Adaptation Thresholds Method for Developing City's Carrying Capacity Model

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Abstract

The continuing increase of urban population will cause the increase of the pressure on the city environment. Some environmental problems faced in cities indicate that urban carrying capacity has exceeded. The condition of the environment will degrade if the load pressure on the environment affected by human activities has exceeded the environment carrying capacity. To achieve the sustainable city, it is urgency to develop city plan based on it carrying capacity. In this study, environmental threshold method has been designed to indicate final ecological limits for sustainable development. Ultimate Environmental Thresholds (UETs) method applies the thresholds concept to the definition of carrying capacity. The analysis methods used to achieve the purpose of model development is the description analysis, the quantitative analysis, the scoring analysis, and the spatial analysis. The analysis of the research indicates these thresholds considered as the final boundary to possible location of development, or the final limit of what natural environment can take without irreversible damage. The result being the planning contribution towards defining carrying capacity which indicate what preferred and dominant function should be promoted and where is ecologically safe would become especially relevant. In summary, an overall adaptation of Ultimate Environmental Thresholds provides a simple approach that can be useful tool in defining city's carrying capacity.

Keywords
Carrying capacity, ecological value, environmental thresholds, territorial thresholds, solution space

1. Introduction
The continuous increases of urban population will cause the increase pressures of the city 'environment. The increase of the urban population will cause the increase the demand on the other resources such as clean water, food, fresh air and any other resources. Meanwhile, it will generate more waste disposed to the environment. Some environmental problems faced in the city indicate that urban carrying capacity has exceeded. The condition of the environment will degrade if the load pressure on the environment affected by human activities has exceeded the environment carrying capacity. To the strategy for sustainable of living, carrying capacity has also defined as "….improving the quality of human life while living within the carrying capacity supporting ecosystem" (IUCN, UNEP, WWF 1991). The latter then the concept directly related with the final limit of the Earth ecosystem to the impacts they can withstand without irreversible damage. Sustainable development strongly implies that recognition of final development limits, derived from the requirements of the natural environment, is the main step to be urgently taken. It is the same in planning; there will be no use in dealing with the problem in a more detail and sophisticated way before these limits are identified in the early stage of any planning. The concept of limits is well implicated in the field ecological studies. (Watanabe 1999) described system option to overcome energy issues and environmental limitation while also maintains

sustainable development. Some of the ecological assumption underlying the environmental limits approaches the sustainable development of agriculture (Tait and Moris 2000). (Prato 2001) also developed modeling carrying capacity for national parks. This capacity ultimately limited by environmental thresholds to accommodate development impacts and requirements (Sanga and Widjajawati 2004). Therefore, any development proposal should be considered within these constrains to decision being made

Based on the condition, there is challenged to establishing the methodologies for identifying appropriate limit (thresholds) and defining acceptable impact to the desired condition. The aims of the research are to develop the city carrying capacity model by adaptation of the thresholds method and to examine the model develop to analyze the carrying capacity Northern Region of Mie, Japan, as the study area. The proposed of planning method was developed because the concept grew out of concern planning method for protected area were not addressing some issues such as a lack detail analysis, use of borrowed methods, a lack of acceptance that management can mitigate against potential environmental impacts. To overcome the concern raised above, this study selected planning method to isolate an ideal approach. UETs combined with GIS, while each having some limitations, appeared to have potential for further refinement and development in complementary way.

In this study, environmental threshold method has been designed to indicate final ecological limits for sustainable development. Ultimate Environmental Thresholds (UETs) method applies the thresholds concept to the definition of carrying capacity. The analysis of the research indicates these thresholds considered as the final boundary to possible location of development, or the final limit of what natural environment can take without irreversible damage. The result defines an ecologically sound "solution space" within which development activities would have to be generated and contained and this space being the planning contribution towards defining carrying capacity. In summary, an overall adaptation of Ultimate Environmental Thresholds provides a simple approach that can be useful tool in integrating both conservation and urban development.

2. Methodology and Material

2.1 Methodology

From the viewpoint of establishing tolerance to development activities, ecological carrying capacity forms an important concept. To further the goal of establishing framework, a study was designed to develop an understanding of the concept of carrying capacity and ecological thresholds and the adaptation of thresholds approach in the development of city's carrying capacity. The concept of Ultimate environmental thresholds (UETs) has been designed to indicate final ecological limit for sustainable use or development. The very essence of the UET has been derived from the assumption that there are environmental thresholds, which can be overcome only at the expense of serious and irreversible damage to the natural environment. These thresholds indicate the final boundary of the possible location, level quality of development they can defined as "the stress limit beyond is given ecosystem becomes incapable of returning to its original condition and balance" (Kozlowski 1986, 1990, Kozlowski et all 1988). The UETs method is to assist in determining environmentally safe land use possibilities of the area concerned based on the analytical process which would ensure that environmental elements of highest value and/or degree of resistant and transformation be identified and accordingly safeguard. The method fulfills the prime objectives of environmentally based planning by assessing the development possibilities of environment through identification of stress limit beyond which development must be excluded if development it to be sustainable. In this study, the following qualitative ecological value features were identified in the Northern Region of Mie, as selected study area, for the proper definition of UETs criteria which include Uniqueness, Transformation, and Resilience.

In this study, it was decided that with some modification Ultimate Environmental Thresholds (UETs) was to be used collaboratively with GIS to provide a comprehensive approach. This comprehensive method was be used to identify area and development level to which various forms of development activities should confined. This collaborative planning method was developed within the Northern Region of Mie, Japan (Sanga and Widjajawati, 2004).

To establish the value of investigated forest, the area of Northern region of Mie divided into number of forest districts (rinpan). Two hundred two rinpan were distinguished and characterized on the basis analysis and assessment of forest elements within them. The analysis and assessment were carried out using UETs criteria which include uniqueness, resilience, and transformation. The evaluation procedure pronounces the effect of existing land uses, topographic attributes, forest cover and soil characteristics to define the ecological value (uniqueness, resilience, and transformations). Appropriate classes distinguished within each criterion were applied. The result of the analysis and assessment for each forest district then were recorded in separate data files using GIS. Synthesis of all resources categories into a total study area analysis to be performed to establish territorial environmental thresholds and solution space. To obtain an overview of this method, a generalized process is presented in Figure 1.

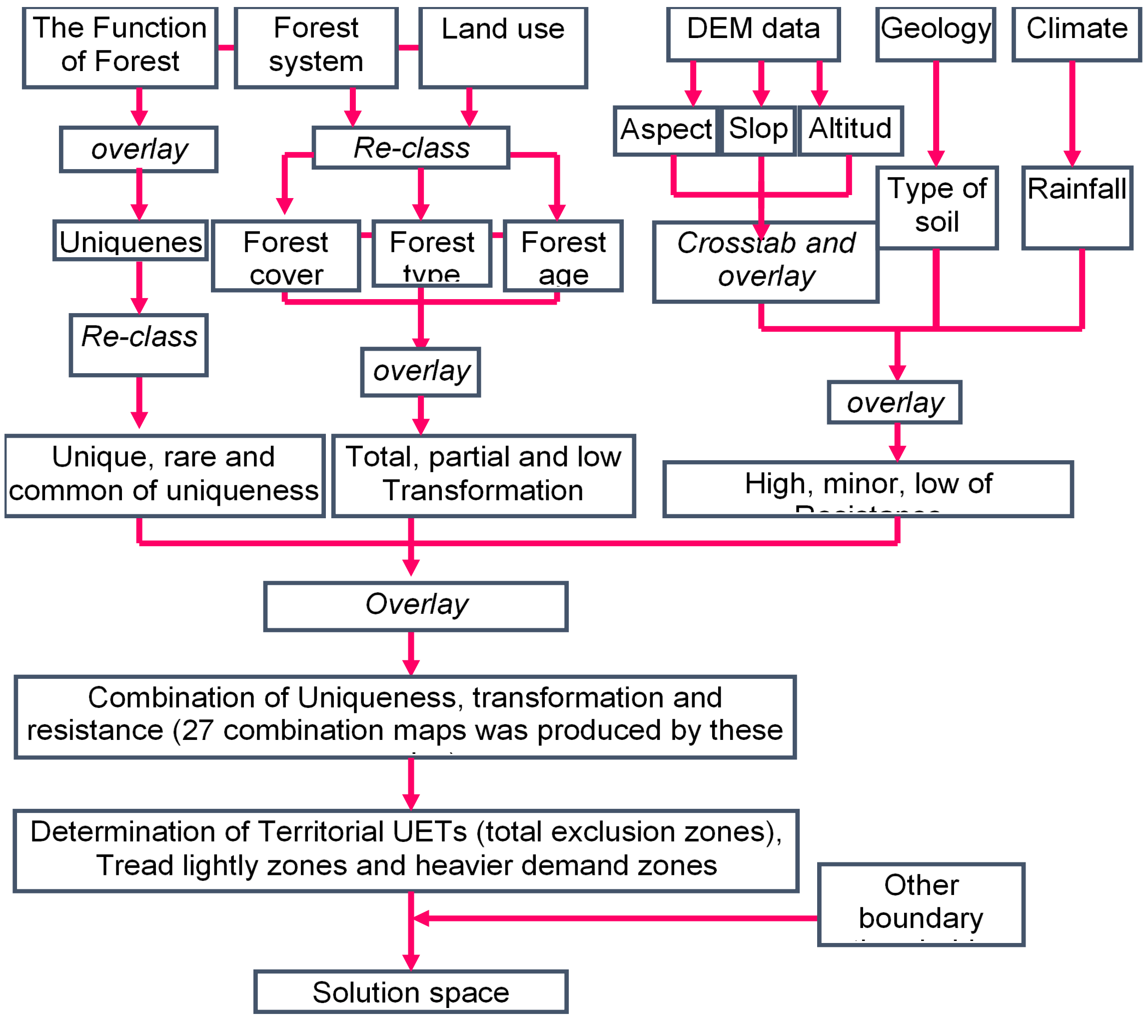

Figure 1: Collaborative method

3.3 Material

The primary feature of the Northern Region of Mie is its abundance of natural landscape. The northern part (over 400 m above sea level) is the most mountainous and is dominated by forest stands, with slopes that exceed 20%. There is some farming in the lower part of this layer (100-400m) and extended forest clearing can also be found in this part (see Figure 2). The remaining landform types in the southern part is almost totally cleared for residential and other urban facilities that has resulted into major changes to the existing forest and agriculture. The second dominant feature is urban development, which is largely concentrated in the south of Northern region of Mie. This emphasizes the obvious overspill, which is occurring from two cities of Nagoya and Yokkaichi. External forces from Nagoya, Yokhaichi and the continual influx of migrants will require that NROM accommodates further development and from the two big cities. It can also be indicated that human intervention affected the southern part first and then its effect extended to the northern part of this region

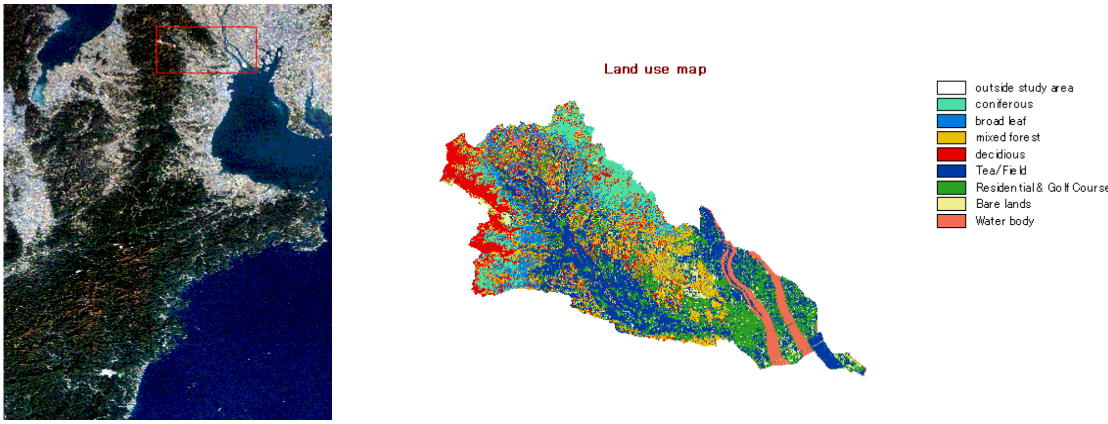

Figure 2 Study area and Land use map

The study area was examined using the Idrisi 32 GIS software. The data available for this study include topography, land use classification, soil map, forest maps. Topographic attributes, slope, elevation, and aspect layers were calculated from Digital Elevation Model (DEM) data with resolution of 50-m. Using the commonly of the surface analysis module of Idrisi 32, three layers are derived from DEM data, namely elevation data, slope gradient and slope aspect. The soil map used in this research is based on Soil map of Mie prefecture (Widiyanto A and Widjajawati E in 2019). The map covering the study area describes the soil unit and reclassified into seven unit of soil: Brown Forest soil, dry brown forest soil, andosols, yellow soil, gray low land soil, grey soil and immature regosols soil. General characteristics of soil profile was described and classified according to the FAO systems

4. Analysis Results and Discussion

4.1 Criteria for scoring ecological value

Thresholds can be determined by combining the potential threats and assessment of the main environmental elements. The assessment is expressed by degree of ecological value (uniqueness, transformation, and resilience) of the resources involved. Scores from the three ecological values were aggregated into a single matrix to identify the low, medium and the greatest degree. Finally, these scores from all three categories were aggregated into single matrix and were summed to form to identify environmental territorial thresholds

4.1.1 Uniqueness

The uniqueness of a given environmental element is indicated as any element or resources has a unique value providing the ecosystems itself, or a component part, and is ecologically important or already subjugated to some form of protection. Specific protection is required for elements that have highest value and safeguard the distinct environmental character and ecologically important of a given local area. Survival of the elements is particularly threatened if degree of occurrence and their size of population are low. For these reasons it is recommended that assessment of uniqueness be carried out by identifying the degree of occurrence in the area concerned. These qualitative classes can be distinguished in this stream: unique, rare and common

4.1.2 Transformation

In the context of Northern region of Mie, transformation determined the degree of modification of the condition of forest in relation to its original state. Changes in plant communities and removal of the plant cover recognized as a major transformation from natural state. The analysis should aim not only at objective environmental evaluation but also at the identification of acceptable limits for transformation. Three qualitative classes of transformation are proposed minimal, partial and total.

4.1.3 Resilience

To examine the physical parameter contributing to the initiation of resilience, the resilience of forest was correlated with those parameter considered to have influence on their resilience (Arrowsmith C and Inkabaran, 2002). In the context of the Northern region of Mie the following factors determining resilience of forest were identified. These physical parameters include slope, elevation, aspect and soil.

4.1.4 Aggregating scores into single matrix

In this study, thresholds can be determined by combining the potential threats and assessment of the main environment elements. The assessment is expressed by degree of ecological value (uniqueness, transformation, and resilience) of resources involved. Scores from the three ecological values will aggregated into single matrix to identify the low, medium and the greatest degree. Finally, the scores from all categories were summed to identify environmental territorial thresholds (see Table 1).

Table 1: Determination Zones
(A combination of degree of uniqueness, transformation, and resistance)

Determination of zones (unique by transformation and resilience)

UNIQUE		Transformation		
		Low	Partial	High
Resilience	Low	Total Exclusion	Total Exclusion	Total Exclusion
	Medium	Total Exclusion	Total Exclusion	Total Exclusion
	High	Total Exclusion	Total Exclusion	Total Exclusion

Determination of zones (rare by transformation and resilience)

RARE		Transformation		
		Low	Partial	High
Resilience	Low	Total Exclusion	Total Exclusion	Tread Lightly
	Medium	Total Exclusion	Tread Lightly	Tread Lightly
	High	Tread Lightly	Tread Lightly	Tread Lightly

Determination of zones (common by transformation and resilience)

COMMON		Transformation		
		Low	Partial	High
Resilience	Rare	Total Exclus ion	Total Exclusion	Tread Lightly
	Medium	Total Exclusion	Tread Lightly	heavier demand
	High	Tread Lightly	heavier demand	heavier demand

The thresholds analysis for each resource integrated on the matrix, associated the activity with sensitivity relationships in the survey area. The principal objective was to isolate the zone of exclusion (territorial thresholds). Following this, qualitative dimensions were derived by the determination of two further zones (the tread lightly zone and heavier demand zone). The identification of these zones permitted the allocation of particular activities to areas of appropriate environmental tolerance.

4.1.5 Solution space

The remaining area which is unaffected by the final thresholds is solution space. The information from analysis from assessment environment permits the establishment of criteria solution space. Solution space is defined as areas with maximum potential to accommodate development without adversely affecting the environment. This involved the application of the environmental territorial thresholds and definition of boundary thresholds (restrictive planning) to define solution space for development concerned. A combined application of environmental thresholds assessment (uniqueness, transformation, and resilience) and other boundary thresholds (existing residential area, topography slope>20%, land/forest owned by government, river and existing farmland) was applied of identifying the solution space.

4.2 Assessment of Ecological Value

Since forest can be established based on defining the limit of ecosystem in the Northern Region of Mie (NROM), Japan, the value of the forest has to be determined and classified in order to establish these limits. Three major classes were distinguished to classify the three degrees of uniqueness, transformation, and resilience.

- The uniqueness criterion adopted from UETs method, and it is understood as spatial differentiation of occurrence of a given resources or its elements. Differences of occurrence forest can be grouped into three major classes unique, rare, and common, see Figure 3. The occurrence of broad leaf and deciduous forest is a unique phenomenon within NROM as they have unique value and has been already subjugated only for conservation. This typical forest is indicated as a natural system category and it is found in low density (25-50%), its distribution was not widespread. They have been allocated mostly as forest area to manage and control the water and soil use and classified as modified natural condition. They have been allocated mostly as forest area to manage and control the water and soil use and classified as modified natural condition. Common forest has been rated as having high density (more than 50 %) and indicated as forest for land development and wood production. In the context of ecosystem condition, this typical forest classified as cultivated and build system category.

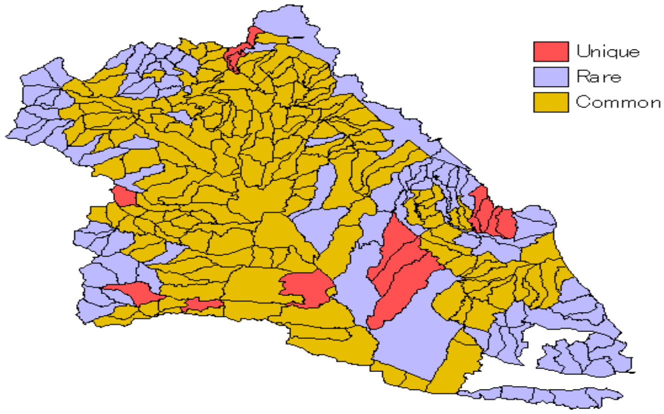

Figure 3: The value of forest (uniqueness)

- Transformation determined the degree of modification or the condition of forest in relation to its original state. To assess the degree of transformation known areas of natural vegetation cover were compared with area currently occupied by vegetation known to be either introduced or succession. Changes of species composition and changes in plant cover were recognized as a major transformation from natural state. Any historic records information would also be of significant assistance in the case of vegetation and fundamental in the case of analyzing forest transformation. It was suggested that three major classes which described the degree of transformation can be distinguished: low; partial; and high. Selected of various classes of forest transformation, relevant in the Northern Region of Mie, are shown that the combination of area with relative dominant forest cover more than 90% and natural system condition has resulted low transformation of the northeast and northwest part of the study area. High transformation including areas with relative dominates of forest cover less than 30% and mostly young, planted forest. On the Southern part in which areas mostly modified and occupied by building, road, and other human structure dominant is classified as high transformation as natural vegetation is unable to regenerate. The remaining area is the combination of forest cover 30-90% and mostly modified system category forest and has resulted in partial transformation. Degree of transformation of forest on the Northern Region of Mie is presented on Figure 4.

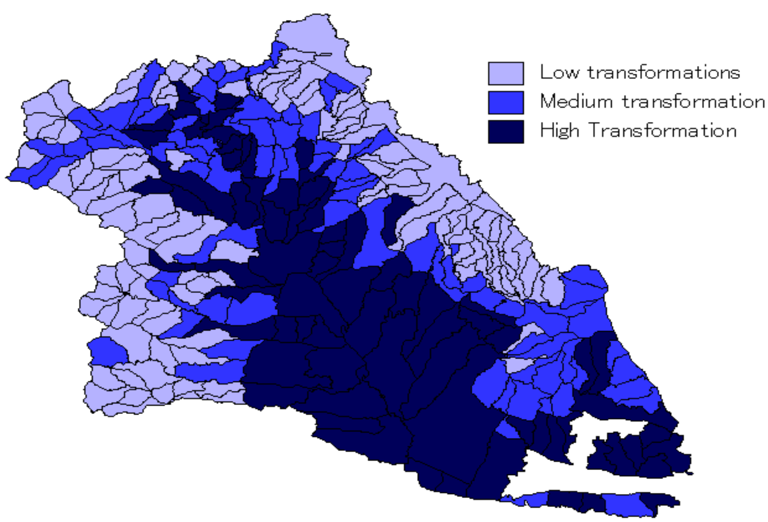

Figure 4: The value of forest (transformation)

- Resilience is defined as the ability of the ecosystem to maintain relationship within it and to respond to disturbance. In this study the following factor determining resilience of forest was identified: Slopes, altitude above sea level, type of tree, and biological attributes of plants forming a given community. To assess resistance have recommended map of plant communities and DEM data. Steep slopes characterize mostly the northwest and Northeast part of NROM, Japan, with altitude above 400 m and this area identified has low resilience. Result from the aspect map indicates that areas of south facing slopes were more resilience than other aspects. Slope, elevation, and aspect were combined and reclassified into a topographic resilience map.
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  In the NROM, Japan, the dominant of soil types were brown forest soil, which mostly located on the northeast and northwest. The results show that the location with brown forest soil has low resilience as a slope steeper and elevation more than 400 meters. However, on the southern part of NROM dominated with low gradient slope and elevation were indicated has a medium and high resilience. To create resilience of forest, soil map also reclassified into the topographic resilience map. The combination of topographic resilience map and soil type map indicates the influence of different soil types on forest resilience on NROM.

  Based on the result, the different topographic layer (slope, elevation and aspect) and soil were classified into 3 resilience categories. Using the combination of topographic resilience map and soil type map, the degrees of resilience of forest was developed on the NROM. Three major classes were distinguished to classify the degrees of forest resilience, as a result the following classes of resilience of forest were distinguished, see Figure 5.

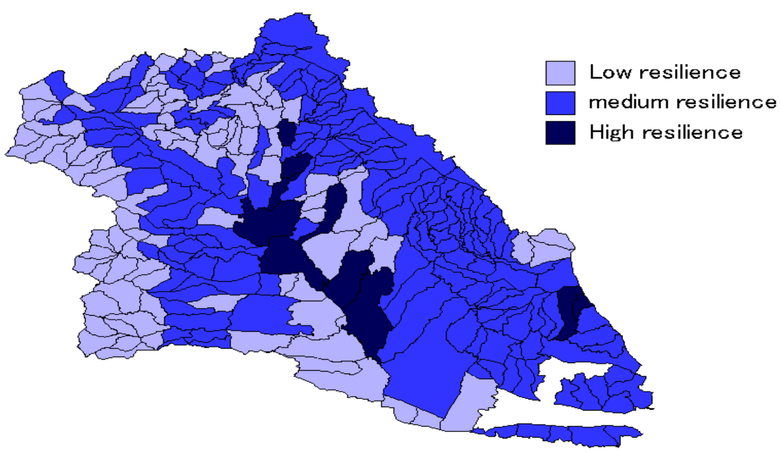

Figure 5: The value of forest (resilience)

4.3 Determination of "territorial" environmental thresholds

This part of the process consists of determining the boundaries of territory in which some area can be permitted, and some others excludes for development. In this phase partial territorial environmental thresholds were determined first. Criteria and decision rules for the definition of territorial thresholds were established. Step towards the determination of territorial environmental thresholds were performed using Idrisi 32. Data files, in which information uniqueness, transformation and resilience was recorded, were used to identify where most limitation for a given development exist in the NROM. The basis set criteria indicated; in particular, what combination of uniqueness, transformation and resilience should determine environmental thresholds in each case. Twenty-seven of maps of zone were determined through a combination of degree of uniqueness, transformation and resilience.

As a result of combination, three types of zone forest tolerance defined. The principal objective was to isolate and establish the zone of exclusion. Figure 6. shows the territorial environmental thresholds zone/total exclusion for development which zone so environmentally sensitive that all transgression has to be excluded. Following this, qualitative dimensions were derived by determination of two further zones (the tread lightly zone and the heavier zone) as can be seen on the figure. The identification of the zones permitted the allocation of activities to areas of appropriate environmental tolerance.

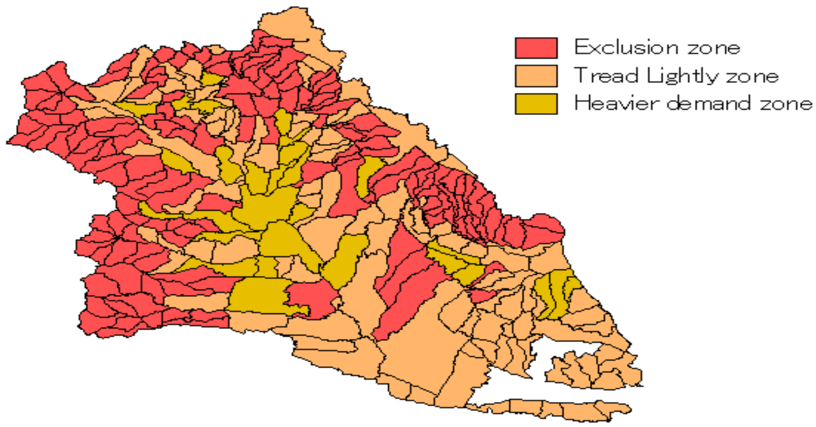

Figure 6: Territorial environmental thresholds zone

In a parallel analysis, criteria for defining other boundary development thresholds were established in a parallel analysis with environmental thresholds. They were derived from such factor includes existing residential area, topography slope>20%, land/forest owned by government, rivers and existing farmland. The two types of thresholds jointly indicated final exclusion zones for activity. The overlapping of these thresholds leads to the definition of ecologically solution space for activity. The remaining area which is unaffected by these final thresholds is the solution space. The resultant map (see Figure 7) is solution space containing various development option within carrying capacity which identified where, and which activities should be developed in the Northern Region of Mie.

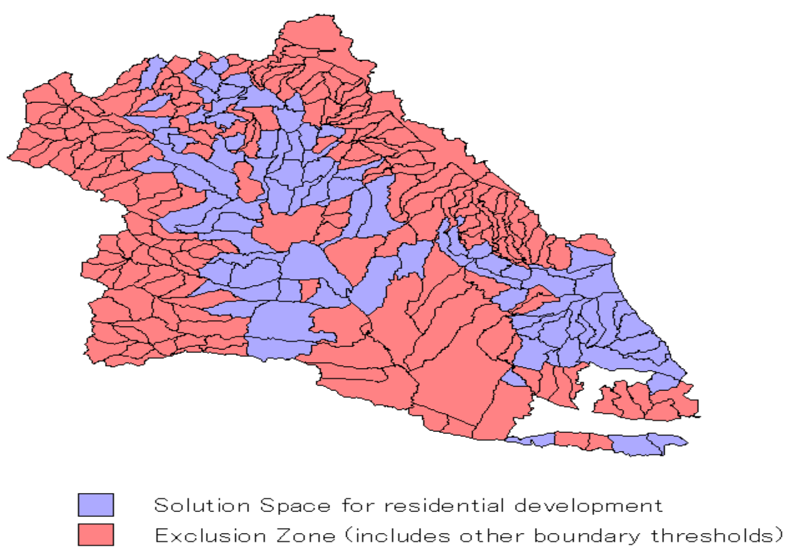

Figure 7: Solution Space

The study area covers 301.06 km2 of which 66.74 per cent belongs to strict reserves (total exclusion) and 33.26 per cent to solution space. A comparison on figure solution space and the map current sitting development on NROM (land use/land cover) illustrates the dominant existing land use within solution space is forest 53.35 percent, followed by agriculture (25.12%), urban area (12.81%) and water (0.3%). Finally, the remaining area is estimated available land for urban expansion within solution space (8.42%).

4.4 Implication from UETs for Northern Region of Mie

Two points of concern emerged from the UETs Analysis. First, it is necessary to rationalizing development of Northern Region of Mie. Second, NROM management plan is not based on principle of containing development within ecological limits. The lease boundaries and the location of residential areas and golf course are not related in any meaningful way to the location of those resource which are of high ecological significance and sensitive to human resources.

There is need to establishment territorial thresholds zone through determining ecological value. From the of this research indicated that zones for total exclusion were areas in which any of the environmental elements considered to be unique or any of the environmental elements considered to be rare or common with low/minor resilience and with only minimal and partial transformation (Table 2)

Table 2:
The identification of zones permitted the allocation to areas of appropriate environmental tolerance

Land Use (hectares)	Category Exclusion zone	Tread Lightly Zone	Heavier Demand zone
Coniferous	3369	221	109
Broad leaf	2365	889	443
Mixed forest	3123	2038	691
Deciduous	3915	728	379
Tea/Field	3611	1339	1608
Residential and Golf course	1880	828	518
Bare Lands	978	575	308
Water body	78	26	5

By overlying the decision main boundaries and other boundary thresholds, a solution space was produced which identified areas on NROM where development facilities would not so conflict with environmental integrity. Following this, qualitative dimension was derived by determination of two further zone within solution space (tread lightly zone and heavier demand zone). Determination zones based on this operation illustrates on the area percentage of different land use types was estimated that 66.74 per cent belongs to strict reserves (total exclusion area) and only 33.26 per cent to solution space (see Table 2). The result was indicated that the area major within exclusion zone cannot to be considered available for development and it indicates that very little additional area expansion of development. This implied that the maximization of the use of resources requires that management practice must be oriented toward minimizing conflict between users, and between users and the natural resources base. There is no doubt that thresholds method such as UETs are useful in the planning process as they may be used to anticipate problem by defining “outer limit” of development.

The UETs analysis provides a guide to how development of, at present, should proceed. The importance of UETs to the location of facilities on ecologically significant and sensitive area is stressed. This study provides in what should not have been done in the past and what should be avoided in the future. This situation does not apply now in the Northern Region of Mie. The UETs analysis highlights the main inadequacy of the management plan, in that it does not respect ecological limit. The impact of infrastructure development varies depending on the location of each in relation to the exclusion zones. To have insight the conflict likely arises in NROM it’s associated with current pattern of land use, the data describe above also allow adapted to evaluate the land use conflict. Territorial UETs method applied to the spatial domain which will define area form which activities should be excluded from on environmental grounds. From the Figure 8 showing a comparison on environmental thresholds zone and the map illustrates current sitting of development on NROM demonstrates that development with medium and high transformation categories is already located in the exclusion area.

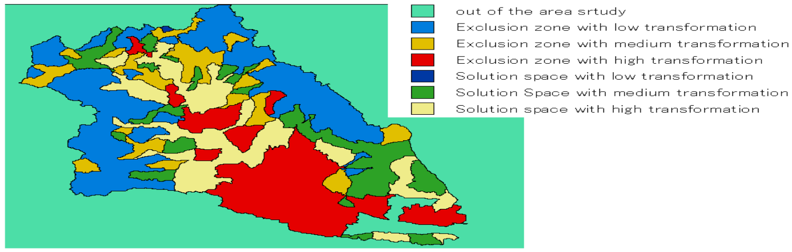

Figure 8 Conflict between territorial environmental thresholds and existing land use

The Figure 8 shows that the area includes the exclusion zone with present high and medium transformations are 35 % of the study area. The result was also indicated the area with highly modified within solution space (19%) cannot to be considered available for development and it indicates that very little additional area expansion of development. The areas (14%) was indicated as first thresholds within solution space with low transformation and intermediate thresholds with medium transformation will become area for expansion urban development. The calculated area on different land use option is shown in Table 3

Table 3:
Determination zones that were generated based on the possible conflict of resulting pattern of territorial environmental thresholds and existing land use

Category	Hectares
Total Exclusion zone with low transformation	9500.84
Exclusion zone with medium transformation	3480.84
Exclusion zone with high transformation	7112.08
Solution space with low transformation	27.57
Solution space with medium transformation	4258.28
Solution space with high transformation	5726.85

5. Conclusion

The application of the UET analysis on the Northern Region of Mie indicates that a spatial analysis of the interrelationship between natural resources and development is necessary, if decision about the location of the future is to be based on ecological criteria. This study does not present a solution to the problems facing Northern Region of Mie; however, it does provide a s useful framework for addressing the major issues, points to some shortcomings in the present approach and how the can be reduced. The spatial dimension dealt with current research may be seen as the initial phase of more comprehensive analyses that addresses the problems of carrying capacity (quantitative UET) and seasonal constraint (temporal UET).

This research is to ensure the continued viability of significant elements of the environment. The combination of uniqueness, resilience and transformation of forest resulted in environmental territorial thresholds map. This map provided a base model to determine an ecologically solution space for development activities on the Northern Region of Mie. A solution space should primarily be determined by these constraints, which can be considered as having final (boundary, ultimate) character that indicate where and which kind of development should take place, so that a rational use of natural resources can be secured. This research demonstrated that an ecologically solution space that was produced in the Northern region of Mie provides a firm basis upon which developers can exercise their flexibility in sitting specific development proposal in their area on what and where is to be generated and contained. The result being the planning contribution towards defining carrying capacity which indicate what preferred and dominant function should be promoted and where is ecologically safe would become especially relevant. From the viewpoint of establishing tolerance to development activities, ecological carrying capacity forms an important concept. Talking the point, carrying capacity is the amount of activity or use that can be handled by system before it begins to deteriorate, another way to describe carrying capacity is determining how much use a given setting can absorb before unacceptable impact occur.

In summary, an overall adaptation of Environmental Thresholds approach provides a simple approach that can be useful tool in defining city's carrying capacity. Finally, we recommend that (1) The extensions of the UET method appear to be viable and necessary (2) UETs must be further develop as a basis to formulate policy guidelines for implementing Carrying Capacity all over Indonesia areas.

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