Urban Spatial Scenario Design Modelling (USSDM) in Addis Ababa: Background Information

Modelling urban settlement dynamics in Addis Ababa

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This document is designed to provide background information for Urban settlement spatial dynamics in Addis Ababa. In case you have feedback or questions, please send them to hanywafa@mytum.de

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Glossary

Influencing factors: Specific factors that have an influence on the transformation of cells into settlement cells based on previous urban dynamics studies and the local experts input

Transformability index: An index that is calculated using weighted overlay of several influencing factors raster files where cells could be then ranked based on this index.

Land use dynamic influencing factor: a factor that represents the probability of transformation to settlements based on geospatial change detection analysis of Addis Ababa's development in the period 2006-2011 along with the local experts input.

Centrality influencing factor: a factor that represents the centrality of a location indicating the amount of opportunities that exist within a certain location using the distance to the nearest Addis Ababa sub-center.

1 Introduction

In the context of urban development in Addis Ababa, its vulnerability and adaptation to climate change hazards, an urban settlement spatial dynamics scenario model was developed. This model simulates different scenario of spatial growth of settlement in Addis Ababa according to projected population growth data.

The model calculates a transformability index based on specific influencing factors (input by user) and determines the cells that should be transformed in three iterations (2015, 2020, and 2025) based on this transformability index. The number of cells being changed in each iteration and the excluded cells are defined by the user.

2 Model Aim and Usage

The model aims to help visualising the spatial changes in Addis Ababa due to settlement growth. The model can be used as a tool to understand and manage the different outcomes of distinctive urban development strategies on growth patterns (e.g. different population density, population resettlement flood prone areas). It also helps to understand the interaction between different development strategies and climate change drivers, such as loss of green areas.

3 Model Concept and Scope

3.1 Population driven Model

The basic driving force for the model is the population development of Addis Ababa (see Figure 1).

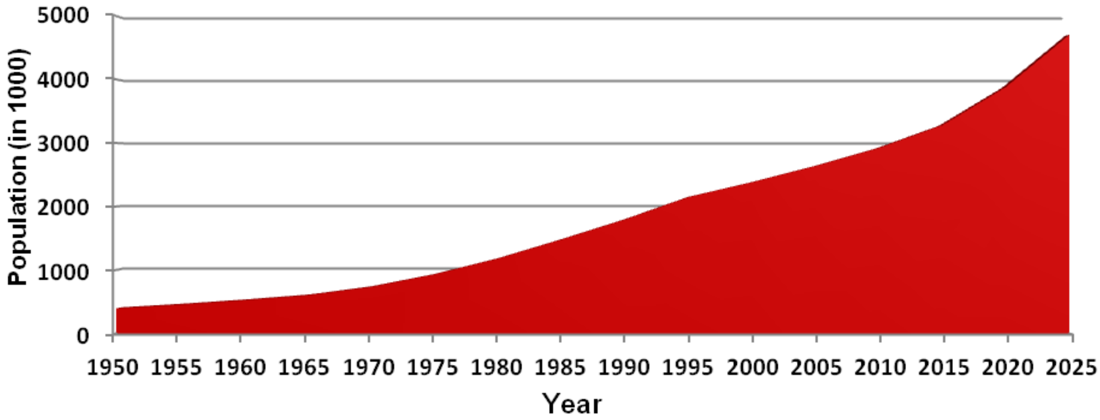

Figure 1: Population development in Addis Ababa, 1950 – 2025. Source: United Nations, Department of Economic and Social Affairs (http://esa.un.org/unpd/wup/unup/index.html).

3.2 GIS-based Model

The software that was used in this model is ArcGIS 10.1. The model is built in the Model builder environment of the software. Some operations in the model require the spatial analyst extension. In order to edit the model, you use the Modelbuilder. A detailed description and manual of the model is given in a separate detailed Technical user Guide.

3.3 Cell/Raster based Model

The model is raster based. The whole study area is divided into cells of each 50m x 50m. The grid value of the cells can represent the state of the cell (settlement or non-settlement), the urban morphology type, and the influencing factor score (see section 6). The model calculates for each cell, how likely it is – under the given assumptions – that the cell will transform into settlement area, indicated by the Transformability Index (TI). On this basis, the spatial growth of settlement is projected.

3.4 Conceptual Model

Figure 2 shows a graphical representation of the conceptual model. The model starts with the exclusion of specific areas that will not be processed by the model. The transformability index is then calculated based on nature based factor (slope), UMT based factor (land use dynamic), Location based factor (road proximity and centrality) and neighbourhood based factor. The cells are then being ranked based on the transformability index and then transformation of a specific number of cells which is the required settlement area increase (number of settlement cells needed to cover the population demand). The exogenous factor takes into account the required area for population growth excluding the population that will settle in other formal alternatives (e.g. condominiums). After each iteration, the excluded areas and neighbourhood influencing factor are updated to include the new settlement areas that were transformed in the previous iteration.

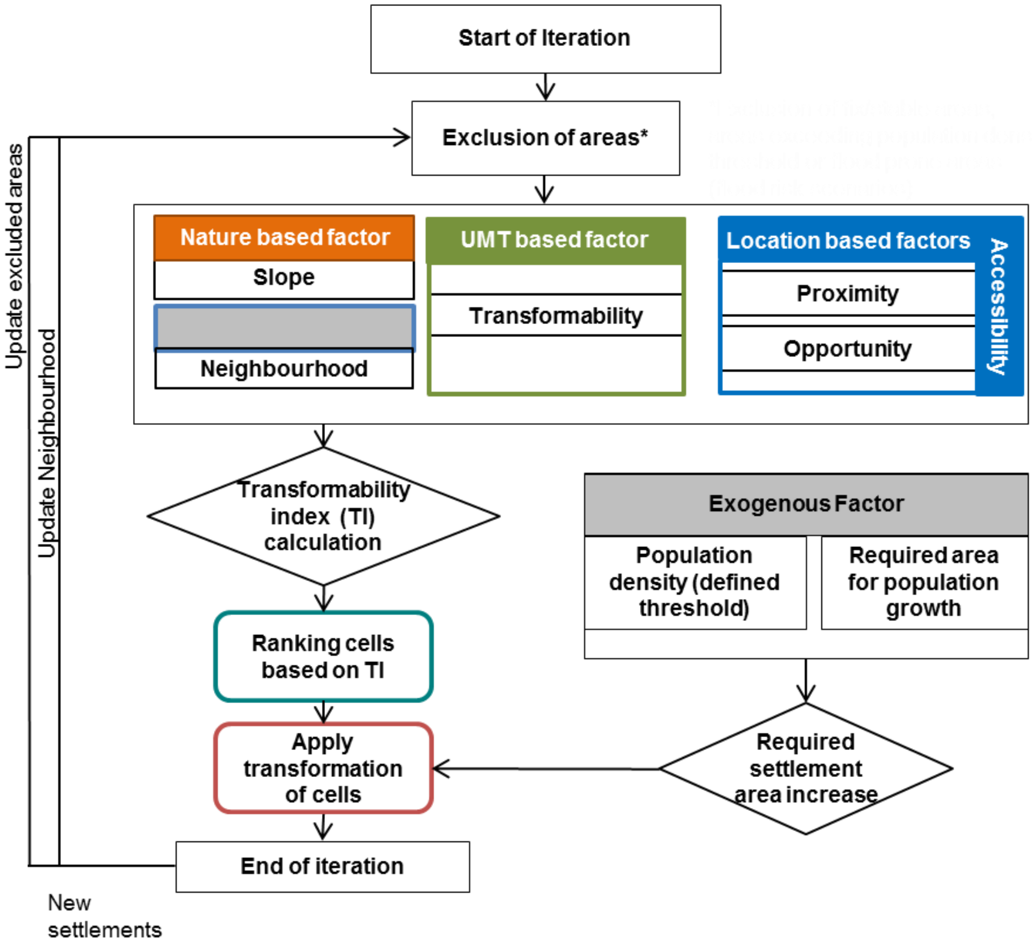

Figure 2: Visual overview of the general structure of the model. (own illustration)

Temporal Scope of the model

Starting from 2011 on, spatial development scenarios are built for 2015, 2020 and 2025. Further time steps can be included; the time span can be extended by your GIS expert.

Spatial scope of the model

For the purpose of investigating the urban dynamics, the spatial extent of the research covers the whole administrative boundary of Addis Ababa. The study area claims an area about 520 km². The modeling work is focused only on the non-settlement areas which are mainly bare land within or outside settlement areas, vegetation or agriculture areas that might be transformed to settlements in the future. Although the existing settlement areas are excluded before running the model however the interaction of population moving from old settlement areas to the new peripheral settlement areas is taken into account in the population demand which is the exogenous factor that is driving the model. Figure 3 shows the research area.

Figure 3: Research Area location, Administrative boundary of Addis Ababa Source: World Atlas, www.nazret.com

4 Input Data

The outcome of the model and its accuracy depend strongly on the data input. Following data was available and included into the model:

4.1 Population data

The total population of Addis Ababa inhabitants in 2011 was based on the central statistical agency (CSA) which is the national agency responsible for statistical data collection and analysis. For the population growth rates, data from the United Nation Department of Economic and Social Affairs UNDESA Population Division were used. Table 1 shows the population of Addis Ababa and the population annual growth rate in the period of 2015-2025.

Table 1: Population of Addis Ababa

Year	2007	2010	2011	Source: CSA
Population	2739551	2980001	**3041002**	
Period	2010-2015	2015-2020	2020-2025	Source: UNDESA
Population annual growth rate	2.33	3.37	3.85	

4.2 Condominium Housing Projects

The condominium housing projects data was provided by the condominium housing office in Addis Ababa. The population that moved to condominiums in the new settlement areas is subtracted from population growth at each iteration.

4.3 Urban Morphology Types

As part of the task 2.7 in CLUVA project, Urban Morphology Types (UMT) maps were prepared. Urban Morphology Types (UMTs) maps are used as input data for land use dynamic influencing factor and to exclude certain cells from being transformed by the model. The UMTs were selected when compared to land cover or land use maps as they combine both urban form and function (CLUVA D2.7). Urban Morphology Maps for the years 2006 and 2011 were provided by EiABC, Technical University of Munich and the University of Manchester.

4.3 Land use dynamic

Based on the comparison analysis of the 2006 and 2011 UMT maps, the dynamism of each UMT class was classified (CLUVA D2.8).

4.4 Road network

The road network of Addis Ababa dataset was provided by Addis Ababa urban planning institute. The road network was classified based on importance into three classes. The classes are the ring road which was recently constructed as an orbital road around the periphery of the central business district, major roads which have varying widths ranging from 30m to 60mand minor streets and roads which include all streets and roads that have lower hierarchy than the other two classes. The road network of Addis Ababa is shown in figure 4

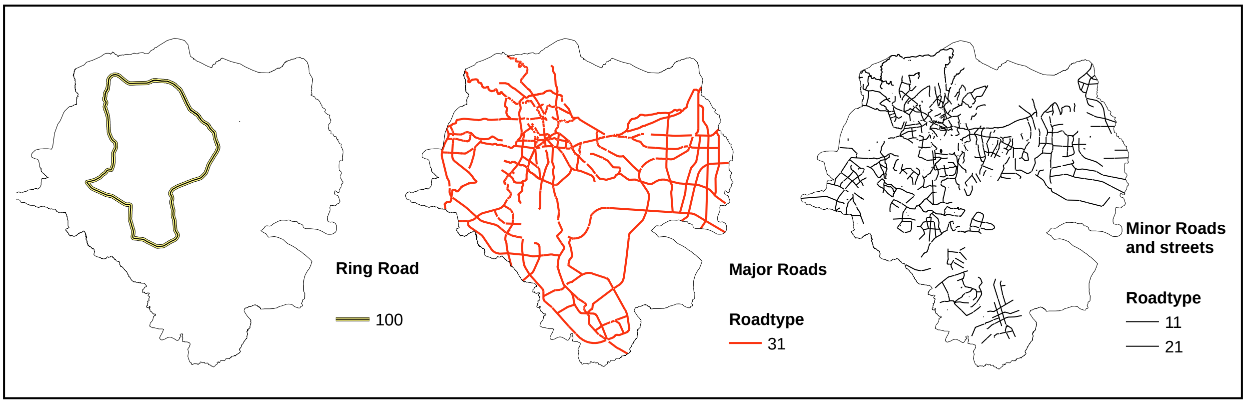

Figure 4: Road Network of Addis Ababa. (Source: CLUVA 2012)

4.5 Centrality

The sub centers data of Addis Ababa was provided by the local African partner university team. The hierarchy of sub centers was not considered in calculating the centrality influencing factors. Centrality of Addis Ababa is shown in figure 5.

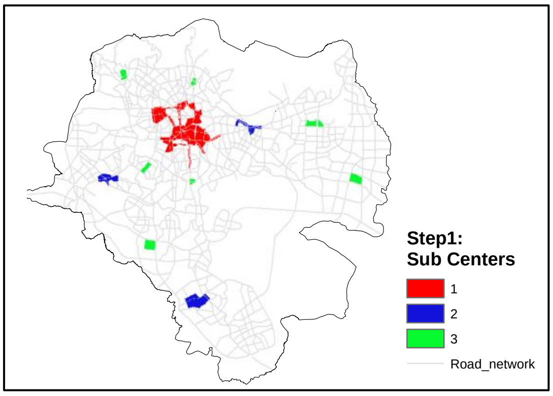

Figure 5: Centrality of Addis Ababa (Source: EIABC)

4.6 Elevation Data

Elevation data that was used is based on a 5m contour map provided by the EiABC team.

5 Influencing factors

Not all areas in Addis Ababa are probable to transform into settlement areas at the same level where different conditions make certain areas more attractive for people to settle in. For example, people prefer to live close to a road network, or in neighbourhood of other settlement areas. In the model, this attractiveness is expressed by different influencing factors.

The following influencing factors are included into the model:

- Land use dynamic: Dynamicity of UMT's (based on geospatial change detection analysis of Addis Ababa's development in the period 2006-2011 and expert's interviews)
- Slope
- Centrality: distance to sub-centers of Addis Ababa.
- Road network: Distance to minor roads and streets, major roads and ring road. For each road type the distance was calculated and proximity scores were set. As the road types are of different attractiveness, the combined road network factor includes a hierarchy where more attractive roads were weighted more heavily: minor roads and streets 25%, major roads 35%, ring road 40%. Although it can be assumed that the road network will develop dynamically together with settlement growth, the model did not take into account future changes of the road network due to missing data.
- Neighbourhood: The surrounding areas of existing settlement areas (settlement cells). The surrounding area is defined as a rectangle of 4 cells height and 4 cells width (200m x 200m). For each cell the sum of the surrounding cells (indicating whether it is an existing settlement cell or not) is calculated.

Each factor has a score range from 0 – 100:

0 = least probable to transform to settlements

100 = most probable to transform to settlements.

Figure 6 shows the influencing factor maps.

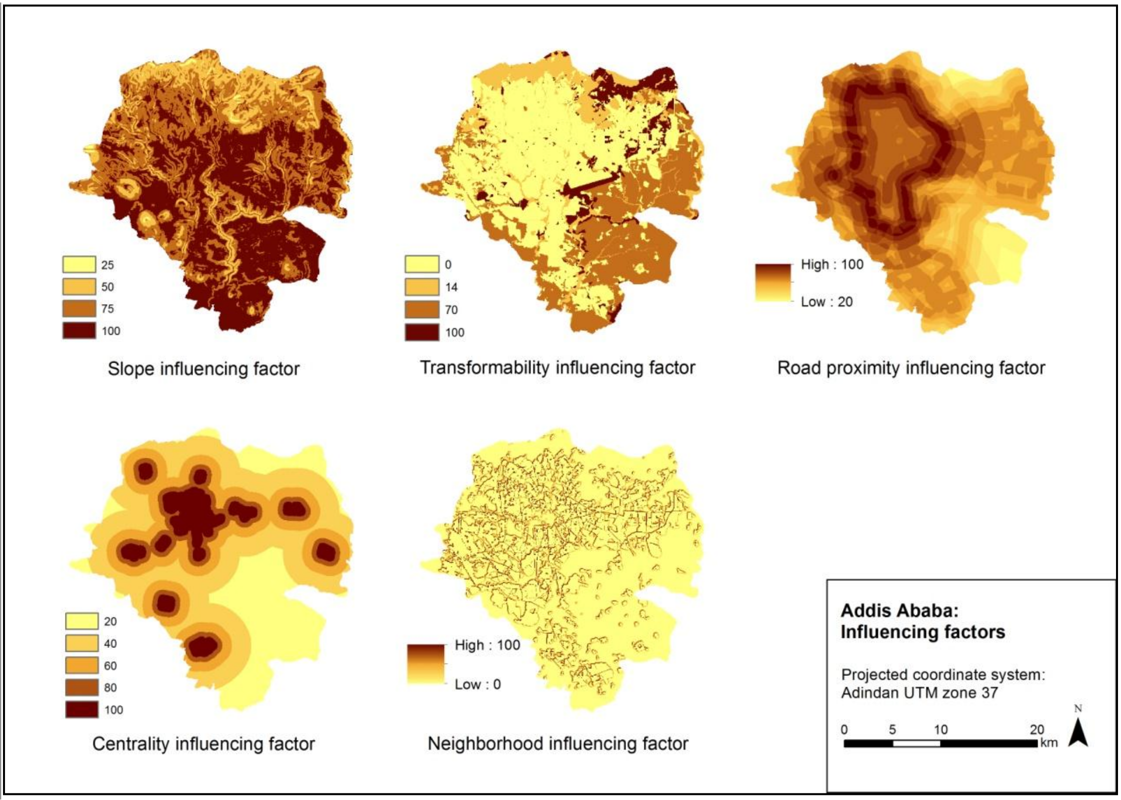

Figure 6: Influencing factors of urban growth dynamics (source: CLUVA 2012)

6 Overlay of the influencing factors

To calculate the Transformability Index, the influencing factors are overlaid. The values of different influencing factor scores are summed up. The higher the sum of a cell the higher the cells' potential to be transformed into settlement area. Figure 7 shows the overlay equation and Figure 8 shows a graphical representation of the process.

Transformability index = SF+RP+CY+TF+NH

Where
SF is the slope influencing factor
RP is the road proximity influencing factor
CY is the Centrality Score
TF is the transformability score
NH is the neighborhood score

Figure 7: Transformability index equation

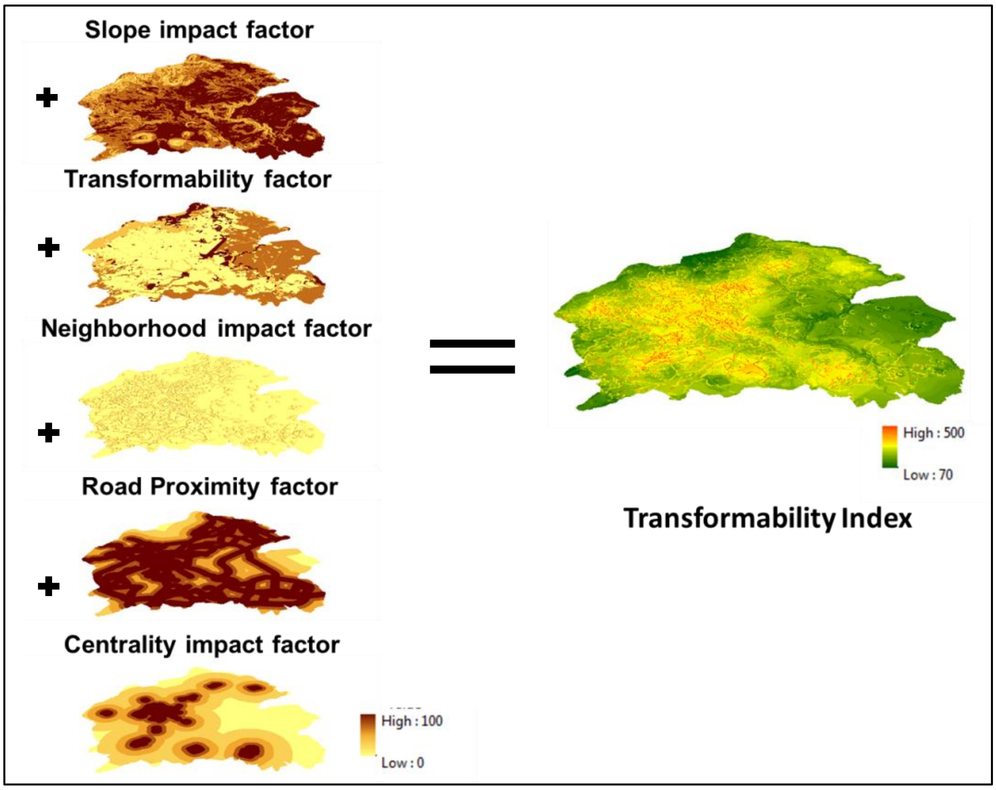

Figure 8: Transformability Index Calculation by weighted overlay method (source CLUVA 2012)

Weighting of Influencing factors

One of the features of the model is the possibility to give different weights to the influencing factors. This could be used to stress the importance of one (or more) influencing factors, the weighting of these factors can be changed.

7 Modelling Scenarios

Based on different planning strategies, four different scenario types were considered. Two parameters of planning strategies were chosen: population density and the allowance/prohibition of settlements in highly flood prone areas. Figure 9 shows the four different scenarios that were modeled.

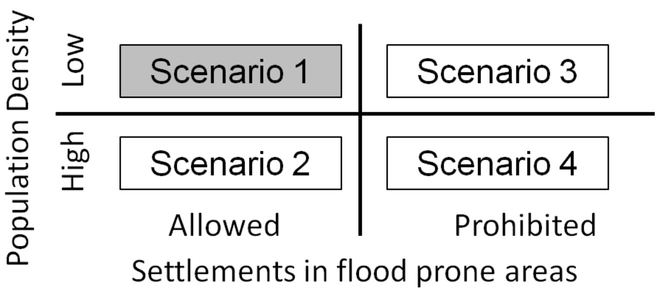

Figure 9: Modeling Scenarios

8 Results

Figure 10 shows the settlement development in each of the 4 scenarios output. Each scenario has the same population growth input.

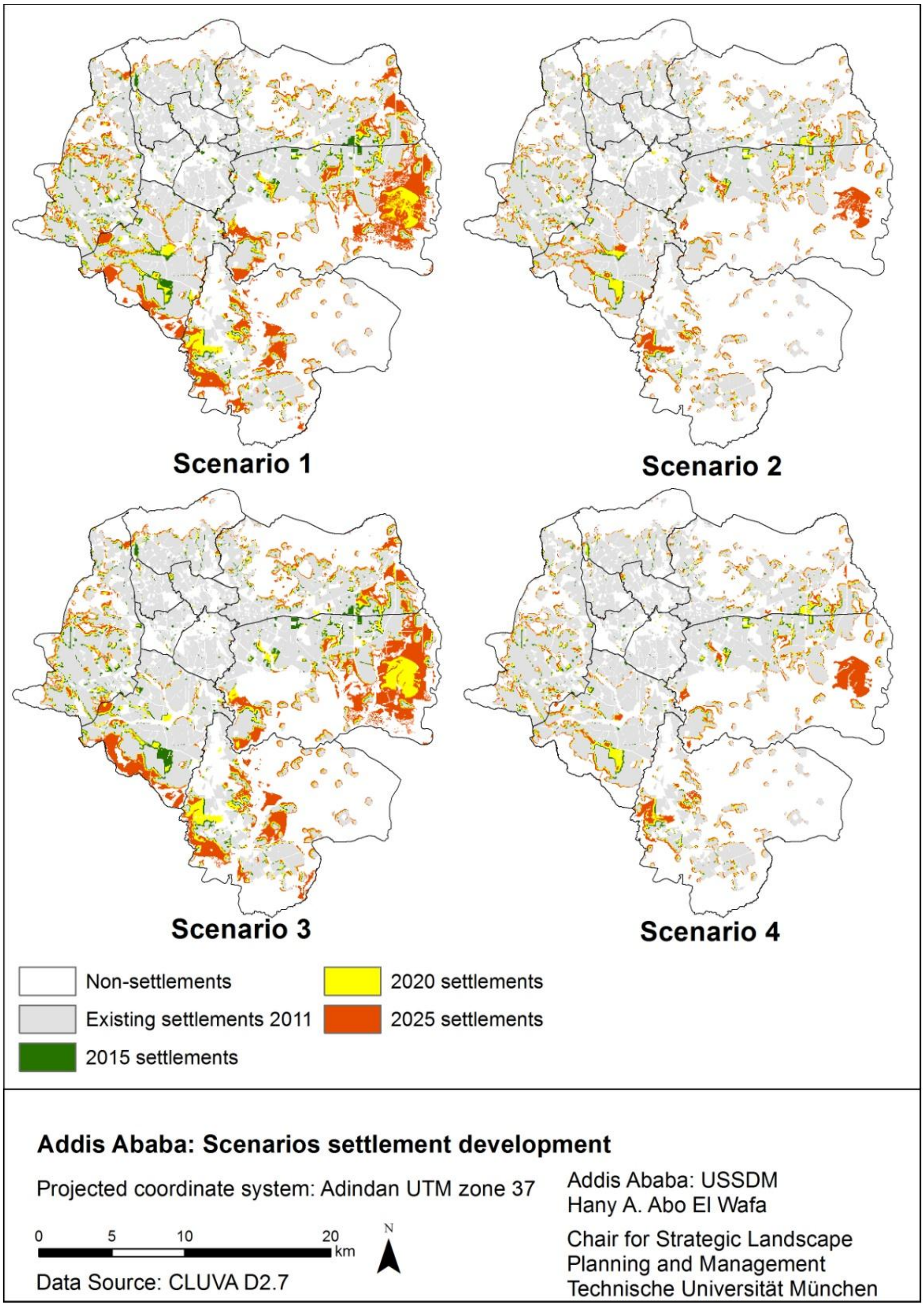

Figure 10: Modeling Scenarios Results

9 Applicability and Transformability

9.1 Applicability

In this research, application of the model was governed by specific aspects that were considered suitable to the scope of research, the current conditions and the available information, data and time however the model could be adjusted to simulate different scenarios by changing the following:

Modeling type: Modeling other attributes of a spatial nature. (Other land cover or UMT) **Influencing factors:** Adding other influencing factors to the model (real estate price, access to water)

Excluded areas: Excluding other areas based on the needed scenario and allows for the other UMT's to be transformed for example to examine the interaction between the settlement areas and different UMT's within the built areas.

Population exogenous factor: Changing the population demand input by the use.

A combination of changes in the previously mentioned factors could be also applied to simulate different scenarios that range in complexity level.

9.2 Transferability

The same model could be used to simulate another spatial extent (City. Transect of a city) in another temporal extent. This could be done by changing the input files (influencing factors. excluded areas. and residential value 1) and the population demand input by user. The selection and preparation of the input data is however needed to accommodate for the different conditions of the spatial and temporal extents.