USING DEVELOPABLE LAND UNITS AS AN INDICATOR OF RATE OF GROWTH OF AN URBAN AREA

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Keywords: Developable Land Units, Urban Growth Modeling, Growth Rate Index

Abstract

Developable Land Units (DLU) have been used in combination with remotely sensed data as an indicator for tracking the rate of urban growth. The variables used to model this indicator(DLU) are namely available vacant land, high land value, moderate elevation and compatibility with already existing land uses. Dar-esalaam, Tanzania, is used as the case study, specifically existing land use information (1992) is used to provide data pertaining to available vacant land and neighbourhood (i.e. compatibility), elevation data used was derived from ERS (1/2) data, whereas land value is obtained from mapped landform characteristics. The modelled developable land units is combined with new developed areas from 1998 SPOT multispectral data to estimate the amount of development occurring within this period i.e. between 1992 to 1998. The advantage of remotely sensed data in providing information continuously has been exploited in this regard, thus enabling a growth rate index to be estimated based on developable land units. The results obtained show that developable land units can be used successfully for monitoring growth and not only for predominantly allocating new developments as has been the case in the past.

1 Introduction

Approximately, 70-80% of information and activities pertaining to local governments are location related [Somers, 1987]. In general land cover plays an important role for the description and study of the environment. The productivity for the terrestrial ecosystems can be defined in terms of land and it's cover. Moreover it is the easiest detectable indicator of human interventions on land.

In this regard, it is becoming increasing inevitable for planners not to rely on remotely sensed data as a source of information particularly in the management of the urban resources. In order for planners to make sound and informed decisions they require appropriate approaches which deliver reliable information. However, lack of information and suitable techniques are always cited as bottlenecks in the effective management of urban resources. This is especially critical, for urban applications where cities are often dynamic which result in diminishing of vacant land within the urban growth boundary. Moreover uncontrolled growth leads to inefficient usage of vacant land, and ultimately loss of revenue. A measure of the rate of conversion of vacant land into developed areas, would facilitate the scale of needs, amount of resources available and growth prediction to be established.

Within the context of urban growth and management, local governments have the legal empowerment to ensure that property developments are within some stipulated standards. Zoning controls are normally employed to ensure that developments take place within growth boundaries. However, diverse and inter-related variables contribute differently to dynamic urban growth and these include, population, land use restrictions, employment location policies, the location of commercial areas, transport costs(mode and network structure), prevailing economic conditions, etc. Galster et. al.[2000] describe eight measures for urban growth or sprawl, namely density, continuity, concentration, compactness, centrality, nuclearity, diversity and proximity. Nevertheless, although most of the variables can to some extent be controlled, rural to urban migration which entails the freedom to choose where to live is an ingrained part of the nation's political and social culture, hence it is futile for the local governments to attempt to apply prohibitive measures. The consequences thereof has been emergence of mega cities with constrained resources and excessive use of vacant land, predominantly characterised by squatting, irregular allocation, and garbage disposal a scenario prevalent in developing countries.

In urban areas developable land units have ideally been used by planners to allocate specific land uses i.e. for strategic planning as shown in figure 1. Developable land has been defined as any vacant land free of any environmental or policy constraints to development [San Diego Associations of Governments, 1998]. Different land use variables e.g. availability, suitability in terms of location with respect to proximity to necessary infrastructure with respect to any given use, compatibility, environmental friendly, etc, are used in the extraction of developable land units. The most appropriate land use based on some criteria e.g. maximum profit returns is then allocated for subsequent development. An example of a land use allocation model is [ULAM 99]. This study proposes an extension of the use of developable land units together with remotely sensed data for establishing the rate of developments, which would also be useful in the assessment and distribution of resources.

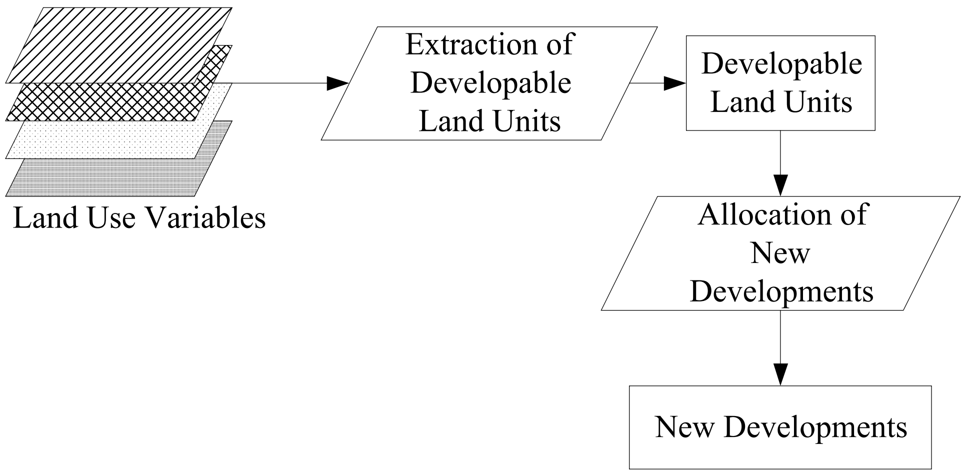

Fig. 1: Current Application of Developable Land Units in an urban environment

2 Background

The integration of developable land units with information pertaining to developed areas derived from remotely sensed data can facilitate in the estimation of growth of an urban area. The continuous determination and documentation of the growth rate index exposes the trend of urban expansion. Within the DrivingForce-Pressure-State-Impact-Response model this indicator can be viewed as a driving force type [UN CSD, 1997]. Different criteria have been used in various studies in establishing developable land units or areas and for various applications, e.g. Kehm[2001], Galster et. al.[2000], etc. On the other hand growth rate index has largely been used in the fields of economics, demography, environmental as an indicator in the various trends, e.g. financial stability, population growth rate, land use change, pollution, or phenological monitoring of plants [UN CSD, 1997]. Related indices used for urban growth is one described as sprawl index [Theobald, 2001]. The following section elucidates the concept adopted with emphasis on the determination of the DLU and the estimation of the Growth Rate Index.

3 Methodology

The main objective is to develop an approach which can be used to define and determine developable land units, which are used in combination with developed areas derived from automatic image interpretation to yield a Growth Rate Index. Figure 2 shows an overview of the methodology.

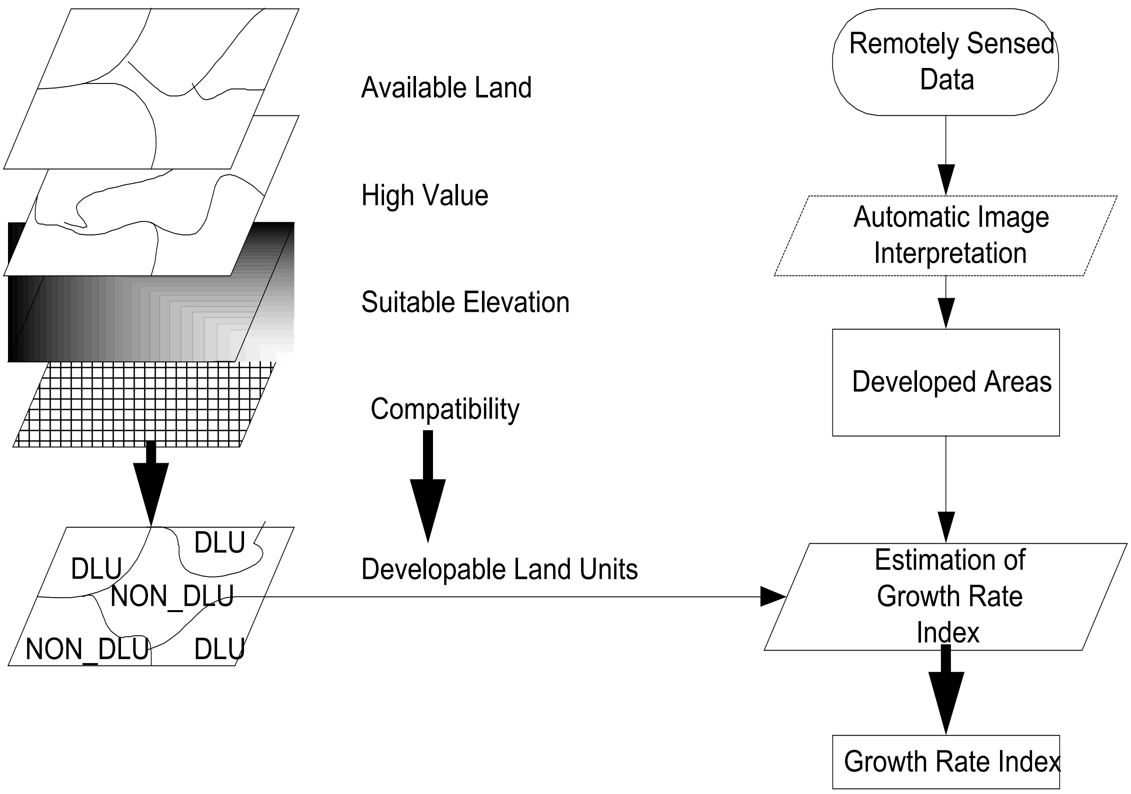

Fig. 2: Methodology Overview

3.1 Determination of the Developable Land Units

Ideally developable land can be defined as land that is vacant and attractive for development in terms of strategic location and within the legal right for the purpose under consideration. Different parameters influence different developments differently which can be evaluated in terms of cost. For instance, not all vacant land is developable, some of the constraints that determine whether or not it can be developed include environmental, ecological and policy constraints, existing development and land use policy and accessibility. In this study, four variables were considered namely availability, suitability for development in terms of value and elevation, and compatibility with existing developments. Standard GIS operations were employed which include clipping, buffering and zoning, where clipping is basically used to highlight areas of interest based on two themes e.g. in this case areas designated as having high value as well as vacant. Buffering is useful in generating neighborhood information e.g. in this case it was used for compatibility modeling. On the other hand zoning was largely used to extract attribute information based on raster data, for instance incorporating elevation data as one of the attributes for the vector data. Figure 3, shows the process adopted in defining the developable land units.

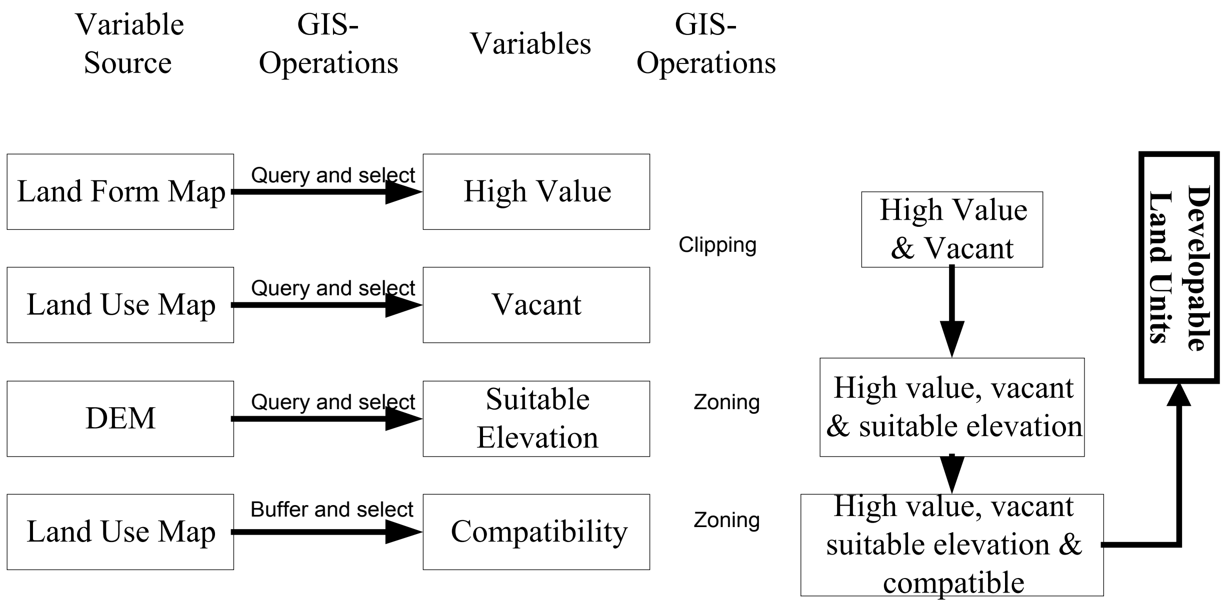

Fig. 3: Process of Generating Developable Land Units

3.2 Automatic Image Interpretation

An existing interpreted image was used as the source for extracting developed areas. In general, the interpretation was done within a knowledge based system, specifically the rule system, [Karanja and Lohmann, 2001].

3.3 Estimating Growth Rate Index

The assumption here is that growth has already taken place and using the developable land units Growth Rate Index can be estimated. The advantage of remotely sensed data in yielding information pertaining to new developments continuously is being exploited in this study. The developable land units are integrated with the new developed areas to establish the level of correspondence between them. Figure 4 shows a hypothetical scenario whereby on the left is the vector data with the established developable and non-developable land units (DLU and NON_DLU respectively) whereas on the right is the interpreted image depicting the two classes namely developed (D) and non-developed (R). Visual or automatic comparisons between the vector and the raster data sets reveal that developable land units labeled DLU_1, 2 and 4 have undergone development, whereas DLU_3 has remained undeveloped as well as the non-developable land units labeled NON_DLU1 and 2. On the basis of this information it is possible to estimate the rate of conversion of developable land units over time as shown in the equation 1, i.e. Growth Rate Index.

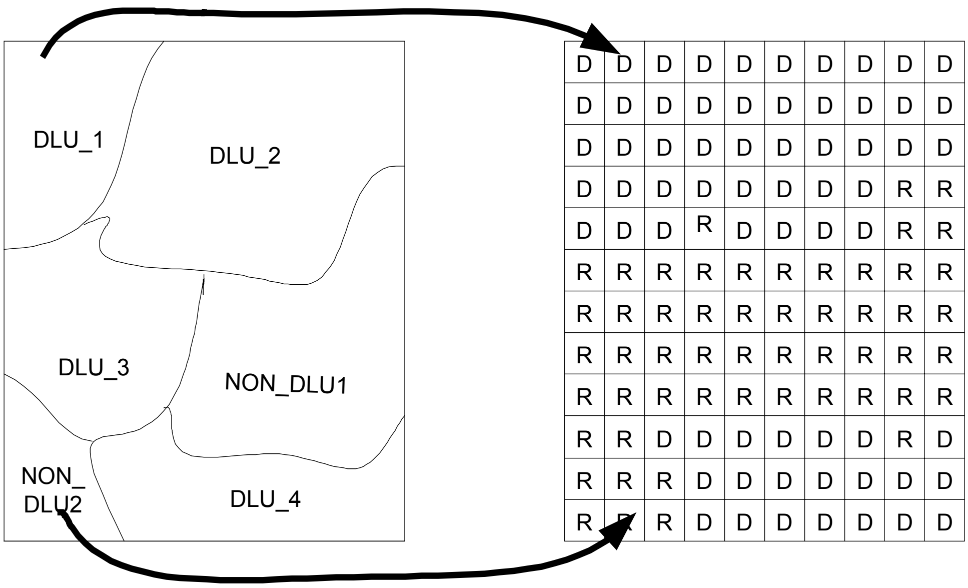

Fig. 4: Relationship between established developable land units and extracted developed areas

$$Growth\ Rate\ Index = \frac{Total\ DLU\ polygons\ developed}{Total\ DLU\ polygons} \qquad (1)$$

4 Experiment

4.1 Data Sets

Data from Dar-esalaam, Tanzania was used to test the methodology. The data sets included:-

- Land use map, 1992
- Landform map
- Elevation Data from ERS (1/2)
- Interpreted 1998 SPOT XS

4.2 Processing

The concept developed in this study on determining the Growth Rate Index is based on two main sets of information namely developable land units and newly developed areas.

The criteria adopted in the identification of developable land units include:-

- Land should be available, i.e. Vacant Land, where in this study, the 1992 land use map was used as the source of this information.
- It should be attractive for development, thus the value is high. Existing Landform map giving a general indication of the value is used to zone the areas that are of high value.
- The terrain should be suitable to ensure that costs are kept at minimum i.e. Moderate Elevation (10-150m).
- Compatible with existing land uses

On the basis of these assumptions, the following procedure was adopted in the determination of developable land units:-

- Vacant areas falling within high land values were delineated, which involved clipping vacant areas from the land use map based on the landform data.

- To these high value vacant areas additional attribute on the elevation is added based on the ERS (1/2) elevation data using vector raster zoning operation.
- This information on the elevation is used to select only those polygons that have moderate elevation whereby in this case elevation between 10-150m was adopted.
- The next step entailed establishing those areas that will be compatible with existing land uses. Hence, neighborhood based on existing built up areas where a search criteria of buffer width greater than 5pixels was used.

The result of these operations, is a map depicting two types of land units namely developable and non-developable.
The developable land units identified are used as inputs in combination with developed areas derived from remotely sensed data for the estimation of the Growth Rate Index. For each developable land unit detected in 1992, an investigation was conducted to establish whether any development has occurred based on 1998 interpreted SPOT image. The number of developable land units which have been developed and the total number of developable land units are employed in computing the Growth Rate Index, according to the expression given in equation 1.

5 Results and Discussions

Figure 5 shows the developable and non-developable land units. A total of 14 polygons which corresponds to 3 % of all the polygons were detected as non-developable whereas a total of 449, i.e. 97% as developable land units as shown in table 1. On the other hand figure 6 depicts the actual developed areas based on the 1998 remotely sensed data. A growth rate index of 89% which translates to a total of 411 developable land units polygons were detected as developed whereas 38 of the polygons remained undeveloped, as illustrated in table 2. The implication is that such a method could be used to monitor growth over time and by documenting the growth rate index, the trend of growth can be understood. The criteria used can be expanded to include other variables that influence urban growth thus making the modeling of developable land units more robust. The incorporation of more variables would also minimize errors in assigning wrong status to some areas e.g. as developable when in actual fact they are non-developable and vice versa. Correct identification of developable land units and interpretation of developed areas from remotely sensed data in this regard are important since they are used as inputs in the tracking of the rate of development namely the Growth Rate Index.
In general, the Growth Rate Index should be understood in the context of the inherent accuracy of the data sets used and the algorithms used to model or extract the variables. Nevertheless, it does give some indication that something is happening, which could serve as a starting point for enacting any necessary measures.

Fig. 5: Detected Developable and Non-Developable Land Units

Fig. 6: Detected Developed areas

Land Units	Total Polygons	Corresponding %
Developable	449	97
Non-Developable	14	3
Total	463	100

Table 1: Number and type of Modeled Land Units

Status of DLU	Total Polygons	Corresponding %
Developed	411	89
Non-Developed	38	11
Total	449	100

Table 2: Status of the detected DLU based on the interpreted 1998 image

6 Conclusions

A measure of rate of growth of an urban area specifically the conversion of vacant land to developed land is necessary if the available resources are to be used efficiently. This has been found to be useful due to the fact that the demand for land has outstrip supply. In this study, it has been demonstrated that GIS can be used to extract developable land units which can be tracked over time based on remotely sensed data thus giving an indication of the trend of urban expansion. This is a new dimension on the use of developable land units as opposed to the current one whose emphasis is on land use allocation. The criteria used to generate developable land units in this study were general in nature and can be further constrained or expanded to include other variables. Moreover, this method has the advantage of ease of implementation and use, as well as transferability.

Acknowledgements

The data sets used in this study were obtained from the University College of Land And Settlements, University of Dar-esalaam, through the courtesy of Dr. Mtalo.

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