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APPLICATION OF REMOTE SENSING AND GIS TO AGRICULTURAL LAND ENCROACHMENT ANALYSIS: A CASE STUDY OF SOKOTO-RIMA VALLEY

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ABSTRACT

The Sokoto-Rima valley is agriculturally important and has witnessed encroachment from Sokoto metropolis. This study therefore used Remote Sensing (RS) and Geographic Information System (GIS) tool to map this encroachment. A Quick-bird image of 0.5m resolution of 2003 and readings from a Global Positioning System (GPS) hand-held receiver of 2009 were combined as data in the Idrisi 15 (Andes Edition) GIS software and changes were mapped and extrapolated. Results show that between 2003 and 2009, the city expanded by about 15.82% (26.48 hectares) and that the agricultural land lost the same land mass to the city. Agricultural job loss, poor yield, loss of farmland, flooding, pollution and possibility of land filling were fingered as the consequences of continued expansion of the city into this valley. It was therefore recommended that further expansion be stopped, the dwellers resettled for agricultural land reclamation and better agricultural land management through the help of government was also established.

Key words: Land encroachment, Expansion, Remote Sensing; GIS.

INTRODUCTION

The Sokoto-Rima River valley is of high agricultural importance to its surrounding villages and Sokoto city at large. This valley is annually flooded, providing alluvium which is fertile soil. Due to the fertility of this valley, coupled with water availability, crops such as onion, tomatoes, sweet potatoes, pepper, and other vegetables are cultivated continuously. In dry season, cultivated land close to the Sokoto river part of the valley is irrigated as a result of water recession due to dryness. The farm produce harvested from the valley find market in the Sokoto city which is adjoining to this valley. This, in part, illustrates the interdependence between the rural and the urban settlements.

For many years, the boundary between the Sokoto city and this valley stood at a precipice so that building houses beyond the boundary would mean descending a rapid slope. The stability of the city boundary also resulted from slow pace of city expansion.

The re-introduction of democracy into Nigeria in 1999 engendered monetization of the system through salary increase and money politics. Being the state capital where most salary earners are civil servants, increase in salaries has also increased the economic status of the people so that people have extra income to build more houses. In addition, the fact that it is the political hub of the state has made the city become busier politically, economically and socially than it was during the military era. Increase in these activities and population brought about the need for more space for the growing urban centre. This scenario led to the expansion of Runjin-Sambo into the agricultural land area of the valley. As the slope surrounding the old city boundary was overcome, expansion became rapid into the valley (Plates 1 and 2).

The expansion of the city into this valley has serious consequences for both the rural agrarian area and the city itself. Mapping the extent and rate of encroachment can aid crucial decision making regarding this indiscriminate use of the land. Remote Sensing and Geographic Information System (GIS) are powerful tools for monitoring environmental changes and making decision (Debashis and Rabi, 2007). Accordingly, Cater (1988) suggested methods of generating elevation models towards the sustainability of lowlands and wetlands. It is in the light of this that this study was carried out as an early warning towards developing a comprehensive expert decision support system. Results from this study will assist in forestalling future crises emanating from the encroachment of this valley and probably similar areas.

The aim of this study was to map-out the encroachment of agricultural land towards Sokoto-Rima river valley (northern fringe of Runjin-Sambo area) between 2003 and 2009. The objectives were to demarcate between agricultural land and built-up area; and to quantify the extent of agricultural land space encroached upon by the city between 2003 and 2009.

MATERIALS AND METHODS

Study Area

The study area (Figure 1) covers an area between longitudes $5^0\,11'\,55''$E to $5^0\,13'\,05''$ E and latitudes $13^0\,3'\,55''$N to $13^0\,4'\,3''$N. This location is at the northern fringes of Runjin-Sambo area which covers a total area of 1.7km^2. The area is drained by River Sokoto close to the city and River Rima in the north, providing alluvial soil especially in the wet season.

The study area is characterized by rapid slope with altitudinal difference between the upland and the valley of about 13 metres, where the highest point is 263 metres and the lowest being 240 metres. Generation of a Digital Elevation Model (DEM) particularly of lowland areas will give an insight to the degree of steepness and to a large extent certain encroachments (Udosen, 1998).

According to Olayinka (2003), annual rainfall of Sokoto is about 640mm, with the raining season lasting between May and October. The dry season spans between November and April. Temperature is as high as 43^{0}C around March/April (middle of the dry season) and as low as 23^{0}C in December/January (the middle of the cold season). Being a basin drained by two rivers both of which have water all the year round, the basin supports continuous farming throughout the year.

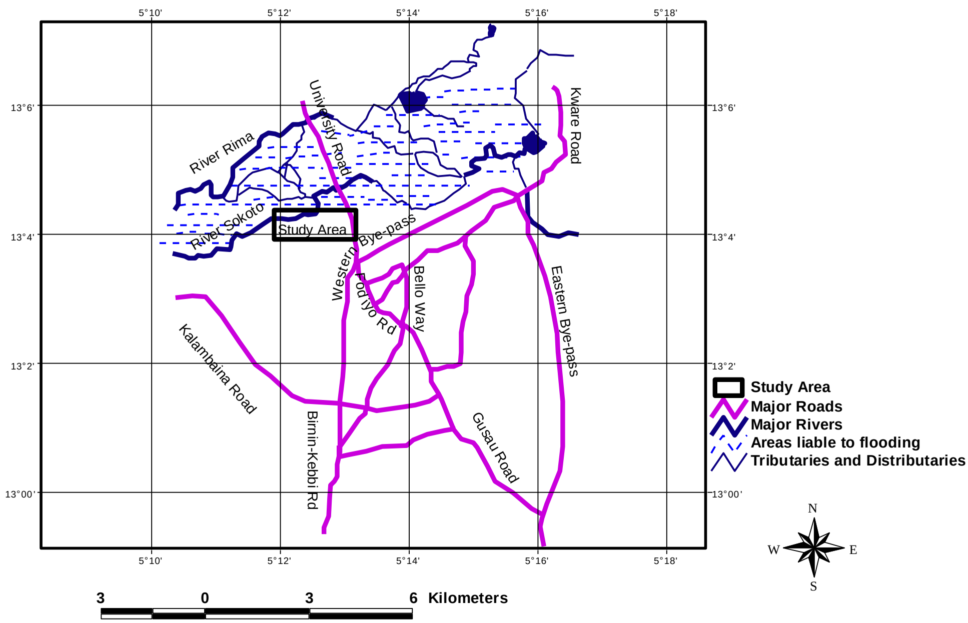

Figure 1: The Study Area

Data Collection and Analysis

The methodology used for this study is summarized in Figure 2. Two categories of data were used for this study. The first is a Quick-bird image of 0.5m resolution covering Sokoto metropolis for 2003 (Figure 3). This image came in tiles which were later mosaiced to form a single coverage of the city out of which the study area was re-mapped. The second category comprised data gathered with a Global Positioning System (GPS) hand-held receiver which is a most recent technology for navigation and surveys (Gillore and Brunini, 1999; Chia Chang, 2000). With the GPS receiver, three types of data were collected: the waypoints and track-log outlining the current expansion of the city into the valley, some ground control points (GCP) for geo-referencing the image of the study area and elevation values for generating the digital elevation model (DEM) of the study area. All these data were imported into Idrisi 15 (The Andes Edition) GIS software for processing and analysis.

The portion covering the study area was windowed (mapped-out) from the imagery covering Sokoto township in the Idrisi environment and subsequently geo-referenced. Ground Control Points (GCP) of known points were picked through ground truth test and subsequently used for geo-referencing the image. Figure 3 shows the study area geo-referenced. Also, altitudes of 50 points were collected at some spectacular depressions and elevations with the GPS receiver to create the digital elevation model (DEM) for the study area. This model is a height image representing the altitudes of the area. Figure 4 presents the detail.

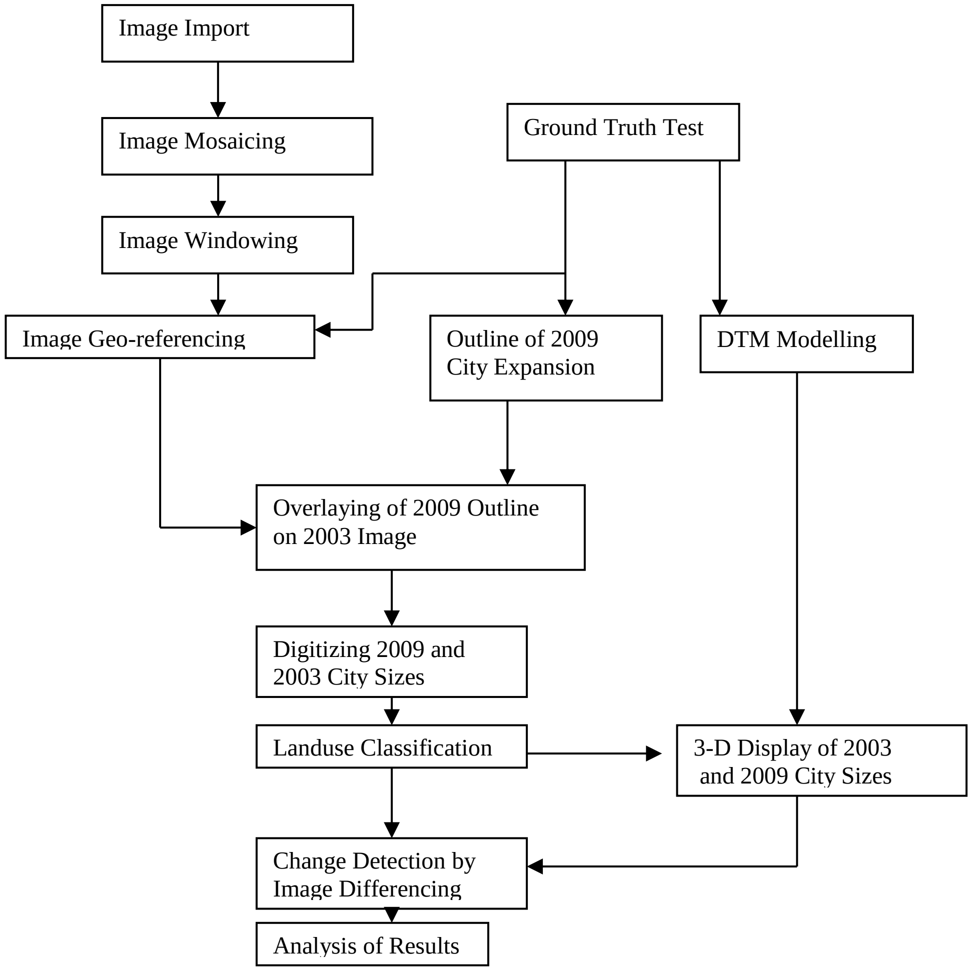

Figure 2: Summary of Methodology

Figure 3: Quick-bird image of part of Sokoto township.

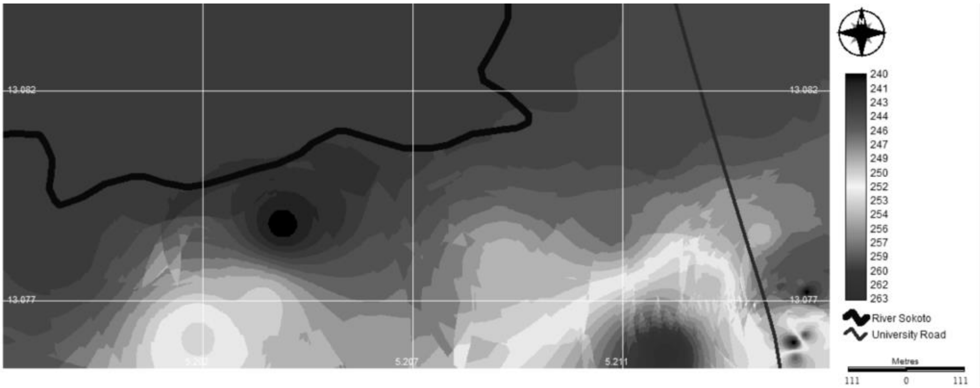

Figure 4: The Digital Elevation Model of the Study Area showing the heights of points. The altitudinal difference is 23 metres.

The study area is presented in three dimensions to show the movement of the city down the slope. Figure 5 shows the detail.

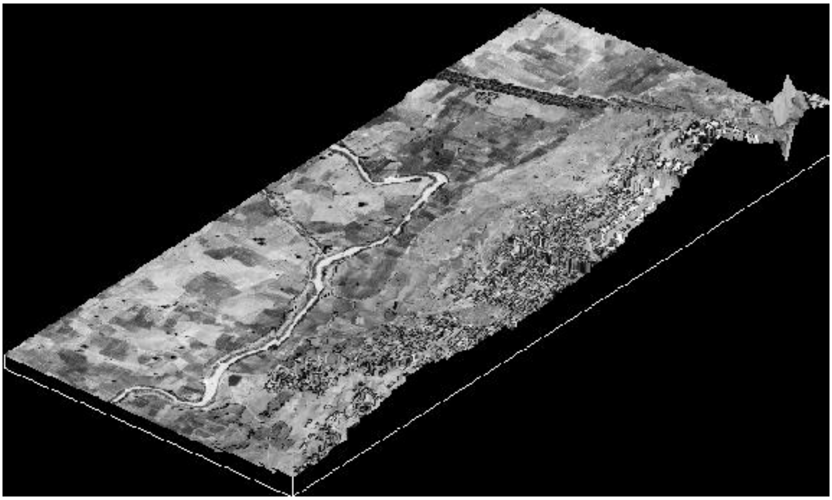

Figure 5: Three-dimensional View of the Study Area. The 2003 quik-bird image was draped on the DEM

To map the expansion of the city into the valley, the 2003 image was digitized on-screen in the Idrisi environment to map the boundary of the city in 2003 (Figures 6 and 7).

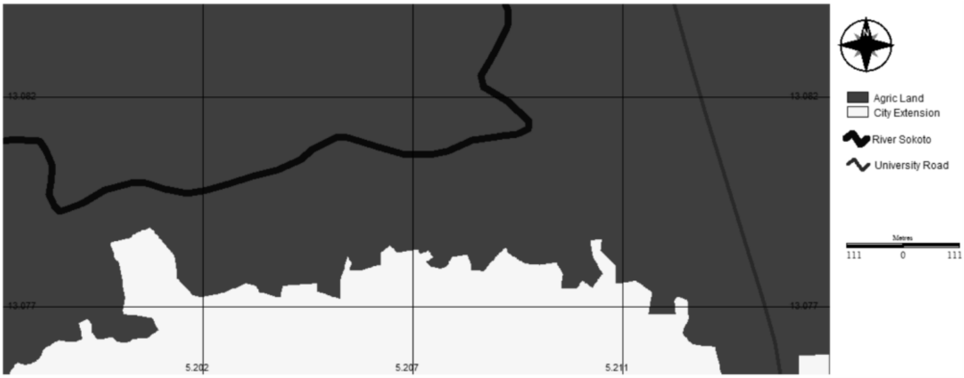

Figure 6: City extent as at 2003.

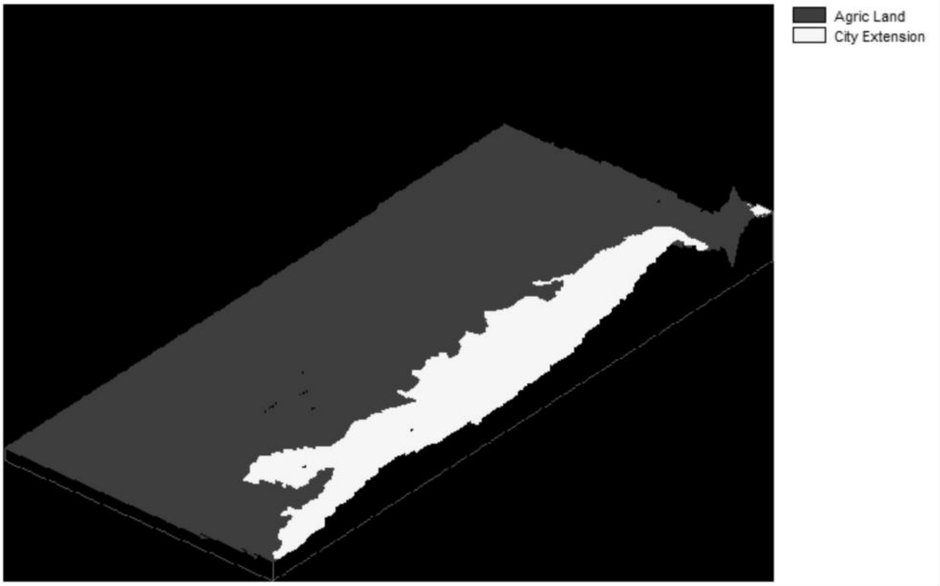

Figure 7: Three-dimensional view of the city boundary as at 2003.

The waypoints and track-log outlining the city boundary as at May 30th 2009 were imported from the GPS receiver through the GARMIN Map Source software and later converted into boundary map. Being already geo-referenced data, the outline was overlaid on the georeferenced 2003 Quick-bird imagery of the study area so as to create a polygon for mapping the 2009 expansion of the city into the agricultural land (Figures 8 and 9).

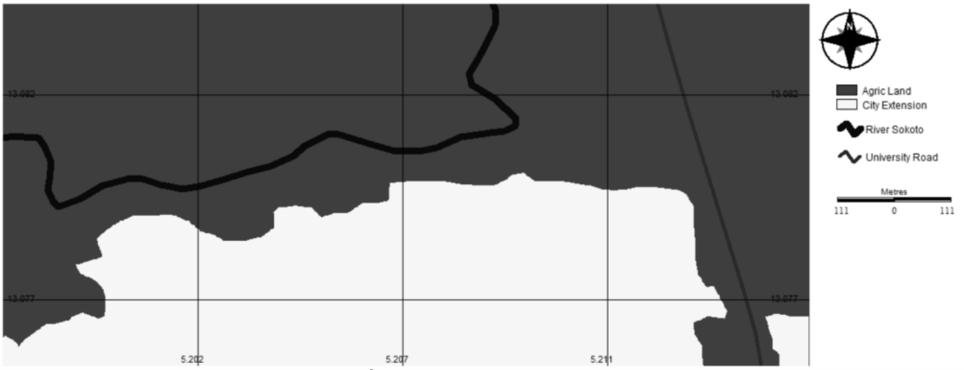

Figure 8: City extent as at May 30th 2009.

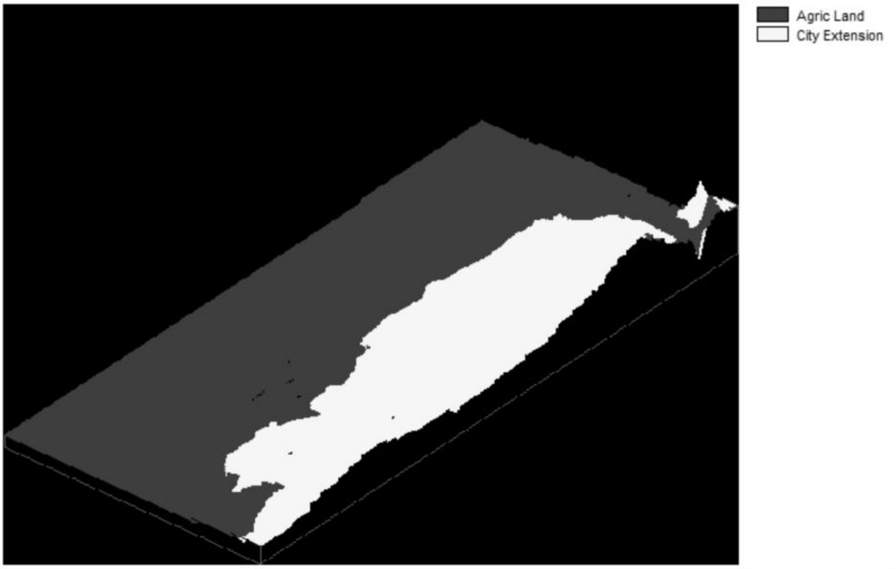

Figure 9: Three-dimensional view of the city boundary as at 2009.

Change Detection

The 2003 and 2009 expansions were overlaid as shown in Figures 10, indicating the city expansion between 2003 and 2009. City encroachment into the valley was mapped by image differencing. It is a simple method of subtracting two maps of different dates from each other to produce a map showing changes between them (Eastman *et al*, 2007). In this study, the earlier map was subtracted from the latter. The output is presented in Figure 11.

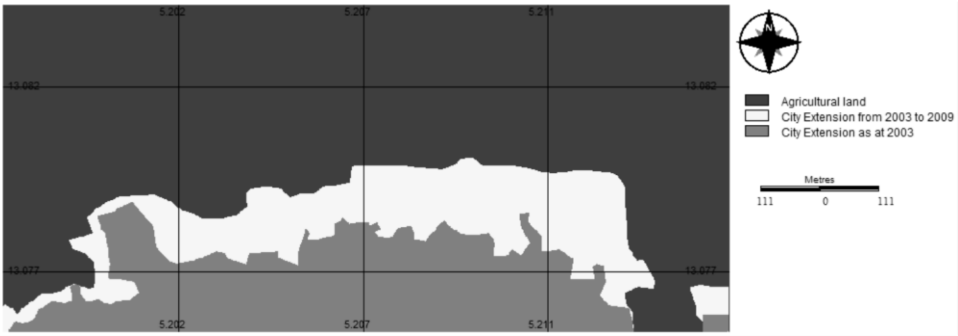

Figure 10: Map Overlay of 2003 on 2009

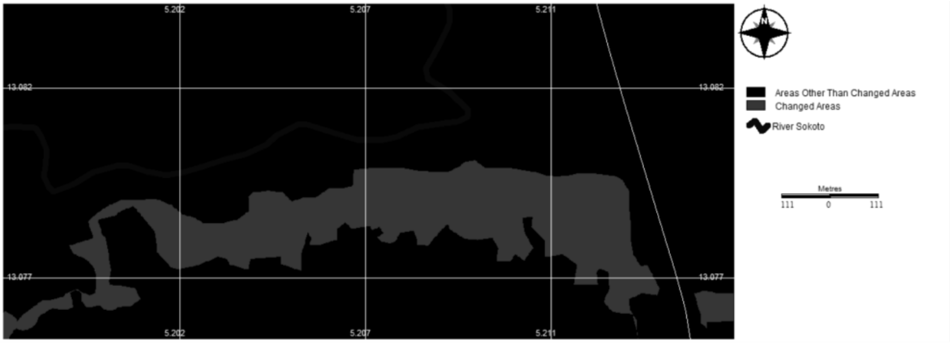

Figure 11: City expansion between 2003 and 2009. This map shows the amount of space by which the city encroached between the two dates.

RESULTS AND DISCUSSION

The study shows that the city size within the valley as at 2003 was 33.92 hectares, while the agricultural land was 133.48 hectares. In 2009, the city size had grown to 60.4 hectares, while the agricultural land had reduced to 107 hectares (Table 1). The expansion of the city into the valley between 2003 and 2009 (a period of six years) is about 15.82%, while agricultural land reduced by the same percentage within the same period (Table 2). Figures 6, 7, 8 and 9.

Table 1: City and Agric Land Area Coverage (Hectares)

Year	City Area	Agric Land	Total Land Area
2003	33.92	133.48	167.4
2009	60.4	107	167.4
Difference (2009-2003)	26.48	-26.48	0

Source: Derived from Figures 6 and 8 within Idrisi Andes

Table 2: Percentage Coverage of City and Agric Land

Year	Percentage of City Area	Percentage of Agric Land	Total
2003	20.26284	79.73716	100
2009	36.08124	63.91876	100
Difference (2009-2003)	15.8184	-15.8184	0

Source: Derived from Figures 6 and 8 within Idrisi Andes

The encroachment on agricultural land within the valley has a lot of consequences. With 15.82% loss of agricultural land to city expansion, the agricultural yield of this area has reduced, thereby causing food crises particularly the vegetables and cereals being grown in the area. Though impalpable, there is no doubt that the prices of the farm produce will significantly increase at the market where incidentally there is more demand for the produce. Another effect of this phenomenon is loss of job by the farmers. The translation of farmland into buildings will create a shift in the different occupations and may render some farmers redundant.

With regard to the expansion of the city into the valley, this will no doubt lead to waste generation by the dwellers. Such waste will definitely find their ways into the river channels causing pollution. Waste disposed into the river may block the free flow of water thereby creating flooding especially during the raining season and consequently resulting in loss of crops, lives and properties. The encroachment of the city into the valley will further cause run-off acceleration along the sloppy area thereby depositing debris into the water way, causing flood within the wetlands.

CONCLUSION

The agricultural importance of the Sokoto-Rima valley cannot be overemphasized. It provides jobs to farmers in the areas of crop cultivation, animal rearing and fishing. The city also benefits from the farm produce and livestock and fish protein. Should this expansion be allowed to continue, all these benefits will quickly be replaced by the aforementioned consequences. It is therefore recommended that the State Government should as a matter of urgency come up with a policy towards sustaining this valley. Such policy should involve agricultural zoning which restricts the construction of non-farm buildings in agricultural areas. Resettlement of those who already built up houses along the valley should be carried out as a measure of agricultural land reclamation. Furthermore, proper agricultural management practices should be embarked upon through the support of the government so as to fully optimise the utility of this resource. Finally, an expert decision support system for agricultural sustainability that will deter further encroachment into the valley should be developed and established.

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