DETERMINATION OF LAND SUITABILITY FOR GROWTH OF LEUCAENA LEUCOCEPHALA AND PREDICTION OF THE FEED SECURITY IN KUPANG DISTRICT

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STATEMENT

I, Bogarth K. Watuwaya, hereby stated that this thesis entitled:

DETERMINATION OF LAND SUITABILITY FOR GROWTH OF
LEUCAENA LEUCOCEPHALA AND PREDICTION OF
THE FEED SECURITY IN KUPANG DISTRICT

is a result of my own work under the supervision advisory board during the period February until July 2011 and that it has not been published before. The content of the thesis has been examined by the advising the advisory board and external examiner.

Bogor, August 2011

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ABSTRACT

BOGARTH K. WATUWAYA. Determination of Land Suitability for Growth of *Leucaena leucocephala* and Prediction of The Feed Security in Kupang District. Under the supervision of IDAT G. PERMANA and HARRY IMANTHO

The availability of forage for ruminant derived from leguminous especially like *Leucaena leucocephala* to be beneficial to farmers in Kupang district, along with the increasing population of livestock will also increase needs of continuously forage throughout the year; to find a suitable location for development of *L. leucocephala*, expected that growth and production will be optimum. The objectives of this study were to (1) determine the land suitability for development of *L.leucocephala* (2) predict feed security and (3) simulate the distribution patterns of *L.leucocephala* based on the created scenario. The application of Geographic Information System (GIS), Analytical Hierarchy Process (AHP), ICPRC and LQ were used to process the data to determining the land suitability, Carrying Capacity and livestock base area in a region. Research result was simulated by model based on the principle of Cellular Automata. The research result showed that Kupang district has actual potential suitability land to be developed by *L. leucocephala* an area of 2,462.69 km², comprising an area of 36.39 km² classes S1, 1,890.52 km² area of S2 class and area 205.78 km² of class S3; ICPRC result that at least 481.714 AU can be added and LQ resulted 80% location is a livestock base. Simulation model show that both of scenario 2.5% and 5% of growth rate has a same value in carrying capacity although difference in distribution pattern.

Keywords: land suitability, *Leucaena leucocephala*, GIS, AHP, ICPRC, cellular automata, Kupang District
ABSTRAK

BOGARTH K. WATUWAYA. Penentuan Kesesuaian Lahan untuk Pengembangan Leucaena leucocephala dan Pendugaan Ketahanan Pakan di Kabupaten Kupang. Dibawah bimbingan dari IDAT G. PERMANA dan HARRY IMANTHO

Ketersediaan Hijauan bagi ternak ruminansia asal leguminosa khususnya Leucaena leucocephala sangat penting bagi peternak di Kabupaten Kupang, seiring dengan peningkatan populasi ternak akan meningkatkan pula kebutuhan akan hijauan yang berkesinambungan selama kurun waktu setahun; melalui pengembangan penanaman L. leucocephala pada lokasi yang sesuai diharapkan akan meningkatkan pertumbuhan dan produksi yang optimum. Tujuan dari penelitian ini adalah (1) menentukan kesesuaian lahan bagi pengembangan L. leucocephala (2) memperkirakan ketahanan pakan dan (3) melakukan simulasi pola distribusi pengemabangan L. leucocephala sesuai dengan scenario yang dibuat. Penerapan Sistem Informasi Geografis (SIG), Proses Analisis Bertingkat (AHP), Kapasitas Penambahan Populasi Ternak Ruminansia (KPPTTR), Penentuan daerah basis (LQ), dipakai untuk menentukan kesesuaian lahan, kapasitas tampung dan daerah basis ternak. Hasil dari penelitian ini kemudian ditampilkan melalui sebuah model simulasi berdasarkan prinsip Selular Automata. Hasil dari penelitian ini menunjukkan bahwa Kabupaten Kupang memiliki lahan yang sesuai untuk dikembangkan L. leucocephala seluas 2.462,69 km² yang terdiri dari 36,39 km² kelas S1, 1.890,52 km² kelas S2, dan 205,78 km² kelas S3; nilai KPPTTR menunjukkan kurang lebih 481.714 ST masih dapat ditambahkan pada Kabupaten Kupang, sedangkan hasil LQ menunjukkan bahwa 80% wilayah Kabupaten Kupang merupakan wilayah basis ternak. Model simulasi menunjukkan bahwa baik skenario laju pertambahan populasi sebesar 2,5% atau 5% memiliki nilai kapasitas tampung yang sama, yang membedakan adalah pola sebarannya.

Kata Kunci: kesesuaian lahan, Leucaena leucocephala, SIG, AHP, KPPTTR, selular automata, Kabupaten Kupang
SUMMARY

BOGARTH K. WATUWAYA. Determination of Land Suitability for Growth of Leucaena leucocephala and Prediction of The Feed Security in Kupang District. Under the supervision of IDAT G. PERMANA and HARRY IMANTHO

This research aims to study and develop a system that can calculate the capacity of the land to sustain life and estimate the resilience of livestock feed from Leucaena leucocephala and simulate the spatial distribution pattern of development of Leucaena leucocephala in Kupang district. CA Application of GIS and modeling technologies are used to prepare and process spatial data.

Determination of land suitability for development of Leucaena leucocephala obtained from calculations of the growing conditions used by LREP 1994 which refers to the regulation of FAO (1976). Land suitability classification structure in the framework of FAO (1976) can be distinguished according to its level, namely the level of the Order, Class, Subclass and Unit. The Order is a state of global land suitability. At the level of orders suitability distinguishes between land that is classified as suitable (S) and not suitable (N). The term land suitability used by a lot of land classification system, especially by the Soil Conservation Services, USDA; in the USDA system, the soil mapping units are grouped primarily on the basis of ability or suitability of land for producing agricultural crops and fodder.

Leucaena leucocephala is a forage legume, which contains high protein required for animal growth. L.leucocephala has been used as the main fresh forage throughout the year for Bali cattle in Amarasi Sub District with satisfactory results, the legume has a big impact in supporting the productivity of Bali cattle. (Piggin and Nulik, 2005); Depending on variety, Leucaena is either a tall tree or a branchy bush. L.leucocephala can be used for timber, firewood, fiberboard, paper, forage, fertilizer, landscaping, soil reclamation, shading for sun-sensitive crops, windbreaks and firebreaks as well as for dye, mucilage, jewelry and even human food. Moreover, Leucaena seems adapted to many soils too barren for conventional crops and it is one of the fastest growing plants measured. It obtains its own nitrogen fertilizer from air, survives drought, tolerates the salt of costar areas and has a high resistance to pests and diseases. L.leucocephala is very well adapted to the semi-arid climate and the alkaline or relatively neutral soils of the area. The plant is deep-rooted and drought resistant and, being a legume, is adapted to low-N soils. Although its early growth is slow and susceptible to grazing and weed competition, L.leucocephala has proven easy to establish and is very persistent in most situations.

Determination of land suitability classes will be very difficult without using tools, in this study is felt a very precise method of AHP in assisting researchers in the weighting process. Weight values obtained from 8 (eight) people classified as expert as a team of experts in agriculture from BPTP. Suitability of this data will then be given a weighting based on scores from the expert through a process commonly
known as Multi Criteria Analysis. The data have been obtained subsequently processed using the method of spatial analysis in order to obtain a map of land suitability with respect to areas of constraint. Constraint area is an area that should not be used as a development area *L. leucocephala*. This area is made up of water bodies, forests, protected areas, agricultural areas of wetland, water body, protected forest, protected areas, forest folk, produced forest, settlement, and wet land farming.

Kupang district has the actual potential area to be developed of *L. leucocephala* an area of 2,462.69 km², comprising an area of 366.39 km² classes S1, S2 class area of 1,890.52 km² and S3-class area of 205.78 km², ICPRC analysis obtained values show a different trend for each sub-district, but the overall figures show that the district ICPRC still able to accommodate 481.714 AU of cattle to rely solely on native grasses and agricultural by product as feed. Location Quotient analysis resulted 10 areas in Kupang District showed that most areas is the livestock base area, except in sub-district Sulamu, Fatuleu, South Amfoang, and Southwest Amfoang are not be the base area, although the difference is only 0.1 compared to other regions.

ICPRC analysis obtained values show a different trend for each sub-district, but the overall figures show that the district ICPRC still able to accommodate 481.714 AU of cattle to rely solely on native grasses and agricultural by product as feed. Location Quotient analysis resulted 10 areas in Kupang District showed that most areas is the livestock base area, except in sub-district Sulamu, Fatuleu, South Amfoang, and Southwest Amfoang are not be the base area, although the difference is only 0.1 compared to other regions.

Based on the results obtained by both of the Business as usual scenario and Spatial Plan scenario can be seen that the pattern of development based on the sequence of *Leucaena leucocephala*, the development used first the grassland area as a priority and the next is pastures and other utilization (mine area). This can be happened because of the calculation process in the simulation model will first consider land suitability classes and then based on the weight of the driving force and constraints that apply in the scenario. In either scenario, business as usual with a Growth Rate of 2.5% or 5% in the year 2020 required the addition of land for the development of *Leucaena leucocephala* respectively 1861 ha and 4354 ha; that sets it apart is the pattern of its spread.

Keywords: land suitability, *Leucaena leucocephala*, GIS, AHP, ICPRC, cellular automata, Kupang District
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LEUCAENA LEUCOCEPHALA AND PREDICTION OF
THE FEED SECURITY IN KUPANG DISTRICT

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Hopefully, this thesis could give positive and valuable contribution for anyone who reads this thesis.

Bogor, August 2011

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CURRICULUM VITAE

Bogarth K. Watuwaya was born in Salatiga, Central Java, Indonesia, on October 12\textsuperscript{nd} 1976. He spent his elementary school in Salatiga until finished on 1989, and then continued his higher school level in Kupang, East Nusa Tenggara. He achieved his undergraduate degree in 2000 from Nusa Cendana University, Faculty of Animal Husbandry, Majoring in Nutrition and Animal Feed. In 2009, Bogarth K. Watuwaya pursued his Master degree at Master of Science in Information Technology for Natural Resources Management (MSc in IT for NRM), Bogor Agricultural University. His final project for thesis is entitled “Determination of Land Suitability for Growth of *Leucaena leucocephala* and Prediction of The Feed Security in Kupang District.”
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I. INTRODUCTION

1.1 Background

Land suitability is the degree of suitability of a parcel of land for specific use. Land suitability can be assessed for the current state (the actual land suitability) or after a repair (potential land suitability). Land suitability classification structure in the framework of FAO (1976) can be distinguished according to its level, namely the level of the Order, Class, Subclass and Unit. The Order is a state of global land suitability. At the level of orders suitability distinguishes between land that is classified as suitable (S) and not suitable (N). The term land suitability used by a lot of land classification system, especially by the Soil Conservation Services, USDA; in the USDA system, the soil mapping units are grouped primarily on the basis of ability or suitability of land for producing agricultural crops and fodder.

The increase in of beef demand by society will lead to an increase in cattle population to meet those needs. The Indonesian government policy to make meat self-sufficiency by 2014 is expected to become reality by taking into several factor such as supporting quality and availability of forage throughout a year.

These problems are challenging the government of East Nusa Tenggara province to return the predicate in year 1970s that is East Nusa Tenggara as a cattle source, with a policy that Kupang District is either one as center of Bali cattle (Bos Sondaicus) producers. To be able to support that programs, District Kupang government must give special attention to the availability of animal feeds, because in order to develop Bali cattle (Bos sondaicus) on a large scale is needed necessary availability of adequate and sustainable feeds throughout the year. The given climatic conditions of the region are relatively dry; it needs a fodder crops which can survive in poor conditions like this. East Nusa Tenggara is in a good position to encourage the growth of the livestock sector, especially since the central government looked at East Nusa Tenggara as one of the two main sources of animal cattle in Indonesia (Christie, 2007).
Leucaena leucocephala is a forage legume, which contains high protein required for animal growth. L. leucocephala has been used as the main fresh forage throughout the year for Bali cattle in Amarasi Sub District with satisfactory results; the legume has a big impact in supporting the productivity of Bali cattle. (Piggin, 2003, Nulik, 2002); Depending on variety, Leucaena is either a tall tree or a branchy bush. It can be used for timber, firewood, fiberboard, paper, forage, fertilizer, landscaping, soil reclamation, shading for sun-sensitive crops, windbreaks and firebreaks as well as for dye, mucilage, jewelry and even human food. Moreover, Leucaena adapted to many soils too barren for conventional crops and it is one of the fastest growing plants measured. It obtains its own nitrogen fertilizer from air, survives drought, tolerates the salt of costar areas and has a high resistance to pests and diseases (Benge, 1980; Vietmeyer, 1980)

A recent experiments have shown that improved breeds of cattle will gain as much as 1 kg in weight per day when fed a 100% ration of protein-rich Leucaena for a 3 month-period prior to slaughter. These tests were conducted by the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia. The leaves of improved strains of Leucaena contain 23%-30% protein by dry weight. Cattle can consume a high intake of Leucaena for a period of four months without any adverse effects, a length of time ideal for the fattening of cattle prior to slaughter (Vietmeyer, 1980)

A Geographic Information System (GIS) is a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the earth. GIS refers to computer software that provides data storage, retrieval, and transformation of spatial (field) data. GIS software for digital agriculture will store data such as soil type, nutrient levels, etc, in layers and assign that information to the particular field location. A fully functional GIS can be used to analyze characteristics between layers to develop application maps or other management options (Jessica, 2009). Information technology, especially Geographic Information System can be used to determine land suitability for growth of L. leucocephala and predict the carrying capacity to support feed security. This technology is applied to selecting area
by considering many factors such as rainfall, temperature, soil type, topography and other socio economic factors.

Cellular Automata (CA) is usually associated with synchronous deterministic dynamics, and their asynchronous or stochastic versions have been far less studied although significant for modeling purposes. CA has attracted growing attention in growth simulation because their capability in spatial modeling is not fully developed in GIS. CA can be extended and integrated with GIS to help planners to search for potential suitability of *L. leucocephala* for sustainable development. The cellular automata model is built within a grid-GIS system to facilitate easy access to GIS databases for constructing the constraints. The essence of the model is that constraint space is used to regulate cellular space. Driving force and constraints play important roles in affecting modeling results. Combination of GIS and CA can be used as a strong couple to model the *L. leucocephala* growth to take advantages of both the technique. In case of GIS, its spatial data analysis capacities may be insufficient to handle the complex of *L. leucocephala* growth dynamic.

1.2 Scope of Study

The area of study is restricted to district level. This study is focused to find land suitability for growth of *L. leucocephala* in Kupang District, East Nusa Tenggara Province. It covers suitable area for *L. leucocephala* growth by considering several factors such as climate factor, physical factor, social and culture or attractiveness factor, and than predict the feed security for livestock's farming.

1.3 Problem Statement

Beef cattle's farming requires the continuous availability of feeds, in other side *L. leucocephala* is one of the forage that has many advantages can be reliable for the less fertile areas such as Kupang District. The Amarasi Farming System has been proven to support the existence of Bali cattle feedlot business based on *L. leucocephala*. Kupang District has a fairly broad region expected to be developed as potential fodder like a *L. leucocephala* to support the Bali Cattle industry, which is
area is suitable to be developed a \( L.\) \textit{leucocephala}; it will be answered with consider various criteria such as climatic factors, soil factors, topography factors, driving force factors and constraints.

### 1.4 Research Objectives

The objectives of the study are to determining 1). Land suitability for growth of \( L.\) \textit{leucocephala} and 2). Develop a model that can represent spatial distribution pattern of \( L.\) \textit{leucocephala} and then 3). Predict the carrying capacity to support feed security for Bali cattle industry in Kupang District with used integrated of GIS and Cellular Automata (CA) modeling to develop the growth simulation model.
II. LITERATUR REVIEW

2.1 The Amarasi Farming System base on *Leucaena leucocephala*

Bali cattle (*Bos sondaicus*) was introduced in 1912 under Dutch encouragement, adapted well to Timor but did little to solve the problems of feeding the population. Livestock, including cattle, water buffaloes and horses, were used mainly for social and ritual purposes and were rarely eaten. Rulers and heads of villages commonly accepted distributed livestock and sold the offspring for slaughter in major centre, or for export. Lack of knowledge about livestock and grazing management systems, or watering systems and improved pastures, resulted in high mortality and low productivity. Uncontrolled, open range, and indiscriminant grazing was also a problem to unfenced crops, and for the regeneration of forest areas after cropping (Ormeling, 1955; Metzner, 1981).

In the 1930s, experimental plantings of *Leucaena leucocephala* were made under the guidance of the Dutch administration on abandoned fields around the village of Baun (Ormeling, 1955; Metzner, 1981, 1983). In 1932, the *raja* (ruler) pronounced an *adat* or traditional regulation, which obliged every farmer in Amarasi to plant contour rows of *L. leucocephala* not more than 3 m apart on cropping areas before they were abandoned (Piggin, 2003).

The *adat* regulation was reinforced in 1948 when the government introduced the "Peraturan Tingkat Lamtoro* (L. leucocephala Level Regulation). It compelled all shifting cultivators to plant *L. leucocephala* hedges along contour lines (Ormeling, 1955). Over time, the plant moved out from the rows and quickly formed an even cover, apparently because the hedges were not trimmed and *L. leucocephala* colonized the inter-row spaces (Metzner, 1981).

*Leucaena leucocephala* based cropping systems were further promoted in 1938 with the introduction of land use zoning regulations. These set aside 10 zones exclusively for cropping. Small livestock, including pigs, goats and sheep, had to be penned and large livestock such as cattle, buffalo, and horses had to be tethered (Nulik, et al. 2002).
The zones were amalgamated and expanded in 1960 and 1967, to include most of western Amarasi. Any livestock straying onto cropping land could be killed on the spot. Outside the zones, cattle could graze freely but had to be corralled once a week. The successful implementation of land use zoning eliminated the need to build fences, a pursuit which, according to Ormeling (1955), took up 25–30% of the time Timorese farmers spent on cropping. Thereafter, farmers were able to spend more time on other agricultural activities.

The widespread and successful adoption of *L. leucocephala* in Amarasi was only possible because of the supportive regulations introduced and enforced by the adat ruler (*raja*), who was later appointed administrative head (*camat*) of Amarasi Sub district. He was able to pronounce his regulations because of an adat law stipulating that all land belonged to the ruler. Local farmers were given the right to cultivate the land by the local ruler’s representatives in each of the 62 Amarasi communities. A farmer’s right to use the land expired as soon as he ceased to cultivate it (Piggin, 2003).

Cattle production was further stimulated in 1971 by the provincial Government’s introduction of the feedlot or cattle fattening scheme. The government bought cattle from central Timor and distributed them to interested farmers for fattening by feeding them with cut-and-carry legume fodder. After reaching slaughter weight, the cattle were sold through traders for export, with 85% of the profit going to the farmer and 15% to the government. More recently, many farmers have bought and sold cattle on their own account. Of all the farmers in East Nusa Tenggara, those in Amarasi benefited most from the feedlot system because theirs was the only district with abundant cut-and-carry fodder. An adat law obliging each family in Amarasi to fatten between two and seven cattle further increased numbers and evened out the distribution of livestock. (Piggin, 2003).

The average Amarasi farmer of the 1980s was described by Metzner (1981), and many features from this time prevail today. The family is composed of six persons and their farm covers 2 ha. *L. leucocephala* grows over the entire farm at a density of 10,000 trees per ha. As previously described, *L. leucocephala* hedgerows
have not been evident in Amarasi for a long time, and crop and livestock activities require harvesting or cutting the fallow forest of *L. leucocephala* and associated species. Usually 1–1.3 ha is used to provide fodder for tethered or penned livestock and 0.6–1 ha is used for crop production. The average farmer raises three head of Bali cattle that he has bought from local markets near the end of the dry season.

*Leucaena leucocephala* (Lamark) de Wit 1961 is the most economically important species in the genus *L. leucocephala*, which is in the tribe Mimoseae of the subfamily Mimosoideae of the family Leguminosae (*Fabaceae*). Closely related genera are *Desmanthus*, *Calliandropsis* and *Schleinitzia*. (Cowan 1998).

*L. leucocephala* is a perennial non-climbing, non-spiny shrub or tree. Native to tropical America, two of the three subspecies now have a pan-tropical distribution facilitated by its use as a fodder, wood source and reclamation species (Walton, et.al, 2003).

*Leucaena leucocephala* is very well adapted to the semi-arid climate and the alkaline or relatively neutral soils of the area. The plant is deep-rooted and drought resistant and, being a legume, is adapted to low-N soils. Although its early growth is slow and susceptible to grazing and weed competition, *L. leucocephala* has proven easy to establish and is very persistent in most situations. It was devastated when the *Heteropsylla cubana* entered East Nusa Tenggara in 1986, but has since recovered much of its productivity and remains a persistent and dominant species in many village areas. (Piggin, 2003)

Village life is harsh in East Nusa Tenggara, and villagers struggle with many constraints. *L. leucocephala* is a multi-purpose plant contributing a multitude of village needs, from firewood and building timber to forage for livestock, mulch for crops, weed suppression, shade for tree crops, and soil stabilization. In Amarasi, it has become like a forest and supports more or less permanent slash-and-burn cropping as a fallow species which improves soil fertility and suppresses weeds. Its capacity to supply nutritious forage has led to the development of a large-scale industry involving the fattening of tethered cattle in Amarasi.
Some weaknesses found in Measurements of *L. leucocephala* in East Nusa Tenggara, the mineral content of *L. leucocephala* suggest that low sodium, phosphorus and copper may limit its nutritive value and, consequently, its role in animal production. However, farmers in Amarasi already compensate for sodium deficiency in *L. leucocephala* by the common practice of adding salt to drinking water.

Figure 1 *Leucaena leucocephala* (Hughes, 1998)
Leucaena leucocephala is a tropical species requiring warm temperatures (25-30°C day temperatures) for optimum growth (Brewbaker et al. 1985). At higher latitudes and at elevated tropical latitudes growth is reduced (Brewbaker et al. 1985), suggest that temperature limitations occur above 1000 m elevation within 10°C latitude of the equator, and above 500 m elevation within the 10-25°C latitude zone. L. leucocephala can be found performing well in a wide range of rainfall environments from 650 to 3,000 mm. However, yields are low in dry environments and are believed to increase linearly from 800 to 1,500 mm, other factors being equal.

Leucaena leucocephala has been one of the foremost tropical fodder trees, often being describe as the alfalfa of the tropics (Bray, 1986; Pound et al., 1983; National Academy of Sciences, 1984; Brewbeker, 1990., Shelton et al, 1995). L. leucocephala is, in most respect, one of the highest quality and most palatable fodder trees of the tropics (Jones, 1979; 1994b; Pound et al. 1983; Brewbeker, 1987b; Shelton et al, 1995; Norton et al., 1995). Leaf quality of L. leucocephala compare favourably with alfalfa or lucerne in feed value except for its higher tanain content (Jones, 1979) and mimosine toxicity to non ruminants (Bray, 1986). Leaves of L. leucocephala have a high nutritive value (high palatability, digestibility, intake and crude protein content), resulting in extremely impressive animal production with 70-100% increases in animal live weight gains compare to pure grass pasture (Shelton et al. 1994; Jones, 1994b). In addition, L. leucocephala is very persistent over several decades of cutting grass and can grazed with minimal losses due to tramping or grazing (Jones, 1996).

Leucaena leucocephala is very drought tolerant even during establishment. Young seedlings have survived extended periods of dry weather and soil and plant studies have confirmed that L. leucocephala exhibits better drought characteristics than a number of other tree legumes (Swasdiphanich 1992). L. leucocephala does best on deep, well drained, neutral to calcareous soils; it is often found naturalized on the rocky coralline terraces of Pacific island countries. However, it grows on a wide variety of soil types including mildly acid soils (pH > 5.2). It is well adapted to clay
soils and requires good levels of phosphorus and calcium for best growth (Cowan, 1998).

2.2 Increasing Capacity Population of Ruminant Cattle (ICPRC)

The Potential distribution and livestock development area is the capacity of the territory to accommodate the additional population of ruminants. The increased potential of ruminant livestock population has understanding of the dynamic, changing over time, can grow and can be reduced. Rollinson and Nell (1974) was develop a model called ICPRC or Increasing Capacity Population of Ruminant Cattle. This method is useful to see how big an area has the potential to increase the population of ruminants based on ability of forage in a region.

Based on the results of data processing of livestock population analysis with ICPRC model obtained a values show a different trend for each region. ICPRC positive value indicates a tendency that relevant districts still allow the addition of ruminant livestock population of the existing number of livestock units, whereas negative values indicate a tendency ICPRC concerned that the region needs to be directed to the development of the area of land that is the carrying capacity of principal farm businesses, such as grassland and the agriculture area.

Table 1 Conversion value base on wide of forage produce land (Rollinson and Nell, 1974)

<table>
<thead>
<tr>
<th>No</th>
<th>Real Wide Land</th>
<th>Available Land for Grass production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pasture / Grassland</td>
<td>Whole area</td>
</tr>
<tr>
<td>2</td>
<td>Non productive paddy field</td>
<td>20% x paddy field area x 10%</td>
</tr>
<tr>
<td>3</td>
<td>Paddy field dike</td>
<td>2.5 x paddy field area</td>
</tr>
<tr>
<td>4</td>
<td>Plantation</td>
<td>5% x Plantation area</td>
</tr>
<tr>
<td>5</td>
<td>Forest</td>
<td>5% x forest area</td>
</tr>
<tr>
<td>6</td>
<td>Side Road</td>
<td>0.5 ha x length of road</td>
</tr>
<tr>
<td>7</td>
<td>Dry farming</td>
<td>1% x dry farming area</td>
</tr>
</tbody>
</table>

2.3 Criteria and Measurement for Land Suitability

There are some criteria that can influence the determination of suitable area for growth of L. leucocephala. The criteria are divided into three main factors; those factors are climate factors, soil factors and topographic factors.
2.3.1 Climate Factors

Climate factor is one of the physical and environmental factors that affect the quality and quantity of growth and development. This factor needs to get a specific study, because of the climate variables is a variable that can not be given treatment or modified to make them correspond with the requirements of growing plants. Even if can be done changes in climate variables, it will require huge costs and no efficient compared with the results or the production of agricultural commodities and have been determined. Climate factors consist of:

- Annual temperature (°Celsius).

  The temperature effect in a metabolisms functions as a determinant of growth and development phase of the plant. Each plant has a certain temperature limits, so it can grow and develop optimally. Analysis of air temperature for zoning crop is using the average air temperature taken from the existing climatologically station data and compare with the topography of the region using Braak equation.

  \[
  T = 27.3 - 0.0061h \\
  \text{for } 0 < h > 2000 \text{ asl}
  \]

  \[
  T = 25.5 - 0.0052h \\
  \text{for } h > 2000 \text{ asl}
  \]

- Rainfall (mm/month).

  Annual rainfall is one important factor in plant survival because it directly relates to the availability of water during the period of one year from the end of the rainy season until the beginning of the next rainy season.

- Dry Months.

  Number of wet months and dry months is used as the basis for determining the level / phase of generative plants. As a limitation to distinguish the dry season and rainy season, then used the number of consecutive dry months.
A condition called dry months when average monthly rainfall less than 60mm. The availability, timing and distribution of water is the primary factor shaping the dynamics of the savanna ecosystem. The savanna experiences recurrent episodes of drought lasting 4-8 months out of the year. During this periods is plant activities is growing, dying, decomposing, but at vastly reduced rates. Some studies have shown that resistance to drought is more important to savanna vegetation than resistance to fire. The plants that thrive in the savannas employ many strategies to exploit available water and to survive from this condition. The mechanisms of survival endow the savanna with its characteristic appearance.

The primary water recruitment strategy of savanna tree species is to maintain an extensive root system. The root system may extend deep underground, sometimes reaching the water table, or it may be a shallow, lateral system designed to harvest water over a broad area. Most leaves are lost during the dry period. Seeds grow within thick casings that allow them to survive until the first rainfall before germinating. And in the midst of this thorny, corky, leathery protection, delicate, showy flowers bloom briefly on grasses and shrubs.

In contrast to the grasses, savanna trees may conduct the entirety of their reproductive cycle during the dry season. Such a strategy would maximize the amount of foliage available for photosynthesis during the rainy season.

2.3.2 Soil Factors

Physical and chemical soil conditions are physical factors that serve as the planting medium. In contrast to climatic factors, soil variables that affect plant growth and development can be given a treatment that can alter soil conditions to conform to the requirements of growth and development of plants. Soil treatment is relatively more efficient than modifications to the climate.
Soil determines whether the deep roots will grow to their potential length. Different soils have different moisture-holding and drainage capacities. The soils underlying savannas cover a wide range of types, and it is thought that at least some of these soils are inhospitable to tree growth, thereby maintaining the characteristic physiognomy of the savanna. Soil type and geology bedrock have a major controlling influence over the plant communities that will grow in them. Depending on their structure, degree of porosity, and so forth, the major soil types may determine whether a savanna is classified as moist or arid, independent of the amount of rainfall. There are usually noticeable disconformities in soil type at the boundary between forest and savanna, and again at the boundary between savanna and desert. Soil factors consist of:

- **Soil Texture.**
  Soil texture is an indicator that can indicate the ability of soil to hold water. By using soil texture data determined the value of field capacity and permanent wilting points are used to determine the limits of land to provide water for plants.

- **Effective Depth (cm).**
  Effective depth of soil is soil physical properties that become limiting for the depth of plant roots. This property is often called the top soil layer which shows a layer of soil that contain lots of nutrients with high fertility rates that are necessary for plant growth and development. The more in an effective depth of soil, then plant the opportunity to get the nutrients are also getting bigger.

- **Soil Acidity (pH).**
  The nature of soil pH levels to explain about the availability and absorption of nutrients the soil. Based on the nature of the pH, the soil may be acidic (pH<7.0), neutral (pH = 7.0) and bases (pH>7.0). Land is often the lowest water (paddy field or swamp) are generally acid, while the chalky soil or dry climates are generally alkaline. The nature of the soil pH affects plant growth and development. Each plant has the ability to grow optimally at
the appropriate pH range and can tolerate a certain pH range. Land can be classified into classes of land suitability for each crop based on a pH range where plants can grow and produce normally.

2.3.3 Topography Factors.

Compliance is assessed on the basis of topographic height of a place of sea level and slope factors are calculated based on the interval contour lines. Elevation somewhere correlated with average air temperature. Topography factors consist of:

- Slope (%).
  
  Gradient (slope) is expressed in percent, is impacting on many factors, other variables such as drainage, cultivation techniques and optimal planting area. In areas with high slope, Drainage will be fast mainly surface flow, while on a sloping drainage area will be slower. Related to the impact on cultivation techniques and the area planted, the areas with low slope variation would be better if compared with areas with high slope variations that will require more effective soil treatment.

- Elevation (m).
  
  The average air temperature will decrease with increasing elevation of a place, so that the elevation would be limiting for plant development process. Much more appropriate commodities grown in areas with an elevation of 0 to 700m above sea level, whereas at the higher regions more suitable for horticultural commodities.

2.4 Geographic Information System (GIS)

Sustainable development planning, decision-making, and management are comprehensive processes which deal with multiple-dimension problems aiming at achieving balanced economic development, environmental protection, and social equity and welfare. The use of (geographic) information to support (spatial) decision-
making requires availability of data, and tools to analyze data to be integrated in complex information systems.

A Geographic Information System (GIS) is integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts (Wyatt, 2003). A GIS application is automated process that generates a spatially oriented product or result needed by user. GIS application may include: map update or map production, data query and display, spatial analysis, or other processes that use GIS software and geographic data (Ogaja, 2011).

Currently, the application of GIS for agricultural purposes has been widely developed, GIS is becoming a more utilized business management tool for farmers because of current trends that will continue to the future, GIS will see improvement in hardware and software, changes in the way companies market and communicate to their clients, development of full-services precision agriculture providers, internet-based data access, and the increased use of GIS to ensure environmental compliance (Pick, et al 2005).

The methodical approach to a GIS system design includes a GIS need assessment and system architecture design. The system architecture design is based on user workflow requirement identified in the GIS needs. The most effective system design approach consider user need and system architecture constraints throughout the design process (Ogaja, 2011).

2.5 Multi Criteria Evaluation (MCE) with Analytical Hierarchy Process (AHP)

Land use change is often modeled as function of socio-economic and bio-physical variables that act as driving force or factors of land-use change. Driving forces are generally categorized into three main groups: socio-economic driver (e.g. population pressure, income levels and agricultural production) bio-physical driver
Multi Criteria Decision Making (MCDM) or Multi Criteria Evaluation (MCE) problems involve a set of alternative that are evaluated on the basis of a set of evaluation criteria (Jacoba et.al. 2008). Using MCE, different factors or change drivers can be combined using appropriate weights assigned to the factors. The result of such a combination is numerical value map representing the land transition suitability or transition potential value (scores) that describe the potential of cell to undergo transition from a current state (e.g. forest) to a new state (e.g. built-up).

A number of methods has been proposed for weighting factors. Examples include direct weighting, rank-order weighting and Analytical Hierarchy Process (AHP). Of these approaches, AHP has been identified as weighting strategy that can overcome the problem of weighting bias which is obvious short-coming of the direct and rank-order methods. (Deekshatulu et.al.1999) AHP can be used to determine the relative importance of a set of activities or criteria through a pair-wise comparison of the various factors.

The first step of the AHP is to form hierarchy of objectives, criteria and all other elements involved in the problem. Once the hierarchical structure has been formed, comparison matrices are developed as result of evaluation made by the decision-makers on the intensity of difference in importance, expressed as a rank number on given numerical scale for each level in the hierarchy. Some MCE modeling methods require that the factors be standardized prior to computation of the final transition suitability (potential) map (ILWIS, 2007)

Therefore numerical values expressing a judgment of the relative importance (or preference) of one factor against another have to be assigned to each factor. Saaty (1991) suggested a scale for comparison consisting of values ranging from 1 to 9 which describe the intensity of importance, where by a value of 1 expresses equal importance and a value of 9 is given to those factors having an extreme importance over another factors.
Table 2 Scale of preference between two elements (Saaty, 1991)

<table>
<thead>
<tr>
<th>Intensity of Importance</th>
<th>Description</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equally Preferred</td>
<td>Two activities contributes equally to the objective</td>
</tr>
<tr>
<td>3</td>
<td>Moderately Preferred</td>
<td>Experience and judgment slightly favor one activity over another</td>
</tr>
<tr>
<td>5</td>
<td>Strongly Preferred</td>
<td>Experience and judgment strongly or essentially favor one activity over another</td>
</tr>
<tr>
<td>7</td>
<td>Very strongly Preferred</td>
<td>An activity is strongly favored over another and its dominance demonstrated in practice</td>
</tr>
<tr>
<td>9</td>
<td>Extreme Preferred</td>
<td>The evidence favoring one activity over another is the highest degree possible of affirmation</td>
</tr>
<tr>
<td>2,4,6,8</td>
<td>Intermediate values</td>
<td>Used to represent compromise between the preferences listed above</td>
</tr>
</tbody>
</table>

Reciprocals  Reciprocals for inverse comparison

The pair-wise comparison generates a matrix of relative rankings for each level of hierarchy. The numbers of matrices depend on the number elements at each level. The order of the matrix at each level depends on the number of element at the lower level that links to it. After all matrices are developed and all pair-wise comparison are obtained, eigenvectors or the relative weights, and the maximum eigen-value ($\lambda_{\text{max}}$) for each matrix are then being calculated.

The ($\lambda_{\text{max}}$) value is an important validating parameter in AHP. It is used a reference index to screen information by calculating the consistency ratio (CR) of the estimated vector in order to validate whether the pair-wise comparison matrix provide a completely consistent ratio. The consistency ratio is calculated as per the following steps;

a) Calculate the eigenvector or the relative weights and $\lambda_{\text{max}}$ for each matrix of order n
b) Compute the consistency index for each matrix of order \( n \) by the formula:

\[
CI = \frac{\lambda_{\text{max}} - n}{(n - 1)}
\]

where \( \lambda_{\text{max}} \) is the maximum eigenvalue of the matrix.

c) The consistency ratio is then calculated using formula:

\[
CR = \frac{CI}{RI}
\]

where \( RI \) is a known random consistency index obtained from a large number of simulations runs and varies depending upon the order of matrices of order 1 to 10.

If the value of \( CR \) is equal to, or less than that value, it implies that the evaluation within the matrix as acceptable or indicates a good level of consistency in the comparative judgments represented in that matrix. In contrast, if \( CR \) is more than the acceptable value, inconsistency of judgment within that matrix has occurred and evaluation process should therefore be reviewed, reconsidered and improved.

Table 3 Average random index (RI) based on matrix size (Saaty, 1991)

<table>
<thead>
<tr>
<th>Matrix size (n)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
<td>0</td>
<td>0</td>
<td>0.58</td>
<td>0.90</td>
<td>1.12</td>
<td>1.24</td>
<td>1.32</td>
<td>1.41</td>
<td>1.45</td>
<td>1.49</td>
<td>1.51</td>
<td>1.48</td>
<td>1.56</td>
<td>1.57</td>
<td>1.59</td>
</tr>
</tbody>
</table>

Multidiscipline expert with difference knowledge background will result a various judgments value, it's important to checking one by one those consistency of judgments. After that process, the selected result has good consistency should merging into one value. To merging values of expert judgment use geometric mean method.

\[
G = \sqrt[n]{\prod_{i=1}^{n} X_i}
\]

Where: \( X_G \) = Geometric mean

\( n \) = Total Respondent

\( X_i \) = Judgment value from respondent \( i \)

The result from calculate with used by geometric average method will calculate as there is in Pair-wise Comparison process.
2.6 Cellular Automata (CA) Model

Cellular Automata (CA) are dynamic models that can be employed to simulate the evolution or dynamic of wide variety of natural and human systems. They are processing algorithms that were originally conceived by Ulam and Von Neumann in the 1940s to study the behavior of complex systems. CA models present a powerful simulation environment represented by a grid of space (raster). In which a set of transition rules determine the state attribute of each given cell taking into account the attribute of cell in its vicinities. These models have been very successful in view of their operationality, simplicity and ability to embody both logic and mathematics-based transition rules, thus enabling complex global patterns to emerge directly from the application of simple local rules. A cellular automaton system consists of a regular grid of cells, each of which can be in one of a finite number of states, updated synchronously in discrete time steps according to local, identical interaction (transition) rules. The state of a cell is determined by the previous state of its surrounding neighborhood of cell. The types of spatial problems that can be approached using CA models include spatially complex systems (e.g., landscape processes), discrete entity modeling in space and time (e.g., agricultural systems, population dynamics) and emergent phenomena. From the application perspective, CA is a dynamic model that inherently integrates spatial and temporal dimension.

CA is composed of quadruple of elements as defined in the following equation (White et al. 2000)

\[ \text{CA} = \{X, S, N, R\} \]

where
- CA = Cellular Automaton;
- $X$ = CA cell space;
- $S$ = CA states;
- $N$ = CA cell neighborhood;
- $R$ = CA transition rule;
**Cell space:** the cell space is composed of individual cell, although these cell may be in any geometric shape, most CA adopts regular grids to represents such space, which make CA very similar to the cellular structure of raster GIS

**Cell states:** the state of each cell may represent any spatial variable, e.g. the various land-use type. The state transition of a CA is defined by the following relation:

\[ t+1 S_{i,j} = \tilde{a} ((tS_{i,j},(tN_{i,j}), (tR_{i,j})) \]

where \( t+1 S_{i,j} \) = new (next) state of a cell, \( C_{i,j} \) at time \( t+1 \);

\( t S_{i,j} \) = initial state of a cell, \( C_{i,j} \) at time \( t \);

\( tN_{i,j} \) = neighborhood of a cell, \( C_{i,j} \) at time \( t \);

\( tR_{i,j} \) = transition rule applied to cell, \( C_{i,j} \) at time \( t \);

Transition rules guide and control the dynamic evolution of CA. In classical CA, transition rules are deterministic an unchanged during evolution. In several recent studies, however they modified into stochastic and fuzzy logic controlled methods (Wu, 1998).

Neighborhood, this is defined by local neighbors of a cell. In two dimensional cellular automata model there are two common types of neighborhood: the Von Neumann neighborhood with four neighboring cell and the Moore neighborhood with eighth neighbors. Figure below shown 3x3 neighborhood kernel.

![Fig 2](https://via.placeholder.com/150)

(a) Moore Neighborhood; (b) Von Neumann Neighborhood
The future state of a cell in CA is dependent on its current state, neighborhood states, and transition rules which are setup and fine-tuned using transition suitability or potential score of individual cells. Iterative local interaction between cell within the neighborhood finally produce the global pattern.

Simulation of land use changes is important for a variety of planning and management issues as well as for academic research. It can provide the baseline growth scenario to show the future land development pattern when the current land development process continues into the future. The simulation of land use changes can help to assess development impacts, prepare land use plans, and seek optimal land use patterns. It can forecast the consequences of specific human behavior and land use policies. It can also identify the possibility of severe land use problems, such as the encroachment on important environmental areas, including croplands and wetlands. Strict land use zoning may be required to prevent the potential land use problems identified by the simulation. The simulation of land use changes will enable planners to provide the public with necessary facilities and services to sustain the development (White et.al 2000).

The rapid development of GIS helps to foster the application of CA. Some researches indicate that cell-based GIS may indeed serve as a useful tool for implementing cellular automata models for the purposes of geographical analysis (Itami, 1994). It is amazing to see that real land suitability can be modeled based on microscopic behavior that may be the CA model's most useful advantage. However, the `top-down`critique nevertheless needs to be taken seriously. An example is that central governments have the power to control overall land development patterns and the amount of land consumption.

b. Pendangan hidup merupakan pendekatan yang wajar bagi penerapan permentan pemanfaatan ledakan. 

c. Pendangan hidup merupakan pendekatan pemanfaatan ledakan. Penulisan bobong lembaga, perusahaan logam, pemanfaatan ledakan, dan masyarakat setempat.

b. Diwarnai dengan edaion okto setahun Kopra Lili ini terkait meneuna ledakan dan meneunaan kumpeh.
III. METHODOLOGY

3.1. Time and Location

The research was conducted from February to May 2011. The area concerns in Kupang District, East Nusa Tenggara. It is bounded between longitude 9°19'0.57" and 10°22'-12.44"S and 121°15'-124°11" longitude, with an area of approximately 5,431.23 km². The administrative boundaries of Kupang District are as follows:

- **North**: Savu Sea and the Strait of Ombai
- **East**: Timor Tengah Selatan (TTS) District, Timor Tengah Utara (TTU) District and District Ambenu (Timor Leste)
- **South**: Timor Sea
- **West**: Rote Ndao District and Savu Sea

![Figure 3 Location of the study area](image-url)
The topographical conditions of Kupang District are almost dominated by the elevation between 0-100 meters above sea level covering almost half the area of Kupang District (24 sub districts). Some sub districts are at an elevation of 100 to 1000 m above sea level (asl). Several sub districts in the area of Amfoang for example be between 500 - 1000 above sea level, and some areas such as Semau, West Kupang and Nekamese had altitude 0-100m asl. Based on the state of rock, in Kupang District the dominant soil type alluvial, regosol, andosol, glei humus, mediterranean red yellow, latosol, podzolic red yellow and rendzina. This soil texture are from fine to coarse.

This district has dry climates and according to Oldemam divide to type D4, and D4, this climatic conditions has very short wet season of 3-5 months, while the dry season of 7-8 months. Short wet season occurs only in December to March. These climatic conditions are certainly affects the pattern of cultivation and farming communities in Kupang District where 3% of the area is a dry rice field soil and 97% is dry soil in the yard or swidden cropping (Piggin, 2003).

3.2. Data Sources

The data Mainly has been used for this research acquired from government institution, as in the table below

<table>
<thead>
<tr>
<th>No</th>
<th>Data and Information</th>
<th>Type</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Base map of Kupang</td>
<td>Vector</td>
<td>BAKOSURTANAL</td>
</tr>
<tr>
<td>2</td>
<td>Geology Database</td>
<td>Vector</td>
<td>BPDAS N-B Kupang</td>
</tr>
<tr>
<td>3</td>
<td>Climate data</td>
<td>Vector, Tabular</td>
<td>BMG Kupang, NOAA</td>
</tr>
<tr>
<td>4</td>
<td>Supported data</td>
<td>Tabular</td>
<td>BPS Kupang</td>
</tr>
<tr>
<td>5</td>
<td>Spatial Plan and policy</td>
<td>Vector, Tabular</td>
<td>BAPPEDA Kupang</td>
</tr>
<tr>
<td>6</td>
<td>Forest and Protected area</td>
<td>Vector, Tabular</td>
<td>BPKH Kupang</td>
</tr>
<tr>
<td>7</td>
<td>Livestock Population</td>
<td>Tabular</td>
<td>Kupang Animal Services</td>
</tr>
<tr>
<td>8</td>
<td>Expert Interview</td>
<td>Tabular</td>
<td>BPTP Kupang</td>
</tr>
<tr>
<td>9</td>
<td>Validation of L.leucocephala</td>
<td>Vector, Tabular</td>
<td>Ground Truth</td>
</tr>
</tbody>
</table>
3.3 Tools Requirements

The processing data of this research was done at laboratory of Master of Science in Information Technology for Natural Resources Management (MSc in IT for NRM) at SEAMEO BIOTROP. Supporting software were used in this research are listed below.

<table>
<thead>
<tr>
<th>No.</th>
<th>Tools</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Microsoft Office</td>
<td>Documentation</td>
</tr>
<tr>
<td>2.</td>
<td>ArcGIS 9.3</td>
<td>Spatial Analysis Process</td>
</tr>
<tr>
<td>3.</td>
<td>Microsoft Visual Studio 2008</td>
<td>Model Simulation</td>
</tr>
<tr>
<td>4.</td>
<td>ArcGIS Engine 9.3</td>
<td>Model Simulation</td>
</tr>
</tbody>
</table>

3.4 Methodology

There are some important stages of working with our data: the first one is data preparation and entry in which data about the study area is collected and prepared to be entered and/or used into the system, data analysis and the last part is a model simulation (Figure 5). To build the model, different processes have been conducted. Figure 4 are the criteria to be fulfilled in order to reach the objective which is to identify the land suitability for growth of *L. leucocephala* in Kupang District and to determine the carrying capacity to support feed security.

3.4.1 Determine Goal and Objectives

Goals and objectives to be achieved is obtained through a method of interviewing and filling questionnaires by experts who are competent in the field of their own. The questions raised are expected to provide important input in determining land suitability class. In order to reach the goal, there are some sets of objective that also should be considered as stated follows:

- What are the more important factors between criteria (climate, soil and topography) and sub-criteria for obtaining the land suitability for growth of *L. Leucocephala*. 
What factors are a greater influence in determining the proper location for the development of *L. leucocephala*, such as how much influence the one driving force compare one to another driving force.

**Figure 4 Flow Chart of Methodology**
3.4.2 Spatial Analysis and Analytical Hierarchy Process for Determining Potential Land Suitability

Assessment of land potential is often done with agro-ecological zone approach with the physical environment as a supporting and limiting factors for planting of a commodity plant at a specific region. If only this approach, then the only plant zoning based on land capability class is not consider other factors such as social, economic and cultural. It is therefore necessary developed a method that can include all the factors affect plant zoning. In this research used the stages modified from agro-ecological zoning method to include attractiveness elements (driving forces) and constraints.

Prior to conducting the analysis to every stage, were first carried out weighting based on expert judgment that is very competent in this field. Analysis of agro-ecological zones; this analysis was based on suitability to grow of *L. leucocephala* on the condition of the physical environment consisting of climate, soil, and topography of the region. Analysis of the attractiveness (driving force) of this space were analyzed the results of agro-ecological zoning by adding a factor of closure, roads, livestock market and the existing land use, like a folk forest, protected forest, protected area, produced forest, industry area, water body, and wetland farming.

Land suitability criteria used in this research based on the Second Land Resources Evaluation and Planning Project (LREP II) in 1994; where the system itself refers to the land suitability criteria issued by FAO (1976). According to the basic concept of Land Evaluation Framework (FAO, 1976) the land suitability was distinguished on the physical land suitability (qualitative) and land suitability in the economic (quantitative). Land suitability was physically divided into 4 classes, namely: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and is not suitable (N). While economically differentiated into 5 classes, namely: Class 1 is very suitable (S1), its use is very profitable; Class 2 moderately suitable (S2), its use is beneficial; Class 3 according to the marginal (S3) use the marginal benefit; Class 4 does not fit economically (N1), its use is possible but not profitable today,
and by improving the management to raise its class, Class 5 is not as permanent, economically (N2) usage is not possible, and this class is physically derived from the class N. Predicting the suitability of land for agricultural commodities are necessary criteria for land suitability class of the most suitable (S1) to inconsistent (N). The criteria for land suitability of *L. leucocephala* shows on Table 6.

**Table 6 Criteria for Land Suitability of *L. leucocephala* (LREP II 1994; FAO, 1976)**

<table>
<thead>
<tr>
<th>Quality/land characteristics</th>
<th>Unit</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>N1</th>
<th>N2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Temperature (°C)</td>
<td></td>
<td>21-30</td>
<td>&gt;30-34</td>
<td>-</td>
<td>-</td>
<td>&gt;34</td>
</tr>
<tr>
<td>Annual Rainfall (mm)</td>
<td></td>
<td>&gt;750-1000</td>
<td>&gt;1000-2000</td>
<td>-</td>
<td>-</td>
<td>&gt;2000</td>
</tr>
<tr>
<td>Texture</td>
<td></td>
<td>L, SCL, SiL, SiCL</td>
<td>LS, SL, SiC, C</td>
<td>Massif</td>
<td>-</td>
<td>Gravel, Clay, Str C</td>
</tr>
<tr>
<td>Effectiveness (cm)</td>
<td></td>
<td>&gt;100</td>
<td>75-100</td>
<td>-</td>
<td>&gt;50-75</td>
<td>&lt;50</td>
</tr>
<tr>
<td>Soil Acidity (pH)</td>
<td></td>
<td>7.0-8.0</td>
<td>&gt;8.0-8.5</td>
<td>-</td>
<td>-</td>
<td>&gt;8.5</td>
</tr>
<tr>
<td>Slope (%)</td>
<td></td>
<td>&lt; 8</td>
<td>8-15</td>
<td>&gt;15-30</td>
<td>&gt;30-50</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Elevation (*) (m)</td>
<td></td>
<td>0-750</td>
<td>750-1000</td>
<td>-</td>
<td>&gt;1000</td>
<td>-</td>
</tr>
</tbody>
</table>

Description:
- *S* = Sandy
- *L* = Loam
- *CL* = Clay Loam
- *SC* = Sandy Clay Loam
- *SiC* = Silt Clay
- *SiL* = Silt Loam
- *Si* = Silt
- *Cl* = Clay
- *Str C* = Structured Clay

*additional parameter

Analytic Hierarchy Process (AHP) is a decision analysis approach developed by Thomas L. Satty in 1971. As an easy-use and very practical tool based on a simple theory, AHP is capable to extract the comments of multiple experts and decision makers, and is mainly applicable to handling the problems arising in an uncertain environment in which multiple evaluation criteria exist. The AHP are used to systemize complicated problems and dissolve these factors into different levels from various directions. A comprehensive analysis is conducted via the process of quantification to assist decision makers in the selection of appropriate plans.

Many factors must be taken into consideration when operating the evaluation mechanism. The study uses AHP to establish a hierarchical structure for all affecting factors and acquires the weight of each factor by pair-wise comparison. The acquired
weight distribution is more objective than setting the weight for individual factors. 

The steps of the analysis are described as follows:

A. Establishment of the Hierarchical Structure.

After the final goal of establishing the hierarchical framework is achieved, a mutually independent hierarchical relationship is built by interviewing experts and doing surveys (secondary goal), and analyzing the elements that might affect the secondary goal. The elements of similar importance are collected on the same level in this step.

B. Weight between the Elements on Different Levels

The calculation of the weight between the elements on different levels is completed though the following four steps:

- Establishment of Pair-wise Comparison Matrix: The element comparison is conducted in this step. The parent element of an element on a lower level is used as an evaluation criterion for the pair-wise comparison.

- Calculation of Priority Vector. Divided each comparison value by the sum of the values in Corresponding fields for the aggregation of the rows; namely, the sum of the percentage each comparison value occupies in its corresponding row.

- Calculation of the Maximum eigenvalue $\lambda_{\text{max}}$:

Multiply the entire matrix with the acquired priority vector to produce $n \times 1$ matrix. Then divide this matrix by the priority vector to acquire unit vectors. Calculate sequentially the average of the unit vectors to acquire the maximum eigenvalue $\lambda_{\text{max}}$.

- Examination of Consistency: During the pair-wise comparison, discrepancies might occur between the results of the comparison and the decision. The consistence ratio of Satty’s AHP is used to examine the consistency of the entire matrix.
3.4.3 Calculation of Increasing Capacity Population of Ruminant Cattle (ICPRC)

This analysis is used to determine cattle population cattle can be added in every sub-district in Kupang District by calculate the availability of potential forage using Rollinson and Nell, (1974) approach. Secondary data used is the data in year 2009 from BPS of Kupang District. Based on the results of data processing of livestock population analysis with ICPRC model obtained a values show a different trend for each region. ICPRC positive value indicates a tendency that relevant districts still allow the addition of ruminant livestock population of the existing number of livestock units, whereas negative values indicate a tendency ICPRC concerned that the region needs to be directed to the development of the area of land that is the carrying capacity of principal farm businesses, such as grassland and the agriculture area. The potential forage capacities predicted as follows:

\[
\text{Total Potential Forage} = \text{Forage Production} + \text{Straw Production (Total)}
\]

\[
= \frac{(\text{Total Potential Forage, DM Tons / Year})}{(\text{DM consumption Ton / AU / Year})}
\]

\[
\text{ICPRC} = \text{Carrying Capacity} - \text{Real Population}
\]

Potential forage availability is based on several sources namely: pasture, fallow fields, shipyards rice fields, plantations, forest type, secondary forest, roadside and moor. Total areas of all components were considered capable of providing dry material as much as 3.75 tons / hectare / year. To reach the numbers required for the calculation ICPRC accordance with the steps above, also required some other numbers that the converter capable of converting land to provide fodder, as well as converting straw value are available or can be used for livestock. Thus, the total forage production (tons DM / year) for each district was calculated by the following formula:
\[ TFP = 3.75 \sum + \sum \]

Where:
- TFP = Total forage production of a district in one year (ton DM / year).
- LE = Effective forage area (ha) to \( i \); where \( i \) = field in Rollinson and Nell’s Table.
- PJ = Straw Production (tons DM / year) from the source \( J \), where \( J \) = field in Rollinson and Nell’s Table.

Every single Animal Unit (AU) of ruminants requires 5.38 tons DM forage / year, thus Ruminants Carrying Capacities (RCC) each region is calculated as follows:

\[
\text{RCC} = \frac{(\text{Total Potential forage, DM Tons / Year})}{5.38 (\text{DM consumption in ton / AU / Year})}
\]

Further analysis of location quotient is used to determine whether a location can be classed as a base region or not a base region.

\[
\sum \frac{e_{ir}}{E_{i}}
\]

Where:
- \( e_{ir} \) = cattle population in sub-district \( r \)
- \( \times e_{ir} \) = total big size ruminant livestock in sub-district \( r \)
- \( E_{i} \) = cattle population in district
- \( \times E_{i} \) = total big size ruminant livestock population in district

### 3.4.4 Model Simulation

After obtaining the results in the form of a map of potential land suitability and after overlaying with constraint factors, then obtained the actual land suitability maps. The model simulation will be dynamically with the determination of scenarios.
that can be set by the user using different assumptions or scenario. The simulation model of *L. leucocephala* development are very influenced by 2 main factors, namely driving force and constraint.

Driving force and constraints are the key factor in the of *L. leucocephala* development context. Driving force can be defined as causes or factors influence for *L. leucocephala* growth modeling. In this research, road network, animal market, and Neighborhood Effect were selected as a driving force input in modeling of *L. leucocephala* growth in Kupang District. Whereas, protected forest, folk forest, protected area, production forest, industry area, wet land farming, swamp, weir/ water body, settlement and mining area were selected as a constraint factor in this study area.

Driving force of *L. leucocephala* can be simply defined as cause for factors influence for growth modeling and in the opposite, whereas constraint is a limitation imposed or by nature or by human being that do not permit certain action to be taken (Keeney, 1980). Definition for each driving force and constraints for *L. leucocephala* development in this study was explained below:

A. Neighborhood Effect

Location has very large influence on the growth development of *L. leucocephala*. at a small scale, *L. leucocephala* tends to growth in the areas nearby the development agriculture area. Neighborhood, in another word, transition from non- *L. leucocephala* to *L. leucocephala* was much affected by the adjacent area. if the vicinity of a cell is developed area, this cell has much higher potential to change to *L. leucocephala* form if it was non-*L. leucocephala* before.

B. Distance to Road Network

Road network has proved to be the key factors in many evolution processes, as well as the development plans of planting *L. leucocephala* as forage. Road, heavily impact the plan development priority (settlement, industry etc.) and also land price. While the relationship between road network and *L. leucocephala* growth development is far from clear. Closer the distance of
the location from main roads, the land has higher probability to becoming developed to other purposes then to growth *L. leucocephala*.

Transport is a very important role in the success of development especially in support of economic activities, no exception in rural areas. Existing transportation system intended to improve mobility services and other resources that can support the growth of economics of rural areas. With the hopes of transport can relieve isolation and provide a stimulant to the development in all areas of life, whether trade, industry and other sectors in rural areas.

C. Distance to Location of Livestock Market

The existence of animal market has a very important function in the development of a suitable location for the planting of *L. leucocephala*. For consumers, the market will make it easier to obtain a cattle\(\alpha\) for needs. As for the farmer, the market becomes a place to ease the process of distribution of livestock. In general, the market has three main functions namely as a means of distribution, price formation, and as a promotion. The closer a location to a livestock market will be even greater opportunities to develop the site into areas of planting *L. leucocephala*.

D. Probability of Preference Location

*L. leucocephala* development will begin from the existing field, and will develop on area belonging to the class S1 and S2 which are not included in constraint areas such as pastures, grassland, dry land farming or plantations. Each selected region has a different weight to be taken into account in certain scenarios when the model is run.

Constraints are limitation imposed by nature or by human being that do not permit certain action to be taken (Keeney, 1980). The specification of constraint is typically based on available resources and regulation and involves value or professional judgment. The constraint factors indicate those limitations posed on the *L. leucocephala* development such us water body, protected forest, protected area,
folk forest, produced forest, settlement, and wet land farming is not allowed to develop the *L.leucocephala* growth area.

There are two kinds of spatial default scenario that is designed to look at the distribution pattern of *L.leucocephala*. The default scenario is:

1. Business as usual, in this scenario, the state is considered normal running as it should.
2. Spatial plan as constraints, in this scenario mining site plans will be a constraint.

Both the two scenarios mentioned above have default values in accordance with the current state, but those values can be set in accordance with the needs to be achieved.

Microsoft Visual Studio 2008 and ArcGIS Engine 9.3 is used to build simulation models for prediction the feed security of *L.leucocephala* to support Bali cattle during a certain period. The scheme of simulation model chart can be seen in the Figure 5.
Figure 5 Flow Chart of Model Simulation
IV. RESULTS AND DISCUSSION

4.1 Spatial Analysis Results

Management of spatial data is essential in the Geographical Information System data management. Geographic Information Systems (GIS) not only serves to move / transform the map of conventional (analog) into digital form (digital map), furthermore this system has the ability to process and analyze data based on geographic location into valuable information. Spatial analysis in this research is overlaying process of the spatial data based on certain criteria. Those criteria are taken from literature and interview data with 8 (eight) experts from BPTP (Assessment Institute for Agricultural Technology), Indonesian Agriculture Ministry. The spatial analysis resulted in three most suitable candidate areas for developing *Leucaena leucocephala* based on growth suitability from climate, soil and topography. At the last spatial plan is used for a criterion to avoid using the restricted area to plantation *L.leucocephala*. The most suitable condition for growth of *L.leucocephala* based on climate, soil and topography are listed below:

Table 7 Physical requirement for growth factors of *L. leucocephala*

<table>
<thead>
<tr>
<th>Climate factors</th>
<th>Soil factors</th>
<th>Topography factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>Annual Rainfall (mm)</td>
<td>Dry Months</td>
</tr>
<tr>
<td>21-30</td>
<td>&gt;750-1000</td>
<td>3-4</td>
</tr>
<tr>
<td>L, SCL, SiL, Si, CL, SC, SiCL</td>
<td>7.0-8.0</td>
<td>&gt;100</td>
</tr>
</tbody>
</table>

4.1.1 Climate Suitability

Climate factor is one of the physical and environmental factors that affect the quality and quantity of growth and development. This factor needs to get a specific study, because the climate variables are a variable that cannot be given treatment or modified to make them correspond with the requirements of growing plants.
4.1.1.1 Temperature Suitability

*Leucaena leucocephala* can reach the optimum growth in 21 to 30 °C. In the tropical countries, commonly temperature has a close relationship with the altitude. The higher altitude has the lower temperature. *L. leucocephala* is a essentially a tropical species requiring warm temperature for optimum growth, with poor cold tolerance and significantly reduce growth during cool winter month in subtropical areas (Brewbeker and Sorrenson, 1990).

Kupang District divided into 3 categories of temperature suitability namely N2, S1 and S2. At least 96.96% of Kupang district or 4,976.2 km² has land suitability value S1, the second sequence followed by the S2 class at 2.59% or an area of 132.87 km², and the last is N2 class with a total area of 23.41 km², or approximately 0.46% of District of Kupang. Areas included in the category N2 are a region of land suitability that has an average temperature of less than 19°C. Land suitability maps based on the temperature can be seen in the Figure 6.

![Temperature Suitability Map](image)
4.1.1.2 Annual Rainfall Suitability

Most species of *Leucaena leucocephala* grow in their native range in seasonally dry forest. Mean annual precipitation and length of dry season vary across species from 550-700 mm with 7 month dry season. Most species lie in between with annual rainfall 750-1500 mm and dry season of 4-5 months (Karachi et al, 1997). *L.leucocephala* does not perform well in drier environments, with less than 650 mm annual rainfall, and a dry season more than 4–6 months. Further testing will be required to assess drought tolerance of other species, particularly in relation to dry season leaf retention for livestock fodder production. It is unlikely that any species of *L.leucocephala* will perform as well as species of other genera, such as *Acacia* or *Prosopis*, with rainfall less than 500 mm.

Annual rainfall data obtained from the monthly rainfall of 7 (seven) climatology stations in Kupang District and 23 climatology stations from other district around Kupang District; then the data were analyzed with Kriging method for estimating the rainfall distribution pattern in the form of Thiessen polygons. The Thiessen polygons have the unique property that each polygon contains only one input point, and any location within a polygon is closer to its associated point than to the point of any other polygon.

From spatial data processing, Kupang District divided into 3 categories of land suitability namely N2, S1 and S2. At least 94.13% of Kupang District or an area of 4,831.72 km² obtaining land suitability value S2, the second sequence followed by the N2 class at 3.75% or an area of 192.62 km², and the last is S1 class with a total area of 2.11 km². Areas included in the category N2 are a region of land suitability that has an average of rainfall is less than 600 mm or higher than 2000 mm. Land suitability maps based on the rainfall can be seen in the Figure 7.
4.1.1.3 Dry Months

The long period of dry months is closely linked to the availability of water during the dry season, water is essential to plant. To survive, plants need water, as well as nutrients, which are absorbed by the roots from the soil. Plants contain 90 percent water. Water is transported throughout the plant almost continuously to keep its vital processes working. Roots absorb water from the soil, which is then carried through the plant. Much of the water is taken up through the root hairs, which are tiny rootlets that penetrate the soil around the roots and increase the root's surface area. Water is a solvent that absorption of minerals from the soil up through the plant. As the soil dries, the root growth slows. If the soil is saturated with water, the roots could drown.

Based on the results of spatial data processing, Kupang District divided into 3 categories of dry month suitability namely N2, S1 and S2. At least 53.84% of
Kupang District or an area of 2,763.7 km$^2$ obtaining land suitability value N2, the second sequence followed by the S2 class at 39.56% or an area of 2,032.37 km$^2$, and the last is S1 class with a total area of 388.81 km$^2$, or approximately 6.6% of the size of the entire District of Kupang. Areas included in the category N2 are a region of land suitability that has dry months of more than 6 months. Land suitability maps based on the dry months can be seen in the figure 8, dry month suitability map.

![Dry Month Suitability Map](image)

**Figure 8 Dry Months Suitability Map**

To get a map of potential land suitability based on climatic factors, then performed a pair-wise comparison process which in this stage will be given each climate factor scores and then performed pair-wise comparison process. Score for each factor was obtained from the assessment of climate experts. The following is a table showing the weighting of each criterion.
Based on calculations in the weighting process, it acquired a land suitability map based on climatic factors which consists of three fitness classes, namely the first is the class S1 of 2.11% or 107.09 km²; then followed by the S2 class at 97.23% or 4,938.42 km² and the last is N class with a land area of 33.56 km², or around 0.66%. Land suitability maps based on climatic factors can be seen in the Figure 9 below.

Table 8 Pair-wise comparison of sub criteria from Climate factors

<table>
<thead>
<tr>
<th></th>
<th>Rain Fall</th>
<th>Temperature</th>
<th>Dry Month</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain Fall</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>63.33</td>
</tr>
<tr>
<td>Temperature</td>
<td>0.33</td>
<td>1</td>
<td>3</td>
<td>26.05</td>
</tr>
<tr>
<td>Dry Month</td>
<td>0.20</td>
<td>0.33</td>
<td>1</td>
<td>10.62</td>
</tr>
</tbody>
</table>

CR = 0.03   CI= 0.01

4.1.2. Soil Suitability

Physical and chemical soil conditions are physical factors that serve as the planting medium. In contrast to climatic factors, soil variables that affect plant growth
and development can be given a treatment that can alter soil conditions to conform to the requirements of growth and development of plants. Soil treatment is relatively more efficient than modifications to the climate.

4.1.2.1 Soil Texture

Soil texture shows a comparison of the relative fraction of clay, dust and sand. This property affects the water binding capacity, cation exchange capacity, porosity, infiltration, hydraulic conductivity and soil aeration. Indirectly, soil texture affects root growth.

Based on the results of spatial data processing, Kupang District divided into 3 categories of soil texture suitability namely N, S1, and S2. At least 93.85% of Kupang District or an area of 4,837 km² obtaining land suitability value S1, the second sequence followed by the S2 class at 4.56% or an area of 235.23 km², and the last is N class with a total area of 81.7 km², or approximately 1.56% of the size of the entire District of Kupang. Areas included in the category N are a region of land suitability that has sandy or gravel land. Land suitability maps based on the soil texture can be seen in the Figure 10.
4.1.2.2 Effective Depth

Effective Depth is the depth measured from ground surface to impermeable layer, sand, gravel, stone or plintit. Effective depth affects root growth and development of *L. leucocephala*. Soils with a shallow effective depth of root cause inhibition of growth of plants, otherwise the soil with an deep effective depth of the shall have good aeration and drainage, and able to support the development of roots and plant it better.

Based on the results of spatial data processing, Kupang District divided into 2 categories of land suitability namely N1 and S2. At least 72.22% of Kupang District or an area of 3,707.11 km² obtaining land suitability value N1, the second sequence followed by the S2 class at 27.78% or an area of 14,2578km². Areas included in the category N1 are a region of effective depth that has an effective depth >50 - <75 cm. Land suitability maps based on the Effective depth can be seen in the Figure 11.
4.1.2.3 Soil Acidity

*Leucaena leucocephala* is known to be intolerant of soils with low pH, low P, low Ca, high salinity, high aluminum saturation and water logging (Brewbeker, 1987) and has often failed under such condition (Hutton, 1981, Oakes and Foy, 1984, Brewbeker, 1987; Shelton, 1994; Blemmy and Hutton (1995). The possible approaches to use of *L. leucocephala* on acid soil were reviewed by Hutton (1995) and Blemmy and Hutton (1995) who conclude that high production is not possible without significant selection and breeding. Recent testing of a wide range of species and seed sources has confirmed the poor survival and low acid soil tolerance of *L. leucocephala* species in several sites in Asia (Khoa et al., 1997; Castillo et al., 1997)

Based on the results of spatial data processing, Kupang District divided into 3 categories of land suitability namely N, S1 and S2. At least 80.35% of Kupang District or an area of 4,225.78 km² obtaining land suitability value S1, the second

Figure 11 Effective Depth Suitability Map
sequence followed by the S2 class at 9.91% or an area of 521.13 km², and the last is N class with a total area of 512.24 km², or approximately 9.74% of the size of the entire District of Kupang. Areas included in the category N are a region of land suitability that has pH value less than 4. Land suitability maps based on the temperature can be seen in the Figure 12.

To get a map of potential land suitability based on soil factors, then performed a pair-wise comparison process which in this stage will be given each soil factor scores and then performed pair-wise comparison process. Soil score for each factor obtained from the assessment of experts. The following is a table showing the weighting of each criterion.
Table 9 Pair-wise comparison of sub criteria from Soil factors

<table>
<thead>
<tr>
<th></th>
<th>Texture</th>
<th>pH</th>
<th>Effective Depth</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture</td>
<td>1</td>
<td>0.3</td>
<td>1</td>
<td>22.90</td>
</tr>
<tr>
<td>pH</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>60.08</td>
</tr>
<tr>
<td>Effective Depth</td>
<td>2</td>
<td>0.20</td>
<td>1</td>
<td>17.02</td>
</tr>
</tbody>
</table>

CR = 0.04  CI=0.08

Based on calculations in the weighting process, it acquired a land suitability map based on soil factors which consists of three fitness classes, namely the first is the class S1 of 78.29% or 3,976.18 km²; then followed by the S2 class at 12.09% or 613,93 km² and the last is N class with a land area of 488.71 km², or around 9.62%.

Land suitability maps based on soil suitability factors can be seen in the figure below.

Figure 13 Soil Suitability Map
4.1.3 Topography Suitability

Compliance is assessed on the basis of topographic height of a place of sea level and slope factors are calculated based on the interval contour lines. Elevation somewhere correlated with average air temperature.

4.1.3.1 Slope Suitability

Factor is determined by the steepness of slope, length and shape of the slope. Management of soil on steep slopes require more energy and capital than the flat areas; it is associated with many problems in water management and erosion on the steeper slope areas. Slope affects the speed and surface runoff. The more steep a slope then the greater the surface flow velocity, thus it will be increasingly short of water is also an opportunity to infiltrate the surface so that the flow becomes large. The length of the slope affects the amount of surface runoff flow, the length of a slope, the greater of runoff. If the runoff volume is large then the chances of erosion will greater.

Figure 14 Slope Suitability map
The length and slope index can be determined by measuring the density of contour lines per unit length. Various types of soil have different erosion sensitivity. Soil content that affect the sensitivity of soil erosion in the nature of that influence infiltration rate, permeability, water holding capacity, soil characteristics that affect the resistance of soil structure on the dispersion and erosion by rain falls and runoff water.

Based on the results of spatial data processing, Kupang District divided into 4 categories of land suitability class namely S1, S2, S3 and N. At least 58.93% of Kupang District or an area of 3,026.6 km² obtaining land suitability value S3, the second sequence followed by the S2 class at 14.17% or an area of 727.57 km², then followed by S1 class at 12.31% or an area 632.15 km² and the last is N class with a total area of 749.9 km², or approximately 14.6% of the size of the entire District of Kupang. Areas included in the category N are a region of land suitability that has a slope more than 30 percent. Land suitability maps based on the temperature can be seen in the Figure 14.

4.1.3.2 Elevation Suitability

The elevation of a place is affected the air temperature and intensity of light received by plants. The higher a place, have lower in temperature of that place, similarly, the intensity of the sun will be minor. Temperature and radiation is what will be used to classify plants according to what the highlands or lowlands. Elevation also is critical of flowering plants, plants grown in the lowlands bloom earlier than those grown in highlands. Environmental factors will affect physiology processes in plants. All physiology process temperature may be affected and some processes will depend on the light. The optimum temperature required for plants can be best utilized by plants. Temperatures that are too high will inhibit plant growth and vice versa too low the temperatures can lead to death. While light is a source of energy for plants.
Based on the results of spatial data processing, Kupang District divided into 3 categories of land suitability class namely N, S1, and S2. At least 86.93% of Kupang District or an area of 4,461.93 km² obtaining land suitability value S1, the second sequence followed by the S2 class at 12.62% or an area of 647.54 km², and the last is N class with a total area of 23.41 km², or approximately 0.46% of the size of the entire District of Kupang. Areas included in the category N are a region of land suitability that has an elevation of more than 1000 m above sea level. Land suitability maps based on the elevation can be seen in the Figure 15.

To get a map of potential land suitability based on topographic factors, and then performed in a pair-wise comparison process which is on this stage, each topographic factor will be given scores. Topographic Score for each factor obtained

![Figure 15 Elevation Suitability Map](image-url)
from the assessment of experts. The following is a table showing the weighting of each criterion.

Table 10 Pair-wise comparison of sub criteria from Topography factors

<table>
<thead>
<tr>
<th></th>
<th>Slope</th>
<th>Elevation</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>1</td>
<td>3</td>
<td>76.9</td>
</tr>
<tr>
<td>Elevation</td>
<td>0.3</td>
<td>1</td>
<td>23.1</td>
</tr>
</tbody>
</table>

CR = 0.00    CI=0.00

Based on calculations in the weighting process, it acquired a land suitability map based on topographic factors which consists of three fitness classes, namely the first is the class S1 of 12.21% or 620.33 km²; then followed by the S2 class at 73.09% or 3712.20 km² and the last is N class with a land area of 746.73 km², or around 14.70%. Land suitability maps based on soil factors can be seen in the figure below.
4.2 Potential Land Suitability for Development of *Leucaena leucocephala*

The Land Suitability Analysis is a Geographic Information Systems (GIS) based tool for evaluating the relative suitability of land for development in Kupang District, East Nusa Tenggara Province. The end product is a generalized map showing areas of the district that are categorized as having either least, not suitable (N), suitable (S1), moderate suitable (S2) and marginal suitable (S3) for development of *L.leucocephala*. The following is a table that contains the pair-wise score of each factor or criterion that can affect the potential land suitability maps, while the potential suitability land map can be seen in the picture below.

<table>
<thead>
<tr>
<th></th>
<th>Climate</th>
<th>Soil</th>
<th>Topography</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate</td>
<td>1</td>
<td>0.33</td>
<td>3</td>
<td>25.94</td>
</tr>
<tr>
<td>Soil</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>63.45</td>
</tr>
<tr>
<td>Topography</td>
<td>0.33</td>
<td>0.20</td>
<td>1</td>
<td>10.61</td>
</tr>
</tbody>
</table>

CR = 0.03  CI=0.02

![Figure 17 Potential Land Suitability Map](image)
Results of spatial data processing of Kupang District divided into 4 categories of Potential land suitability class namely N, S1, S2 and S3. At least 73.10% of Kupang District or an area of 3,752.39 km² obtaining land suitability value S2, the second sequence followed by the S1 class at 16.98% or an area of 871.781 km², and the third sequence followed by S3 class at 9.80% from total area or 502.54 km², and the last one is N class with a total area of 6.16 km², or approximately 0.12% of the size of the entire Kupang District.

Potential suitability map that has been generated not necessarily be directly used as a guide to develop of *L. leucocephala* because the results obtained maps should be juxtaposed with the existing land cover and existing areas that cannot or are not allowed using the selected as an area for planting and development of *L. leucocephala*.

Figure 18 Actual Potential Land Suitability Map
To get the actual area for the development of *L. leucocephala*, an obtained existing map of the potential land suitability has overlaid with land cover maps and land use maps in which a predetermined constraint factors that can not be violated. Here are the results of overlay of maps of potential land suitability with constraint factors.

<table>
<thead>
<tr>
<th>Class</th>
<th>Area (Km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constraint</td>
<td>2,642.03</td>
</tr>
<tr>
<td>N</td>
<td>3.85</td>
</tr>
<tr>
<td>S1</td>
<td>371.61</td>
</tr>
<tr>
<td>S2</td>
<td>1,907.85</td>
</tr>
<tr>
<td>S3</td>
<td>207.55</td>
</tr>
</tbody>
</table>

Determination of the location of development of *L. leucocephala* to be more specific with overlaid with the driving force factors, which is a distance of the location from the road network and the distance of the potential development location to the nearest livestock market. Figure 19 above show the potential land suitability that has been overlaid with the distance buffering range to road network and livestock market location.
The area of actual land suitability can only be obtained after the whole process of the overlay above. In more detail following the table that can show the data area of actual land suitability classes based on the driving factor that is a road network.

Table 13 Actual land suitability class with constraint in each road range buffer

<table>
<thead>
<tr>
<th>Classes</th>
<th>Range 1st (km²)</th>
<th>Range 2nd (km²)</th>
<th>Range 3rd (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>122.50 (7.24%)</td>
<td>187.11 (7.63)</td>
<td>56.78 (4.35%)</td>
</tr>
<tr>
<td>S2</td>
<td>573.21 (37.17%)</td>
<td>945.48 (38.54%)</td>
<td>371.83 (28.50%)</td>
</tr>
<tr>
<td>S3</td>
<td>77.48 (4.04%)</td>
<td>105.80 (4.31%)</td>
<td>22.50 (1.72%)</td>
</tr>
<tr>
<td>N</td>
<td>-</td>
<td>-</td>
<td>3.85 (0.30%)</td>
</tr>
<tr>
<td>Constraint</td>
<td>536.11 (51.47%)</td>
<td>1,214.63 (49.51%)</td>
<td>849.88 (65.13%)</td>
</tr>
</tbody>
</table>

The existence of the animal market as the driving factor may also be one of the deciding criteria in decision-making to the development process of cultivation of *L. leucocephala*. Coordinates of each point made animal market is a ring buffer which
is assumed coverage of the service area of the animal market. The range used of each within 5 km, 10 km, 15 km and 20 km.

Based on the overlaid results of actual land suitability map with livestock market buffer area, obtained an area are included in each class of land suitability; data may be seen in the table below.

<table>
<thead>
<tr>
<th>Classes</th>
<th>Range 1st (km²)</th>
<th>Range 2nd (km²)</th>
<th>Range 3rd (km²)</th>
<th>Range 4th (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>45.75 (11.96%)</td>
<td>45.98 (5.62%)</td>
<td>37.09 (5.52%)</td>
<td>57.16 (13.28%)</td>
</tr>
<tr>
<td>S2</td>
<td>175.93 (46.01%)</td>
<td>272.45 (34.13%)</td>
<td>208.94 (31.08%)</td>
<td>146.27 (33.98%)</td>
</tr>
<tr>
<td>S3</td>
<td>22.43 (5.87%)</td>
<td>44.60 (5.45%)</td>
<td>22.57 (3.36%)</td>
<td>38.27 (8.88%)</td>
</tr>
<tr>
<td>Constraint</td>
<td>138.26 (36.16%)</td>
<td>448.78 (54.81%)</td>
<td>403.57 (60.04%)</td>
<td>188.73 (43.85%)</td>
</tr>
<tr>
<td></td>
<td>382.37</td>
<td>818.81</td>
<td>672.18</td>
<td>430.42</td>
</tr>
</tbody>
</table>
4.3 Increasing Capacity Population of Ruminant Cattle (ICPRC)

The important aspect of livestock development planning is based on the potential of farm zoning and adequate land carrying capacity for livestock enterprises. Resource potential of livestock and livestock in the form of the potential diversity of livestock species, the potential of human resources (farmers) and the potential of livestock area (carrying capacity of land and land suitability) should be the initial reference for planning future development. By considering some of the elements associated with the zoning plan, then the desired goals can be achieved by the Kupang District to devise strategies in accordance with regional characteristics.

Rollinson and Nell (1974) method is a comparative method which limits themselves only to the sources listed forage area or size in the statistical report. The potential supply of forage from the source is converted to the potential of natural grasslands after a few empirical studies. In addition to forage grasses, forage taken into account the potential for agricultural output with the rest of the rational utilization coefficient.

ICPRC processed data is the data statistic census results of 2009 combined with land cover maps of each district. ICPRC value show the number of ruminants that can be added to each location, the negative sign indicates number of livestock that at this sub-district has exceeded the carrying capacity so that policies need to be taken to make improvements to the producer of forage. The following are the results of calculations ICPRC for each sub-district in Kupang District.

Land capability value in Kupang District for the provision of feed grass / straw for livestock naturally without any effort to plant fodder in particular can be seen in Table RCC and ICPRC. With the planting efforts in particular animal forage, such as L leucocephala is expected to increase ICPRC values more than the 481,714 AU.
### Table 15 RCC and ICPRC

<table>
<thead>
<tr>
<th>No</th>
<th>Sub-District</th>
<th>Potential grass production ((3.75 \times \text{sum of grass land area})) (1)</th>
<th>Ruminant Carrying Capacity ((AU) ((1)/2.55 \text{ton})) (2)</th>
<th>Real Population in 2009 ((AU)) (3)</th>
<th>ICPRC ((AU)) (2) - (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Semau + South Semau</td>
<td>56,786</td>
<td>22,226</td>
<td>8,330</td>
<td>13,896</td>
</tr>
<tr>
<td>2</td>
<td>West Kupang + Nekamese</td>
<td>90,119</td>
<td>35,272</td>
<td>9,746</td>
<td>25,526</td>
</tr>
<tr>
<td>3</td>
<td>Central Kupang + Taebenu</td>
<td>59,494</td>
<td>23,285</td>
<td>6,405</td>
<td>16,880</td>
</tr>
<tr>
<td>4</td>
<td>Amarasi + South Amarasi + West Amarasi + East Amarasi</td>
<td>208,596</td>
<td>81,642</td>
<td>19,923</td>
<td>61,719</td>
</tr>
<tr>
<td>5</td>
<td>East Kupang + East Amabi Oefeto + Amabi Oefeto</td>
<td>156,421</td>
<td>61,222</td>
<td>36,060</td>
<td>25,162</td>
</tr>
<tr>
<td>6</td>
<td>Sulamu</td>
<td>64,762</td>
<td>25,347</td>
<td>8,146</td>
<td>17,201</td>
</tr>
<tr>
<td>7</td>
<td>Fatuleu + West Fatuleu + Central Fatuleu</td>
<td>312,348</td>
<td>122,250</td>
<td>17,829</td>
<td>104,421</td>
</tr>
<tr>
<td>8</td>
<td>Takari</td>
<td>140,732</td>
<td>55,081</td>
<td>16,212</td>
<td>38,869</td>
</tr>
<tr>
<td>9</td>
<td>South Amfoang + Southwest Amfoang</td>
<td>143,933</td>
<td>56,334</td>
<td>16,756</td>
<td>39,578</td>
</tr>
<tr>
<td>10</td>
<td>North Amfoang + Northwest Amfoang + East Amfoang</td>
<td>394,231</td>
<td>154,298</td>
<td>15,835</td>
<td>138,463</td>
</tr>
</tbody>
</table>

| Total |                             | 636,956                                                                  | 155,242                                         | 481,714                           |

3.75 Constanta; 2.55 = DM native grass daily intake by AU in 1 year

Analysis Location Quotation / LQ is used to determine whether an area is categorized as a base livestock area or non-base. If the numbers of Location Quotation more than 1 indicates that the location is a livestock base area, whereas if less than one the area has not become the basis of livestock.
Table 16 Location Quotation (LQ) values

<table>
<thead>
<tr>
<th>No</th>
<th>Sub-District</th>
<th>Cattle Population in 2009</th>
<th>Location Quotient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Semau + South Semau</td>
<td>8,330</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>West Kupang + Nekamese</td>
<td>9,746</td>
<td>1.1</td>
</tr>
<tr>
<td>3</td>
<td>Central Kupang + Taebenu</td>
<td>6,405</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>Amarasi + South Amarasi + West Amarasi + East Amarasi</td>
<td>19,923</td>
<td>1.0</td>
</tr>
<tr>
<td>5</td>
<td>East Kupang + East Amabi Oefeto + Amabi Oefeto</td>
<td>36,060</td>
<td>1.0</td>
</tr>
<tr>
<td>6</td>
<td>Sulamu</td>
<td>8,146</td>
<td>0.9</td>
</tr>
<tr>
<td>7</td>
<td>Fatuleu + West Fatuleu + Central Fatuleu</td>
<td>17,829</td>
<td>1.0</td>
</tr>
<tr>
<td>8</td>
<td>Takari</td>
<td>16,212</td>
<td>1.1</td>
</tr>
<tr>
<td>9</td>
<td>South Amfoang + Southwest Amfoang</td>
<td>16,756</td>
<td>0.9</td>
</tr>
<tr>
<td>10</td>
<td>North Amfoang + Northwest Amfoang + East Amfoang</td>
<td>15,835</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Base on LQ analysis of at 10 areas in Kupang District showed that most areas is the livestock base area, except in Sub-District Sulamu, Fatuleu, South Amfoang, and Southwest Amfoang are not the base area, although the difference is only 0.1 compared to other regions. In both areas with values below 1 may be an area for local food advocates who have included the area surrounding the base; local government policy to increase the number of cattle population in the two areas will greatly assist in improving the status of the livestock base.

4.4 Model for Prediction of Feed Security

At a time when productivity is increases and the need of *L.leucocephala* for cattle as fodder been able to exceed the amount provided by the existing land, the expansion of land that is not *L.leucocephala* to become *L.leucocephala* field will be happen, of course with considering several policies that already exist like a constraint regions.
The Decision-making of which areas could be developed of *L. leucocephala* can be facilitated using a simulation model based on the principle of cellular automata. The pattern of development of deployment location is strongly influenced by the constraint factor and the driving factors. In this research the driving factors were divided into six criteria, namely C1, C2, C3, C4, C5 and C6. Through the process of pair-wise comparison (Analytical Hierarchy Process) obtained the weights of each criteria, the weights are obtained by filling the questionnaire by experts. Each of these criteria and the weighting of each value can be seen in the table below.

### Table 17 Pair-wise comparison of driving force factors

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>5</td>
<td>7</td>
<td>68.5</td>
</tr>
<tr>
<td>C2</td>
<td>0.33</td>
<td>1</td>
<td>3</td>
<td>24.8</td>
</tr>
<tr>
<td>C3</td>
<td>0.14</td>
<td>0.05</td>
<td>1</td>
<td>6.6</td>
</tr>
</tbody>
</table>

CI = 0.03   CR = 0.06

Where:
- C1 = Probability of land changing from bush to *L. leucocephala*
- C2 = Probability of land changing from dry land farming to *L. leucocephala*
- C3 = Probability of land changing from plantation to *L. leucocephala*

### Table 18 Pair-wise comparison of driving force factors

<table>
<thead>
<tr>
<th></th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>35.8</td>
</tr>
<tr>
<td>C2</td>
<td>0.33</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>20.3</td>
</tr>
<tr>
<td>C3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>26.2</td>
</tr>
<tr>
<td>C4</td>
<td>0.50</td>
<td>0.17</td>
<td>1</td>
<td>1</td>
<td>17.7</td>
</tr>
</tbody>
</table>

CI = 0.06   CR = 0.07

C1 = Distance of chosen location from road
C2 = Distance of chosen location from livestock market
C3 = Neighborhood effect
C4 = Existing Land Cover

There are two scenarios that are used in simulating this model; the first scenario is business as usual, where *Leucaena leucocephala* can be developed at all potential areas except in the constraint areas. In this scenario the rate of increase in
livestock population follow a normal state at 2.5% per year and 5% per year as optimistic will. The second scenario is the use of spatial plan (areas for other uses) as a factor limiting the development of Leucaena leucocephala, while the rate of increase in livestock population follow a normal state at 2.5% per year and 5% per year as optimistic will.

![Figure 21 Comparison distribution pattern between difference growth rates in Business as usual scenario](image)

<table>
<thead>
<tr>
<th>Land Cover</th>
<th>Original Area</th>
<th>GR 2.5%</th>
<th>Changing Area</th>
<th>GR 5%</th>
<th>Changing Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Land</td>
<td>24,665</td>
<td>24,665</td>
<td>-</td>
<td>24,665</td>
<td>-</td>
</tr>
<tr>
<td>Constraint</td>
<td>253,503</td>
<td>253,503</td>
<td>-</td>
<td>253,503</td>
<td>-</td>
</tr>
<tr>
<td>Grassland</td>
<td>201,515</td>
<td>199,898</td>
<td>- 1,626</td>
<td>19,7842</td>
<td>-3,673</td>
</tr>
<tr>
<td>L. leucocephala</td>
<td>4,916</td>
<td>6,777</td>
<td><strong>1,861</strong></td>
<td>9,270</td>
<td><strong>4,354</strong></td>
</tr>
<tr>
<td>Other Utilization</td>
<td>7,667</td>
<td>7,416</td>
<td>- 222</td>
<td>7,003</td>
<td>-643</td>
</tr>
<tr>
<td>Pasture</td>
<td>13,381</td>
<td>13,368</td>
<td>-13</td>
<td>13,3344</td>
<td>-38</td>
</tr>
<tr>
<td>Plantation</td>
<td>7,669</td>
<td>7,669</td>
<td>-</td>
<td>7,669</td>
<td>-</td>
</tr>
</tbody>
</table>
Figure 22 Comparison distribution pattern between difference growth rates in Spatial plan scenario

Table 20 Fulfilled area in spatial plan scenario

<table>
<thead>
<tr>
<th>SPATIAL PLAN SCENARIO (ha)</th>
<th>GR 2.5%</th>
<th>GR 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Land Farming</td>
<td>24,665</td>
<td>24,665</td>
</tr>
<tr>
<td>Constraint Area</td>
<td>253,503</td>
<td>253,503</td>
</tr>
<tr>
<td>Grassland</td>
<td>201,515</td>
<td>199,898</td>
</tr>
<tr>
<td>L. leucocephala</td>
<td>4,916</td>
<td>6,777</td>
</tr>
<tr>
<td>Other Utilization</td>
<td>7,646</td>
<td>7,416</td>
</tr>
<tr>
<td>Pasture</td>
<td>13,382</td>
<td>13,368</td>
</tr>
<tr>
<td>Plantation</td>
<td>7,669</td>
<td>7,669</td>
</tr>
</tbody>
</table>

Based on the results obtained by both of the Business as usual scenario and Spatial Plan scenario can be seen that the pattern of development based on the sequence of *Leucaena leucocephala*, the development used first the grassland area as a priority and the next is pastures and other utilization (mine area). This can be happened because of the calculation process in the simulation model will first consider land suitability classes and then based on the weight of the driving force and constraints that apply in the scenario.
V. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Based on research results and discussion, there are following conclusion derived:

1. Kupang District has the actual potential area to be developed of \textit{L.leucocephala} an area of 2,462.69 km$^2$, comprising an area of 366.39 km$^2$ classes S1, S2 class area of 1,890.52 km$^2$ and S3-class area of 205.78 km$^2$. Assume that 50% land should be planted with \textit{L.leucocephala}; there are 1,231.35 hectares of \textit{L.leucocephala} fields which can support more than 19,701.52 head of cattle over a year.

2. ICPRC analysis obtained values show a different trend for each Sub-District, but the overall figures show that the district still able to accommodate 481.714 AU of cattle to rely solely on native grasses and agricultural by product as feed. Location Quotient analysis resulted that 10 areas in Kupang District showed that most areas is the livestock base, except in Sub-District Sulamu, Fatuleu, South Amfoang, and Southwest Amfoang are not be the base area, although the difference is only 0.1 compared to other regions.

The simulation results can be seen that the distribution pattern for development of \textit{L.leucocephala} based on land suitability showed the same value in each scenario, which sets it apart though is the location of development remains surround the cattle market. In general it can be seen that the area suitable for development of \textit{L.leucocephala} are in West Amarasi, South Amarasi, East Amabi Oefeto and Fatuleu.

5.2 RECOMMENDATION

1. The result of this research recommended and helps the decision-makers in local government to determining the direction of agricultural policy in the livestock sector in particular regional development planning process,
especially in calculating the carrying capacities of a region in providing fodder to ensure feed security.

2. Application of wide variety of fodder in this method would provide more optimal results in ensuring feed security.

3. Application of human resources, social and agricultural cultural habits as variables will more provide added value in decision making.

4. This is a beginning research; the model is really depending on the data input and process inside. Regarding to that conditions, it need the improvement and development the model in the future.
REFERENCES


Jones, R.J., and R.M. Jones. 1996. Thickening up of Leucaena Stand in Australia A Caution. LEUCNET News. 3: 19-20


APPENDICES

Appendix 1 User Interface

Appendix 2 Running Mode of Simulation Model
Appendix 3 Existing *Leucaena leucocephala* in Kupang District
Appendix 4 Cattle Population Density Base on Region and Spatial Plan Scenario

Cattle Population Density Base on Region

Legend:
- Livestock_market
- Dry Land Farming
- Constraint
- Grassland
- L. leucocephala
- Other Utilization
- Pasture
- Plantation

Scenario Model : Spatial Plan
Simulation Year : 13 years (2007-2020)
Population Base : 147,475
Growth Rate : 5 %
Appendix 5 Cattle Population Density Base on Region and Business as Usual Scenario

Scenario Model: Business as Usual
Simulation Year: 13 Years (2007-2020)
Population Base: 147,475
Growth Rate: 5%