Developing the National Land Resource Database for Supporting Spatial Land Use Planning

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Key words:

SUMMARY

BAKOSURTANAL (The National Coordination Agency for Surveys and Mapping) holds the government role in surveys and mapping. BAKOSURTANAL mission is to provide the infrastructure on spatial data as the bases for exploration and developing natural resource information systems. In the 1980s', BAKOSURTANAL cooperated with the Ministry of Transmigration and the Government of the United Kingdom in selecting suitable areas for new transmigration settlements. The joined project was called the *Regional Physical Planning Programme for Transmigration* (RePPProT). The project's goal was to produce systematic regional reconnaissance maps of physically land resources in the transmigration receiving areas.

RePPProT employed landforms as the key to a land system classification intended for land resource mapping. It used hierarchical classification methods. The RePPProT land systems were distinguished into two biogeographic zones (along the Wallace's line), in each of which there were four agro-climatic zones, up to 13 physiographic types, numerous lighologic categories, and a total of 414 land systems. It also grouped information into eight broad categories of lithology, hydrology, climate, vegetation, land use, soil, physiography and land fragmentation.

Currently, the RePPProT land systems are not comparable to the national georeference system. The paper describes BAKOSURTANAL efforts in adjusting the RePPProT data to the national georeference system. In addition, attribute features are corresponded with the national coding system. The standardized land systems are intended to be utilized by the related agencies as the land resource database for spatial land use planning.

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1. INTRODUCTION

1.1 Background

Indonesia is the biggest archipelago country in the world, which has 17,508 islands and more than 80,000km long of coastline. The total land area of Indonesia is approximately 1,909,049 km^2. Indonesia's territory, which is located at 6^o North Latitude - 11^o South Latitude and 9^o - 141^o East Longitude, has an enormous and varied potential of renewable and non-renewable natural resources. These natural resources can be used as a basic capital for national development. For supporting national development, BAKOSURTANAL has a mission to provide the infrastructure on spatial data as the bases for exploration and developing natural resource information systems. Between 1984 and 1989, BAKOSURTANAL cooperated with the Ministry of Transmigration and the Government of the United Kingdom to map the land resources of Indonesia through RePPProT project. The project's goal was to allocate suitable land for transmigration settlement. The important task of this project was to create a land resource database for supporting a regional planning (Wall, 1987).

For resource planning in Indonesia, the information on landform distribution and its characteristics is certainly the most important factor. Landforms are the key to a land resource mapping methodology employed by RePPProT. Following this method, the landscape of Indonesia is divided into specific kinds of land units called land systems. Land systems are natural ecosystems in which rocks, climate, hydrology, topography, soils and organisms are correlated in a specific way (RePPProT, 1990). The land systems provide useful information for regional planning allowing rapid identification of land suitability for specified types of land use.

Using the JOG (Joint Operations Graphic) topographic maps with a scale 1: 250.000 as its base maps, the RePPProT project systematically mapped the land systems of the whole of Indonesia. However, the spatial database of the land systems developed by RePPProT are not yet comparable to the national georeference system. In addition, the reliability of the attribute data of the land systems are not constant due to the various sources of secondary data with various reliability levels, namely: reliable, probable, tenable, plausible, and no data.

The national development needs the availability of current and accurate geospatial data. Considering the importance of the availability of the geospatial data, through the National Spatial Data Infrastructure Development (NSDI) program, BAKOSURTANAL has a commitment to achieve a mission to provide the infrastructure on spatial data as the bases for exploration and developing natural resource information systems. The RePPProT land systems as the land resource data are one of the thematic geospatial data useful for supporting spatial land use planning. The land systems data are assets that should be maintained and developed for supporting spatial land use planning. In addition to the identification of land suitability for transmigration settlement, many related agencies also used the RePPProT land systems for various purposes, such as for agricultural development, agroforestry, spatial planning, etc.

1.2 Objective

The objective of the land resource database development is to organize and standardize the land systems for supporting spatial land use planning. The standardization of the land systems includes spatial data, feature codifications, database transformation, and metadata creation. The organized and standardized land systems are expected to be easily accessed and integrated with other thematic data by related agencies for spatial land use planning.

2. MAPPING METHODOLOGY

The RePPProT project used the land system concept for mapping the land resource of Indonesia. The key to this method is to divide the landscape of Indonesia into specific kinds of land units called land systems. The land system concept, as explained by Christian and Stewart (1968), is based on ecological principles and presumes closely interdependent links between agroclimate regime, rock types, landforms, soils, hydrological conditions and living organisms. The land system mapping is initially landform and rock type mapping. In addition, the land systems are grouped by the ecological differences between the east and the west of Indonesia, following the Wallace's line. Every land system is given a local name near the location it was first established, and its own unique symbol and a number (Wall, 1987; RePPProT, 1990). The schematic hierarchy of land systems in Indonesia is shown in Figure 1.

The land system mapping through landform identification was mostly conducted using air-photography at 1:50,000 - 1:100,000 scales. In some areas where there were no air-photographies, Landsat or radar imageries at scale 1: 250,000 were also used. The land systems interpreted from the imageries were then transferred to the JOG topographic maps at scale 1: 250.000. The physical properties of the land systems such as lithology, hydrology, climate, topography, forest types, land use, soil were obtained from secondary data which have various reliabilities.

The physical properties of the land systems were grouped into 8 categories, namely: lithology, hydrology, climate, vegetation, land use, soil, topography and land fragmentation. Most categories contain several subsets of data. The information included under each category was given reliability rating which was classified into 5 classes, namely: reliable (based on detailed field survey), probable (based on reconnaissance surveys), tenable (based on image interpretation), plausible (based on exploration surveys), and no data. These properties were recorded on data cards as shown in Figure 2. Using these physical land system characteristics, the RePPProT project already evaluated the land suitability for agriculture, livestock (cattle), brackish fisheries and agroforestry

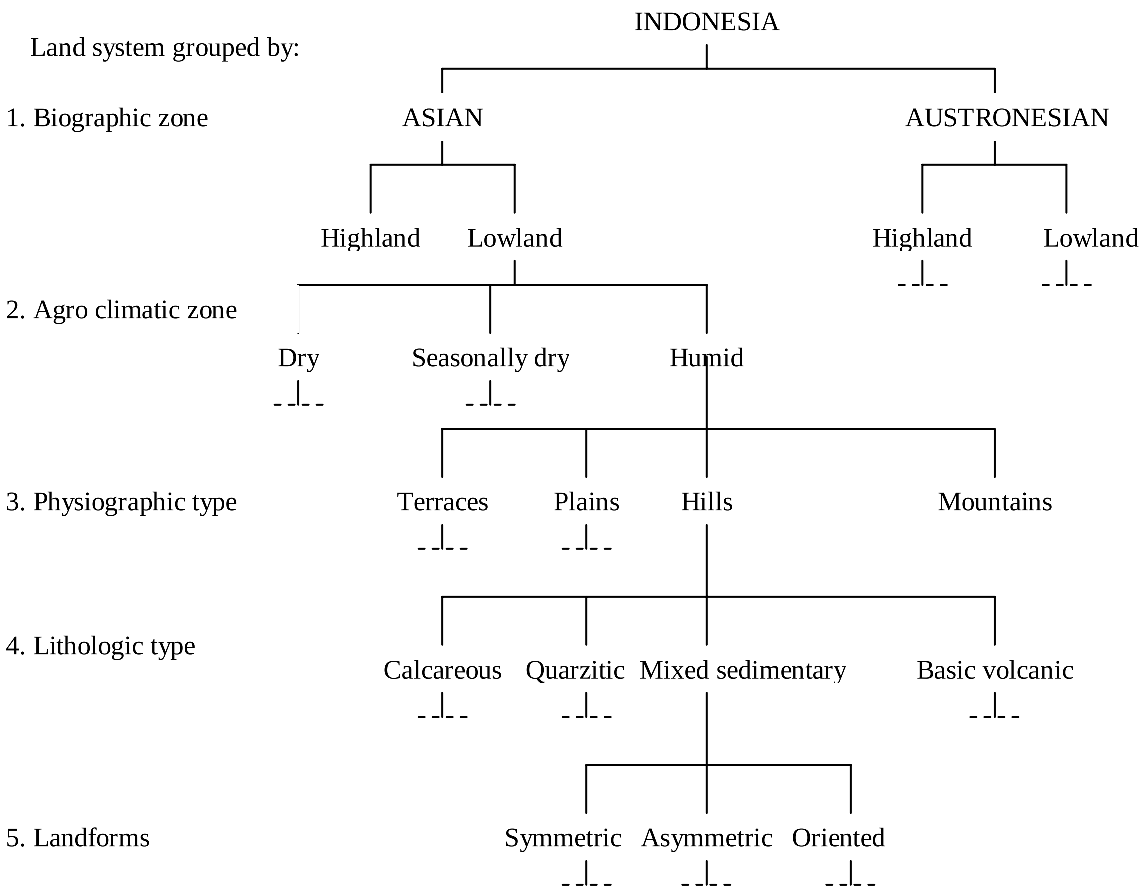

Figure 1: Schematic hierarchy of land systems in Indonesia (RePPProT, 1990)

3. DATABASE DEVELOPMENT

The RePPProT land system data of the whole of Indonesia were digitized using the Arc/Info GIS (Geographic Information System) software and presented with the RePPProT index map numbering system. The existing RePPProT land system database contain only spatial data. The spatial database construction was based on the georeference of the JOG topographic map. The attribute data, which describe the properties of the land systems, were not yet stored in digital format. These existing RePPProT land system database, therefore, were not ready to be integrated with other thematic data using the national georeference system. The following efforts are trying to organize and standardize the RePPProT land system database so that their quality meets with the specification of designing the national integrated natural resource database, particularly for supporting spatial land use planning.

3.1 Spatial Data Standardization

In Indonesia, one of the NSDI programs is to develop national spatial data standards. This effort is to answer the current trend of GIS users in applying the integrated data for various purposes. As explained by ESCAP (Economic and Social Commission for Asia and the Pacific) United Nations (1998), the data integration in GIS applications relies heavily on the development of spatial data standards. The standardization of the spatial data in the data sets for the GIS application certainly needs a georeference standard.

As already mentioned, the RePPProT land system maps used the JOG topographic maps as base maps which used a Bessel ellipsoid. To standardize the spatial data of the RePPProT land systems, their georeference system is transformed into the RBI (*Rupabumi*) maps which use the DGN'95 (*Datum Geodesi Nasional Tahun* 1995). According to Matindas, *et. al.* (1997), the DGN'95 adopts the ellipsoid of the World Geodetic System 1984 (WGS'84). The grid system of the RBI map uses the geographic and UTM (Universal Transverse Mercator) grids with a 6^o x 6^o zone. The coverage area of Indonesia spans from 90^o to 144^o east longitude and from 10^o north latitude to 15^o south latitude. The area can be divided into 9 UTM zones, ranging from zone 46 to zone 54. Each zone is then divided into certain numbers of rows and columns according to its map scale. At 1: 250,000 scale, each RBI map has a 15' x 15' size. These RBI maps are used for standardizing the RePPProT land systems. Figures 3 shows the RBI index map at 1: 250.000 scale. The total map sheets of the RePPProT land systems that needs to be standardized amounted to 237 sheets.

The method to standardize the spatial data of the RePPProT land systems is as following. First, the UTM coordinates of the RBI layers which include hydrography, transportation, hypsography, administration boundary, and geographical names are transformed into the geographic coordinates using the algorithm available in the Arc/info GIS software. The UTM coordinate systems of the RePPProT land systems are also transformed into the geographic coordinates. The RePPProT land system layer is then superimposed onto the hydrographic layer. All of the coast lines of the RePPProT land systems are replaced with the coast lines obtained from the hydrographic layers of the RBI maps. To keep the topological consistency, the land system layers between adjacent map sheets are edge-matched to each other.

Figure 3 gives an example of the RePPProT land system layer superimposed onto the RBI hydrographic layer. This example shows that the deviation of RePPProT land system layer to the RBI hydrographic layer is less than 2mm (0,5 km). Such deviation is acceptable for map accuracy at 1: 250,000 scale.

3.2 Feature Codification

Bakosurtanal adopts a standardized codification for its feature data types. A feature codification is developed to represent the RePPProT land unit systems (see an example on Figure 4). The codification is based on a hierarchical system. Each land unit is given a unique identifier. This key identifier includes information on scale type, biographic and physiographic zones as well as the landform type. The first two digits of the key represent the main Bakosurtanal classification system under which the land unit systems fall into. The next digit represents the land unit system class. The following digit displays the scale type. Bakosurtanal geodatasets are classified into three levels of scales namely: national, provincial, and local scales. The scale divisions are greater than 1,000,000; between 1:1,000,000 and 1:250,000; and lesser than 1:250,000, respectively. The next digit on the codification represents the biographic zone at which this land unit belongs to. The RePPProT divides Indonesia into two major biographic zones: the Asian and the Austranesian zones. The following two digits represent physiographic zones of the land unit (see Figure 2). The last two digits correspond to the landform type.

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                                                LAND SYSTEM 47  MIWA (MWA)

LAND SYSTEM MWA - Miwa       :AREA 14,262 km2:   Ref.No. IJ 47
PROVINCES  27 /  %,  /  %,  /  %,  /  %,  /  %,  /  %,  /  %,  /  %,  /  %:
LAND TYPE  Dissected old coastal plain with plateau remnants               :
LAND REGION sed mixed hillocky plain  :DESAUNETTES CODES DOM P67 INC P62,A21-2:
SATELLITE SCENES  04/101/64 of 21/03/83                          :
AERIAL PHOTOS 36E/8473/044,35E/8473/027,34E/9409/139;   /   /   ,   /   /  :


LITHOLOGY sedimentary                                   INDURATION  soft
  GRADE  mixed               MINERALOGY  mixed
  ROCK TYPE  alluvium 27*, 28*, 29*                          :ROCK OUTCROP none:
WATER GROUNDWATER  fresh      DOMESTIC SOURCE rain,medium,deep wells :
FISHERIES  none              :RIVERS FLOOD RISK  none      INUNDATION  none    :
CLIMATE MEAN ANNUAL RAIN 1800-4500mm WET MTHS 04-12 DRY MTHS 00-05 GROWING
  PERIOD ARABLE 135-365d TREE CROPS 105-365d MEAN TEMP min 21oC max 34oC:
VEGETATION/LAND USE moist primary lowland forest,
                                                              AREA USED   0%:
ACCELERATED EROSION EXTENT  common   EVIDENCE  slips,gullies, var
SOIL GT GPS DOMINANT>60%  Paleustults     ASSOCIATED 20-60%
                                    TEXTURE TOP/SUB SOIL DOM   mod fine/fine
ASSOCIATED  20-60%                                                            :
SOIL CHARACTERISTICS OF DOMINANT SOIL GREAT GROUP
  DEPTH PEAT           cm          MINERAL SOIL   76-100cm DRAINAGE  well
  EXCH  K TOP  low     SUB  v.low  TOTAL K TOP  v.low  SUB  v.low
  AVAIL P TOP  v.low   SUB  v.low  TOTAL P TOP  low    SUB  v.low
  CEC pH7 TOP  low     SUB  low    pH(H20) TOP 4.6-5.0 SUB  5.1-5.5
  AL SATN TOP  low     SUB  med    EXCH AL TOP         SUB
  ACID SULPHATE HAZARD AT          cm SALINITY         mmhos/cm EC at 25oC


ALTITUDE MIN  10m MAX  50m RANGE      10-50m: PLAN/PROF DOM 4L INC 1L ,      :
DRAINAGE PATTERN  dendritic          DENSITY    2.1-4.0/k2   VAR  low        :
SLOPE STEEPNESS  9-15% VAR  med LENGTH   101-200m VAR high CURVATURE  convex  :
SLOPE DISTBN VALLEYS(0-3%) 10%  INTERFLUVES(0-8%) 30% (9-25%) 60% (26-50%)   %:
RELIEF AMPLITUDE   11-50m VAR  med  : TERRAIN rolling                        :
CRESTS SHAPE undulating LENGTH   500-1000m VAR  med  WIDTH  50-500m VAR  high :
SPURS PROMINENCE  clear          STEEPNESS    <25%:
VALLEY FLOOR WIDTH   25-200m VAR  low:
FACETS  1 slopes   60% area   2 und plateau   30% area  3 valleys     10% area:
FRAGMENTATION VALLEYS small blocks INTERFLUVES   small blocks:


RELIABILITY   GROUNDWATER QUALITY 2, WATER SOURCE 2, FLOODING/INUNDATION   ,
  CLIMATE 2, SOIL GRUOP 2, SOIL TEXTURE 2, SOIL DEPTH 2, SOIL DRAINAGE 2,
  SOIL NUTRIENTS 2, ELEVATION 2, SLOPE 2, FACETS 2, FRAGMENTATION  2 :

ADDITIONAL NOTES  Derived from CSIRO Morehead, Unit 18, as BST-KNG-KP1

                                                                             :

*For explanation of codes,  class limits,  definitions and data recording con-
ventions, see Annexe 1.2, `Ground rules for data card'.
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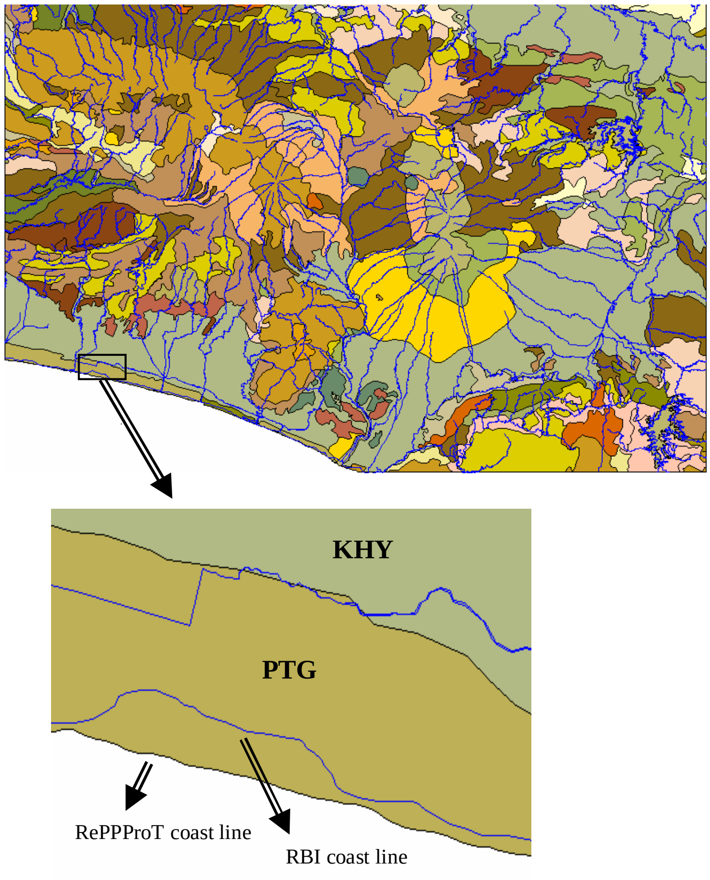
Figure 2: An example of a MWA land system data card (RePPProT, 1990)



Before standardized

Figure 3: An example of the RePPProT land system layer superimposed onto the RBI hydrographic layer (sheet number 1408)

By adopting the codification system, a single value can represent each land unit system as well as the scale, physiographic and biographic zones, and landform type. Representing all of these pieces of information as a single value will ease further analyses while still retaining much of the information.

3.3 Database Design

RePPProT classifies Indonesia into land unit systems. Calculation of land unit systems are based on 8 parameters, namely: physiographic, biological, climate, soil types, land cover, geology and land use types. We model the spatial database to represent the theoretical design of the land unit systems. The geodatabase consists of 8 tables to represent each land unit parameter. The tables are related to each other by means of the land unit class (see Figure 5).

KHY (Kahayan) **29**21010301 — Land Cover Type

29**2**1010301 — Land Unit Systems

292**1**010301 — Scale (for provincial level– 1:250,000 to 1:1,000,000)

2921**01**0301 — Biographic Zone (West and North of Wallace's Line)

292101**03**01 — Physiographic Zone (Alluvium)

29210103**01** — Landform Type (Tidal Flat)

Figure 4: Each land unit system is given a unique key identifier. The key is a combination of various parameters which include scale, biographic and physiographic zones as well as the landform type.

Currently, all of the tabular information in the RePPProT data are available only as paper print outs. The first task is to digitize these tables and link them to the spatial data. Next, the database is modeled following the theoretical design of the land unit systems. The land unit systems are based on 8 major classes. The tabular data are also classified into 8 main tables. The tables relate to each other using the land unit system as their main key. The main objective of the RePPProT data creation is for identifying suitable land units for development areas. The information on RePPProT data enables identification on physical limitations for various land use types. Suitable ratings for each land unit are calculated using this information.

The suitable ratings are valuable information for development planning. Bakosurtanal is developing a Decision Support System (DSS) software for utilizing these ratings for decision makers such as land use planners and local executive officers. With this software, the land planners can create various land use development plans and simulate the effects of these plans on land coverages. The development plans utilizes the suitability ratings in limiting the choices on land use changes that are suitable for a particular area.

Lithology

LandSys	Group	Grade	Rock Type	Mineralogy	Induration

Soil

LandSys	Group	Texture	Depth	Drainage	Potassium		Potassium		CEC	Soil Reaction	Al Saturation
					Exchange	Total	Exchangeable	Total			

Physiography

LandSys	Altitude		Drainage		Slope		Valley Facet	Terrain
	Min	Max	Pattern	Density	Steepness	Length		

Hydrology

LandSys	Groundwater	Domestic Source	Rivers Flood	Fisheries	Inundation

Climate

Landsys	Mean Annual	Wet Months	Dry Months	Growing Period Arable	Tree Crops	Mean Temp		Vegetation/ Land Use
						Min	Max	

Reliability

Landsys	Ground Water	Water Source	Flooding	Climate	Soil					Facets	Fragmentation
					Group	Texture	Depth	Drainage	Nutrients		

Suitability Ratings

Rubber

Land System	Soil	Hydrology	Climate	Physiography	Lithology	Landform

Coconut

Land System	Soil	Hydrology	Climate	Physiography	Lithology	Landform

Table 5. RePPPRoT database management system. The RePPPRoT parameters are classified into several tables which are connected according to their land system units. The parameter values are used to calculate suitability ratings for various crops (see text for description).

3.4. Metadata Creation

Another Bakosurtanal major role is in the development of National Spatial Data Infrastructure (NSDI). The NSDI is defined as the technologies, policies, and people necessary to promote sharing of geospatial data throughout all levels of government, the private and non-profit sectors, and the academic community (NSGIC, 1997). Through NSDI, Bakosurtanal is required to provide a structure for relationships among data producers and users as well as facilitate data sharing and use. There are major initiatives that are required to fulfill the creation of NSDI. One of the initiatives is the development of standards for data documentation, collection and exchange (metadata standards).

One of the most adopted standardized metadata is the Federal Geographic Data Committee (FGDC) metadata that was approved on June 8, 1994 (FGDC, 1998). Later, the FGDC metadata Standard was used as the base document for International Organization for Standardization (ISO) (FGDC, 2000). Bakosurtanal employs metadata that are modified from the FGDC standard to support Bakorsurtanal geospatial data. The modifications were made to enable the adoption of the standard by balancing Bakorsurtanal's needs and capabilities.

3.4.1 Bakosurtanal Metadata Software Tools

Bakosurtanal has developed a software tool for entering, storing, and releasing metadata information. The tools enable user to develop a database for metadata for organizational usage. In addition, it can release each record into a digital file format that can be transferred over the Internet. It was meant to support Bakosurtanal's clearinghouse role. The user interface eases entering the information into the metadata. Each metadata would be stored into a database. The user interface enables a user to input, edit, and create reports for other purposes. In addition, the tool provides a method to export each metadata record as Hyper Text Macro Language (HTML) file for attaching the metadata into a web-based geospatial catalogue system. Using the software, a metadata for the RePPProT land unit systems is also developed. The RePPProT metadata will enable potential users to search for geospatial datasets that are suitable for their needs.

4. USE FOR SPATIAL LAND USE PLANNING

The main purpose of spatial land use planning is to achieve sustainable development. The essence of the sustainable development is to restrain development in a way as well as preserve our environment. The main reason to protect our environment is that land as well as its biological components is the habitat for human life, vegetation, and animals. Some of these destructions of this natural resource is irreversible. For example, the use of unsuitable land for agricultural in mountainous areas will cause erosion in upper land and flooding in lowland. To manage our environment, we have to make sure that the land is properly utilized.

In Indonesia, since 1992 the government has published the Act 22, 1992 about spatial planning. The Act basically provides rules for the spatial land use planning called RTRW (Rencana Tata Ruang Wilayah or *Spatial Land Use Planning).* The spatial land use planning is designed from national to district levels. The RTRW is the result of structure and plan for spatial utilization (BKTRN, 2002). The structural spatial utilization explains the hierarchy of environmental components and the interrelationships among them. The plans for spatial utilization creates the blue-print for land, water, air, and other natural resources which describe their control, use and utilization (BKTRN, 2002).

The land system database can be used for supporting the creation of an RTRW at a provincial level. The land suitability provided by the land system database is useful for allocating agricultural zones. These agricultural zones can be classified into 5 zones, namely wetland agricultural zone, dry land agricultural zone, estate/tree crop zone, fishery zone, and livestock zone.

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