LAND SUITABILITY FOR DAIRY CATTLE FARM SELECTION USING
SPATIAL ANALYSIS AND ANALYTICAL HIERARCHY PROCESS
(Case Study: Bener Meriah District, Nanggroe Aceh Darussalam Province)

PANJITRESNA PRAWIRADIPUTRA

A Thesis submitted for the degree of Master of Science
Of Bogor Agricultural University

MASTER OF SCIENCE IN INFORMATION TECHNOLOGY FOR
NATURAL RESOURCES MANAGEMENT
GRADUATE SCHOOL
BOGOR AGRICULTURAL UNIVERSITY

August 2008
STATEMENT

Hereby I, Panjitresna Prawiradiputra, do declare that this thesis entitled "Land Suitability for Dairy Cattle Farm Selection Using Spatial Analysis and Analytical Hierarchy Process (Case Study: Bener Meriah District, Nanggroe Aceh Darussalam Province)" is my own work and has not been submitted in any form for another degree or diploma programs (course) to any university or other institution. The content of the thesis has been examined by the advising committee and the external examiner.

Bogor, August 2008

Panjitresna Prawiradiputra
ABSTRACT


Best area for dairy cattle farm in Bener Meriah district, Nanggroe Aceh Darussalam province has been discovered by using Spatial Analysis and Analytical Hierarchy Process (AHP). Bener Meriah district has potential areas to develop dairy cattle farm since that area is located in highland. Milk as product of dairy cattle can be alternative income for local people to increase their prosperity. Spatial Analysis is used to find candidates of most suitable areas in the district based on physical factors such as construction, water supply, climate and soil factors. Beside Spatial Analysis, Carrying Capacity test is performed to ensure the candidates area able to carry dairy cattle. Analytical Hierarchy Process (AHP) is used to select the most suitable area for dairy cattle farm from those candidates based on experts’ judgments. Economic factors such as marketing and cooperation availability and technical factors such as distance to town and road condition are considered as factors to be judge in Analytical Hierarchy Process. Based on experts’ judgment, marketing is considered as the most important factor. The final result is an area as large as 11 hectares width in Kute Lintang village. Feasibility study in this area is needed to ensure the area proper in marketing, milk processing industry and waste management

Keyword: dairy cattle farm, GIS, Analytical Hierarchy Process
SUMMARY


Bener Meriah district in Nanggroe Aceh Darussalam province is located in highland, that is suitable to develop dairy cattle farm. To find best location of dairy cattle farm, physical factors should be considered such as rainfall, temperature, settlements, availability of roads, land cover, altitude and water supply. Beside physical factors, there are technical factors such as road condition and distance to town, economical factors such as marketing and cooperation availability and carrying capacity factors.

Overlying physical factors is resulted three candidates area for dairy cattle farm and two candidate areas for pastures. Those areas are Area A, located in Kute Lintang village and area B and C that located in Reje Guru village. Analytical Hierarchy Process (AHP) is used to decide the best location from those candidate areas. AHP calculates the priorities of technical factors and economical factors that given by the experts.

According to AHP calculation, marketing is discovered as the most important factor and Area A, located in Kute Lintang village as the most suitable location for dairy cattle farm. Second best is area C and the third one is area B, both located in Reje Guru Village.

Since there are good places in Bener Meriah district to develop dairy cattle farm, local government support in infrastructures, loans and experts are needed to help farmers through livestock sector. In the other hand, if local government develops more infrastructures such as road network, more suitable areas for dairy cattle farm will discovered.
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CURRICULUM VITAE

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I. INTRODUCTION

1.1 Background

Human population in Indonesia is increasing rapidly. This condition is the reason of raising milk demand in the country. Livestock is made to fulfill the people needs of animal product especially milk. According to BPS (Indonesia Statistic Central Committee), the milk production in Indonesia from 2000 - 2004 is around 34 -35 million liter per annum, only 30% of the demand. Dairy cattle farm cannot be developed in any where because a lot of criteria to be considered. Since the population in Indonesia is increasing, the area for developing livestocks especially land for growing pasture for animal feed is getting scare because it should compete with human settlement.

There are a lot of local dairy cattle farms that do not reach maximum production of milk because the farmers do not consider factors that may influence the production of milks such as unsuitable land for dairy cattle and pasture. This is a very important thing since dairy cattle is sensitive livestock especially to the environment. Beside that, the suitable area for pasture also should be considered. Not every kind of grass can grow in any area. That is why determining suitable area for dairy cattle farm development is very important.

The development of dairy cattle farm will be difficult in the future, especially in high density population area. This is because of the competition of land development for livestock and settlement. Both sectors need land and livestock usually is not a highest priority.

Information technology, especially Geographic Information System (GIS) can be used to determine suitable areas for dairy cattle farm development. The technology is applied for selecting area by considering all factors such as rainfall, water supply, temperature, soil type, elevation and other socio economic factors.

The study is located in Bener Meriah district since this area is potential for developing dairy cattle farm, where it is rich of high land, has good temperature and large bare land. However, there are no dairy cattle exists in the area.
1.2. Scope Study

The area of study is restricted to district level. This study is focused to find potential land for dairy cattle milk development in Bener Meriah district, Nanggroe Aceh Darussalam province. It covers suitable area for livestock and its pasture by considering physical factors, excluding conservation area determination livestock. This study also does not count livestock waste and its effect to the environment.

1.3. Objective

The objective of the study is to determine suitable areas for dairy cattle farm development in Nanggroe Aceh Darussalam (NAD) Province. In General the result of the study may help the decision maker to consider alternatives area to develop dairy cattle farm in NAD province. The specific objective of the project is to give recommendation for humanitarian organization or government to assist people locating in the most suitable cattle farm in the study area so it will improve the local economy.
II. LITERATURE REVIEW

2.1 Dairy Cattle

The development of one commodity is established by its influence to people and also by how important the commodity needs by the people. In other countries, like most of European country, American and Australia, milk is already become daily beverages so the milk consumption is high. Eventhough the milk consumption in Indonesia is still low, the milk production is still not enough to cover all demand. The milk demand in Indonesia is 1.35 billion liters per year. According to ministry of Internal Affair, nowadays Indonesia still imports around 1 billion liter or 70% of milk demand from other countries such, as Australia, New Zealand and Netherlands.

Nowadays Indonesia is trying to increase the milk production to fulfill the demand by adding population of cattle. Friesian-Holstein is compatible species in Indonesia and the most popular species of dairy cattle in Indonesia. In the past, there are other dairy cow species in Indonesia such as Shorthon, Ayrshire and Jersey. Among the other dairy cow species, Friesian-Holstein has best milk production. Friesian-Holstein was imported from Netherlands in 1891-1892. The male weight can reach 800 kg – 1000 kg and the female 570 kg – 730 kg. In high land the production of Friesian-Holstein is more than 6000 kg per lactation with fat value is 3.6%. (Siregar, 1989).

2.2 Pasture

The fine grass species and have high productivity usually need high degree of soil fertility. Elephant grass (Pennisetum purpureum) is growing in Indonesia. This grass originally from Nigeria and can grow up to 4.5 meter tall. The characteristics of elephant grass are dry endure, has high nutrient value and can fix soil fertility. It is also have high productivity level. In humid area or in area that have good irrigation, the production of elephant grass can reach 290 tons/ha/year. (McIlroy, 1976)

Successful pasture establishment is obtained by providing the right conditions of seeds or cutting to strike and grow, and by eliminating unwanted
species. Favorable conditions for establishment imply absence of moisture stress, often associated with good soil / seed contact induced by rolling, and sufficient aeration, lights is needed for some seeds. Soil crusting may stop the emergence to delicate seedlings. Soil and air temperatures should be satisfactory for germination and seedling survival. Pathogens, such as damping off fungi (*Phytophthora*), and predators, such as seed harvesting ants, are additional hazard. (Humphreys L.R., 1980).

2.3 Geographic Information System

GIS is defined as a computerized system that facilitates the phases of data entry, data analysis, and data presentation especially in cases when we are dealing with geo-referenced data (de By, 2000).

A GIS supports several views for working with geographic information:

1. The geodatabase view: A GIS is a spatial database containing datasets that represent geographic information in terms of a generic GIS data model— features, rasters, topologies, networks, and so forth.

2. The geovisualization view: A GIS is a set of intelligent maps and other views that show features and feature relationships on the earth’s surface. Various map views of the underlying geographic information can be constructed and used as ‘windows into the database to support queries, analysis, and editing of the information.

3. The geoprocessing view: A GIS is a set of information transformation tools that derive new geographic datasets from existing datasets. These geoprocessing functions take information from existing datasets, apply analytic functions, and write results into newly derived datasets.

These three GIS views are represented in ESRI® ArcGIS® by the catalog (a GIS is a collection of geographic datasets), the map (a GIS is an intelligent map view), and the toolbox (a GIS is a set of geoprocessing tools). Together, all three are critical parts of a complete GIS and are used at varying levels in all GIS applications. (ESRI, 2005)

2.4 Analytical Hierarchy Process

The Analytical Hierarchy Process is a decision-aiding method developed by Saaty (1988). It aims at quantifying relative priorities for a given set of
alternatives on a ratio scale, based on the judgment of decision-maker, and stressed the importance of the intuitive judgments of a decision-maker as well as the consistency of the comparison alternatives in the decision making process. The strength of this approach is that it organizes tangible and intangible factors in a systematic way, and provides a structured yet relatively simple solution to the decision-making problem. (Al-Harbi, 2001)
III. MATERIAL AND METHOD

3.1 Time and Location

The research was conducted in March 2007 until June 2007. The area of study is covering the whole area of Bener Meriah district. The area is located between 96.649192 to 97.332778 East Longitude and 4.971228 to 4.567314 North Latitude.

![Bener Meriah District Map]

Figure 1. Bener Meriah District

3.2 Type of Data and Sources

The data provided are elevation data, spot heights data, contours data, landcover data, soil type data, rainfall data, river and lake data, population density, geology data, and ecology data. The other data available are administrative data such as province, district and subdistrict and village boundaries, settlement data such as capital, main cities and villages, and also ports, and road network data. The data here taken from Bakosurtanal, Badan Rehabilitasi dan Rekonstruksi
(BRR), and owned by ICRC (International Committee of the Red Cross)

Table 1. Type of data and its sources

<table>
<thead>
<tr>
<th>No.</th>
<th>Data</th>
<th>Type</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Administrative Boundaries</td>
<td>Vector</td>
<td>BRR ICRC, Bakosurtanal</td>
</tr>
<tr>
<td>2</td>
<td>Settlement</td>
<td>Vector</td>
<td>Bakosurtanal</td>
</tr>
<tr>
<td>3</td>
<td>Elevation</td>
<td>Raster/Vector</td>
<td>Bakosurtanal</td>
</tr>
<tr>
<td>4</td>
<td>Spot Heights</td>
<td>Vector</td>
<td>Bakosurtanal</td>
</tr>
<tr>
<td>5</td>
<td>Contours</td>
<td>Vector</td>
<td>Bakosurtanal</td>
</tr>
<tr>
<td>6</td>
<td>Landcover</td>
<td>Vector</td>
<td>Bakosurtanal</td>
</tr>
<tr>
<td>7</td>
<td>Soil Type</td>
<td>Vector</td>
<td>Bakosurtanal</td>
</tr>
<tr>
<td>8</td>
<td>Rainfall</td>
<td>Vector</td>
<td>Bakosurtanal</td>
</tr>
<tr>
<td>9</td>
<td>Population Density</td>
<td>Vector</td>
<td>Bakosurtanal</td>
</tr>
<tr>
<td>10</td>
<td>Road Network</td>
<td>Vector</td>
<td>Bakosurtanal</td>
</tr>
</tbody>
</table>

3.3 Methodology

The study consists of Spatial Analysis and Analytical Hierarchy Process to determine suitable area for dairy cattle farm development, in Bener Meriah district, Aceh Province. Spatial Analysis used to create map of suitable area. The method of the study is:

1. To determined the objectives. The objective of this study is to find out suitable area for dairy cattle farm development.
2. To determined unit analysis of the study area. It is determined that District level is to be used as unit analysis.
3. Identified the criteria of suitable area for dairy cattle farm development.
4. Data collection.
5. Data analyzing.

The following diagram represents the overview of the research process structure.
Figure 2. Flowchart of Research Process
3.3.1 Model for Determining Suitable Area of Dairy Cattle Farm

The model for determining suitable area of dairy cattle farm is shown in hierarchical model below.

Figure 3. Model for Determining Suitable Area of Dairy Cattle Farm
3.3.2 Criteria and Its Measurement

The criteria that influence the determination of suitable area are divided into four factors. Those factors are carrying capacity, physical factors, technical factors and social-economic factors.

a. **Carrying Capacity**

Carrying capacity describes the average number of animals that can be placed on a pasture for a season without harming them. This is to measure the number of animals that can be breed in such area.

Available Carrying Capacity calculated by using the following formula:

\[
\text{Carrying Capacity} = \frac{\text{Forage Production}}{\text{Average Daily Intake}} \times \frac{\text{Utilization Rate}}{\text{Length of Grazing Season}}
\]

Equation 1. Carrying Capacity

Annual forage production is the total amount of forage dry material produced per acre on an annual basis. Seasonal utilization rate is the percentage of the annual forage production that will actually be harvested by the grazing livestock, this will be very dependent upon rotation frequency and expected level of animal performance. Average daily intake should be set at the level that will be required to yield the desired animal performance level. Length of the grazing period is a function of how many paddocks are available and the required rest period.

b. **Physical Factors**

Physical factors consists of four sub factors, those are water supply, climate factors, soil factors and constructions factors.

(1) Water Supply
Water is an essential factor for life. Dairy cattle needs high amount of water to live and maintain the cleanliness of the area. Typically, cattle will consume approximately 12 gallons or 45 liters of water per day (Siregar, 1989). Sanitation is one of the most important factors in managing dairy cattle, since it will influence to the quality of milk produced. Elephant grass is fairly tolerant to soil condition, but does not withstand to flood or water logging well (Humphreys, 1980). The sources of the water supply are from lakes and rivers around the area.

(2) Climate Factor consists of:

- Temperature (degree Celsius). Animals can survive only in certain temperature. In the case of dairy cattle, it will effect its milk production. Dairy cattle should live in low temperature area at around 12-23 Celsius degree. (Vercoe, 1999)

- Rainfall (mm/month). This is an important factor for cattle's water supply and pasture growth. Elephant grass growths in the area received over than 1100 mm rainfall (Humphreys, 1980). Cattle are not directly influenced by rainfall as long as they have sufficient water supplies. (Vercoe, 1999)

(3) Soil Factors consists of:

- Landcover. Landcover selected are bushes and open or unused field hence it will not sacrifice the forest, agricultural land or other natural resources. According to Humphreys (1980), scrub soil gives best growth to elephant grass. The cattle itself can live at any kind of land as long they have good pastures and water.

- Altitude (m). This factor is one of the most important factors in developing dairy cattle farm. Altitude has close relationship with temperature. The best dairy cattle farm must be located above 1000 m of sea surface level.

(4) Constructions Factors consists of:
• Roads. The farm should not be located too far from the road. This is to enable the farmers to have easy access to the town to sell their production. It is recommended that development of the farm is within 1 km from the road.

• Settlement. The farm should be build 1 km away from the settlements to avoid animal waste from the dairy cattle farm.

c. Technical Factors

(1) Accessibility.

Accessibility means the easy access to reach the area. This is important for milk marketing reason. There are two factors that influence accessibility:

• Road condition. It is define from condition of the road cover. (good, moderate, poor)

• Distance to town. It is related with marketing and selling the product to town. The site that located far away from the town will give less benefit to the farmer since the transportation cost is higher than the one closer to town.

d. Economic Factors

(1) Economic Factor

Economic factor has close relationship with money circulation. Economic Factor consists of:

• Marketing. Means how potential the area for milk marketing, how far the farm to market and how is the accessibility. Those factors above may influence the milk price in the market.

• Cooperation. The existence of cooperation to support the farmer.

3.4 Analysis

The analysis method use for this project is the Analytical Hierarchy Process. Through this method, decision was made to determine the most suitable area to develop dairy cattle farm. This method is based on expert's or decision-maker's judgment. The decision-maker has to give score to each factor given, and
the Analytical Hierarchy Process decides the level of importance of the factors to be considered. This method is useful, especially for unmeasured factors such as technical factors and social-economic factors.

The AHP is based on the concept of "exploding tree", also referred to as a value tree which allows splitting a goal into sub-criteria. It is assumed that the relevant importance of one attribute influenced a goal over other attributes can be determined via a pair-wise comparison. These comparisons are executed between all attributes in all combination to avoid repetitions. The tree may consist of several levels, where a goal for the lower level at the same time can be a sub-criterion for the upper level (Atthirawong and MacCarthy, 2001).

3.4.1. Establishment of a Structural Hierarchy

This step allows a complex decision to be structured into a hierarchy descending from an overall objective to various 'criteria', 'sub-criteria', etc, until the lowest level. The objective or the overall goal of the decision is to represent at the top level of the hierarchy. The criteria and sub-criteria contributing to the decision are represented at the intermediate levels. Finally, the decision alternatives or selection choices are laid down at the last level of the hierarchy.

3.4.2. Establishment of Comparative Judgments

Once the hierarchy has been structured, the next step is to determine the priorities of the elements at each level ('elements' here means every member of the hierarchy). A set of comparison matrices of all elements in a level of the hierarchy with respect to an element of the immediately higher level are constructed to priorities and convert individual comparative judgments into ratio scale measurements. The preferences are quantified by using a nine-point scale. The description of each scale measurement is explained in Table 1. The pair-wise comparisons are given in terms of how much element A is more important than element B.
Table 2. Scale of preference between two elements
(adapted from Saaty, 2000; Atthirawong and MacCarthy, 2001)

<table>
<thead>
<tr>
<th>Preference weights / level of importance</th>
<th>Definition</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>Extremely 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>Intermediates Value</td>
<td>Used to represent compromise between the preferences listed above</td>
</tr>
<tr>
<td>Reciprocals</td>
<td>Reciprocals for inverse comparison</td>
<td></td>
</tr>
</tbody>
</table>

3.4.3. Synthesis of priorities and the measurement of consistency

The pair-wise comparisons generate a matrix of relative rankings for each level of the hierarchy. The number of matrices depends on the number elements at each level. The order of the matrix at each level depends on the number of elements at the lower level that links to it. After all matrices are developed and all pair-wise comparisons are obtained, eigenvectors or the relative weights (the degree of relatives importance amongst the elements), global weights, and the maximum eigenvalue ($\lambda_{max}$) for each matrix are then being calculated.
The $\lambda_{\text{max}}$ value is an important validating parameter in AHP. It is used as 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 provides a completely consistent evaluation. The consistency ratio is calculated as per the following steps:

1) Calculate the eigenvector or the relative weights and $\lambda_{\text{max}}$ for each matrix of order $n$.
2) Compute the consistency index for each matrix of order $n$ by the formula:
   \[ CI = (\lambda_{\text{max}} - n)/(n-1) \] (3) .................................equation 2
3) The consistency ratio is then calculated using the formula:
   \[ CR = CI/RI \] (4) .................................equation 3

Where RI is a known random consistency index obtained from a large number of simulations runs and varies depending upon the order of matrix. Tables 2 shows the value of the random consistency index (RI) for matrices of order 1 to 10 obtained by approximating random indices using a sample size of 500 (Atthirawong and MacCarthy, 2001).

Table 3: Average random index (RI) based on matrix size
(Adapted from Saaty, 2000; Atthirawong and MacCarthy, 2001)

<table>
<thead>
<tr>
<th>Size of matrix (n)</th>
<th>Random Consistency Index (RI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0.52</td>
</tr>
<tr>
<td>4</td>
<td>0.89</td>
</tr>
<tr>
<td>5</td>
<td>1.11</td>
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<tr>
<td>6</td>
<td>1.25</td>
</tr>
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<td>7</td>
<td>1.35</td>
</tr>
<tr>
<td>8</td>
<td>1.40</td>
</tr>
<tr>
<td>9</td>
<td>1.45</td>
</tr>
<tr>
<td>10</td>
<td>1.49</td>
</tr>
</tbody>
</table>
If the value of CR is equal to, or less than that value, it implies that the evaluation within the matrix is 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 judgments within that matrix has occurred and the evaluation process should therefore be reviewed, reconsidered and improved.
IV. RESULTS AND DISCUSSIONS

4.1 Spatial Analysis

Spatial analysis in this study is overlying process of the spatial data based on certain criteria. Those criteria are taken from literatures and interview with experts of Department of Agriculture. The spatial analysis resulted in four most suitable candidates' area for developing dairy cattle farm and two best areas for pastures. Altitude, temperature, rainfall and river are the requirements for dairy cattle and pasture. Land cover is a criterion to avoid using the restricted places to develop dairy cattle farm and settlement and road are criteria related to social-economic problems. Basically, dairy cattle has more criteria to be fulfilled than pastures since dairy cattle has to be taken care carefully and elephant grass can grow easily in every spot in the district. Best suitable area for dairy farm and pastures are listed below:

Table 4. Criteria of best suitable area of dairy cattle and pastures based on literature and interview with the experts.

<table>
<thead>
<tr>
<th></th>
<th>Altitude</th>
<th>Temperature</th>
<th>Rainfall</th>
<th>Landcover</th>
<th>Settlement</th>
<th>Roads</th>
<th>Rivers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dairy Cattle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 - 2000 m asl</td>
<td>12-23 celcius</td>
<td>-</td>
<td>Open land</td>
<td>and</td>
<td>1 km from</td>
<td>within</td>
<td>within</td>
</tr>
<tr>
<td></td>
<td>m asl</td>
<td></td>
<td></td>
<td>bushes</td>
<td>settlement</td>
<td>the road</td>
<td>the river</td>
</tr>
<tr>
<td><strong>Pastures</strong></td>
<td></td>
<td></td>
<td></td>
<td>Open land</td>
<td>below 3000</td>
<td>1700-2000</td>
<td>-</td>
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<tr>
<td></td>
<td>m asl</td>
<td>mm/month</td>
<td></td>
<td>bushes</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The best suitable altitude for dairy cattle is 1000m – 2000m above sea level and for elephant grass is below 3000m above sea level. The suitable altitude in Bener Meriah district is mostly located in the middle of the district, covering east part of Pintu Rime Gayo and Timang Gajah sub district, almost whole area of Permata and Bandar sub district, whole area of Wih Pesem and Bukit sub district and around 40% area of Syiah Utama sub district. The highest area in the district
is Geureudong Mountain that located 2870m above sea level and the lowest area is around 600m above sea level in the east of the district.

![Suitable Altitude for Dairy Cattle & Pasture](image)

**Figure 4. Suitable Altitude for Dairy Cattle and Pasture in Bener Meriah District, NAD Province**

### 4.1. b. Temperature

Temperature has a close relationship with altitude in tropical countries. The higher altitude has the higher temperature. Dairy cattle have to live in low temperature area to keep them healthy and have maximum production of milk. The best temperature for dairy cattle is 12 – 23 Celsius degree. Elephant grass does not have specific requirement regarding the temperature as long as not in extremely high or low temperature. The best suitable area in Bener Meriah district according to 2004 Aceh Geology data is located Timang Gajah and Pintu Rime Gayo sub district around Geureudong Mountain area. It is also located in several parts of Permata sub district. The other area is along south area of the district, across three sub district, Bukit, Bandar and Syiah Utama sub district.
Figure 5. Suitable Temperature for Dairy Cattle in Bener Meriah District, NAD Province

4.1. c. Rainfall

Rainfall does not have any effect to dairy cattle as long as their water needs fulfilled. In the other hand pasture depends on rainfall to live. The ideal rainfall for pasture is 1700 – 2200 mm/month, located in most area of Syiah Utama and Permata sub district and small areas of Pintu Rime Gayo, Timang Gajah, Wih Pesem, Bukit and Bandar districts.
Figure 6. Suitable Rainfall for Pasture in Bener Meriah district, NAD Province

4.1. d. Landcover

The project tries to develop unused areas to be more productive. The idea is to convert open land and bushes area into dairy cattle farm and pasture area. Open land means unused area that contains of grass and careless plantation. The area should be considered conservation area as well. It should be outside conservation forest. The area selected spreads separated in most sub district except in Permata and Wih Pesem sub district. The conservation area and production forest lie in southeast area of Bener Meriah district.
4.1. e. Settlements

Figure 7. Open Land and Bushes in Bener Meriah District, NAD Province

Figure 8. Settlement (Villages & Towns) 1 km buffered
in Bener Meriah District, NAD Province

Dairy cattle farm should be developed at least 1 km outside the settlement area. The main consideration of this condition is animal waste that can be polluting settlement area. The settlement area in Bener Meriah district mostly located along main road Bireun - Takengon in Aceh Tengah District from northwest to south, and also around main road from Takengon in the south to Simpang Tiga, capital city of Bener Meriah district.

4.1. f. Roads

For economical reason, the dairy cattle farm should be developed at least 1 km from the roads, it is either from the main road and small roads. If the sites located near the roads, either main or small roads, it will be easy for the farmers to send the product to the market. The access also influences a lot of things such as workers availability, growth of the areas, etc. The main roads in Bener Meriah district is the state roads from Bireun to Takengon and from Takengon to Simpang Tiga. A small road is connecting settlements and villages and most of them are in an average condition.

Figure 9. Area 1 km within the road
in Bener Meriah District, NAD Province

4.1. g. Rivers

The rivers locations have influence to dairy cattle farm area. Since dairy cattle need a lot of water to live and the river is the only way to supply the water for cattle, the farm is restricted to 200 meters from the river or at least there is a river within 200 meters from the farm. Although pasture needs water to live as well as cattle, but water supply from pastures commonly comes from rainfall. The river in Bener Meriah district spreads in all over area of the district. In the western area of the district, the water flows from Geureudong Mountain to low land areas in south. In eastern areas, the water spread evenly from highland to lowland through the forests.

Figure 10. Area 200m within the river in Bener Meriah District, NAD Province

4.1.1 Pasture

There are two suitable areas for pastures in Bener Meriah district. The first one (P1) is in Kute Lintang village and the other one (P2) is in Reje Guru and
Delung Tue village. Site P1 has 72.22 hectares and covering farm site A. In the other side, P2 that has 559.18 hectares covering farm site B, C and D. According to the scientist from the Department of Livestock, the pasture site is usually not very far away from the cattle farm site. It is around 2 km around the area but it also depends on the number of livestock in the farm since it has a close relationship with the area carrying capacity of the livestock. Since the aim of the project is developing a middle scale of farm that contains no more than 50 dairy cattle, 2 km pastures buffer from the farm is adequate.

Those two areas are laid in hilly land except for the north side of P2 area which is flatter than the other parts. This condition could be an obstacle for the farmer to plant the grass. However, hilly land should not be a big constraint for the farmers since the relief is not too extreme.

![Image of suitable pasture areas in Bener Meriah District](image)

**Figure 11. Suitable areas for Pasture in Bener Meriah District**

### 4.1.2 Dairy Cattle

After overlying maps of criteria selected above that may influence the
development of dairy cattle farm, there are 3 candidates to be considered. All candidates' suitable areas for the farm are located in Bukit sub district. One of them (site A) is located in Kuta Lintang village and the other two (site B and C) are located in Reje Guru Village.

Figure 12. Suitable Area for Dairy Cattle Farm in Bener Meriah District, NAD Province

Site A has 11.43 hectares width. It located in the middle of Kuta Lintang village area 7.5 km away from Takengon, the main city of Aceh Tengah. There are small road very close from the area and province road is just 500 meters from the site but there was no access to the main road. Most of this area is covered by bushes and non-productive plants. The river flows near the area can fulfill the cattle need of water.

Site B is located in Reje Guru Village. It lies in 13.19 hectares land. There is a river across the area. The transportation could be a problem in this area because the only road available is 1.3 km away from the site. The only road available is narrow and it takes 11 km to the nearest city Takengon. If this area
selected to be the best area then the farmers should build a road to support the marketing of dairy products.

Site C that has 7.04 hectare width is located in north of site B. The nearest main city from both sites is Simpang Tiga, the capital city of Bener Meriah. The benefit of this site is that it is located only 200 meter from the main road so it is very accessible. The distance from both sites to Simpang Tiga is 4.5 km and to Takengon is 12 km.

4.2 Carrying Capacity

Carrying capacity is the stocking rate that is economically and environmentally sustainable for a particular grazing unit throughout the grazing season. Carrying capacity is largely determined by four factors: 1) annual forage production, 2) seasonal utilization rate, 3) average daily intake, and, 4) length of the grazing season. These terms can be expressed in the mathematical formula below:

\[
\text{Carrying Capacity} = \frac{\text{Annual Forage Production}}{\text{Average Daily Intake}} \times \frac{\text{Seasonal Utilization Rate}}{\text{Length of Grazing Season}}
\]

Equation 1. Carrying Capacity

Annual Forage Production is the total amount of forage dry matter produced per hectare on an annual basis. McIlroy said that Annual forage production for elephant grass can reach 290 tons/ha/year, but 100 tons/ha/year is moderate production.

Seasonal utilization rate is the percentage of the annual forage production that will actually be harvested by the grazing livestock. Figure 13 can be used to estimate approximate seasonal utilization rate based on average grazing period length. Based on the curve below, the growth rate for pasture is around 70% since elephant grass can be harvested in 2 months time or 60 days.
Average daily intake should be set at the level that will be required to yield the desired animal performance level. Average forage dry matter intake values for high, medium, and low performance of either cattle or cow-calf pairs would be 3.5 percent, 3.0 percent, or 2.5 percent as a percentage of the animal's bodyweight. (0.035, 0.03, 0.025). Assuming that the intake would be in moderate level, so intake is entered at 3 percent of bodyweight, which is 0.03.

Length of the grazing period is a function of how many pastures are available and the required rest period. Since elephant grass can be harvested in 2 months or 60 days, the length of grazing period entered is 60 days.

Carrying capacity is calculating as:

\[
\frac{100,000 \text{ kg forage/ha} \times 0.7}{0.03 \text{ kg forage/} \times 60 \text{ days}} = 38888 \text{ kg liveweight/ha}
\]

kg liveweight

If it assumes the average of liveweight of cattle is 600 kg, then carrying capacity is

\[
\frac{38888 \text{ kg liveweight/ha}}{600 \text{ kg liveweight}} = 64 \text{ cattles/ha}
\]
According to spatial analysis, pasture area 1 or P1 has width 72 hectares and pasture area 2 or P2 has area of 559 hectares. That means that P2 can carry 72 x 64 = 4608 cattles and P2 can carry 559 x 64 = 35776 cattles. It shows that both areas are available to develop middle level dairy cattle farm with around 100 dairy cattle or even to develop big farm that can carry thousands of dairy cattle.

Figure 14. Suitable Area for Pasture and Carrying Capacity in Bener Meriah District, NAD Province

4.3 Analytical Hierarchy Process

Analytical Hierarchy Process method is made to find the best area to develop dairy cattle farm in Bener Meriah district. This method is using the expert judgments. The decisions are made by 6 scientists from the Department of Agriculture. The criteria to find the best area for dairy cattle farm are the distance to town, road condition, marketing and cooperation availability.

Since the judgments made by the experts are separated into 6 criteria tables, next step is to combine those 6 criteria tables into 1 overall criteria table.
Overall criteria table indicates marketing is the most important factor to be considered. The second one is cooperation availability. Road condition and distance to town are the last factors to be considered.

Table 5. Overall criteria dairy cattle farm factors

<table>
<thead>
<tr>
<th></th>
<th>Distance to Town</th>
<th>Road Condition</th>
<th>Marketing</th>
<th>Cooperation</th>
<th>Vector priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to Town</td>
<td>1.00</td>
<td>0.50</td>
<td>0.13</td>
<td>0.22</td>
<td>0.047</td>
</tr>
<tr>
<td>Road Condition</td>
<td>2.33</td>
<td>1.00</td>
<td>0.13</td>
<td>0.30</td>
<td>0.096</td>
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<tr>
<td>Marketing</td>
<td>8.00</td>
<td>7.83</td>
<td>1.00</td>
<td>4.35</td>
<td>0.538</td>
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<tr>
<td>Cooperation</td>
<td>5.67</td>
<td>4.33</td>
<td>1.56</td>
<td>1.00</td>
<td>0.519</td>
</tr>
</tbody>
</table>

Next step is to determine matrix of pairwise comparison for candidate area of dairy cattle farm. It compares area A in Kuta Lintang village and area B and C in Reje Guru village based on factors considered.

Table 6. Pairwise comparison table – Distance to Town

<table>
<thead>
<tr>
<th>Distance to Town</th>
<th>Area A</th>
<th>Area B</th>
<th>Area C</th>
<th>Priority Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area A</td>
<td>1</td>
<td>6.00</td>
<td>3.00</td>
<td>0.632</td>
</tr>
<tr>
<td>Area B</td>
<td>0.17</td>
<td>1</td>
<td>0.33</td>
<td>0.095</td>
</tr>
<tr>
<td>Area C</td>
<td>0.33</td>
<td>3.00</td>
<td>1</td>
<td>0.274</td>
</tr>
</tbody>
</table>

Table 7. Pairwise comparison table – Road Condition

<table>
<thead>
<tr>
<th>Road Condition</th>
<th>Area A</th>
<th>Area B</th>
<th>Area C</th>
<th>Priority Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area A</td>
<td>1</td>
<td>4.00</td>
<td>6.00</td>
<td>0.691</td>
</tr>
<tr>
<td>Area B</td>
<td>0.25</td>
<td>1</td>
<td>2.00</td>
<td>0.204</td>
</tr>
<tr>
<td>Area C</td>
<td>0.17</td>
<td>0.5</td>
<td>1</td>
<td>0.105</td>
</tr>
</tbody>
</table>

Table 8. Pairwise comparison table – Marketing

<table>
<thead>
<tr>
<th>Marketing</th>
<th>Area A</th>
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<th>Area C</th>
<th>Priority Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area A</td>
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<td>6.00</td>
<td>4.00</td>
<td>0.623</td>
</tr>
<tr>
<td>Area B</td>
<td>0.17</td>
<td>1</td>
<td>0.25</td>
<td>0.080</td>
</tr>
<tr>
<td>Area C</td>
<td>0.25</td>
<td>4.00</td>
<td>1</td>
<td>0.297</td>
</tr>
</tbody>
</table>

Table 9. Pairwise comparison table – Cooperation Availability

<table>
<thead>
<tr>
<th>Cooperation Availability</th>
<th>Area A</th>
<th>Area B</th>
<th>Area C</th>
<th>Priority Vector</th>
</tr>
</thead>
<tbody>
<tr>
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<td>5.00</td>
<td>0.645</td>
</tr>
<tr>
<td>Area B</td>
<td>0.17</td>
<td>1</td>
<td>0.25</td>
<td>0.076</td>
</tr>
<tr>
<td>Area C</td>
<td>0.20</td>
<td>4</td>
<td>1</td>
<td>0.279</td>
</tr>
</tbody>
</table>
From tables above, Area A (Kuta Lintang village) has the highest value in all criteria. Area B (Reje Guru village) has higher value than Area C (Reje Guru village) in Road Condition criteria, but Area C has higher value than Area B in Distance to Town, Marketing and Cooperation Availability criteria. The process of AHP is not stop in this point. Last step is to determine global priorities of areas. The value of Vector of Overall Priorities came from sum of priorities vector of area multiplied by the priority of the criteria.

Table 10. Determining the Overall Priorities

<table>
<thead>
<tr>
<th></th>
<th>Distance to Town</th>
<th>Road Condition</th>
<th>Marketing</th>
<th>Cooperation</th>
<th>Vector of Overall Priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area A</td>
<td>0.047</td>
<td>0.096</td>
<td>0.538</td>
<td>0.319</td>
<td>0.637</td>
</tr>
<tr>
<td>Area B</td>
<td>0.632</td>
<td>0.691</td>
<td>0.623</td>
<td>0.645</td>
<td>0.091</td>
</tr>
<tr>
<td>Area C</td>
<td>0.274</td>
<td>0.105</td>
<td>0.297</td>
<td>0.279</td>
<td>0.272</td>
</tr>
</tbody>
</table>

The result of global priority vector shows that area A in Kute Lintang village is the most suitable area to develop dairy cattle farm in Bener Meriah district Nanggrooe Aceh Darussalam province, considering 7 physical criteria: altitude, temperature, rainfall, landcover, settlement, road, river and 4 social-economic factors: distance to town, road condition, marketing and cooperation.
Figure 15. Best Suitable Area for Dairy Cattle Farm  
Kute Lintang Village, Bener Meriah District

Based on expert judgement in AHP, it is very obvious that economic factors is running an important role to find best suitable area for dairy cattle farm. Experts were considering marketing factor and cooperation availability factor in the area as important factor than technical factors such as distance to town and road condition. Eventhough distance to town and road condition factors have close relationship with marketing, it is not considered as an important factor since the population of the town in that area is mostly low. Technical factors still important to compare the factors that influence the selection of dairy cattle farm. To make the selection of dairy cattle farm more precise, additional physical, technical, economical and social factors is needed.

Site A in Kute Lintang village is located near one of the largest town in the area, Takengon, the capital city of Aceh Tengah. This condition makes Site A in Kute Lintang village have more benefit from marketing side compared to Site B
and Site C in Reje Guru village. Site B and C are located closer to Simpang Tiga, the capital city of Bener Meriah district, than site A, but Simpang Tiga is not as big as Takengon and have low population. This condition is not good for marketing.

Before this project implemented in the field, government support through comprehensive feasibility study is needed. Pilot project of dairy cattle farm in that area should be done to see from bioecosystem and social economy side and also from overall comprehensive feasibility study in term of bussiness planning that related with marketing, milk processing industry and waste management.
V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Nanggroe Aceh Darussalam province has some highlands that are suitable for developing dairy cattle farm since dairy cattle needs low temperature areas as their best living place. The Bener Meriah district is chosen to be the research area because this area is a highland. Located in the central of Aceh province, Bener Meriah still has wide area of bare land and some parts are not located in a conservation area or protected forest.

To find the best location for dairy cattle farm, there are several factors to be considered such as, physical factors, carrying capacity, technical factors and economic factors. Physical factors are to find the best location for dairy cattle farm and pasture based on availability of roads, settlements, rainfall, temperature, land cover, altitude, and water supply. The result of overlying those factors above in candidate areas of dairy cattle farm and pasture. Carrying capacity is used to see if those candidate areas are able to carry at least 100 cattle. There are two areas, one in Reje Guru village and the other one in Kute Lintang village that suitable for pasture. Overlying process also indicates 3 good locations for dairy cattle farm.

The result of overlying physical factors and carrying capacity are 3 candidates location. First area is located in Kute Lintang village. The second and third areas are located in Reje Guru village. Both area is located in south of Bener Meriah district.

Analytical Hierarchy Process (AHP) is used to find the best area for dairy cattle farm from those candidates. AHP calculates the score of technical and economic factors made by the experts. Technical factors such as road condition and distance to town, and economic factor such as marketing and cooperation availability is considered in AHP calculation. AHP states that marketing is the most important factor to be considered. Next factors are cooperation availability, road condition and distance to town. Based on the result above, AHP calculates priorities of the candidate areas as the best location for dairy cattle farm.

AHP decides area A, located in Kute Lintang village as the most suitable
place to develop dairy cattle farm. Second best is area C and the third one is area B, both located in Reje Guru village.

5.2 Recommendations

NAD province has a dark past related with armed conflict and security problem. In the past, villagers were displaced to other province in order to save their lives. Since, at the moment the situation is back to normal, they are returning to their village to start over.

Livestock development is an option for local people to improve their economy. Especially in Aceh Tengah and Bener Meriah highlands, dairy cattle could be one of the best options to be considered. Based on this study there are good places that can be developed as dairy cattle farms. Support from local government is absolutely needed to help farmers to start over with their livelihood through dairy cattle farming. Local government support could be in developing the facilities, loan for farmers and provide livestock experts to help farmers to improve their knowledge of dairy cattle and pasture.
REFERENCES


De Boer AJ. 1999. Socio-economic aspects of smallholder dairy farmers. Smallholder dairying in the tropics.3:45-59


APPENDICES
Appendix 1

Relation of technical - economic factors that influence the decision to select best suitable area for dairy cattle farm

<table>
<thead>
<tr>
<th></th>
<th>Distance to Town</th>
<th>Road Condition</th>
<th>Marketing</th>
<th>Cooperation</th>
</tr>
</thead>
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<td>1/8</td>
</tr>
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<td>1/8</td>
<td>1/7</td>
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<td>Marketing</td>
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<td>1/2</td>
</tr>
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1 : Equal importance  
2 : Equal to moderate importance  
3 : Moderate importance  
4 : Moderate to strong importance  
5 : Strong importance  
6 : Strong to very strong importance  
7 : Very strong importance  
8 : Very to extremely importance  
9 : Extremely importance

Name : Ir. Elan Masbulan

Function : Agriculture Social Economic Scientist

Date : 24/07/07
Appendix 2

Relation of technical - economic factors that influence the decision to select best suitable area for dairy cattle farm

<table>
<thead>
<tr>
<th></th>
<th>Distance to Town</th>
<th>Road Condition</th>
<th>Marketing</th>
<th>Cooperation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance to Town</td>
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<td>1/3</td>
<td>1/8</td>
<td>1/8</td>
</tr>
<tr>
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<td>1/5</td>
</tr>
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</tr>
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<td>1</td>
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1 : Equal importance  
2 : Equal to moderate importance  
3 : Moderate importance  
4 : Moderate to strong importance  
5 : Strong importance  
6 : Strong to very strong importance  
7 : Very strong importance  
8 : Very to extremely importance  
9 : Extremely importance

Name : Ir. Dwi Priyanto

Function : Livestock Scientist

Date : 16/07/07
Appendix 3

Relation of technical - economic factors that influence the decision to select best suitable area for dairy cattle farm

<table>
<thead>
<tr>
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<th>Marketing</th>
<th>Cooperation</th>
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</thead>
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<td>1/9</td>
<td>1/5</td>
</tr>
<tr>
<td>Road Condition</td>
<td>2</td>
<td>1</td>
<td>1/9</td>
<td>1/2</td>
</tr>
<tr>
<td>Marketing</td>
<td>9</td>
<td>9</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Cooperation</td>
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<td>2</td>
<td>1/9</td>
<td>1</td>
</tr>
</tbody>
</table>

1 : Equal importance  
2 : Equal to moderate importance  
3 : Moderate importance  
4 : Moderate to strong importance  
5 : Strong importance  
6 : Strong to very strong importance  
7 : Very strong importance  
8 : Very to extremely importance  
9 : Extremely importance

Name : Dr. Bambang Risdiono
Function : Expert Scientist of Agricultural System
Date : 24/07/07
Appendix 4

Relation of technical - economic factors that influence the decision to select best suitable area for dairy cattle farm

<table>
<thead>
<tr>
<th></th>
<th>Distance to Town</th>
<th>Road Condition</th>
<th>Marketing</th>
<th>Cooperation</th>
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</thead>
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</tr>
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</table>

1 : Equal importance  
2 : Equal to moderate importance  
3 : Moderate importance  
4 : Moderate to strong importance  
5 : Strong importance  
6 : Strong to very strong importance  
7 : Very strong importance  
8 : Very to extremely importance  
9 : Extremely importance  

Name : Ir. Iwan Herdiawan  
Function : Agrostology Scientist  
Date : 18/07/2007
Appendix 5

Relation of technical - economic factors that influence the decision to select best suitable area for dairy cattle farm

<table>
<thead>
<tr>
<th></th>
<th>Distance to Town</th>
<th>Road Condition</th>
<th>Marketing</th>
<th>Cooperation</th>
</tr>
</thead>
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<td>1/7</td>
<td>1/2</td>
</tr>
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<td>1/9</td>
<td>1/2</td>
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<td>1</td>
<td>7</td>
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<tr>
<td>Cooperation</td>
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<td>2</td>
<td>1/7</td>
<td>1</td>
</tr>
</tbody>
</table>

1 : Equal importance  
2 : Equal to moderate importance  
3 : Moderate importance  
4 : Moderate to strong importance  
5 : Strong importance  
6 : Strong to very strong importance  
7 : Very strong importance  
8 : Very to extremely importance  
9 : Extremely importance  

Name : Ir. Sajimin  
Function : Livestock Scientist  
Date : 17/07/07
Appendix 6

Relation of technical - economic factors that influence the decision to select best suitable area for dairy cattle farm

<table>
<thead>
<tr>
<th></th>
<th>Distance to Town</th>
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</tr>
</thead>
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<tr>
<td>Road Condition</td>
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<td>1/7</td>
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<td>Cooperation</td>
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<td>7</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

1 : Equal importance
2 : Equal to moderate importance
3 : Moderate importance
4 : Moderate to strong importance
5 : Strong importance
6 : Strong to very strong importance
7 : Very strong importance
8 : Very to extremely importance
9 : Extremely importance

Name : Ir. Achmad Farundi
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Date : 15/05/08