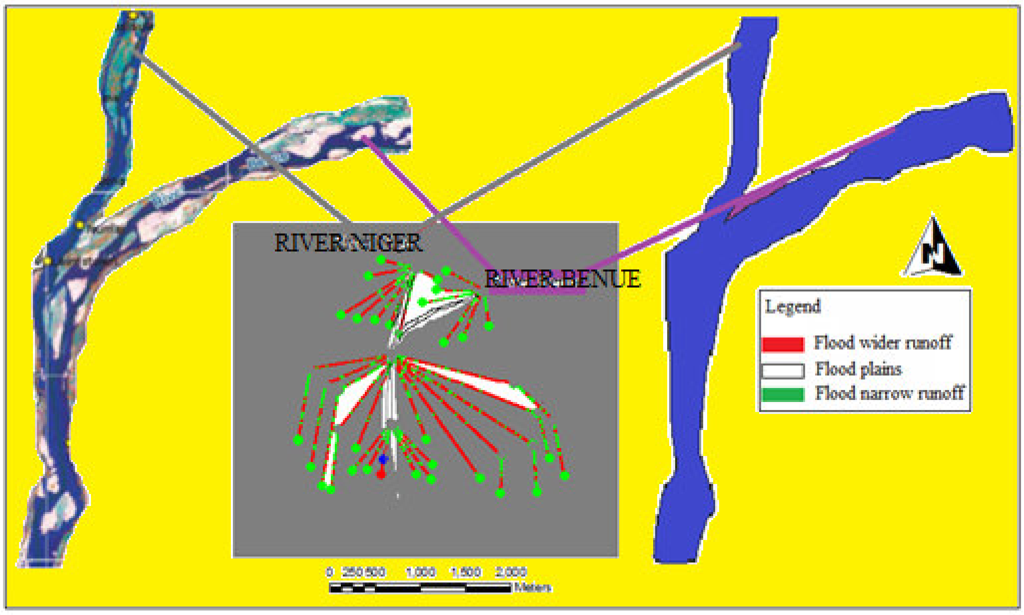

Figure 6. Schematic layout of the flood dimensional distribution

Figure 7 shows the generalized flood ecology including the direction of flow, flood plain areas and runoffs trend at the up and down stream of both river. The Figure 7(a) shows the potential flooding areas, while Figure 7(b) indicates the potential flood runoff-route. This study buttresses those of Brakenridge (2006) and Brakenridge (2007) that uses MODIS-Based Flood Detection for Mapping and Measurement flood event.

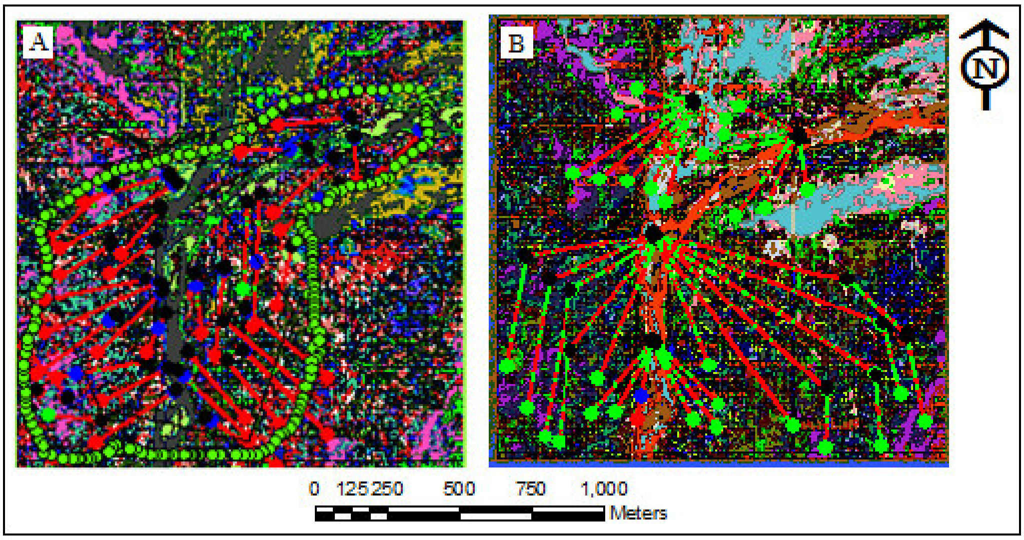

Figure 7. Mapping the potential Flood prone regions using line-of-sight method

4.3 Regression function

Figure 8 shows positive relationships of the observed potential flood runoff-route and some specific areas (Ganaja, Adankolo, Confluence hotel, Confluence center, Phase-1, Phase-2 and Phase-3), of which the coefficients of determination R^2 are 0.6242 (62%). This result indicates that the potential flood runoff-route did correlate with the state of the location of the study area. The Figure 9 also shows a high strength in their relationship.

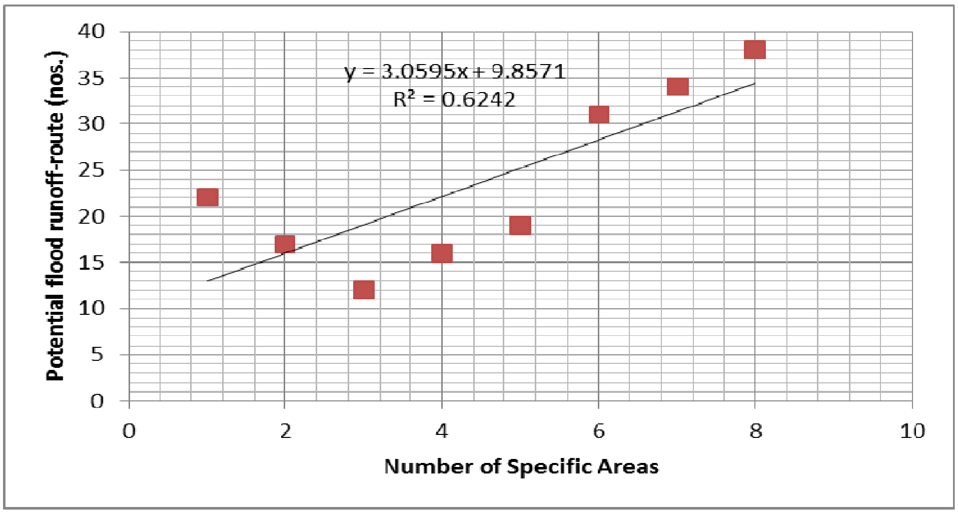

Figure 8. The potential flood runoff-route relationship with the study areas

4.4 Discussions

A close assessment shows that the classified sensor image algorithms of MLC and ISO-data have proven adequate toward interpretation and classification of flood prone areas. The Figures 2 and 3 shows that the verification result from MLC as the most approximate method for discriminating flood prone areas ahead of ISO-clustering unsupervised classification indicates MLC 54.89% and ISO-DATA 45.11% accuracy (Table 1). The Table 1 illustrates that the MLC and ISO-data has a spectral agreement on the interpretation and classification of LULC in the flood prone areas as follows; water body (MLC 46.43% & ISO 53.57%), dense vegetation (MLC 50.80% & ISO 49.20%), farmland (MLC 49.94% & ISO 50.06%), wetland flood plain (MLC 47.37% & ISO 52.63%) and urban built-up areas (MLC 49.15% & ISO 50.85%). The same can be said of their disagreement (Table 1), Bare ground (MLC 58.84% & ISO 41.16%), rock out-crop (MLC 62.83% & ISO 37.17%), forest reserve (MLC 46.34% & ISO 53.66%), low vegetation canopy (MLC 45.68% & ISO 54.32%), savannah grass (MLC 34.42% & ISO 65.68%), cluster river weeds (MLC 88.00% & ISO 12.00%), rural built-up (MLC 66.22% & ISO 33.78%), medium vegetation (MLC 64.46% & ISO 35.54%), cultivated land (MLC 38.83% & ISO 61.17%) and plain sand island (MLC 73.74% & ISO 26.26%). The result of regression analysis conducted explains that potential flood prone areas has cordial relationship with the study areas, particularly Adankolo, Ganaja, Phase-1, Phase-2, Phase-3, Confluence hotel areas indicating 0.6242 (62%) of coefficients of determination and has an appreciable level of confidence on their relationship. The results also illustrates the presence of narrow channels along the two river course, particularly at the upper level to river Niger and Benue respectively, and lower level of the convergence (Figure 9).

Table 1**.** The Summary of the classifications accuracy

LULC	MLC (%)	ISO-DATA (%)	TOTAL (nos)	ACCURACY (%)	
				MLC	ISO-DATA
Water Body	12.23	14.11	26.34	46.43	53.57
Bare Ground	3.46	2.42	5.88	58.84	41.16
Dense Vegetation	6.34	6.14	12.48	50.80	49.20
Rock out-crop	5.63	3.33	8.96	62.83	37.17
Forest Reserve	4.05	4.69	8.74	46.34	53.66
Low vegetation canopy	5.23	6.22	11.45	45.68	54.32
Savannah Grasses	5.08	9.72	14.80	34.32	65.68
Cluster River Weed	1.76	0.24	2.00	88.00	12.00
Rural Built-up areas	4.90	2.50	7.40	66.22	33.78
Farmland	12.31	12.34	24.65	49.94	50.06
Medium Vegetation	3.70	2.04	5.74	64.46	35.54
Isolated Settlement	4.07	3.28	7.35	55.37	44.63
Cultivated Land	3.39	5.34	8.73	38.83	61.17
Wetland Flood Plain	14.42	16.02	30.44	47.37	52.63
Urban Built-up Areas	10.06	10.41	20.47	49.15	50.85
Plain sand island	3.37	1.20	4.57	73.74	26.26
Total and Mean Average	100.00%	100.00%	200.00	878.32 (54.89%)	721.68 (45.11%)

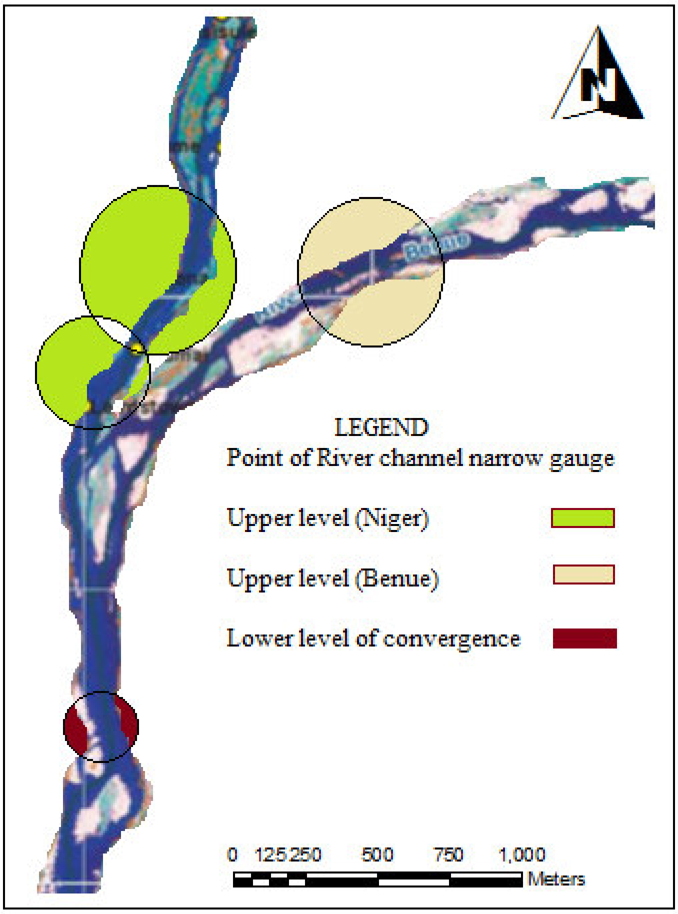

Figure 9. Schematic layouts of river channel narrow gauge

5.0 Conclusion

Our interest is a technical but more of space-borne approach to the understanding challenges that lies ahead in advancing NigriaSat-1 sensor to monitoring, evaluating and control of flood runoff, routes and ecology. Thus, the use of space borne satellite should be construed as a call for replacement of other traditional methods for flood prone areas simulation. We expect that the successes and limitations revealed in this study will lay the basis for applying more advanced space borne methods to capture the dynamic variability of the hydrologic process for global flood plain, runoff-routes and patterns monitoring in real time. Although this study is able to demonstrate the potential and capability of using Nigeria based satellite to identify opportunities that can be derived along these river channels, as well as using it for planning ecological purposes. Furthermore, these narrow channels along the river course can be dredged and expanded for free flow of water to forestall flooding in case of torrential precipitation (rainfall).

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