Livestock Waste Management in East Asia
LWMEA (GCP/RAS/215/WBG)

The World Bank | Global Environment Facility | The Food and Agriculture Organization

FRAMEWORK FOR A SPATIAL DECISION SUPPORT TOOL FOR POLICY AND DECISION MAKING

Technical outline

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Summary

The main challenge of developing of a spatial DST to support the decision making on future livestock production will not be a technical one, but instead a challenge of meeting the context requirements of the tool, such as the characteristics of the country-specific spatial planning and decision-making process, the wishes of the potential users of the tool and its output as well as the country-specific policies and regulations. The spatial DST which is being proposed in this report therefore does not include complex and state-of-the-art GIS techniques, but instead tries to be as clear and simple as possible, in order to give the potential users a full understanding during the analysis process and with using the output of the tool.

A spatial DST can easily become a 'black box' if the users do not fully understand the limitations of the tool and its output. Despite the fact that output maps of GIS systems may look very detailed and suggest a high degree of accuracy, they are often not. This will entirely depend on the availability of reliable and detailed input data. Most likely, many of the produced output maps should be used in an indicative way only. Therefore, the output of the spatial DST needs to be accompanied by supporting information on the reliability of the output and the shortcomings due to unreliable or missing input data, as well as the consequences for use of the output. Therefore, a comprehensive meta-data assessment system is proposed as an integrated part of the spatial DST. The distribution of the output will also require tools to produce more sketch-like presentations, e.g. using fuzzy borders and aggregated maps, which are another important feature of the spatial DST.

CONTENTS

1. Introduction

1.1. Context of the report

For the context of this report, the reader is directed to some previous reports that have been prepared in the past two years as well as the LWMEA project documentation itself.

Carsjens, G.J., Gerber, P., 2007.Decision support tool for spatial planning and decision making. Technical report. FAO, GCP/RAS/203/WBG Livestock Waste management in East Asia Project, August 2007, 32 p

Carsjens, G.J., 2006. Spatial planning and decision support of livestock production in East Asia. FAO, GCP/RAS/203/WBG Livestock Waste management in East Asia Project, November 2006, 37 p. This report is an updated and revised version of the final report of the preparation phase of the LWMEA project (see below), based on the results of the mission and regional workshop in Hanoi, Vietnam, in October 2006.

Carsjens, G.J., 2004. Spatial planning of future livestock production, Livestock waste management in East Asia. GEF project GCP/RAS/203/WB, Report of the international consultant on Spatial Planning, Land Use Planning Group, Wageningen University, The Netherlands, September 2004, FAO, 2004, 41 p. This report is the final report on spatial planning and decision making of the preparation phase of the LWMEA project, and includes a description of the conceptual framework of a spatial planning DST, based on the experiences of the Area-Wide Integration (AWI) pilot projects.

The recommendations and framework for the development of a spatial DST, derived from the reports listed above, are summarized in the next section.

1.2. Recommendations for the development of a spatial DST

The development of this (and any) DST will basically follow the next nine phases:

1. *Domain analysis or conceptual modeling*

   Usually the developers of a DST are not an expert in the subject area, so the first task is to investigate the so-called domain or usage context of the software. Another objective of this work is to make the analysts who will later try to elicit and gather the requirements from the area experts or professionals, speak with them in the domain's own terminology and to better understand what is being said by these people. Otherwise they will not be taken seriously. So, this phase is an important prelude to extracting and gathering the requirements. In general, this first phase has already become quite clear from the Area-Wide Integration (AWI) projects of FAO-LEAD, the LWMEA project preparation phase, and the result of the April 2007 mission. The basic context, concept and requirements of the spatial DST have been published before in the several project documents (see also Section 1.1 of this report) and related international scientific publications.

2. *Software elements analysis*

   The most important task in creating a software product is extracting the requirements. The end-users typically know what they want, but not what software should do, while incomplete, ambiguous or contradictory requirements are recognized by skilled and experienced software engineers. Frequently demonstrating live code may help reduce the risk that the requirements are incorrect. These requirements have been (partially) identified during the country specific workshops, but need to be further elaborated upon during the development process and testing phase.

The phases 1 and 2, developing the conceptual model and identifying the requirements of the DST, have basically been dealt with in the Area-Wide Integration (AWI) projects of FAO-LEAD, the LWMEA project preparation phase, and the April 2007 mission. The basic concepts and requirements, as well as the general components of the spatial DST have been previously published in the several project documents (see Section 1.1 of this report) and related international scientific publications. The next steps will be:

3. *Specification*

   Specification is the task of precisely describing the software to be written, possibly in a rigorous way. This phase includes, for example, the development of data flow diagrams or flow charts, workflow diagrams, and detailed component diagrams, required for the programming of the source code. During this phase also the needs and requirements of the (geo-)database needs to be specified. This phase should be carried out by the international contractor and expert in spatial planning and spatial decision support tools (IC-Planning), who will also need to coordinate the further development and implementation of the spatial DST.

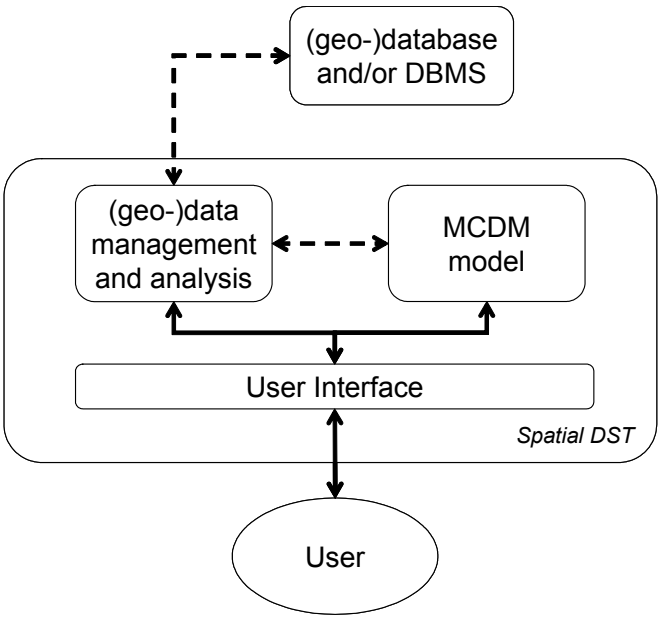
4. *Software architecture*

   The architecture of a software system refers to an abstract representation of that system. Architecture is concerned with making sure the software system will meet the requirements of the product, as well as ensuring that future requirements can be addressed. The architecture step also addresses interfaces between the software system and other software products (such as present Data Base Management Systems or DBMS), as well as the underlying hardware or the host operating system. This phase should be carried out by the international contractor responsible for the software coding (IC-Software) in close communication with the IC-Planning. During this phase, the IC-Software and IC-Planning will also need to communicate with the national contractor for spatial planning and database development (NC) who is responsible for coordinating the country-specific testing, documentation and training, as well as the (geo-)database development. The collection of geo-data and development of the country-specific (geo-)databases will also start in this phase. The IC-Software and IC-Planning need to communicate regularly with the NC's on their progress.

5. *Implementation or actual software coding*

   Reducing a design to code may be the most obvious part of the software engineering job, but it is not necessarily the largest portion. If the specifications and software architecture are clear, the actual coding by the IC-Software is a relatively smooth job.

   However, not all components of the DST should be developed simultaneously, but preferably in separated modules. The general modules of the spatial DST are shown below (during the phase of specification these should be further detailed in more specific modules).



The development of the actual source code should start with the MCDM model, the heart of the spatial DST. Afterwards, the user interface and geo-data management and analysis tool will be developed. Finally some supplementary products are developed, such as a glossary, help functions and language modules (first in English, later-on in the process in Chinese, Thai and Vietnamese). In-between these steps the phase of testing will commence (see below).

6. *Testing*

   Testing of (parts of) the spatial DST aims to identify the strengths and weaknesses (and errors) of the software, but is also especially useful to have the end-users reflect upon the software and assess required additions and other changes to make the DST better fit to the context or planning process it is being developed for. The testing of the software will be carried out by the NC's and end-users, coordinated by the IC-Planning and IC-Software.

7. *Documentation*

   An important (and often overlooked) task is documenting the internal design of software for the purpose of future maintenance and enhancement. Documentation is most important for external interfaces. This task should be carried out by the IC-Software and IC-Planning and afterwards translated under the responsibility of the NC's.

8. *DST training and support*

   A large percentage of software projects fail because the developers fail to realize that it doesn't matter how much time and planning a development team puts into creating software if nobody in an organization ends up using it. People are occasionally resistant to change and avoid venturing into an unfamiliar area so, as a part of the deployment phase, it is very important to have training classes for the most enthusiastic software users (build excitement and confidence), shifting the training towards the neutral users intermixed with the avid supporters, and finally incorporate the rest of the organization into adopting the new software. Users will have lots of questions and software problems which leads to the next phase of software maintenance.

9. *Maintenance*

   Maintaining and enhancing the DST to cope with new discovered problems or new requirements can take far more time than the initial development of the software. Not only may it be necessary to add code that does not fit the original design but just determining how software works at some point after it is completed may require significant effort by a software engineer. In general, about ⅔ of all software engineering work is maintenance, although only a small part of that is fixing bugs. Most maintenance is about extending systems to do new things, which in many ways can be considered new work that falls out of the scope of the LWMEA project. However, for the implementation and a successful future use of the spatial DST it is of utmost importance to identify the needs and secure the means for future maintenance, especially given the fact that the development of the spatial DST is a regional and not a national task and responsibility.

A framework and tentative time schedule of these phases is provided in Annex 3 and 4.

1.3. Outline of the report

Chapter 2 describes the objectives and rationale of the spatial DST, as well as the general background from the AWI pilot projects. The country specific requirements and context of use of the spatial DST are described in Chapter 3. The information of both chapters comes from previous reports on the spatial DST (see section 1.1). Chapter 4 describes the outline, modules and tasks for the development of the spatial DST.

2. Background

This chapter describes the results of the first experiences with the spatial DST in the Area-Wide Integration (AWI) initiative of FAO-LEAD and the problem description and objectives for developing a spatial DST in the LWMEA project..

2.1. Problem description

Livestock production is developing very fast in most parts of Asia, mainly supported by industrial systems, with series of environmental impacts such as nutrient overload. The livestock production tends to concentrate in areas favored by cheap input supplies (in particular feed), and by good market outlets for livestock products. Such conditions are found in the vicinity of large cities. The proportion of livestock production met by industrial systems production is increasing rapidly, as those systems react faster to growing demand. The rapid growth in scale is general, and the new settlements directly compete with land-based, small-scale production, sometimes supplanting them. The industrialization of production leads to a disconnection between livestock activities and cropping activities. This happens on a functional level (large-scale livestock production shifting to industrial type management), and on a spatial level (industrial livestock activities moving towards peri-urban areas).
Thailand, Vietnam and Guangdong province of China, which are the countries that are participating in the GEF project, expressed their need for a more sustainable spatial planning of future livestock production, and GIS as a supporting tool. The use of GIS as a decision support (DSS) tool should allow them to support the adoption of zoning policies and regulations for the spatial planning of future livestock production. The actual use of GIS as a DSS tool in the decision making process with regard to the spatial distribution of livestock production in the participating countries will therefore be an important output indicator for the GEF project.

2.2. Objective

The basic objective of the spatial planning part of the GEF project is therefore to prepare a methodology and GIS tools to support the spatial planning of livestock production in Southeast Asia. The methodology and tools should allow the identification and assessment of potential suitable and unsuitable areas for the development of livestock production. The methodology and tools should be implemented at the relevant governmental organizations that are involved with the decision making on environmental and spatial planning and policy making for livestock production. The use of the methodology and tools should initiate a more sustainable spatial planning of livestock production. By spatial planning we intend a holistic approach of the livestock activity, including its impacts and requirements in order to define the specific land characteristics needed for its sound development. The general observation is that livestock production is shifting from an agricultural use of the land, based on biophysical criteria (e.g. soil quality, water system, climate, length of growing period), towards an industrial use of land, based on socio-economic and infrastructure criteria such as transport infrastructure, labor costs, and services. Spatial planners and policy makers should be made aware of the positive environmental benefits of using the methodology and tools in spatial planning and policy making, by training and workshops. This should be supported by the adoption of zoning policies, regulations and integrated environmental management approaches through appropriate incentives and regulatory schemes.

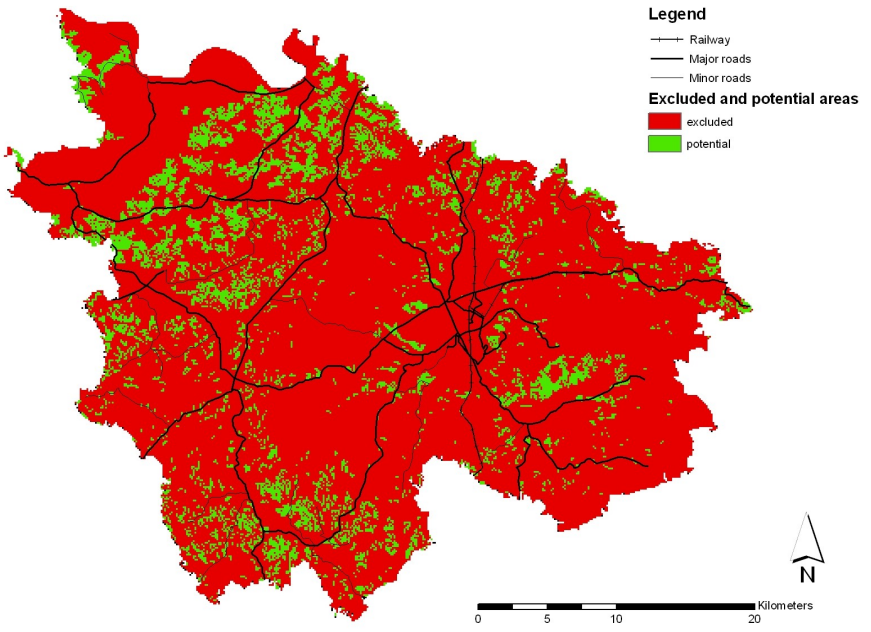
2.3. Rationale

While mitigation of environmental pollution by animal waste can be tackled by improving waste management practices at farm level, the spatial planning of the livestock production is an approach to prevent environmental impacts from future livestock production. With spatial

analysis one can identify areas that are sensitive for environmental pollution by pig farms, and by zoning and buffering prevent some negative environmental impacts, such as smell pollution in residential areas. In case mitigation measures at farm level are (partly) failing, a proper spatial allocation will also prevent that other environmental impacts, such as soil and (ground)water pollution by nutrients take place nearby very sensitive areas, such as nature reserves. However, the development of zoning policies and regulations will be required for a successful implementation and enforcement of the output of the spatial DST.

2.4. An outline of the methodology: Experiences from AWI

The Livestock, Environment and Development (LEAD) Initiative is an inter-institutional project with the secretariat in FAO. The work of the Initiative targets at the protection and enhancement of natural resources as affected by livestock production and processing in the context of poverty reduction and public health enhancement, through better policy formulation for appropriate forms of livestock development (see also the website http://www.lead.virtualcentre.org). Three topics of major importance were identified, structuring the LEAD programs: 1) improved-decision making in addressing livestock's role in dry land management; 2) improved decision-making in addressing livestock's role in the deforestation process; and 3) improved decision-making in addressing land, water and air pollution by industrial livestock production. Each program is developed along activities including: collection and provision of basic data; analysis and assessment; design of policy and technology options; testing, validation and up-scaling of options; provision of decision-support tools; development of guidelines and standards; and capacity building and uptake.
One of the basic objectives of the LEAD-AWI project was to experiment with the use of GIS as a tool to assess the present locations of pig farming as well as to find suitable locations for future pig farming. Other techniques that were used are multi-criteria and zoning techniques. The basic methodology that was set up for the GIS analyses included the identification of restricted and unsuitable areas for pig farming respectively, and the assessment of the remaining areas for their suitability. Restricted areas are areas where pig farming is not allowed by national or provincial regulations, while unsuitable areas have physical or environmental limitations. The use of GIS allows presenting the excluded and potential remaining areas for pig farming in a map. An example of the Wannian County project is presented below.



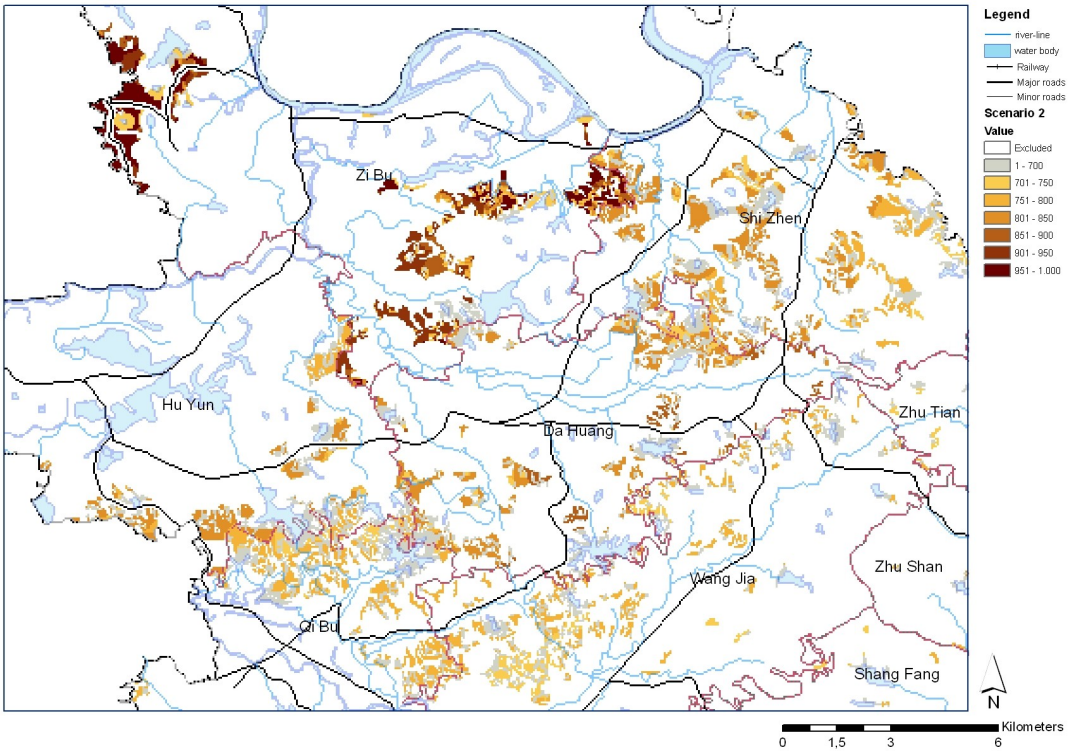
Map of excluded and potential areas for pig farming, Wannian County

The remaining potential areas were assessed for their suitability for pig farming. Criteria that are used for the suitability analysis include social, economical, physical and environmental criteria. The use of GIS requires that for all criteria basic maps are available. These maps include, e.g., land-use, soil, elevation, nutrient balance, and administrative boundaries. The assessment for all criteria will result in suitability maps that are to be integrated by multi-criteria techniques in order to derive a final suitability map. In order to compare and combine the criteria, all criteria need to have a uniform scale. For the analyses an ordinal scale is used, e.g. ranging from 0 (not suitable) to 100 (very suitable). The use of multi-criteria techniques also implies the use of scenario techniques, in order to identify different sets of weights for the criteria that are used. Examples of scenarios that are to be used, each with different weights are: (1) a scenario from environmental perspective; (2) a neutral scenario; and (3) a scenario from production and distribution perspective. See example below.

Weights used in the multi-criteria analysis, AWI project Wannian County, China.

	Weights		
Criteria	**Scenario 1**	**Scenario 2**	**Scenario 3**
Distance to road	4	2,5	1
Distance to main surface water	4	2,5	1
Slope	1	2,5	4
P-balance	1	2,5	4

Since the methodology is flexible, it allows including other scenarios easily. The results for each of the criteria and for the different scenarios are presented in maps. An example of a resulting final suitability map of the AWI-project in Wannian County is presented below.



Suitability map for pig farming, northwest part of Wannian County.

The methodology can be applied at different scale levels, but in the case of Wannian County will be most relevant for policy and decision making at provincial level and county scale level. At provincial level the methodology is to be used for assessing larger regions (counties

or townships) and identifying the suitability of these regions for future pig farming, and at county level for assessing and identifying the suitability of more specific locations. At each scale level specific objectives and criteria will be important. For example, at provincial level it might be important to include social objectives and criteria, such as poverty reduction, and environmental objectives and criteria, such as maintaining a nutrient balance at the regional level, in order to identify regions where pig farming should be restricted or promoted. At county level more site-specific criteria such as slope of the area, soil type, distances to nature reserves, roads and built-up area, will be relevant in order to identify suitable locations for establishing new pig farms more specifically. The structure of the suitability assessment in the AWI project in Thailand is shown below.

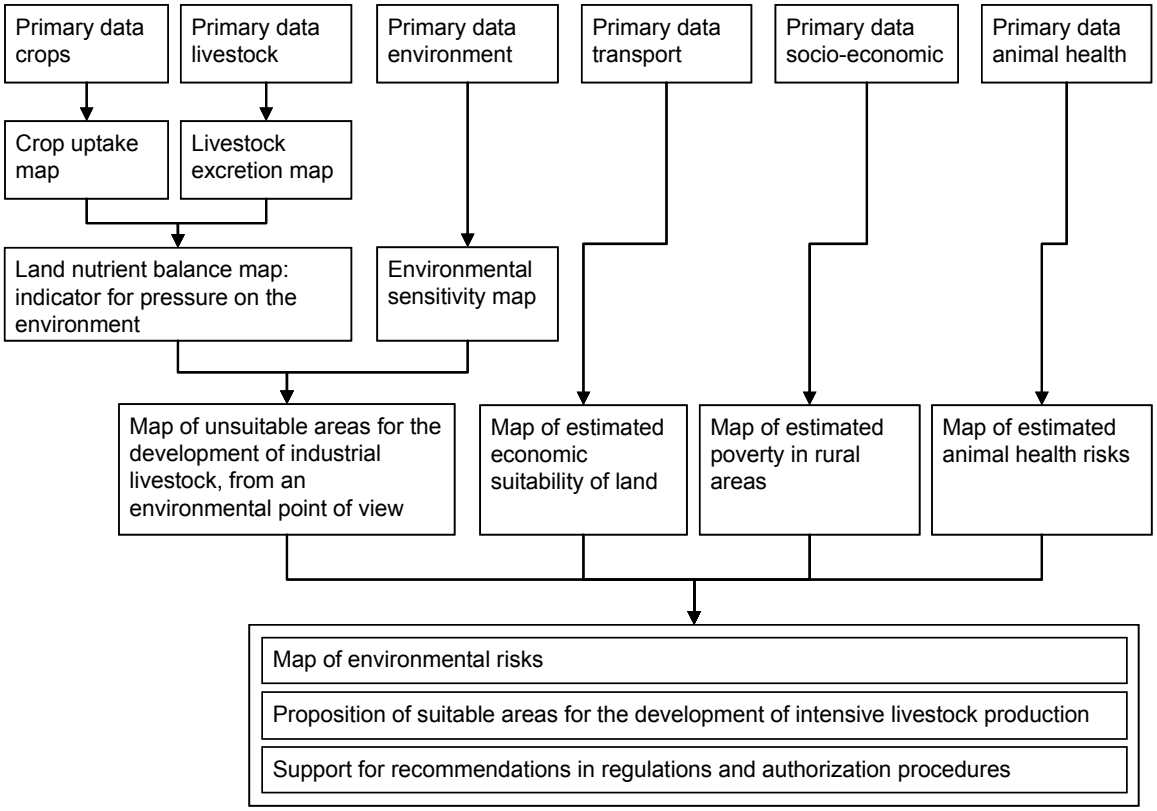


Table 1 Structure of the suitability assessment in Thailand.

The data which are required to produce the nutrient balance map will not be included in the spatial DST, but should be derived from the output of the nutrient-balance DST which will be developed too in the LWMEA project. A proper linkage tool between both DST should therefore be developed.

Conclusion from the AWI projects

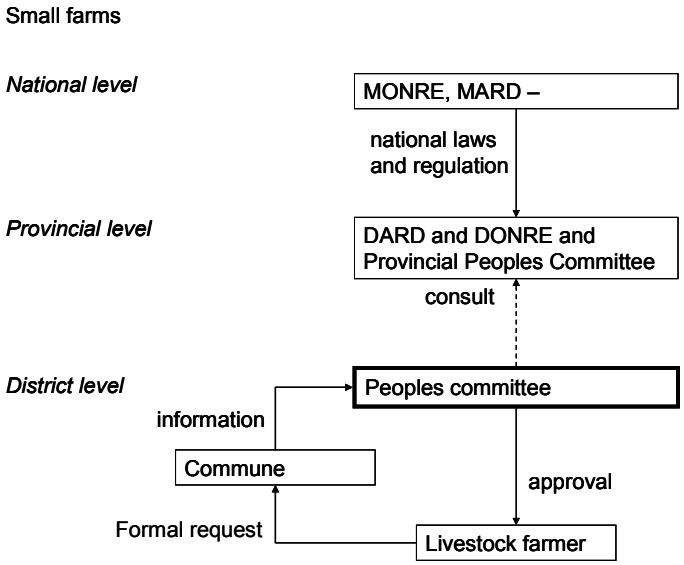
From the experiences with GIS in the AWI project can be concluded that GIS is a promising tool to support the spatial planning of future livestock production. However, the experiences also show that making use of the common analysis tools that are available in the GIS software is very time-consuming, because of the intensive data analyses that are necessary, and the many repetitive and often complex steps that have to be carried out during the analyses. In order to make the methodology that has been developed in the AWI project more suitable for use in practice, the potential users of the methodology should be able to perform these analyses in a more user-friendly way with assisting tools that are available within the GIS software. That will require specific data preparation and analysis tools to be built. The methodology that has been developed in the AWI project will be a useful basis for the construction of these tools.

3. Country requirements

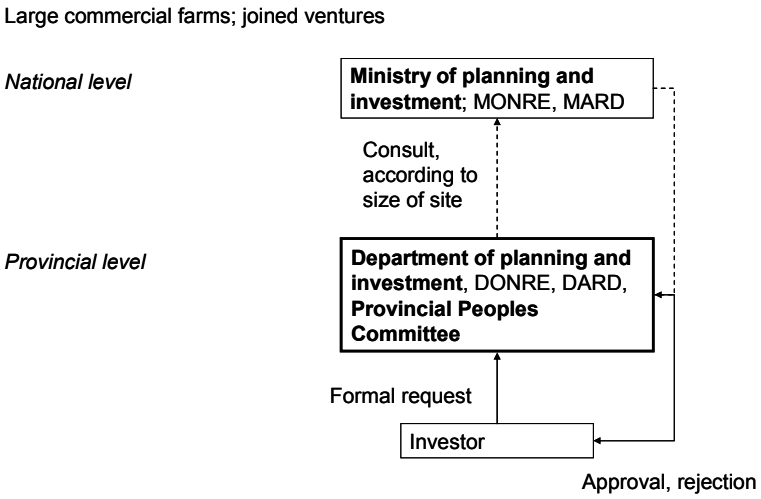
During April 2007 some country-specific workshops have been held in order to identify the context of use of the spatial DST. This included the identification of the intended users of the tool and its output, the decision-making process in which the tool will be used, the potential participants in the process of developing and using the tool, and the potential country experts that might contribute to the development process. The results will be described in the next sections.

3.1. Vietnam

Two decision-making processes were identified, one for farms smaller than 200 pigs livestock inventory and one for larger farms. For small farms the decisions are primarily been made at district level by the peoples committee. The committee sometimes consults the province, and also has to comply with national laws and regulation in their decision making.



Large farms (> 200 pigs) are regarded as enterprises under the business law, and decisions are primarily been made at province level. Therefore, the department of planning and investment (DPI), and the provincial peoples committee (PPC) hold a key position in the decision making procedure (in bold). In some situation the province needs to consult the ministries at national level, based on the size of the enterprise.



The required type of products of the spatial DST that were identified are: (1) printed maps with an explanatory manual, and (2) the spatial DST itself. Based on these products the users of these products were identified, and are listed below. The table also includes a column with specific actions that are needed, e.g. training. The main users of the spatial DST that were identified are MONRE, MARD, and possibly the DONRE and DARD of some selected provinces. MPI, DPI and the PPC were identified as users of the output maps of the spatial DST, and not the spatial DST itself.

Users	**Products**		**What is needed?**
	Printed maps (output of DST) with explanatory manual	**GIS-Application (DST)**	
MONRE	X	X	Training
MARD: NIAPP, NIAH	X	X	Training
MPI: Department of SME management	X		
Ministry of Trade, Department of business promotion	X		
Provincial Peoples Committee PPC	X		
DONRE	X	X Selected provinces	Training of selected provinces ESRI-ArcGIS for selected provinces
DARD	X	X Selected provinces	Training of selected provinces
DPI	X		
Association of medium and small enterprises	X		
Universities – Technical Univ. Agricultural Univ.	X	X Partners in the project – supply of high-quality trainers	Supply CD-ROM
District Peoples Committee (DPC)	X		
Animal Husbandry Union	X		

NIAPP = National Institute for Agricultural Planning and Projection
NIAH = National Institute for Animal Husbandry

The purposes to involve ministries, departments and other stakeholders were identified as (1) data provision, (2) setting policy objectives, (3) setting technical criteria and (4) providing training. Who should be involved for these purposes was then discussed and the results are presented in the table below. MONRE, MARD and MPI were identified as important data holders. The results also include an extensive list of ministries, departments, NGOs and other to be invited in the policy objective and/or technical workshops of the project.

Stakeholders/institutions	**Purpose**			
	Data provision	**Policy objectives setting**	**Technical criteria setting**	**Training**
Ministry of Natural Resources and the Environment (MONRE)	Digital maps (topography, admin, hydrology, soil, land use, water sheds, river basin, ...) Statistical data (rainfall, climate, population, eco-	X	X	

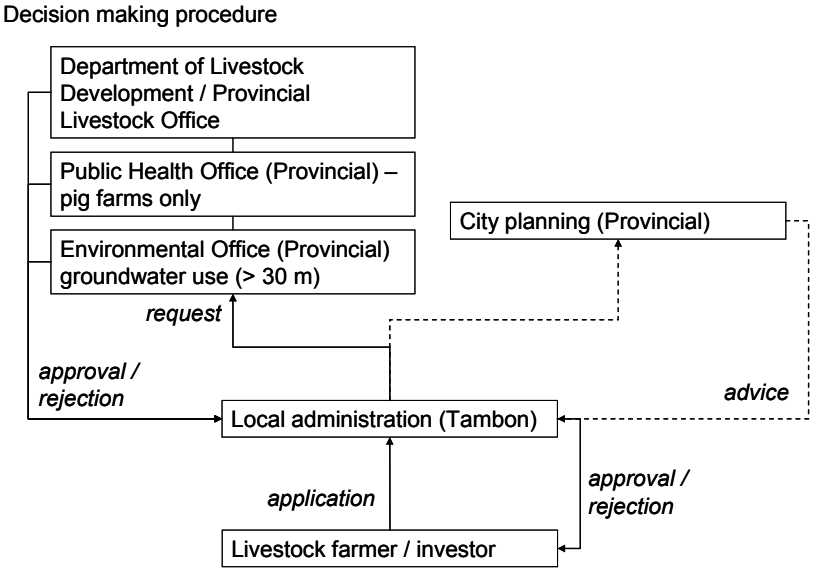
	nomic, ...)			
Ministry of Agriculture and Regional Development (MARD)	Statistical data of agricultural production (crops, animals, ...)	X	X	
Ministry of Planning and Investment (MPI)	Master plans at national and regional level – paper map	X		
General Department of Statistics of MPI	Statistical yearbooks			
Provincial and District Peoples Committee	Master plans from province to district level – paper maps. Slaughterhouses (DARD)	X		
Animal Husbandry Association	Farm- and livestock enterprises data, types of farms	X	X	
Association of Animal Feed	Feed mills	X	X	
University			X	X
National and international experts			X	X
Environmental NGO		X	X	X
Ministry of Health	Community health		X	
Vietnam Farmer Union		X		
And others				

Technical meetings at Hanoi Agricultural University (HAU) and the Database and Information Systems Center (DISC) of MONRE revealed that:

- A potential problem for the DBMS will be different formats of data that currently exist between the different provinces in Vietnam
- The Vietnamese Academy of Agricultural Sciences (VAAS) has data on land use and crops, while livestock data is the responsibility of the National Institute for Animal Husbandry (NIAH).
- HAU is primarily interested in cooperating in the training part of the spatial DST.
- MONRE is providing training in GIS and hard- and software to the DONRE's, funded by another project of the World Bank.
- At MONRE a Land Information System is being set up. This system is set up by DISC, programmed in Visual Basic (VB) and in ArcGIS database format. However, own GIS software is being developed and used, as well as MapInfo software. The Land Information System includes data up to the local level.
- A more simple land use management model at province level will be distributed among the DONRE's.
- Currently only geo-data of urban areas are available. These data include soil, land use, water, road, elevation and other data.
- A map with administrative boundaries is available, including national to commune level.
- Given the current lack of geo-data it will be important to focus first at some selected provinces in the Hanoi and Ho Chi Min City region.
- It will be important to establish a link between the Land Information System and the spatial DST of the LWMEA project, consequently making DISC an important partner. Further contacts will be made by the RFO, in coordination with the PMO.

3.2. Thailand

A decision making scheme for decision making on future livestock production was identified as follows.



The local administration at Tambon level plays a key role in the decision making procedure, as well as the Environmental Office and Public Health Office at Province level administration. DLD identifies new livestock production areas, and is therefore an important user of the spatial DST. However, DLD does not work directly with local administration, only with a livestock officer at provincial level. Therefore, for the implementation of the output also Tambon local administration and the Ministry of City Planning and Interior were identified as important potential users of the output. Three years ago a National Pig Board was established, that is involved in policies concerning raising and processing pigs. This advisory board includes representatives of other relevant organizations.

The required type of products of the spatial DST that were identified are (1) printed maps at provincial level, 1:50.000 scale, (2) printed maps at national level, 1:100.000-1:500.000 scale, and (3) the spatial DST itself. Based on these products the users of these products were identified, and are listed below. The table also includes a column with specific actions that are needed, e.g. training. The main users of the spatial DST that were identified are DLD and PLO, the Ministry of natural resources and environment, and universities.

Users	**Products**			**What is needed?**
	Printed maps at provincial level 1:50.000	**Printed maps at national / regional level 1:100.000 – 1:500.000**	**GIS-Application (DST)**	
DLD – DG office		X		
DLD – Bureau of livestock standards and certification			X	Training GIS and DST
DLD - Bureau of disease control			X	Training GIS and DST
DLD - Bureau of Livestock development and technology transfer		X	X	Training GIS and DST

DLD – IT Center			X Provide training	Training DST
DLD regional		X		
PLO	X			
Ministry of Natural Resources and Environment – Department of Pollution control		X	X	?
Ministry of Natural Resources and Environment – Department of groundwater		X	X	?
National Pig Board (advisory board)		X		
Governor office	X			
City Planning Provincial Office	X			
Local District Organization	X			
Farmers	X			
Universities – Master level			X For training purposes	

DLD = Department of Livestock Development
PLO = Provincial Livestock Office

The purposes to involve ministries, departments and other stakeholders were identified as (1) data provision, (2) setting policy objectives, (3) setting technical criteria and (4) providing training. The stakeholders and institutions that should be involved are presented in the table below. DLD/PLO and Land Development Department were identified as important data holders, but many other departments/organization are holding specific other data. The results also include an extensive list of ministries, departments, NGOs and other to be invited in the policy objective and/or technical workshops of the project.

Stakeholders/institutions	**Purpose**			
	Data provision	**Policy objectives setting**	**Technical criteria setting**	**Training**
DLD – DG office		X		
DLD – Bureau of livestock standards and certification			X	
DLD - Bureau of disease control			X	
DLD - Bureau of Livestock development and technology transfer	Locations of livestock markets		X	
DLD – IT Center	Quarantine stations			X
DLD regional			X	
PLO	Farm locations, feed mills, slaughterhouses (GPS), Livestock statistics (animal population)		X	
Ministry of public health			X	
Pig producer association		X	X	
CP group			X	
Betagro group			X	
Ministry of Agriculture and cooperative - Office of agricultural	Agricultural statistics	X	X	

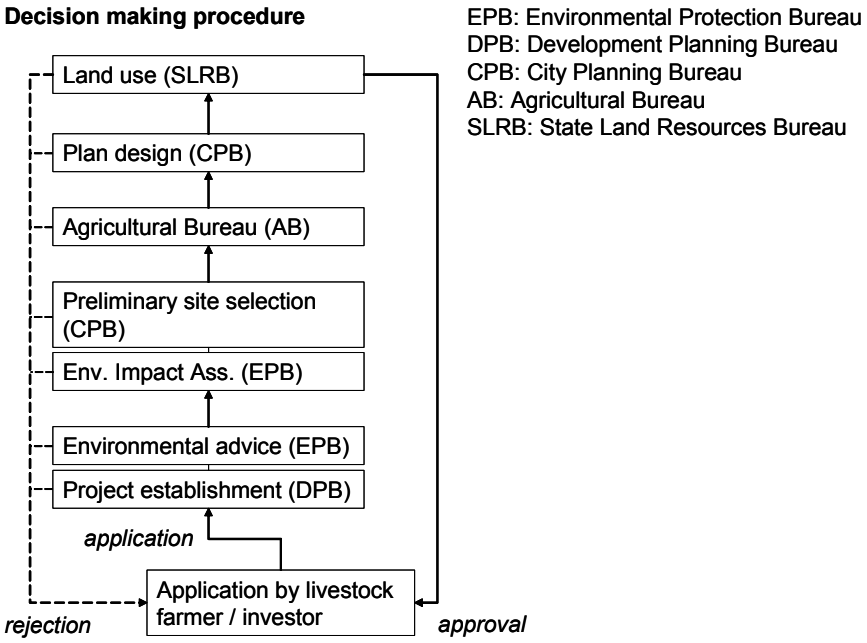
economics				
Katsesat University			X	X
Chulalongkorn University				X
NSDB National Social and Economic Development Board	Poverty data and rural development	X	X	
Land Development Department - Soil survey and classification division	Soil maps, Land use maps, elevation data	X	X	
Department of Agriculture			X	
Ministry of Natural Resources and Environment – Department of Pollution control			X	
Ministry of Natural Resources and Environment – Office of environmental planning and policy	Watershed boundaries	X		
Ministry of Natural Resources and Environment – Mangrove and wetland department			X	
Ministry of Natural Resources and Environment – Groundwater department	Groundwater level		X	
Environmental NGOs		X		
Ministry of transport - Road and highway department	Road infrastructure			
Prime Minister Office – Department of budget		X		
Geo-Information and Space Technology Development Agency	Satellite images (LandSat support)			X
Royal Irrigation Department	Water, streams, channels, river basins		X	
Ministry of Defense - Military Map Department	Aerial photos (1:5.000 for free)			

Technical meetings at the Space Knowledge Development, Geo-Informatics and Space Technology Development Agency (GISTDA) and the Asian Institute of Technology (AIT) revealed that:

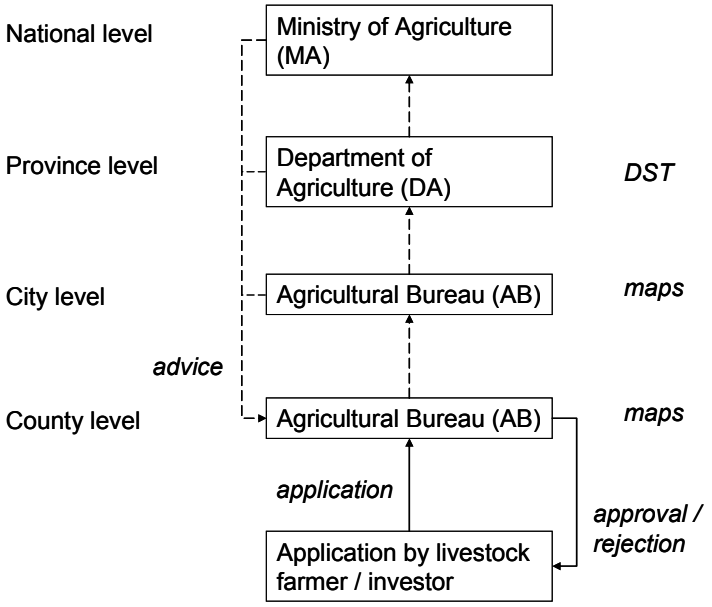
- GISTDA provides an annual training program for DLD in GIS (ArcGIS) and RS (Geomatica)
- GISTDA is primarily interested in cooperating in the training part of the spatial DST, but would also be interested in the more detailed theoretical model and programming part of the spatial DST.
- AIT includes a GIS group that has extensive experience in SDSS programming (including ArcGIS, Visual Basic and VBA), DBMS construction and training support.
- The average costs of a research associate for e.g. programming are approximately 600 US$ per month.
- AIT is interested in participating in all three components: the programming of the spatial DST, the DBMS construction, and also supporting the training.

3.3. Guangdong Province in China

Two decision making schemes were identified, one for very large farms (> 100.000 pigs production) and activities. The scheme for large farms includes a comprehensive procedure, involving bureaus from local to state level.



For smaller farms (< 100.000 pigs production) usually not the whole procedure is required, and especially the Department of Agriculture (DA) and Environmental Protection Bureau (EPB) at count level are the most important decision makers in the process, and therefore DA and EPB are the most relevant organization for implementation of the spatial DST.



The required type of products of the spatial DST that were identified are (1) printed maps at county level, (2) printed maps at provincial/city level, and (3) the spatial DST itself. Based on these products the users of these products were identified, and are listed below. The table also includes a column with specific actions that are needed, e.g. training. The main users of the spatial DST that were identified are AD, EPB, and the State land resources bureau. However, given the limited number of participants in the workshop not all of the required information could be retrieved or verified.

The provincial organization has very limited GIS expertise; most GIS expertise is present at the universities and some special bureaus, e.g. statistics departments. GIS is currently being used at the Center of Epidemic Control of Guangdong Province for monitoring disease

spread, and at EPB more often e.g. for analyzing water supply and distribution. The Station of Environmental Protection in the Department of Agriculture is mainly in administrative issues and not using GIS.

Users	**Products**			**What is needed?**
	Printed maps at county level	**Printed maps at provincial / city level**	**GIS-Application (DST)**	
Agricultural Bureau (county and city)	X (county)	X (city)		
Agricultural Department (province)		X	X	Training, equipment, software, etc. (there is currently no GIS capacity)
Environment Protection Bureau (county and city)	X (county)	X (city)		
Environment Protection Bureau (province)		X	X	?
Development Planning Bureau (province)			?	
City Planning Bureau			?	
State land resources bureau			X	

The purposes to involve ministries, departments and other stakeholders were identified as (1) data provision, (2) setting policy objectives, (3) setting technical criteria and (4) providing training. Who should be involved for these purposes was then discussed and the results are presented in the table below. DA, EPB, State Land Resource Bureau, Meteorological Bureau and Statistics Department were identified as important data holders, but the participants were not able to specify which type of data is available at these bureaus and departments. The results also include an extensive list of ministries, departments, NGOs and other to be invited in the policy objective and/or technical workshops of the project.

Stakeholders/institutions	**Purpose**			
	Data provision	**Policy objectives setting**	**Technical criteria setting**	**Training**
Department of Agriculture (Province), including Veterinary division and Water division	X	X	X	X
Environment Protection Bureau (Province)	X	X	X	
Rural Policy Research Center (Province)		X		
Development Planning Bureau – Rural division		X		
Department of Finance – Rural division		X		
Department of Finance – Rural development office		X		
Department of Science and		X		

Technology – Rural division				
South China Agricultural University			X	X
Agricultural College of Zhongkai			X	X
Technology College of Foshan			X	X
Department of Health			X	
Supervision Department of Export and Import		X		
Department of Economics and Trade		X		
Department of Business Administration		X		
Poultry Association			X	
Pig Producer Association			X	
Feed Association			X	
Dairy farming Association			X	
Fertilizer Association			X	
Department of Fisheries		X		
Academy of Agricultural Science		X	X	X
State land resources bureau	X (maps – both paper and digital)	X		
Meteorological Bureau	X			
Statistics Department	X (tables)			

A technical meeting with a representative of the Environmental Protection Bureau (EPB) – Environmental Monitoring Center (EMC) revealed that:

- EPB is using ArcGIS but AD is not.
- SEPA – National Environmental Monitoring Center provides data for specific projects and also licenses in ArcGIS for use in these projects only.
- Required expertise and capacity (hardware, software) is available at the Environmental Monitoring Center (EMC) and at universities, e.g. South China Agricultural University. Therefore AD and/or EPB might cooperate with the EMC or a university in order to get the required data, hardware and software. A letter of agreement might be option here. After the mission Prof. Hu Yueming of South China Agricultural University was contacted about the project, and he expressed a profound interest in the project.
- For the development of a DBMS the EMC or a university should be contacted.
- Training can be provided by universities.
- Some contacts should be established with relevant groups at universities to get more information and discuss their potential contribution in the project in more detail.

3.4. Conclusions from the country-specific workshops

Despite the considerable differences in the number of participants and type of organizations present during the workshops as well as the technical consultation meetings, some substantial progress has been made with the delineation of the preparation of a spatial DST. In all three countries, the context (goal and objectives) of the DST has been discussed, the types of products and its users identified, and the purposes to involve what (type of) stakeholders during the preparation and implementation phase have been browsed. Despite some (minor) differences among the participating countries, some general conclusions are:

All three countries stressed the need for a tool capable to be used at macro as well as micro level. At macro level the tool should be able to support the more strategic scanning of the different options for spatial development of livestock production at regional scale. The indicative scale at macro level: 1:100.000 to 1:500.000. At micro level the tool should be able to support

more detailed decision making of allocation of livestock farms. Indicative scale at the local level: 1:50.000. The prospects to use the tool at the local level will, of course, depend highly of the availability and quality of data, especially the required geo-data. Nonetheless, the use of the spatial DST at two different scale levels is an important issue to be taken into account during the construction phase of the spatial DST and the (geo-)database.

There are large differences among the three countries with respect to the available (geo-)data. Although the construction of a (geo-)database and, if applicable, a DBMS (Data Base Management System) is a country-specific task, in each country the spatial DST should be able to communicate with these databases and DBMS. Therefore, the requirements for communication and data formats need to be identified.

In each of the countries some organizations have been identified that might be able to provide the required national expertise for the development of a (spatial) database and the implementation and training with respect to the DST. In case the contractors are not associated with the organizations that hold the end-users of the spatial DST, a tight communication and cooperation framework needs to be established between both.

The preparation of the spatial DST in ArcGIS is a regional activity. During the technical consultation meetings it became clear only few organizations in the participating countries have expertise in ArcGIS programming, with exception of the Asian Institute of Technology (AIT) in Bangkok, Thailand. This international institute holds a group of experienced programmers, who are also able to communicate in English. This is important since they need to cooperate closely with an international contractor who will coordinate the spatial DST development. Another argument in favor of this institute are their relative low fees for programmers (approx. 600 US$ per month), especially compared to the fees of programmers from e.g. western countries.

4. Technical outline of the spatial DST

4.1. Introduction

To provide a practical contribution to spatial decision support for livestock policy making, a method is needed, that (a) fosters participatory processes, (b) allows for inclusion of quantitative and qualitative parameters, (c) can be run on standard computers, (d) is not prohibitively data demanding to parameterize, and (e) can evaluate uncertainty. On these grounds, the spatial DST fosters a combination of an additive technique (weighted linear combination) with a comparative technique (analytical hierarchical processes). The techniques are parameterized using participatory processes and implemented on spatial data using a geographical information system.

The method proposed has two steps: first, to characterize, describe and parameterize the decision rule and second, to evaluate alternatives by attributing scores according to their suitability. The technical and policy aspects of the decision making are separated and addressed within the framework of two different workshops. First, a policy workshop is organized, gathering representatives from government and main stakeholders, including livestock keepers (large scale integrators and representatives from small scale producers) as well as members of environmentalists and consumers organizations. Participants interact in proposing the policy goal and its contributing objective(s). The objectives are ranked and weighted according to their respective relevance to the goal, using the analytical hierarchical processes technique with a 9-point comparison scale.

Then, during a technical workshop, a multidisciplinary group of experts identifies, defines, standardizes and weights criteria for each objective. Standardizing criteria involves re-scaling factor values within a standard range, such that increasing values correspond to increasing suitability for the objective under evaluation. Constraints are defined where selected criteria scores are "restricted", excluding that alternative regardless of its scores for other criteria. Weights are then assigned to reflect the relative contribution of criteria to the objectives, using the analytical hierarchical processes technique.

Analytical hierarchical process

Analytical hierarchical process is a step-by-step multiple objective approach: comparisons are first implemented between pairs of objectives with regard to the overall goal, and these are used to determine objectives weights. Pairwise comparisons are then implemented at the criterion level, with regard to each objective, in order to determine criteria weights. Pair wise comparisons are finally implemented at the alternative level with regard to each criterion. At each step, a matrix of pair wise comparisons is built. The eigenvector associated with the largest eigenvalue of the matrix is then computed and normalized. It is unique and gives the respective weight of each element. A consistency ratio is calculated to check the transitiveness of the pairwise comparisons.

Weighted linear combination

Alternatives are ranked by implementing weighted linear combination on raster maps stored in a GIS. Weighted linear combination, or weighted summation, is the most widely known and used technique for decision support. S, the suitability of the alternative being considered (value of a raster cell in the suitability map) is defined as shown in the equation below.

$$S = \sum_{i=1}^{n} w_i x_i \prod_{j=1}^{m} c_j$$

where w_i is the weight of objective i, x_i is the criterion score of objective i (value of corresponding the raster cell in the criterion raster map), n is the number of objectives, c_j is the criterion score (1 or 0) of constraint j (value of corresponding the raster cell in the constraint raster map) and m is the number of constraints. The same computation is then made at the level of objectives: it is a step-by-step multiple objective approach.

The results from the workshops, i.e. the identified objectives and criteria, with their relative weights, possibly from the perspective of different groups of stakeholders, are the input data for the spatial DST.
The second step of the tool is to evaluate alternatives by attributing scores according to their suitability. However, the spatial DST can easily become a 'black box' if the users do not fully understand the limitations of the tool and its output. Despite the fact that output maps may look very detailed and suggest a high degree of accuracy, they are often not. This will entirely depend on the availability of reliable and detailed input data. Most likely, most of the produced output should be used in an indicative way only. Therefore, the output of the tool needs to be accompanied by supporting information on the reliability of the output and the shortcomings due to unreliable or missing input data, as well as the consequences for use of the output. Therefore, a comprehensive meta-data assessment system is proposed as an integrated part of the spatial DST. The distribution of the output will also require tools to produce more sketch-like presentations, e.g. using fuzzy borders and aggregated maps, which should be implemented as another important feature of the output module (see next section).

4.2. Outline of the spatial DST

The results of the preparation missions showed that the spatial DST should be able to support the strategic decision making on future livestock production areas (suitability assessment) at regional and national level, and also support the decision making (recommendation) on the allocation of new livestock farms. While the latter requires comprehensive and detailed data, and may be difficult to implement given the general lack of such data, this specific task is included in a separate module in the outline of the spatial DST, as shown in Figure 1.

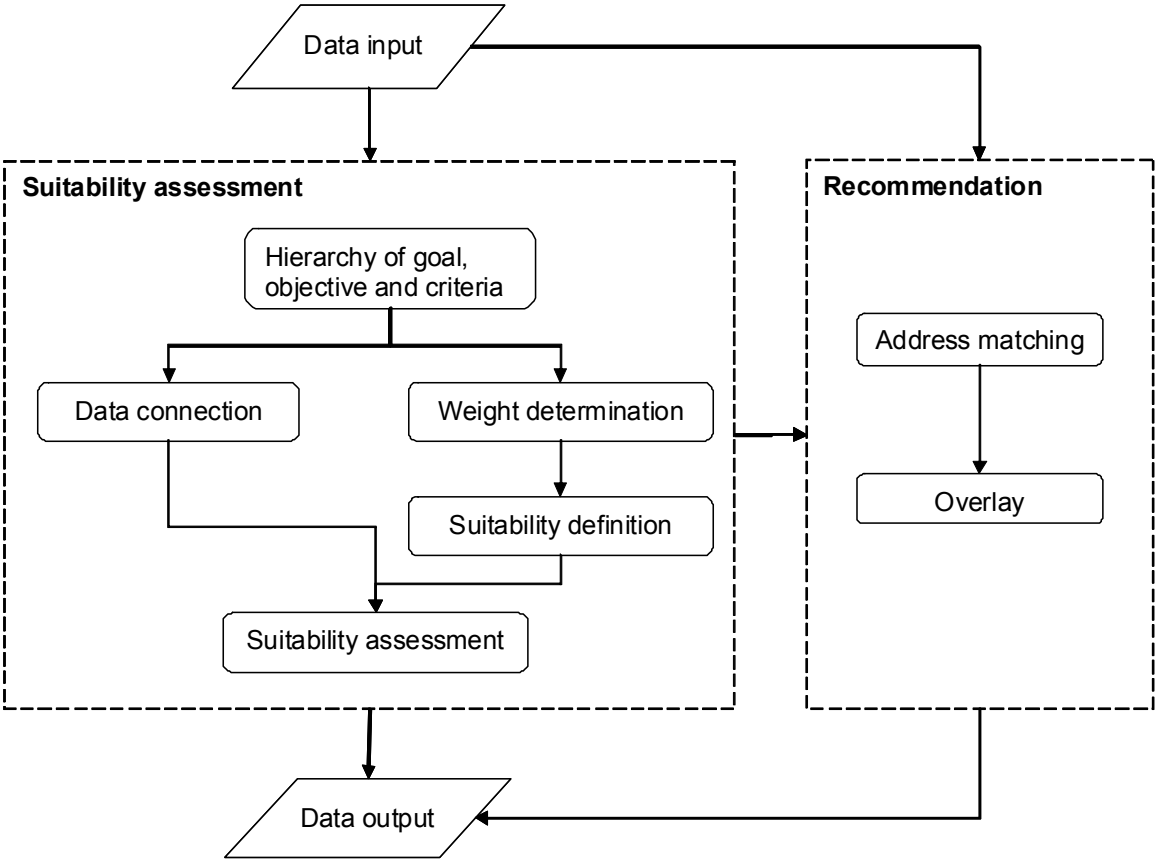


Figure 1 Outline of the spatial DST

Based on the outline, six general tasks can be identified for the development of the DST. These are:

1. Background scanning (policy review and assessment, and collecting geo-data and statistical data)
2. Construction of an initialization module (component for setting and changing some default settings of the spatial DST, such as language)
3. Construction of an input module (components for entering the data for the suitability assessment of livestock production and the farm location data for making a recommendation)
4. Construction of a suitability assessment module
5. Construction of a recommendation module
6. Construction of an output module

Each of these tasks consists of a number of sub-tasks, as shown in Figure 2.

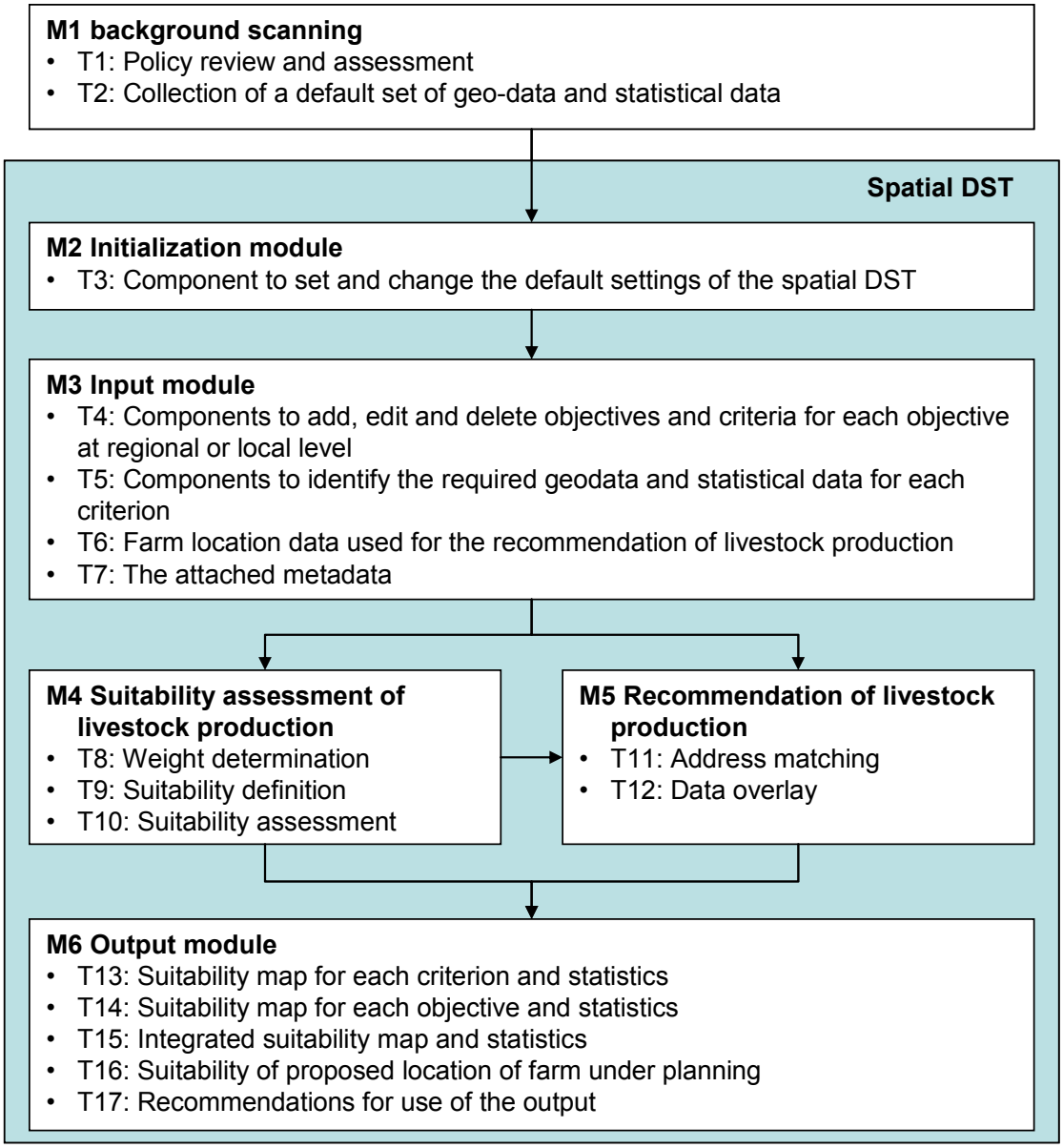


Figure 2 Tasks and subtasks for developing a spatial DST in the LWMEA project

The modules, tasks and sub-tasks will each be described in more detail in the next sub-sections.

4.2.1. Module M1: Background scanning

Context of the module
This module involves a preparation task for the spatial DST, aiming at scanning and assessing livestock production and management policies, laws and regulations, as well as other relevant policies (e.g. environmental, financial, economical and on land-use) which may affect the spatial planning, distribution and management of livestock production. These policies and regulations will be relevant for the suitability assessment (M4) and may serve as guidelines for the weight determination (T8) and/or identifying the objectives and corresponding criteria setting (T4, T5). In addition to the policy review, this module involves the generation of a default geo-data and statistical dataset. Therefore the module includes two sub-tasks: a policy review and assessment (T1) and the collection of a default geo-data and statistical data set (T2).

T1: Policy review and assessment
Summary task description T1:

- The scanning and assessment of policies, laws and regulations on livestock production and management;
- The scanning and assessment of other relevant policies such as economical, land-use, financial and environmental policies and regulations relevant for the spatial planning and management of livestock production.

Input data required
Laws, acts, regulations, policies, plans and other documents on livestock production, social-economical issues, land-use, and the environment.

Output
Comprehensive list with restrictions and guidelines from relevant national, regional and local policies which are relevant for the assessment and references to laws, acts, regulations, policies, plans, and other documents. Examples are the areas prohibited for use for livestock production due to environmental and land-use policies such as distances to be maintained between residential (urban) areas and livestock farms, and laws and regulations identifying sensitive areas such as national park, wetlands, and other areas.

T2: Collection of a default set of geodata and statistical data
The use of the spatial DST will require an initial set of geo-data and statistical data which should be available for Guangdong province in China, Thailand and Vietnam at two different scale levels.
Summary task description T2:

- A default set of geodata for use at national/regional and the local level
- A default set of statistical data for use at national/regional and the local level

Options and output
The output of T2 includes two default sets of geodata and statistical data to be used at the national/regional or the local level. The format of the geodata should be compatible with ESRI ArcGIS. The geodata at national/regional level should be at a scale ranging from 1:100,000 to 1:500,000. If the geodata are collected at local level, the scale of the base map should be at 1: 50,000 scale. An initial list of required geodata and statistical data is provided in Annex 1.

After the implementation of the tool, the geodata and statistical data sets needs to be updated regularly and expanded with new data depending on the specific context and needs.

4.2.2. Module M2: initialization module

Context of the module
This module is a supporting module for setting the default settings of the spatial DST. This module will be used irregular, for instance for changing help functions and adding languages.

T3: Component to set and change the default settings of the spatial DST
Summary task description T1:
This component of the spatial DST defines the default glossary, help functions and language modules (English, Chinese, Thai or Vietnamese). This module allows the user to set and change these features. Also, during the development process of the spatial DST some other settings may be identified that should be included in the initialization module.

4.2.3. Module M3: input module

Context of the module
This module involves the data input module of the spatial DST, aiming at providing sufficient data with good quality for the suitability assessment (M4) and the recommendation (M5). The module includes such tasks as developing components to add, edit or delete objectives, criteria for each objective at regional or local level (T4), components to identify and select the required geo-data and statistical data for each criterion (T5), a component for submitting farm location data used for the recommendation of the allocation of livestock farms (T6) and setting up a system for attached metadata (T7). The general data flow of the input module which provides the data for the suitability assessment module (T4 and T5) is shown in Figure 3.

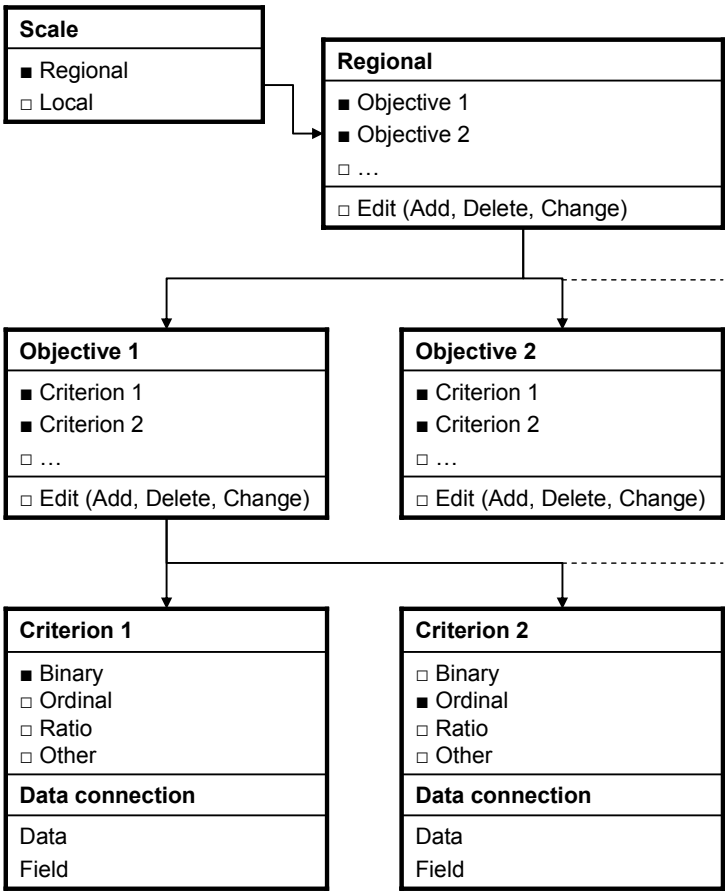


Figure 3 Data flow of the part of the input module which supports the suitability assessment module of the spatial DST (T4 and T5).

The input module will also need to provide the location data of a proposed farm for the farm recommendation module (T6), and the data flow of this part of the input module is shown in Figure 4. Besides the specific X and Y coordinates of the farm, this might also involve other specific data, such as animal numbers.

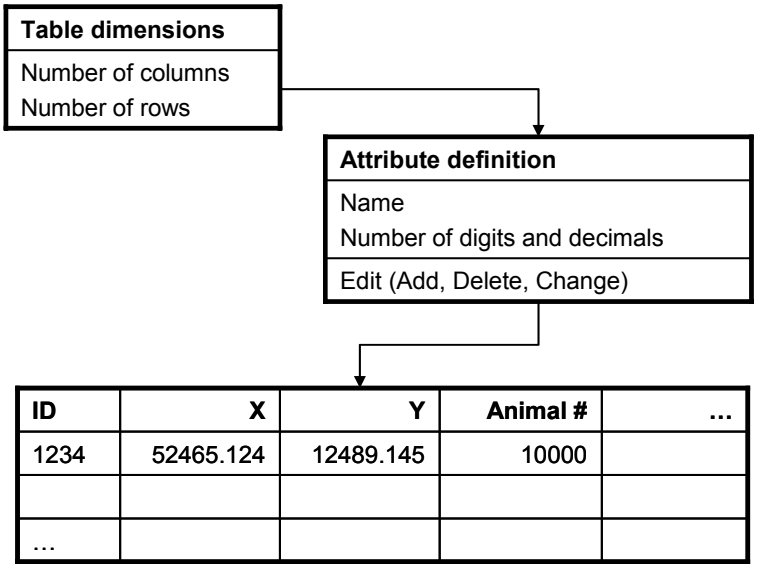


Figure 4 Data flow of the part of the input module which supports the recommendation module of the spatial DST (T6).

An additional feature to be included in the input model involves the input of optional data which might be relevant to show in supporting output maps, for example statistical data on animal numbers, population numbers, production capacity of farms, farm sizes (large, medium, small), that might be linked to maps with administrative boundaries or a topographical map. This should be further discussed with experts from the three participating countries in order to identify the requirements and an initial list of optional data.

T4: Component to add, delete and edit objectives and criteria
Summary task description:

- Components to add, change or delete objectives at local or regional level,
- Components to add, change or delete criteria for each objective at regional or local level

Output
Guided by module 1, the hierarchical and logical relationships among the relevant objectives and criteria at regional or local scale are established. A set of default objectives and criteria for local and regional level should be set up, using the results from the AWI pilot projects. Initial sets of objectives and criteria at the regional level can be derived from the AWI project in Thailand, which are included in Annex 2.

Options
Since the decision making on livestock production areas and location will be influenced by many different factors, such as physical, social and economical characteristics of an area as well as the country specific policies and regulations, the objectives and criteria of the suitability analysis will change in time and space. T4 should therefore be very flexible in order to meet the present and future user's requirements. With T4, the objectives and relevant criteria are organized in a hierarchical way, also involving assigning weights to the objectives and criteria (derived from workshops – see Chapter 2).

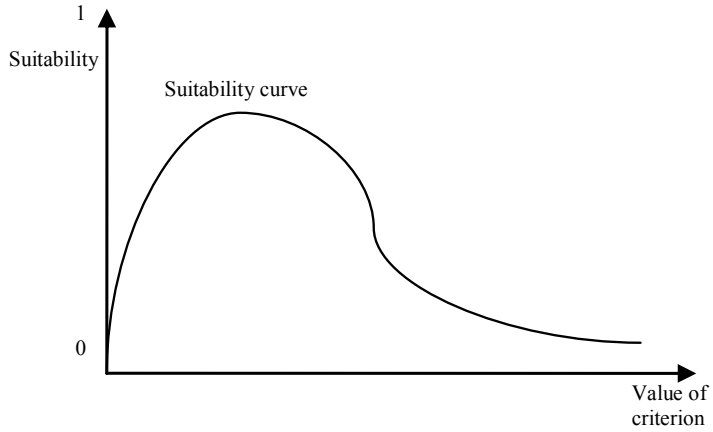
Objectives	Weights
Objective 1 Objective 2 …	Weight 1 Weight 2 … _____ Total weight

Objective 1	
Criteria	**Weights**
Criterion 1 Criterion 2 …	Weight 1 Weight 2 … _____ Total weight

Figure 5 Structure of objectives, criteria and weights.

As shown in Figure 3, the scores with the criteria can have different scales, most likely ranging form ratio (quantitative), ordinal (qualitative) to binary (0/1) scales. Within T4 these different scales should be transformed and standardized to a uniform (ordinal) scale, for example ranging from 0 to 1. The two examples below show some obvious options to be included into the system.

Example 1. Ratio scale



Example 2. Ordinal scale with a range of classes

Classes	Unsuitable	1	2	3	…	10
Criterion 1	0	< 100 m	100-200 m	200-300 m	…	> 1000 m
Criterion 2	…					
Suitability	**0,0**	**0,1**	**0,2**	**0,3**	**…**	**1,0**

Most likely the hierarchy of objectives and relevant criteria will not change dramatically over time. Therefore, it is rational to include a default hierarchical structure with default values based for Guangdong province of China, Vietnam and Thailand. The initial default set from the AWI project in Thailand (see Annex 2) should therefore be replaced in time by country specific default settings.

T5: Component to identify required statistical and geodata per criterion
Summary task description:

- Identifying the geodata data for each criterion
- Identifying the attribute data for each criterion

Output
The output of this task includes the identified fields and formats of both spatial and attribute data required for suitability analysis.

Options
The data required can be prepared within the system in case the data are not available or needs to be updated. Since the system will be developed using the existing components of ArcGIS(AO), the data format should be compatible with ArcGIS in case the data are created out of the DST. For example: Arc/Info-coverage or shape-files. A data format transformation function should be available for expected differences between the system requirements and the actual data provided.

T6: Component to include farm data
Summary task description:

- Determination of farm location under development,
- The description of surroundings of farm under development.

Input
The collected farm data (e.g. GPS location data, and other relevant data about size, type and location of the proposed farm).

Output
The location data and attribute data (i.e. animal numbers, production capacity, farm scale) in the system.

Options
This part of the spatial DST might support the use of GPS technology. The location and attribute data relevant for the suitability determination are defined by this task.

T7: Meta data component
The reliability of the output of the suitability assessment will depend strongly on the quality of the input data. Therefore, the DST should include a warning system that identifies the risk of incorrect decision making due to unreliable output. Metadata with a fixed format should therefore be ached to all the input in system.
Summary task description:

- The metadata establishment,
- A warning system to users, checking the possible errors due to the data used.

Input
Information about the source and characteristics of all data created or imported in the system.

Output
Database with metadata, including a structure of indicative thresholds to be used for identifying the reliability of the output.

Options
Some key elements included in the metadata are, for example, the date of collection, a description of the precision (either in position or attributes), and the scale of the base map.

A thresholds system might be set up by classifying the data into low, moderate and high suitability for analysis. The warning system can use the information from metadata and assess the reliability of the output by comparing the metadata characteristics with the thresholds. The warning system should provide the user of the output with specific recommendations for use of the output.

4.2.4. Module M4: Suitability assessment of livestock production

Context of the module
This module is the core module for the SDT of livestock production, aiming at calculating integrated suitability maps based on weighted linear combination. Module M3 provides its input and M6 presents its output. Module M4 also provides the base map for module M5. It includes the tasks of weight determination (T8), suitability definition (T9) and suitability assessment (T10).

T8: Weight determination
This component determines the weights of criteria and objectives to be applied with the calculation of the suitability maps.
Summary task description:

- Identifying the weight determination method and relevant data
- Calculating the weights of objectives and relevant criteria.

Input
The input of task T8 is derived from the policy and technical workshops (see also the introduction). The module should allow storing the relevant output of these workshops, such as the results of a paired comparison.

Output
The weights of objectives and corresponding criteria.

Options
There are many methods to determine weights. During the AWI pilot projects analytic hierarchal process (AHP), and paired comparison were used, but other methods might be included in this task as well.

T9: Suitability definition
Component T9 of the spatial DST defines the suitability classes for each criterion. The suitability score can range from 0 (unsuitable) to 1 (most suitable) or from 0 (unsuitable) to another maximum value.
Summary task description:

- Indicator definition and
- Classification of suitability

Input
The input of T9 is criteria defined in T4 of module M3.

Output
Standardized criteria.

Options
The suitability standards might be entered as either a table (see example 2 with T4) or a graph (see example 1 with T4). This component should allow the user to choose from default table classes and values or preset curves, but should also allow the user to change

these values and curves easily, for instance by adjusting a curve by pointing and dragging it with a mouse. Different standardization methods may be offered here, for calculating the standardized suitability classes.

T10: Suitability assessment
Component T10 calculates and integrated the suitability maps, using multi-criteria methods and standard functionalities of ArcGIS, such as buffering, cost-weighted distance functions, intersecting and overlays.
Summary task description

- Calculating the suitability of each criterion ,
- Calculating the suitability of each objective, and
- Integrating suitability.

Input
The input of component T10 involves the weights defined in T8 and the suitability standards defined in T9.

Output
The output includes all the information required by the output module M6, including a suitability map for each criterion, the integrated suitability maps per objective and a final integrated suitability map.

Options
T10 covers most of spatial analysis methods in GIS, such as reclassification (classifying values according to suitability standard), buffer analysis (forming the values of criteria), overlay (integrating map) etc. Some standard multicriteria methods should be offered too, such as weighted linear combination.

4.2.5. Module M5: Recommendation of livestock production

Context of the module
This module aims to provide output for decision making on individual livestock farms, based on a suitability assessment at the local level. This module is not relevant for regional or national level analyses. While M4 is not a daily task, module M5 offers tools for day-to-day local decision making. It includes such tasks as address matching (T11) and data overlay (T12).

T11: Address matching
Component T11 imports the location and other attribute data of potential farms.
Summary task description

- Transforming location data to the DST and ,
- Importing attribute data to the DST.

Input
The location and attribute data of potential farms, e.g. provided by GPS.

Output
A GIS layer with the location and attribute data of the farms under development.

Options
There are basically two options for importing data to the system. If the software of GPS is compatible with the DST, such as Arcpad, the data can be imported directly to the system. If not, the location recorded in the GPS system can be used by means of address matching, in which the x and y coordinates recorded in GPS can be transformed to spatial data.

T12: Data overlay
T12 makes an overlay of the farm data of T11 and the suitability assessment results of T10 in order, and produces the information to come to a recommendation about the locations which has been chosen for livestock production.
Summary task description

- Overlay between farm data and integrated suitability assessment map,
- Overlay between farm data and suitability assessment map of objectives and
- Overlay between farm data and individual criterion maps.

Input
The farm data of T11 and the results of local level suitability analysis of T10

Output
Set of overlay maps and associated attribute tables.

4.2.6. Module M6: Output module

Context of the module
The input and output modules are the most dominant features in the user interface of the spatial DST. The output module does not generate new information but present the results of the calculations (maps and tables) and highlights the recommendations that can be derived from it. Furthermore, the output module also provides the means to access background information. The input and output modules together should make the DST accessible to the user as a real interactive tool which allows the user to evaluate different alternatives, evaluate their merit and drawbacks and use the DST and its output as a supporting tool to assist decision making.

General requirements of this module
Printed suitability maps for livestock production are one of the most important requirements of the DST under development. In order to make these maps easily accessible to the users of these maps, some basic characteristics of the area under evaluation, such as road and rail infrastructure, land-use data and administrative boundaries should be available in these maps. The common rules of cartography should be followed, while the tool should also address the specific rules of each country (China, Vietnam and Thailand). The DST should also provide some basic statistics with the output maps. The DST should allow the user to adapt the content of these statistics to the specific country requirements. During the process of developing the spatial DST, this should be discussed with country experts and potential users.
Also, the distribution of the output in tasks T13 to T16 may require the production of more sketch like presentations, e.g. using fuzzy borders and aggregating the results. Therefore, the output module should provide the user with means to select the required level of detail of the maps and statistics. The assessment of meta-data (see T17) may also result in specific requirements to lower the resolution of the output maps.

Contents of T13: Suitability map of each criterion and statistics
This component presents a suitability map of each criterion. Furthermore, the selected statistics should be provided at the selected administrative level, such as the mean suitability score, standard deviation, area of suitability score range defined by user. The statistics could be presented either by table or graph.

Contents of T14: Suitability map of each objective and statistics
This component presents a suitability map for each objective. Again, the selected statistics should also be presented for the selected administrative level.

Contents of T15: Integrated suitability map and statistics
This component presents the final suitability map, which has been derived by integrating the suitability maps of all objectives. Again, the selected statistics should also be presented for the selected administrative level.

> Options
> For ease-of-use the output module might provide the option to select a range of maps as described with tasks T13 to T15 at once.

Contents of T16: Suitability of the proposed location of farm under planning
This component produces a suitability map for a selected area surrounding the location of the proposed farms. Some selected statistics should be provided for this area. This component may also produce an indicative recommendation, based upon the suitability score of the integrated map and maps for each criterion and objective. This will require some thresholds to be set for the relevant maps.

Contents of T17: Recommendations for use of the output
As discussed before, the spatial DST can easily become a 'black box' if the users do not fully understand the limitations of the tool and its output. Therefore, the output of the tool needs to be accompanied by supporting information on the reliability of the output and the shortcomings due to unreliable or missing input data, as well as the consequences for use of the output. This component should allow assessing the meta-data, and arrive at recommendations for use. Therefore, the implications of some standard situations should be discussed during the development of the spatial DST with the country experts.

5. Next steps in the process

As described in the introduction (Chapter 1), this report focuses at the specification phase, and describes the requirements, outline and components of the software to be written. Also, the basic needs and requirements for geo-data and statistical data have been identified. The next two steps in the process include a rigorous technical description of the software architecture, including the interfaces between the software system and other software products (such as present Data Base Management Systems or DBMS), the underlying hardware and the host operating system. Afterwards the actual software coding can start.

Looking at the workflow of the process (see Annex 3 and 4), the next step involves preparing a technical workshop, focusing at detailed technical discussions between the IC-Planning, IC-Software and the NC's, with this report as a starting point. Based on these discussions:

- This detailed specification can be finalized
- The software architecture can be written, and
- The required geo-data and statistical data (including scale, format and other characteristic) can be identified for each country

However, given the experiences with (the limited success of) the previous workshops, a better option might be to have a technical discussion about this report between the IC-Planning and IC-Software coding first. This allows the further detailing of this report and also to produce an initial software architecture description. This discussion can be supported by exchanging written information by email, video-conferencing techniques, and if necessary a face-to-face meeting at location.

Afterwards, the report and initial software architecture can be discussed in country-specific workshops, allowing more planning and GIS-experts per country to participate, and also enables to discuss and finish the NC's selection and contract arrangements at location.

Appendices

Annex 1. Initial list of required statistical data and geodata.

Statistical data

The required statistical data include data for the most recently available year, and should be updated yearly. These data should be collected for the administrative units from state to the local level. The required data include:

1. Livestock data according to available statistics.
2. Statistics on numbers of inhabitants, number of districts, rural population, number of households.
3. Information on social indicators and socio-economic data.
4. Cultural background and heritage, land tenure status, nature reserves, non-agricultural employment opportunities, potential for tourism and scenic areas.

Geographical data

The geographical data should be collected as shape files or other format that allows a conversion to ArcGIS. The geodata should be available for the national/provincial/regional level (scale 1:100.000 to 1: 500.000) and the local level (1: 50.000 scale). The required geodata are:

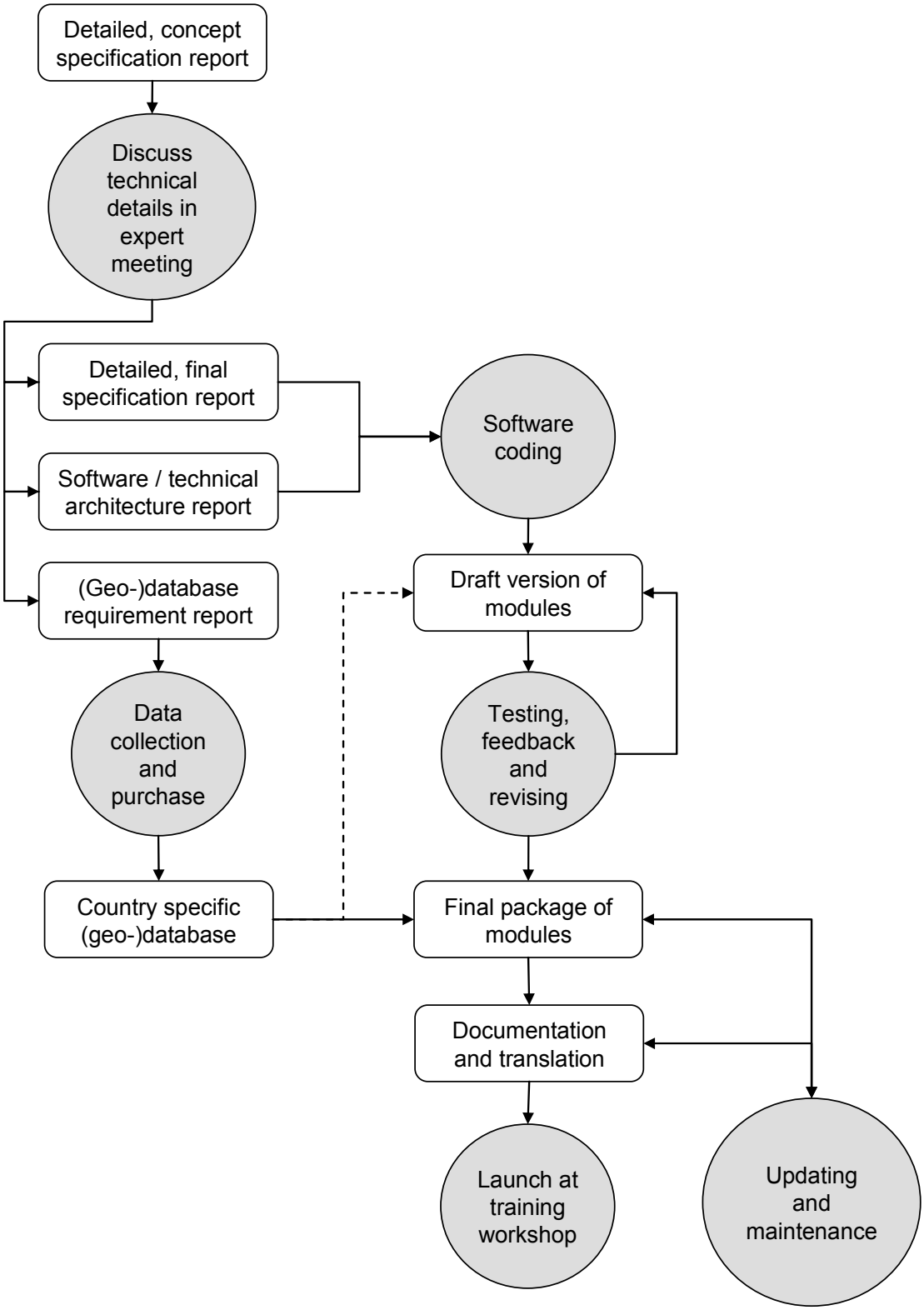
1. The administrative boundaries for national to local administrations.
2. The main road and rail infrastructure.
3. Surface water elements, such as rivers, streams and lakes, and the borders of basins.
4. Elevation data.
5. Soil data, including data on soil texture, and, if available, soil structure, porosity, permeability, infiltration, seepage and percolation, and erodibility, soil depth, pH, Total P, and TKN and heavy metals (Zn, Cu, As, and Fe).
6. Soil erosion and soil erodibility.
7. Groundwater depth.
8. Direction of surface and groundwater flow, if available.
9. Land use map, covering at least 20 to 30 different land use classes, including different types of agriculture (major crops), forest and natural areas, and built-up area (urban and different types of industrial areas).
10. Nature reserve areas, natural parks, wetlands, areas with protected animal or plant species.
11. The locations of livestock farms, especially large commercial farms.
12. The locations of other important elements of the livestock production chain, such as slaughterhouses, feed mills, distribution centers, and others.

Annex 2. Default set of objectives and criteria to be included in the spatial DST

Criteria	Unit	**Class 1** very low suitability	**Class 2** low suitability	**Class 3** medium suitability	**Class 4** high suitability	**Class 5** very high suitability	Restriction
Objective: **Economic profitability of pig production is maximised**							
Distance to feed mill	km			>50	10-50	<10	
Distance to slaughterhouse >10	km	>100		61-100		5-60	< 5
Distance to main road	km	>15		5-15		<5	
Poverty index	-		“progress“	“moderate“	“backward“		
Planned Foot and Mouth Disease free zone	-			elsewhere	buffer zone	free zone	
Human population density	indiv./km^2		<72	72-170	>170		
Current livestock density	pig/km^2		>1000	201-1000	0-200		
Objective: **Environmental impacts of pig production are minimized**							
Distance to inhabited area	m	<200	200-400	401-600	601-800	>800	
Distance to mangroves/wetlands	m	<200	200-400	401-600	601-800	>800	
Runoff risk	-	“very high“	“high“	“medium“	“low“	“very low“	“restricted”
Leaching risk	-	“very high“	“high“	“medium“	“low“	“very low“	“restricted”
Number of large pig and poultry farms in district	farm	>8	7-8	5-6	2-4	<2	
Current nutrient balance (P_2O_5)	%	>1	0.71-1.0	0.51-0.7	0.3-0.5	<0.3	
Current livestock densities	LU/km^2	>50	31-50	21-30	10-20	<10	
Distance to main road	m	<100	100-200	201-300	301-400	>400	
Current land use	-	“paddy“; “rice”; “agriculture useless“; “forest“; “lowland“; “bamboo“	“vegetables“	“field crops“; “grassland“	“fruit trees“; “orchards“	“plantations“	“protected areas“; “mangrove“; “wetland“

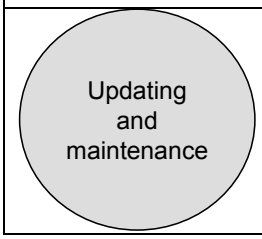
Criteria	Unit	**class 1** very low suitability	**class 2** low suitability	**class 3** medium suitability	**class 4** high suitability	**class 5** very high suitability	Restriction
Objective: **Public and animal health are protected**							
Distance to inhabited area	km	<5		5 to 10		>10	"populated areas"; "water bodies"
Distance to streams and water bodies	m	0-100		101-500		>500	
Human population density	indiv./km^2	>200	151-200	101-150	51-100	<51	
Distance to slaughterhouse	km	<2		2-5		>5	
Planned Foot and Mouth Disease free zone	-	elsewhere	buffer zone			free zone	
Current livestock densities	LU/km^2	>80	61-80	41-60	21-40	0-20	
Leaching risk	-	"very high"	"high"	"medium"	"low"	"very low"	"restricted"
Distance to feed mill	km	<5		5-10		>10	
Number of large pig and poultry farms in district	farm	>5		3-5		0-2	
Poverty index	-		"backward"	"moderate"	"progress"		
Objective: **Rural development and poverty reduction are fostered**							
Distance to main road	km	>15		5-15		<5	
Poverty index	-	"backward"	"progress"		"moderate"		
Human population density	pers./km^2	>170		72-170		<72	
Current land use	-	"agriculture useless "; "coconut"; "lowland"; "forest" non planted	"irrigated rice";	"field crops"; "grassland"; "horticulture"; "fruit trees"; "mixed orchard"	"rain fed rice"; "plantations"; "planted forest"		"protected areas"; "mangrove; "wetland"
Planned Foot and Mouth Disease free zone	-		elsewhere	buffer zone		free zone	
Current nutrient balance (N_{total})	%	96-150		26-95		0-25	
Distance to slaughterhouse	km	>100		61-100		5-60	<5
Current nutrient balance (P_2O_5)	%	76-150		26-75		0-25	
Distance to feed mill	km			>50	10-50	<10	
Number of large pig farms in district	farm			1-4	5-8	>8	

Annex 3. Overall workflow of the process of developing the spatial DST.



Annex 4. Tentative time schedule of tasks.

Detailed, concept specification report	This report	Phase 1: The preparation of a concept detailed specification report Contracting the IC-SOFTWARE and NC's
	Month 1	Preparation of a regional workshop / expert meeting
Discuss technical details in expert meeting	Month 2	Regional workshop or expert meeting (start of Phase 2)
Detailed, final specification report Software / technical architecture report (Geo-)database requirement report	Month 3 - 4	Phase 2: The description of the software architecture and statistical and geo-data base requirements; final specification report and technical architecture report; start of database development; Detailed working scheme for phases 3 to 6, and maintenance program.
Software coding Draft version of modules Testing, feedback and revising	Month 6 - 11	Construction and testing (Phases 3 and 4) Includes a mission to each country with presentations of draft components (August or September). This mission also includes a policy and technical workshop to identify the initial country-specific objectives, criteria and sets of weights, for implementation in the final package.
Final package of modules Documentation and translation	Month 12	Documentation (including translation) and preparation DST training workshop (Phase 5)
Launch at training workshop	Month 13	Launch of the final package in a DST training workshop per country (Phase 6)

	Month 14 and further	Monitoring and maintenance (Phase 7)