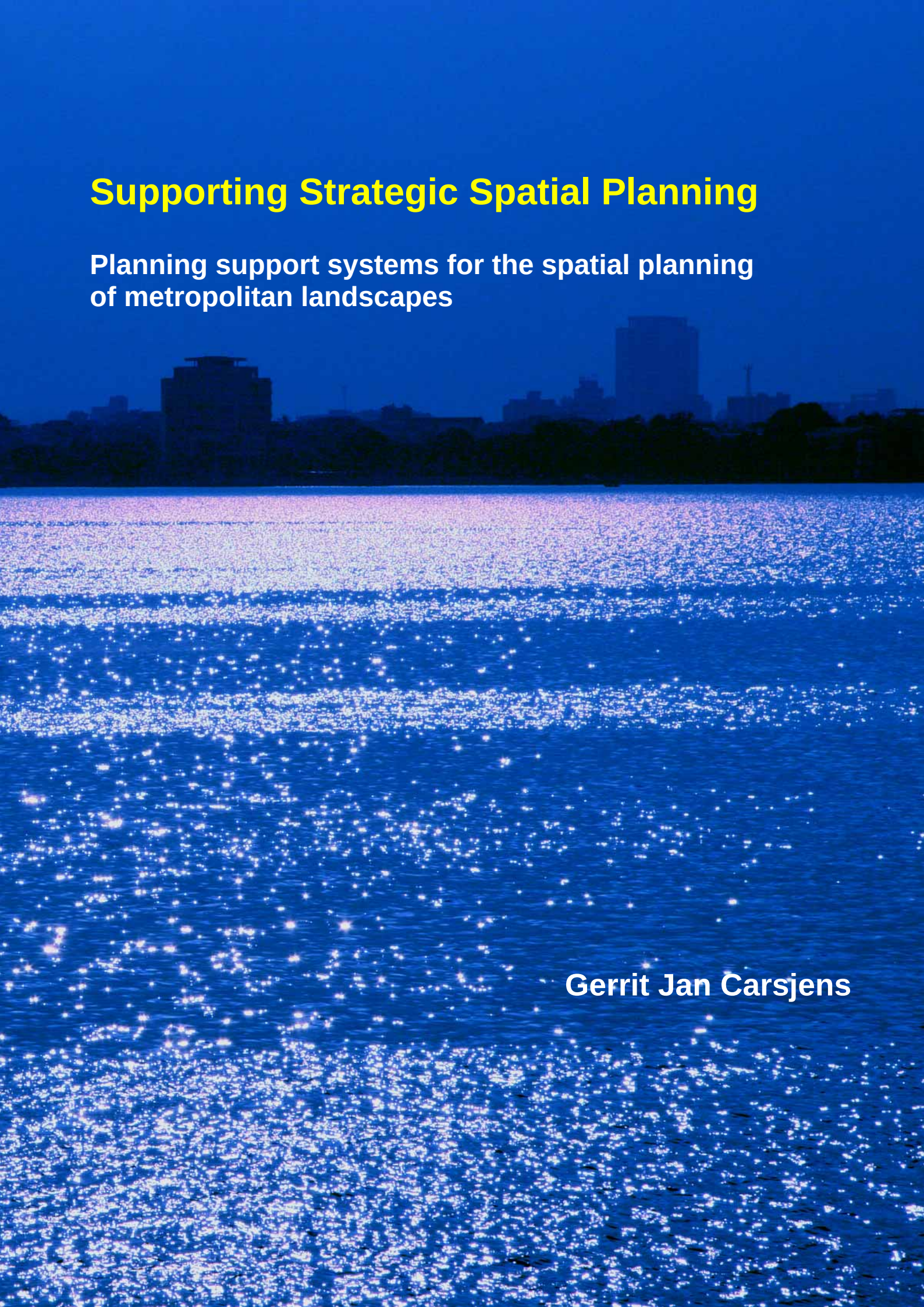

Supporting Strategic Spatial Planning

Planning support systems for the spatial planning of metropolitan landscapes

Gerrit Jan Carsjens

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Planning support systems for the spatial planning of metropolitan landscapes

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At last, a long-standing ambition has been fulfilled. Ever since my appointment at the Wageningen University in 1990, it was clear that I was supposed to obtain my PhD. But starting as an assistant professor, it took me so much time to invest in our course program, especially in a context of numerous reorganizations during the 1990s, that the first ten years did not bring this target any closer. In the early 2000s, I started to realize that trying to accomplish a PhD-research independent from my other activities was not realistic, and I should better try to bring together some various elements in my research and educational work. The areas of planning support systems and strategic spatial planning showed to be prominent threads in my work so far, and two major research projects came forth that created the opportunity to publish a series of scientific papers. Writing the theoretical and concluding chapters underpinning these papers was a final task. Unfortunately, the research was disrupted yearly by the classes that kept me fully occupied from January until the summer holidays.

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Although much remains to be explored, I am relieved to have tied up a few loose ends and finish this thesis.

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Chapter 1

Introduction

This research integrates the domains of land-use and environmental planning and decision making, with the domain of spatial planning-support systems. This chapter introduces the problem statement, goal and research questions, and delineates the scope of the research.

1.1 Problem description

The domain of the Wageningen spatial planning program is traditionally the land-use and environmental planning of rural areas. The last decades, this domain is facing the growing complexity of the metropolitan landscape of Western Europe, where planners and decision-makers have to deal with a diversity of increasingly involved stakeholders, with often conflicting objectives (van der Valk 2002, Albrechts 2004a). Contemporary land-use planning is caught between the increasing pressure on the rural area for economic and urban development and the need to preserve farmland and natural resources. The challenge is to find a balance between both, as in practice this balance often turns in favor of economic development, especially near to urban areas. This asks for an integrated approach which synthesizes socio-economic as well as physical and environmental information at various levels of detail, in order to enable realistic assessments of more sustainable future spatial developments (Pettit & Pullar 2004).

Albrechts (2004a) argues that the spatial planning for these complex situations asks for the ability to combine the creation of strategic visions for the future development of areas with short-term actions. However, long-term, strategic, future-oriented spatial planning is nowadays seen as a relic of the past, and "[…] planning has little choice but to surrender its responsibilities to local public participation. Planning *for* the people is obviously no longer acceptable and planning *with* the people proved too complex, so planning *by* the people has become the rallying cry of many 'new' planners" (Couclelis 2005: p. 1358). However, the growing complexity of the metropolitan landscape and its many relationships with other spatial and temporal scales cannot be properly addressed by local communities and the public only. Local participative planning is not a substitute for strategic planning (Couclelis 2005), and thus also requires a spatial planning framework for formulating and evaluating more long-term, holistic future perspectives. Couclelis (2005) differentiates in the degree of future orientation of planning, and provides a list of actions that planning may take to implement its operational, managerial and strategic functions, ranked from least to most future oriented (see Table 1-1). She argues "[…] that planning has retreated from the strategic, future-oriented end of the scale to become absorbed in operational and managerial activities characterized by short-term horizon and value choices likely to be equally shortsighted and ad hoc"(Couclelis 2005: p. 1357).

Table 1-1 Planning actions and functions: from past to future (Couclelis 2005).

Time orientation	Planning actions	Planning functions
Past	React	*Operational*
↓	Respond	
	Mitigate	
	Control	
	Manage	
Present	Adapt	*Managerial*
↓	Anticipate	
	Prepare	
	Change	
	Shape	
Future	Create	*Strategic*

The shift in focus towards local, participatory planning also showed it drawbacks, and resulted in an increased concern about the rapid and apparently random development of (especially) urban areas, further strengthened by the growing complexity, the problems of fragmentation and an increased interest in environmental issues (Albrechts 2004b). As a response, recent years show a renewed emphasis on the need for long-term thinking and a strong revival of strategic and regional spatial planning (Salet & Faludi 2000, Friedmann 2004, Dimitriou & Thompson 2007a).

The process of strategic and regional spatial planning is one of the most complex tasks of public organizations (Vonk et al. 2006). Planners have to deal with a wide range of often conflicting objectives at different spatial and temporal scales, have to handle large amounts of information of various types and qualities, and need to synthesize feasible alternatives in a communicative setting with a range of stakeholders, in a process where relatively straightforward and effective decisions are ultimately required (Vonk et al. 2006, Dimitriou & Thompson 2007b). The last decades, an increasing number of computer-based geo-information tools or spatial decision support systems (SDSS) have been developed to support such complex decision-making processes (Uran & Janssen 2003, Geertman & Stillwell 2004), stimulated by the recent major developments in information and communication technology (Geertman & Stillwell 2003). Newer generations of GIS offer more sophisticated and extensive database management and display capabilities, and are much more user-friendly (Malczewski 2004). Furthermore, the availability of affordable geo-data has increased. A specific group of spatial decision support tools has materialized under the generic term Planning Support Systems (PSS) (Harris 1989, Brail & Klosterman 2001, Geertman 2002, Geertman & Stillwell 2003). PSS intend to support planning processes (Geertman 2002), based on the assumption that an increase in access to relevant information will lead to a greater number of alternative scenarios, and thus a better informed public debate (Shiffer 1995). However, recent studies show that the adoption and use of PSS is far from widespread, and PSS are far from being effectively integrated into the planning process (Stillwell et al. 1999, Uran & Janssen 2003, Geertman

& Stillwell 2004, Vonk et al. 2005). Although planners and designers have more and more access to large volumes of geo-data, the use of geo-information systems (GIS) focuses mainly on spatial queries and generating thematic maps. Progress towards the use of GIS beyond these basic activities to help solve key planning problems through more sophisticated analyses has been very limited (Stillwell et al. 1999, Vonk et al. 2005). Only a small percentage of planners consider geo-technology as an intrinsic and indispensable tool for performing their job properly. Couclelis (2005) argues that the role of land-use modeling in general remains problematic, especially with respect to the enhancement of the future-oriented, strategic mission of planning.

Some explanations for this situation are the diversity of analytical tasks that planners perform, the relatively small market for public sector software, and the expense of developing and supporting commercial software (Geertman & Stillwell 2003). Despite the fact that the application of GIS within planning practice has increased (Geertman 2002), current geo-information tools are too complex, too inflexible, incompatible with most planning tasks, and technology driven rather than user oriented (Nedovic-Budic 1998, Geertman & Stillwell 2003, Urun & Jansen 2003, Vonk et al. 2007a).

1.2 Goal and research questions

The main goal of this thesis is to explore the use of spatial planning support systems (PSS) for regional, strategic spatial planning of metropolitan landscapes. The emphasis is on PSS that support the balancing of economic against environmental objectives in spatial planning.

The two basic research questions are:

1. What strategic spatial planning approaches and methodologies are required to deal with the complex and dynamic development of metropolitan landscapes?
2. What type of planning support systems (PSS) are needed to support the strategic spatial planning of metropolitan landscapes and what are the requirements for the successful implementation and use of such PSS in planning practice?

1.3 Scope of the research

Since the domains of spatial planning and planning support systems (PSS) are very wide, the scope of this research is limited to PSS for supporting strategic spatial planning processes. Furthermore, the research specifically addresses the use of PSS in two case studies: (1) the integration of environmental issues in spatial planning in the Netherlands, (2) the sustainable spatial planning of future intensive livestock farming in South-East Asia. The research methods applied will be described with the successive case studies and papers included in this thesis. The use of the terms *strategic* and *spatial* in combination with *planning* in the thesis is explained below.

Strategic planning in general can be described as the systematic, integrated approach of policy making, which takes into account context, resources and the long term (Dimitriou & Thompson 2007a). Strategic planning has a holistic view and is widely employed in the world of the military, commerce and knowledge management (Steiner 1997, Dimitriou 2007).

Spatial planning is an overarching term, which gives geographical expression to the economic, social, cultural and environmental policies and demands of society. Spatial planning according to the European Spatial Planning Observation Network (ESPON) aims to create a more rational territorial organization of land uses and the linkages between them, in order to balance the demands for development with the need to protect the environment, and to achieve social and economic objectives. Dimitriou (2007: p. 46) defines spatial planning as: "[…] a set of policies and tools of intervention at different levels and for different horizon dates, designing to assist the management of strategic change taking place within territories, their economies and societies, directed largely (but not exclusively) by the public sector." Planning in this context is (Dimitriou 2007):

- Spatial – deals with the specific needs and characteristics of places;
- Sustainable – looks at short-, medium- and long-term issues;
- Integrative – in terms of knowledge, objectives and actions involved;
- Inclusive – recognizes the range of actors involved in planning.

Strategic spatial planning concerns major spatial developments, which may arise on any scale, but are more typical for the regional and national scale (Faludi 2000). This thesis especially focuses at the regional scale. Strategic spatial planning at this level is a typically public-sector-led socio-spatial process, aimed at influencing the future spatial distribution of activities (Albrechts 2004a, Dimitriou & Thompson 2007a). According to Albrechts (2004a) this requires a planning approach that produces visions, actions and means for implementation, which shape and frame the present and future spatial organization of an area. He sees spatial plans as strategic frameworks for action, and strategic spatial planning as a set of concepts, procedures and tools which must be tailored to the specific situation at hand.

Strategic spatial planning processes are more democratic and transparent, more complex in character and often slower to arrive at an agreement compared to processes in the corporate and military worlds. A main reason is the large number of stakeholders, "[…] many of whom have greater expectations of their views being taken into account than is often realistically possible" (Dimitriou 2007: p. 47).

The adjective *strategic* may have several other meanings and associations which are important to clarify (Faludi & van der Valk 1994). The first association is of strategic planning as the opposite of operational planning (cf. Table 1-1). Faludi & van der Valk (1994) suggest that the difference between the two is better expressed by using *project planning* instead of operational planning. Another complementary association is that of strategic projects. These are a specific group of large-scale projects that

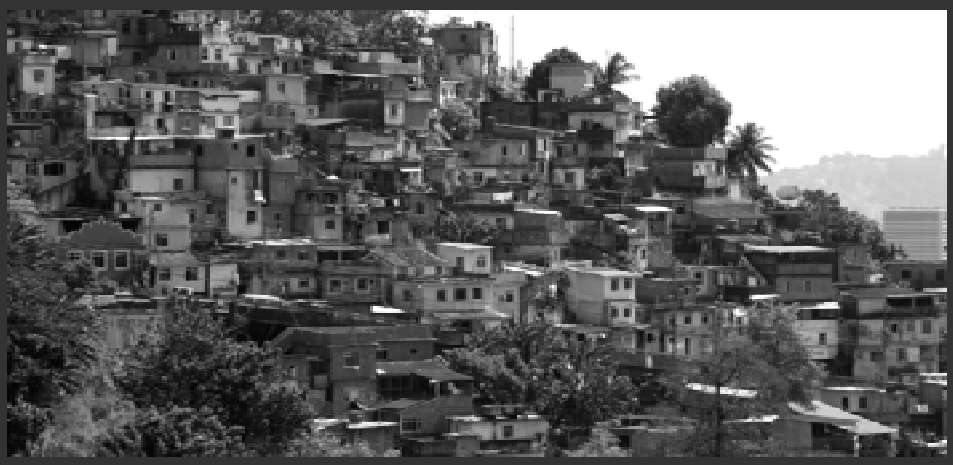
are considered strategic because they determine the context in which planning takes place (Faludi & van der Valk 1994). A third association is that with strategic choice, as advocated by the strategic choice approach (Friend & Hickling 2005, see also Section 2.3). Strategic choice specifically refers to the complexity of decision making and the dilemma of rational choice from a range of relevant decision options. A fourth association is with corporate strategic planning, for example, in the United States described as the opposite of comprehensive planning. However, Dutch spatial planning is precisely this: comprehensive, holistic and addressing the various aspects of development of an entire area (Faludi & van der Valk 1994).

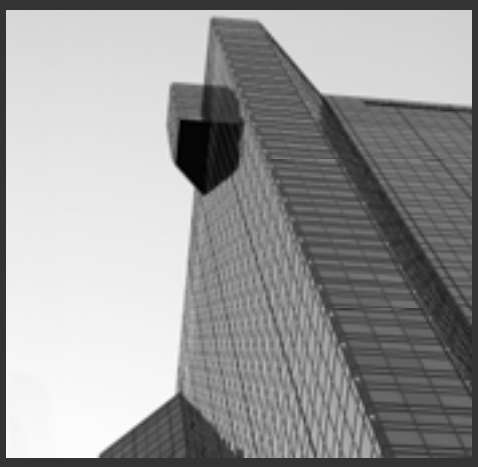
1.4 Organization of the thesis

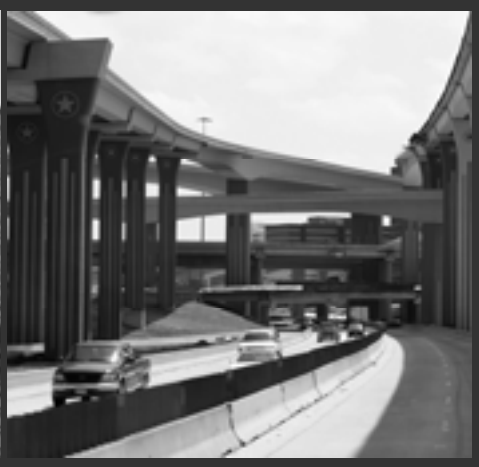
Chapter 2 provides the underlying planning theory of the thesis by introducing the domains of land-use and environmental planning of the Wageningen spatial planning program. The domains of this program are traditionally the land-use and environmental planning issues in rural areas and the urban-rural interactions. The last decade, these domains are facing the growing complexity of the metropolitan landscapes in the Netherlands, Western Europe and many other parts of the world. The Wageningen planning program focuses at intertwining two (seemingly) contrasting planning philosophies: a design-oriented and a decision-oriented view of planning. It tries to find a balance between procedural, substantive and communicative knowledge and skills, all necessary to deal with the increased complexity of strategic spatial planning for the metropolitan landscape. Chapter 3 provides an overview on the field of planning support systems (PSS), and introduces the different case studies of the thesis. Chapter 4 includes a series of five papers with the results of these case studies, published in internationally reviewed journals and a book. Chapter 5 discusses the overall results of the cases and concludes the thesis by presenting some general conclusions and recommendations.

Chapter 2

Spatial planning for metropolitan landscapes







This chapter provides the theoretical framework of the thesis by introducing the domains of land-use and environmental planning in the tradition of the Wageningen planning program. This planning program tries to balance procedural, substantive and communicative knowledge and skills, all required to deal with the increasing complexity of spatial planning for the metropolitan landscape, by promoting the intertwining of elements from two (seemingly) contrasting planning philosophies: the decision-oriented and the design-oriented view of planning. Section 2.1 provides a brief introduction to planning theory, meant to frame the decision- and design-oriented views of planning. Section 2.2 describes the context and object of planning in this thesis: the metropolitan landscape. The decision- and design-oriented views of planning are introduced and described in more detail in the Sections 2.3 and 2.4 respectively. Section 2.5 discusses the philosophy and revenues of intertwining the design- and decision-oriented views of planning, in the context of strategic spatial planning for the metropolitan landscape. This section also describes the experiences with intertwining both approaches in the Wageningen spatial planning program. Section 2.6 discusses the implications for the development of spatial planning support tools.

2.1 Introduction

'What is planning?' is not an easy question to answer. In general, planning refers to a systematic process of preparing activities or actions that are required to create a desired future. Friedmann (1987: p. 48) defines planning as "[…] an attempt to relate scientific and technical knowledge to actions in the public domain". Actions in this definition include both social guidance and transformation. Healey (1997: p. 7) states that planning "[…] represents a continual effort to interrelate conceptions of the qualities and social dynamics of places with notions of the social processes of 'shaping places' through the articulation and implementation of policies". In this definition 'conceptions' represent knowledge, and 'social processes' represent actions (as in Friedmann's definition). Both definitions illustrate the close relationship between planning and its social context. As a result, the specific meaning of planning will depend on the political, social and economical context in which it is being used and the purpose of the planner (Sandercock 1997).

Planning in the context of this research refers to public policy and decision making. This type of planning usually involves planning processes that are described in formal procedures, and results in the creation of documents, plans, strategies or other specific output. De Roo (2003) and de Roo & Voogd (2004) distinguish three elements of governmental planning, related to three action-oriented questions:

- What must be achieved? This involves the material object or content of planning (goal- or object-oriented);
- How can it be achieved? This concerns the rationalization of choices made in the decision-making process (decision-oriented);
- Who will be involved? This has to do with the organization of the decision-making process (institution-oriented).

These questions touch upon the classic debate on the relative importance of procedural planning theory, substantive knowledge and, more recently, communicative skills in planning (Faludi 1978, Schön 1987, Osawa & Seltzer 1999, Alexander 2001, White & Mayo 2004, Fubini 2004). The distinction between procedural and substantive theory has been dominating the debate on planning theory since the 1960s. It originates from the systems and rational views of planning that emphasize process above substance (Almendinger 2002b). Systems and rational planning approaches perceive planning as a general societal management process (Healey et al. 1982), based on the underlying assumption that the developments in society can be predicted and controlled (Almendinger 2002a). Therefore, planning theory is traditionally highly affected by social science theory (e.g. Friedmann 1996). In the early 1980s, influenced by post-modernism and post-positivism, planning theory started to move away from causal reasoning and to reject the logic of positivism. This resulted in a variety of new perspectives on planning.

As a consequence, the planning literature contains hundreds of different approaches of planning. Some of the core planning approaches discussed in the literature include the rationalist approach (Dror 1963), the incrementalist approach (Lindblom 1959), the mixed scanning approach (Etzioni 1967), the systems view approach (McLoughlin 1969, Chadwick 1971), the decision-centered view of planning (Faludi 1978, 1987) and more recent, postmodern planning (Beauregard 1989, Sandercock 1997), the institutional approach (Salet 2000) and collaborative planning (Healey 1997, Forester 1999, Innes & Booher 1999, Huxley 2000). Providing a detailed study and typology on all approaches falls not within the scope of this thesis. Such overviews are presented, for example, by Healey et al. (1982), Friedmann (1987), Yiftachel (1989) and Almendinger (2002b). Instead, some specific planning views and methods, promoted by the Wageningen spatial planning program, and relevant in the context of this thesis will be identified and discussed.

The domains of the Wageningen planning program and of this thesis as well, are traditionally the land-use and environmental planning of rural areas and the urban-rural interactions. The last decades, these domains are facing the growing complexity of the metropolitan landscapes that can be found in Western Europe and many other areas in the world (see also Section 2.2). In metropolitan landscapes, planners and decision-makers have to deal with a diversity of increasingly involved stakeholders, with often conflicting objectives (van der Valk 2002, Albrechts 2004a). Albrechts (2004a) argues that the spatial planning for these complex situations asks for the ability to combine the creation of strategic visions for the future development of these areas with short-term actions. The Wageningen planning program promotes a similar philosophy. The planning program aims to gradually teach, practice and intertwine methods and techniques from design- and decision-oriented views of planning, and tries to find a balance between procedural, substantive and communicative knowledge and skills, necessary to deal with the increased complexity of spatial planning for the metropolitan landscape.

The decision-oriented view originates from the rational process theories of planning and decision making (Faludi 1987). Rational process planning typically involves a logical and systematic process of identifying policy goals, analyzing, generating and evaluating policy alternatives, and monitoring performance (Healey et al. 1982). Rational process planning was an answer to the criticism that systems planning failed to deal with the complexity of competing objectives of the growing multitude of actors, offered only limited possibilities for stakeholder involvement and simply imposed a blueprint on them (Faludi 1987, Faludi & van der Valk 1994). Systems theory does not appreciate the extent of the political complexity involved (Almendinger 2002a).

But contrary to the rational process theories, the decision-oriented view promotes a bottom-up approach of planning in order to enhance the effectiveness and legitimacy of spatial planning. The different interests of stakeholders in society are taken as a starting point of planning and decision-making. Therefore, decision-oriented planning is also referred to as 'sociocratic' planning (Faludi & van der Valk 1994). Sociocratic planning pays attention to the views of the different actors or stakeholders involved. The authorities are considered as one of these actors, and the planner's role is less central compared to technocratic or blue-print planning (Faludi & van der Valk 1994). Sociocratic planning is a form of collaborative or communicative planning. Communicative planning generally involves an interactive process of consensus building, plan development and implementation (Lowry et al. 1997, Margerum 2002). In communicative planning the planner's technical rationality based on knowledge and expertise, is replaced by communicative rationality, which is achieved by communication between actors and their effort to reach mutual understanding or consensus (Healey 2003). Decision making in this respect, is the outcome of discussions, and often conflicts, among actors with various forms and degrees of power (Faludi & van der Valk 2001). Decision-making by consensus is up to today a dominant planning style in the Netherlands (van der Valk 2002).

A representative decision-oriented method is the strategic choice approach that was developed by the Institute of Operational Research in the UK (Friend & Hickling 2005). Section 2.3 describes the philosophy of the decision-oriented view of planning and the method and techniques of the strategic choice approach in more detail.

The design-oriented or exploratory view of planning (in Dutch: 'Planning als richtingzoeken') emphasizes the construction of scenarios for the future spatial organization of an area (Kleefmann 1984, Hidding 2006). The design-oriented view promotes the construction of alternative futures with the help of creative leaps, then taking consecutive steps backward in time in order to arrive at feasible policy guidelines. It encompasses elements of a traditional survey-analysis-plan approach to planning, and makes use of scenario techniques (e.g. Dammers 2000, Xiang & Clarke 2003, Pettit & Pullar 2004). These techniques are indispensable for initiating debate about preferred or plausible futures. The design-oriented view of planning offers inspired visions of the future, founded upon existing planning policy or used to formulate new planning policy (Stillwell et al. 1999).

The design-oriented view should not be confused with the paradigm of planning as design that dominated city planning during the late 19th and first half of the 20th century. In the late 19th century, city planning emerged as a response to the demands in big industrial cities for better hygienic conditions. At first, city planning focused only at improving the infrastructure of cities, but at the turn of the century planners wanted to create more harmonic spatial systems, including both urban and rural areas. Different models and metaphors were designed that tried to "[…] achieve a balance between city and nature, economy and environment, and concentration and diffusion" (Salet 2000). Some examples are Howard's Garden City, Mumford's Regional Model, and the City Beautiful Movement (Hall 1988). Planning primarily focused at the physical form, the morphology and organization of spatial development, seeing the planning result as a design product. This type of planning is also referred to as technocratic planning, blue-print planning, and top-down planning (Healey 1997). Decision makers often had no alternative other than to accept or reject a plan as a whole, since the underlying assumptions remained largely hidden (Yewlett 2007).

The design-oriented view in contemporary planning builds upon the strengths of the rationalist approach and has its foundations in the systems approach of planning (McLoughlin 1969, Chadwick 1971). The basic objective of planning as a design discipline is to generate and assess tentative policy programs for realizing a desired spatial disposition of activities (Needham 2000), and to make policy makers and stakeholders aware of the potential implications of their choices, as well as to explore the boundaries of the range of choices. These should allow arriving at a more balanced judgment. However, Needham (2000) points to an important difference between spatial planning and many other design disciplines, e.g. architecture, industrial design, and interior design. As he states: "[…] it can be misleading to think of spatial planning – as a design discipline – as being mainly the designing of the spatial disposition of activities, buildings, and spaces (such as making a spatial plan, although that can indeed be part of the activity)" (Needham 2000: p. 443). The spatial configuration of an area in practice is created and changed by many public and private actors, while public bodies which practice spatial planning have only limited and often indirect influence on spatial developments. The design-oriented view of planning, therefore, aims to influence the actions of those who shape the spatial organization, by initiating a debate on likely and desired futures with spatial scenarios and map representations. The design-oriented view and some relevant methods and techniques will be described in more detail in Section 2.4.

Before going into more detail on the design- and decision-oriented views of planning, and the relevance of intertwining both, the context of planning in this thesis – the metropolitan landscape – will be further explored in Section 2.2.

2.2 Metropolitan landscapes

Tress & Tress (2004) present four definitions of the concept *metropolitan landscape*: (1) as a synonym for urban landscape, (2) as an agglomeration or administra-

tive area of a city or city region, (3) as a large supra-regional area and (4) as all space that is under the influence of urbanites and urban spheres. They argue that these categories do not reflect the precise meaning of metropolitan landscape, but summarize some general differences of the concept as used in current landscape research literature (Tress & Tress 2004). In this thesis the fourth, broad definition for metropolitan landscapes is being used, i.e. the area under the influence of urban activities and processes. Urban areas, in this respect, are defined as large cities and towns where a majority of the population has an income from activities in the urban economy.

Urban areas have been growing fast worldwide from the start of the 20th century. The urban population has increased from 13% in 1900 to 29% in 1950, reaching 50% in 2007. By 2030, 60% of the world population is expected to live in cities. The absolute numbers are even more impressive: from 220 million in 1900, to 732 million in 1950, and 3.2 billion in 2005 (United Nations 2006). Although some debate on the definitions of urban and rural area and the reliability of the projections of the United Nations (Bocquier 2005), the general trend of rapid urbanization is without any doubt.

Figure 2-1 and Table 2-1 show some significant differences in the rate of urban development between the different regions of the world, especially between the more developed and less developed countries. The table and figure also illustrate two of the dimensions of the process of urbanization: the proportion of the total population that lives in urban areas, and the growth in the proportion of the total population living in urban areas. This is further illustrated in Figure 2-2.

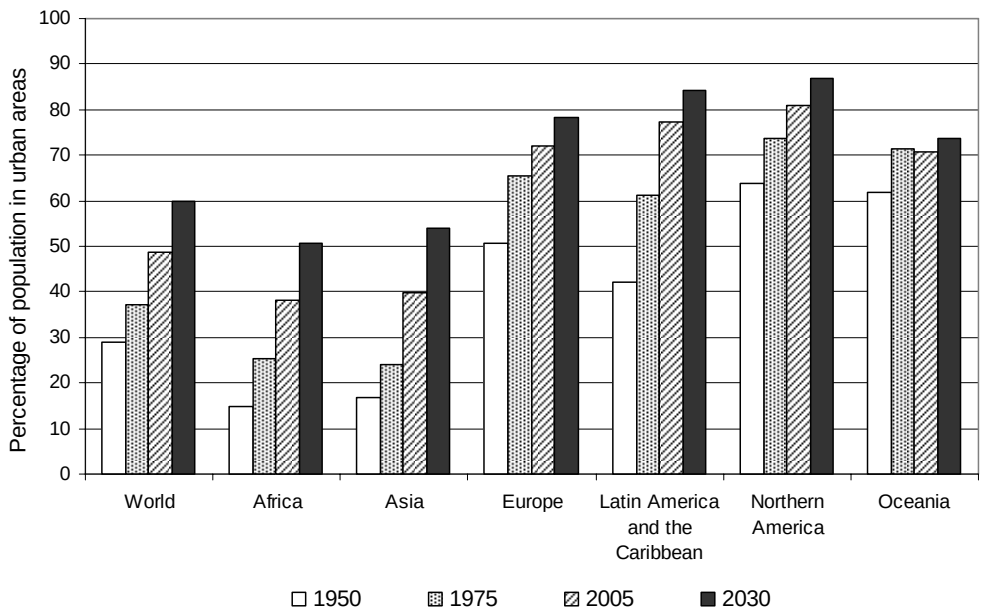


Figure 2-1 Percentage of population residing in urban areas in 1950, 1975, 2005 and the projected percentage in 2030 (United Nations 2006).

At present, 74% of the population in the more developed regions is living in urban areas, compared to 43% in the less developed regions. But the total number of urban residents is much higher in the less developed regions, and is projected to be four times as large by 2030 compared to the more developed regions, boosted by the rapid growth of the population in the less developed regions, and the stagnating growth in the more developed regions. Other driving forces of the urban growth in the less developed regions are the migration from rural to urban areas, accounting for 40 to 50% of the urban population growth, and the transformation of rural settlements into urban area (United Nations 2006). Figure 2-2 also shows another important difference, concerning the rural population. In the more developed regions the rural population has been declining steadily, while that of the less developed regions has been growing and is expected to growth further in the next decade.

Table 2-1 Total, urban and rural population by major area (United Nations 2006).

	Population (millions)				Average annual rate of change (%)	
Major area	1950	1975	2005	2030	1950-2005	2005-2030
Total population						
Africa	224	416	906	1463	2.54	1.92
Asia	1396	2395	3905	4872	1.87	0.88
Europe	547	676	728	698	0.52	-0.17
Latin America & Caribbean	167	322	561	722	2.20	1.01
Northern America	172	243	331	400	1.19	0.76
Oceania	13	21	33	43	1.72	1.01
Urban population						
Africa	33	105	347	742	4.29	3.04
Asia	234	575	1553	2637	3.44	2.12
Europe	277	443	526	546	1.17	0.16
Latin America & Caribbean	70	197	434	609	3.31	1.35
Northern America	110	180	267	347	1.62	1.05
Oceania	8	15	23	31	1.96	1.18
Rural population						
Africa	191	310	559	721	1.95	1.02
Asia	1162	1820	2352	2236	1.28	-0.20
Europe	271	232	203	152	-0.53	-1.16
Latin America & Caribbean	97	125	127	113	0.49	-0.45
Northern America	62	64	64	53	0.05	-0.73
Oceania	5	6	10	11	1.25	0.58

Historically, the largest urban growth takes place in countries with the highest economic growth rates, like today occurs in the South-East Asia region (Montgomery et al. 2003). Urban growth is generally a response to the concentration of the most dy-

namic economic activities and the related growth in the number of jobs in urban centers. Concentration produces economies of scale (cost reductions realized by increasing the size of operations) and leads to social and economic benefits. Cities are therefore at the forefront of economic, social, political and cultural change (United Nations 2006). A significant difference at present is that the less developed countries are industrializing rapidly, while the more developed countries are shifting from manufacturing industry to finance, specialized services and information processing (Montgomery et al. 2003).

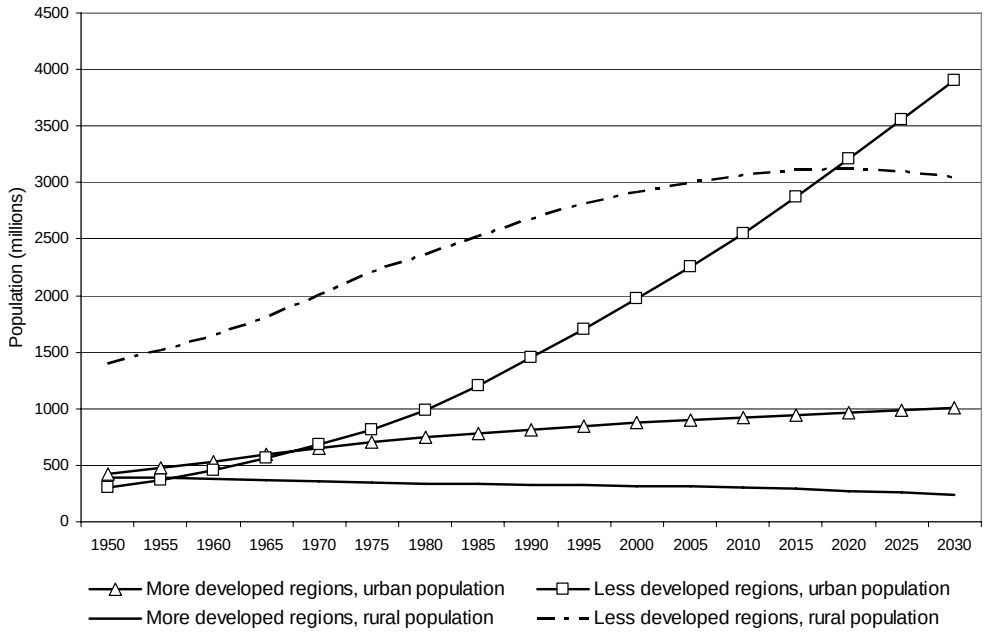


Figure 2-2 Urban and rural population of more and less developed regions, 1950-2030 (United Nations 2006).

Typically, metropolitan landscapes also include rural areas, which are exposed to many, increasing urban-rural interactions. The development of these areas is closely tied to the dynamics of the urban areas. Urbanization usually results in the loss of farmland, but the remaining rural area also becomes increasingly urban in character. A typical phenomenon is an increasing density of (economic) activities, residential houses, and recreational facilities, such as holiday homes, riding stables and golf courses. Urbanization significantly transforms the rural landscape, affecting physical, ecological and socio-economical processes at local to regional scale (Breuste et al. 1998, Luck & Wu 2002). Furthermore, due to a rise in the price of land and changes in the urban market, farms tend to change their agricultural production, and intensify or increase the scale of their operations, or diversify their production by extending the range of activities, e.g. by selling regional products or providing tourist accommoda-

tion. These developments usually have a large impact on the rural landscape, e.g. due to the construction of buildings or greenhouses (MNP 2006). Consequently, the urban-rural distinction is becoming more fuzzy (Antrop 2004b), and is often more a difference in degree rather than in kind (Montgomery et al. 2003).

Table 2-2 shows another major shift in agricultural production that is taking place in the metropolitan areas of developing countries such as China, Brazil and India, where livestock production is rapidly growing as a result of rising incomes and population growth (Delgado et al. 2002, FAO 2003, Steinfeld et al. 2006). In general, the growth in livestock production is supported by local governments for its importance to the employment of the local rural population, the export earnings, and its contribution to the local economic growth. The growth in production is mainly supported by industrial systems, achieved through growth in scale and a shift towards monogastric species production (Delgado et al. 2002, FAO 2003). The livestock production tends to concentrate near urban centers, favored by cheap input supplies (in particular feed) and good market outlets for livestock products. However, the quality of the environment is deteriorating as a result of the expansion of intensive and unsustainable farm practices, this in turn adversely affecting human health and the productivity of natural resources. The potential for maintaining fast economic growth may even be affected as the state of the environment continues to deteriorate (OECD 2005).

Table 2-2 Past and projected consumption of meat in developing and developed countries (Steinfeld et al. 2006).

	Developing countries					**Developed countries**				
Food demand	1980	1990	2002	*2015*	*2030*	1980	1990	2002	*2015*	*2030*
Annual per capita meat consumption (kg)	14	18	28	32	37	73	80	78	83	89
Total meat consumption (million tons)	47	73	137	184	252	86	100	102	112	121

Given the increasing rate of urbanization (and related processes) throughout the world it is increasingly important in spatial planning to deal with the consequences (Luck & Wu 2002). However, planning metropolitan landscapes also means dealing with many types of uncertainty (Antrop 2004a). These uncertainties are related to, for example, the dynamics of urban development, the complexity of processes, and the lack of reliable and up-to-date information. The already complex task of managing the growth of cities in the metropolitan landscape is becoming even more complex, since cities and their influences at the rural area tend to expand beyond existing administrative and political boundaries. Furthermore, management and governance are undergoing fundamental changes, as many national governments are decentralizing policy and decision making to the lower tiers of government. In general, many local governments are not well equipped with the capacity and means to take on these new responsibilities (Montgomery et al. 2003).

Spatial planning in metropolitan landscapes is often caught up between two seemingly contradictory dimensions: economic development and environmental conservation. Development in this respect refers to durable socio-economic existence, while conservation refers to the safeguarding of our natural systems and resources. Planners and policy makers, in the tradition of rational planning, typically aim to maximize the benefits and minimize the costs of land use, usually facing short-term economic benefits and long-term environmental costs (Birkeland 2002). Local governments tend to accentuate the first and undervalue the second, especially in growing economies such as China (Beyer 2006). Due to decentralization and economic reform, the Chinese local government has transformed from a passive regulator in the previous planned economy to an entrepreneurial agent that initiates local developments (Oi 1995, Walder 1995). The local government typically favors economic benefits from urban development and industrialization over the protection of farmland and natural resources, and national policies and regulations have not been very effective in reducing environmental impacts (OECD 2005, Beyer 2006). As a result, the state of the environment in China is deteriorating fast, adversely affecting human health and natural resources. It is estimated that the damage caused by environmental pollution and degradation of natural resources consumes up to 8% of China's GDP, roughly equal to the annual growth of the country's economy (Schmidt 2002). The current Chinese spatial planning system is unable to manage and guide the process of urbanization, involving many different stakeholders, conflicting interests and rapid transformations. Some important reasons are the traditional top-down character of policy and planning, conflicting interests at the different administrative levels, and a lack of engaging relevant stakeholders and the general public (Friedmann 2004). These problems are typical for many other developing regions in the world.

Many authors make a plea for reaching socio-economic goals without compromising the environment (e.g. McHarg 1969, Forman 1995, Birkeland 2002). Given the rate of urbanization and its related problems this poses considerable challenges for planners and governments. The spatial planning of these complex situations asks for strategic, regional perspectives on the future spatial developments of metropolitan areas, as well as measures and tools to affect and redirect current developments. Albrechts (2004a) states that the spatial planning for the complex metropolitan landscape asks for approaches that combines the creation of strategic visions for the future development of these areas with short-term actions. It can be argued that such approaches will be relevant for complex, dynamic spatial planning problems in general.

2.3 Decision-oriented planning

The decision-oriented view of planning (Faludi 1987, Faludi & van der Valk 1994, Faludi 2000) emphasizes the communicative and interactive nature of planning practice (see e.g. Forester 1999, Healey 1997, Innes 2004). It is a response to the more traditional approaches where governmental agencies dominate spatial planning processes, which raised questions in terms of legitimacy and effectiveness (Salet & Faludi 2000). Planning as a communicative or collaborative process has gained increasing

popularity in contemporary literature on planning theory (Almendinger 2002a), and marks the shift from the logical-positivist tradition towards theory based on participation and communication (de Roo 2003). Communicative planning has also become one of the most accepted approaches in contemporary planning practice (Salet & Faludi 2000). Communicative planning takes the interaction of the diverse actors, including planners and decision-makers, as a starting point. Communicative planning intends to achieve – the idea of – interdependence between actors (Innes & Booher 2000), as the actors familiarize with each others interests through communication. If the interests are diverging, the actors discuss and negotiate about their common goals and interests. The planner's role is to organize and facilitate the communication and negotiation process. Van Ark (2005) showed the important role of trust in these processes. Trust among actors is an important condition for coping with complexity and uncertainty. "If trust is absent, co-operation in networks will not last" (van Ark 2005: p. 176). Ideally, the actors will reach inter-subjective understanding and recognize each other's interests, which is a prerequisite for formulating common goals and developing a strategy or spatial plan (Aarts & Maarleveld 1999).

The decision-oriented view of planning has its scientific foundation in Popperian social philosophy and epistemology (Faludi 1986). Decision-oriented planning takes day-to-day decisions and the anticipated consequences as a starting point. It focuses on systematically working towards policy frames and a commitment package. The emphasis is on the here and now. Decision-oriented planning is built on the foundations laid by the pioneers of strategic choice (Friend & Jessop 1969, see also Burns 2004). Planning in this respect is considered a process of choosing strategically through time, in a context of uncertainty (Friend & Jessop 1969, Friend & Hickling 2005). The process results in operational decisions, taken by the actors involved, who declare definite commitment to the decisions at stake (Faludi 1987). The objects of planning are decisions, and planning in this respect is synonym to decision-making. It comprises all activities that play a role in arriving at a decision, except for the formal enactment or authorization. The essence of planning in the decision-oriented view is that of a rational process of weighing the pros and cons of some alternative courses of action or packages of measures for the future. A coherent package of related measures is considered a plan.

Faludi (2000) recognizes strategic choice as the best application of rational decision making in practice. Strategic choice has been introduced in the Wageningen planning program by van der Valk in 1999 (van der Valk & Carsjens 2005). The program addresses the method and techniques of strategic choice as described in the book 'Planning under Pressure' by Friend and Hickling (2005). The book explains the intricacies of choosing strategically, the organizational context, the dilemmas of decision making and the responses to uncertainty. The emphasis is on the philosophy of strategic choice perceived as a joint learning process.

The method of the strategic choice approach lays emphasis on the many feedback mechanisms in the planning process and its dynamics (Friend & Jessop 1977). These mechanisms and dynamics are shown in Figure 2-3, representing the four modes in the decision making process according to Friend and Hickling (2005).

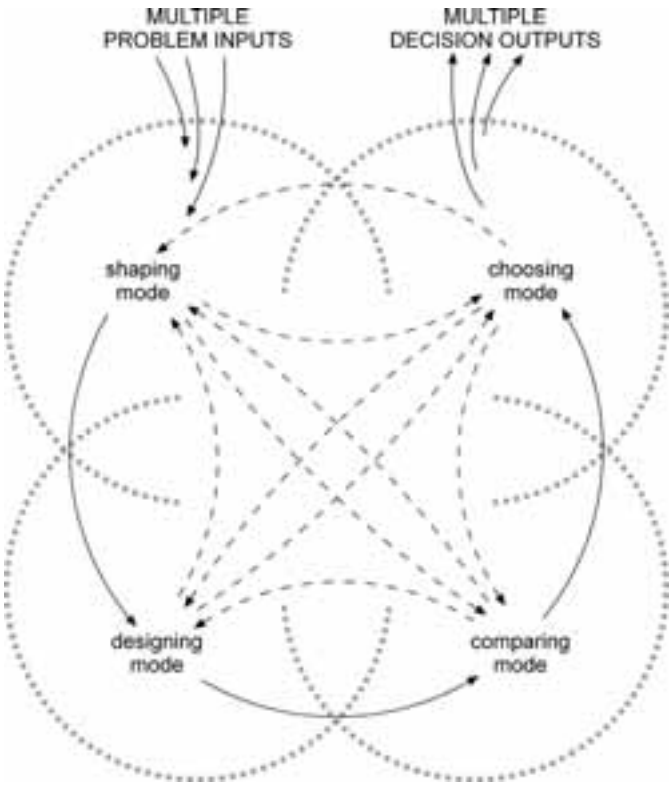


Figure 2-3 The decision process according to Friend & Hickling (2005).

The four modes of the decision making process will be described in some more detail below.

Shaping mode

The shaping mode focuses at identifying and structuring a complex decision problem resulting in a set of decision areas. A decision area is the most fundamental element of strategic choice, and defined as a problem situation where people see an opportunity to choose from different courses of action (Friend & Hickling 2005). In more complex problem settings, such as metropolitan landscapes, decision makers usually face a range or set of different decision areas. Typically, many decision areas will be interconnected. The power of the method is to draw a graphical representation of the structure of the problem in a so-called 'decision graph', as shown in Figure 2-4. In this graph the decision areas are represented by labeled circles, while connecting lines represent the presence or absence of a (decision) link. It sometimes will be possible to narrow down the complexity of the problem at hand, by re-arranging the graph and identifying a cluster of decision areas, the so-called 'problem focus' (and example is shown in Figure 2-4).

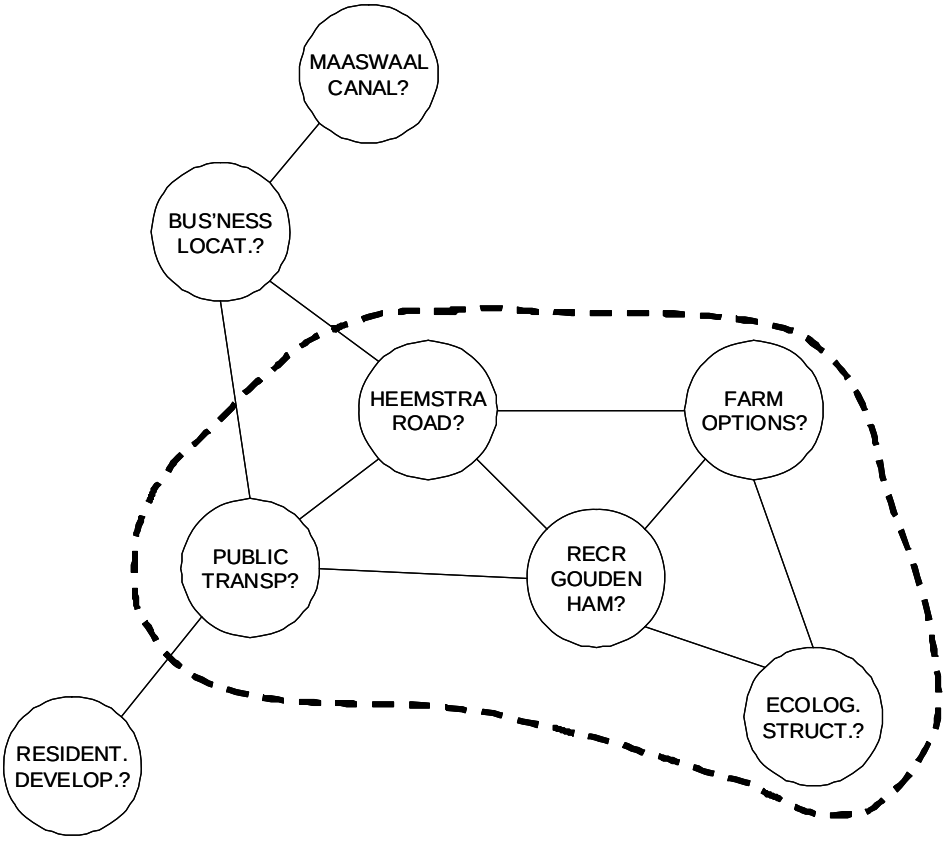


Figure 2-4 A decision graph representing a set of inter-connected decision areas, and a selected subset or problem focus (result from a regional strategic planning studio at the Wageningen University).

Designing mode

At this point, the designing mode commences, in which each decision area is explored further by identifying the decision options. These options should be mutually exclusive. Once the options are identified, a so-called 'option-graph' can be drawn, similar to a decision graph, but in this case showing the compatibilities and incompatibilities between pairs of options from different decision areas (see Figure 2-5). Subsequently, different combinations of compatible options, one from each decision area, can be identified. These alternative combinations of options can be graphically represented by a so-called 'decision scheme' or option tree (Figure 2-6). The many graphs and schemes that are drawn during the process are powerful instruments to facilitate discussion (Yewlett 2007). It is important to realize that these graphs are not static, but tend to change frequently during the process as work on the problem proceeds (Friend & Hickling 2005).

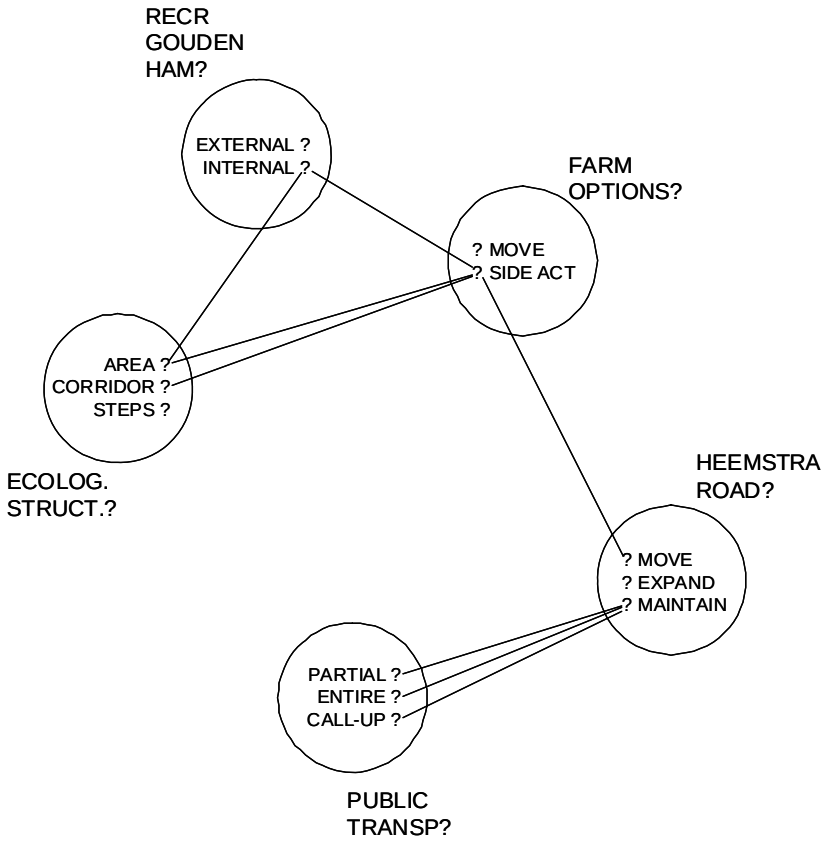


Figure 2-5 An option graph representing the incompatibilities (lines) and compatibilities of options within the problem focus (result from a regional strategic planning studio at the Wageningen University).

Comparing mode

The comparing mode focuses at the comparison of the consequences of the alternative schemes or courses of action, by building up a set of comparison areas that reflect the more important areas of difference between the options at hand. Therefore, several assessment techniques and sources of information might be used, ranging from highly intuitive to precise calculations, depending on the specific context and information and expertise at hand. Since the designing mode usually results in a huge range of possible alternative schemes, it may also be necessary to reduce these to a more restricted working list, e.g. by using constraints or by ranking the schemes on each of the comparison areas.

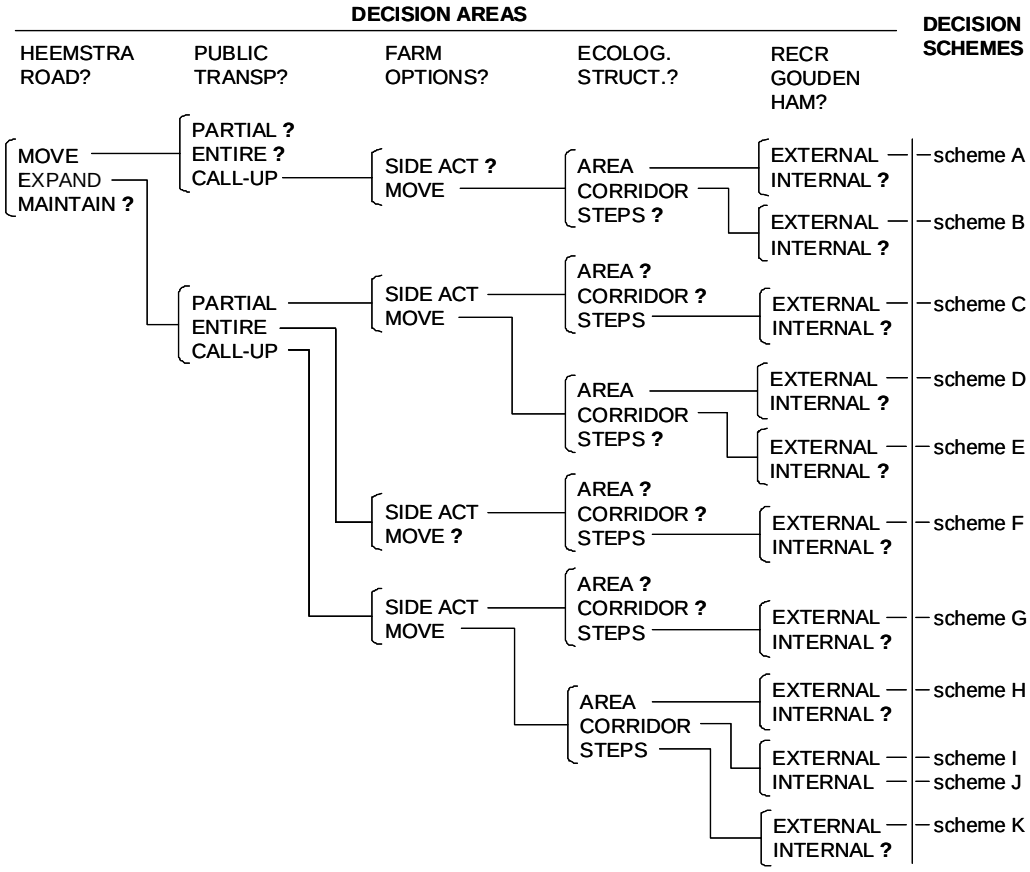


Figure 2-6 An option tree showing decision schemes, the feasible combinations of options (result from a regional strategic planning studio at the Wageningen University).

Choosing mode

The choosing mode deals with the management of uncertainties and development of commitment in time. The time dimension comes to the fore, as the urgency for immediate actions are balanced against concerns that the decisions may be too difficult to address before further explorations are carried out (Friend & Hickling 2005). The term 'strategic choice' (Friend & Jessop 1977) reflects the key concept that decision makers constantly meet uncertainties of various types in the decision process, and search for strategies to deal with these uncertainties, recognizing that uncertainties are unavoidable and cannot be ignored (Yewlett 2007). Friend and Jessop (1977) distinguish uncertainties related to the nature of the working environment and the likely results of proposed actions (UE), uncertainties related to the guiding values of involved stakeholders (UV), and uncertainties that come with agencies operating in related areas of choice (UR) (see Figure 2-7). More recently, Couclelis (2005) added a fourth category of uncertainty related to the reliability of planning support models (UM). The first three types will be explained here, the latter discussed in Chapter 5.

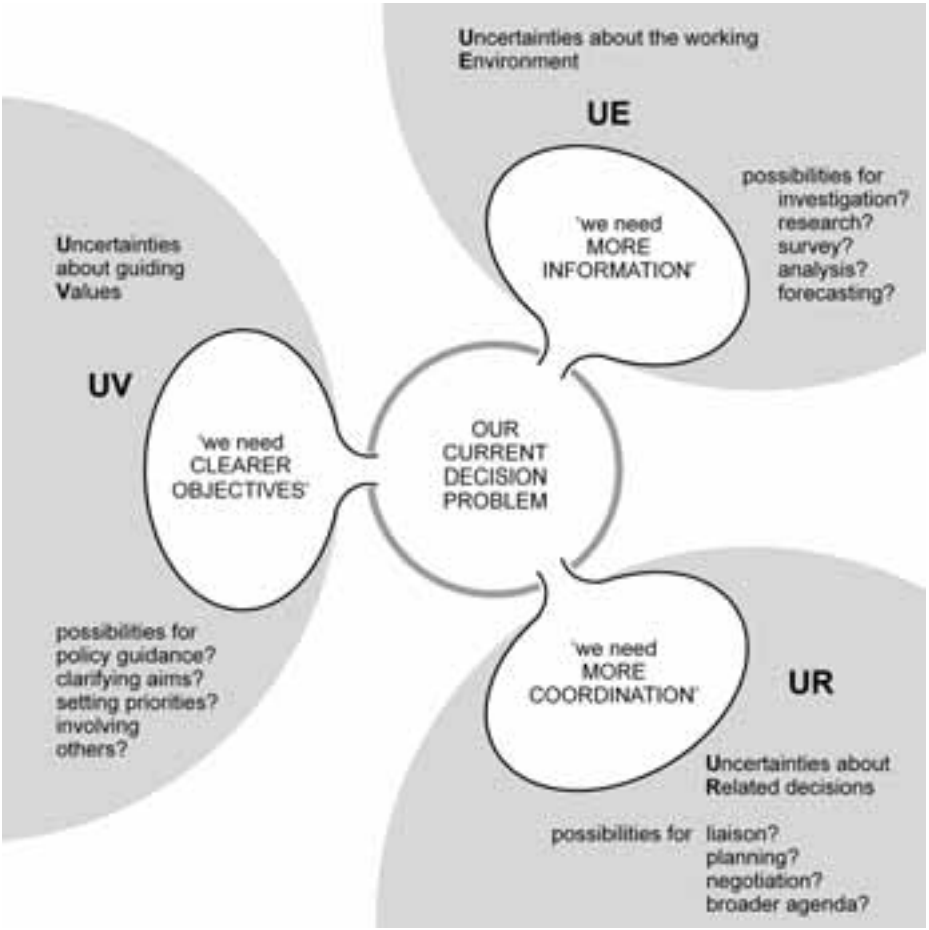


Figure 2-7 Three types of uncertainty in decision making (Friend & Hickling 2005).

The uncertainties about the working environment (UE) are associated with the common struggle of policymakers with the feeling that there is a shortage of information. These uncertainties can usually be reduced by conducting research and surveys. The strategic choice approach accentuates the importance of carefully analyzing the uncertainties before making any decisions about conducting research. Decision makers should consider the relevance of additional information and the available resources first, in order to prevent large quantities of irrelevant information or a waste of money.

The second category of uncertainties (UV) concerns the fact that the government manifests itself in many forms, such as different administrative tiers (municipalities, provinces, and national government), functional administrative bodies and semi-governmental organizations. Even in a situation that legislation and rules appear to be clear, in practice these are often interpreted differently by various governmental organizations, as a result of diverging values and beliefs, which also tend to change in time. These uncertainties might be reduced by consulting political leaders and decision

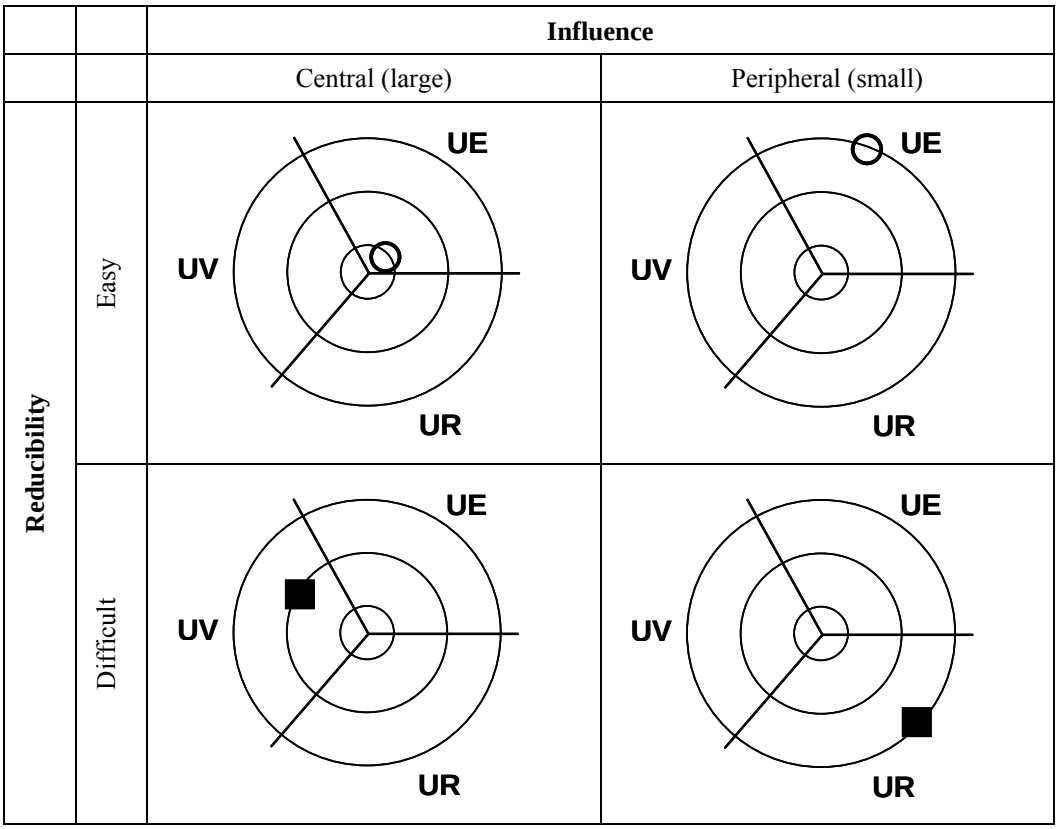
makers, and the participation of relevant societal groups in the planning process, especially in the phase of formulating aims and objectives.

The third category (UR) concerns the uncertainties about the relationship or coherence of decisions and measures. Governmental organizations prepare many plans and measures, in multifaceted as well as sector policy fields, which have spatial consequences. When preparing a new spatial or land-use plan, it often shows difficult to determine the relationships with measures in these other plans. These uncertainties may be resolved by coordination between individuals and organizations and the gathering of information, through the exchange of information between actors in the social network.

The strategic choice approach offers techniques to map the magnitude and reducibility of the uncertainties involved, and to assess the possibilities to reduce their influence on the relevant decisions. First, the influence exerted by a specific form of uncertainty is estimated, which results in a differentiation in central and peripheral uncertainties. Central uncertainties are considered of crucial importance in ranking and selecting the remaining alternative schemes, while peripheral uncertainties are of minor importance. A second distinction is being made in the required effort to reduce a specific uncertainty. Uncertainties that can easily be reduced are referred to as soft uncertainties, while uncertainties that cannot be reduced, or only with great effort, are referred to as hard uncertainties. The uncertainties can be presented graphically in a diagram in the form of a target, with three target areas representing the three types of uncertainty (see Figure 2-8). Four categories of uncertainties can be distinguished in the target:

1. *Central, soft uncertainties.* The obvious advice is to reduce this category of uncertainty. This situation requires research (UE), alignment between the parties (UR) and/or participation and political consultation (UV).
2. *Central, hard uncertainties.* This is a difficult category for which no unequivocal advice can be given. If uncertainties cannot be reduced, it makes sense to incorporate as much flexibility into the plan or policy as possible.
3. *Peripheral, hard uncertainties.* Since this category of uncertainties cannot be reduced easily and is of only minor importance, the most rational option will be to disregard these uncertainties.
4. *Peripheral, soft uncertainties.* Although these uncertainties are of minor importance, it makes sense to explore how much effort is required to reduce the uncertainty. For example, if one telephone call will be sufficient, it is worth the effort to reduce the uncertainty.

Summarizing, the strategic choice approach provides different techniques for identifying and managing uncertainties in a way that gives decision makers flexibility of future choice. The basic idea is that some alternatives (decision schemes) leave open more opportunities for future choice than other alternatives, and therefore have advantages in their capacity to respond to eventualities in future (Friend & Hickling 2005).



Soft uncertainties (see text for explanation)

Hard uncertainties (see text for explanation)

Figure 2-8 Determining the magnitude of uncertainties.

The strategic choice approach offers a simple technique for comparing action schemes for flexibility, by the use of the so-called robustness index. Friend and Jessop (1977) define robustness as the insensitivity to assumptions, and they argue to make plans robust whenever outcomes are uncertain. A robust action is preferable to other actions, since it leaves open a wider range of acceptable paths for the future (Friend & Hickling 2005). It might be useful to defer decisions on decision areas which are urgent but subject to major uncertainties that can be reduced by further exploration. The choosing mode therefore aims to design a commitment package, including a set of immediate decisions on actions and explorations to reduce uncertainties on the one hand, and a set of deferred choices and contingency planning on the other hand. The active management of uncertainties thus allows decision makers to decide upon some key decisions to be taken, while keeping other options open (Yewlett 2007).

The strategic choice approach thus offers some valuable tools and techniques for effectively dealing with the complexity and uncertainties inherent in the spatial planning of metropolitan landscapes. However, Faludi (1978) argues that even the best

multi-disciplinary team cannot combine all the knowledge necessary to solve the more intricate planning problems, indicating that uncertainties cannot be managed completely.

Friend and Hickling (2005) argue that the strategic choice approach should not be seen as a rigid recipe. It is important to realize that in planning practice, each problem is different and requires its own specific process. Therefore, the method of strategic choice should not be regarded a blue-print for solving problems, but instead as a toolbox with various tools, modes, techniques and activities which can be chosen to fit the problems at hand. Friend and Hickling state: "[…] there is no one right way to use the approach. There can be no 'correct' sequence in which to do things, and no prescribed combinations to adopt […]" (Friend & Hickling 2005: p. 214).

Relevance of strategic choice for contemporary planning

Almost forty years have passed since the foundations of strategic choice were first published by Friend and Jessop (1969). It seems appropriate to raise the question on the relevance of the method of strategic choice for contemporary planning and decision-making processes, and the development of PSS to support these. This question has also been addressed in several recent publications (Rosenhead & Mingers 2001, Bryson et al. 2004, Yewlett 2007).

An argument in favor of strategic choice is the increasing need for strategic and regional planning (Dimitriou & Thompson 2007a), especially in metropolitan landscapes (see also Section 2.2). This results in a need for approaches able to address complex planning issues in an interactive setting with stakeholders. In this context, the method of strategic choice offers valuable tools and techniques for dealing with the complexity of today's communicative planning and decision-making processes, especially with regard to organizing such processes and dealing with the many uncertainties involved.

An argument against strategic choice is that the method gives only little emphasis to substantive matters (Needham 2004), since its object of planning are decisions. The long-term consequences of these decisions on the physical and social environment are hardly explored. Furthermore, De Roo (2003) argues that the results of an interactive planning process can only be predicted to a limited extent, and will depend for the most on the actors involved. Consequently, some main potential problems and causes for decision failures in these processes are related to:

1. Mental models and cognitive maps that include decision premises or policies (Chermack 2004). Mental models are the lenses through which we see the world. These models house our biases, values and beliefs about how the world works. Cognitive maps give our sense of place and time, and are conceptions about where we are, what we are doing, our immediate path and where we are heading. Chermack (2004) argues that the mental models of actors or decision makers should be adjusted in order to change or expand their decision rules.
2. The bounded rationality of actors and decision makers. People are only partly rational and experience limits in processing information, and formulating and solving complex problems (Simon 1957, Chermack 2004). The concept of

bounded rationality is a response to strong criticism against rational choice theory. These critics refer to the fact that it is impossible to develop objective criteria for choosing between alternatives, that actors will never be able to generate and understand all feasible alternative courses of action, and to accurately predict and assess the consequences of these alternatives (Chermack 2004). Decisions on alternatives tend to be made on relatively few sources of information that are available and with less uncertainties involved (Morecroft 1985). Thus, rationality is context dependent and decisions are being made in the inter-subjective or constructed realities of actors (de Roo 2003). This form of rationality is also referred to as communicative rationality, as opposed to traditional (positivist) functional rationality. A 'drawback' of communicative rationality is that the resulting alternatives from a process of communicative decision making are bound by the knowledge about which a group of actors has reached agreement (Woltjer 1997, Voogd & Woltjer 1999). The exchange of arguments in a collaborative setting tends to result in 'grey' alternatives, which are acceptable to all the actors involved. Actors are often not able to see things from a new perspective (Higgins & Morgan 2000). Consequently, strategic choice can be regarded an obstacle for more inspiring and creative alternatives.

3. The stickiness of information and knowledge. Stickiness is a characteristic of information and refers to difficulties in the transfer of information among people and organizations. Stickiness is related to the costs of sharing and transferring knowledge and expertise which are required for decision making (Chermack 2004).

The method and techniques of strategic choice do not offer an entire solution to the complex and dynamic problems of the metropolitan landscape. Strategic choice lacks a more holistic, long-term perspective of the consequences for the environment of the choices at hand. Faludi (1987: p. 125) states that "[…] plans must be made *before* operational decisions, and from a *broader perspective* which […] represents a necessary […] addition to the considerations of operational decision-makers". But Faludi (1987) also argues that the longer in advance plans are made the larger will be the uncertainties involved. This requires flexibility of plans, in terms of the ability to match the content of a plan with operational decision-making as well as the ability to respond to new situations (Faludi 1987). Creative thinking can help to break away from traditional ways of thinking that may have lost their meaning and to unlock potential (Higgins & Morgan 2000). Creative processes can reinterpret information in a novel way and produce innovative solutions, which is particularly helpful in dealing with complexity and rapid changes. Higgins and Moran (2000: p. 126) state: "In order to meet the challenges of the 21st century, planners need to not only develop the capacity to creatively solve problems, but also develop a vision of what they want to achieve, and a mindset that is capable of reframing questions in new ways". This is where the design-oriented view of planning becomes of interest.

2.4 Design-oriented planning

Compared to the decision-oriented view of planning, design-oriented planning focuses less at the planning process (the 'how' question – see Section 2.1), and much more at the content of planning (the 'what' question). The prime object of planning in the design-oriented view is the spatial organization of the landscape. Design-oriented planning has been introduced in Wageningen by Kleefmann (1984). Planning in the design-oriented view aims to influence the actions of those who shape the spatial organization (thus also addressing the 'who' question), by initiating a debate on likely and desired futures with spatial scenarios and map representations. A spatial plan in this respect is regarded as a guiding document which describes a future situation, but a rough target and not a mandatory one like the blue-print plans of the 19th and 20th century (see Section 2.1). Steigenga (1962) describes such a planning process as not only descriptive and analytical, but above all constructive or action oriented. Kleefmann (1985) considers the 'action' as a learning process, with four subsequent phases with many feedback mechanisms (see Figure 2-9).

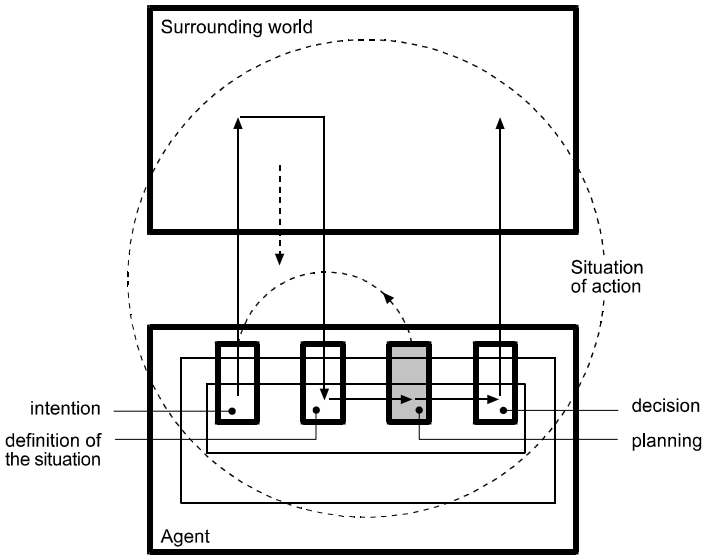


Figure 2-9 Planning as an action process (Eweg 1994, after Kleefmann 1985).

The four phases include (see also Eweg 1994):

1. Determining the intentions, the normative base, of actors. These intentions can be seen as the driving forces behind the action.
2. Constructing a definition of the situation, including a description and interpretation of the problems, opportunities and threats of an area. The process of defining and re-defining a situation results in new knowledge and views of actors.

3. The actual planning, including the generation of possible actions and the visualization of the consequences of these actions.
4. The evaluation of the results of the previous phases, including a comparison with the intentions. Afterwards, the actual decision-making will take place.

The goal of design-oriented planning is to develop tentative policy programs. These tentative programs should assist policy and decision makers in choosing the most desirable direction for future spatial development of an area (Eweg 1994). According to Kleefmann (1985) a tentative policy program should at least include a cartographic representation and description of the future spatial organization and its management aspects, a financial analysis, and a description of the processes that lead from the present situation to the described future. Its construction includes two basic steps: (1) the development of one or more coherent normative premises or so-called normative models, and (2) the construction of one or more conceptual or spatial models of the future spatial organization, based on these normative premises. Given the complexity it can only be constructed by an interdisciplinary team of specialists and planners working together (see also Steigenga 1962). Therefore, planning is regarded as a social learning process (Friedmann 1987) and an instrument for reconnaissance, i.e. a process of identifying tentative directions of development. Kleefmann (1985) argues that deriving the future situation from a systematic and projective analysis of the current situation, trends and policies only, which he calls a process of "overkraging" or corbelling, is often inadequate. Compiling a set of tentative directions for development is a complex task that cannot be achieved by simply modifying current trends. Kleefmann (1985) suggests a more holistic and prospective approach of bridging the gap between the present and the future by making leaps into the future (see Figure 2-10), which requires design competencies, especially inspiration, intuition and creativity. If attractive prospects are found, the consequences of these prospects as well as the opportunities to bridge the gap with the present situation can be analyzed and evaluated. Consequently, analysis, design and evaluation are alternating activities in the design-oriented view of planning, each requiring specific methods and tools.

Futures studies or visioning are at the foundation of design-oriented planning (Hidding 2006). Marien (2002) describes futures studies as a fuzzy multi-field with a huge variety of different types of future thinking. Similar, the term visioning has a wide range of different meanings (Shipley & Newkirk 1999). Marien (2002) defines six basic categories of futures, which are taken as a starting point for this research:

1. Probable futures, involving forecasting or predicting likely futures.
2. Possible futures, involving constructing alternative futures and scenarios.
3. Preferable futures, involving desired futures, and goal-setting and normative thinking for planning and policy making.
4. Present changes, including historical analysis, trend spotting and analysis.
5. Panoramic views, involving holistic, integrative thinking, mapping and environmental scanning.
6. Questioning, focusing at debate, reformulating, rethinking, participation, value and goal clarification.

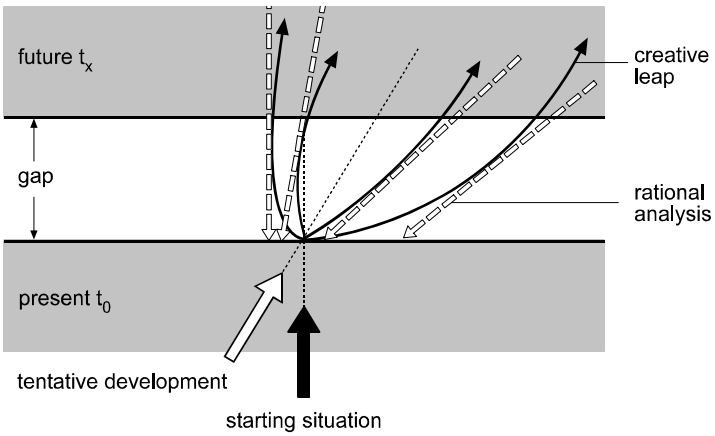


Figure 2-10 Bridging the gap between present and future (after Kleefmann 1985).

Marien (2002) argues that futures studies, ideally, include elements of all six categories in order to achieve a broad, integrative or panoramic view. Many other typologies of futures studies focus primarily at the first three categories of futures (e.g. Masini 1993, Dreborg 2004, Couclelis 2005), while the last three categories are considered an integral part of the first three. Some typologies are constructed along the line of epistemologies in science (e.g. Inayatullah 1990, Tapio & Hietanen 2002, Bell 2003). The first three categories of futures of Marien also correspond with some principle questions decision makers or actors might ask about the future. These are (Börjeson et al. 2006: p. 725, in analogy with van Notten et al. 2003): "*What will happen?*, *What can happen?*, and *How can a specific target be reached?*". Börjeson et al. (2006) present a typology of future scenarios along the line of these three questions, with as main categories (a) predictive, (b) explorative and (c) normative scenarios, each divided in two sub-categories. The typology of Börjeson et al. (2006) is presented in Figure 2-11.

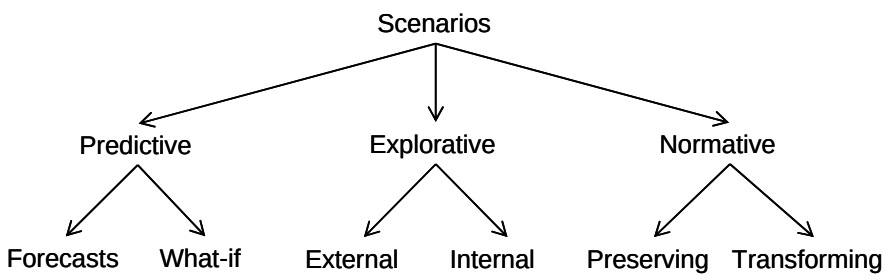


Figure 2-11 A scenario typology (Börjeson et al. 2006).

Ad a. Predictive scenarios

Predictive or projective scenarios aim to predict what will happen in future, and are related to concepts of probability and likelihood (Börjeson et al. 2006). Predictive scenarios include forecasts and what-if scenarios. Forecasts predict what happens if the most likely developments will unfold. What-if scenarios predict what happens if some specified event will occur. Predictive scenarios are usually developed from the present situation and are most suited for the short term, since the uncertainties involved for the long term are usually too great.

Ad b. Explorative scenarios

Explorative or prospective scenarios explore situations or developments that might happen, usually resulting in a set of scenarios from a variety of perspectives (Börjeson et al. 2006). Explorative scenarios resemble what-if scenario, but with a long-term horizon instead, and usually with their starting point in the future. Explorative scenarios are especially useful for strategic issues. Explorative scenarios include external scenarios and internal scenarios. External scenarios only focus at external factors that are outside the control of the relevant actors, such as climate change. Policies are usually not an integral part of external scenarios, but the scenarios can help to develop policies and strategies, or so-called robust strategies, that survive some kind of external development (Börjeson et al. 2006). The robustness of scenarios may be explored by considering potential crossing events. Robustness provides flexibility to allow for future change (see also Section 2.3). External scenarios are well known in the process of scenario planning (e.g. Peterson et al. 2003), in which they can act as a basis for discussion, and contribute to the creation of a common understanding among actors involved (van der Heijden 1996). Scenario planning was introduced by Royal Dutch-Shell around 1970, inspired by previous work of the American RAND cooperation during the 1950s and 1960s (Kahn & Weiner 1967, Dreborg 2004). Shell incorporated scenario development and the use of scenarios in the strategic planning of the company. Sets of different scenarios were developed in a participative process, including scenario analysis workshops with people of several management levels of the company.

Internal scenarios focus on internal factors which can be affected, and take external factors into account. These scenarios aim to describe how the consequences of a strategic decision may vary, depending on how the future developments unfold (Börjeson et al. 2006). Internal scenarios are useful for policy analysis and research.

Ad c. Normative scenarios

Normative scenarios have explicitly normative starting points, and focus on how specific situations or objectives can be achieved (Börjeson et al. 2006). Normative scenarios include preserving and transforming scenarios. Preserving scenarios are appropriate in situations when the future situation can be achieved within the current system, while transforming scenarios are appropriate if structural changes in the system are required. Preserving scenarios are usually about cost-effectiveness and optimization. In regional planning this is done in a qualitative way, where planners and

experts make judgments on cost-effective ways to reach specific environmental, social, economical and cultural targets (Börjeson et al. 2006).

In transforming scenarios the specific target cannot be reached if the current developments continue. This type of normative scenarios is well known in backcasting (e.g. Dreborg 1996, Quist & Vergragt 2006). Backcasting first creates a normative scenario – this might be a desirable future or undesirable future – followed by looking back at how this desirable future can be achieved or the undesirable future can be avoided and responded to (Robinson 1990). Main emphasis is to broaden the scope of actors involved, by describing new options and different futures. Usually a trend break will be necessary to achieve to target. Dreborg (1996) argues that backcasting is especially relevant in complex situations – alike those emerging in metropolitan landscapes – with a need for major changes, and where dominant developments are part of the problems at hand. Therefore, backcasting became popular in sustainability issues, such as exploring alternative energy futures, sustainable transport systems and regional developments (Quist & Vergragt 2006). Backcasting usually results in a number of target-fulfilling future images, and a discussion about the changes which are required to reach the images. It often has a long-term perspective, for example spanning 25-50 years depending on its context (Robinson 1990). Dreborg (1996) makes a plea for broadening backcasting by involving actors and stakeholders (see also Robinson 2003). In recent years, participative backcasting, involving broad stakeholder involvement, has been applied in several projects, e.g. in scenarios for sustainable urban living (Street 1997), sustainable areas in Europe (Rotmans et al. 2000), sustainable technology development (Quist & Vergragt 2006), and community visioning (Shipley et al. 2004, Gaffikin & Sterrett 2006).

Some basic characteristics of the presented types of scenarios are shown in Table 2-3 (after Börjeson et al. 2006).

Table 2-3 Characteristics of scenarios (Börjeson et al. 2006).

Scenario type	Quantitative/qualitative	Time-frame
PREDICTIVE – What will happen?		
Forecasts	Typically quantitative, sometimes qualitative	Often short
What-if	Typically quantitative, sometimes qualitative	Often short
EXPLORATIVE – What can happen?		
External	Typically qualitative, quantitative possible	Often long
Internal	Qualitative and quantitative	Often long
NORMATIVE – How can a certain target be reached?		
Preserving	Typically quantitative	Often long
Transforming	Typically qualitative with quantitative elements	Often very long

Design-oriented planning typically involves a combination of methods and techniques of scenario planning (external scenarios) and backcasting (transforming scenarios). Such a two-scenario-approach has also been suggested by Dreborg (2004). The basic idea is that the external scenarios of a scenario planning process provide a range of developments regarding factors that are outside the control of the actors involved, while backcasting offers a complementary range of possible developments for dealing with the issues at stake. The scenarios resulting from backcasting are also called policy scenarios, and typically include the use of policy measures leading to predetermined goals (Dreborg 2004). External and policy scenarios avoid the problem of trying to specifically predict the future, by not suggesting one single future but several possible or preferable futures, which is appropriate in complex situations with a high degree of uncertainty. External and policy scenarios can provide useful hints to select a way forward. The process of constructing external and policy scenarios usually includes some common steps (Schwartz 1991):

- Identify the focal issues to be addressed.
- Determine the certain and uncertain forces that are the key drivers over the defined period of time.
- Develop some alternative futures (external scenarios) around the key drivers.
- Develop narratives that describe likely pathways (policy scenarios) between the present and alternative futures, as a way of exploring the implications of different futures in order to make the actors understand some of the potential implications of the planning options at hand.

These steps are also included in a cyclic process described by Dammers et al. (2005), shown in Figure 2-12.

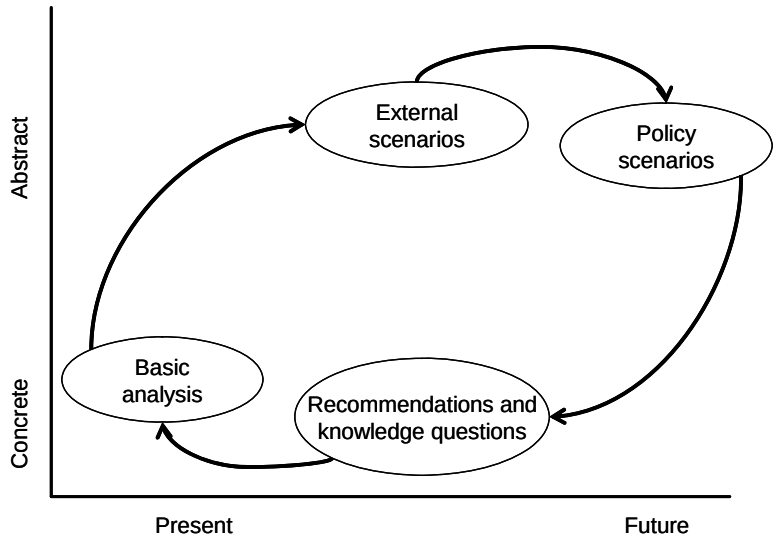


Figure 2-12 Cyclic scenario approach (after Dammers et al. 2005).

The cyclic scenario approach consists of four building blocks, including a basic analysis, the development of external scenarios and policy scenarios, and formulating recommendations and knowledge questions. The process moves along the axes from concrete to abstract and back again to concrete, and from the present to the future and back to the present. The building blocks are loosely coupled in content and sequence, and the cycle can be passed through repeatedly, at first briefly and in subsequent cycles in more detail (Dammers et al. 2003). The basic idea is that the actors progressively widen their scope during the process, which results in a fundamental "reframing" and allows the resolving of frame conflicts (cf. Schön & Rein 1994). This requires the actors involved to take a leap away from their usual perception of problem definitions, through the sharing of ideas and perspectives and by developing mutual trust (Schön, 1983). Therefore, the relevant actors need to be involved in the learning process actively, in order to stretch their perspectives on future developments and present policy making (Dammers 2000). The building blocks of the cyclic scenario approach will be described in more detail below.

Basic analysis

The basic analysis aims to provide a structured description of the present situation, dynamics and trends, including relevant policies and programs. The analysis should allow comparing the present situation with the future perspectives further on in the process. An important element of the analysis is to identify so-called focal issues. These are issues and trends that decision makers and actors consider relevant within the context of the spatial planning problem. Focal issues bear some resemblance with the decision areas in the strategic choice approach (see Section 2.3). Focal issues might be identified with the help of, for example, workshops, Delphi techniques, expert panels, mind mapping and brainstorms (ESPON 2004). From the focal issues a list of driving forces or exogenous variables are to be identified, which are considered the most significant in the external environment (Schwartz & Ogilvy 1998). In general, driving forces are the elements that drive the trends and the plot of a scenario, and determine the plausibility of their outcome (Schwartz 1991). In the domain of spatial planning, driving forces can be seen as external forces which directly or indirectly affect the planning problem at hand, and have a great impact on the future spatial development of an area. Driving forces can be related to social processes, such as demographic and economic development, but also to biophysical processes, such as climate change (Turner et al. 1995). Five basic types of driving forces are social, political, technical, environmental, and economical driving forces (Brandt et al 1999, Maack 2001). Table 2-4 gives an indicative overview and some examples of the different categories of external driving forces, without suggesting any strict boundaries between these categories. Which driving forces are relevant for landscape change, is determined by the spatial, temporal and institutional scale of the system under study (Bürgi et al. 2004). Driving forces are context specific and subject to change and uncertainties (Klijn 2004). The choice of driving forces depends on the actors' perspectives and normative values.

Table 2-4 Indicative categories of external driving forces (after Maack 2001).

Domain	Category	Examples
Social	Social factors	Education levels, social priorities, cultural and class tensions, land and water rights, gender issues
	Demographic patterns	Age, family, household and ethnic structures, migration patterns, wealth distribution
Economical	Macro-economic conditions	Gross domestic product, trade balance, inflation rate, financial markets, changes in national economic structure, regional trading blocks
	Micro-economic conditions	Change in size, type and ownership of firms, labor force structure, changes in economies of scale of key industries
	Market forces	Spending patterns of consumers, international demand for key exports, distribution and efficiency of rural and urban markets, sources of competition
	Impacts of global economy and development	Assistance from multilateral and bilateral agencies, harmonization, risk tolerance and conditions for entry and exit by international firms, stake in local economy by international firms
Environmental	Physical environment	Air, water and soil pollution trends and locations, environmental quality issues (global warming)
	Natural resources	Energy prices and availability, raw materials, land use (farming methods, erosion), sustainability (strategic use of resources), regional distribution of natural resources
Political	Geopolitical	Trends in international relations, levels of tensions, conflicts, trade and protectionism
	National	Change in governmental development strategy and policy, changes in legislation, changes in structure and responsibility of ministries, changes in rules governing formation and functioning of parties, governmental stability, likelihood of change/overthrow
Technological	Infrastructure	Level of technology in key industries, emerging technologies, capacity to manufacture technology for export
	Future directions	Basic research and technical education trends, digital divide, computer and telecom infrastructure and trends, potential for rapid diffusion of new technologies from abroad

The analysis of driving forces of landscape change is becoming increasingly difficult in the context of the complex and rapidly changing metropolitan landscapes (see Section 2.2). Therefore, the analysis might benefit from a supporting structure, such as shown in Table 2-4, or the embedding in a conceptual analytic framework, such as the social-physical organization model (Kleefmann 1984, Hidding 2006), the multi-layer approach (Sijmons 2002, Zonneveld 2005) or the network approach (Hidding & Teunissen 2002, Priemus 2007).

The social-physical organization model describes the spatial organization of the landscape as the result of intertwining processes between human society (the social organization) and the natural landscape (the physical organization) (see Figure 2-13). In the model, the natural landscape with its natural, self-regulating principles, e.g. eco-systems, is sub-divided in a biotic sub-system (living organisms) and a-biotic sub-system (soil, water, and atmosphere). Society with its social organization principles is sub-divided in economical, political and cultural sub-systems. The social-physical organization model is a comprehensive model, rooted in the system cybernetics, which allows the systematic spatial analysis of the complexity of the metropolitan landscape. Contrary to Table 2-4 the model accentuates the many different relationships between the several sub-systems and the resulting spatial organization of the landscape. The structure and dynamics of these subsystems, as well as their spatial needs and implications need to be understood in order to incorporate the socio-economic, political and ecological dimensions of a problem in the planning process. The social-physical organization model is being used in the spatial planning program in Wageningen. However, the model has not been applied widely outside the Wageningen University. A possible reason might be the high level of detail of the model (not further elaborated upon in this thesis) and, consequently, its relative complexity.

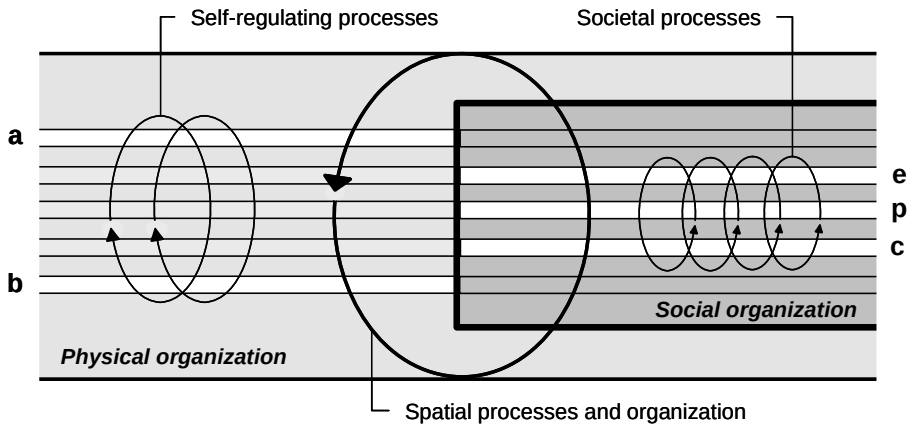


Figure 2-13 The social-physical organization model (adapted from Kleefmann 1984 and Hidding 2006). The subsystems are: (a) a-biotic, (b) biotic, (e) economical, (p) political, and (c) cultural.

The multi-layer approach emphasizes the rates of change in the landscape. Therefore, it distinguishes three layers, each subject to a different rate of change, depending on the characteristics of a layer. These layers are (Sijmons 2002):

- The physical substratum, including soil, water system and nature. This layer basically matches the a-biotic and biotic sub-systems of the model of Kleefmann (1984). Major changes in this layer usually take a considerable amount of time, often many decades or centuries, to settle.

- The network layer, which basically includes the infrastructure networks, such as roads and railways, but also digital networks. The rate of change in this layer is larger than in the physical substratum, as changes in the network usually take a few decades to settle.
- The occupation layer, which includes the different types of human activities and land use, such as residential housing, industry, recreation and agriculture. This layer is the most dynamic one, as changes usually take no more than a few years to settle.

The multi-layer approach was motivated for several reasons: a) to increase the transparency of complex policy issues, b) to break down the existing barriers between policy sectors, c) to challenge the traditional emphasis on urban planning, and d) to cross existing administrative boundaries (Zonneveld 2005). The multi-layer approach has been adopted in Dutch national spatial planning (Ministry of VROM 2001b, 2004). Figure 2-14 shows some maps from the analysis section of the 5th National memorandum on spatial planning (Ministry of VROM 2001b). The approach makes explicit gradations in the governmental involvement in each layer, e.g. the management of the physical substratum is regarding the explicit task of the government. The approach has also been applied as an analytical tool for integrating a wide range of issues, as well as to deal with the mutual interactions between the layers and the policy fields to which they are related. Sijmons (2002) argues that the layers also assume a hierarchy for sustainable planning, where the physical substratum establishes the conditions for the other layers and the network layer guides the developments in the occupation layer. However, in Dutch planning practice the occupation layer is usually dominant over the other two layers (Sijmons 2002, Zonneveld 2005). In the last decades planners have had a bias towards occupation patterns, and have been neglecting the substratum and networks (Priemus 2007). Remarkably, the multi-layer approach which so clearly dominates the analysis sections of the 5th Memorandum, is absent in the policy section of the memorandum and its successor, the national spatial strategy (Ministry of VROM 2004). One reason is that many of the issues addressed with the approach are outside the domain of the Ministry of Housing, Spatial Planning and the Environment (VROM), such as the network layer which is typically the domain of the Ministry of Transport, Public Works and Water Management. Another reason is the weakened position of the Ministry of VROM (Healey 2004, Zonneveld 2005) (see also Chapter 3).

The network approach offers some amendments to the layer approach and suggests a typology of spatial networks. Albrechts & Mandelbaum (2005) provide an overview of the prominent role of networks in spatial planning and governance nowadays. Hidding & Teunissen (2002) describe different network concepts and present an extensive list of opportunities and obstacles for use of these concepts, e.g. at different spatial scales. Priemus (2007) links these ideas with the network approach and distinguishes networks in each layer: the green and blue networks of the substratum, the road, rail, air, ICT and utility networks, and the urban networks. An urban network is

defined as the mix of infrastructure networks and occupational patterns. The network approach not only distinguishes lines, but also nodes where people, goods and/or information are exchanged (e.g. van der Knaap 1997, van der Vlist 1998, Bertolini 1999). Tjallingi (1996) argues that urbanization often takes place around the nodes in the infrastructure network. Local and regional authorities should therefore safeguard the logic of networks and related occupational pattern, which should be adapted to the characteristics of the substratum (Priemus 2007).

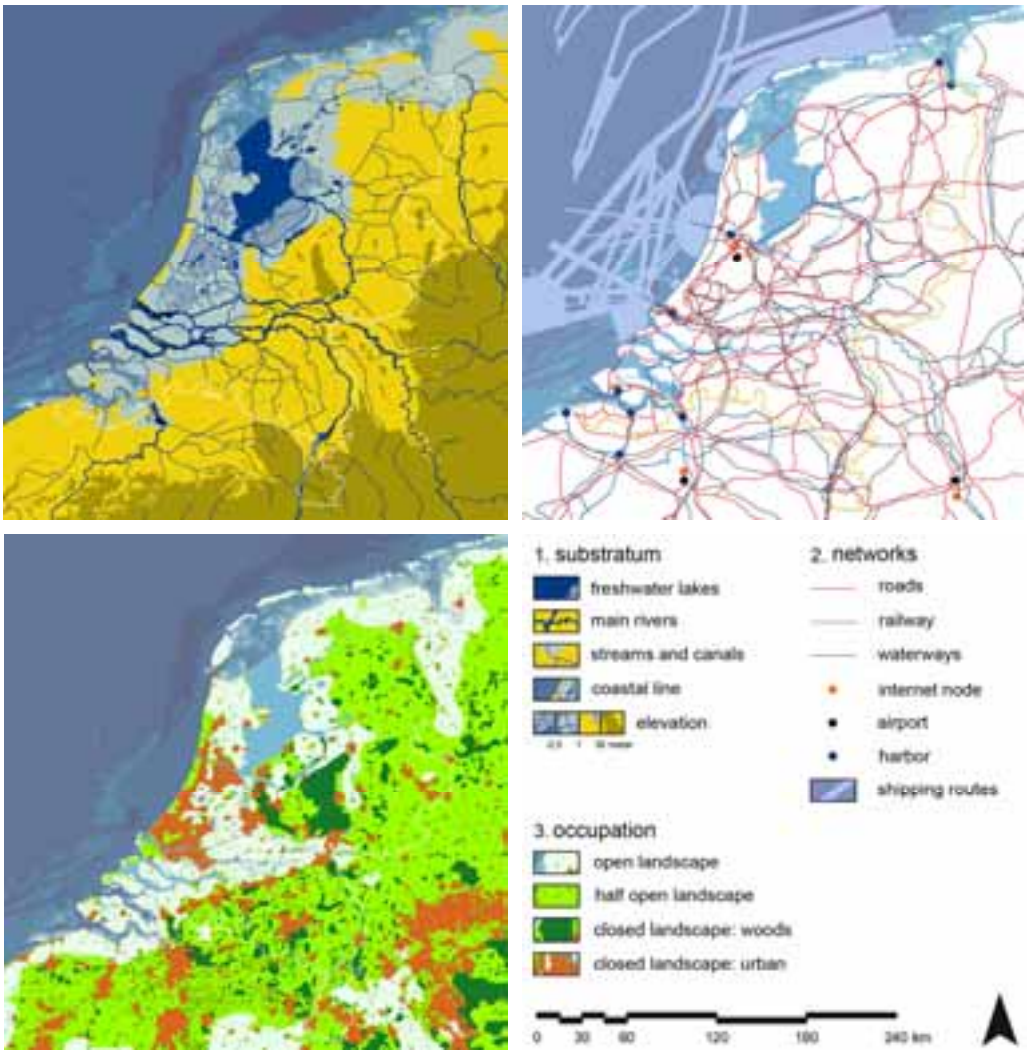


Figure 2-14 Maps of the substratum, network and occupation layers, included in the Dutch 5th National memorandum on spatial planning (Ministry of VROM 2001b).

External scenarios

External scenarios aim to explore some possible alternative courses of social, economical, technological developments and other trends together with their driving forces (Dammers et al. 2005). Since the basic analysis may result in many different driving forces, the next step is to reduce the larger set of forces to those that are considered most important. An easy way of identifying the most relevant driving forces is with a so-called impact-uncertainty matrix or diagram. In this matrix the driving forces are ranked on the basis of two criteria: the magnitude or degree of impact on future developments, and the degree of uncertainty related to the driving forces, which may lead to quite opposite developments. During the ranking process it is important to consider and discuss the interaction between the driving forces and the apparent direction of these forces at present (Maack 2001). An example of an impact-uncertainty matrix is given in Table 2-5.

Table 2-5 Focus areas in an impact-uncertainty matrix (Maack 2001).

		Degree of uncertainty		
		Low	*Medium*	*High*
Degree of impact	*High*	**Critical planning issues** Highly relevant and fairly predictable (can often be based on existing projections). Should be taken into account in all scenarios.	**Important scenario drivers** Extremely important and fairly certain. Should be used to differentiate scenarios. Should be based on projections but potential discontinuities should be investigated.	**Critical scenario drivers** Factors and forces essential for success and highly unpredictable. Should be used to differentiate scenario plots.
	Medium	**Important planning issues** Relevant and very predictable. Should be figured into most scenarios.	**Important planning issues** Relevant and somewhat predictable. Should be present in most scenarios.	**Important scenario drivers** Relevant issues which are highly uncertain. Plausible, significant shifts in these forces should be used to differentiate scenario plots.
	Low	**Monitorable issues** Related to the decision focus but not critical. Should be compared to projections as scenario is implemented.	**Monitorable issues** Related but not crucial to the decision focus. Should be monitored for unexpected changes.	**Issues to monitor and reassess impact** Highly unpredictable forces that do not have an immediate impact on the decision focus. Should be closely monitored.

Note: Shaded cells indicate key focus areas.

The matrix can be used for ranking the driving forces in nine different categories. The most interesting driving factors are those positioned in the upper left and right corners, which are the categories of predetermined elements and critical uncertainties (Schwartz 1991). Predetermined elements are driving forces with a high impact and low uncertainty, that are highly relevant and have predictable outcomes for which planning in all scenarios must prepare (Maack 2001). For example, the ageing of the population can be predicted well with demographic models, and will not vary among the different scenarios. Critical uncertainties are driving forces with a high impact and high uncertainty that will shape the different futures which planning should take into account (Maack 2001). For example, the future energy prices may vary from very low to very high, with substantial different impacts on transport systems and logistics. The future can go in quite opposite directions here.

The results of the impact-uncertainty matrix are seldom conclusive (Maack 2001). If a larger number of forces will cluster in the upper right corner, the aim is to select two factors that are considered most important. These will be used to set up a scenario matrix with the selected factors as the axes. Only two factors are selected in order to cut through the many complex issues, and prevent that the focus is lost in countless different scenarios (Maack 2001). To arrive at distinct scenarios, it is important to explore (extreme) opposite directions of development of the factors and to choose value-free extremes and factors that do not resemble each other. The four permutations of the selected driving forces are then worked out and external and policy scenarios are built around them. Figure 2-15 gives an example of a scenario matrix. Although the two selected driving forces set the tone for each of the four external scenarios, these should also describe how a large number of other forces are likely to behave in future. The external scenarios basically reveal four different future environments. Each may also sketch some opportunities and threats for the future spatial development of the metropolitan landscape.

Policy scenarios

Policy scenarios aim to explore some alternative policy strategies and courses of action which lead to different plot types (Dammers et al. 2005). This is the most creative step in the process. Common examples of different plots types that may handle the same forces are (after Schwartz 1991):

- Winners and losers: In these plotlines strong nations, organizations and social forces will get stronger, while weak ones get weaker.
- Challenge and response: These plotlines are an adventure story of overcoming obstacles, in which society and its organizations grow stronger by learning to respond to the obstacles that face them.
- Evolution and revolution: In evolution plotlines changes are going slowly and gradually, while in revolution plotlines the changes are taking place suddenly and quickly.
- Cycles: These plotlines fit closely to cycles in economy and society, e.g. cyclical economic and market trends, and the rise and fall of social groups.

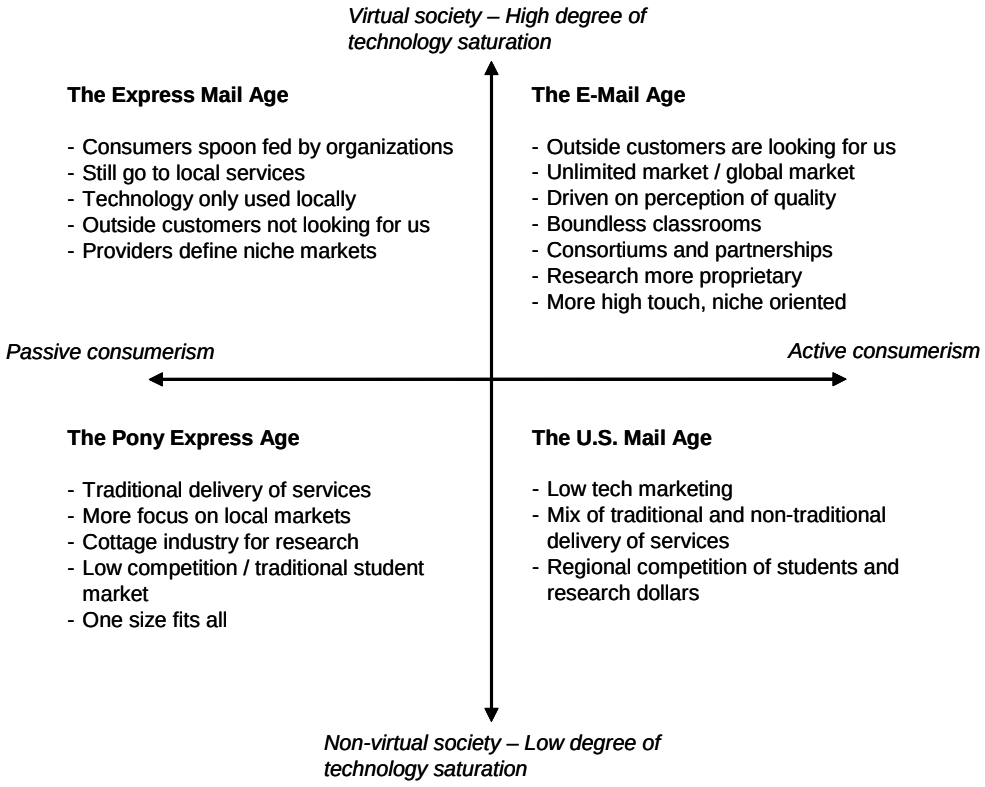


Figure 2-15 Example of a scenario matrix (UTMB 2002).

Policy scenarios describe the implications of the plots in the context of different future environments (external scenarios). The plot or narrative of a scenario combines the driving forces and key issues in a dynamic, coherent and logic story that can easily be recognized by the actors and decision makers (Maack 2001). Schwarz (1991) compares the process of developing a plot with writing a screenplay, which tells the actors how the world gets from here to there. It is often useful to give each scenario a representative and memorable name and logo (see Figure 2-15). A common way to start the process is by taking leaps into the future and defining a few end-states or targets that may result from the interaction of the driving forces. The next step is to confront each of these end-states with the different future environments, and subsequently work backwards to explore what policies and measures might be needed to arrive at a certain point. Since this can lead again to many different combinations, it may be necessary to concentrate on some diverging scenarios that challenge existing thought patterns, but are also sufficiently balanced to withstand immediate rejection. After creating the outline of the scenario plots, and further research and detailing, the scenarios need to be written down as full-length stories. These stories interweave the social, political, technical, environmental, and economical driving factors into smooth narratives

that are easy to read and understand (Maack 2001). The impact of these stories might be enlarged by input from journalists and novelists (Xiang & Clarke 2003).

Maps can be used to visualize these stories. The design of conceptual or spatial models with map representations, also referred to as 'territorial scenarios' or 'land-development scenarios' (Xiang & Clarke 2003), is an important element of design-oriented planning (Eweg 1994). The spatial models and maps aim to illustrate the geographic or spatial implications of the scenarios and plots, and support the development of spatial policy strategies (see the next step of the cyclic scenario approach). The design can be supported with a range of tools, such as visualization tools, graphic images, spatial modeling techniques or spatial planning support tools using a geographical information system (GIS) (e.g. Stillwell et al. 1999). The use of these tools helps decision makers, actors and the general public to understand the potential spatial implications of the scenarios, and the consequences of potential decisions and actions. The use of spatial planning support tools will be further explored in Chapter 3.

Recommendations and knowledge questions

The recommendations phase aims to support the development of policy strategies by deriving lists of measures for the short and long term. The basic idea is that short-term measures ought to be compatible with all scenarios, while long-term measures are specific for one or more policy scenarios. The process might also lead to specific knowledge questions, which are usually related to the uncertainties involved. Couclelis (2003) argues that uncertainty is an intrinsic property of complex knowledge. Knowledge questions might activate further research. This part of the process is closely related to the focal issues of the method of strategic choice.

A common procedure is to develop so-called contingency plans and a master plan. Contingency plans are strategies which are specific to one scenario, while a master plan includes the elements that are suggested by all scenarios. Maack (2001) describes three actions for making contingency plans:

- The decision makers and actors should step into each scenario (narrative) by envisioning themselves in this future world, and ask how it would change their professional and personal lives.
- The implications should be discussed, and a standard set of questions should be derived related to the decisions that are to be made. These questions might involve, for example, identifying which actors, sectors, policy fields, or geographic areas are the most affected by a scenario. What are the major risks and opportunities of each scenario, who are the winners and losers? The set of questions should be answered for each scenario.
- The next action is to identify how to respond to the implications, and identify a set of proposed actions for each scenario. These actions may include things to be done, or things to avoid.

The next action is to develop a master plan, by identifying common actions that are included in all scenarios. These actions will be key parts of any strategic plan (Maack 2001). In order to monitor how developments in reality will unfold, scenario

indicators or sign posts can be identified (Maack 2001). These are commonly used in business scenarios, but rarely in spatial planning scenarios. Scenario indicators enable to assess the actual developments compared to the developed scenarios. They can activate the rethinking of scenario plots, or the construction of new policies and measures to address the new conditions.

Relevance of the design-oriented view for contemporary planning

The basic objective of design-oriented planning is to influence the frames, actions and choices of those who shape the future spatial organization, by initiating a debate on likely and desired futures with spatial scenarios and map representations. This objective recognizes that "our society has significant control over future outcomes" (Sharma et al. 2006: p. 98). Spatial scenarios aim to broaden the scope of those involved, raising awareness on the possible consequences of choices at hand, and formulating strategies. The most interesting scenarios are often those that are rather provocative, which challenge and oppose current situations and developments, and require trend breaks to reach a desired future. Such scenarios help to reflect on current developments, prepare for sudden changes, weaken dominant logics and stretch the mental maps of actors. Scenario studies thus address some potential problems of decision-making processes: the drawbacks of bounded rationality and mental models of actors and decision makers (Chermack 2004, Korte & Chermack 2007, see also Section 2.3).

Scenarios should not be seen as alternative options for development or, even worse, future realities. These "realities" will most likely be thwarted down the road by many unforeseen events (Couclelis 2005). Couclelis argues: "Really helpful scenarios are those that help planners make strategic decisions in the present that will serve a range of plausible futures: futures that are for the most part outside the planners' control" (Couclelis 2005: p. 1354). In fact, the decision making on spatial development in practice is influenced by many public and private actors, while public bodies which practice spatial planning usually have only limited and often indirect influence on the actual spatial developments (Needham 2000).

The design-oriented view of planning offers method and techniques to widen the scope of actors and decision makers, and to explore the possible consequences of current choices and developments for a range of future perspectives. Although developing coherent, imaginative and challenging scenarios is certainly important, the ultimate reason and justification for the exercise is to translate these into strategic decisions and actions (Wilson 2000). Innes (2002) argues that without a process for developing a shared understanding of the problem, allowing stakeholders to cooperate in the process, and forcing decision makers to pay attention to the findings, even the best designed information will have little influence on the decision making process. This underlines the importance of incorporating relevant stakeholders in the process of developing scenarios. Nonetheless, using scenarios proves to be much more difficult than developing them, and as a result scenario projects often fail because they have no impact at all on the decision making process (Wilson 2000). In particular, the translation of scenarios into strategic decisions and actions shows to be problematic. Some common failures and pitfalls are a lack of support of key decision makers, unrealistic goals

and expectations, a lack of time to build scenarios or to relate these to strategies, a lack of transparency or attractiveness of scenarios, and a lack to connect the resulting scenarios to the planning process (Godet 2000, Maack 2001). Typically, the reasons are not because scenarios are unimaginative or poorly constructed, but more since they are usually lacking an institutional embedding, do not cope with the power relationships between key actors, and evoke a technocratic bias and inherent suppositions about the plausibility, credibility, knowability and makeability of the presented futures. Disconnecting 'imagination' and 'realization' challenges the credibility of future studies as an instrument for change, especially when it becomes detached from real-world politics, economics and delivery mechanisms (Gaffikin & Sterrett 2006). Couclelis (2005) argues that the strategic dimension of contemporary planning is often lost in theoretical, practical and political doubts. Using scenarios involves a new way of thinking which needs a transformation in the planning culture, and requires instituting scenarios as an integral part of strategic planning. Scenarios are to be considered as a process, which needs to be used and refined over time in order to become effective (Maack 2001). Actors and decision makers also need to be aware that the process does not automatically produce action plans. Choices and actions usually do not match only one scenario. Defining strategic choices is a normative step, related to the questions "What can we do?", "What are we going to do?", and "How are we going to do it?"(Godet 2000). Questions similar to the ones that are being addressed with decision-oriented planning (see Section 2.3).

2.5 Intertwining design- and decision-oriented planning

Section 2.2 illustrates that the spatial planning of metropolitan landscapes is becoming more and more complex, while planners and decision-makers have to deal with a diversity of increasingly involved stakeholders with often conflicting objectives. It was argued that the spatial planning for the complex metropolitan landscape asks for planning approaches that combine the creation of strategic visions for the future development of these areas with short-term actions (e.g. Albrechts 2004a). From this perspective it seems attractive to combine the fruits of the methods and techniques from the decision- and design-oriented view of planning, as promoted in the Wageningen spatial planning program (van der Valk & Carsjens 2005). This section discusses the philosophy and revenues of intertwining both views of planning, and the experiences with intertwining both views in the Wageningen planning program.

The combination of strategic choice and scenarios shows especially relevant, as it might silence complaints about the negligence of creativity and substance in the decision-oriented view of planning on the one hand (Section 2.3), and bridge the gap between scenarios and actual decision-making in the design-oriented view of planning on the other hand (Section 2.4). Sections 2.3 and 2.4 suggest that both views have much in common. This is confirmed by Table 2-6, which summarizes the many common characteristics and interchangeable elements of decision- and design-oriented planning. The table also shows that the weaknesses of the one are generally the

strengths of the other, backing the assumption that decision- and design-oriented planning are complementary indeed.

Table 2-6 Summary of characteristics, strengths and weaknesses of decision- and design-oriented planning.

	Decision-oriented planning	Design-oriented planning
Definition	- Planning is a process of decision-making	- Planning is a process of social learning through reconnaissance
Object of planning	- Decisions	- Spatial organization of the landscape
Goal	- To systematically work towards policy frames and a commitment package	- To influence the frames and actions of those who shape the spatial organization with future scenarios and map representations
Methods and time-frame	- Methods to facilitate decision-making processes in an interactive setting with stakeholders - Mainly short-term	- Scenario and spatial analysis methods for making creative leaps into the future - Mainly long-term
Common characteristics	- Both rooted in the rationalist and systems approach of planning and adapted to a participatory setting with stakeholders - Both have their starting point in focal issues (cf. decision areas) - Both result in a range of alternatives (decision trees and scenarios) - Both promote involvement of relevant actors in the planning process - Both offer techniques for uncertainty management - Both address the robustness of alternatives (cf. action schemes) - Many mutually interchangeable techniques and tools	
Strengths	- Offers methods to arrive at strategic decisions and actions in complex situations - Stimulates the design of new tools and adoption of tools from other tool boxes (“open technology”)	- Offers methods to broaden the scope (reframing) of actors and decision makers - Offers a cartographic representation and description of the future spatial organization - Offers holistic, long-term perspectives
Weaknesses	- Obstacle to creativity - Does not cope with the drawbacks of bounded rationality - Lacks to address more long-term, fundamental problems - As a consequence, limited added value to decision-making	- Lack to translate scenarios in strategic decisions and actions - Often negligible impact on the decision-making process - As a consequence, limited added value to decision-making

A combination of different approaches to cope with complex planning issues has been widely suggested in planning literature (e.g. De Roo 2003, Albrechts 2004a, Chermack 2004, Gaffikin & Sterrett 2006, Quist & Vergragt 2006). Albrechts (2004a) promotes a (strategic) planning process which allows constructing alternative futures in an open and creative way, able to respond to growing complexity, new demands and prevailing power structures. He argues that this requires a shift towards governance, i.e. a government willing to mobilize the plurality of actors with often competing interests, goals and strategies, in order to develop creative and territorial differentiated solutions to problems and challenges. Albrechts proposes a four-track approach, as shown in Figure 2-16, including a working track for (Albrechts 2004a):

- Developing a long-term vision, or integrated strategic plan, related to the context of social values in a particular environment (Track 1).
- Developing short-term and long-term actions. Short term actions should create trust among actors, while tackling problems in view of the long-term vision (Track 2).
- Involving key actors, needed for their substantive contribution, procedural competences, and their role in getting acceptance, basic support and providing legitimacy (Track 3).
- Involving the general public with major decisions, in order to create a mutual understanding (Track 4).

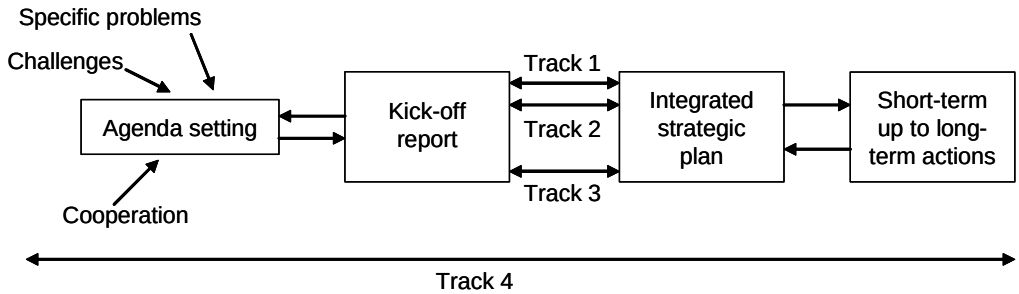


Figure 2-16 Framework for a four-track approach for a strategic planning process (Albrechts 2004a).

The end products of the process include an analysis of the main processes shaping the environment, a dynamic, integrated and indicative long-term vision, a plan with short- and long-term actions, a budget and a strategy for implementation. The output of the process also represents the consensus or (partial) disagreement between actors. The actual implementation will require credible commitment, needed to enter moral, administrative and financial agreements to realize the actions (Albrechts 2004a). Likewise, Friend and Hickling (2005) make a distinction between visible and invisible products. Visible products are the end products, and invisible products the fuller understanding of other people's values, their ways of working and the pressures and constraints acting on them (Friend & Hickling 2005). The four-track approach of Albrechts includes many elements that can be linked to the methods and techniques of

decision- and design-oriented planning, such as the agenda setting (focal issues or decision areas), the construction of alternative futures (scenarios), and short- and long-term actions (commitment package). Albrechts does not provide specific recommendations for linking the different working tracks. He argues that (strategic) planning is a dynamic and creative process which does not flow smoothly from one phase to the next. Albrechts' approach has some similarities with the mixed-scanning approach of Etzioni (1967, 1986). Mixed scanning is a hierarchical mode of decision making, combining high-order, fundamental policy-making processes which set basic directions, with incremental processes which prepare for fundamental decisions. Etzioni (1967) argues the approach is a useful strategy for decision-making in environments of varying stability and actors with varying control and consensus-building capacities.

The intertwining of the decision- and design-oriented view of planning has been promoted for several years in the spatial planning program at the Wageningen University (van der Valk & Carsjens 2005). For educational purposes it seems highly attractive to develop sophisticated methods for learning, combining the fruits of both perspectives for planners, architects and other professionals-in-training. Therefore, the program includes problem oriented courses and design studios, in which the students are challenged to analyze and solve complex problems taken from practice. Interdisciplinary research and stakeholder participation is a necessary ingredient of this approach. In the 3rd year of the program, strategic choice and scenarios are at the heart of a full grown strategic spatial planning course that includes several weeks of full-time exercises. The course reflects an incremental and cyclical planning process. The students are working in project groups of approximately ten members, and are challenged to produce a strategic, regional spatial plan, including a long-term vision and a commitment package with short-term actions, for a complex region in the Netherlands. The students also write a detailed report on the process and their role in it. The combination of design-oriented and decision-oriented planning diverts the attention from seemingly unsolvable conflicts and helps in reframing contested decisions. In the course, emphasis is laid upon the argumentative part of the work and the role of professionals in planning. Students work under very strict time constraints and are thus confronted with a range of uncertainties. The experiences with the planning course over time illustrate the diversity in working processes, as discussed by Albrechts (2004a). In general, the working process is reflected by the framework of Figure 2-17, which has many similarities to that of Albrechts.

The first step in the working process involves developing a detailed work plan. A work plan includes the planning of the subsequent steps of the working process (or workflow), a description how these steps are interconnected, and a description of the required input, the methods and techniques used, and the expected output of each step. Core data are taken from real time planning processes. The work plan, acting as a tender, should convince the (simulated) provincial government that the project group is capable of producing the required regional, strategic plan. Most important, the work plan needs to be embedded in the specific context of the planning task at hand. Students are only allowed to proceed with the process after the authorization of the pro-

vincial officials. Basically, the working process for developing a strategic plan involves three main tracks, where the first two tracks in Figure 2-17 are quite similar to the tracks of Albrechts (see Figure 2-16). The experiences show that the process of working towards a commitment package usually follows the process of the developing a long-term vision. In track 3 the communication with the government, stakeholders and the general public is simulated. Staff members perform the role of advisers on the job. This 3rd track runs through the whole process, including a formal hearing with feedback of stakeholders and the general public at the end. The strategic plan involves the integrated document which presents the long-term vision and commitment package, and especially reflects upon the coherence between both.

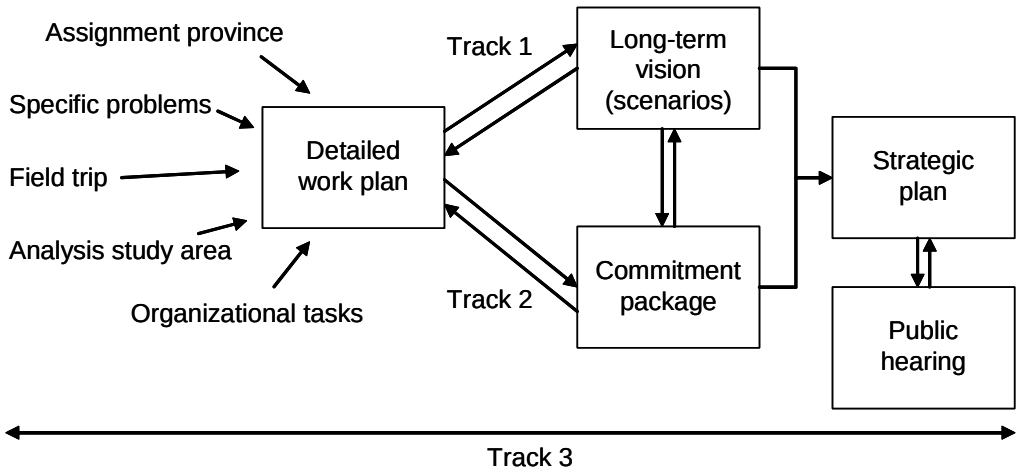


Figure 2-17 General organization of the working process of the strategic spatial planning course.

However, linking the long-term vision and the commitment package often shows to be a difficult step, as the project groups run into questions such as: "How can we use the output of the scenarios in a process of strategic choice?" and "How do we assess the short-term actions for their long-term consequences and the implications for the scenarios?". These questions are usually related to the differences in the object of planning, the timeframe and sometimes also the spatial scale of the long-term vision and the commitment package. Moreover, the questions do not have a univocal answer. The prescriptions taken from planning methodology classes are, of course, a starting point for dealing with the questions, but these need to be put into and adapted to the specific context of the planning task at hand. The process of adaptation includes generating and revising new knowledge ("learning by planning") as well as monitoring, evaluating and adjusting strategies and outcomes ("learning by doing") (Wiek et al. 2006). Friend and Hickling (2005) argue that in complex situations, where the shape of a problem may be obscure and a matter of possible controversy, the relevance of expert techniques to produce outputs of advice, characteristic for more routine decision-making arrangements, becomes considerably reduced. These situations require

so-called ‘open technology’ which supports communication and interaction between many different experts, to cut across the inter-meshed decision areas, for instance about finance, location, techniques, marketing, people, contractual and procedural issues (Friend & Hickling 2005). Open technology leaves scope for add-ons taken from other domains, which support the construction of richer arguments by way of combining substantive and procedural knowledge. Similarly, Almendinger (2002a) argues that planning practitioners tend to ‘pick and mix’ theory as “[…] it is hardly surprising that different justifications and approaches are required in different circumstances” (Almendinger 2002a: p. 24). Consequently, planners do formulate, interpret and use theory based on a variety of influences. Almendinger argues that we “[…] should be asking questions about *why* this particular theory was used, *who* is using it and for *what* purpose” (Almendinger 2002a: p. 25).

Planning literature shows a variety of other interpretations on how to organize working processes and facilitate communication and interaction between actors and stakeholders. Some suggest introducing collaborative planning institutions (Innes & Booher 2000), by creating so-called arenas for argumentation (Healey 2003) or communities of practice (COP) (Brown & Duguid 1991). Although such institutions are difficult to simulate in the context of an educational program, these showed to be very relevant in some of the case studies, especially for placing theory and approach within a specific political and socio-economic context (see Chapter 4 and the discussion in Chapter 5).

2.6 Conclusions for the development of PSS

The complexity and dynamics of spatial planning for metropolitan landscapes, as illustrated in the previous sections, involve making difficult choices and understanding the complex trade-offs associated with different options and developments. The working process in complex situations does not flow smoothly from one phase to the next, but is highly dynamic and flexible. Moreover, the metropolitan landscape as an entity is a complex system that generates elements of surprise and novelty. Batty and Torrens state that complex systems “[…] have an extensiveness in their elements or objects that makes any fixed description incomplete” (Batty & Torrens 2005: p. 747). Such a process is also referred to as ‘planning-as-learning’ (Faludi 2000). The dynamics of complex systems, involving novel and surprising adaptation, mutation and transformation, cannot be anticipated through predictions based on past and current trends. This requires an approach that enables exploring different future options as a result of present and future choices. Planners face the task to acquire an (integrated) overview and make the actors and decision-makers aware of the potential spatial implications of the choices at hand. If people have a better understanding of the links between choices and consequences, it is more likely they make a well balanced and sustainable choice (Sharma et al. 2006).

Spatial decision support tools can support planners and decision makers with this complex task, as was described in the problem description in Section 1.1, by improving their understanding of present and future problems. Examples of such tools are

visualization tools, graphic images, spatial modeling techniques and spatial planning support systems using GIS (e.g. Stillwell et al. 1999). The use of planning support systems (PSS) in planning practice will be further explored in Chapter 3, but the previous sections revealed some distinct characteristics regarding the context and process of strategic spatial planning that will have to be kept in mind when constructing and implementing PSS for strategic spatial planning. These characteristics are:

a) *Context specificity.* As was discussed throughout this chapter the problems and issues of decision makers and stakeholders are, in general, area- and context specific, e.g. influencing the identification of key issues and trends. Consequently, planning support systems should be flexible to adapt to the specific context of the planning task and process at hand.
b) *Ability to support an integrated approach.* Exploring future options and producing a long-term vision ask for an integrated approach, addressing the physical as well as the social dimensions of the key issues under discussion. Integrated models offer ways to integrate knowledge across disciplines, approaches, and degrees of certainty (Sharma et al. 2006). Integrated models are typically designed to present broader, but less detailed results compared to detailed disciplinary models. The broad results of an integrated model will provide a more holistic (balanced) perspective.
c) *Ability to involve actor and stakeholder interests.* Arriving at a commitment package asks for a participatory approach, as has frequently been expressed throughout this chapter. Stakeholders no longer accept to be involved only at the final stage of the planning process, e.g. in a phase of choosing between a set of options that have been pre-selected and analyzed by 'experts'. Instead, they demand to be involved all along the process, starting with the identification of key issues. In fact, stakeholders nowadays play an important role in identifying problems and options, and also provide the planning process with substantive knowledge and information. Decisions from participatory planning processes also show to be more socially accepted. Therefore, planning support systems should support stakeholders to take part in the planning process and incorporate the specific problems and issues they face. In order to engage the range of actors and stakeholders involved, also requires that key issues and outcomes are dealt with in an easy-to-understand way.

These characteristics will be further explored in the case studies of Chapter 4 and used as a framework for discussing the results with respect to PSS in Chapter 5.

Chapter 3

Planning support systems for the spatial planning of metropolitan landscapes

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This chapter provides an overview on the field of planning support systems (PSS) and introduces the case studies of the thesis. Section 3.1 includes a brief introduction to decision support systems (DSS), with special emphasis on spatial decision support systems (SDSS) and the use of geo-information in spatial policy and decision-making. Section 3.2 focuses at a specific type of supporting system: planning support systems (PSS), which are geo-information tools specifically designed to support spatial planning processes. The case studies will be introduced in the Sections 3.3 and 3.4. Section 3.3 describes the development of a PSS for integrating environmental aspects in Dutch spatial planning, and Section 3.4 a PSS to support the spatial planning of future livestock farming. These last two sections also include specific references to the papers in Chapter 4 of this thesis.

3.1 Introduction

Decision support systems (DSS) are interactive, computer-based systems that aim to enhance a person's or group's ability to make decisions, i.e. by supporting the use and management of data, documents and knowledge, and modeling unstructured or semi-structured decision problems and processes (e.g. Sprague & Carlson 1982, Sage 1991). DSS provide support to decision makers in terms of increasing the effectiveness of their decision-making effort. This involves the development of alternatives, the analysis of their impacts, and an interpretation and selection of appropriate options for implementation (Sage 1991). DSS are especially relevant in complex situations and poorly structured decision problems, where decision makers face difficulties in conceptualizing or dealing with the entire problem, or in reducing uncertainties in decision-making about future options (Sojda 2007) (see also the conclusions of Section 2.6). DSS usually include a combination of models, analytical techniques and information to support the formulation and assessment of alternatives. The primary components of a DSS are a data-base management system (DBMS), a modeling system and a user interface system, as shown in Figure 3-1. The data-base management system includes tools to generate and store data, to convert and transfer data with the given model, and to retrieve data from storage. The DBMS includes a database with data that are relevant for the given modeling system. The modeling system can be seen as a toolbox with different methods, techniques and tools, such as analytical, scenario, design and evaluation tools, that can be selected by the user for dealing with the specific study of concern. The user interface system supports the communication of the user with the modeling system and the DBMS. The user interface takes care of the representation and distribution of the data sets from the DBMS and the input of output of the modeling system (Sposito et al. 2006). A DSS generally also includes metadata (data about data), involving generic information on the data in the DBMS, such as source, compilation date, scale, resolution and accuracy. Metadata can also involve generic information about the modeling system, such as data requirements, and recommendations and constraints with regard to the use of the model and its output.

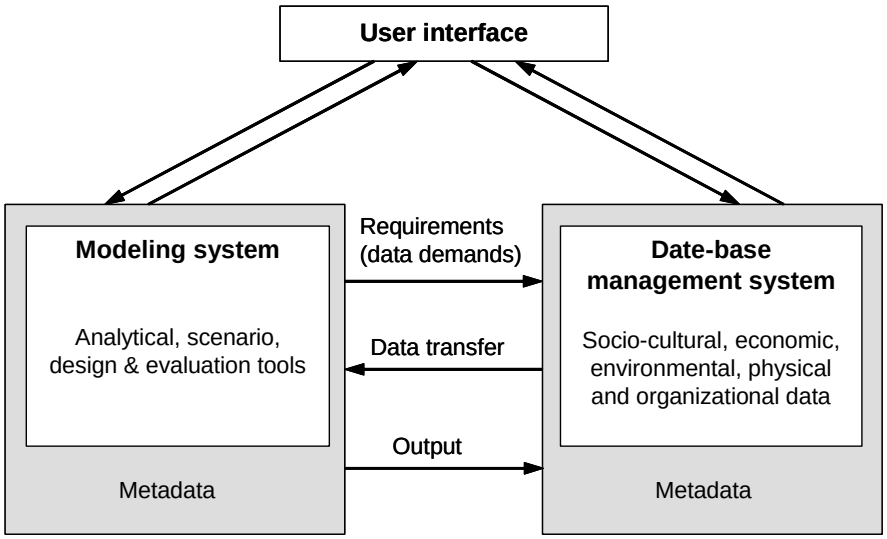


Figure 3-1 Generic components of a decision support tool (after Sposito et al. 2006).

The term DSS covers a wide range of different systems, tools and technologies. Classifications of types of DSS have been described by, for example, Alter (1980), Holsapple & Whinston (1996), Power (2002), and Arnott & Pervan (2005). Power (2002) distinguishes between model-driven DSS, data-driven DSS, communication-driven DSS, document-driven DSS, and knowledge-driven DSS. Model-driven DSS stem from the late 1960s, and emphasize the access to and manipulation of statistical, financial, optimization or simulation models. These DSS draw on data and parameters provided by decision-makers to aid them in analyzing a situation, and are not data intensive. Data-driven DSS emphasize the access and manipulation of time-series of data. These DSS range from simple file systems with query and retrieval tools, to data warehouse systems and on-line analytical processing. Communication-driven DSS support more than one person working on a shared task, using network and communication technology which facilitates collaboration and communication relevant for the decision-making process. Examples of such technology are groupware or group decision support systems, video conferencing and electronic bulletin boards. Document-driven DSS manage, retrieve and manipulate unstructured information in a variety of electronic formats, such as scanned documents, images, sounds and video. These DSS facilitate the access to documents such as policies and procedures, catalogs and historical documents. Knowledge-driven DSS provide specialized problem-solving expertise in a particular domain, stored as facts, rules and procedures. These DSS can suggest actions to decision makers. Examples of knowledge-driven DSS are medical diagnostic systems, expert systems for scheduling manufacturing operation, artificial intelligence systems to detect fraud and expedite financial transactions and web-based advisory systems (Power 2007).

Keen and Scott-Morton (1978) differentiate in the use of DSS for strategic and operational decision making (see also Chapter 1). However, Sage (1991) argues that

DSS are predominantly intended for use in strategic decision making and less for operational situations. Keen and Scott-Morton (1978) also distinguish some general, task dependent characteristics of DSS data and information, relative to a strategic or operational decision situation. As the spatial planning of metropolitan landscapes typically involves making strategic decisions (see Chapter 2), the data and information in such situations are often uncertain, imprecise and incomplete; highly aggregated; focused at the long-term; used infrequently; broad scoped; highly qualitative and rather old (Keen and Scott-Morton 1978, Sage 1991). These characteristics will affect the reliability of decision support models that draw on such input. Couclelis (2005) discusses a new type of uncertainty related to the use of models (UM) (see also Section 2.3).

In the domain of spatial planning, decision support systems typically aim to support decision processes with a strong geographic or spatial component. These DSS are generally known as spatial decision support systems (SDSS) (e.g. Jankowski & Richard 1994, Uran & Janssen 2003). Unlike DSS, SDSS include the functionalities to analyze and visualize spatial data, such as detecting or evaluating spatial structures and networks (Jarupathirun & Zahedi 2007). The data-base management system of an SDSS therefore includes spatial and non-spatial data, and the graphical user interface (GUI) of an SDSS can represent data and model outputs in the form of traditional (2D) maps, three-dimensional (3D) visualization, or even in time (4D) (Sposito et al. 2006). Crossland et al. (1995) showed that SDSS enable decision makers to complete their tasks quicker, more efficiently, and with greater understanding of the problem through visualization. In another study, Mennecke et al. (2000) show that when the complexity of tasks increases, SDSS enable decision makers to work more efficient and accurate.

Whereas DSS traditionally make use of mathematical models, SDSS apply geographical information system (GIS) technology for storing, analyzing and presenting spatial data and output. Some authors argued that GIS at itself is a DSS (Maguire 1991). However, while GIS applications may contain information relevant for a decision making process, in general a GIS is a multi-purpose system and not focused at a particular decision making context (Keenan 2004). Although GIS techniques can make an important contribution, most complex problems will require particular problem related models. A standard GIS usually lacks the support that the use of customized models can provide (Keenan 2004). SDSS is a relatively new research area, whose potential for rapid growth has been facilitated by recent technical development of computer hardware and GIS software. Keenan (2004) identified some main categories of decision makers who may find that SDSS can contribute to their decisions. These include the traditional areas of application of GIS, in disciplines like geology, forestry and land-use planning, decision making in the fields of routing and location analysis, but also in disciplines where the importance of spatial data and modeling has been neglected so far, such as marketing. Some examples of the application of SDSS in these areas are siting problems (Maniezzo et al. 1998), land assessment (Nehme & Simões 1999), vehicle routing (Keenan 1998) and housing mobility (Johnson 2005). A specific group of SDSS are the so-called planning support systems (PSS), which specifically aim to support spatial planning processes (Harris 1989). PSS are further explored in Section 3.2.

3.2 Planning Support Systems (PSS)

The 1990s witnessed some major developments in information and communication technology (Geertman & Stillwell 2003). Newer generations of GIS offer more sophisticated and extensive database management and display capabilities, and are much more user-friendly (Malczewski 2004). Furthermore, the availability of affordable geo-data has increased. These trends have stimulated the development of geotechnology tools to support different aspects of the planning process, particularly tools in which participation is a key element (Geertman 2002). These participatory GIS tools have materialized under the new generic term Planning Support Systems (PSS) (Harris 1989, Brail & Klosterman 2001, Geertman 2002, Geertman & Stillwell 2003). PSS are spatial decision support systems (SDSS) that have primarily been developed to support spatial planning processes (Geertman 2002). PSS are based on the assumption that an increase in the access to relevant information will lead to a greater number of alternatives, and thus a better informed public debate (Shiffer 1995). The underlying ideas for PSS have been promoted for a long time by Harris (see e.g. Harris 1999). Harris proposes to link a sketch planning approach, the rapid and partial description of alternatives, to the modeling of the implications of these alternatives (Harris 1999, Geertman 2002). A wide diversity of these so-called 'what-if' scenario builders exist within PSS (Geertman 2006).

In general, three basic types of PSS can be distinguished: informing PSS, communicating PSS and analyzing PSS (Geertman & Stillwell 2003, Klosterman & Pettit 2005, Vonk 2006). Informing PSS intend to make information and knowledge accessible through a flow of information from an access point to the users. Communicating PSS aim to facilitate communication and discussion among the participants in a planning process, and can include elements of informing and analyzing PSS. Analyzing PSS aim to facilitate the advanced processing of data and information modeling, for projection, simulation and evaluation (Vonk 2006). Examples of PSS, mostly partly realized, are visualization tools for participatory spatial planning (e.g. Lange et al. 2004, van den Brink et al. 2007), land-use modeling tools to examine urban growth (e.g. Barredo et al. 2003, Weber 2003) and farming systems (Sterk 2007), collaborative planning and decision-making tools (e.g. Klosterman 1998, Klosterman 2001, Jankowski & Nyerges 2001, Ligtenberg 2006), GIS-based multiple criteria evaluation tools (e.g. Pettit & Pullar 1999), and Web-based planning support tools (e.g. Shiffer 1995, Al-Kodmany 2002, Voss et al. 2004). Recent overviews on the diversity of PSS have been presented by Brail & Klosterman (2001) and Geertman & Stillwell (2003).

However, the adoption and use of Planning Support Systems in planning practice is far from widespread, and far from being effectively integrated into the planning process (Stillwell et al. 1999, Uran & Janssen 2003, Geertman & Stillwell 2004). Klosterman (1998) wrote that planning support tools did not become more developed in ten years time. Although planners have an increasing access to large volumes of geo-data, the use of GIS focuses mainly on spatial queries and generating thematic maps. Progress towards the use of GIS beyond these basic activities to help solve key planning problems through more sophisticated analyses has been very limited (Still-

well et al. 1999). Only a small percentage of planners consider geo-technology as an intrinsic and indispensable tool for performing their job properly. Couclelis (2005) argues that the role of land-use modeling in general remains problematic, especially with respect to the enhancement of the future-oriented, strategic mission of planning. "[…] PSS developers must bear at least a small part of the responsibility for this state of affairs, by not providing the kinds of tools that planners really need" (Couclelis 2005: p. 1355). Vonk (2006) describes that recent studies also indicate that the usage of PSS varies per type and context. He states: "[…] they show that users demand simple systems for storage and retrieval, visualization, communication, while advanced analysis and modeling tools are hardly used in planning practice" (Vonk 2006: p. 74).

Some explanations for this situation are the diversity of analytical tasks that planners perform, the relatively small market for public sector software, and the expense of developing and supporting commercial software (Geertman & Stillwell 2003). Despite the fact that the application of GIS within planning practice has increased (Geertman 2002), current geo-information tools are too complex, too inflexible, incompatible with most planning tasks and technology driven rather than user oriented (Nedovic-Budic 1998, Geertman & Stillwell 2003, Urun and Jansen 2003). Vonk (2006) presents an overview of potential bottlenecks explaining the limited use of PSS in planning practice. He distinguishes three categories of bottlenecks. The first category is related to a poor instrumental quality of the PSS, thus hindering users to fulfill their tasks well with the PSS. A second category involves a poor transfer of the PSS towards planning practice, hindering the diffusion of the PSS among potential users. The third category is related to a limited acceptance of the PSS by potential users, thus hindering the actual use of the PSS. The last two categories are closely related to the diffusion and acceptance of innovations in society (see Rogers 1995). The acceptance process is influenced by the characteristics of users, instruments, organization, social environment, external environment and facilitating conditions (Vonk 2006). These factors have been framed in the so-called 'Technology Acceptance Model' shown in Figure 3-2, first published by Davis (1986) and afterwards refined numerous times (e.g. Dishaw & Strong 1999, Venkatesh & Davis 2000, Venkatesh et al. 2003). Vonk (2006) uses the model for explaining the limited use of PSS from a user perspective.

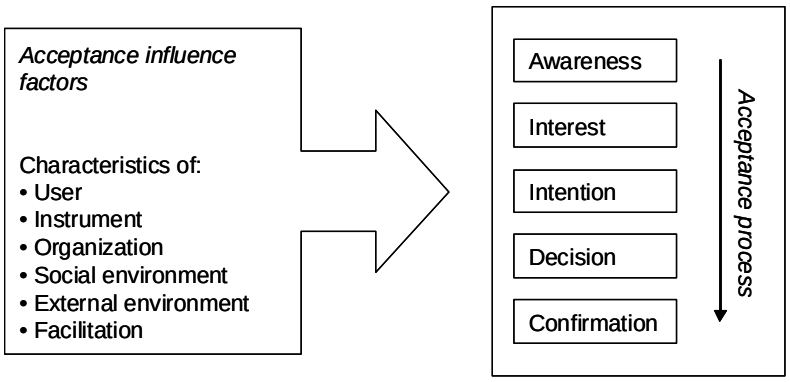


Figure 3-2 Essence of the Technology Acceptance Model (Vonk 2006).

An overview of potential bottlenecks, grouped in the three categories previously mentioned, is presented in Table 3-1 (Vonk 2006, see also Vonk et al. 2005 and Vonk et al. 2007b).

Table 3-1 Bottlenecks hindering the use of PSS, related to the instrumental quality, the diffusion and the acceptance of PSS by users (after Vonk 2006, p. 78).

Instrumental quality	Diffusion	Acceptance
- Poor fit to planning task and user for advanced systems - Demand for simple systems, supply of advanced systems - Poor fit to politician demands	- Insufficient take up from the organizational environment - Hampered bottom-up initiation - Lack of PSS usage decisions - Top-down strategies without PSS - Lack of cooperation between geo-information specialists and planners - Implementation control risk	- A diversity of bottlenecks - Lack of awareness of PSS - Lack of experience with PSS - Lack of intention to use PSS - Lack of user friendliness - Insufficient organizational facilitators - Negative social influences - Lack of usefulness - Data related issues

A comparison of these bottlenecks with the characteristics of strategic spatial planning processes, which were identified in Section 2.6, reveals some interesting observations. The bottlenecks regarding the instrumental quality illustrate an inability to link to the *context* of the planning process in which a PSS is used. The PSS apparently do not match with the needs of intended users, which is also being reflected by some other bottlenecks regarding diffusion and acceptance. The lack of cooperation between geo-information specialists and planners shows an in*ability to support an integrated approach*, and may reflect differences in disciplinary views. The lack of awareness and intention to use a PSS may reflect the inability of a PSS to *involve the actor and stakeholders interests*. These issues will be further explored in the Chapters 4 and 5.

3.3 Integrating environmental aspects in spatial planning

The development of planning support systems for environmental planning is rapidly progressing, supported by a growing awareness of the complex interactions between the natural environment and societal processes. Many of these supporting systems originate from the growing interest of the scientific, environmental modeling community to extend the research objectives from environmental analysis and modeling towards the application in planning and decision making processes. However, the most common users of these systems appear to be system analysts or environmental scientists themselves, sometimes working together with environmental managers or decision makers, while the use in a more collaborative setting remains very limited (Matthies et al. 2007).

This section describes the development and use of a planning support system for environmental planning which aims to improve the coherence between spatial and en-

vironmental policy at the Dutch local and regional level, by stimulating the exchange of relevant information among the involved disciplines and decision-makers, and providing a means for exploring alternative future spatial scenarios. First, the Dutch spatial and environmental policies of the 1980s and 1990s, which are at the base of the development of the planning support tool, will be introduced (Section 3.3.1), as well as some more recent policies which inspired the further development of the tool (Section 3.3.2). The implementation and testing of the tool in planning practice will be described in Section 3.3.3, and the experiences of the use of the most recent version of the tool in some spatial planning courses in Section 3.3.4.

3.3.1. Spatial and environmental policy in the 1980s and 1990s

For many decades, the Dutch national government has been facing the challenge of protecting its green open areas from urban development. As a result a comprehensive framework of restrictive spatial and environmental policy and planning at all administrative levels has been set up (van der Valk 2002, Needham 2007). Over the years, an important objective of these policies has been urban compaction. Urban compaction and multifunctional land use for the promotion of sustainable development and preserving the rural and natural areas became prominent in Europe during the 1980s (Jenks et al. 1996, Williams et al. 2000, Breheny 2002). Dutch spatial planning has been strongly influenced by the concept of the 'compact city' (Needham & Faludi 1999, Breheny 2002, de Roo 2003). The objective of compact urban growth is to increase the efficient use of land, by regulating the geographical spread of urban areas, their built form and patterns of movement and interaction (Clark 2005). It is comparable to the more recent smart growth policies in e.g. the United States (Daniels 1999, Dieleman & Wegener 2004).

The restrictive policies have been relatively successful in protecting areas such as the Green Heart in the west of the Netherlands (see e.g. Needham 2007). Without these policies, urban development would have been considerably more widespread (MNP 2006), although the policies did not entirely resist urban developed. Figure 3-3 shows that the urban pressure on the Green Heart has considerably increased in the previous decade. Not surprisingly, a recent assessment of Dutch spatial planning shows that, for example, provinces and planning professionals are not quite satisfied with what has been achieved (Needham 2007). Due to urban compaction another problem emerged as well, namely how to preserve the environmental quality of the urban and semi-urban areas (de Roo 2000). Because the urban activities were concentrated, the related environmental problems like noise, dust and toxic pollutants did become more prominent due to the concentrated effect in a smaller area. This conflict between the spatially-oriented 'compact city' concept and its environmental drawbacks has been called 'the compact city paradox' (de Roo 2003).

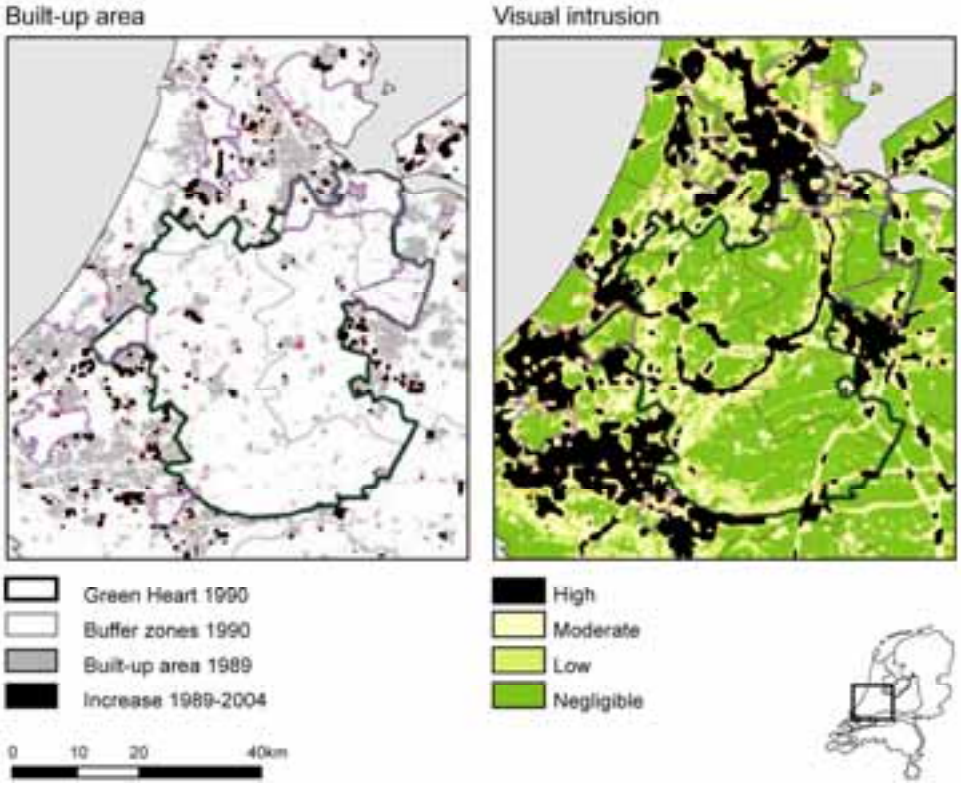


Figure 3-3 Urban development and visual intrusion in the Delta metropolis (MNP 2006).

Concern about the environmental quality of the compact city arose in the 1980s, and triggered some new environmental policies. In 1989 the Dutch Ministry of Housing, Spatial Planning and the Environment (VROM is the Dutch abbreviation) introduced the Integrated Environmental Zoning (IEZ) system (Ministry of VROM 1990, see also de Roo 2003). IEZ was intended for the spatial planning of areas bordering industrial sites. The IEZ system is based, for the most part, on the calculation of zones of influence. These zones are derived from standardized levels for industrial noise, risk from industrial installations, smell, and carcinogenic and toxic substances. A classification system (see Table 3-2) of 5 sectoral classes, ranging from negligible (A) to unacceptable (E), is used for balancing the various standards. The classification incorporates existing residential areas as well as housing development (new) areas. An aggregation table (see Table 3-3) is used to determine an integrated class for a given location, based on different combinations of sectoral classes. The aggregation table includes 6 integrated environmental quality classes, ranging from class I to VI. Class I is the 'white' area where pollution is negligible and housing development can take place without any restrictions. In other words, Class I areas can be considered an opportunity for housing development. Classes II to V are the 'grey area' with increasing planning constraints for housing development. In class VI, the 'black area', the level of pollution is considered unacceptable, or a hard constraint, for residential areas.

Table 3-2 Classification table of the IEZ system (see also de Roo 2003).

Sectoral class[a]	**E**	**D**		**C**	**B**		**A**
Category	existing	existing	new	existing & new	existing	new	new
Industrial noise in dB(A)	> 65	65-60	> 60	60-55	< 55	55-50	< 50
Risk from industrial installations, as individual mortality risk per year	$> 10^{-5}$	10^{-5}-10^{-6}	$> 10^{-6}$	10^{-6}-10^{-7}	$< 10^{-7}$	10^{-7}-10^{-8}	$<10^{-8}$
Smell, in smell units per m^3 as 98th percentile	> 10	10-3	> 3	3-1	< 1	< 1	< 1[b]
Carcinogenic substances, as individual mortality risk per year	$> 10^{-5}$	10^{-5}-10^{-6}	$> 10^{-6}$	10^{-6}-10^{-7}	$< 10^{-7}$	10^{-7}-10^{-8}	$<10^{-8}$
Toxic substances, as percentage of cumulative No Observed Adverse Effect Level (NOAEL)	> 100	100-10	> 10	10-3	< 3	3-1	< 1

[a] Sectoral class A does not apply to existing situations, and class E not to new situations.
[b] As a 99.5 percentile score
[c] The maximum cumulative risk is $n \times 10^{-6}$, where n = the number of substances, with a maximum risk of 10^{-5}

Table 3-3 Aggregation table of the IEZ system (see also de Roo 2003).

Integrated class	**Combination of sectoral classes**	
	existing situation	new situation
I	Only B, no C, D or E	Only A, no B, C or D
II	Maximum of 2 times C, no D or E	Maximum of 2 times B, no C or D
III	Maximum of 3 times C, no D or E	Maximum of 3 times B, no C or D
IV	Maximum of 1 time D plus 1 time C, or maximum of 4 times C, no E	Maximum of 1 time C plus 1 time B, or maximum of 4 times B, no D
V	Maximum of 2 times D, or maximum of 1 time D plus maximum of 4 times C, no E	Maximum of 2 times C, or maximum of 1 time C plus maximum of 4 times B, no D
VI	3 times D or more, or 1 time E or more	3 times C or more, or 1 time D or more

The Ministry stimulated the efforts to implement the IEZ system at the local and regional level. The local and regional authorities could submit project proposals to employ the IEZ system at local and regional levels. The municipality of Zwolle (approximately 100,000 inhabitants) and the Wageningen University worked on a municipal version of an IEZ support system and its implementation in GIS (Streefkerk 1992, van Slagmaat et al. 1992, van Lammeren et al. 1994). The resulting Environmental Quality Assessment tool focused upon intrusive environmental influences like local air pollution, noise, local terrain contamination and hazards. A comparative study undertaken by Groningen University (Humblet & de Roo 1995) judged this particular tool as the most promising of all comparable systems.

The IEZ system, however, was never implemented in Dutch environmental policy. Its top-down approach and consequently the system met with resistance. Local authorities were especially worried that the IEZ system would result to stricter standards (de Roo 2003). Political attention shifted towards more interactive approaches based on participation and communication, such as the ROM approach, a Dutch acronym for Spatial Policy and the Environment (de Roo 2003). Despite considerable interest from local authorities and consultants, neither was the municipal tool a success, partly due to inadequate information and computer technology in the early 1990s (see Section 3.2). Furthermore, due to the long tradition of restrictive, sectoral environmental policy, spatial planners, urban developers and environmental specialists were mainly focused on the domains of their own discipline, and hardly open to new, more integrative approaches. Consequently, spatial planners, urban developers and even environmental specialists were skeptical about this and similar new systems. Despite the fact that the basic principles of the tool were very promising, its use in planning practice remained disappointing.

3.3.2. Recent policy developments

From 2000, Dutch national policy plans emphasize the responsibility of local authorities to support a sustainable environment. For example, the 4th National Environmental Policy Plan (Ministry of VROM 2001a) describes that in many cases the local government is more capable of improving the quality of the living environment than the national government. As spatial planning at a local level has direct impacts on the urban and rural environment, the coherence between spatial and environmental policy needs to be improved through a more integrative, area-based planning approach. The 4th National Environmental Policy Plan also states that the local government must be afforded greater freedom and as much integrated responsibility for the living environment as possible.

The national government does not leave its policy of setting rigid, minimum standards for environmental quality, but the environmental qualities for various types of areas are formulated jointly, based on the classification of areas in the 5th National Policy Document on Spatial Planning (Ministry of VROM 2001b). The national government recognizes that for the assessment of the quality of an area, values other than that of the environment must also play a role.

The Netherlands has been experimenting with integrated, 'area-specific', policy since 1997. In the City and Environment project of the Ministry of VROM, urban planners have been working alongside environmental specialists on complex urban redevelopment projects (Ministry of VROM 2001c), often coming up with creative solutions. It appears that the environmental legislation actually provides much more room to maneuver than has been appreciated previously. A special feature of the project is that, although the 25 municipalities that participate in the City and Environment project must put up with European legislation, they may, under very strict conditions, deviate from national environmental standards. In such circumstances they need the permission of the Minister of the Environment, and they have to compensate for such deviations in one aspect by improving the local environment in other aspects, i.e. standards may be relaxed only if there are offsetting benefits. The municipalities also need the support of local residents. The approach was governed by the Experimental City and Environment Act (1988), which was introduced for the purposes of this trial arrangement. The government evaluated the City and Environment project in 2004. Its positive results triggered the Interim City and Environment Act (2006) that opens the City and Environment Act to all municipalities in the Netherlands (Arents 2006).

There is a particular need for an area-based approach with respect to public policy on noise. The 4th National Environmental Policy Plan underlines that the noise abatement policy of previous environmental policy plans was too ambitious. The new policy target for noise is to achieve a particular standard of acoustic quality by 2030, which has to be in line with the use of an area. Acoustic quality means that noise originating from an area can be heard within, and that it is not subsumed by noise emanating from outside the area. The draft act on the Modernization of Noise-Policy Instruments (MIG) (Ministry of VROM 1998) stipulates the use of this area-based approach, but attempts to create a compact city may, for example, run up against stringent noise standards. Similar to the City and Environment Act, the draft act allows local governments to depart from the national environmental noise standards.

These developments towards an area-based approach emphasize the need to incorporate environmental aspects in the early phases of the planning process rather than within assessments late in the process (see also Pedersen et al. 2004). Consequently, local authorities and urban planning offices have a need for tools that support area-based approaches. This has resulted in a renewed interest in the tools and methods of the previous decade. In 1998, a research project started at Wageningen University that aimed to develop a GIS-based Strategic Tool for integrating Environmental aspects in Planning Procedures (STEPP). The STEPP tool is based on the experiences with the municipal Environmental Quality Assessment tool, and aims to improve the coherence between spatial and environmental policy at the local level, by stimulating the exchange of relevant information among involved disciplines and decision-makers and providing a means for exploring alternatives. STEPP especially aims to identify potential options in the early phases of the process, and thus has a quick-scan character.

The basic principles and components of STEPP are described in the paper by Carsjens, van Lammeren and Ligtenberg (2003b), included in Section 4.1.

3.3.3. The implementation and testing of STEPP in planning practice

In March 2001, a one-day workshop was organized for a dedicated group of planners and environmental specialists of S.A.B. office for urban planning (Arnhem, The Netherlands). The group included two environmental planners, an urban designer, a social geographer and an acoustic expert. The main objective of the workshop was to assess the potential applicability of STEPP for planning practice. The morning program of the workshop included an introduction to STEPP and some basic exercises. In the afternoon a development project of a new residential area in the municipality of Goor was analyzed, which was an actual project at S.A.B. at that time. The input data for this project was provided by S.A.B. only a few days before the workshop. Some more details of this case study are described in Carsjens et al. (2003b) (Section 4.1). An extensive questionnaire with open-end questions was used to record the experiences with the different aspects of STEPP. The results were discussed. The main conclusions from the questionnaire and the discussion were:

1. The participants concluded that STEPP is user-friendly and easy-to-use, especially given the fact that only one of the consultants had some previous experiences with GIS (ArcView).
2. STEPP does not provide the tools for analyzing the environmental impacts of road traffic, which the participants consider an essential topic for local spatial planning.
3. The defined categories of receptive environment (the six function classes) should be more detailed, especially regarding the distinct types of residential areas that are being used in planning practice.
4. Additional data and information might improve the applicability of STEPP, e.g. information on the traffic intensity (see also point 2) and the qualitative aspects of houses in residential areas (see also point 3).
5. STEPP stimulates discussion between professional disciplines.
6. The participants concluded STEPP is a fast, efficient and representative tool to analyze the environmental aspects.

Given the positive results of the workshop, a project of S.A.B. and Wageningen University was started to explore the use of the STEPP tool in planning practice, with the objective to enhance to tool and make it more suited for planning practice. From the autumn of 2001 to the spring of 2003, STEPP was used at S.A.B. in several projects for the municipalities of Goor, Bergeijk and Nijmegen. Furthermore, an explorative research was carried out, including an inventory among spatial planners and environmental experts at municipalities and universities (Schaminée 2002).

The results of the use of STEPP in the case study for the municipality of Nijmegen are described in the paper by Carsjens and Ligtenberg (2007), included in Section 4.2.

The experiences with STEPP in the projects in Goor, Bergeijk and Nijmegen showed that the STEPP tool required some basic changes, in order to make the tool more fit for the regular working process and the most essential data used in this type of projects. The project did result in a revised version of STEPP, including the intro-

duction of road and rail infrastructure as linear sources of environmental impact, the removal of the qualitative types of impact, changes in the sensitivity matrix and several changes in the layout and user-interface (see also Carsjens & Ligtenberg 2007). Disappointingly, the revised version of STEPP has hardly been used by S.A.B. since. Main causes are a lack of suitable projects, a reduced size of the environmental division at S.A.B., and especially the key driving persons who left S.A.B. (see also Chapter 5). At present, STEPP is only being used in a few planning courses involving a case study in the Netherlands, which will be described in the next section.

3.3.4. Experiences with STEPP in spatial planning courses: The case of Ede-Veenendaal

Since 1998 different versions of STEPP have been used in two spatial planning courses at Wageningen University and a postgraduate course at the Mediterranean Agronomic Institute of Chania (MAICh) in Greece. These courses include practical assignments, where students are working with the application individually or in small groups. From 2005, the revised version of STEPP is being applied for the case study area Ede-Veenendaal (see Figure 3-4), including identical assignments for the course at MAICh and one of the courses at Wageningen University. This section describes the case study area, the assignments and the experiences with STEPP in both courses.

Figure 3-4 The location of the study area Ede-Veenendaal (box) in the Netherlands.

The case study area Ede-Veenendaal is located in the central part of the Netherlands. The area is particularly attractive to companies, thanks to such factors as its strategic location in the heart of the Netherlands, between the Randstad in the west of the Netherlands with cities as Utrecht and Amsterdam, and the German *Ruhrgebiet*. The case study area includes the rural area between the cities of Ede in the east and Veenendaal in the west (see Figure 3-5), with a cross section of 6.5 km from east to west and 4.7 km from north to south, covering 30 km^2. The municipality of Ede has over 100,000 inhabitants and Veenendaal over 60,000, and both municipalities are rapidly growing. Ede and Veenendaal have various industrial areas, including sites for service companies and research institutes, industry, transport and logistics and for high-tech companies.

Figure 3-5 The case study area Ede-Veenendaal.

The level of facilities in Ede and Veenendaal is high, and includes a customs office and intercity railway stations. By road, Ede and Veenendaal are accessible via the A12 and A30 highways. A new circular road at the east side of Veenendaal is currently being constructed and will connect to the highway A12. The main railway line (dotted line north to the highway A12) will also be the location of the future high speed train between Amsterdam and Germany. As a consequence, several new urban

developments are expected to take place in the next years, including thousands of new homes and new business and industrial areas.

The rural area between both cities is highly influenced by these urbanization processes, and numerous urban activities are located in this rural area, such as transport companies, garden centers, and shops. A growing part of the (former) agricultural buildings is inhabited by urban residents. The remaining agricultural activities in the study area are dominated by intensive livestock farms, especially pigs and poultry.

The data of activities in the study area include point and area activities, as well as road and rail infrastructure, each incorporated in a separate GIS layer (ArcView theme). The related tables include the characteristics of the activities in the study area, such as: name, address, a unique code, a description of the activity, and indicative impact distances. The three themes with activities, as well as the built-up area, are shown in Figure 3-6. The differentiation between point and area sources is solely based upon a functional differentiation in agricultural activities (point layer Puntbronnen) and activities related to the urban area including the larger industrial sites (polygon layer Vlakbronnen).

Figure 3-6 Point, line and area activities in the study area Ede-Veenendaal.

The point activities (Puntbronnen) in Figure 3-6 represent the midpoint of the farm buildings of intensive livestock farms. The most important impact of these farms is smell nuisance. The study area includes 89 livestock farms, dominated by pig and poultry farms. The point sources are all located in the rural area. The area activities (Vlakbronnen) in Figure 3-6 represent mostly urban related activities, such as industrial zones, industrial buildings, company premises and sewage plants. The study area includes 53 area activities, including industrial zones (service industries and offices,

wholesale trade, manufacturing industry, and heavy industry). The industrial zones are all located in the urban area, and the individual activities are located in the urban as well as the rural area. Table 3-4 shows a list of the area activities in the study area, derived from the table of the theme Vlakbronnen (area sources) in ArcView. The table also includes information on the impact distances of each activity, derived from lists of the organization of Dutch municipalities (VNG, see Sections 4.1 and 4.2).

Table 3-4 Area activities in the study area Ede-Veenendaal.

	Name	Address	SBI-code	Description	Smell	Dust	Noise	Risk
1	Veenendaal N	Veenendaal	T 02	Wholesale trade	30	10	50	30
2	Sewage Ede	Dwarsweg 5	B 9000.1 1	- < 100.000 residents	200	10	100	10
3	Frankeneng N	Ede	T 03	Manufacturing industry	100	50	100	30
4	Galvanistraat W	Ede	T 03	Manufacturing industry	100	50	100	30
5	Galvanistraat SW	Ede	T 02	Wholesale trade	30	10	50	30
6	Copernicuslaan East	Ede	T 02	Wholesale trade	30	10	50	30
7	Galvanistraat N	Ede	T 02	Wholesale trade	30	10	50	30
8	Galvanistraat S	Ede	T 02	Wholesale trade	30	10	50	30
9	Frankeneng SW	Ede	T 03	Manufacturing industry	100	50	100	30
10	Frankeneng SE	Ede	T 03	Manufacturing industry	100	50	100	30
11	Frankeneng E	Ede	T 02	Wholesale trade	30	10	50	30
12	De Klomp S	De Klomp	T 03	Manufacturing industry	100	50	100	30
13	De Klomp W	De Klomp	T 03	Manufacturing industry	100	50	100	30
14	De Klomp E	De Klomp	T 02	Wholesale trade	30	10	50	30
15	De Klomp N	De Klomp	T 02	Wholesale trade	30	10	50	30
16	Tree nursery	Ederveen	B 0111	Arable farming and fruit farming (farm buildings)	10	30	30	10
17	Garden Center	Ederveen	B 5211	Super markets, department stores, builders' merch	0	0	10	30
18	Woodwork	Manen	B 203	Woodwork factories	0	30	100	0
19	Kievitsmeent	Ede	T 03	Manufacturing industry	100	50	100	30
20	Manure processing	Ede	B 9000.3 A	- manure processing plant	500	10	100	10
21	Cars	Manen	B 501	Car and motorbike dealers, repair and service com	10	0	30	10
22	Contruction	Ederveen	B 45 A	Building and construction companies with workshop	10	30	50	10
23	Metal fences	Ederveen	B 287 B	Other metal works not previously mentioned	30	30	100	30
24	Horse riding	Veenendaal	B 9261.2 E	Riding schools	50	30	30	0
25	De Kade	Ede	T 03	Manufacturing industry	100	50	100	30
26	Agricultural transpo	De Kade	B 014	Agricultural services	30	10	50	10
27	Cars and recycling	Manen	B 501	Car and motorbike dealers, repair and service com	10	0	30	10
28	Cars	Manen	B 504 A	Car and motorbike dealers, repair and service com	10	0	30	10
29	Paving stones center	Manen	B 5211	Super markets, department stores, builders' merch	0	0	10	30
30	Snack bar	Manen	B 553	Restaurants, cafeteria's, snack bars, fish dealer	30	0	10	10
31	Manen S	Ede	T 02	Wholesale trade	30	10	50	30
32	Manen N	Ede	T 02	Wholesale trade	30	10	50	30
33	Agricultural machine	Manen	B 014	Agricultural services	30	10	50	10
34	Plastic recycling	De Klomp	B 5157.2	Other wholesale trade in waste and scrap	10	30	100	10
35	Soil tillage machine	De Klomp	B 014	Agricultural services	30	10	50	10
36	Petrol station	De Klomp	B 505 2	- without LPG	30	0	30	30
37	Agricultural machine	Ederveen	B 014	Agricultural services	30	10	50	10
38	Cars	Ederveen	B 501	Car and motorbike dealers, repair and service com	10	0	30	10
39	Electro technical se	Ederveen	B 316	Electro technical industry not previously mention	30	10	50	30
40	Trailers	Ederveen	B 501	Car and motorbike dealers, repair and service com	10	0	30	10
41	Paving stones	Ederveen	B 5211	Super markets, department stores, builders' merch	0	0	10	30
42	Agricultural transpo	Ederveen	B 014	Agricultural services	30	10	50	10
43	Garden center	Ederveen	B 5211	Super markets, department stores, builders' merch	0	0	10	30
44	Cars	Ederveen	B 501	Car and motorbike dealers, repair and service com	10	0	30	10
45	Restaurant	Ederveen	B 553	Restaurants, cafeteria's, snack bars, fish dealer	30	0	10	10
46	Garden machines	Ederveen	B 501	Car and motorbike dealers, repair and service com	10	0	30	10
47	Contruction company	Ederveen	B 287 B	Other metal works not previously mentioned	30	30	100	30
48	Horse riding	Ederveen	B 9261.2 E	Riding schools	50	30	30	0
49	Vlastuin transport	Ede Doesburg	B 6024	Freight transport	0	0	100	30
50	Mestpro BV	Ede Doesburg	B 9000.3 A	- manure processing plant	500	10	100	10
51	Cafe-restaurant	Ede Doesburg	B 553	Restaurants, cafeteria's, snack bars, fish dealer	30	0	10	10
52	Installatiebedrijf	Ede Doesburg	B 45 A	Building and construction companies with workshop	10	30	50	10
53	Hovenier	Doesburg	B 0141.1	Garden maintenance companies	10	10	10	10

For the strategic planning of new industrial areas, STEPP also includes four types of industrial zones, including average influence distances of representative activities. The linear sources (line layer Wegenbronnen) in Figure 3-6 represent the major road

and rail infrastructure in the study area, including the highways A12 and A30, the railway line Utrecht-Arnhem along the A12, and a small part of the railway line Ede-Barneveld to the north. The most important impacts of the road and rail infrastructure are noise and local air pollution. These impacts are derived from indicative figures for representative types of road and rail infrastructure, based on traffic intensity, maximum speed and the relative amount of fright traffic.

The assignments

The assignments start with the hypothetical case that the local authorities of Ede and Veenendaal appoint an urban project agency (represented by a pair of students) to assess the spatial-environmental issues in the area, and to develop a strategic vision for the future spatial development of the area. The vision should include a description of some spatial alternative scenarios for the future urban development of the area and an assessment of the environmental implications. The vision should support the local authorities in the spatial planning and decision-making process. The local authorities aim to develop new residential areas as well as industrial zones, but also intend to protect the rural area for its importance as an open, green buffer area between both cities. Therefore, large parts of study area should maintain its agricultural character or might be developed into natural reserves or water areas. The strategic plan should be illustrated with maps, which show the spatial-environmental implications of the different alternative scenarios. The project includes three successive assignments. The first assignment includes the scoping of the study area (similar to the scoping phase of an environmental impact assessment). The scoping aims to identify the most important types of impacts, activities and functions in the study area. Since the study area is very large, the analysis progressively focuses in more detail at a selected area of approximately 1 km^2 of the rural-urban fringe of Ede or Veenendaal. The students can select this area themselves. The selected area will be studied further in a second assignment, where several spatial alternatives need to be designed. The results of the analyses are presented in a report with supporting maps. The report should demonstrate whether or not industrial and business zones or other activities can be allocated in the selected area, how present and future residential areas and/or other sensitive areas can be allocated together with these zones, and which (indicative) measures could be taken to prevent or reduce impacts ('mitigation'). The report should present the variety of options the local authorities have with regard to the spatial development of the selected area, and the implications of each of these options from environmental perspective. The third assignment involves an evaluation of the assignments and the STEPP method and tool.

The results

In general, the results from the individual evaluation assignment show that the students appreciate the STEPP tool for its ability to easily develop and assess different spatial scenarios, and the resulting maps for their clarity in showing the spatial implications of the scenarios and their environmental impacts. Also, the tool stimulates the strategic discussion among students about the different options. However, the majority

of students find it difficult to understand the practical implications of the choices at hand, as they generally tend to focus in too much detail on the area, and consequently lack the required detailed environmental knowledge, e.g. on applicability and effectiveness of potential measures. It usually takes some time for the students to start thinking and working at a more strategic, generic and less detailed level, in terms of indicative options. However, at the end of the course most students show to be able to generate a strategic vision for the study area, supported by a smaller or larger range of scenarios and a discussion of the strengths and weaknesses of these scenarios.

The scoping of the area (assignment 1) generally results in a range of maps showing the specific impacts and qualities in the area, such as those of smell, risk and noise impacts from infrastructure, like the ones presented in Figure 3-7. With respect to the study area, the scoping shows that risk, noise from activities and dust are occurring locally in the direct vicinity of the activities, while smell and noise from infrastructure have a much more significant impact in the area. The maps show the difficulty of the task that the students are facing, since the impacts cover almost the entire area.

Figure 3-7 Examples of maps resulting from the process of scoping of the study area (for further explanation see the papers in Sections 4.1 and 4.2).

The exploration of alternative options usually results in a variety of different scenarios. Some characteristic examples for a detailed area are shown in Figure 3-8.

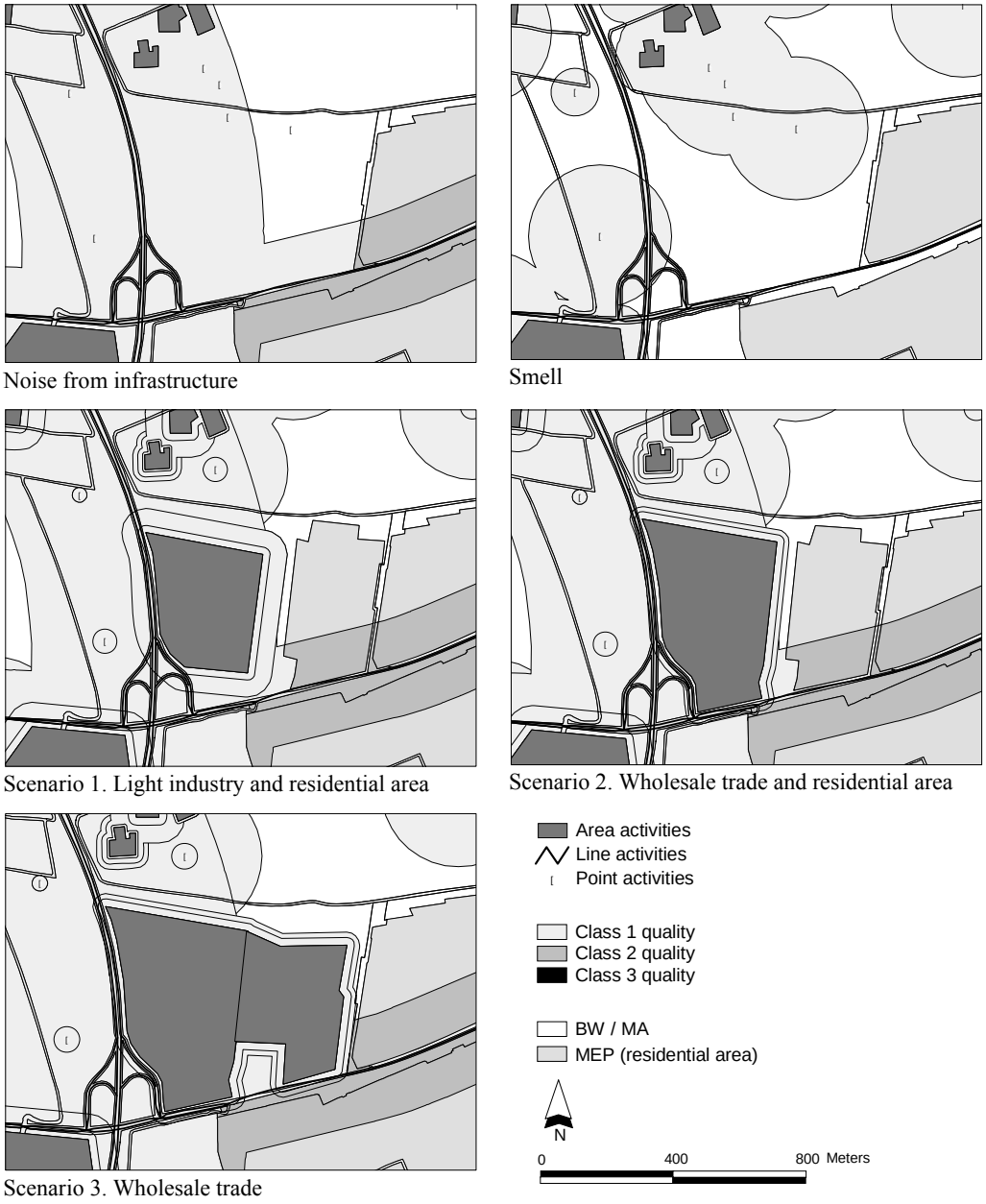


Figure 3-8 Examples of explorative maps for a detailed area. The upper two maps show the current impacts, and the other three maps are results from different scenarios.

Students may find it difficult to recognize that the use of STEPP does not involve making the final decisions themselves, but presenting stakeholders and decision makers with some relevant alternative future options, and demonstrating the environmental consequences of each of these options. A common strategy is to identify the range between the likely or preferable options on the one hand, and the less suitable or undesirable options on the other hand. Students also need to realize that the results of STEPP in practice will only be a part of the input to the decision making process, where many other issues will play a role, not in the least: finances.

Many international students at MAICh, originating from European, Asian and African countries in the Mediterranean area, point to the fact that the basic data which are being used by the STEPP tool, such as the data on impact distances, are generally not available in their home countries. Consequently, the applicability of the tool in these and other countries with a lack of similar data seems to be limited.

3.4 Spatial planning of future livestock farming

Globally, progress in the agricultural sector has resulted in a remarkable output growth in terms of volume, range and quality, and has allowed agricultural production to cope with population growth and rising demand (Gerber 2006). This also involved a shift towards the production and consumption of animal products (Bruinsma 2003, Steinfeld et al. 2006). In 1965 the per capita meat consumption in the developed countries reached 62 kg per year, which steadily increased to 83 kg in 2005 (FAO 2006). Up to the 1980s, daily meat and milk consumption were only common to people in the developed countries, such as the Netherlands, and a small, wealthy class elsewhere. But the demand for animal products in the developing countries has been growing rapidly since, driven by rising incomes, growing populations and urbanization (Delgado et al. 1999, Steinfeld et al. 2006). The per capita consumption of meat in the developing world rose from 14 kg in 1980 to 30 kg in 2005 (FAO 2006). The livestock sector is responding to this demand-led surge in livestock products through some drastic transformations, and undergoes structural changes along the whole supply chain: distribution, processing and production sites are all affected (Gerber 2006). This so-called "livestock revolution" (Delgado et al. 1999, Delgado 2003) is characterized by an increase of large retailers, a tendency towards vertical integration and coordination along the supply chain, and industrialization of the production process. The FAO concludes that we "[…] need to accept that the intensification and perhaps industrialization of livestock production is the inevitable long-term outcome of the structural change process that is ongoing for most of the sector" (Steinfeld et al. 2006: p. 283).

The transformations in livestock production have had some serious drawbacks. Globally, intensive livestock production and its structural changes are associated with a range of environmental impacts (Steinfeld et al. 2006). These impacts, such as the impacts on the landscape, water and soil quality, as well as public health risks, are increasingly criticized (Gerber 2006). Typically, there shows to be a strong geographic component in many of the involved issues, such as livestock distribution, access to markets, disease risk and environmental impacts (Steinfeld et al. 2006). In general,

livestock production tends to concentrate in peri-urban areas, especially in the developing countries, favored by cheap input supplies (in particular feed) and market outlets for livestock products, which can be found in the vicinity of large cities. As a consequence, large intensive livestock farms and their environmental impacts are an increasingly dominant phenomenon in metropolitan landscapes.

This section describes the development of a planning support system which aims to support a more sustainable spatial planning of future livestock production in South-East Asia. The system originates from several pilot research projects in the Netherlands (Section 3.4.1), China and Thailand (Section 3.4.2). The experiences from these pilot studies should allow the construction of a planning support system to be used by national and regional administrations in South-East Asia (Section 3.4.3).

3.4.1. Livestock farming in the Netherlands

The agricultural cluster is a key area of the Dutch economy, accounting for 10% of the national income and employments in the Netherlands, and using about two-thirds (1.9 million hectares) of the total land (Ministry of LNV 2005). The basic strengths are the mild climate and fertile level soils, good transportation links to the major population centers of northwest Europe, but also the efficient chain of supply, production, processing, distributing and marketing of agricultural products. Dutch agriculture has a high level of professional expertise, knowledge, research and training, making it an innovative and internationally competitive sector. Main weaknesses are the relative scarcity of labor and land, and resulting high prices of farmland, forcing the primary sector to either diversify or to increase the production per hectare, animal and person (Ministry of LNV 2005). Diversification includes all kinds of side activities, such as recreational facilities, overnight accommodation, energy production, and farms shops. Intensification especially focuses at a further specialization of the primary production and an increase in scale and intensity. Gies et al. (2007) describe a recent rapid incline in very large livestock farms in the Netherlands. According to the IPPC (Integrated Pollution Prevention and Control) Directive of the European Union such farms are to be regarded as industrial activities (EU 1996). But intensification also showed it drawbacks in the past decades, in particular with respect to the environmental impacts of livestock farming. Furthermore, outbreaks of various animal diseases, such as classical swine fever in 1997, have seriously disrupted the development of intensive livestock farming in recent years (Ministry of LNV 2005).

These developments triggered a research project at the Wageningen University with the aim to assess the suitability of areas for future intensive livestock farming, and developing a spatial planning support method using a combination of GIS and multi-criteria techniques (Carsjens & Smits 1997, van der Knaap & Carsjens 1999). The method includes two basic phases: (1) identifying restricted areas, and (2) assessing the suitability of the remaining areas for different scenarios, using GIS and multi-criteria techniques. The method has been applied at the local level for dairy farming, and at the regional level for pig farming.

The results of the research project are described in the paper by Carsjens and van der Knaap (2002), included in Section 4.3.

The paper illustrates that the research has been set up to demonstrate the potential applicability of a method using GIS and multi-criteria techniques to support the scanning of alternative future spatial scenarios, taking a variety of economical and environmental issues into account. The research did not include any specific issues related to the process of planning and decision making, and has primarily been set up from the perspective of design-oriented planning. The results have not been used in actual planning practice.

However, the results showed to be relevant for the Food and Agricultural Organization (FAO) of the United Nations. In 2002 the Land Use Planning Group became involved in a research project of FAO that aims at developing a spatial planning support tool for the strategic spatial planning of future livestock production in developing countries. This project will be described in the next section.

3.4.2. Livestock farming in developing countries

Livestock production is developing very fast in the developing countries. The growth in production is mainly supported by industrial systems, achieved through growth in scale and a shift towards monogastric species production, such as pigs and poultry (FAO 2003, Delgado et al. 2002). The livestock production also tends to concentrate in areas favored by cheap input supplies (in particular feed) and by good market outlets for livestock products (Steinfeld et al. 2006). 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, often supplanting them. In general, 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). These changes have serious impacts on the environment, animal and public health and the welfare of small holders (Steinfeld et al. 1997, de Haan et al. 2001, Gerber et al. 2005). Many smallholder farmers are being pushed out of the livestock sector because they are unable to compete with the new large-scale commercialized production. Rural people who know of no other life than farming, face falling into poverty if their farms no longer supports them and if they find no alternative sources of income (Gerber 2006). While cheap animal protein favors poor consumers, the poverty and equity effects of industrial livestock production are, on balance, largely negative (de Haan et al. 2001). Furthermore, most developing countries, such as China, Thailand and Vietnam in South-East Asia, are lacking appropriate and effective policy and regulations to address these problems.

In 1998 the Livestock, Environment and Development (LEAD) Initiative, based at the Food and Agricultural Organization, started the Area Wide Integration (AWI)

project that aims to reduce the environmental impacts of the rapidly growing livestock production sector, by integrating specialized livestock production with cropping activities on a regional scale (Gerber 2006). The AWI project includes four main issues: (1) the assessment of current manure management strategies; (2) an economic and policy analysis of these strategies; (3) the spatial analysis and planning of livestock production, and (4) the design and evaluation of technical and policy options for a more sustainable future development of livestock production. The spatial planning of livestock production is important given the major influence of the geographical component that is included in many of the involved issues, such as livestock distribution, access to markets, disease risk and environmental considerations. This section describes the results of the AWI project with regard to spatial decision support of planning and policy making of future livestock production. A spatial planning support method was developed and applied in AWI case study areas in China and Thailand.

Spatial planning support method

The spatial planning support method was specifically designed to support the scanning of alternative future spatial scenarios, but also to address specific context-related requirements: (a) it should be easy-to-master by decision makers, (b) able to include a variety of qualitative and quantitative criteria, (c) able to run on standard computer sets and (d) allow stakeholder participation. The method thus involves not only elements from design-oriented planning, but also decision-oriented planning. The basic approach, shown in Figure 3-9, involves a first step to characterize, describe and parameterize the decision rules, i.e. by using workshops to identify objectives, related sets of criteria and their relative importance (weights) for different scenarios.

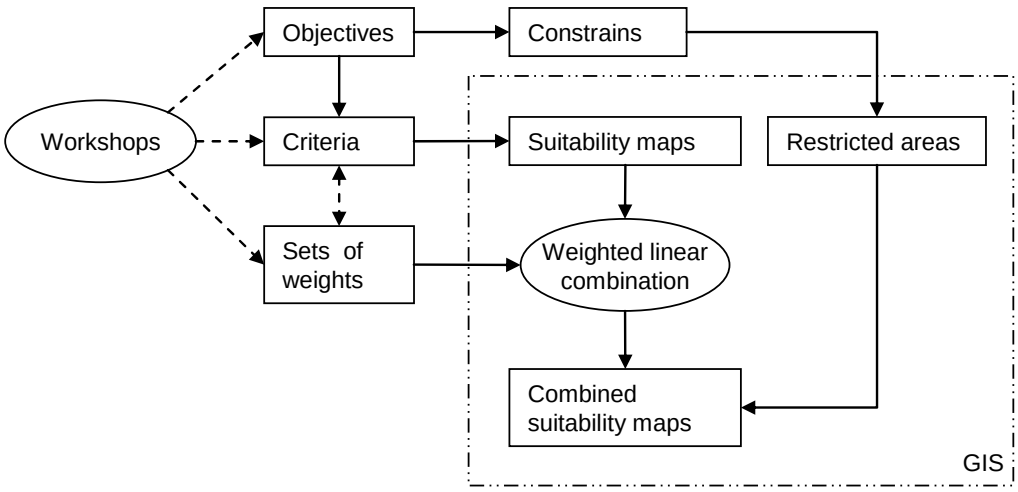


Figure 3-9 Basic approach of the planning support method (for explanation see text).

The second step concerns the assessment of the study area for each of these scenarios, i.e. by identifying restricted areas, and assessing of the suitability of the re-

maining locations. This last step has a similar structure as the method described in Section 3.4.1, and includes the use of GIS and multi-criteria techniques (see also Sections 2 and 3 of Gerber et al. 2008, included in Section 4.5 of this thesis).

From technical perspective the method is transparent and simple, and starts with consulting the relevant policy makers and stakeholders in workshops. In these workshops the required types of output were discussed, as well as the use in planning and decision making of future livestock farming in the area. The policy- and decision-making context was an important focal point in the process of applying the method in the case study areas. Below, the use of the method is described in more detail for the pilot projects in China and Thailand (see Figure 3-10).

Figure 3-10 Location of two case study areas, Wannian County, Jiangxi Province of China (left) and South-Eastern Thailand (right).

Wannian County

Wannian County is located in Jiangxi Province of China, with an area of 1,140 km^2. The livestock production sector in the county is dominated by pig production, covering 93% of the total meat production. In 2001 a total of 310.000 pigs were marketed from the county, of which 10% for export to Hong Kong and Macao, 25% for the local market, and 65% for other domestic markets, such as Shanghai. The livestock farms in the county contribute to the environmental pollution of Poyang Lake, the largest fresh water lake in China. The most significant environmental impacts are from large, industrial pig farms. The local authorities decided to focus on designing and implementing a 'fertilizer plant' to process organic fertilizer from large pig farms solid manure, and identified spatial planning (zoning) of livestock production as an effective measure to accommodate future developments in pig production (Narrod et al. 2002, Gerber et al. 2004). The spatial planning support method was implemented to accommodate the process of selecting suitable areas for the fertilizer plant and pig production areas. The underlying principles of the method and the preliminary results with the use of the planning support method in Wannian County have been published

in Carsjens et al. 2003a and Carsjens et al. 2004. The final technical report of the pilot project was published in 2005 (Ke Bingsheng et al. 2005).

The results of the project, including the use of the planning support method for selecting suitable areas for the fertilizer plant, are described in the paper by Carsjens, Gerber and Vadnjal (submitted), included in Section 4.4.

During the two workshops that were organized in 2002 (see the paper above) also a set of criteria and weights was derived for the suitability assessment for future pig farming. The resulting criteria and weights from informal discussions and consensus building among the participants are shown in Table 3-5. The criteria include constrains to indentify restricted areas as well as criteria to assess the suitability of the remaining areas.

Table 3-5 Criteria with relative weights for pig development areas.

	Unit	Restricted	Suitability classes			Weights		
			low (0)	moderate[1] (0-1)	high (1)	envir.	neutral	econom.
Distance to inhabited area	m	< 300						
Slope	%		>20	0-20	0	0.4	0.25	0.1
Current nutrient balance (P_2O_5)	%		<3	3-40	40	0.4	0.25	0.1
Distance to main road	m	< 100	max[2]	600-max	200-1500	0.1	0.25	0.4
Distance to surface water	m	< 200	max[2]	1500-max	200-1500	0.1	0.25	0.4
Distance to large and medium pig farms	m	< 2000						
Current land use	-	arable land						

[1] max represents the maximum distance from any point in the area to main road/surface water
[2] the moderate suitability class was implemented as a gliding scale from 0 to 1

The table shows that the sets of weights, from farm economical perspective, environmental perspective and the combination of both (neutral scenario), are set up in analogy to those used for identifying suitable locations for a fertilizer plant. A resulting final suitability map for future pig farming was derived using weighted linear combination, and shown in Figure 3-11.

As described in the above paper, the suitability maps were used successfully by the local government to identify a suitable location for the fertilizer plant. The area that was finally selected for the construction of the plant was among the highest ranked areas, but was selected only after additional field visits, showing some specific local characteristics, e.g. the possibilities to obtain the area and to provide it with the

required supply of electricity. Such local characteristics are generally too detailed to be included in the analysis, and demonstrate the indicative nature of the results of the analysis. The maps did successfully support the selection process by effectively narrowing it down to the most suitable areas. The approach and results of the suitability assessment for future pig farming have been published in a Chinese paper by Zhao, Carsjens and Gerber (2006). This Chinese scientific paper and its English translation are included in the Appendix.

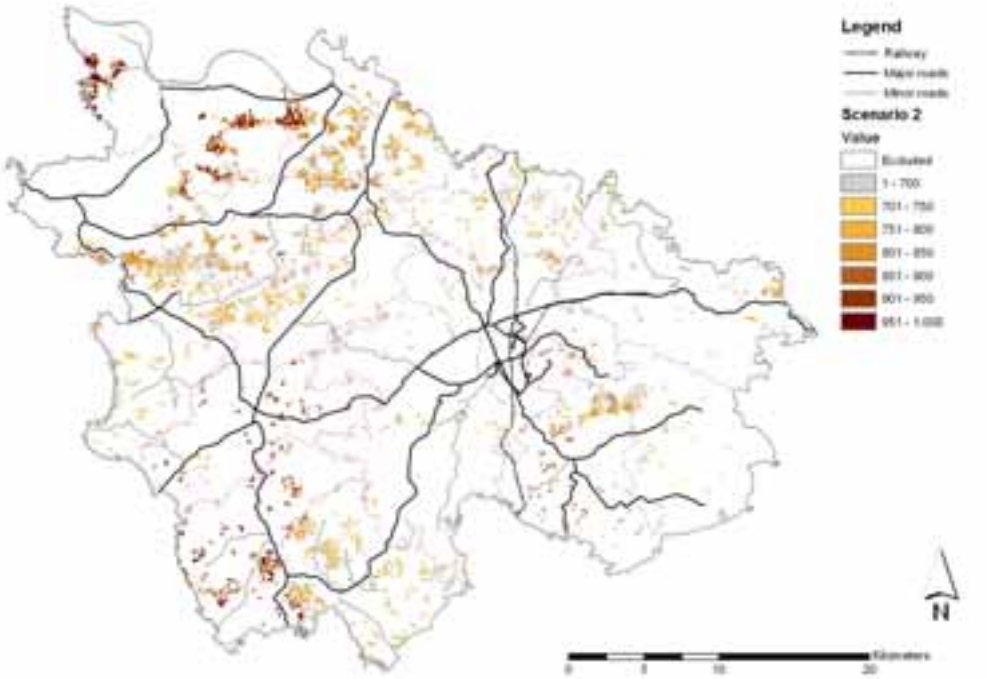


Figure 3-11 Final suitability map for pig development areas, neutral perspective.

Thailand

The study area, Region 2, includes 9 provinces in the southeast of Thailand, with an area of 38,000 km^2 (see Figure 3-10). The area is located in the vicinity to major consuming centers (Bangkok, Chachoengsao) and has been designated by the Thai government as a growth area for pig and poultry production. It can be expected that the livestock production will rise sharply in the next 10 years, with severe impacts on the environment, public health and rural development (Rattanarajcharhul et al. 2000). The Department of Livestock Development (DLD) of the Ministry of Agriculture and Cooperatives identified spatial planning (zoning) of livestock production as a potential measure to improve the social benefits and mitigate the negative impacts. The planning support method was implemented to accommodate the process and support the participation of a variety of stakeholders.

Two workshops were organized in 2003. The first was a policy workshop, including 39 participants from central and decentralized governmental offices, livestock producers, and NGOs. The participants discussed the public policy goal and a list of contributing objectives in three groups, and ranked and weighted the objectives to their respective relevance to the goal, using the Analytical Hierarchical Process (AHP) (e.g. Saaty 1987) with a nine-point continuous comparison scale. A second workshop with 20 technical experts was organized to identify, standardize and weigh a list of criteria for each objective, again using the AHP. The experts covered a range of thematic areas, including animal and public health, economics, livestock production, manure management, rural development, soil science, agronomy, natural and water resource management and environmental protection. They were split into four groups, each group covering one of the objectives. Finally, the workshops resulted in four objectives and 18 criteria, with subsets for each objective (see Table 7 in Gerber et al. 2008, included in Section 4.5). The general procedure used in Thailand for deriving the suitability maps from these objectives and criteria is shown in Figure 3-12.

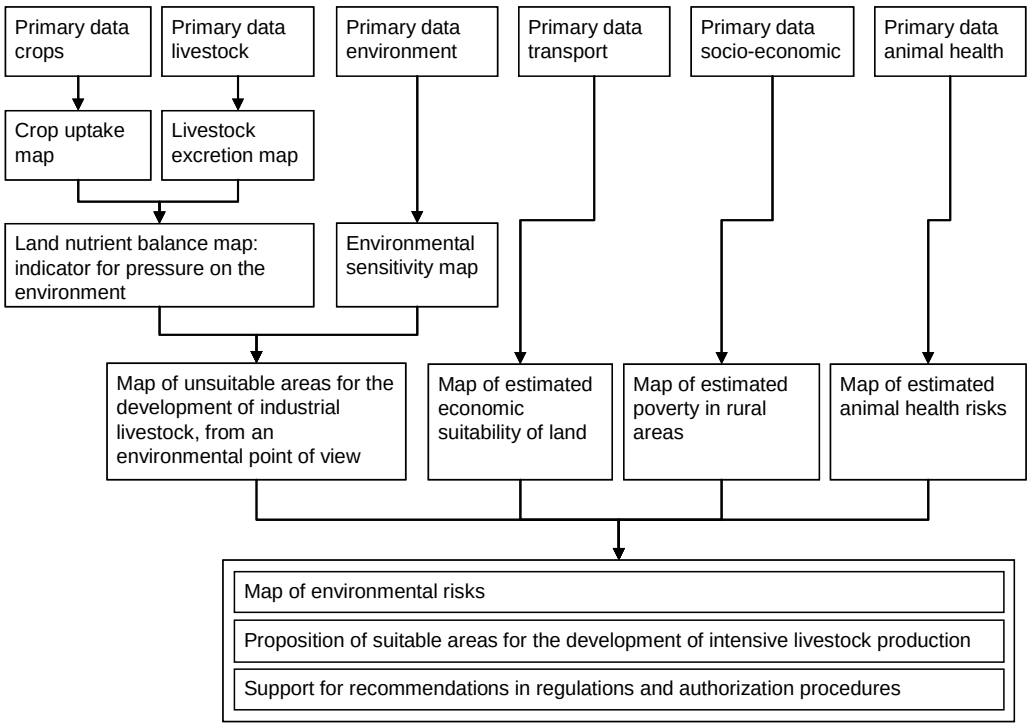


Figure 3-12 Procedure for deriving the suitability maps in GIS.

For each objective a suitability map was derived using GIS. The combined suitability maps were obtained with weighted linear combination, using the sets of weights attributed to the objectives by the three groups of local policy makers and

stakeholders in the policy workshop. Afterwards, some more generic maps were derived, appointing each administrative area to a certain suitability class.

The results with respect to the use of the planning support method in Thailand are described in the paper by Gerber, Carsjens, Pak-Uthai and Robinson (2008), included in Section 4.5. The paper also describes the results of use of the method in another FAO project in Uganda. Since this project was not included in the AWI project nor linked to the presented case studies on future livestock production in this thesis, no further details will be provided on the Uganda case.

Conclusion

The case studies show that the spatial planning support method can substantially improve decision making for livestock production. While mitigation of environmental pollution by animal waste can be tackled by improving waste management practices at farm level, the spatial planning of livestock production should reduce environmental impacts through a proper zoning and buffering, avoiding negative environmental impacts in sensitive areas. Although zoning is not new to livestock policies, the method supports stakeholder participation and makes the decision making process more transparent. The use of GIS improves communication by providing detailed and clear maps to stakeholders and decision makers. However, although the output maps may look very detailed and accurate, quite often they are probably not. Local circumstances can very easily differ from the more generic maps. Decision makers should be aware of the fact that the maps are merely indicative, and should be used as such. Furthermore, the output will strongly depend on the availability and quality of the input data (see also the Uganda case in the paper in Section 4.5). Although the availability of data progressively increases in most countries, this remains a potential weakness of the method (in this respect the classic adage "garbage in, garbage out" is still true). Other uncertainties are inherent to the use of multiple criteria techniques (e.g. Voogd 1983, Triantaphyllou 2000), for example: Are all relevant criteria and stakeholders included? Some of these uncertainties may be tackled with a sensitivity analysis (Qureshi et al. 1999, Delgado & Sendra 2004).

From the experiences of the AWI project can be concluded that the planning support method is potentially very useful for the spatial planning of future livestock production. However, the experiences also show that using the analysis tools that are available in the standard GIS packages makes it a very time-consuming process, because of the intensive data analyses, and the many repetitive steps. A more user-friendly tool requires that the potential users are able to perform the analyses more easily and quickly. Therefore, additional tools should be made available within the GIS software. This requires specific data preparation and analysis tools to be built. The method that has been developed in the AWI project will be a useful basis for the construction of such tools.

The positive results from the AWI project triggered an initiative for a follow-up project that should result, among other things, in a more operational, easy to use and

distribute spatial planning support tool, based on the method that was developed in the AWI project. This project is described in the next section.

3.4.3. Follow-up project

Given the promising results of the AWI projects, the FAO supported the preparation of a follow-up project, instigated by three South-East Asian countries: Vietnam, Thailand and Guangdong Province of China. In 2004 the three countries started preparations to apply for funding by the Global Environmental Facility (GEF) of the World Bank. The objective of this Livestock Waste Management in East Asia (LMWEA) project (World Bank 2006) is to reduce the negative local and global environmental impacts of the rapidly increasing livestock production in some selected demonstration areas in China, Thailand, and Vietnam that drain into the South China Sea and Gulf of Thailand. The proposed project and its replication should lead to a reduction of land-based pollution from livestock production to these international waters.

The project consists of four components, of which three are implemented in each country and one is implemented regionally (World Bank 2006). This design takes into consideration the specific local conditions of each country while maintaining coherence of project objectives, project composition, criteria for selection of demonstration areas, and regional learning from experiences and coordination.

Component 1. *Livestock waste management technology demonstration.* This component aims to demonstrate a sustainable environmental improvement through the use of proper livestock waste management technology at farm level.

Component 2. *Policy and regulatory development.* This component is expected to lead to the development and implementation of more effective policies for livestock production and waste management with strengthened and better-enforced regulations, policy measures, and strengthened institutions as well as financial incentives for enforcement and compliance.

Component 3. *Project management and monitoring.* This component provides the project management and monitoring and evaluation of the social, economic, environmental and other changes brought about by the project.

Component 4. *Regional support services.* This component develops common decision support tools, conducts periodic evaluations for policy makers, facilitates the exchange of information and lessons learned amongst the three countries participating in the project, and disseminates experiences to other countries in the region. In each of the participating countries it is evident that a growing awareness of environmental and public health issues associated with livestock waste mismanagement is often not translated into action because of a lack of knowledge and experience about how to deal with the issue. On the other hand, many

> of the analytical tools and approaches required to effectively address the issue would be the same in Thailand, Vietnam and Guangdong province, as well as in other countries and provinces bordering the South China Sea. It therefore makes sense to draw on cross-country synergies, skills and economies of scale in pursuing the achievement of the project's objectives through a regional component serving each of the participating countries.

The development of a spatial planning support tool is included in the regional component 4 of the project, but also has strong links to the country specific policy and regulations in component 2. During the preparation process of the project proposal in 2004 and 2005, the three participating countries 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 planning support tool should allow them to support the adoption of zoning policies and regulations for the spatial planning of future livestock production. The basic objective of the spatial planning part of the project is therefore to prepare a method and GIS tool to support the spatial planning of livestock production in Southeast Asia, based on the experiences in the AWI project. The method and tool should allow the identification and assessment of potential suitable and unsuitable areas for the development of livestock production. The method and tool should be implemented at the relevant governmental levels that are involved with the decision making on environmental and spatial planning and policy making for livestock production. The use of the method and tool should initiate a more sustainable spatial planning of livestock production. Therefore, spatial planners and policy makers should be made aware of the positive environmental benefits of using the method and tool 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. The results of the preparation process are described in the FAO technical report by Carsjens (2004).

The project proposal was given a positive response by the World Bank, and accepted for Global Environmental Facility (GEF) funding (World Bank 2006). In 2006 and 2007 two preparation meetings were organized to discuss the further implementation of the project, including the preparation of the planning support tool (Carsjens 2006 and Carsjens & Gerber 2007). An important first step of the design of the tool was to identify the potential users and their specific needs. Among users, we differentiate users of the tool and the users of the output (resulting maps) of the tool. The missions' objectives were to identify and discuss (1) the decision making procedure, (2) the operational users of the tool and its output or products, and (3) the relevant ministries, departments and other stakeholders that need to be involved in setting the policy objectives and criteria. As an example, the results for Vietnam are presented below.

Ad 1. Two different decision making situations were identified for establishing new pig farms in Vietnam. Large commercial farms (> 200 pigs) are regarded as enterprises under the business law, and decisions are primarily been made at province level (see Figure 3-13). Therefore, the department of planning and investment (DPI),

and the provincial peoples committee (PPC) hold a key position in this decision making procedure, with some minor consultation at the department of natural resources and the environment (DONRE) and the department of agriculture and regional development (DARD). In some situation the province needs to consult the respective ministries (MPI, MONRE and MARD) at the national level, depending on the size of the enterprise. For small farms the decision is primarily been made at the district (local) level by the peoples committee (see Figure 3-14). The committee sometimes needs to consult the province, and obviously has to comply with national laws and regulations in their decision making.

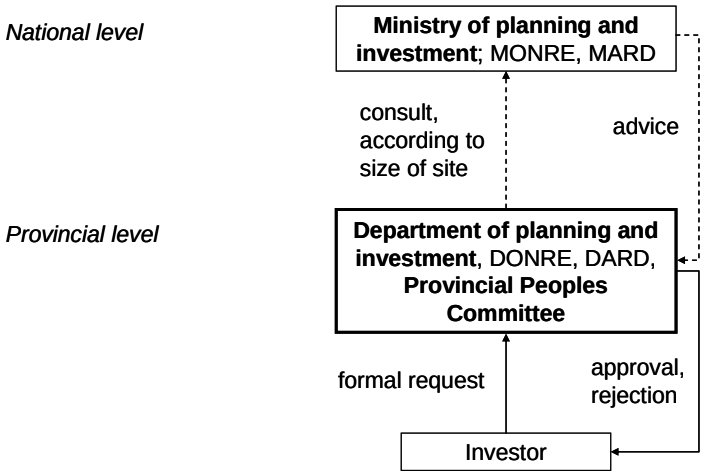


Figure 3-13 Decision making procedure in Vietnam for large commercial pig farms (key decision makers in bold).

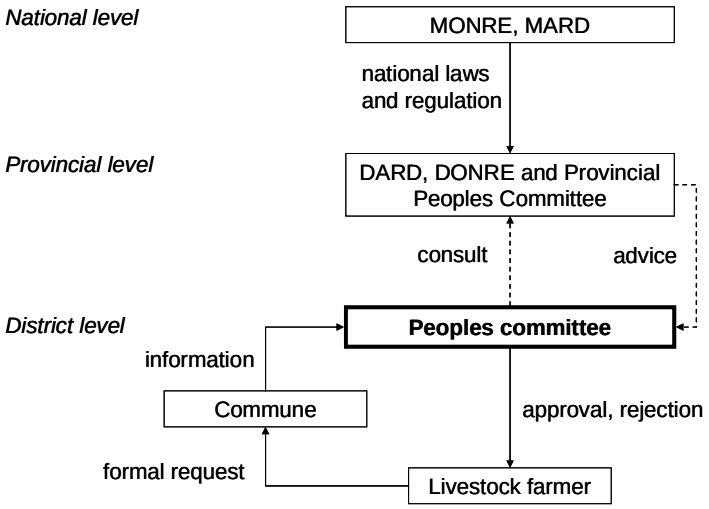


Figure 3-14 Decision making procedure in Vietnam for small pig farms (key decision maker in bold).

Ad 2. The two basic types of output of the project that were discussed and identified are printed output (suitability) maps with an explanatory manual, and the planning support tool. Based on these products the users of these products were identified, listed in Table 3-6. The table also includes a column with specific actions that are needed, e.g. training. The main users of the planning support tool that were identified are the national ministries MONRE and MARD, and possibly the provincial DONRE and DARD of the selected provinces that contribute to the project. Also, the tool will be of interest for educational purposes at universities. A wide range of other ministries, provincial departments and stakeholder groups were identified as potential users of the output maps of the tool.

Table 3-6 The identified users of the tool and output, and their needs in Vietnam.

Users	**Products**		**What is needed?**
	Printed maps with explanatory manual (output tool)	GIS-Application (spatial planning support tool)	
MONRE	X	X	Training
MARD – National institute for agricultural planning and projection, and National institute for agricultural planning and projection	X	X	Training
MPI – dept of small and medium size enterprises	X		
Ministry of trade – dept of business promotion	X		
Provincial Peoples Committee PPC	X		
DONRE	X	X Selected provinces	Training of selected provinces and software (ArcGIS)
DARD	X	X Selected provinces	Training of selected provinces
DPI	X		
Association of medium and small enterprises	X		
Universities – Architectural and Agricultural University	X	X Partners in project; supply of high-quality trainers	Supply CD-ROM
District peoples committee	X		
Animal husbandry union	X		

Ad 3. The third part in the preparation mission addressed the question which stakeholders and institutions should be involved in the project and for what purpose? The purposes that were identified are: (1) data provision, (2) setting policy objectives, (3) setting technical criteria and (4) providing training. The stakeholders and institutions that should participate in the project are listed in Table 3-7.

Table 3-7 Stakeholders and institutions to be involved in the project in Vietnam.

Stakeholders and institutions	**Purpose**			
	Data provision	Policy objectives setting	Technical criteria setting	Training
Ministry of Natural Resources and the Environment (MONRE)	Digital maps (topography, administrative areas, hydrology, soil, land use, water sheds, river basins, ...) Statistical data (rainfall, climate, population, economic, ...)	X	X	
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	
Universities			X	X
National and international experts			X	X
Environmental NGO		X	X	X
Ministry of Health	Community health		X	
Vietnam Farmer Union		X		

The national ministries MONRE, MARD and MPI were identified as important data holders. The results also include an extensive list of ministries, departments,

NGOs and others that should participate in the policy objective and/or technical workshops of the project.

In addition, some technical meetings with national experts were organized to further discuss the technical issues of the spatial planning support tool, especially with respect to the construction (including software coding) of the spatial decision support tool (which is a regional activity), the development of a country-specific database, and providing country-specific training in the use of the spatial decision support tool.

An important conclusion from the preparation missions was that the participants from 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 for macro level was identified as 1:100.000 to 1:500.000. At micro level the tool should be able to support more detailed decision making regarding the allocation of livestock farms. Indicative scale at the local level is 1:50.000. The prospects to use the tool at the local level will, of course, depend highly on the availability and quality of data, especially the required geo-data. In this respect, there are large differences among the three countries. At present, early 2008, the project is about to commence with the actual software coding of the tool.

3.5 Evaluation and conclusions

This section describes the methods for evaluation of the cases and draws some conclusions with respect to the results of the individual cases (see Chapter 4, which may be read first). The general results of the research will be discussed in Chapter 5.

A comparison of the characteristics of the spatial planning support methods applied in the presented cases reveals some similarities and differences. These are shown in Table 3-8. The last column in the table illustrates that in all cases the PSS have distinct design-oriented characteristics. Basically, the presented PSS aim to provide a basis for planners and policy makers to explore and evaluate different future options and to conduct many 'what-if' scenarios. Even more important, the tools can support the assessment of the environmental consequences of these scenarios when it is most valuable: at the beginning of the planning process. The participation of stakeholders and communication between disciplines became more important over time in both the STEPP as the livestock cases, which is also reflected in the PSS.

The developed methods and PSS have been evaluated through a verification and validation. Verification is to ensure that a model is correctly built from a formal point of view, whereas validation assesses a model's usefulness to the user, i.e. its ability actually to improve the decision-making process (Sojda 2007, Qureshi et al. 1999). Sensitivity analysis further contributed to the validation of the decision support systems (cf. Sojda 2007). The verification of the developed methods especially addressed the use of multiple criteria techniques. Malczewski (2000) and Robinson et al. (2002) highlight three assumptions regarding the definition of objectives and criteria when using weighted linear combination in a GIS environment, they should (a) cover all relevant aspects of the decision problem, (b) be independent and (c) linear. The AWI

cases (see Section 4.4 and the Appendix) show that the first assumption can be difficult to tackle, especially in developing countries where the selection of criteria is often necessarily driven by data availability. This may not allow all relevant criteria to be included. If data for a given key criterion are unavailable and can not be replaced by a proxy, the criterion (and possibly its related objective) should be explicitly removed from the decision support model, and the results interpreted accordingly.

Table 3-8 Characteristics of the presented cases.

Case	Scale and objectives	Techniques	Design/decision oriented
STEPP *(Section 4.1)*	- Single-objective - Local scale	- Linear combination - ArcView with supporting tools	- Design-oriented - Supports communication between disciplines - Stakeholder participation not included
Revised STEPP *(Section 4.2)*	- Single-objective - Local and regional scale	- Linear combination - ArcView with supporting tools	- Mainly design-oriented, but more closely tied to specific elements of decision making in planning practice - Supports communication between disciplines - Stakeholder participation not included
Dutch livestock *(Section 4.3)*	- Single-objective - Local and regional scale	- Weighted linear combination - ArcInfo with manual analysis	- Design-oriented - Stakeholder participation not included
AWI China *(Section 4.4 and the Appendix)*	- Multi-objective - Regional scale	- Workshops - Weighted linear combination - ArcGIS with manual analysis	- Design-oriented and partly decision-oriented - Participation of policy makers and experts in objective and criteria setting
AWI Thailand *(Section 4.5)*	- Multi-objective - Regional scale	- Workshops - AHP - Weighted linear combination - ArcGIS with manual analysis	- Design-oriented and partly decision-oriented - Participation of a wider range of policy makers, experts and stakeholders in objective and criteria setting
Follow-up LWMEA *(Section 3.4.3)*	- Multi-objective - Regional and national scale	- Workshops - AHP - Weighted linear combination and other MCE techniques - ArcGIS with supporting tools	- Design- and decision-oriented - Support participation of the full range of relevant policy makers, experts and stakeholders in objective and criteria setting

The validation involves the model's usefulness to the user, which has been addressed with questionnaires and user interviews. The results of the STEPP cases show that an intuitive user interface, transparent analysis steps, clear cartographic representation of the results, and reasonable requirements for hard and software enable a quick and efficient use, even by people who are not an expert in GIS (see Sections 4.1 and 4.2). Tools like STEPP assist an interdisciplinary project team to explore more alternatives. This in turn might lead to better decision making. The use of a shared representation of the planned objects and the impact of these objects on the environmental quality also improves the mutual understanding of the problems and consequently the communication among disciplines. However, the STEPP cases also demonstrate that the disciplines involved may have a very traditional view of their role in the planning process. The implementation of a planning support tool therefore relies heavily on the willingness of the participants in the process to cooperate and communicate on an equal basis, in order to increase the level of understanding and awareness, and allowing each participant to intervene in the planning process from the early beginning.

The encouraging results of the AWI projects did initiate the LWMEA regional cooperation project of the governments of Thailand, Vietnam and Guangdong province of China. This cooperation project aims to further develop the AWI method by preparing guidelines to support participatory decision making processes, and developing a user-friendly interface by which to implement the method. The AWI cases suggest that the proposed method, although not fully developed and implemented yet, has much to offer, in particular with respect to its ability to incorporate expert knowledge and stakeholder opinion into decision-making processes. But participatory decision-making processes require the (political) will to involve relevant stakeholders in the process and the skills to implement a challenging process (Norton 2004). The success of the participatory process also depends on the ability of stakeholders to make definitive, consensual and consistent decisions. Therefore, the participatory process will require specialist input, for instance in the areas of stakeholder analysis, process facilitation and negotiation techniques (cf. Norton 2004, Friend & Hickling 2005). The AWI cases highlighted the method's strengths and limitations in this regard. The spatial information provided helped the diverse groups to reach a common view on the identification of areas for future pig production, although these cases also showed that not all relevant stakeholders were actually involved in the process.

At the core of the AWI planning support method is the reliance on technical experts to parameterize the decision rule, whereas other approaches, based on economic and bio-physical models and in particular those relying on systems dynamics modeling, may provide more robust ways to capture complex sets of interrelations and to predict dynamic policy outcomes (Sterman 2000). The use of complex models to support policy making may, however, be undermined by their lack of transparency. This has been identified as a major reason for the limited use of planning support systems in Europe and North America, where, for example, Vonk et al. (2005) and Couclelis (2005) concluded that the many years of research emphasizing the development of transparent and easy-to-use systems have not substantially improved users' perception. Their conclusion can most likely be extended to developing countries with limited

modeling capacity and less familiarity with models. The AWI planning support method avoids this pitfall by calling on expert knowledge to parameterize the decision rule. But as a consequence, the validity of the resulting models is highly dependent on the quality of the expert knowledge. The cases on Dutch livestock production (Section 4.3) and the AWI cases also demonstrate that the results (and thus a method's usefulness to decision makers) rely heavily on the quality of input data in general. The Thai example shows that detailed information is already available in some countries, and this is likely to be increasingly so.

The AWI cases illustrate that the spatial planning support method provides planners and policy makers with a tool which can substantially improve the spatial allocation of industrial livestock production, thus preventing environmental impacts in environmentally sensitive areas in the future. But the effective implementation of the tool also requires regulations or official decisions by the government, explicitly stating that only areas indicated in the maps as environmentally acceptable are allowed for establishing new livestock farms. In doing so, the maps will become an authoritative tool for enforcing a proper spatial allocation of new livestock farms. Complementary policy will also be needed to impose improved manure management on farms. Monitoring and enforcement of waste discharge standards and fines to non-compliance should be applied to improve waste management. The AWI cases show that awareness raising and capacity building among farmers and the government is a prerequisite to promote agricultural good practices and to elicit the necessity to comply with the regulations. Continuous efforts to develop and strengthen professional capacity are and will be a key factor for success in addressing livestock related environmental issues.

Chapter 4

Cases

4.1 STEPP: Strategic tool to integrate environmental aspects into planning procedures

Publication Citation: Carsjens, G.J., R.J.A. van Lammeren & A. Ligtenberg, 2003. STEPP: Strategic Tool to integrate Environmental aspects into Planning Procedures. In: S. Geertman & J. Stillwell (Eds.), Planning Support Systems in Practice, Chapter 8, pp. 139-154. Springer, Berlin. ISBN: 3-540-43719-3

This chapter describes a research project that aims to improve the quality of physical plans on a local level, and to create a basis for communication between disciplines and stakeholders that are dealing with environmental and spatial planning. A GIS-tool for integrating environmental aspects in planning procedures has been developed. Although the research shows the potential for the use of the tool in practice, we still are very far away from supporting participatory planning. The research clearly indicates that the current planning practice is not well equipped to deal with real-time participation.

1. Introduction

Local authorities have their own responsibility for creating a sustainable environment. Physical planning on a local level has direct impacts on the urban and rural environment. In practice this means finding a sustainable balance between the influences of present and proposed human activities and the sensitivities of the urban and rural environment. However, simple and uniform tools that analyse and visualise the environmental aspects of local physical plans are not available.

A research project of Wageningen University and Research Centre intends to develop a GIS based Strategic Tool for integrating Environmental aspects in Planning Procedures (STEPP). The basic aims of the project are to improve the quality of physical plans on a local level, and to create a basis for communication between disciplines and stakeholders that are dealing with environmental and spatial planning. STEPP is intended to support the work of local authorities throughout the spatial planning process, especially with regard to identifying options in the early phases of the process. It can also be used as a tool for communication with stakeholders or to serve educational purposes.

Section 2 gives a brief history of the Dutch interest in the environmental aspects of spatial planning. Section 3 presents the principles of STEPP, while Section 4 describes the professional experiences with STEPP. The concluding section (Section 5) focuses on the communicative perspectives of this type of planning support systems.

2. Brief history

The Dutch interest in the environmental aspects of spatial planning has been strongly influenced by the concept of the “compact city”. This concept from the early nineteen-eighties was adopted as the Dutch spatial planning answer to the problem of urban sprawl. Taking into consideration the small size of the country, the high population density, and the impressive economical growth the compact city approach was intended to stop any unnecessary waste of open space (rural area). Furthermore, by concentrating urban activities, the benefits could be less commuter traffic, less pollution and possibly less energy use. Despite these good intentions, however, a new problem arose. This was how to preserve the environmental quality of the ‘grey space’ (urban and semi-urban areas) as well as the ‘green space’ (rural and natural areas). By con-

centrating the rural activities, the environmental problems related to the ‘grey space” like noise, odour, dust, toxic pollutants and calamities, became more prominent. This conflict between the spatially oriented “compact city” concept and the environmental drawbacks has been named “the compact city paradox” (e.g. de Roo 1999).
The concern about the environmental quality initiated some new environmental policies. The period of 1989 was a pivotal one. It was the time during which these policies were developed. It was also in 1989 that the Dutch Ministry of Housing, Spatial Planning and Environment (VROM is the Dutch abbreviation) introduced a system that allowed for the integration of sector environmental standards and their related spatial zones into one wholly integrated environmental zone. The Integrated Environmental Zoning (IEZ) system was intended for areas around industrial sites (VROM 1990). The IEZ approach is based, for the most part, on the calculation of influence zones. These zones are the combination of environmentally intrusive activities and their sensitive surroundings. The sensitivity of the surroundings is derived from the sensitive (land-use) functions in the surrounding areas.
The IEZ approach offered an impressive and challenging field for information system developments. The Ministry stimulated the efforts to develop computer systems, preferably based on geo-information that could support the IEZ system. On the other hand the Ministry carefully scrutinised the effect of this top-down approach on the local and regional authorities. The local and regional authorities could submit project proposals to scale down the IEZ system. The municipality of Zwolle (approximately 100.000 habitants) worked on the municipality version of an IEZ system (Streefkerk 1992). This particular system, so called BM (initials for the Dutch words of Environmental Quality Assessment) focussed on intrusive environmental influences like local air pollution, noise, local terrain contamination and hazards. From the earliest beginnings of the development of BM, Wageningen University was involved and had the task to develop a dedicated GIS application (van Slagmaat et al. 1992, van Lammeren et al. 1994). A comparative study undertaken by Groningen University (Humblet and de Roo 1995) qualified the BM as the most promising of all comparable systems.
In subsequent years the Dutch government intended to adapt the IEZ system to a more consensus based approach and to make it more convenient to future oriented objectives of the different planning actors. There were important reasons to do this. The local political impact of the IEZ was one reason. Because of the top-down approach, the results of the IEZ looked more like missives then politics. A procedure to change this ‘parachuting’ was based on the consensus approach and called ROM, a Dutch acronym for Spatial Policy and Environment (de Roo 1999).
The ROM procedure dealt with 'grey' as well as 'green' environments. In the rural cases new ‘intrusive’ components like acidification, drying out, fragmentation, and manure-based soil-contamination were taken into account. The activities of Wageningen University continued by adapting the original BM application into a system that could support the ROM-procedure. Acidification especially had been the main focus (van den Brand 1992) which finally resulted in ADIS (van Lammeren 1994): a geo-information system that supports planning by information input about agricultural activities in relation to the output of ammonium. Despite much interest by local authori-

ties and consultants, the BM application has hardly ever been used in practice. The main reasons seem to be a lack of promotional activities and insufficient computer tools and facilities. In addition, the possibilities to use the BM outside of local governments were limited.
In 1998 a follow-up project at Wageningen University began (Carsjens et al 1999, Groenveld 2000, Kluskens 2000). The main objective of this project was to develop a GIS-based **S**trategic **T**ool for integrating **E**nvironmental aspects in **P**lanning **P**rocedures (STEPP). STEPP is based on the previous experiences with BM. The basic aims of the project are to:

- Improve the quality of physical plans (green as well as grey) on a local political level.
- Create a basis for communication between spatial planning and environmental disciplines.
- Update and extend BM to a more uniform tool.

STEPP aims to support the work of local authorities throughout a spatial planning process, while also offering possibilities for communication with stakeholders. The first edition of STEPP was implemented in the GIS-software ArcView and its programming language Avenue.

3. Challenging approach

In comparison to the IEZ system and according to the ideas of the ROM approach, STEPP offers an analytical as well as a design component (Figure 1). The analytical component of STEPP (Figure 1A) includes a definition of the sensitivity of delineated receptive areas in a certain geographical domain, and a definition of areas with a specific degree of intrusion of pollutants or contamination. A spatially based confrontation of sensitivity and intrusion gives a certain environmental quality. The location and the nature of human activities in an area can be adapted (Figure 1B). The design component offers an opportunity to apply different scenarios, based on new spatial arrangements of human activities.

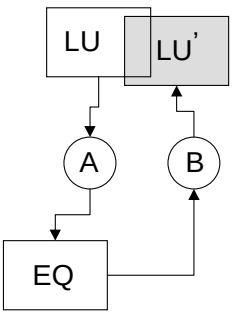


Figure 1 STEPP components (A: analytical component B: design component; LU: land use; LU': modified; EQ: environmental quality).

The analytical component consists of five different steps (Figure 2):

1. Determining the human activities and types of receptive environment in a study area, based on land-use data.
2. Determining the areas where environmental impacts occur (zones of influences).
3. Combining the zones of influences and the sensitivities of receptive areas to produce an environmental quality map for each category of environmental impact.
4. Cumulating the zones of influences into an integrated environmental impact map.
5. Combining the individual quality maps into an integrated environmental quality map.

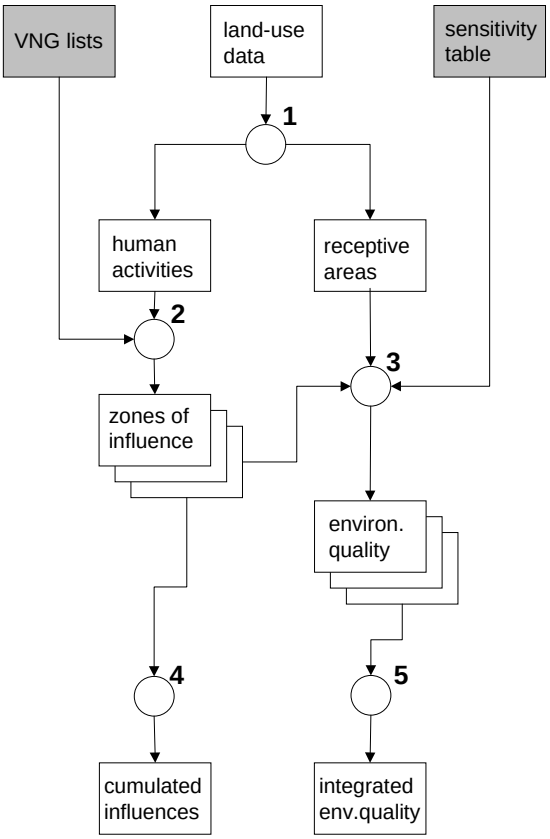


Figure 2 The basic steps of the analytical component of STEPP.

Information on land use is a very valuable source to determine spatially located human activities (step 1). Most human activities are related to physical objects like industrial and company buildings, farmland parcels, roads and railways. Some typical environmental impacts of these activities are smell, dust, nuisance, fire and explosion hazards,

and local air and soil pollution. The data on activities can be derived from (mostly analogue) information available through the Dutch municipalities.
Information on land use can also be used to define receptive areas (step 1). Two basic geographical information databases, the Digital Topographical Map 1:10.000 (published by the Dutch Topographical Service) and the Digital Land-Use Statistics (published by the Dutch Central Bureau of Statistics) provide the necessary information. STEPP distinguishes three categories of receptive environment:

- Areas with human inhabitants, subdivided in areas with large numbers of humans (such as shopping malls), areas where humans have permanent residence (such as private residences) and areas that humans occasionally visit (such as recreation areas).
- Areas with (unique) ecological values (such as parks and nature areas).
- Areas without (unique) ecological values, subdivided in soil and water areas (such as gardens and canals) and paved areas.

The second step in the analytical component of STEPP begins with an analysis of the activities in the study area, in order to derive the zones where environmental impacts occur. The implications of the spatial scale of environmental impacts of most activities can be derived from lists of the Organisation of Municipalities in The Netherlands (VNG 1999). These VNG lists are based on practical experience, and contain information on average distances necessary between various activities and sensitive functions. These distances can be used to calculate zones per impact category around the location of each activity. Table 1 gives an example of the VNG lists.

The concept of influence distances of the VNG lists has been adopted in STEPP. The additional information on environmental impacts (the codes and index values) are converted to distance measures in order to make them suitable for STEPP. Three additional impact categories with influence distances are added to STEPP: (1) visual disturbance, (2) traffic disturbance and (3) local soil pollution. Table 2 describes the conversion that takes place.

In addition to the individual activities listed in the VNG lists, STEPP also includes a tool to introduce four different types of industrial zones. Each type of zone is characterised by average influence distances of representative activities in the VNG lists. The four types of industrial zones are:
1. Service industries and offices
2. Wholesale trade
3. Manufacturing industry
4. Heavy industry

The third step starts with an analysis of the sensitivity of functions for each impact category. Table 3 gives an example of how these sensitivities can be classified.

Table 1 An example of activities in the VNG lists, with a selection of impact zones per category (VNG 1999).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SBI	**nr**	**definition**	**smell**	**dust**	**noise**	**hazard**	**traffic**	**visual**	**B**	**D**	**L**
1581	0	Bread factories and confection-eries:									
1581	1	- capacity < 2,500 kg flour/week	30	10	30	10	1	1			
1581	2	- bread- and biscuit factories	100	30	100	30	2	2			
271	0	Pig iron and steel plants:									
271	1	- prod. capacity < 1,000 ton/yr	700	500	700	200	2	2	B		
271	2	- prod. capacity >= 1,000 ton/yr	1500	1000	1 500	300	3	3	B		L
5122		Wholesale trade flowers and plants	10	10	30	0	1	1			
5231, 5232		Pharmacies and drugstores	0	0	0	10	1	1			
9272.2		Model aircraft airfields	10	0	300	100	1	1			
I 0037		Radar installations	0	0	0	1500	1	3		D	

Explanation of the columns
1: Unique code for each type of activity (SBI-code)
2: Serial numbers for activities within the same SBI-code
3: Definition of the activity
4, 5, 6, and 7: Distance in meters per impact category
8, 9: Index number representing a small (1) to large (3) attraction of traffic or visual disturbance
10, 11: Codes indicating soil (B) and air (L) pollution
12: Code indicating a diversity of activities within the SBI-code

Table 2 Conversion from index values and codes in the VNG lists to distances (in meters) in STEPP. In case an index value or code is not applicable the impact distance is zero.

	Impact category in the VNG lists						
	Traffic			Visual			Soil pollution
Impact category in STEPP	1	2	3	1	2	3	B
Traffic disturbance	30	100	300				
Visual disturbance				30	100	300	
Soil pollution							10

Table 3 Sensitivity of functions for each impact category (3 = very sensitive; 2 = sensitive; 1 = not sensitive).

Sensitive function	Code	Level of sensitivity per impact category						
		smell	dust	noise	hazard	air poll.	soil poll.	visual
human beings								
concentrations	MEC	3	3	2	3	2	3	2
permanent	MEP	2	2	2	2	2	3	2
occasional	MEN	2	2	1	2	2	2	1
ecological values								
unique ecological values	EC	2	2	2	1	3	3	1
no ecological values								
soil and water	BW	1	1	1	1	1	3	1
materials	MA	1	1	1	1	1	1	1

STEPP compares the impact zones for each impact category with the sensitivity of the functions present in each zone. This gives a quality indicator map for each impact category. The general idea is that:

- Areas without influences have good quality (indicator value 0).
- Areas with functions that are not sensitive for a specific impact have a reasonable quality (indicator value 1).
- Areas with functions that are sensitive to a specific impact have a moderate quality (indicator value 2).
- Areas with functions that are very sensitive to a specific impact have a poor quality (indicator value 3).

The fourth step incorporates the different impact maps into an integrated environmental impact map. It calculates the different impacts at any one location. The fifth step incorporates the different quality indicator maps into an overall integrated environmental quality map. This process entails summarising the values of the different quality indicator maps. The importance of an individual quality indicator map depends on the situation and/or the sensitivities involved. Thus it is then possible to rank one map higher than another. Figure 3 gives a schematic example of the computations in the fourth and fifth step.

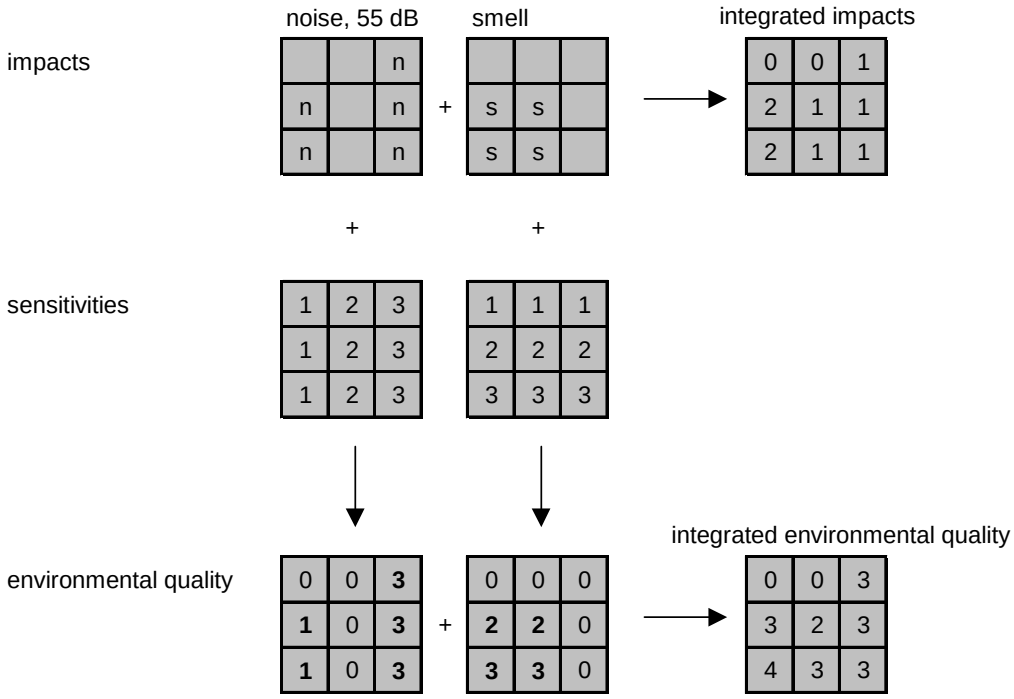
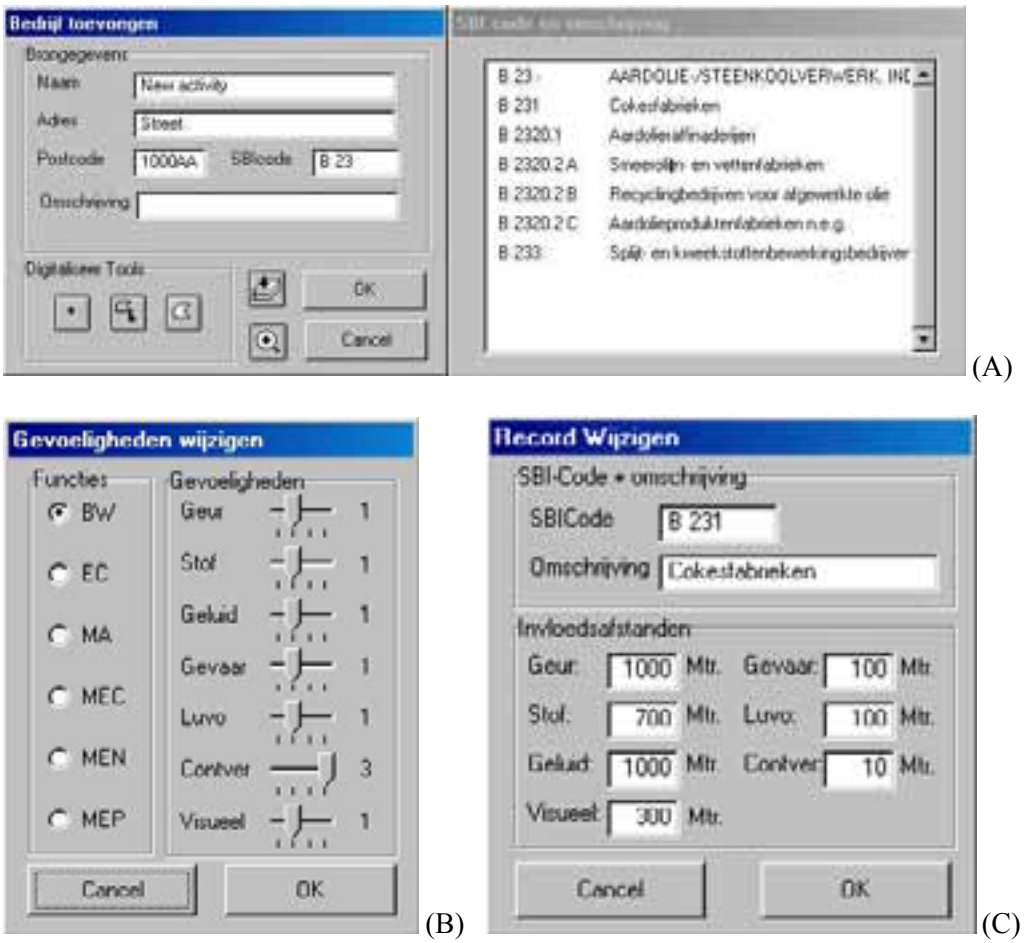


Figure 3 Example of the computations in the fourth and fifth step (without ranking the individual maps).

The design component (Figure 1B) offers an opportunity to work with scenario studies based on new spatial arrangements of human activities. Most input data and parameters that are used by STEPP can be modified, e.g.:

- The locations of (human) activities (see Figure 4A).
- The shape and size of specific areas.
- The different types of receptive areas (function of an area).
- The sensitivity of receptive areas (Figure 4B, see also Table 3).
- The activity-based environmental impact parameters (the influence distances of the VNG lists as well as impact distances of individual activities) (Figure 4C, see also Tables 1 and 2).

Intended measures to improve the environmental quality (e.g., filter installations or noise barriers) have to be ‘converted’ to a reduction in impact distance before they can be introduced in STEPP.



(A) (B) (C)

Figure 4 (A) Screen to introduce new activities, (B) screen to modify the sensitivities of receptive areas and (C) screen to modify the influence distances of the VNG lists.

4. Professional experiences

STEPP has been used for educational purposes as well as in actual planning practice. Two cases using the application will be described: (1) the application of STEPP in two planning courses at Wageningen University and (2) the results of a workshop where STEPP was used by planning consultants for a housing project in the town of Goor (The Netherlands).

Planning courses

Since 1998, STEPP has been used in two spatial planning courses at Wageningen University. One course focuses on "the relationship between planning and environmental aspects" (Carsjens 2001) and a second course focuses on "physical planning at

local scale level" (Jaarsma and van der Knaap 2000). Both courses contain practical assignments, where students themselves are working with the application.
The experiences with both courses helped to test and improve the user-interface of STEPP. The results of both courses indicate that STEPP stimulates the discussion on the environmental aspects of physical plans. STEPP also showed to be easily accessible.

Workshop Goor
In March 2001, a one-day workshop was organised for a dedicated group of planners and environmental specialists of S.A.B. office for urban planning (Arnhem, The Netherlands). The main objective of the workshop was to evaluate the applicability of STEPP in practice. The workshop aimed at a development project of a new residential area in the municipality of Goor (The Netherlands). The proposed location of the housing project is a vacant site within the town's boundaries (see Figure 5).

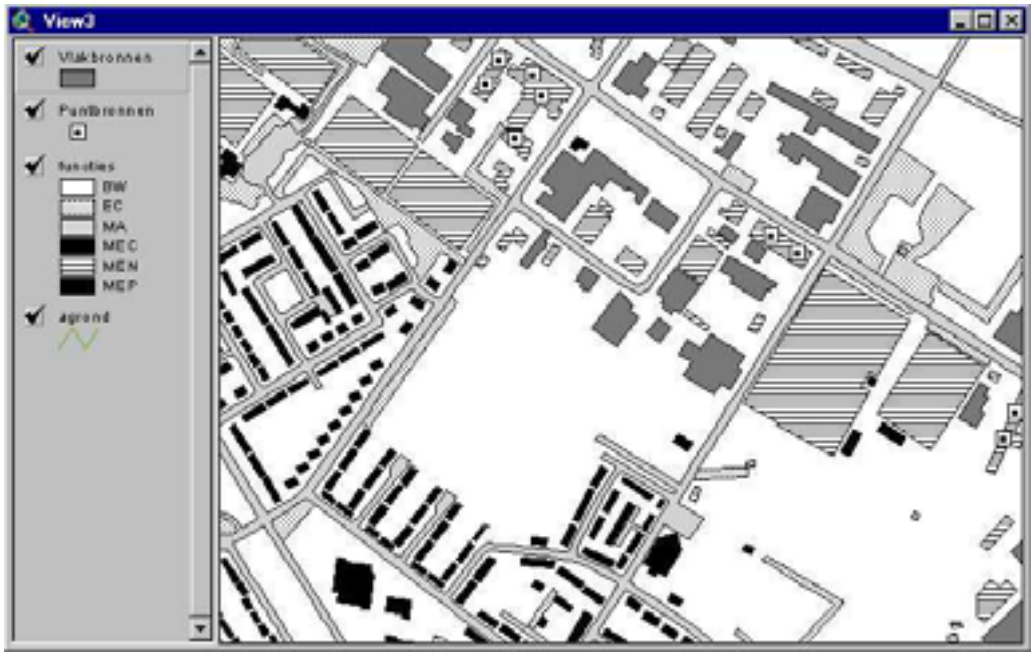


Figure 5 Map with the basic input data of STEPP: the activities and functions of the study area Goor.

The location is surrounded by residential areas to the south and the west, but also borders an industrial park in the Northeast. The activities are defined as point or area objects (depending on the size of the activity). For an explanation of the function codes see table 3. The 'empty' area in the middle of the map is the proposed site of the new residential area. The main questions were which potential impacts could occur at the

proposed site and how to mitigate these impacts. STEPP was used to analyse this problem. The morning programme of the workshop included an introduction to STEPP and some basic exercises. In the afternoon the housing project in Goor was analysed. One of the resulting maps of these analyses is shown in Figure 6.

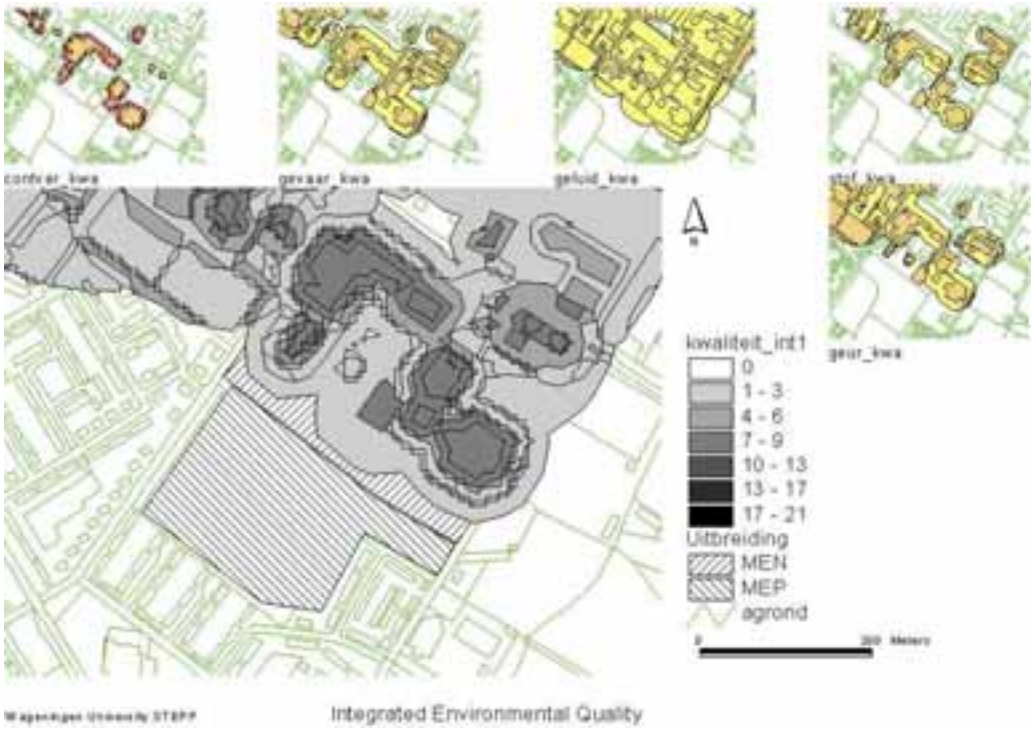


Figure 6 An integrated environmental quality map for the study area Goor.

The large map shows the location of the residential area (code MEP) with a transition zone at the north side, containing a mixture of private houses and company premises (code MEN). The zones at the north side represent the different environmental quality zones. The remaining area, outside these zones, is not influenced and has the best quality. The transition zone prevents the influence zones reaching the residential area. The only activities that are allowed in the transition zone are those without significant environmental impacts (e.g. offices) and that are less sensitive to the impacts from the industrial park. The five small maps show the environmental quality zones for each of the different impact types.

An extensive questionnaire was used to record the experiences with the different aspects of STEPP. The results were also discussed. The main conclusions from the questionnaire and the discussion are:

1. STEPP is a fast, efficient and representative tool to analyse the environmental aspects.
2. STEPP is user-friendly and easily accessible, especially given the fact that only one of the consultants had some basic knowledge of ArcView.
3. STEPP at present is not equipped to analyse the environmental impacts of road traffic.
4. The defined categories of receptive environment (the six function classes) should be more detailed, especially regarding the distinct types of residential areas.
5. Additional information can improve the applicability of STEPP, e.g. information on traffic intensity (see also point 3) and qualitative aspects of residential houses (see also point 4).
6. STEPP stimulates discussion between professional disciplines.
7. The application will be purchased by the participants of the workshop (S.A.B.) and will be used for at least two years with different types of projects. This will, of course, give an even better perspective on the applicability of STEPP in practice, and will help to improve and develop the application further.

5. Communicative perspective

This section describes the communicative perspective of STEPP, in relation to the potential developments of planning support systems. Given the increasing number of interested parties that participate in spatial planning, the outcomes of planning processes tend to be more and more the result of negotiations, based on the best mutual acceptance of interested parties (see for example de Jong 1986, van Woerkum 2000). The FAO defines the concept of interested parties as "individuals, communities or governments that have a traditional, current or future right to co-decide on the use of the land" (FAO 1996). Participation of interested parties in data collecting, planning, implementation and monitoring can (Dalal-Clayton and Dent 1993):

- Mobilise the energies and skills of a wide range of people.
- Facilitate an equitable definition of needs and distribution of responsibilities and benefits.
- Secure commitment from people for the plan.

The increasing level of participation has led to a shift in the perception of planning, from a centralised view towards a more systemic and process oriented approach. By encouraging an increasing number of participants to join the spatial planning process the demands on communication with interested parties has moved beyond the traditional simple (formal) hearings. Interested parties want to have an active role from the initial stages (formulation of goals, exploration of alternatives) right up to the final decision-making.
Information and communication technology (ICT) can have a major influence in supporting participatory planning. ICT-tools can support participatory planning at five levels of participation, also called the ICAPD levels (after NRLO 1998). Furthermore,

we also distinguish four levels of time and place of use of these tools by participants. Both types of classification are presented in Table 4.

Table 4 The different levels of participation and levels of time and place of use of ICT-tools.

Levels of participation		Time and place of use of ICT-tools	
I	Inform	SS	Same time, same place
C	Consult	DS	Different time, same place
A	Advice	SD	Same time, different place
P	Co-produce	DD	Different time, different place
D	Co-decide		

The current trend in participatory planning is towards advice and co-producing of spatial plans. This is catalysed by the advances made in ICT like the mass acceptance of e-mail and Internet, allowing interested parties to access information more easily and enable them to respond in a more direct way.

Applications that facilitate planning at the same time in the same place can be found in the field of group-ware solutions. These include software that facilitates co-operative brainstorming and decision-making, for instance, among interested parties. There are examples of approaches within the domain of land-use planning that can be found in the GEVIS project (Bongers et al. 2000) and OntwerpGis (Geertman et al. 2000). These approaches, however, are restricted in a way that only invited parties are able to join the planning process. The current STEPP application is also an example of a same time, same place application. It can facilitate discussions and the formulation of alternatives at “runtime.” The intuitive interface, the clearly defined steps in the program, the qualitative and cartographic representation of the model results, and the reasonable requirements for hard and software enable an quick and efficient use, even by people who are not an expert in GIS (see the conclusions in Section 4).

The second approach can be found in examples such as information pillars installed in town halls, that are a result of the Dutch national program "Public Counter 2000" (in Dutch: Overheidsloket 2000)[1]. This program aims at creating a nation-wide network of desks, to be consulted by citizens, trade and industry for information and public products and services, based on the use of information and communication technology. Information pillars are devices that enable citizens to consult digital information and communicate with the “ones behind”, using e-mail and other electronic means of communication. The pillars can also be used to present plans to citizens allowing them to then submit their opinion. Co-producing spatial plans is not really possible using these devices due to their limited interactivity. However, these devices have proven to be eminently suitable for informing, consulting and asking advice about spatial plans.

[1] http://www.ol2000.nl/english/default.htm

The third and fourth approaches can be established through the Internet (and perhaps in the future by mobile phones and personal digital assistants as well). The Internet allows interested parties to participate regardless of time and/or place. Many provinces and some larger cities in The Netherlands are already presenting their spatial plans and related spatial information on the Internet. Examples are the websites of the province of Gelderland[2] and the city of Groningen. Groningen created a website[3] where citizens can discuss and give their opinion on reconstruction plans for each district of the city. In 2000, the Dutch Ministry of Housing, Spatial Planning and Environment started the project "Digitally exchangeable spatial plans" in order to make all spatial plans in The Netherlands available through the Internet by the year 2010. A new standard (IMRO) has been developed (Ravi 2000) that enables an exchange of information between the different types of spatial plans to occur.
A part of the research project of STEPP at Wageningen-UR focused on the aspect of communication and participation using Internet. A pilot Internet application has been designed called LODERWEB[4] (Kluskens 2000) that extends the STEPP method to a system that allows interested parties to express their concerns, opinions or alternatives. A map-server was used to present the STEPP outcomes on the Internet. This gave additional means for users to zoom, pan and query the outcomes. Users can comment by clicking on a location in the map and enter their opinions, alternatives etc. In addition, the system enables users to view and comment on the points made by others.
As previously mentioned, “modern ways” of spatial planning require simple and clear methodologies and tools. STEPP has proven to be able to deliver valuable tools that enable participants to quickly explore and interact with various scenarios (see Section 4). The qualitative results of these interactions also enable non-experts to interpret the outcomes. The clearly defined steps within STEPP make it easier to comprehend the model thus preventing it from being a black box.

Conclusion
Although experiments clearly show the potential for the use of distributed applications in spatial planning, we still are very far away from supporting a “new way of planning". Figure 7 indicates the current status of planning support systems in The Netherlands, with respect to the levels of participation, and the autonomy of the participants. The Grey colour indicates the current levels of use in the Netherlands. Co-producing and Co-deciding on spatial plans are still not practical applicable. The research on STEPP/LODERWEB clearly indicates that, besides a number of technical issues, the current planning practice is not well equipped to deal with real-time participation. Important questions that remain are: how to process the often conflicting opinions; how to give feedback to the contributions given; how to deal with the increasing time con-

[2] http://geodata.prv.gelderland.nl/km/kaartenbak/

[3] http://www.groningen.nl/forum

[4] http:// www.geo-informatie.nl/loderweb

straints imposed by the direct-react-direct-response expectations of the new media; etc. Currently, we consider participation through these technologies limited to only the first two levels of ICAPD. The search for a sustainable balance between the influences of human activities and the sensitivities of the urban and rural environment isn't merely a quest for a suitable tool, but also means a quest for a suitable participative communication.

increasing autonomy →

increasing level of participation ↓

	SS	DS	SD	DD
I	1	2	4	4
C	1	2	-	-
A	3		5	5
P	3	-	-	-
D	-	-	-	-

Figure 7 The status of planning support systems (1 = STEPP, 2 = information pillars, 3 = GEVIS/OntwerpGIS, 4 = the province of Gelderland, 5 = LODERWEB).

References

Bongers F, Hollan C, Heusden M, Hidding M, 2000, Een theoretisch model voor een GEVIS (concept), Landbouw Economisch Instituut, Den Haag.

Carsjens GJ, 2001. Relaties tussen landgebruik en milieu. College en practicum. Syllabus onderwijselement K100-251, Leerstoelgroep Landgebruiksplanning, Wageningen Univeriteit, Wageningen.

Carsjens GJ, Kluskens R, van Lammeren RJA, 1999. Methodology to integrate environmental aspects into physical planning. In: Musy A, Santos Pereira L, Fritsch M (eds) Emerging Technologies for sustainable Land use and water management. Presses polytechniques et universitaires romandes, Lausanne, abstract p 32, CD-ROM 7 p.

Dalal-Clayton B, Dent D, 1993. Surveys, Plans and People: review of land resource information and its use in developing countries. Environmental planning issues no 2. IIED, London.

de Jong MJ, 1986. Idee- en consensusvorming in de ruimtelijke ordening: een sociaalwetenschappelijk onderzoek naar de totstandkoming van het Streekplan Friesland 1982. Proefschrift Wageningen Universiteit LU-1104, Wageningen.

de Roo G , 1999. Planning per se, Planning per saldo: over conflicten, complexiteit en besluitvorming in de milieuplanning. Sdu Uitgevers, Den Haag.

FAO, 1996. Planning for sustainable use of land resources - towards a new approach, Land and Water Bulletin 2. Food and Agriculture Organization of the United Nations (FAO), Rome.

Geertman S, van Deursen W, Vos E, 2000. OntwerpGis: Ondersteuning voor Participatieve Planvorming. In: Fendel MF (ed) Geo-Informatiedag Nederland 2000: presentaties en demonstraties over onderzoek, ontwikkeling en praktijktoepassing op het gebied van geo-informatie. VGVI, TU Delft.

Groenveld G, 2000. Uitbouw van de BM methode met een implementatie in ArcView. Centrum voor Geo-Informatie, Wageningen Universiteit, Wageningen.

Humblet AGM, de Roo G, 1995. Afstemming door inzicht; een analyse van gebiedsgerichte milieubeoordelingsmethoden ten behoeve van planologische keuzes, Geo Pers, Groningen.

Jaarsma CF, van der Knaap WGM, 2000. Practicum Planning 1. Syllabus onderwijselement K100-250 Wageningen Universiteit, Leerstoelgroep Landgebruiksplanning.

Kluskens R, 2000. An Internet based environment to facilitate multi-actor informing and consulting for environmental planning based on the BM methodology. Centre for Geo-Information, Wageningen University, Wageningen.

NRLO, 1998. ICT: mogelijkheden voor sturing en ontwerp in landelijke gebieden. Ontwikkelingen in wetenschap en technologie. Nationale Raad voor Landbouwkundig Onderzoek (NRLO), Den Haag.

Ravi, 2000. Informatiemodel Ruimtelijke Ordening. Geactualiseerde versie publicatie 97-2. Ravi overlegorgaan voor vastgoedinformatie (RAVI), Amersfoort.

Streefkerk N, 1992. Handboek Beoordelingsmethode Milieu; inhoudelijke achtergronden en handleiding. VNG, Den Haag.

van Lammeren RJA, 1994. Ammoniak depositie informatie systeem. Geografendagen, Den Burg.

van Lammeren RJA, Algra R, van den Bosch G, 1994. Evaluation of the method for assessing environmental quality (BM). In: Molenaar M (ed) Remote Sensing and Geographical Information Processing: concepts and applications for land-use monitoring and agriculture. Wageningen Agricultural University, Wageningen.

van Slagmaat M, van der Meer AM, van Lammeren RJA, 1992. Prototype Beoordeling Milieukwaliteit: handleiding, Landbouwuniversiteit Wageningen, Wageningen.

van den Brand P, 1992. Een regionale beoordelingsmethode milieukwaliteit voor het thema verzuring. Scriptie Landbouwuniversiteit Wageningen, Wageningen.

van Woerkum C, 2000. Communicatie en interactieve beleidsvorming. Samsom, Alphen aan den Rijn.

VNG, 1999. Milieureeks (kgm) Nr 9: Bedrijven en Milieuzonering. VNG Uitgeverij, Den Haag.

VROM, 1990. Ministeriële Handreiking voor een voorlopige systematiek voor de integrale milieuzonering, deel 6, Integrale Milieuzonering. Directie Geluid en

Omgeving, Directoraat-Generaal Milieubeheer, Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, Den Haag.

4.2 A GIS-based support tool for sustainable spatial planning in metropolitan areas

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This paper describes a support tool that incorporates environmental aspects in local spatial planning processes. The tool aims to support the work of local authorities and urban planning offices, especially with regard to identifying options in the early phases of the planning process. The tool has been developed and implemented in a Geographical Information System (GIS) and evaluated for a case study in Nijmegen, the Netherlands. The results show the importance of communicative aspects for these kinds of tools, especially for tools that aim to stimulate several disciplines in working together. The results also show that geo-information tools can easily become too complex, and turn out to be 'black boxes' for participants in the planning process. Therefore, it is important to keep these tools as simple as possible, and to make clear how the results of the planning process will benefit from their use.

Keywords: Planning support systems, environmental planning, zoning

1. Introduction

Growth management and sustainable development are widely considered essential to maintaining the quality of life in metropolitan landscapes (Daniels, 1999; van der Valk, 2002). For example, in the Netherlands the 4th National Environmental Policy Plan (Ministry of VROM, 2001a) and 5th National Policy Document on Spatial Planning (Ministry of VROM, 2001b) emphasize the responsibility of local authorities for creating a sustainable environment, stressing that spatial planning at the local level has direct impacts on the urban and rural environment. In practice, this means finding a sustainable balance between the influences of present and proposed human activities and the sensitivities of the urban and rural environment. This requires coherence between spatial and environmental policies and an integrative, area-specific planning approach at the local level. It is essential for this integrative approach that environmental aspects are incorporated into the planning process at an early stage, instead of being evaluated afterwards. To do so, local authorities and urban planning offices have a need for tools that enable them to review the potential environmental impacts of spatial plans quickly and indicatively, and to explore alternatives in an iterative and interactive way. In 1998, a research project started at Wageningen University that aims to develop a GIS-based **S**trategic **T**ool for integrating **E**nvironmental aspects in **P**lanning **P**rocedures (STEPP) (Carsjens et al., 2002). The objective of STEPP is to support interactive spatial planning processes at the local level, especially with regard to identifying options in the early phases of the process. Therefore, the tool aims to improve communication among the disciplines involved, support interdisciplinary discussions and explorative sessions, and be easy-to-use.

This paper describes the development of the tool, together with its application in a case study in Nijmegen, the Netherlands. Section 2 presents some developments in Dutch environmental planning that triggered the development of the tool. The methodology for developing the tool is presented in Section 3, and its application in the case study in Nijmegen in Section 4, with discussion of the results in Section 5.

2. Background

To control urban sprawl, Dutch spatial planning has been strongly influenced by the concept of the "compact city" (Needham & Faludi, 1999; Breheny, 2002; de Roo, 2003). Urban compaction and multifunctional land use for the promotion of sustainable development and preserving the rural and natural areas became prominent in Europe during the 1980s (Jenks et al., 1996; Williams et al., 2000; Breheny, 2002). The objective of compact urban growth is to increase the efficient use of land, by regulating the geographical spread of urban areas, their built form and patterns of movement and interaction (Clark, 2005), is comparable to the more recent smart growth policies in e.g. the United States (Daniels, 2001; Dieleman & Wegener, 2004). But due to urban compaction a new problem arose, which was how to preserve the environmental quality of the urban and semi-urban areas as well. Because urban activities had been concentrated, its related environmental problems, like noise, dust, and toxic pollutants, became more prominent. This conflict between the spatially-oriented "compact city" concept and its environmental drawbacks has been termed "the compact city paradox" (e.g. de Roo, 2003).

Recent Dutch national policy emphasizes the responsibility of local authorities to support a sustainable environment. The 4th National Environmental Policy Plan (Ministry of VROM, 2001a) notes that in many cases local government is more capable of improving the quality of the living environment than the national government. Therefore, the coherence between spatial and environmental policy needs to be improved through a more integrative, area-based planning approach. The Netherlands has been experimenting with integrated, 'area-specific', policy since 1997 (e.g. Ministry of VROM, 1998 and 2001c). The development towards a more area-based approach emphasizes the need to incorporate environmental aspects in the early phases of the planning process rather than within assessments late in the process (see also Pedersen et al., 2004). Consequently, local authorities and urban planning offices have a need for tools that support area-based approaches. The GIS-based STEPP tool aims to improve the coherence between spatial and environmental policy at the local level, by stimulating the exchange of relevant information among involved disciplines and decision-makers and providing a means for exploring alternatives.

The development of STEPP and similar tools was stimulated by some major developments in information and communication technology in the 1990s (Geertman & Stillwell, 2002). Newer generations of GIS offer more sophisticated and extensive database management and display capabilities, and are much more user-friendly (Malczewski, 2004). Furthermore, the availability of affordable geo-data has increased. These trends have stimulated the development of geo-technology tools to support different aspects of the planning process, particularly tools in which participation is a key element (Geertman, 2002). These participatory GIS tools have materialized under the new generic term Planning Support Systems (PSS) (Harris 1989, Brail & Klosterman, 2001; Geertman & Stillwell, 2002; Geertman, 2002). PSS are spatial decision support systems (SDSS) (e.g. Jankowski & Richard, 1994) that have primarily been developed to support planning processes (Geertman, 2002), based on the as-

sumption that an increase in access to relevant information will lead to a greater number of alternative scenarios, and thus a better informed public debate (Shiffer, 1995). The underlying ideas for PSS have been promoted for a long time by Harris, i.e. to link the sketch planning approach, a rapid and partial description of alternatives, to the modelling of the implications of these alternatives (Harris, 1999; Geertman, 2002). Examples of PSS, mostly partly realized, are 3D-visualization tools (e.g. Lange et al., 2004), land-use modelling tools to examine urban growth (e.g. Barredo et al., 2003; Weber, 2003), collaborative planning and decision-making tools (e.g. Klosterman, 1999 and 2001; Nyerges & Jankowski, 1997), GIS-based multiple criteria evaluation tools (e.g. Pettit & Pullar, 1999), and Web-based planning support tools (e.g. Shiffer 1995; Al-Kodmany, 2002; Voss et al., 2004). Recent overviews on the diversity of PSS have been presented by Brail & Klosterman (2001) and Geertman & Stillwell (2002).

However, the adoption and use of Planning Support Systems is far from widespread, and is far from being effectively integrated into the planning process (Stillwell et al., 1999; Geertman & Stillwell, 2004; Uran & Janssen, 2003). According to Klosterman (1998) planning support tools are no more developed than they were ten years ago. Although planners and designers now have access to much larger volumes of geodata, the use of GIS focuses mainly on spatial queries and generating thematic maps. Progress towards the use of GIS beyond these basic activities to help solve key planning problems through more sophisticated analyses has been very limited (Stillwell et al., 1999). Only a small percentage of planners consider geo-technology as an intrinsic and indispensable tool for performing their job properly. Some explanations for this situation are the diversity of analytical tasks that planners perform, the relatively small market for public sector software, and the expense of developing and supporting commercial software (Geertman & Stillwell, 2002). Despite the fact that the application of GIS within planning practice has increased (Geertman, 2002), current geo-information tools are too complex, too inflexible, incompatible with most planning tasks and technology driven rather than user oriented (Nedovic-Budic, 1998; Geertman & Stillwell, 2002; Urun and Jansen 2003). These pitfalls need to be avoided with STEPP. To strengthen the effective integration of STEPP in the local planning process, the tool combines the embedding of commonly accepted procedures and standards with clear and simple use.

3. The STEPP approach

STEPP offers an analytical as well as a design component (Figure 1). The analytical component supports the assessment of the environmental implications of a land use arrangement, while the design component offers tools to design new spatial arrangements. The analytical component of STEPP (Section ‘A’ in Figure 1) includes both a definition of the sensitivity of delineated receptive areas in a geographical domain, and a definition of areas with a degree of intrusion of pollutants or contamination. A spatially-based combination of sensitivity and intrusion results in an indicator of the environmental quality for each location. The location and the nature of human activi-

ties within an area, in Figure 1 integrated and displayed as types of land use, can be adapted (Section 'B' in Figure 1). The design component offers an opportunity to apply different scenarios, e.g. alternative spatial arrangements of human activities and receptive environment. This subsequently leads into a process of alternating use of both components, which usually starts with the assessment of the current or proposed situation, and then continues with the exploration of alternatives. STEPP is implemented in the GIS-software ArcView 3.2. The components and tools of STEPP, which are described below, are available through a user interface (see also Figure 3).

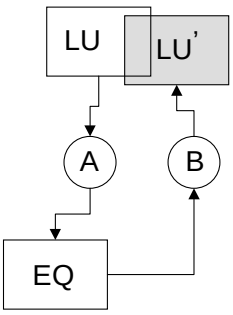

Figure 1 STEPP components (A: analytical component B: design component; LU: land use; LU': modified; EQ: environmental quality).

The analytical component of STEPP consists of five different steps (Figure 2):

1. Determining human activities and types of receptive environment in a study area based upon land-use data.
2. Determining the areas where environmental impacts occur (zones of influence).
3. Combining the zones of influence and the sensitivities of the areas influenced, to produce an environmental quality map for each category of environmental impact.
4. Combining the zones of influence into an integrated, cumulative, environmental impact map.
5. Combining the individual quality maps into an integrated environmental quality map.

Most human activities are related to physical objects, such as industrial sites and office buildings, farmland, roads and railways, information on some of which is usually accessible through data on land use (step 1). STEPP specifically focuses on the environmental impacts of local activities, including smell, dust, noise, fire and explosion hazards, and local air and soil pollution. The effects of these impacts range from effects on human beings, flora and fauna to effects on land, water, air, and climate (e.g. Glasson et al., 1999). Data on the impacts of local activities can be derived from information available through the Dutch municipalities (see further).
Information on land use can also be used to define the types of sensitive area (step 1). Two basic geographical information databases, the Digital Topographical Map 1:10.000 (published by the Dutch Topographical Service) and the Digital Land-Use Statistics (published by the Dutch Central Bureau of Statistics), provide the necessary

information. STEPP distinguishes six categories of sensitive areas, each with a specific code (see also step 3):

- MEC: Areas with large numbers of human inhabitants (such as shopping malls)
- MEP: Areas where humans have permanent residence (such as private residences)
- MEN: Areas that humans occasionally visit (such as recreation areas)
- EC: Areas with unique ecological value (such as city parks and nature areas)
- BW: Soil and water areas (such as gardens and canals)
- MA: paved areas (such as roads and car parks)

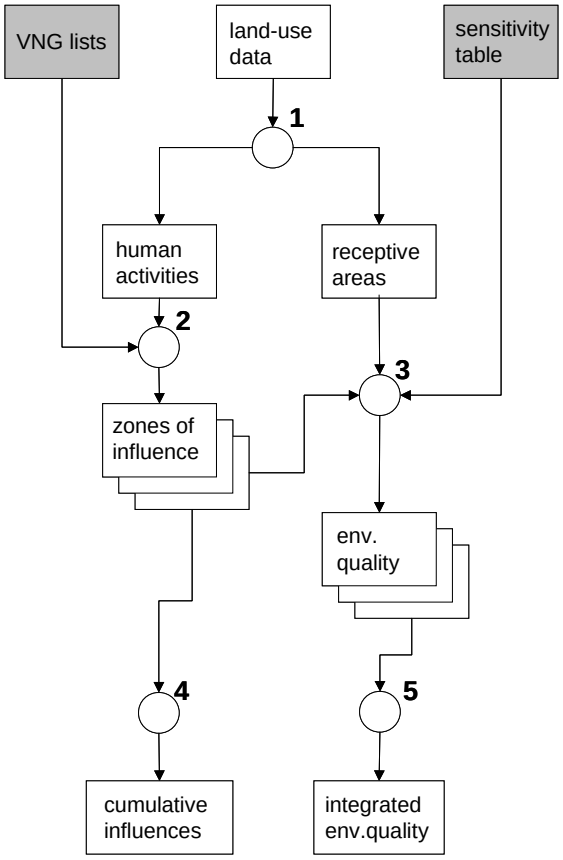

Figure 2 The basic steps of the analytical component of STEPP.

The second step in the analytical component of STEPP begins with an analysis of the activities in the study area in order to derive the zones where environmental impacts occur. The implications of the spatial scale of the environmental impacts of most activities can be derived from published recommendations of the Organization of Municipalities in the Netherlands (VNG, 1999). These so-called VNG lists, which are regularly updated, are based on Dutch environmental standards for emissions from activities, standards for impacts at residential sites, and on practical experience. In

Dutch local planning practice, the VNG lists are used to calculate indicative zones per impact category around the location of each activity. The lists include over 550 different categories of activities. Table 1 provides some examples.

Table 1 An example of activities in the VNG lists, with a selection of impact zones per category (VNG, 1999).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
SBI	**nr**	**definition**	**smell**	**dust**	**noise**	**hazard**	**traffic**	**visual**	**B**	**D**	**L**
151	1	Slaughterhouses	100	0	100	30	2	1		D	
1562	0	Starch factories									
1562	1	- prod. capacity < 10 ton/hour	200	50	200	30	1	2			
1562	2	- prod. capacity >= 10 ton/hour	300	100	300	50	2	3			
1589	2	Self-raising flour and blancmange factories	200	50	50	30	2	2			
271	0	Pig iron and steel plants:									
271	1	- prod. capacity < 1 000 ton/yr	700	500	700	200	2	2	B		
271	2	- prod. capacity >= 1 000 ton/yr	1 500	1 000	1 500	300	3	3	B		L
40A	0	Power station (capacity >= 50 MW) coal-fired	100	700	700	200	2	3	B		L
5231		Pharmacies and drugstores	0	0	0	10	1	1			

Explanation of the columns
1: Unique code for each type of activity (SBIcode)
2: Serial numbers for activities within the same SBIcode
3: Definition of the activity
4, 5, 6, and 7: Distance in meters. The distance for hazard is based on fire and explosion risks.
8, 9: Index number representing a small (1) to large (3) attraction of traffic or visual disturbance
10, 12: Codes indicating potential soil (B) and air (L) pollution
11: Code indicating that the SBIcode includes diverse (D) types of operations; consequently the impact distances are less reliable

For each activity, the VNG lists provide four indicative distances in meters for smell, dust, noise and hazard. These distances between the site of an activity and residential sites are deemed necessary in order to prevent nuisance and harm to people. The distances are divided into ten different categories, ranging from 10 to 1,500 meters. Two additional impact categories, for traffic and visual disturbance, are represented by index numbers, which give a qualitative indication of potential emission or nuisance.

The lists also contain two codes indicating potential emission of pollutants in soil and air. These codes can be important when planning activities in very sensitive areas, such as those under soil protection or close to nature reserves.
Given the generally accepted use of the VNG lists in Dutch local planning practice, the concept of influence distances in the lists has been adopted in STEPP, with the additional information on environmental impacts -the codes and index values- converted to distance measures. Three additional impact categories with influence distances have been added: (1) visual disturbance, (2) traffic disturbance and (3) local soil pollution. In addition to the individual activities listed in the VNG lists, STEPP also includes a tool to introduce four different types of industrial zones. Each type of zone is characterized by the average influence distances of representative activities in the VNG lists. The seven types of impact categories are fixed, but the user can easily adapt the impact distances in the VNG lists, as well as for each individual activity. The user can also select the types of impact to be included in the analysis.

The third step starts with an analysis of the sensitivity of functions for each impact category, for the six functions that are described with the first step. Table 2 gives an example of how the sensitivity of these functions can be classified. However, the user can adapt the values in the table, to meet the requirements of a specific case.

Table 2 Sensitivity of functions for each impact category (3 = very sensitive; 2 = sensitive; 1 = not sensitive).

Sensitive function	**Code**	**Level of sensitivity per impact category**						
		smell	dust	noise	hazard	air poll.	soil poll.	visual
human beings								
concentrations	MEC	3	3	2	3	2	3	2
permanent	MEP	2	2	2	2	2	3	2
occasional	MEN	2	2	1	2	2	2	1
ecological values								
unique ecological values	EC	2	2	2	1	3	3	1
no ecological values								
soil and water	BW	1	1	1	1	1	3	1
materials	MA	1	1	1	1	1	1	1

The impact zones for each impact category are compared with the sensitivity of the functions present in each impact zone, using GIS overlay techniques, producing an indicator map of ‘quality’ for each impact category. The underlying principle is that:

- The quality of areas outside the impact zone is considered good (indicator value 0).

- The quality of areas inside the impact zone with a function that is not sensitive to the type of impact is considered reasonable (indicator value 1).
- The quality of areas inside the impact zone with a function that is sensitive to the impact is considered moderate (indicator value 2).
- The quality of areas inside the impact zone with a function that is very sensitive to the impact is considered poor (indicator value 3).

The fourth step incorporates the different impact maps into an integrated environmental impact map in which the different impacts are calculated for any one location. This map shows the number of different impacts in any location in the study area. The fifth step draws the indicator maps of each quality into one integrated environmental quality (IEQ) map, by summarizing the values (ranging from 0 to 3) of the individual environmental quality (EQ) maps, according to the equation:

$$IEQ = \sum_{1}^{i} EQ(i)$$

with: i = number of individual environmental quality maps included in the analysis

The user can select different combinations of individual maps to be included in an integrated map. STEPP converts the individual, vector oriented maps to grids that allow the summarizing to be executed more easily. As the importance of any individual indicator map might depend on the situation and/or the sensitivities involved, each map could be given a weight, and integrated with other maps using multiple criteria techniques (e.g. weighted linear combination). However, based on discussions with local planning practitioners it was decided not to include these techniques in STEPP. The main argument was that the different types of impacts of the VNG-lists are generally rated equally in Dutch planning practice, and the application should be adapted as close as possible to this situation (neither were multiple criteria techniques included in the IEZ system). Moreover, the integrated maps were considered a by-product, since these maps cannot be interpreted well without the information of the individual impact and quality maps and the underlying data on activities and functions. See also the discussion.

The design component (Section 'B' in Figure 1) is meant to explore alternative spatial arrangements of human activities and functions. Most input data and parameters that are used by STEPP can interactively be modified, e.g. the locations of activities, the shape and size of areas, the different types of receptive areas (function of an area), the sensitivity of receptive areas, and the activity-based environmental impact distances. In Figure 2 these options are represented by the input boxes: VNG lists, land-use data and sensitivity table. Figure 3 shows some examples of the user interface developed to adapt the input data and parameters.

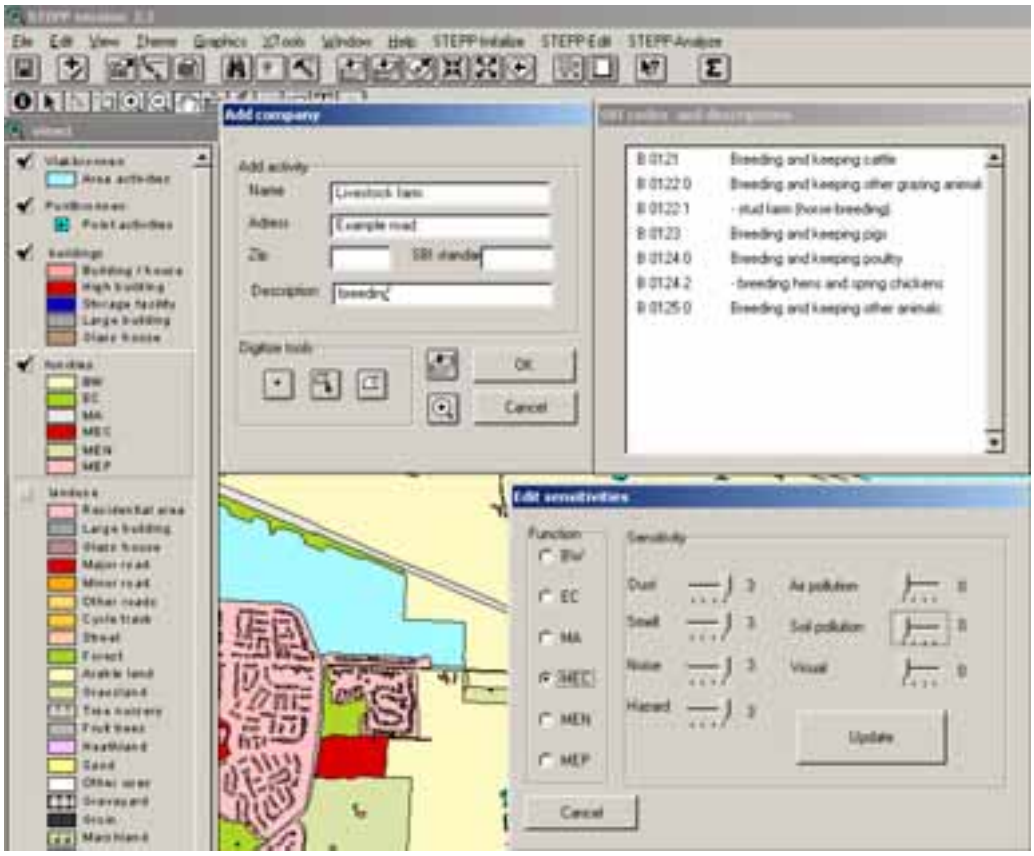

Figure 3 Examples of the user interface of STEPP.

The basic menus at the top bar are: STEPP-Initialize (e.g. to add new views), STEPP-Edit (to edit the input data) and STEPP-Analyze (to assess the environmental quality). Two windows of the STEPP-Edit menu are shown: at the top a window to add an activity to the study area, at the bottom a window to change the sensitivities of the function MEC in the area. At the left hand side some basic themes are shown: the area and point activities, a background theme with buildings, the function theme and another background theme with the topographical map 1:10.000.

Moreover, by comparing the tables of the resulting impact and quality maps of two or more analyses, the effect of measures and alternative spatial arrangements on the impacts quality areas can be analyzed. STEPP can also provide histograms of these changes in impact and quality areas. By comparing the impact and quality maps the areas that benefit most from these changes can be identified.

The user interface allows GIS novices to work with STEPP. Our experiences with STEPP show that a brief introduction generally allows spatial planners, urban developers and environmental specialists to work with the application themselves. Moreover, the output of an analysis can be produced fast, for example, to produce a com-

plete set of individual and integrated maps generally takes less than a minute, and changes in the input data and parameters can be executed instantly.

4. Nijmegen case study

Between autumn 2001 and spring 2003, STEPP was used in several projects at the S.A.B. office for urban planning (S.A.B. is the Dutch abbreviation for the City Planning Advisory Office), a private advisory company in Arnhem, the Netherlands. The objective was to evaluate the use of STEPP in planning practice (e.g. Schaminée, 2002). Several stakeholders in the projects were interviewed, including the people who used STEPP and three representatives of local authorities (clients of S.A.B.). STEPP was used at S.A.B. by three environmental and spatial planners, one urban designer, a social geographer, and an acoustic expert. Most of them were not familiar with GIS. Their experiences with STEPP were systematically reviewed through personal interviews and written evaluation reports. The interviews involved unstructured and generally open-end questions. The key questions were: does STEPP support the planning process and improve the communication between spatial and environmental disciplines, and what are its strengths and weaknesses? The authors were not directly involved with the projects, and conclusions are mainly based on the results of the interviews and reports, which will be discussed in the next section.
This section describes the use of STEPP in a project in the Dutch city of Nijmegen. The project area, known as Nijmegen-West, covers approximately 30 km^2. Figure 4 shows the locations of Nijmegen and the project area.

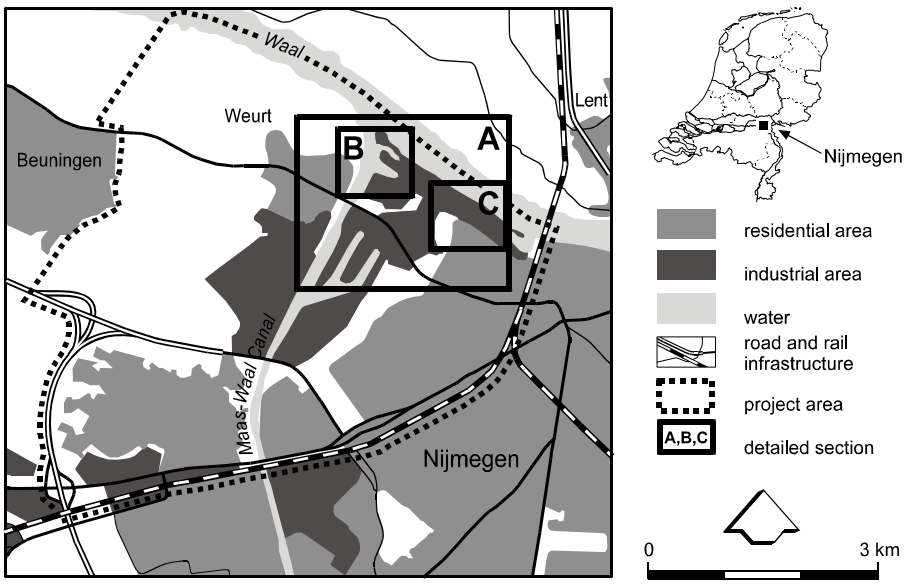

Figure 4 The project area Nijmegen-West.

The area borders the Waal river (the main stream of the Rhine) to the northeast and is divided into two parts by a harbour in the centre of the area, which is located along a canal connecting the Waal with the Maas river (Meuse) in the south. Highways are located in the western part of the area, and a new highway will be built through the agricultural area in the northwest, crossing the Waal at a new bridge. A second new bridge, to be located at the east side of the canal, will connect Nijmegen-West with new residential and industrial areas north of the Waal. The area is dominated by large industrial sites, located along the canal and the Waal, which are bordered by residential areas in the south and southeast and the small village Weurt in the north. Most of the residential areas and industrial sites were developed during the second half of the twentieth century. The environmental quality in the residential areas, especially in Weurt, is under pressure. The project "Koers West" (Course West) of the municipality of Nijmegen aims at restructuring the industrial areas, and at building new homes in the northwestern part of the area along the Waal. One of the main objectives of the project is to improve the environmental quality of the area, despite more intensive and multiple land uses in the future (Feskens & Schoppink, 2003).
At S.A.B. the most significant activities in the study area were identified and approximately 50 enterprises with the largest environmental impacts were selected. The research objectives were to trace the use of STEPP and to evaluate how it could support the process of finding ways to improve the quality of the environment in Nijmegen-West. To achieve this, the environmental impacts of the selected enterprises were analyzed, the results of which will be illustrated in the following examples.
The first step of the analyses included determining the areas where environmental impacts occur. For each selected enterprise its impact zones were derived from the influence distances in the VNG list, as described in the previous section. This step was limited to the four quantitative types of impacts: smell, dust, noise, and hazard. The environmental specialists at S.A.B. choose not to use the other types of impact, since they consider these more qualitative impacts not generally accepted and too subjective to be used in practice. This decision was also made in similar project studies at S.A.B. Figure 5 shows four of the resulting impact maps of detailed section A (see Figure 4). For presentation purposes this detailed section was clipped from the impact maps of the total study area. The detailed area was chosen for its lack of influence zones of activities outside the area.

Figure 5 shows that the largest impact zones in this area are those of noise and dust. These zones are dominated by the impacts of a coal-fired power station (the largest area activity in the centre of the area). Both zones cover some residential areas, especially large parts of Weurt (see also Figure 4). The impact zones of hazards and smell are much smaller. The eastern part of both zones, along the river Waal, is predominantly caused by three activities: a self-raising flour and blancmange factory, a starch factory, and a slaughterhouse. These activities are also listed in Table 1. The consequences of the impacts are described further in the environmental quality maps, which incorporate the sensitivity of the underlying functions for these impacts. Given the characteristics of the area, the impacts on residential areas were considered most im-

portant, and the sensitivities were adapted accordingly. The analyses focused on two categories of residential areas: common residential areas and very sensitive residential areas. The category MEC (code for areas with large numbers of humans, see also Table 2) was used for very sensitive areas, such as nursing homes, with sensitivity 3, for each of the four types of impact included in the analyses. The category MEP (code for areas where humans have permanent residence) was used for common residential areas with sensitivity 2. The other sensitive functions in Table 2 were given sensitivity 1. Examples of resulting environmental quality maps for two detailed areas are shown in Figures 6 and 7.

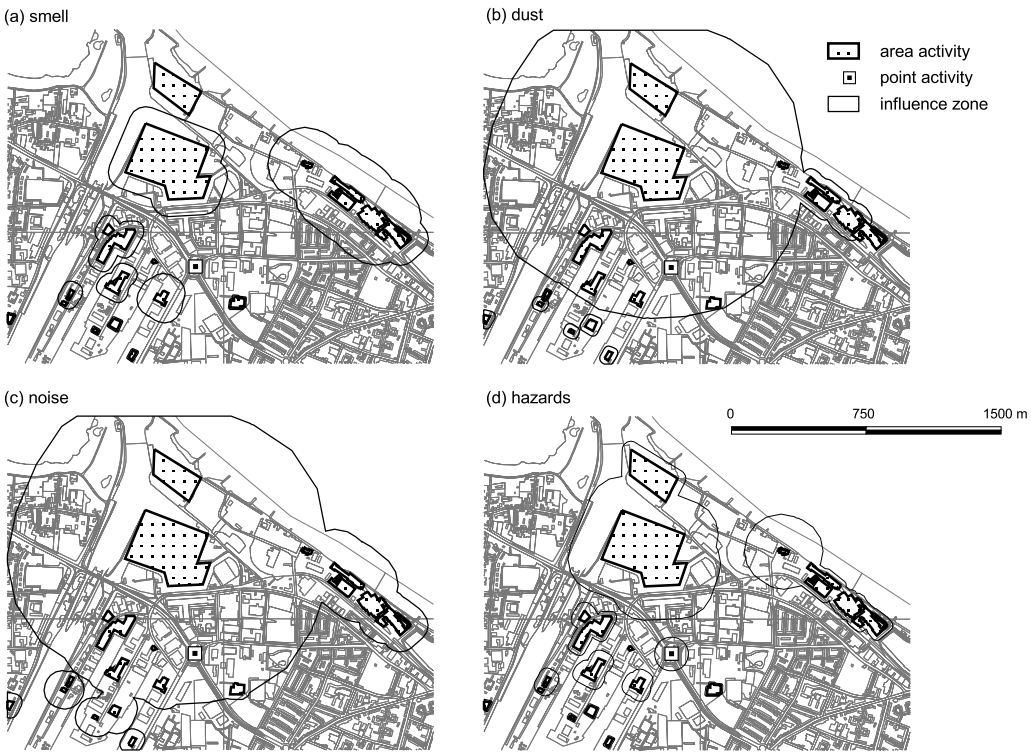

Figure 5 Environmental impact maps for detailed section A of the study area (see Fig. 3).

The environmental quality maps show that the impact zones of hazards (Figure 6) stay within the border of the industrial site; thus, the resulting environmental quality in these zones is reasonable (class 1). The impact zones of noise and dust partly cover the residential areas in the southeast (Figure 7) and especially large parts of Weurt in the west (Figure 6). The impact zone of smell (Figure 7) covers parts of the residential area in the southeast. The quality of the residential areas affected is moderate (class 2) for each type of impact, since residential areas that are very sensitive are not found within these impact zones. Consequently, class 3 areas are not present in both figures, although all three legend classes are automatically shown by STEPP. Nevertheless, the

class 2 residential areas do suffer from potential negative impacts which require to be addressed.

Figure 6 Environmental quality maps of noise (left) and hazards (right) for detailed section B (see Fig. 3).

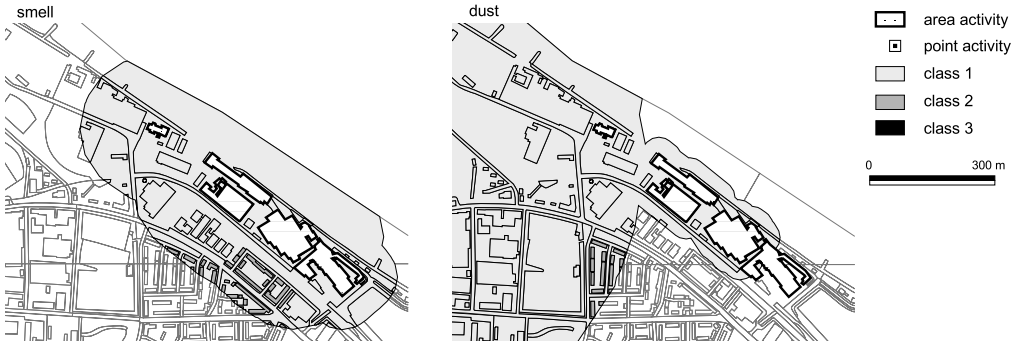

Figure 7 Environmental quality maps of smell (left) and dust (right) for detailed section C (see Fig. 3).

Several potential (hypothetical) measures to improve the environmental quality as well as alternative spatial arrangements in the area were explored. Examples of improvement measures are various reductions of the environmental impact zone of a coal-fired power station and the removal of the three previously mentioned activities to industrial sites elsewhere, necessitated by plans to restrict the area along the Waal to residential housing. Table 3 presents the resulting reduction of impact and quality zones in detailed area A, made after implementing these measures in the design component of STEPP. Only zones of quality class 2, representing a moderate quality that results from impacts on residential areas, are included. Combinations of these zones with the integrated classes 4 and 6 are also shown. Two examples of environmental quality maps for smell and noise are shown in Figure 8. Figure 9 shows the corresponding integrated environmental quality maps that include all four types of impact.

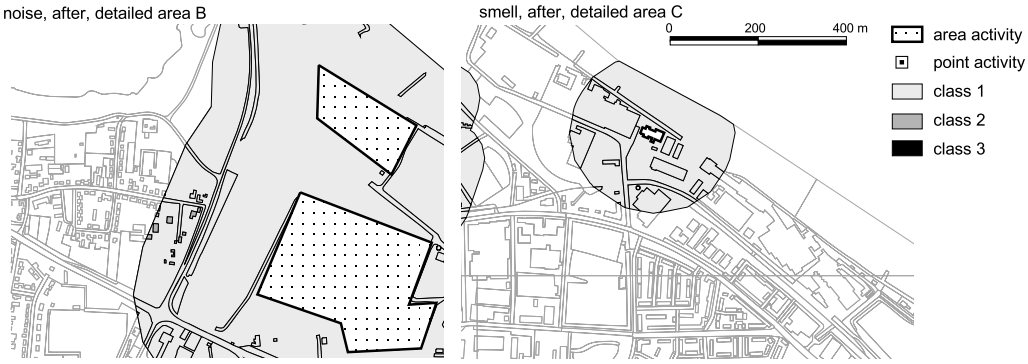

Figure 8 Environmental quality maps of noise (left) and smell (right), after measures had been taken, for two detailed sections B (left) and C (right) (see Figure 3). The maps represent a situation with 50% reduction of the standard impacts of the power station and the removal of three activities (see also Figures 5, 6 and 7).

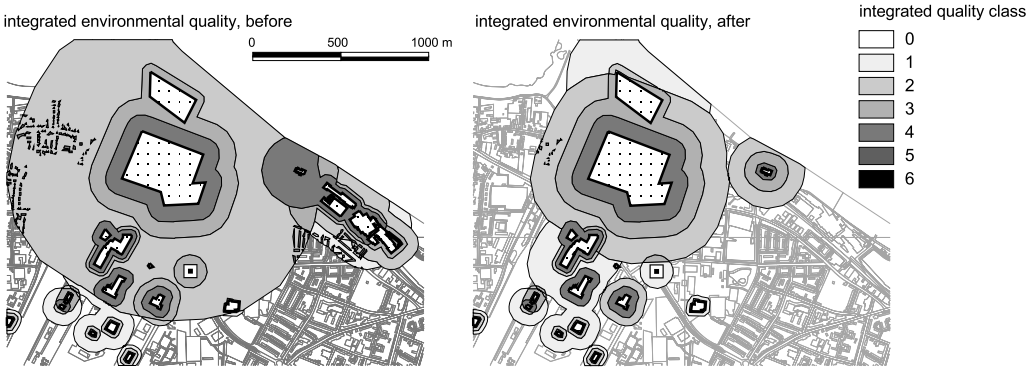

Figure 9 The integrated environmental quality maps before (left) and after (right) measures had been taken for the detailed area A (see Figure 3). The right map again represents the option of removal of three activities and a 50% reduction of the standard impacts of the power station.

The results show that relocating the three industrial activities effectively eliminates all negative impacts on the residential area in the southeast and enables the future development of a residential area along the Waal. The remaining impacts include 25 440 m^2 of dust and noise impacts on residential homes in Weurt, of which 22 110 m^2 by both impacts simultaneously, caused by the power station. This situation can be improved by reducing the standard impacts of the power station. Table 3 shows that a 10% reduction gives a substantial improvement, with a resulting 14 450 m^2 (43% reduction) of dust and noise impacts on residential homes. A further reduction in the standard impacts results in a more gradual decrease in residential homes in Weurt that are influenced by noise and dust. Figures 8 and 9 and Table 3 are examples of the various options that can be explored with STEPP to meet a desired objective.

Table 3 Scores for the most significant impact, quality and integrated quality zones, before and after the removal of three activities and additional reductions of the impact zones of the power plant.

	before	after removal	reduction of impact zones power plant					
			10%	20%	30%	40%	50%	100%
impact map	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
smell	100	70	67	65	63	61	59	36
dust	278	268	236	206	175	146	121	22
noise	306	280	254	229	209	190	173	112
hazard	108	99	94	89	85	81	77	43
quality maps, class 2	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)
smell	10 260	0	0	0	0	0	0	0
dust	25 440	25 440	14 450	10 330	6 280	3 840	1 680	0
noise	28 700	25 440	14 450	10 330	6 280	3 840	1 680	0
hazard	0	0	0	0	0	0	0	0
integrated quality map, class 6	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)
smell, dust, noise	300	0	0	0	0	0	0	0
integrated quality map, class 4	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)
dust and noise	22 110	22 110	12 100	8 590	5 190	3 150	1 270	0

5. Discussion

The Nijmegen and similar case studies at S.A.B. showed the significance of both internal and external communications within the STEPP research project. Internal communication is defined as that between the disciplines involved, such as spatial planners, urban developers and environmental specialists. External communication mainly concerns the communication between local authorities and interested parties or stakeholders. Looking at internal communication, the personal interviews reflect that STEPP facilitates a quick and easy way to generate alternative plans and to assess their respective environmental impacts. This means that an interdisciplinary project team can explore more alternatives. This in turn might lead to better decision making. Furthermore, the use of a shared representation of the planned objects and the impact of these objects on the environmental quality improves the mutual understanding of the problems and consequently the communication among disciplines. An environmental planner of S.A.B. stated: "*STEPP improves the progress, quality and results of the planning process … since environmental planners are able to cooperate in the exploration of alternatives*". Looking at external communication, the interviews reveal that STEPP might assist local authorities to implement or monitor the increasingly complex legislation and regulations. This may stretch their resources, both in the in-

frastructure required to support appropriate levels of decision making, and in the training of manpower to interpret the implications of development proposals across a wide range of impact topics. Tools such as STEPP are a basis for decision-makers to explore and evaluate options and to conduct many 'what-if' scenarios (Klosterman, 1999), perhaps through the necessary use of consultancy firms, but placing more of an onus on the provision of interpretable outputs that can be used to disseminate key results more widely. Even more important, scenarios and sketches by planners and developers can easily be assessed for their environmental consequences when it is of most value: at the beginning of the planning process. The interviews showed consensus among all interviewees about the importance of quick scan tools such as STEPP to support present spatial and environmental policies (see also the background section). A municipal representative stated: "*STEPP stimulates communication between spatial and environmental disciplines and supports explorative sessions … ideally these sessions will result in strategic, area-specific policies that act as a framework for more specific policies and plans*". The use of STEPP as a quick scan tool was also demonstrated in a similar case study at S.A.B., involving an urban development project of the municipality of Bergeijk. An explorative analysis with STEPP in the first phase of this project showed the most promising alternatives for establishing new residential and industrial areas. Afterwards, these alternatives were worked out and assessed with more detailed methods, such as acoustic research.

Given the increasing number of interested parties that participate in spatial planning, the outcomes of planning processes tend to be more and more the result of negotiations among the participants (e.g. van der Valk, 2002). The increasing level of participation has caused the perception of planning to shift from a centralized view towards a more systemic and process-oriented approach. Encouraging an increasing number of participants to join the spatial planning process has caused the demands made on communication among interested parties to move beyond the traditional, simple (formal) hearings. Interested parties expect to have an active role from the initial stages (formulation of goals, exploration of alternatives) right up to the final stage of decision-making, and the influence of information and communication technology (ICT) on participatory planning can aid some aspects of the process (Dalal-Clayton & Dent 1993; Ligtenberg et al., 2001; Malczewski, 2004). Although STEPP might potentially be used for informing or consulting stakeholders such as citizens, thus improving stakeholder participation, this was not included in the initial research objectives. Further research has to answer the questions if STEPP can be adapted to support stakeholder participation and whether or not planning practice has a need for such a tool. Despite the fact that the output maps look very detailed and suggest a high degree of accuracy, they should only be used as indicative, because some input data, such as the impact distances, and therefore the boundaries of impact zones, are indicative. Communication with stakeholders will require a presentation of the results that does not suggest this high degree of accuracy, and sketch like presentations with fuzzy borders will be more appropriate. STEPP might also support stakeholder participation by involving multiple criteria techniques, e.g. weighted linear combination (e.g. Lahdelma et al., 2000). That would allow stakeholders to e.g. assign weights to the different im-

pacts and qualities. Although one municipal representative was in favour of this option, one might argue that such an option will make the tool more complex, and its results more difficult to interpret.

The case studies also revealed that STEPP and similar tools will be successful only if the participants in the planning process are willing to communicate on an equal basis in the early phases of the process. Common planning practice, however, shows that the disciplines involved still have a traditional view of their role in the process (Schaminée, 2002). A municipal representative stated: "*…a tool that supports communication between disciplines is valuable … but it will only be successful if the participants are willing to step outside their traditional role in the process*". In order to make the area-based processes as described in Section 2 a success (e.g. Ministry of VROM 2001c, Pederson et al., 2004), it is essential that the disciplines involved cooperate more closely and are given a role that enable them to monitor and intervene in the planning process from the early beginning. Obviously, the significance of environmental policy in a planning process determines whether or not STEPP can actually support such a process. In many development processes the environmental aspects are of only minor importance and for these processes STEPP will not be relevant.

The case studies also showed that the components of the tool and methodology are not being fully exploited. In general, the embedding of the VNG lists in STEPP is considered a plus by all interviewees, since environmental planners are used to work with these commonly accepted lists. However, the case study analyses were limited to the types of environmental impact with influence distances listed. The additional environmental impacts, derived from the codes and indices, were ignored. The main reason is that in planning practice these codes and indices are generally used as additional descriptive information, and the way they are transferred to distances in STEPP is open to some debate. Furthermore, the analyses in the Nijmegen and similar case studies focused primarily on the impact and quality maps, with the integrated maps hardly used. The interviews revealed that the main reason for neglecting these options is that the more commonly used impact and quality maps are more familiar to the users at S.A.B., whereas the use of integrated maps are not part of the existing routines. Their main argument was that the integrated maps are merely instruments for summarizing the output and they should only be used, and can only be interpreted, together with the single impact and quality maps and associated tables. The interviews and evaluation reports also revealed that STEPP needs extension. At present, it is not equipped to analyze the environmental impacts of road and rail traffic, impacts that S.A.B. considers essential for most projects. Also, the categories of receptive environment (the six function classes) should be defined in more detail, especially with regard to the distinct types of residential areas. Additional information can also improve the applicability of STEPP, e.g. information on traffic intensity and qualitative aspects of residential housing.

Although STEPP was presented in a Dutch planning context, the tool might also be applied outside the Netherlands. However, the use of the concept of environmental zoning within the spatial planning process is a basic requirement for successful application of STEPP. Whereas the VNG lists provide the relevant information for the

Dutch situation, these lists can easily be replaced or modified to meet the conditions in other countries. Obviously, this will only be successful if such lists are accepted as a meaningful assessment tool for environmental planning and policy.

6. Conclusion

The search for a sustainable balance between the influences of human activities and the sensitivities of urban and rural environment is not merely a quest for a suitable tool, but also a search for a suitable means of communication. Planning support tools that support the work of local authorities and planning offices, especially with regard to identifying options in the early phases of the planning process, are interesting from a communicative point of view. The case studies showed that tools like STEPP stimulate internal communication among the disciplines involved. However, this will be successful only if the participants in the process are willing to communicate on an equal basis, in order to increase the level of understanding and awareness amongst all parties, and to work towards a common vision. This requires a change in the mentality of spatial planners, urban developers and environmental specialists, from a monodisciplinary to an interdisciplinary focus. Also, it is important to prevent participants from feeling that they are in the margin of a wider interplay of forces and that they consequently have less influence on the outcome of the planning process.
Planning support tools can easily become ‘black boxes’ if participants do not fully understand the limitations of these tools. It is important to make clear how the results of the planning process can benefit from the use of these tools. In general, the acceptance of planning support tools will improve if there are transparent connections with generally accepted elements of planning practice, availability of suitable data, and functions that target specific regulations and procedures to be undertaken on a regular basis. Planning support tools should be as much concerned with the political and social context as with their more specific substantive content (see also Batey & Breheny, 1978; Wong, 1998).

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References

Al-Kodmany, K., 2002. Using Web-Based Technologies and Geographic Information Systems in Community Planning. Journal of Urban Technology 7: 1-30.

Barredo, J.I., M. Kasanko, N. McCormick & C. Lavalle, 2003. Modelling dynamic spatial processes: simulation of urban future scenarios through cellular automata. Landscape and Urban Planning 64: 145-160.

Batey, P.W.J. & M.J. Breheny, 1978. Methods in strategic planning: a descriptive review. Town Planning Review 49: 259-273.

Brail, R.K. & R.E. Klosterman (Eds), 2001. Planning support systems: integrating geographic information systems, models, and visualization tools, ESRI Press, Redlands, CA.

Breheny, M., 2002. Centrist, decentrist and compromisers: Views on the future of urban form, in: M. Jenks, E. Burton & K. Williams (Eds) The compact city: A sustainable urban form?, Spon Press, Oxford, pp. 13-35.

Carsjens, G.J., R.J.A. van Lammeren & A. Ligtenberg, 2002. STEPP: Strategic tool to integrate environmental aspects into planning procedures, in: S. Geertman & J. Stillwell (Eds) Planning support systems in practice, Chapter 8, Springer Verlag, Heidelberg, pp. 139-154.

Clark, M., 2005. The compact city: European ideal, global fix or myth. Editorial. Global Built Environmental Review 4, 1-11.

Dalal-Clayton B. & D. Dent, 1993. Surveys, plans and people: Review of land resource information and its use in developing countries. Environmental planning issues no 2. IIED, London.

Daniels, T., 1999. When city and country collide: Managing growth in the metropolitan fringe. Washington, D.C., Island Press.

Daniels, T., 2001. Smart growth: A new American apporach to regional planning. Planning Practice & Research 16, 271-279.

de Roo, G., 2003. Environmental planning in the Netherlands: too good to be true: from command-and-control planning to shared governance. Aldershot, Ashgate.

Dieleman, F. & M. Wegener, 2004. Compact city and urban sprawl. Built environment 30, 308-323.

Feskens, J.A.C.W. & M.A.H. Schoppink, 2003. Masterplan revitalisering Noord- en Oostkanaalhavens: Van ambities naar projecten. Gemeente Nijmegen en Grontmij Advies & Techniek bv, Arnhem.

Geertman, S., 2002. Participatory planning and GIS: a PSS to bridge the gap. Environment and Planning B: Planning and Design 29, 21-35.

Geertman, S. & J. Stillwell, 2002. Planning support systems: an introduction, in: S. Geertman & J. Stillwell (Eds) Planning support systems in practice, Chapter 1, Springer Verlag, Heidelberg, pp. 3-22.

Geertman, S. & J. Stillwell, 2004. Planning support systems: an inventory of current practice. Computers Environment and Urban Systems 28, 291-310.

Glasson, J., R. Therivel & A. Chadwick, 1999. Introduction to environmental impact assessment: Principles and procedures, process, practice and prospects, 2nd Edition. London, UCL Press Limited.

Harris, B., 1989. Beyond geographical information systems: Computers and the planning professional. Journal of the American Planning Association 55: 85-90.

Harris, B., 1999. Computing in planning: Professional and institutional requirements. Environment and Planning B: Planning and Design 26: 333-343.

Jankowski, P. & L. Richard, 1994. Integration of GIS-based suitability analysis and multicriteria evaluation in a spatial decision support system for route selection. Environment and Planning B: Planning and Design 26: 393-408.

Jenks, M., E. Burton & K. Williams (Eds.), 1996. The compact city: A sustainable form? Spon Press, London.

Klosterman, R.E., 1998. Computer applications in planning. Environment and Planning B: Planning and Design. Anniversary Issue: 32-36.

Klosterman, R.E., 1999. The What if? collaborative planning support system. Environment and Planning B: Planning and Design 26: 393-408.

Klosterman, R.E., 2001. The What if? planning support system, in: R. Brail & R.E. Klosterman, (Eds.) Planning support systems: integrating geographic information systems, models, and visualization tools, ESRI Press, Redlands, CA.

Lahdelma, R., P. Salminen & J. Hokkanen, 2000. Using multicriteria methods in environmental planning and management. Environmental Management 26: 595-605.

Lange, E., S. Hehl-Lange & I. Mambretti, 2004. Assessment of urban green space qualities using 3D visualization tools, in: M. Koll-Schretzenmayr, M. Keiner & G. Nussbaumer (Eds.) The real and virtual worlds of spatial planning. Springer, Berlin, pp.185-198.

Ligtenberg, A., Bregt, A.K., van Lammeren, R., 2001. Multi-actor-based land use modelling: spatial planning using agents. Landscape and Urban Planning 56: 21–33.

Malczewski, J., 2004. GIS-based land-use suitability analysis: a critical overview. Progress in Planning 62: 3–65.

Ministry of VROM, 1998. Beleidsnota vernieuwing geluidhinderbeleid: een nieuwe sturingsfilosofie voor het toekomstige geluidbeleid. Den Haag, Ministry of Housing, Spatial Planning and the Environment (VROM).

Ministry of VROM, 2001a. Where there's a will there's a world - working on sustainability. 4th National environmental policy plan. Den Haag, Ministry of Housing, Spatial Planning and the Environment (VROM).

Ministry of VROM, 2001b. Making space, sharing space - 5th National policy document on spatial planning 2000/2020. Den Haag, Ministry of Housing, Spatial Planning and the Environment (VROM).

Ministry of VROM, 2001c. Eindrapportage onderzoeksresultaten tussenevaluatie project stad & milieu. Den Haag, Ministry of Housing, Spatial Planning and the Environment (VROM).

Nedovic-Budic, Z., 1998. The impact of GIS technology. Environment and Planning B, 25: 681-692.

Needham, B. & A. Faludi, 1999. Dutch growth management in a changing market. Planning Practice & Research 14, 481-491.

Nyerges, T.L. & P. Jankowski, 1997. Adaptive structuration theory: A theory of GIS-supported collaborative decision making. Geographical Systems 4: 225-259.

Pedersen, Å.Ø., S. Nyhuus, T. Blindheim & O.M. Wergeland Krog, 2004. Implementation of a GIS-based management tool for censervation of biodiversity within the municipality of Oslo, Norway. Landscape and Urban Planning 68: 429-438.

Pettit, C. & D. Pullar, 1999. An integrated planning tool based upon multiple criteria evaluation of spatial information. Computers, Environment and Urban Systems 23: 339-357.

Schaminée, A., 2002. De Beoordelingsmethode Milieukwaliteit: Van academie naar commerciële beroepspraktijk, Wageningen: Land Use Planning Group, Wageningen University.

Shiffer, M.J., 1995. Interactive multimedia planning support: Moving from stand-alone systems to the World Wide Web. Environment and Planning B: Planning and Design 22: 649-664.

Stillwell, J., S. Geertman & S. Openshaw, 1999. Developments in geographical information and planning, in: J. Stillwell, S. Geertman & S. Openshaw (eds.) Geographical information and planning, Chapter 1, Springer Verlag, Heidelberg, pp. 3-22.

Uran, O. & R. Janssen, 2003. Why are spatial decision support systems not used? Some experiences from the Netherlands. Computers Environment and Urban Systems 27, 511-526.

van der Valk, A., 2002. The Dutch planning experience, Landscape and Urban Planning 58: 201-210.

VNG, 1999. Milieureeks (kgm) Nr 9: Bedrijven en milieuzonering, Vereniging van Nederlandse Gemeenten (VNG), Den Haag: VNG-Uitgeverij.

Voss, A., I. Denisovich, P. Gatalsky, K. Gavouchidis, A. Klotz, S. Roeder & H. Voss, 2004. Evolution of a participatory GIS. Computers, Environment and Urban Systems 28: 635-651.

Weber, C., 2003. Interaction model application for urban planning. Landscape and Urban Planning 63: 49-60.

Williams, K., E. Burton & M. Jenks (Eds.), 2000. Achieving sustainable urban form? Spon Press, London.

Wong, C., 1998. Old wine in a new bottle? Planning methods and techniques in the 1990s. Planning Practice & Research 13: 221-236.

Landscape and Urban Planning 58 (2002): 171-179

4.3 Strategic land use allocation: dealing with spatial relationships and fragmentation of agriculture.

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In The Netherlands, a debate continues to take place on how to allocate the available space among several types of land use. The rural area is under constant pressure from urban developments. Multi-purpose land use is becoming more and more important. Land-use allocation problems can be identified as complex planning problems, with a large number of stakeholders involved. Therefore the decisions made with respect to land use must be clear and transparent to these stakeholders. Various methods have been developed to support land allocation issues. Typically, however, the analysis of topological relationships, initiated by biophysical and socio-economic processes, and the spatial configuration of different land uses, is often neglected, especially for agricultural planning. Neglecting the spatial configuration and these relationships can result in spatial fragmentation of land use, thus endangering sustainable land use. This paper focuses on a method to address land-use allocation issues where the topological relationships are taken into account. The method is implemented in a Geographical Information System (GIS). Two cases for Dutch agriculture are discussed.

Keywords: land-use allocation, rural area, fragmentation, agriculture, topological relationships

1. Introduction

In The Netherlands there are many opportunities to study cases on multi-purpose land use. Land uses change regularly and there is therefore on-going debate on how to divide the available space among several types of land use. The segmentation and the layout of the available space are continually changing. Different land users are more often sharing the same space. For example, land that was once used only for agricultural purposes with farms scattered around is now used for aggregated agricultural use, ecological development, and recreational purposes. Various types of land use are often competing for the same locations, especially in highly urbanized areas (e.g., Van der Valk 2000). For many locations, there is a regular transformation in land use with a growing multi-purpose objective.

Land-use allocation problems are complex planning problems. Often, a large number of different stakeholders is involved in the planning process. Therefore the decisions made with respect to land use must be clear and transparent to these stakeholders. Decisions about the land use for a specific location depend on, among other things, the suitability of the land for a specific type of use. This can be assessed by a suitability analysis. A suitability analysis predicts the potentials for the land and constraints on this land for a defined use (Steiner et al. 2000). It provides objective data sets for these potentials and constraints, which influence any decisions on sustainable land use. Suitability analysis techniques integrate three factors of an area: location, development activities, and biophysical/environmental processes (Miller et al. 1998). Various methods have been developed to support suitability or land allocation issues (e.g., Eastman et al. 1993, Stoorvogel et al. 1995, Geertman and Ritsema van Eck 1995, Ren 1997). However, the geographical descriptions of land use concentrate almost entirely on size, location, and the number of land units. The analyses of topological relation-

ships that are the results of the biophysical/environmental and socio-economic processes, and the spatial configuration of different land uses, are either neglected or very limited. In addition to the land-use characteristics, the topological relationships have a direct influence on the suitability of a location.

2. Objectives

A research project at Wageningen University was started in order to explore the possibilities of GIS-based tools to support local and regional land-use allocation issues (Carsjens and Van der Knaap 1996, Carsjens and Smits 1997, Van der Knaap and Carsjens 1999). A main area of the research is how topological relationships can be integrated in a method to support land-use allocation for strategic planning, focusing especially on agricultural land use.

Dutch agriculture is characterized by specialization, intensive land use, high yields, and environmental and sustainability problems and their resulting dynamics (Hoggart et al. 1993, Hoggart et al. 1995). In the next decades, Dutch agriculture must focus on the environmental quality and livability of the rural area (Verkaik, 1998). Dutch agriculture will need to change into a pluralist sector adapting spatial developments and developments for non-agricultural activities, such as recreation and nature development (Verkaik, 1998). Dutch land-use planning deals with socio-economic and management problems of current farming with respect to both nature and environment. It focuses on, among other aspects, preserving and developing natural areas contiguous to and within agricultural production areas. Hence opportunities exist to examine the specific combinations of extensively and intensively used zones of agricultural land within regions or even farms. However, decisions about locations for nature development must be evaluated with respect to their significance for future agriculture use. Topological relationships are important elements to consider when evaluating these issues.

This paper will discuss integrating topological relationships in a method of evaluating land potential for future agricultural use. This method is illustrated with two cases in The Netherlands.

3. Allocation method

3.1. Background

The suitability of any location depends on the demands for the specific type of land use. The characteristics of a location must meet these demands, or criteria, to finally be suitable for the particular type of land use. Multi-criteria techniques can be applied for classifying and weighing the criteria. Multi-criteria techniques are particularly useful where there are large numbers of criteria, with different dimensions to be handled (Voogd 1983, Jankowski 1989). GIS and multi-criteria techniques can be linked together and fully integrated (Pettit and Pullar 1999). Methods based, for instance, on loose coupling make use of a file exchange mechanism between the GIS and multi-

criteria tools outside GIS (Jankowski 1995). Topological relationships are best derived and preserved within a GIS environment, in which multi-criteria techniques are fully integrated, as applied in the allocation method. This combination of GIS and multi-criteria techniques is chosen, because some other techniques that can handle topological relationships, for example, Cellular Automata (e.g., Itami 1994, Ligtenberg et al. 2000) give results that are difficult to replicate.

The potentials and constraints of farmland are the direct results of the physical and socio-economic land evaluation criteria (e.g., soil type and farm production) as well as spatial criteria. These spatial criteria represent the geometrical and topological characteristics of locations. For agriculture on farm level this concerns, for example, the shape and size of parcels, the spatial configuration of the road network, the distance between parcels and farm buildings, and the distance between farm buildings and nature conservation areas.

Rather than focus on the current status of farming, the method focuses on farming for the future, and evaluates current farming from this perspective. Prospective farm types are derived from land-use scenarios and future prospects for Dutch agriculture (e.g. Oosterveld, 1999, Nijssen and Van Scheppingen 1995, Van der Ploeg, 1995). These prospective farm types are, in fact, the reference classes for the evaluation of current farms. We analyze the characteristics of a current farm from the perspective of the characteristics of a prospective farm type. In order to compare the present farms with the prospective farm types, the current trends of the characteristics are extrapolated for a specific timeline of research, for example, 15 or 30 years.

Three phases are distinguished in the allocation method that has been developed (also shown in Figure 1).

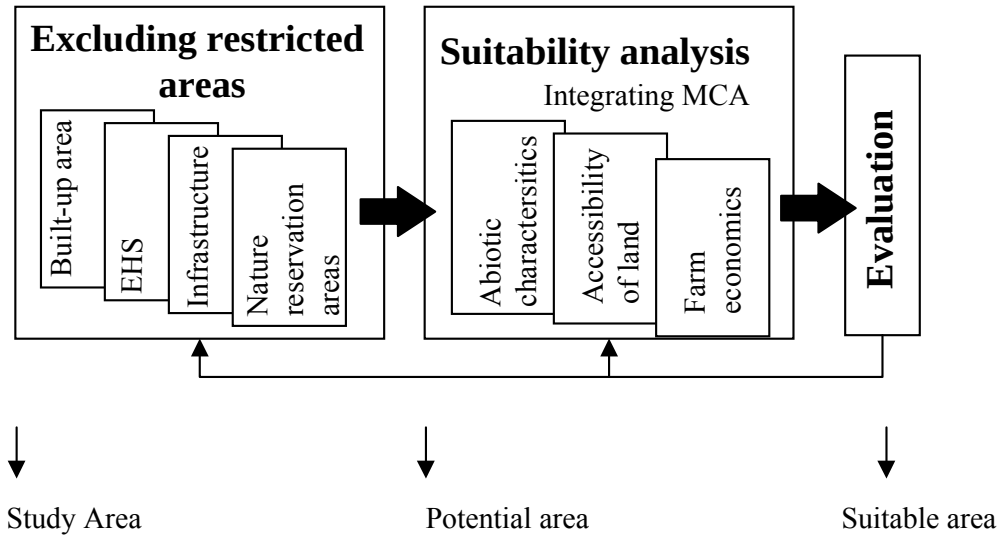

Figure 1 Scheme of the three phases of the method (for explanation see text).

- Phase 1: Excludes areas that are restricted by law or other limitations;
- Phase 2: Analyzes the remaining locations for future agriculture, integrating multi-criteria evaluation (MCE) techniques;
- Phase 3: Tests and evaluates the result.

3.2. Agricultural aspects

Several aspects of the proposed method are important when it is applied for agricultural land use, especially with respect to Phase 2. Given the high costs of relocating farm buildings, and the decreasing number of farms, we make the assumption that the current locations of farm buildings are also the potential locations for future farms. These then are the starting points for the analysis of the potential of each location. The spatial land configuration, in relation to these locations, is an important management issue, especially for dairy farming (see also the first case).

An appropriate spatial land configuration is more sustainable since it can reduce tillage, transport, and machine costs and can minimize the feeding of silage and concentrates as a result of better grazing conditions and grazing management. It also results in fewer working hours, more flexible time-management, and better working conditions (Nijssen and Van Scheppingen, 1995). The spatial land configuration at farm level primarily concerns the shape and size of the parcels and the distance between the parcels and the farm buildings. Fragmentation of farmland is a problem in (Dutch) agriculture. Generally, a distinction is made between farmstead parcels and field parcels. A farmstead parcel includes all the conjoined land upon which the farm buildings are located. The remaining farmland consists of field parcels. However, the size and shape of the parcels are continually changing as a result of changing land ownership or farm management. Consequently, the current geometry of the parcels is unsuitable for this research. Rather than utilizing the current parceling, we have selected larger farmland units, with boundaries that we assume are fixed within the planning timeline of 15 to 30 years. These boundaries are, for example, large roads and waterways, built-up areas, and nature conservation areas. The problems these internal aspects pose on a farm are illustrated by the first case, in which the study focuses on the development potentials for dairy farming.

In addition to the internal topological relationships between a farm and its parcels, there are other important spatial relationships between a farm and its environment. The location of farms in relation to each other within a region can influence the development prospects for each farm. The distance between each farm and the nature conservation areas, recreational accommodations and/or the main infrastructure and the processing industry is another important relationship to consider. These and other external topological relationships are illustrated by the second case, in which the opportunities for pig farming on a regional scale are evaluated with many restrictions, that include environmental criteria, and criteria from both processing industries and animal health.

4. Cases

4.1. Introduction

The results of the two cases present different aspects of the integration of topological relationships in the land-use allocation process, and are partly based on thesis research (Steggink 1999, Van den Bor 1998). The first case, at the farm level, focuses on dairy farming. Dairy farming is the most important sector within the Dutch agricultural economy and is scattered throughout the Dutch countryside (see e.g., Hoggart et al., 1995). The study area is located in the Leijen area in the south of The Netherlands and covers approximately 125 km^2. The second, regional level case focuses on pig farming in the province of Noord-Brabant in The Netherlands. This study area covers approximately 5000 km^2. Figure 2 illustrates both study areas.

Figure 2 Location of the study areas in The Netherlands.

4.2. Farm level

The Leyen area is dominated by sandy aeolic soils. The current landscape of the study area is a mosaic of agricultural land of different reclamation stages, scattered forested areas, several brooks, wooded linear elements and small towns. Approximately 60% of the area is farmland. About 90% of the farmland in the study area is used for dairy farming, and is covered with grass and maize. The study area contains relatively small-scaled landscape types with a fine-grained pattern of wooded elements as hedgerows, lanes, and estates. Large nature areas in the north and south flank the study area. Regional planning for the area aims at developing natural areas within the

agricultural production area. Therefore, the significance of the area for future dairy farming must be evaluated.

Phase one of the allocation process excludes areas not suitable for dairy farming. Those areas are, for instance, nature conservation areas, built-up areas, and main infrastructure. The remaining land is divided in larger farmland units by defining the fixed boundaries (see Section 3.2). The farmland units are subdivided into grid cells. In this case, grid cells of 625 square meters are used. Each grid cell is then evaluated individually during the second phase of the method. In this phase, three steps are defined.

In the first step, each dairy farm is evaluated for its future potential. Several future dairy farming types are identified, and the possibilities that dairy farming may be eliminated altogether. Two examples of future dairy farms are presented in Table 1. Each typology for future dairy farming has its own characteristics with respect to the total area of agricultural land required, the size and number of parcels, the number of cows, and the degree of mechanization.

Table 1 Characteristics of two future dairy farming types.

Characteristics	Intensive farm type	Extensive farm type
Total area	70 ha	25 ha
Total milk production	1,000,000 kg	200,000 kg
Number of dairy cows	120	25
Milk production /cow/year	8,500 kg	7,500 kg
Percentage farmstead parcel (of total area)	70%	50%
Preferred parcel form	Rectangle and length/width < 3	Rectangle and length/width < 3

In the second and third step, the topological relationships are analyzed. Step 2 focuses on the accessibility of farmland to nearby farm buildings. For each grid cell, the five nearest farms are selected that lie within a radius of 2500 meters of the grid cell. If distances are larger, the assumption is made that no extra profit will be gained. The distances between each grid cell and the five selected farms are then calculated, using the current road network. Proximity buffers around the road network provide the distance from a grid cell to the nearest road. The calculated distances, that represent the accessibility of a grid cell, are added up by weighted summoning. The future potentials of the farms provide the weights. The result represents the significance of each grid cell, as field parcel, for future dairy farming.

Step 3 focuses on another important spatial characteristic for dairy farming, the potential farmstead parcel. Generally, the land adjacent to the farm buildings requires the least transport costs. For dairy farming, the daily nursing of the dairy cows is bounded to the farm buildings, because of the highly mechanized and computerized milking and feeding machines. Furthermore, farmers prefer a mixture of fresh grazing grass, silage and concentrates, to maintain a consistent high milk quality and milk production. The daily nursing activities require that the cows be near the farm buildings, as well as enough acreage for grazing. Only grid cells of land units with farm buildings

on it are selected in this process. The farmstead parcels are constructed around each farm with proximity buffers. The size and shape of a farmstead parcel depends on the characteristics of the prospective farm type (see table 1), and the presence of fixed boundaries (see Section 3.2). We assume that grid cells within a potential farmstead parcel have a higher probability to be claimed by future dairy farming than grid cells outside a farmstead parcel. The height of this probability corresponds to the future potential of a farm. The potentials of grid cells in overlapping farmstead parcels are added up. The resulting values represent the probability of a grid cell to be part of a future farmstead parcel. Figure 3 shows an example of a resulting map.

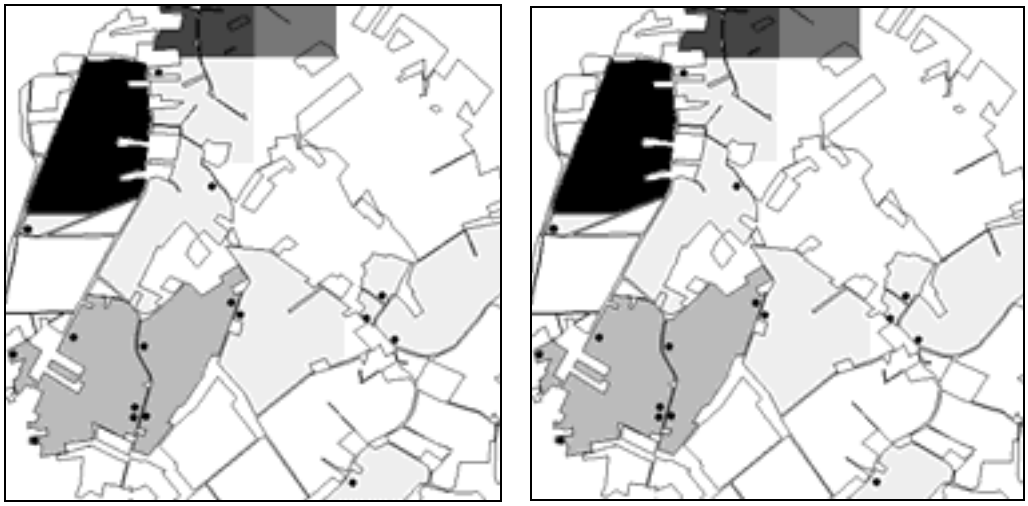

Figure 3 Potential farmstead parcels for a highly productive dairy farming type (left), and an extensive dairy farm type (right). Dark colors represent farmland with a high probability to be claimed by future dairy farming.

The results of the previous steps are combined in an overall classification of each grid cell for each farm type. These results can then be integrated with other aspects, such as the biophysical aspects, using MCE techniques. The combination of this information leads to conclusions as to what areas are the most significant for future dairy farming.

4.3. Regional level

The second case focuses on pig farming in the provinces of Noord-Brabant and the north part of Limburg in The Netherlands, an area with approximately 8 million pigs at 8900 pig farms. In 1997, a swine fever crisis threatened Dutch pig farms. Several thousands of pigs had to be killed in order to control the disease. As a result of this and other crises (BSE, foot and mouth), a discussion started about the future of Dutch livestock production. The discussion was especially focussed on the treatment of animals, and the environmental problems related to the sector. The Minister of Agriculture, Nature Management and Fisheries commissioned a think-tank to advise him on

the future of the Dutch livestock production sector. They concluded that a radical restructuring of the structure and working methods of the sector is required (Ministry of agriculture, nature management and fisheries 2001). Immediately after the swine fever crisis, several new policies and plans were developed (Ministry of agriculture, nature management and fisheries 1997, 1998a, 1998b).
One of the topics in the new policies and plans is to create areas where pig farming is allowed (clusters), and areas without pig farms (pig-free corridors). The areas overall have to alternate. The pig farms must be concentrated in specific clusters due to spatial and environmental reasons, as well as the aspects related to animal health. Only a selected number of farms are allowed in a cluster. Several criteria were formulated to meet these objectives, that include a minimal width for pig-free corridors of 1000 meters and the maximum number of pigs allowed within one cluster of one million. These and other criteria are shown in Figure 4. We used the allocation method to analyze the consequences of the new policies and plans for future pig farming in the study area, and to determine the most suitable areas for allocating the clusters.

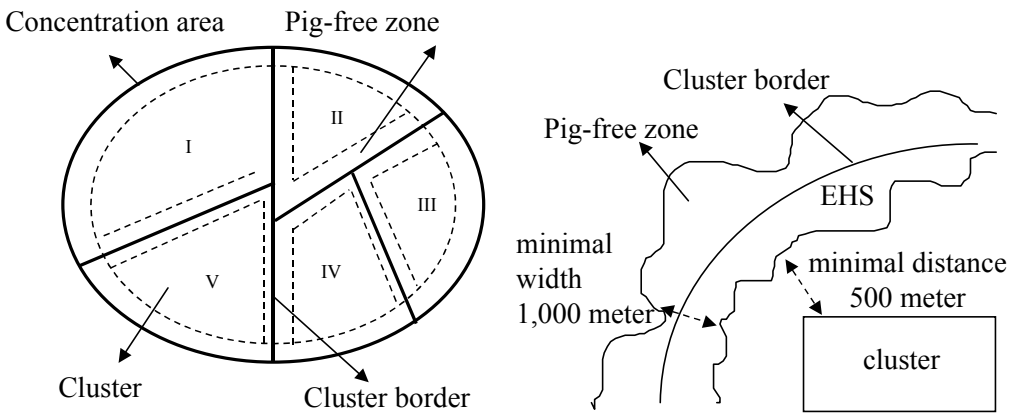

Figure 4 Definitions and characteristics of pig farming zones (EHS is the Dutch acronym for main ecological structure). Source: Ministry of agriculture, nature management and fisheries, 1998b.

The first phase in this case excludes areas not suitable for pig farming. Those areas are, for instance, nature conservation areas and built-up areas. An example of a resulting map is given in Figure 5.
The result of the previous phase is a map where areas are identified in which pig farming might develop (areas that are not excluded). The next phase aims to identify the most suitable remaining areas for allocating the clusters. Different spatial, biophysical, and socio-economic criteria are used to determine which locations are most suitable for pig farming. These include the acidification of the environment, the problems with the growing manure production, the preservation of valuable landscapes, environmental protection areas, vulnerable areas, the productive capacity of each farm, the concentration of farm-buildings, and finally the locations of related industries.

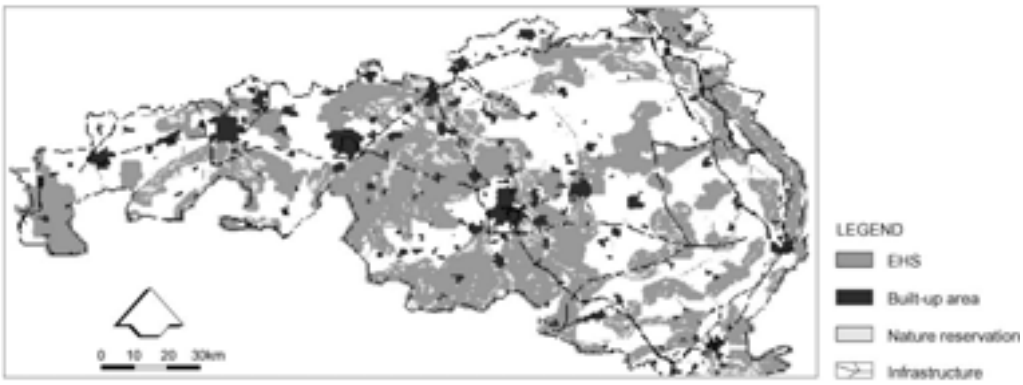

Figure 5 Excluded areas.

Analogous to the first case, several future pig-farming types are identified. Each pig farm is evaluated for its future potential, with respect to these future pig-farming types. These future potentials of pig farms are then integrated in some of the criteria, such as, the concentration of farm-buildings. For each criterion, a separate map is produced in Phase 2 of the allocation method. All these maps, taken together, produce the areas most suitable for allocating the clusters. The maps are combined using MCE techniques, where each map is given a specific weight. A sensitivity analysis looks at the sensitivity for changing values of, for instance, applied weights. An example of a resulting map is shown in Figure 6.

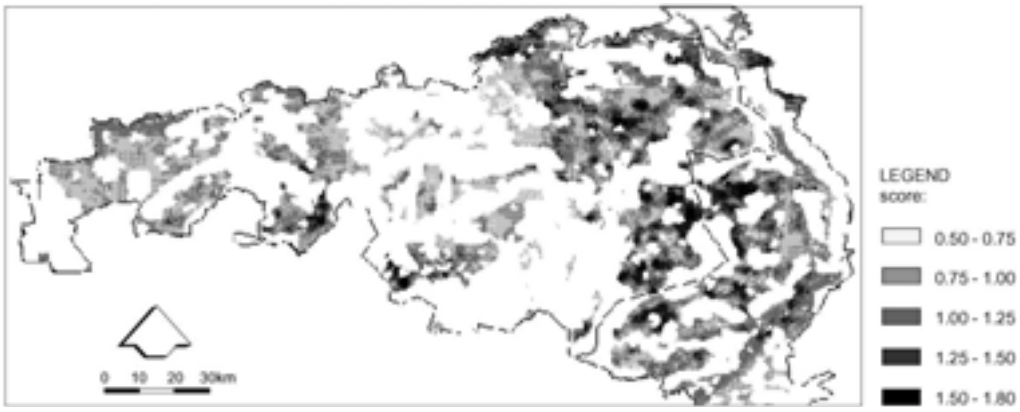

Figure 6 Example of a resulting land suitability map. Dark colors represent suitable areas for the allocation of clusters.

One of the conclusions of this case was that 38 percent of the pig farms in the study area should be eliminated, given the spatial criteria of Figure 4.

5. Discussion

Both cases demonstrate the potential of the proposed method to address the topological relationships in the planning process. On the farm level, the dairy farm case illustrates how spatial relationships influence the importance of farmland for dairy farming, and also illustrates how to deal with those relationships. On the regional level, the pig farming case demonstrates the interaction between the socio-economic aspects and the environmental processes with the overall spatial limitations. For both cases, the results provide some insight into the relative importance of farmland, given the future prospects of present farms. These prospects are an important starting point from which to evaluate the future situation for different farm types. The results of the method can be used in planning processes to assess the claims of future agriculture in combination with other land use claims.

The proposed method offers many opportunities to analyze various scenarios by altering the specific starting points and the applied criteria. The starting points and limiting conditions that are defined for the allocation process are conveniently arranged. This offers an opportunity for the early participation of stakeholders who are involved in the planning process. This is also one of the topics of the current research.

The cases that are presented focus on agricultural land use, although they also included several other environmental aspects. The method is flexible and offers possibilities to integrate more topological relationships of other types of land use.

There are other points to consider as well when applying the method. For instance, combining too many criteria might obscure the allocation process. If there are too many criteria or if the criteria are not arranged in an orderly fashion, or if there is not enough insight as to how they were derived, the multi-criteria analysis process is no longer transparent and it loses some of its advantages. Furthermore, the two cases showed that sufficient and reliable data is necessary to support the decision process. It is obvious that the larger the area, and the greater the level of detail involved, or the number of different land uses to be combined, the greater the necessity for more data. With more data the analysis and the evaluation processes become less transparent. The computer processing time will expand in direct relation tot the amount of data.

The user-interface of the GIS application demands expert-knowledge of ArcInfo. The possibilities to use the application in practice are therefore limited. Currently the method is being developed for transfer to the more user-friendly GIS ArcView program. This also offers possibilities to use the Internet (e.g. Kluskens, 2000). These developments are important because the Dutch planning practice lacks suitable Information and Computer Technology (ICT) instruments to support strategic spatial policy and land-use allocation processes, especially with respect to planning for future agriculture (NRLO, 1999).

References

Carsjens, G.J., and Smits, J.F.J.M., 1997. Topological relationships integrated in land use allocation; assessing potentials for future agriculture. In: S. Hodgson, M. Rumor and J.J. Harts (Editors), Geographical Information '97, From Research to Application through Cooperation, Volume 1, Third Joint European Conference and Exhibition on Geographical Information, Vienna, Austria, IOS Press, Amsterdam, pp. 758-767.

Carsjens, G.J., and Van der Knaap, W.G.M., 1996. Multi-criteria techniques integrated in GIS; applied for land use allocation problems. In: M. Rumor, R. McMillan and H.F.L. Ottens (Editors), Second Joint European Conference and Exhibition on Geographical Information, Barcelona, Spain, IOS Press, Amsterdam, pp. 575-578.

Eastman, J.R., Kyem, P.A.K., and Toledano, J., 1993. A procedure for multi-objective decision making in GIS under conditions of conflicting objectives, Fourth European Conference and Exhibition on Geographical Information Systems, pp. 439-447.

Geertman, S.C.M., and J.R. Ritsema van Eck, 1995. GIS and models of accessibility potential: an application in planning. International Journal of Geographical Information Systems, 9, 1: 67-80.

Hoggart, K., Buller, H., and Black, R., 1995. Rural Europe: Identity and Change. Londen, Arnold.

Hoggart, K., Kyem, P.A.K., and Toledano, J., 1993. A procedure for mulit-objective decision maling in GIS under conditions for conflicting objectives. Fourth European Conference and Exhibition on Geographical Information Systems, EGIS Foundation, Utrecht/Amsterdam, pp. 439-447.

Itami, R.M., 1994. Simulating spatial dynamics: cellular automata theory. Landscape and Urban Planning, 30: 27-47.

Jankowski, P., 1989. Mixed-data multi-criteria evaluation for regional planning: a systematic approach to the decision making process. Environment and Planning A, 21: 349-362.

Jankowski, P., 1995. Integrating geographical information systems and multiple criteria decision-making systems. International Journal of Geographical Information Systems, 9: 251-273.

Kluskens, R., 2000. An Internet based environment to facilitate multi-actor informing and consulting for environmental planning based on the BM methodology. Wageningen University, Department of Environmental Sciences, Centre for Geo-Information and Remote Sensing and Land Use Planning Group.

Ligtenberg, A., Van Lammeren, R.J.A., and Bregt, A.K., 2000. Cellular Automata and Multi Agent Simulation for actor based land use models. In: E.M. Fendel (Editor), Presentaties en demonstraties over onderzoek, ontwikkeling en praktijktoepassing op het gebied van geo-informatie, sessie GI Wetenschap I, p. 1.3-1.8. Geo-Informatiedag Nederland 2000, De Reehorst Ede.

Miller, W., Collins, M., Steiner, F., and Cook, E., 1998. An approach for greenway suitability analysis. Landscape and Urban Planning, 42, 2-4: 91-105.
Ministry of agriculture, nature management and fisheries, 1997. Wet Herstructurering Varkenshouderij. Den Haag.
Ministry of agriculture, nature management and fisheries, 1998a. Concept Reconstructiewet concentratiegebieden. Den Haag.
Ministry of agriculture, nature management and fisheries, 1998b. Concept Rijksuitgangspuntennota. Den Haag.
Ministry of agriculture, nature management and fisheries, 2001. The future of Dutch livestock production. Agenda for the restructuring of the sector. Den Haag.
Nijssen, J.M.A., and Van Scheppingen, A.T.J., 1995. Verkaveling in de melkveehouderij, DLO PR publikatie 107, Lelystad.
NRLO, 1999. Beleidswetenschappen en ICT in de groene ruimte. Speerpunten voor actie. NRLO-rapport nr. 99/11, Den Haag.
Oosterveld, H.J., 1999. Problemen, beleid en scenario's. Rapport Landbouw-Economisch Instituut 4.99.15.
Pettit, C., and Pullar, D., 1999. An integrated planning tool based upon multiple criteria evaluation of spatial information. Computers, Environment and Urban Systems, 23: 339-357.
Ren, F., 1997. A training model for GIS application in land resource allocation. ISPRS Journal of Photogrammetry and Remote Sensing, 52: 261-265.
Steggink, F., 1999. Van waarde voor de landbouw. Thesis Land Use Planning, Land Use Planning Group, Wageningen University.
Steiner, F., McSherry, L., and Cohen, J., 2000. Land suitability analysis for the upper Gila River watershed. Landscape and Urban Planning 50, 4: 199-214.
Stoorvogel, J.J., Schipper, R.A., and Jansen, D.M., 1995. USTED: a methodology for a quantitative analysis of land use scenarios, Netherlands Journal of Agricultural Science, 43: 5-18.
Van den Bor, M., 1998. Locatiekeuze methodiek voor clusters met intensieve varkenshouderij-bedrijven en varkensvrije zones. Thesis Land Use Planning, Land Use Planning Group, Wageningen University.
Van der Knaap, W.G.M., and G.J. Carsjens, 1999. Dealing with topological relationships in land use allocation problems. In: A. Musy, L. Santos Pereira and M. Fritsch (Editors), Emerging Technologies for sustainable Land use and water management. 2nd Inter-Regional Conference on Environment-Water, Lausanne, Switzerland, 1999. Proceedings p. 12 (abstract) and full paper on CD-ROM. Presses polytechniques et universitaires romandes, Lausanne.
Van der Ploeg, J.D., 1995. The tragedy of spatial planning. In: J.F.T. Schoute, P.A. Finke, F.R. Veeneklaas and H.P. Wolfert (Editors), Scenario studies for the rural environment. Kluwer Academic Publishers, pp. 75-90.
Van der Valk, A., 2000. The Dutch planning experience. In: G.J. Carsjens (Editor), Fragmentation and Land Use Planning; analysis and beyond. Proceedings Third International Workshop on Sustainable Land Use Planning, International

Studygroup on Multiple Use of Land (ISOMUL) and Land Use Planning Group, Wageningen University, Wageningen, The Netherlands.

Verkaik, A.P., 1998. De Nederlandse agrosector: Kansen voor de toekomst. Inleiding Studiedag Belgische Boerenbond "Ontwikkelingen in de Landbouw en strategieën voor de komende jaren", Leuven 11 december 1998. NRLO-rapport nr. 98/41, Den Haag.

Voogd, H., 1983. Multicriteria evaluation for urban and regional planning. London, Pion Ltd.

4.4 Balancing economical growth and environmental protection: The case of livestock production in Wannian County, China

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Intensive livestock production in China is increasing fast, as a result of a growing population, rising incomes and urbanization. Local authorities are supporting the growth in livestock production for its importance to the local economy, giving priority to economic development at the expense of environmental protection. As a result, the state of the rural environment is deteriorating fast. Environmental policy and regulations to deal with this problem are weak or not enforced. This asks for a new approach to address the adverse environmental impacts of livestock production recognizing that expansion of livestock production is inevitable under pressure of rising demand. A research project of the FAO aims to identify policy options that enhance the production and consumption of livestock waste, by linking livestock production with cropping activities on a regional scale. This paper describes the results of a case study in China that focused at establishing an organic fertilizer factory. The objective of the paper is to examine the economical viability and the effectiveness of such a factory. The results show that a fertilizer plant establishes a yet undeveloped market for pig manure, but will not solve the whole problem. Complementary policy is needed to address the issue, and to have the maximum effects from establishment of a fertilizer plant. The complementary policy options include measures to improve manure management on farms, awareness raising and capacity building among farmers and the local government, and zoning and assessment of suitable locations for new livestock farms.

Keywords: Environmental policy; enforcement; livestock; manure; developing countries; area-based approach

1. Introduction

Livestock production is rapidly growing in the developing countries, as a result of a growing population, rising incomes and urbanization (Delgado et al. 2002; FAO 2003). China is among the countries with the fastest developing livestock sectors, dominant in pig and poultry. The rapid growth is causing a significant transformation of the structure of the livestock sector (De Haan et al. 1998). In particular, large-scale industrial livestock production is increasing rapidly, as this type of production reacts faster to growing demand. Large-scale industrial farms account for about 80 percent of the total growth in livestock production in China since 1990. In general, the growth in industrial production is supported by local governments for its importance to the employment of the local rural population, the export earnings, and its contribution to the local GDP growth. This even triggered preferential treatment of industrial production, e.g. by subsidized feed provision. The new industrial farms directly compete with traditional production systems, often supplanting them, causing a disconnection between livestock activities and cropping activities and an increasing imbalance between the level of nutrient inputs and absorptive capacity of the land. The environmental quality in rural areas has been deteriorating as a result of the expansion of intensive and unsustainable farm practices, this in turn adversely affecting human health and the productivity of natural resources (OECD 2005). The Chinese authorities recognize that

the potential for maintaining fast economic growth may be affected as the state of the environment continues to deteriorate.

Since the 1990s, China has developed a comprehensive regulatory and institutional framework for environmental management and protection. However, the environmental policies and regulations are generally weak or not effective, due to a lack of coherence among environmental regulations, vague statutory language of laws, conflicting interests at different administrative levels, and a lack of technical capacity and resources with environmental institutions (OECD 2005; Beyer 2006). Furthermore, local authorities have gained considerable administrative and fiscal autonomy, and have to cope more and more with hard budgetary restrictions (Beyer 2006). This generates pressure at the local level to compete in attracting and promoting economy-building enterprises, such as industrial livestock farms. Economic development is given priority at the expense of environmental protection (Beyer 2006, Prato, 2007). As a result, industrial livestock farms bear few of the environmental costs they impose and there are hardly any incentives to reduce them. Moreover, industrial livestock producers are often not fully aware of the environmental problems they cause and the options they have for prevention or mitigation. Given the expected rapid growth in industrial livestock production for the next decades in China (Delgado et al. 2002, FAO 2003), its related problems are likely to grow out of control without some significant changes in environmental policies and motivating local governments to enforce these policies.

In 1998, the Livestock Environment and Development (LEAD) Initiative, based at the Food and Agricultural Organization of the United Nations (FAO) initiated the Area-Wide Integration (AWI) research and development project with the aim of significantly reducing the environmental impact from livestock production (Gerber 2006). The logic underpinning AWI is that it seeks to integrate specialized livestock production with cropping activities on a regional scale. In this way, intensive livestock production should be linked to a land-based system rather than being an often profitable, but undesirable and polluting component of the urban industrial system. Within AWI, five pilot projects where designed in contrasting contexts to refine and test AWI. Two are located in China, one in Thailand, one in Vietnam, and one in Mexico. The projects aim at assessing the strengths and weaknesses of current production and the environmental and social impacts, analyzing present policy and institutional frameworks, and identifying policy options for AWI implementation, with special emphasis on environmental policy that enhances (rather than inhibits) the production and consumption of livestock waste.

This paper describes the results of the AWI-project in Wannian County, Jiangxi Province in China (FAO, 2005). The project addresses the adverse environmental impacts of the livestock (and in particular swine) sector in Wannian County, recognizing its ongoing expansion and its importance for the economical development of the area. In the early phase of the project, the local authorities expressed their wish to establish a fertilizer factory to process organic fertilizer in order to link the production to the consumption of waste. The objective of this paper is to examine the economical viability

and the effectiveness of such a factory, and the additional policy measures that are required to make it work.
Section 2 describes the livestock and waste production, and associated environmental problems in Wannian County, including the present policies and regulations. Section 3 focuses at the methods and approach that were used to assess the market, technical and policy options for a fertilizer factory. In Section 4 we present the results of these assessments, and discuss the initiatives that need to be taken in order to make the approach viable. Finally, we draw conclusions and come to some recommendations.

2. Livestock production in Wannian County

Wannian County, covering 1,140 km^2, is located in the Northeast of Jiangxi province (Figure 1) and one of the 592 national poverty-stricken counties in China. It consists of 16 townships with an average population density just over 300 persons per square kilometer, which is not very high compared to the most populous places in Eastern China. Most parts of the county are plain and low hills. Water resources are very abundant in the county, with an annual rainfall of 1800 mm and a thick network of rivers and streams running northwest to the Poyang Lake. Poyang Lake is the largest fresh water lake in China and includes an important migratory-bird reserve. The lake is connected with the Yangze River. Wannian County is situated up-stream to the lake and close to the reserve.

Figure 1 Wannian County, Jiangxi Province in China, and the location of large and medium size pig farms.

Agriculture is the key economic sector in the county (Ke 2003). More than 80% of the population lives in the rural area and depend on the own agricultural production for their food supply. The average farm size is very small, just 0.3 ha. Approximately 20% of the land in the county, or 20,700 ha, is used for crop production, of which 92% are paddy fields. Rice can be grown twice a year. A significant part of the early rice is used as pig fodder. The latter rice has a better quality. Fodder crops, especially corn, are produced in negligible amounts (Ke 2003).

The per capita GDP of the county in 2001 was US$ 360, less than one dollar a day, and well below the corresponding national average of US$ 920. The average farmers' income in Wannian County was US$ 240, of which 73% was derived from agricultural activities. Crop production covers 45% and livestock production 28%. The livestock-crop ratio of agricultural production is about 40:60, indicating the relative high importance of the livestock sector in Wannian County (the average national ratio in China is 30:70).

The meat production sector in Wannian County is dominated by pig production, covering 93% of the total meat production. In 2001 a total of 310,000 pigs were marketed from the county, of which 10% for export to Hong Kong and Macao, 25% for the local market, and 65% for other domestic markets, such as Shanghai. The other livestock production includes 5% poultry and 2% beef. The average pig density in Wannian County is 8.5 pigs per ha cultivated land. Commercial pig farms take care of 60% of the pig production. At present Wannian County holds 10 large, 5 medium, and approximately 50 small commercial pig farms, while 4 new large pig farms are being constructed. The large farms each produce 10,000 heads or more annually, the medium size farms over 1,000 heads, and the small farms between 500 and 1,000 pigs. The remaining 40% is produced in backyard operation of small household farms, usually with less than five pigs. At these farms pigs are a sideline activity to use by-products of crop production, and to meet the own meat consumption need. An important share of the commercial pig production is directly exported (live animals) to Hong Kong by special trains. Pig transport to domestic markets outside the county takes place by trucks. Most of the feed, such as corn, soybean cakes and bran, are imported from other counties, mainly by train from Northeast China. Wannian County has 13 feed mills, and each of the 10 large farms has its own fodder mixing facility. The large and medium size commercial pig farms are not equally spread over the county, but are located along the main roads and close to the rail infrastructure (see Figure 1). These locations allow the farms to minimize their transport costs, which is a critical issue as they heavily rely on external trade for both their inputs and outputs.

Waste management

Assuming that a hog yearly produces about 1,000 kg of fresh manure, which corresponds to 400 kg of dry manure, the total pig manure production in Wannian County was estimated to be over 80 million kg per year. Similarly, the total amount of liquid manure in Wannian County was estimated to exceed 120 million kg per year. In most large commercial pig farms the standard housing system facilitates waste removal

from the pig house in a slurry form. Manure (solid and liquid) is washed down with water 4 to 5 times a day, consuming up to 30 liters of water per pig per day. The wastewater is collected in gutters on the longitudinal side of each house and is led to the main gutter, which takes the wastewater to a sedimentation pond before being discharged into rivers or reservoirs. The nutrient discharge through the rivers directly affects the water quality in Poyang Lake and its nature reserve area. Some solid manure is collected after sedimentation and used as organic fertilizer, e.g. by fruit farmers, while the remaining solids are being disposed. Transportation costs show to be a main problem, particularly for liquid manure. Most crop farmers also prefer chemical fertilizer to organic fertilizer, despite efforts of the government to encourage the use of organic fertilizers. Chemical fertilizers are found easier to dose and cleaner to handle. Furthermore, liquid manure is very seldom used as a fertilizer source for rice as it is believed to negatively affect yield and quality. Currently there are no rules on the application of fertilizers on crops (organic and chemical) which often results in over-fertilization.

Present policies and regulations

The Chinese central government only recently initiated new policy measures to tackle the environmental impacts of livestock production. At present a variety of measures at national, provincial and local level are being introduced, including laws and regulation, standards, zoning, taxes, fees and subsidies. The most relevant measures for this research involve:

1. The location of farms: A recent decree of the State Council protects arable land, as a result of growing concern over the declining grain production (Heilig 1999). The construction of livestock farms is not allowed in these areas. Also, zoning policies are being introduced to prevent the construction of pig farms in the vicinity of residential areas, or nearby other commercial pig farms (Ke 2003).
2. Waste discharge standards: In 2002 the State Environmental Protection Administration (SEPA) and the State Administration for Quality Monitoring jointly issued a decree with standards for waste discharge from livestock production. Two classes of livestock farms are distinguished in terms of numbers of animals present at a single farm and in a concentrated production area. Each class has its own specific standards (Ke 2003). Despite this decree, in Wannian County no measures have been taken yet to enforce these standards.
3. Economic incentives on waste discharge: Since July 2003 all enterprises in China are obliged to pay waste disposal fee (SEPA 2003). This includes solid as well as liquid manure disposal, air pollution and noise hindering. Livestock farms with an inventory over 500 pigs are charged with 0.08 United States Dollar (USD) per pig per month. If the waste disposal at a farm exceeds the national standards, the fees are doubled. For large commercial pig farms these fees can take up to 10 to 25% of the total farm profit. However, this measure is not implemented yet in Wannian County.

At present, the traditional regulatory approach to prevent environmental pollution is not very successful in Wannian County, due to the low enforcement capacity and the importance of pig production to the growth of local economy. The national control standard regulations are not implemented by the local authorities. These standards should be adapted in order to meet the specific local conditions and to promote the enforcement of the control standards.

Instead, Wannian County has a long history of promoting pig production. Livestock production is important in the county for its employment to the local rural population, its export to Hong Kong and other coastal regions, and its contribution to the growth in GDP of the county. In the past, various measures promoting production were introduced, including subsidized feed provision. The reformation towards a market economy terminated most of these instruments, with a few exceptions. In Wannian County, large pig farms with investments over 600,000 USD get their land for preferential prices on a case-by-case basis. A policy measure of Jiangxi province excludes large agricultural undertakings, including pig farms, with an annual turnover of 3.6 million USD or more from paying corporate income tax, which is as high as 33%. Preferential or differential measures are also made in other areas. For example, there is strict control on slaughterhouses in the country in order to maintain high hygiene and sanitary standards. Only state-designated facilities are allowed to carry out slaughtering activities. However, the provincial government also allows large pig farms with a capacity over 10,000 heads to establish their own slaughtering facilities. Another relevant policy measure is the exemption of value-added tax for fertilizer plants which favors the use of chemical fertilizers by lowering their price. The same policy applies to the production of an organic fertilizer. It can therefore also be seen as a favorable factor for fertilizer production using pig manure as raw material.

The idea of designing and implementing a fertilizer plant to process organic fertilizer from the solid manure of the large industrial farms was suggested during several rounds of political and technical discussions with governmental officials, stakeholders and local experts (FAO 2005). Given the local context, a fertilizer plant is potentially attractive for both the pig producers and the crop farmers. The numerous small-scale and non-commercial farms operating in Wannian County are the main potential market for organic fertilizer, especially for the production of traditional quality rice (Wannian Royal Rice). The decision was also driven by some experiences of the local government with an experimental fertilizer plant in the past. However, it was also recognized that a fertilizer plant will only solve a part of the problem and additional measures should be taken. Since traditional policy measures showed not very effective, the research especially focused at three additional policy instruments: Awareness raising and capacity building among livestock and crop farmers in order to improve nutrient management practices, balancing the production and need of nutrients (land-livestock balance), and spatial analysis and planning including the zoning of livestock production. The next section describes the approach to assess the market, technical and policy options for a fertilizer plant, as an instrument to support a more sustainable future development of livestock production in the county.

3. Method and approach

In order to propose a comprehensive set of measures addressing the issue of pig waste management in Wannian County, three complementary analyses were carried out, including a market analysis to assess the economic viability of a fertilizer plant, an analysis of the production line and management design, and an analysis of additional environmental policy options.

3.1. Market analysis

The market analysis aims to gauge, respectively, the demand (price) for organic fertilizer and the supply (price) of raw materials to the fertilizer plant. The market analysis has been conducted using questionnaire surveys (e.g. Creswell 2003). For the analysis of the potential demand for organic fertilizer a representative cross-section of 176 crop farms were surveyed. Farms were randomly selected from the 11 townships that comprise Wannian County. In each township 16 crop farms were surveyed. Of the 176 farms surveyed 34 are engaged in fruit production, 12 with cash crops such as cotton, sugarcane and oilseeds, 41 with vegetable production and 89 with rice and corn production. For analyzing the potential supply of raw material a total of 20 pig farms, including all medium-size and large commercial pig farms, were surveyed. Of the 20 farms, all established between 1987 and 2001, 3 are classified as state-owned enterprises, 2 are joint ventures with foreign partners and 15 are private enterprises. There is considerable variability in size and livestock inventory, classified as breeding and growing-finishing. In the case of breeding pigs, 9 farms have less than 100 pigs, 6 have 101-1000 pigs and 5 have 1001-2500 pigs. In the case of growing-finishing pigs, 9 farms have 101-1000 pigs and 11 more than 2500. The questions that were used to gauge the demand and supply, as well as the results are presented in the results section.

3.2. Production line and environmental management analysis

Animal manure is a useful resource of nutrients, but it is not of the same homogenous content as chemical fertilizer. The phosphorous content is usually high, which requires for instance, chemical nitrogen to be added (e.g. Eghball and Power 1999). A fertilizer plant should produce different types of organic-inorganic compound fertilizer (OCF), depending on the specific crop-requirements. The questionnaire survey of the crop farms was used to identify the specific types of OCF to be produced. In order to test these types of fertilizer, and to provide accurate advice to crop farmers, pot and field experiments were set up at China Agricultural University in Beijing to analyze the response of several crops to the application of OCF. Also, the application of liquid manure for rice production was tested. Based on these results it was decided that initially two types of OCF should be produced, for grain and commercial crops (fruit and vegetables) (FAO 2005). The production process was designed accordingly. The construction and management of the fertilizer plant was to be set up as a public-private partnership. Therefore, a selection process to acquire a private partner was started.

3.3. Additional policy options

Environmental policies to control pollution by agricultural production generally include a variety of economic instruments, such as taxes, subsidies and user charges (e.g. Horan and Shortle 2001). These instruments are also incorporated in the environmental policies that are being developed by the Chinese national government (see previous section). However, interviews with local officials of Wannian County revealed that the implementation and enforcement of these policies and regulations is not a priority matter (FAO 2005). The local administration favors economic development rather than environmental protection, and also lacks sufficient financial means to promote solutions to address the environmental problems, e.g. subsidies for waste treatment. This supports the more general notion of a lack of effective environmental policy in China (OECD 2005; Beyer 2006). The Wannian project focused at three additional policy approaches in order to meet this problem: (1) Awareness raising and capacity building, (2) balancing the production and need of nutrients (land-livestock balance) and (3) spatial analysis and planning, including the zoning of livestock production.

Awareness raising and capacity building

Reducing the environmental impacts related to the excessive use of nutrients requires that farmers are aware of the environmental problems, that they find these problems relevant and are willing to change their agricultural practices in order to comply with the regulations. Raising awareness is an important pre-condition to develop codes of good agricultural practice among farmers. These codes of good agricultural practice should include, for example, the use of fertilizer plans, general limitations of nutrient application per crop, appropriate nutrient spreading calendars and sufficient manure storage (EC and WHO 2002). Therefore, the spreading of information on the environmental problems and consequences, as well as technical assistance in changing waste treatment and nutrient management are necessary. In the project three extension workshops were set up for local farmers, extensional personnel and officials of related governmental departments in Wannian County to provide training in animal waste management, environmental protection and optimal crop nutrient application.

Land-livestock balance

A nutrient balance represents the total uptake of nutrients by crops compared to the total input of nutrients. The input depends on the applied amount of chemical fertilizer and the excretion of manure by livestock. Balancing the uptake of nutrients by crops and the application of fertilizer and manure is a relevant environmental policy objective, as it ensures that the risk of nitrate leaching and phosphor accumulation is kept at an acceptable level and prevents the related environmental problems. In the AWI-projects of the FAO, a method has been developed to calculate a nutrient balance from generally available statistical data, including the herd sizes, chemical fertilizer use and crop production (Gerber et al. 2005). The excretion of nutrients per animal per year is

estimated using indicative, average excretion values that are representative for China. The nutrient balance is calculated by:

$$\frac{Nutrients\,applied}{Crop\,uptake\,of\;nutrients} \times 100\%$$

The statistical data also allow the calculation of a land-livestock balance, where the livestock density per hectare crop land is derived. A land-livestock balance is interesting, since it places livestock production in an area-wide perspective. If the livestock farms are not equally distributed, then a need will arise for the transportation of manure from areas with excessive production that in turn might lead to a difficult and costly operation (Kjaer, 2001).

Spatial analysis and planning

The spatial distribution of livestock production is also interesting for other reasons. A fast majority of the new industrial production farms in China are concentrated around major urban centers, supported by the Chinese planning tradition to meet the urban demand and to develop commodity based zones for livestock production in order to strengthen technological services and marketing (Kjaer 2001). This concentration of livestock production is problematic for a number of reasons, including environmental, social, and public health concerns (De Haan et al. 2001, Welsh et al. 2003, Gerber et al. 2005, EC and WHO 2002). Spatial analysis and planning are relevant instruments to support spatial policies and development of future livestock production, e.g. by identifying sensitive areas and preventing negative impacts by zoning and buffering. Gerber (2006) observed that an improved spatial distribution of farms substantially reduces the costs of compliance with pollution control measures.

In the AWI-projects a spatial decision support method has been developed to support the future allocation of livestock production. The outline of the method is shown in Figure 2. The method includes workshops for identifying objectives, the related criteria and their relative importance (weights). A geographical information system (GIS) is used for storing the geographical data and calculating distances with buffering and cost weighted functions with in ArcGis software. Suitability maps for livestock production are derived using multiple criteria techniques (weighted linear combination).

From technical perspective the method is transparent and simple, and starts with consulting the relevant stakeholders in workshops. These characteristics are important, since several studies show the lack of successful implementation of spatial decision support systems due to, for example, lack of transparency and stakeholder participation, inflexibility of the system, complexness of the user-interface and inability to cope with the diversity of knowledge and skills of participants (Uran & Janssen 2003, Geertman & Stillwell 2004, Kaliszewski 2004).

The techniques that are used in this method have shown their usefulness in a variety of decision areas. The use of GIS with decision problems related to environmental planning and allocation issues is becoming a common strategy (Geneletti 2004). There are

many applications of GIS-based land-use suitability analysis (Malczewski 2004), participatory approaches using GIS (Jankowski & Nyerges 2001, Geertman 2002, Voss et al. 2004) and the use of multiple criteria methods in environmental planning (Geneletti 2004, Lahdelma et al. 2000, Kaliszewski 2004). Some other examples apply to livestock development. These include the identification of suitable sites for animal waste application (Basnet et al. 2001, Basnet et al. 2002), prioritizing areas for livestock disease control (Robinson 2000) and identifying livestock development areas (Carsjens & Van der Knaap 2002).

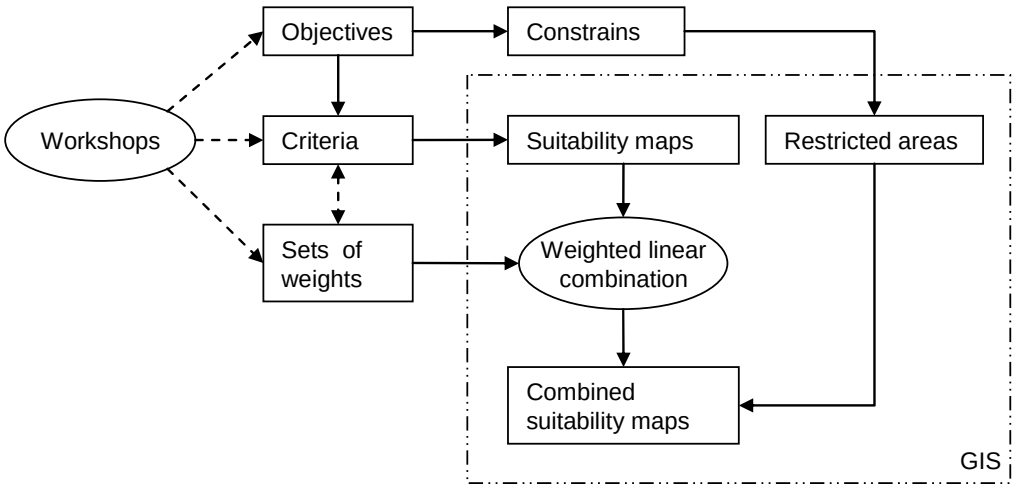

Figure 2 Outline of the spatial decision support method.

4. Results

This section describes the results of the market analysis, the analysis of the production line and management design, and the spatial analysis of suitable locations for a fertilizer plant. Based on these analyses the impact of a fertilizer plant on the pig waste environmental issue is discussed together with a mid-term perspective.

4.1. Market analysis

The crop farmer questionnaire aims to gauge the demand for organic-inorganic compound fertilizer (OCF). For this purpose 176 farmers responding to the questionnaire survey were presented with a hypothetical scenario and asked corresponding questions. The two most important questions are presented below.

To begin with, farmers were told that the project intends to use pig manure and other materials to produce OCF. The production of this fertilizer will not only reduce the environmental pollution caused by commercial pig farms, but will also provide high value fertilizers to local farmers. The OCF will have multiple benefits with its potential to improve soil quality, provide balanced nutrient for crops and improve crop yield

and quality. Farmers were asked: "Would you be possibly interested in purchasing this kind of fertilizer?" In response to this question, 2 farmers answered "no", 18 "don't know" and the remaining 156 (89%) of the 176 farmers surveyed answered "yes". In the case of the "no" answers all were rice farmers and in the case of the "don't know" answers they were either rice farmer or cash crop farmers. Regardless this positive outcome the willingness to purchase the OCF will, inevitably, be highly dependent upon both price and quality.

Then, farmers were told that the application amount of this kind of fertilizer for rice would be about 100 kg per mu (15 mu = 1 ha). Farmers were asked: "What would be the maximum price you would be willing to pay?" The results of the response to this second question are presented in Table 1.

Table 1 Maximum price farmers are willing to pay for OCF.

Price (per ton)	60 – 72 (USD)	73 – 96 (USD)	96 – 120 (USD)	121 – 145 (USD)
Number of Farms	1	27	116	12
% of total	1	17	74	8

The majority of farmers (74%) are prepared to pay a maximum amount ranging between USD 96 and 120 per ton of OCF. Within this range, of the 116 farms, 74 farms (64%) indicate they are prepared to pay a maximum amount of USD 96 per ton of OCF. In 2004, the year after the survey was conducted, the prizes of chemical fertilizer have substantially increased, reacting to a central government lead rise in grain prices. This new market situation will make the OCF even more competitive.

The pig producer questionnaire aims to gauge the supply of raw materials to the fertilizer plant. For this purpose, pig producers responding to the questionnaire survey were asked some background questions about their current waste management practices and then presented with a hypothetical scenario and asked corresponding questions about their future waste management practices. In the case of current waste management practices, of the 20 farms surveyed 16 farms (80%) separate the liquid and solid manure before or after it leaves the farm pens. Where the waste is separated before exiting the pens the usual technique is to dry and wash the waste and where waste is separated after exiting the pens a three-level depositing technique is employed. The waste, whether or not it has been separated, is then deposited in a variety of repositories, including surrounding ditches, rivers, on agricultural land and in fishponds. In the case of 15 farms (75%) varying quantities of solid manure are sold for crop and fish production in the vicinity of the pig farm. This contributes, in addition to revenues earned from the sale of piglets and weanlings and finished growing pigs, revenues of between USD 60 and USD 1800 per ton per year. The respondents were asked two main questions: "What are the costs of separation of solid and liquid manure?" and "At what price are you willing to sell solid manure?" The results of the responses to these two questions are presented in Table 2.

Table 2 Cost of separation of waste and willingness to sell manure.

Cost of Separation (USD/ton)		Willingness to Sell (USD/ton)	
Range	Average	Range	Average
1 – 2	1.5	22 – 27	23

The ratio of cost of separation to willingness to sell is, based on the average figures, approximately 1:15. While the figures range between USD 1–2 per ton and USD 22–27 per ton for the cost of separation and willingness to sell respectively, the averages are at the lower end of the range indicating that the majority of pig producers favor a lower USD/ton.

4.2. Production line and environmental management analysis

Based on the market questionnaires it was concluded that the fertilizer plant could, viably, produce two different types of organic-inorganic compound fertilizer (OCF), one for grain crops and the other one for commercial crops (fruit and vegetable) by using half compost from pig manure and chemical fertilizer as raw materials. The size of the fertilizer plant was designed at 5,000 ton per year, requiring 2,000 ton of half composted manure (moisture content of 10%) and 3,000 ton of chemical fertilizer. The total area of the fertilizer plant, with a production capacity of 5,000 tons per year, should be approximately 10,000 m^2, including a first and second composting area, operating and storage rooms, an office building, and laboratory. The total investment costs are 265,000 USD. The selected private investor in the fertilizer plant, the Wannian County Quarry Company supports 60%, the FAO 33%, and the Wannian County Agricultural Bureau 7% of the total investments costs. The Quarry Company and the Agricultural Bureau will be 60% and 40% owner of the plant respectively, and established a new company that will manage the fertilizer plant.

4.3. Additional policy options

Awareness raising and capacity building

Three technical training courses were organized in 2003 and 2004 to raise awareness and to promote good practices among livestock producers, crop farmers, extension personnel and governmental officials. The target groups and training subjects are listed in Table 3.

The training courses were well advertised and attracted a large audience. In fact, the number of participants had to be restricted due to the maximum number of available seats. In general, the feedback of participants was very positive. Follow-up visits to several crop farms in the months subsequent to the courses showed a general shift in nutrient management practices (although not specifically measured) including better tailored fertilizer plans and an increasing use of OCF (FAO 2005).

Table 3 Target groups and subjects of the technical training courses.

	Target group	Training subjects
Course I 8-9 Jan 2003	120 Participants, including: ▪ Officials of related governmental departments ▪ Owners, managers and technicians of large and medium-size pig farms	▪ Environmental problems related to livestock production ▪ Livestock policy and economy ▪ Technical options for waste management in livestock farms
Course II 27-29 Sep 2003	160 Crop farmers from Wannian County	▪ Supply and demand of fertilizer and fertilizer techniques ▪ Characteristics and application of OCF ▪ Production techniques and management of organic fertilizer ▪ Comparison of organic and chemical fertilizer
Course III 27-28 Apr 2004	200 Participants, including: ▪ 160 crop farmers (10 from each of the 16 townships) ▪ Extension personnel (2 from each township and 8 from the Wannian Agricultural Extension Station)	▪ Crop nutrient requirements, fertilizer characteristics and fertilization plans ▪ Use of OCF on main crops, including paddy fields, vegetables and fruit trees ▪ Use of OCF to improve soil quality ▪ Crop response to the application of OCF and animal manure

Land-livestock balance

The resulting nutrient balance for the county is shown in Table 4. The nutrient balance for manure and chemical fertilizer shows that the input of N and P exceeds the crop uptake. The total surplus of N and P in the county is 220,000 and 35,000 kg respectively. The balance without chemical fertilizer shows that the nutrients in manure cover less than one fifth of the crop uptake of N and K, but two third of the P uptake. This implies that in the future, as the pig population grows, P will be the limiting nutrient for further growth of the livestock sector in Wannian County. In this situation, the export and application of excessive nutrients outside the county might be an option, especially since OCF requires much less transport costs compared to fresh manure as it is both dryer and packet. The resulting nutrient balance was used as input for the spatial analysis and planning.

Table 4 Nutrient balance with and without chemical fertilizer (total available nutrients as a percentage of the crop uptake of nutrients).

Township	Manure and chemical fertilizer			Manure		
	N	P	K	N	P	K
Chen Yun	166%	174%	49%	18%	79%	15%
Shi Zhen	213%	179%	67%	16%	66%	15%
Qing Yun	105%	95%	45%	13%	54%	13%
Zi Bu	49%	71%	38%	12%	48%	15%
Da Yuan	130%	115%	71%	18%	72%	15%
Pei Mei	107%	100%	33%	16%	65%	15%
Hu Yun	93%	118%	50%	18%	75%	19%
Qi Bu	78%	97%	42%	18%	76%	16%
Da Huang	122%	113%	37%	17%	68%	15%
Wang Jia	91%	77%	27%	16%	67%	15%
Zhu Shan	155%	80%	59%	13%	53%	12%
Shang Fang	116%	108%	40%	22%	86%	18%
Shu Qiao	68%	73%	23%	10%	40%	9%
Nan Xi	94%	120%	37%	22%	90%	19%
Fu Lin	148%	138%	51%	22%	85%	18%
Zhu Tian	100%	134%	32%	24%	97%	20%
Total Wannian County	105%	104%	42%	17%	68%	15%

Spatial analysis and planning

Two workshops with local and provincial participants took place in Wannian County in October 2002 and November 2003, including representatives of the local government and technical experts on manure management, economics, livestock production and spatial planning. The objectives to be included in the location analysis were derived from discussions among the participants. The participants not only set up a list of objectives to identify suitable areas for future livestock farms, but also a set to identify suitable locations to establish the fertilizer plant. The criteria and weights were worked out in technical sessions with experts of the Agricultural Technical Extension Station, the Agricultural Energy Station, the Wannian Agricultural Bureau, and Jiangxi Agricultural University. The resulting sets of criteria and weights for identifying suitable locations for the fertilizer plant are shown in Table 5. Three different sets of weights were constructed, from farm economical perspective, environmental perspective and the combination of both (a neutral scenario). These three sets of weights are meant to frame the range of likely perspectives. The criteria without a weight represent the restrictive areas (by law and regulations) that were ranked unsuitable and consequently left outside the suitability evaluation. A resulting final suitability map showing the suitable locations to establish the fertilizer plant for the neutral scenario is shown in Figure 3.

Table 5 Criteria and suitability classes used to identify suitable areas.

	unit	restricted	suitability low (0) ◄►high (100)		weights envir.	neutral	econ.
Distance to inhabited area	m	< 150		> 300			
Current land use	-	arable land					
Slope	%		>20	0	0.40	0.25	0.10
Distance to surface water	m	< 200	max[1]	200-1500	0.40	0.25	0.10
Cost-weighted distance to townships	m		max[2]	0	0.10	0.25	0.40
Cost-weighted distance to large farms	m		max[2]	0	0.10	0.25	0.40

[1] max represents the maximum distance from any point in the county to surface water
[2] max represents the maximum cost-weighted distance from any point in the county

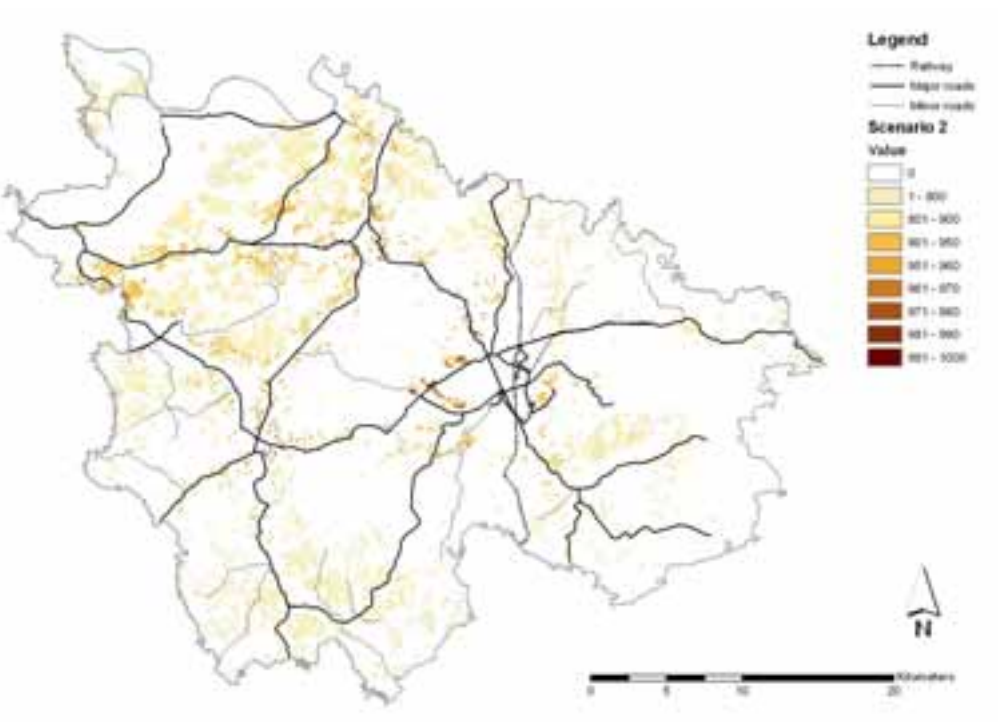

Figure 3 Resulting suitability map showing the suitable locations to establish the fertilizer plant for the neutral scenario.

In the resulting maps of all scenarios, the largest areas of very suitable locations can be found in the northwest part of Wannian County. However, in scenario 3 the total area of very suitable locations is much smaller compared to the other two scenarios. Especially potential locations that are located further away from the main road infrastructure get a worse grading in this scenario, which is consistent with the importance

given to this criterion in scenario 3. The results were further explored by a robustness analysis in order to derive the locations that were classified very suitable in more than one scenario. Based on the resulting maps, technical experts of the Wannian Agricultural Bureau held an additional field survey in order to pre-select a location for the fertilizer plant. Potential suitable locations close to the county capital were especially preferred by the experts and the local government. This area is shown in Figure 4.

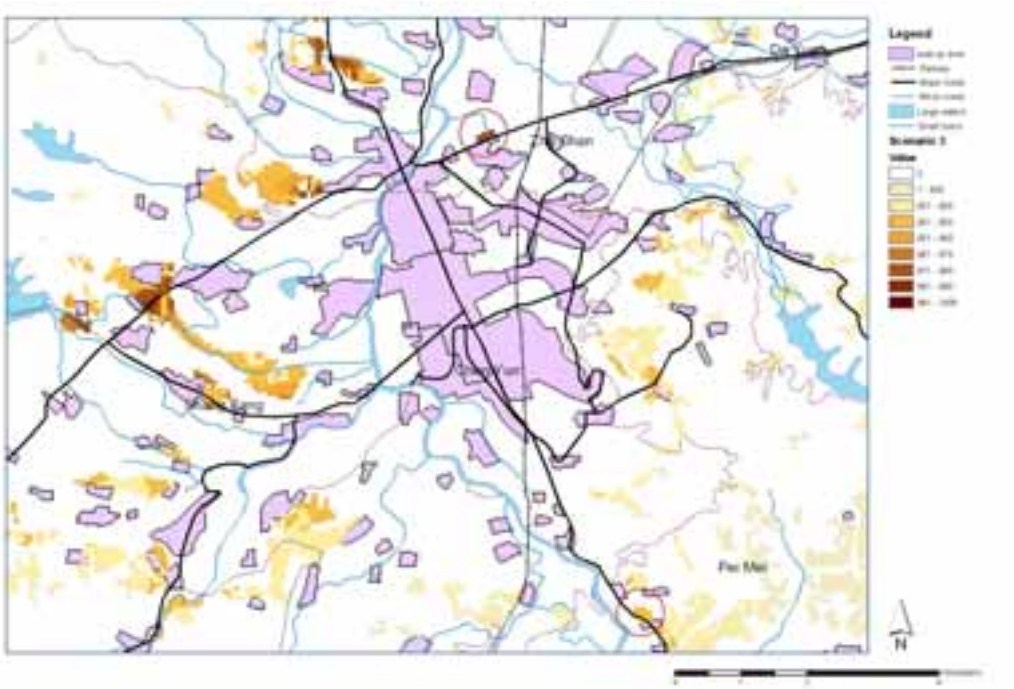

Figure 4 A detail of the suitability map (scenario 3) for the area nearby the county capital. Encircled are the two selected locations for the fertilizer plant.

Two potential locations in Figure 4 are of special interest, and marked with a red circle. The location located north of the county capital city was at first preferred by the county government, because it is the location of an experimental fertilizer plant that has been closed down. The robustness analysis showed that this location has a high suitability score in all three scenarios, ranging between 972 and 993 out of a maximum of 1000. Although this location is very suitable, the location was rejected later on, because new urban developments are expected to take place nearby this area. Therefore, the local authorities finally selected the other red marked area, located south of the county capital city. This location was chosen because the additional field survey showed that the area could easily be obtained and provided with the required electricity supply. Such local characteristics are generally too detailed to be included in the analysis, and demonstrate the indicative nature of the results of the analysis. However, the maps did successfully support the selection process by effectively nar-

rowing it down to the most suitable areas. With this, the local government experienced the potential strength of the spatial decision support tool to support the spatial allocation of future livestock farms. The suitability maps for livestock farming should allow a proper zoning of new farms and protect environmentally sensitive areas. As the county government lacks the technical capacity and knowledge to drive the tool, an agreement was made with Jiangxi Agricultural University to provide the required technical support. This university also provided the required geo-data for the AWI-project.

4.3. Impact on the pig waste environmental issue and mid-term perspective

The production line and environmental management analysis shows that the fertilizer plant will process 2,000 tons of half composted manure. This amount corresponds with the manure produced by 5,000 to 7,000 pigs, or approximately 6% of the manure produced at the commercial pig farms in Wannian County. Consequently, the OCF plant will have a relative small impact on the pig waste environmental issue in the county. The demonstration effect of the fertilizer plant is therefore most important. The direct positive impact of establishing the fertilizer plant will be a reduction of waste disposal into the environment where raw materials are taken form the pig farms. The pig farms will have an incentive to separate the solid manure from the liquid manure. After separating, the polluting contents in the liquid manure will be substantially reduced, as will the amount of wastewater. How this positive impact will be sustained and extended to other pig farms depends on a number of factors:

1. The technical and economic performance of the fertilizer plant is essential. Based on the production and marketing costs it is estimated that the plant will generate a profit of 75,000 USD per year. If the fertilizer plant is run well and continues to make profit, it will continue to purchase pig manure and the pig farms will continue the practice of separating. Ideally, if the fertilizer plant is able to increase gradually the purchasing price of fresh manure, cooperation between the fertilizer plant and pig farms will become more beneficial and sustainable.
2. For the fertilizer plant, both the internal management and marketing will be crucial. The focus should be on quality control. As long as the quality and effectiveness of the OCF remains there will remain an actual and potential market for its products.
3. If the fertilizer plant can maintain sound practices for at least a few years there will be some possibility for up-scaling. Up-scaling can be achieved through the expansion of production capacity, either within the same plant or by setting up a second plant elsewhere in the county. In this regard, new investments can be expected from several different sources. Some large pig farms may be encouraged by the success of the pilot plant and make investments to set up their own fertilizer plant on their pig farm. Or, private companies of the fertilizer industry may also act by setting up joint ventures or single funded plants in the county.

If the above up-scaling process does happen, the capacity of the fertilizer market within the county to absorb production will most likely be exceeded. New markets in the neighboring counties or provinces will have to be developed. In fact, even in the initial phase, marketing to the neighboring regions should not be excluded.

5. Discussion and conclusions

The overall purpose of the project was to address the adverse environmental impacts of the livestock sector recognizing that expansion of livestock production is inevitable under pressure of rising demand. The establishment of one or more fertilizer plants in Wannian County is considered innovative because it establishes a yet undeveloped market in which pig producers sell the raw materials to the plant(s), these are in turn processed, and farmers buy organic-inorganic compound fertilizer (OCF). The advantages of dealing with pig manure and environmental problems in this way are numerous. It responds, for instance, to the general call for economic development (e.g. creating direct and indirect employment opportunities) on the one hand and the urgent need for environmental protection on the other. Facilitating the establishment of manure markets also provides for financial incentives to pig producers to collect and sell solid manure, thus providing organic fertilizer to crop producers at a low cost. It is anticipated that the private-public management will ensure the long term viability of the plant.

However, the establishment of a fertilizer plant will not solve the whole environmental problem. Complementary policy is needed to address the issue, and to have the maximum effects from establishment of the fertilizer plant. Measures to improve manure management on farms are needed. Different technical solutions are to be introduced by the farmers, but the problems caused by solid and liquid manure must be dealt with separately. Separating solid and liquid manure should be encouraged or requested. This will reduce the amount of liquid manure. Two possible ways to solve the liquid waste issue are to build three stage pond systems to reduce the concentration of nutrients and organic matter in the liquid waste, or to discharge it directly into fish ponds. After separation, solid waste can be sold to the fertilizer plant or nearby crop farmers. A contractual relationship between livestock and crop farmers might be established to control the nutrient flows, although this does guarantee safe nutrient management. Experiences with these contracts in the Netherlands also showed the necessity of standards for manure application (Ondersteijn et al. 2002). In order to be successful, manure management solutions need to be economically feasible and acceptable. Generally, technologies reducing livestock waste pollution will generate a net cost to the farmer. Policies are therefore needed to ensure the shift to better practices. Monitoring and enforcement of the waste discharge standards and fines to non-compliance should be applied to encourage cooperation between farms and to improve the waste management. The Wannian project demonstrated that awareness raising and capacity building among farmers and the local government is a prerequisite to promote agricultural good practices and elicit the necessity to comply with the regulations. The local

government intends to develop its capacity by contracting experts for ad hoc technical support and sending local administration technicians on study tours and training.
The spatial decision support method provides the local government with an instrument that can substantially improve the spatial allocation of new pig farms, thus preventing environmental impacts in the future. The use of GIS offers detailed and clear maps to the decision makers, and the Wannian county governmental officials have already expressed their willingness to make use of these maps. However, effective implementation requires regulations or official decisions by the county government explicitly stating that only areas indicated in the maps as environmentally acceptable are allowed for setting up new livestock farms. In doing so, the maps will become an authoritative tool for enforcing a proper spatial allocation of new livestock farms.
Continuous efforts to develop and strengthen professional capacity are and will be a key factor of success in addressing the livestock related environmental issue. Indeed, if awareness is raised and financial means made available by local government and farmers, it is the expertise to drive action that remains the weak point.

References

Basnet, B.B., A.A. Apan & S. R. Raine, 2001. Selecting suitable sites for animal waste application using a raster GIS. Environmental management 28, 519–531.

Basnet, B.B., A.A. Apan & S. R. Raine, 2002. Geographical information system based manure application plan. Journal of environmental management 64, 99-113.

Beyer, S., 2006. Environmental law and policy in the People's Republic of China. Chinese journal of international law 5, 185-211.

Carsjens, G.J., and W.G.M. van der Knaap, 2002. Strategic land use allocation: dealing with spatial relationships and fragmentation of agriculture. Landscape and urban planning 58, 171-179.

Creswell, J.W., 2003. Research design: Qualitative, quantitative and mixed approaches. Sage publications, Thousand Oaks, California, 2nd ed.

De Haan, C., H. Steinfeld & H. Blackburn, 1998. Livestock and the environment: finding a balance, European Commission Directorate-General for Development. Food and Agricultural Organization of the United Nations, Rome.

De Haan, C., T.W. Schillhorn van Veen, B. Brandenburg, J. Gauthier, F. Le Gall, R. Mearns & M. Siméon, 2001. Livestock development, implications for rural poverty, the environment, and global food security. Directions in development. The world bank, Washington D.C., USA.

Delgado, C., M. Rosegrant & S. Meijer, 2002. Livestock to 2020: The revolution continues. World Brahman Congress, Rockhampton.

Delgado, M.G. & J.B. Sendra, 2004. Sensitivity analysis in multicriteria spatial decision-making: a review. Human and ecological risk assessment 10: 1173-1187.

EC and WHO, 2002. Eutrophication and health. Local authorities, health and environment briefing pamphlet series 40. World Health Organization Regional office for Europe and European Commission, Luxembourg.

Eghball, B. & J.F. Power, 1999. Phosphorus- and nitrogen-based manure and compost applications: Corn production and soil phosphorus. Soil Science Society of America Journal 63: 895-901.

FAO, 2003. World agriculture: towards 2015/2030. Food and Agricultural Organization of the United Nations, Rome.

FAO, 2005. Integrated waste management in Wannian County, Jiangxi Province, People's Republic of China, TCP/CPR/0170(A), Final Report. Food and Agricultural Organization of the United Nations, Livestock, Environment and Development Initiative (LEAD), Animal Production and Health Division.

Geertman, S., 2002. Participatory planning and GIS: a PSS to bridge the gap. Environment and planning B: planning and design 29, 21-35.

Geertman, S. & J. Stillwell, 2004. Planning support systems: an inventory of current practice. Computers, environment and urban systems 28, 191-310.

Geneletti, D., 2004. A GIS-based decision support system to identify nature conservation priorities in an alpine valley. Land use policy 21: 149-160.

Gerber, 2006. Putting pigs in their place. Environmental policies for intensive livestock production in rapidly growing economies, with reference to pig farming in central Thailand. Doctoral thesis ETH Zurich, Switzerland.

Gerber, P., P. Chilonda, G. Franceschini & H. Menzi, 2005. Geographical determinants and environmental implications of livestock production intensification in Asia. Bioresource technology 96, 263-276.

Heilig, G.K., 1999. Can China feed itself? A system for evaluating policy options. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

Horan, R.D. and J.S. Shortle, 2001. Environmental instruments for agriculture. In: J.S. Shortle and D.G. Abler (Eds), Environmental policies for agricultural pollution control, Chapter 2, CAB International.

Jankowski, P. & T. Nyerges, 2001. GIS-supported collaborative decision making: results of an experiment. Annals of the association of american geographers 91, 48-70.

Kaliszewski, I., 2004. Out of the mist – towards decision-maker-friendly multiple criteria decision making support. European journal of operational research 158, 293-307.

Ke, B., 2003. Baseline information of livestock sector and related policy in Wannian County, Jiangxi Province of China. TCP/CPR/0170(A) project report, FAO.

Kjaer, S.S., 2001. Proposal for environmental policy options for intensive livestock farms: The case of Jiangsu Province, People's Republic of China. FAO.

Lahdelma, R., P. Salminen & J. Hokkanen, 2000. Using multicriteria methods in environmental planning and management. Environmental management 26, 595-605.

Malczewski, J., 2004. GIS-based land-use suitability analysis: a critical overview. Progress in planning 62, 3-65.

OECD, 2005. Governance in China: China in the Global Economy. OECD Publishing.

Ondersteijn, C.J.M., A.C.G. Beldman, C.H.G. Daatselaar, G.W.J. Giesen & R.B.M. Huirne, 2002. The Dutch Mineral Accounting System and the European Nitrate

Directive: implications for N and P management and farm performance. Agriculture, ecosystems and environment 92, 283-296.
Prato, T. Evaluating land use plans under uncertainty. Land Use Policy 24, 165-174.
Robinson, T., 2000. Spatial statistics and geographical information systems in epidemiology and public health. Advances in parasitology 47, 81-128.
Qureshi, M.E., S.R. Harrison & M.K. Wegener, 1999. Validation of multicriteria analysis models. Agricultural Systems 62, 105-116.
SEPA, 2003. Amendment of measures on administrative penalty for environmental protection. Decree issued by the State Environmental Protection Administration of China, 5 November 2003.
Triantaphyllou, E., 2000. Multi-criteria decision making methods: a comparative study. Kluwer Academic, Dordrecht.
Uran, O. & R. Janssen, 2003. Why are spatial decision support systems not used? Some experiences from the Netherlands. Computers, environment and urban systems 1, 25-43.
Voogd, H., 1983. Multicriteria evaluation for urban and regional planning. Pion Limited, London, UK.
Voss, A., I. Denisovich, P. Gatalsky, K. Gavouchidis, A. Klotz, S. Roeder & H. Voss, 2004. Evolution of a participatory GIS. Computers, environment and urban systems 28, 635–651.
Welsh, R., B. Hubbell & C.L. Carpentier, 2003. Agro-food system restructuring and the geographic concentration of US swine production. Environment and planning A 25, 215-229.

4.5 Decision support for spatially targeted livestock policies: Diverse examples from Uganda and Thailand.

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Public policies are needed to guide livestock sector's changes along a path that is sustainable in economic, social and environmental terms. These policies should include multiple development objectives and be adapted to location-specific contexts. Policy makers need assistance in dealing with such complex issues. Spatial information can be integrated in decision support tools to support policy making, and is becoming increasingly available in the developing world. Spatial information, however, has seldom been used in the livestock sector policy formulation because policy makers generally do not have access to resources for spatial modelling. The objective of this paper is to bridge this gap by proposing an approach to consolidating and analysing spatial information in the context of limited modelling resources. Rooted in practical experience, a method is proposed that combines two multiple criteria decision-making techniques (weighted linear combination and analytical hierarchical processes), parameterised in a participatory process and implemented in a GIS. The method is tested in two different contexts: support to single objective decision-making for targeting trypanosomiasis control interventions in Uganda, and support to multiple objective decision-making for spatial planning of livestock production development in Thailand. The results show the advantages of such an approach, in terms of stakeholder involvement and practical application to support decision-making, but also highlight two shortcomings: dependence on high quality data, and uncertainty with regard to the decision rule. While the former will be addressed as digital information becomes increasingly available, the latter, embedded in any decision-making process, calls for thorough sensitivity analyses and careful scrutiny of results.

Keywords: Multiple criteria decision-making; GIS; zoning; targeting; decision support methods

1. Introduction

Worldwide, livestock production is growing faster than any other agricultural sector and undergoing major changes (FAO, 2003). Concentrated in countries with rapid economic growth, the rise in production is mostly driven by middle-class urban consumers (Delgado et al., 2002) and achieved through structural changes such as vertical integration, growth in scale, geographical concentration and a shift from ruminant to monogastric species; and technical innovations such as adoption of improved breeds and feeding regimes, and better processing, transport and cold chain infrastructures (Costales et al., 2006). These transformations have significant impact on rural development and public goods, such as natural resources and public health (Steinfeld et al., 2006; de Haan et al., 2001).

Public policies are required to address these consequences (Chopra et al., 2005; de Haan et al., 1998) and thus guide livestock sector development along a sustainable path. Such policies must take into consideration that the interactions among livestock, public goods and rural development are location-specific. Indeed, the resilience of the environment, as well as the human perception of environmental impacts such as odours, nutrient overloads, water withdrawal or land use change is highly heterogene-

ous across space. Disease incidence and disease outbreak dynamics are also dependent on location-specific factors such as climate, weather patterns, land use and transportation networks. Similarly, the location of livestock production and processing in rural areas creates opportunities for rural development that are not created when production plants are located close to urban centres (Costales et al., 2006; de Haan et al., 2001). To succeed in achieving their objectives, livestock policy interventions should thus address the geographical variability of production systems, and their design needs to be influenced by spatial criteria such as livestock densities, access to inputs and markets, disease risk and environmental considerations. Furthermore, policy makers have to deal with multiple and geographically heterogeneous development objectives, and livestock policies need to be coordinated with other sectorial policies and underpinned by participatory processes (Chopra et al., 2005; Norton, 2004).

Such complexities in decision-making call for the assistance of specific tools and methodologies, but in developing countries the availability of reliable spatial data and modelling capacity has constrained the use of spatial decision support, especially in the livestock sector. With an increasing number of spatial datasets derived from satellite imagery and field surveys becoming available (see for example www.fao.org/geonetwork), the data availability constraint are currently being released; yet, the absence of an adequate analysis framework still prevents their use. The objective of this paper is to contribute to the development and testing of a spatial decision support method for livestock policy formulation that addresses this shortfall; providing a simple and robust framework to inform decision-making processes, using spatial data and spatial analysis in a context of limited modelling capacity.

In the following section, the most commonly used multiple criteria decision-making techniques are evaluated in view of this objective. In Section 3, a methodology is proposed and in Section 4, it is applied in two case studies. Finally, the validity and applicability of the proposed methodology are discussed, and some concluding remarks provided.

Throughout the paper, ‘‘goal’’ will refer to the overarching development aspiration; ‘‘objectives’’ to the specific development targets as set by the stakeholders; ‘‘alternatives’’ to the potential locations for policy intervention; and ‘‘criteria’’ to the parameters used to evaluate alternatives in terms of achieving the objectives and goal. In the present context, spatial decision support essentially consist of ranking alternative land parcels, which are the pixels (picture elements) of a raster map in a Geographical Information System (GIS), in terms of their suitability to achieving stated objectives.

2. Identifying suitable multiple criteria decision-making techniques

Decision-making in the context of public policies has two overriding characteristics (Eastman et al., 1993a). First, it is ‘multi-criteria’, in that many different criteria interact to determine the suitability of the environment to a particular activity. Second, it is usually ‘multi-objective’. Defining objectives is central to multi-criteria evaluation;

the more clearly the problem is defined the more specific the decision rule can be (Heywood et al., 1995). Eastman et al. (1993a) suggest that balancing objectives and finding the best option are two different levels of the multi-criteria evaluation. When the decision-maker deals with a single objective, he or she has only to balance various options. When objectives are many, however, each option must be evaluated respect to each objective. Objectives may be complementary or antagonistic. If objectives are complementary the approach is equivalent to implementing a multiple criteria evaluation for each objective, and then adding the best alternatives by a union operator. More usually, however, and especially in the case of spatial decision support for livestock policies, there is some degree of conflict among the different objectives being considered. For example, private or short term sector objectives are often opposed to societal objectives. From a theoretical perspective, conflict-resolution requires a compromise among objectives to reach a ''pareto-optimal'' achievement of the goal. In practical terms, however, different objectives are likely to be supported by diverging groups of stakeholders for whom the pareto-optimal achievement of the goal does not represent a satisfactory solution. Policy makers need then to negotiate, convince, and ultimately make a decision. It is to this end that decision support methods can help explore alternatives and reach consensus and compromise amongst stakeholders.

Many multi-criteria spatial analysis tools have been developed to support development of policies and strategies in a number of fields; useful reviews include: Geertman and Stillwell (2004), Malczewski (2004), Malczewski and Jackson (2000), Robinson (2000) and Voogd (1983). Methods developed to support spatial decision-making have, however, for a number of reasons, often fallen short of practical application (Geertman and Stillwell, 2004; Kaliszewski, 2004; Uran and Janssen, 2003). Reasons include: (i) lack of explicit stakeholder-involvement (Kaliszewski, 2004; Uran and Janssen, 2003; Eastman et al., 1993a); (ii) their inability to handle both quantitative and qualitative criteria and objectives (Eastman, 2003; Eastman et al., 1993a; Uran and Janssen, 2003); (iii) their failure to cope with an incomplete information setting (Eastman, 2003; Uran and Janssen, 2003; Lahdelma et al., 2000; Heywood et al., 1995; Winkler, 1982); and (iv) the lack of frequent updating of results, required to adapt policies to a changing context (Uran and Janssen, 2003). These pitfalls need to be avoided when developing new approaches to spatial decision support.

A broad spectrum of multiple criteria decision-making techniques is available, but most have been developed neither with explicit reference to policy making nor in a spatial context. Techniques based on comparative functions, such as concordance-discordance analysis (Carver, 1991; Nijkamp et al., 1990; Voogd, 1983; Nijkamp and Van Delft, 1977) or analytical hierarchical processes (Saaty, 1987; Saaty, 1977) rely on the comparative evaluation of alternatives. Pair-wise comparisons of alternatives are made, and the superiority of one alternative over the other is qualified based on decision makers' preferences. They can support participatory process and can handle both quantitative and qualitative parameters.

Other techniques, such as weighted linear combination (Malczewski, 2000; Eastman et al., 1993a,b), ideal point analysis, goal programming and spatial compromise programming (Tkach and Simonovic, 2001; Lakshminarayan et al., 1994; Charnes and

Cooper, 1977) rely on additive functions to compute suitability scores for each alternative. First, weights are assigned to criteria, reflecting their relative importance in contributing to the defined objective. Then, weighted criterion scores for each alternative are computed using additive functions to obtain suitability scores. Boolean constraints are used to assign zero values to excluded alternatives. Techniques based on additive functions, implemented within GIS, can support large numbers of alternatives (Eastman, 2003).

Alternatives can also be ranked by comparing results from utility (objective) functions. A set of parameters is first associated with each alternative and used to compute a mathematical function that parallels the decision-making rule. Alternatives are then ranked or grouped according to the results returned by the function (Feiring, 1986; Minch and Sanders, 1986). Comparative advantages of techniques based on probabilistic utility functions lie in their ability to evaluate uncertainty in decision-making (Ben-Haim, 2001). However, in the present context, such techniques are probably too demanding of data (Pratt et al., 1994), and are rather complex for implementation by non-specialists, although approaches such as Group Model Building have been proposed to facilitate the construction of relatively complex biophysical and economic models (Vennix, 1996).

To provide a practical contribution to spatial decision support for livestock policy making, a method is needed, that (i) fosters participatory processes, (ii) allows for inclusion of quantitative and qualitative parameters, (iii) is not prohibitively data demanding to parameterise and can handle uncertainty (thus able to operate in an incomplete information setting), and (iv) can be run on standard computers, allowing for frequent updates of results. A summary of how multiple criteria decision techniques, developed for different purposes, meet these requirements, is presented in Table 1.

Based on these conditions, an approach was developed that combines an additive technique (weighted linear combination) with a comparative technique (analytical hierarchical processes). The models are parameterised using participatory processes and applied to spatial data using GIS.

Table 1 Families of multiple criteria evaluation techniques scored for selected criteria relevant to spatial decision support for policy making.

	Support of participatory process	Computing requirements and compatibility with geographical information systems	Ability to include qualitative criteria (objectives)	Data requirements to define decision rule[(a)]	Ability to handle uncertainty
Additive functions	++	+++	+	+++	++
Comparative functions	+++	+	+++	+++	+
Utility functions	+	++	+	+	+++

''+'' = weak; ''++'' = intermediate; ''+++'' = strong

[(a)] The greater the score, the lesser the data requirements

3. Methods

The method proposed below has two steps. First, is to characterise, describe and parameterise the decision rule. Second, is to evaluate alternatives by attributing scores according to their suitability for the stated objective.

3.1. Parameterising the decision rule

3.1.1. Stakeholder involvement and harnessing of local knowledge

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 organised to bring together the main stakeholders, representatives of: government; livestock keepers (both of large scale and small scale producers); environmentalist organisations; and consumer organisations, for example. Participants interact to reach a consensus on a policy goal and contributing objectives. Objectives are then ranked and weighted according to their relevance to the goal, using analytical hierarchical processes (cf. Section 3.1.2).

Then, during a technical workshop, or series thereof, a multidisciplinary group of experts identifies relevant criteria for each objective, which then need to be standardised and assigned weights. Standardising criteria involves rescaling factor values within a standard range, such that increasing values correspond to increasing suitability for the objective under evaluation. Weights are then assigned to reflect the relative contribution of criteria to the objectives, using analytical hierarchical processes (cf. Section 3.1.2). Boolean constraints are used to exclude alternatives from consideration, regardless of how well they perform with other criteria.

3.1.2. Analytical hierarchical process

An analytical hierarchical process is a step-by-step multiple objective approach: comparisons are first made between pairs of objectives with regard to the overall goal, and these are used to determine objectives weights. Pairwise comparisons are made 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, and the eigenvector associated with the largest eigenvalue of the matrix is computed and normalised (Gantmacher, 1960). It is unique and gives the respective weight of each element. A consistency ratio is calculated to check the transitiveness of the pairwise comparisons.

Having made pairwise comparisons, for example using a nine-point continuous comparison scale (Eastman, 2003; Table 2), commercial computer packages such as IDRISI (Eastman, 2003) or Expert Choice (Forman et al., 2005) are available to calculate weights and consistency ratios.

Table 2 Comparison scale used in the analytical hierarchical process technique (Eastman, 2003).

Less important					More important			
extremely	very strongly	strongly	moder-ately	equally	moder-ately	strongly	very strongly	extremely
1/9	1/7	1/5	1/3	1	3	5	7	9

For example, a score of 1 rates both factors equally important in terms of their contribution or significance to meeting a specified objective; 3 rates the first factor to be 'moderately more important' than the second; whilst a score of 1/9 rates the first factor to be 'extremely less important' than second.

3.1.3. Evaluating alternatives

Alternatives are ranked by implementing weighted linear combination (Eastman, 2003; Malczewski, 2000; Eastman et al., 1993a) on raster maps stored in a GIS. The suitability of the alternative being considered (value of a raster cell in the suitability map) is defined as:

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

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 made at the level of objectives.

4. Results of two applications

The method presented above was evaluated for two diverse case studies: support to single objective decision-making for targeting trypanosomiasis control interventions in Uganda, and support to multiple objective decision-making for the spatial planning of the development of commercial livestock production in Thailand.

4.1. Targeting trypanosomiasis control interventions in Uganda

4.1.1. Background

In many African countries where both government resources and donor aid for the control of tsetse-transmitted trypanosomiasis are declining, there is an increasing need to identify areas where intervention is most likely to be technically, economically, so-

cially and environmentally sustainable. Activities then can be focused so that the maximum benefits are obtained from limited resources.

Decision-making in trypanosomiasis control in Uganda (cf. location map, Figure 1) occurs primarily at two different levels: national and district, although some decisions are also influenced by the international arena. At the national or central level the Uganda Trypanosomiasis Control Council (UTCC) is the statutory legal entity with the Coordinating Office for the Control of Trypanosomiasis in Uganda (COCTU) acting as its secretariat. Partners in the decision process include various ministries (agriculture, finance, health, etc.), National Agricultural Research Organisations (NARO), the Secretariat of the Plan for Modernisation of Agriculture (PMA), and the National Agricultural Advisory Service (NAADS). Parliament also has a strong stake in decision-making. The main roles of these national level players are in: policy formulation; technical advice; monitoring and evaluation; advocacy; regulation; and capacity building.

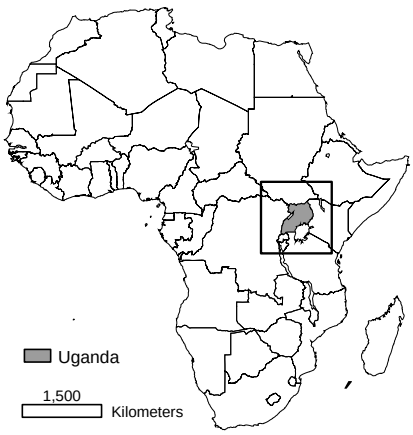

Figure 1 Location map of Uganda.

At the district level, the key players include the ministries responsible for animal health and production, those responsible for human health, local communities, non governmental organisations and district councils. The key role of the players at the district level is in the delivery of services.

Regional influences include the African Union's Inter-African Bureau for Animal Resources (AU-IBAR), under which falls the Pan-African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC), involved in the co-ordination of regional and continental projects, provision of technical support, sourcing funds and advocacy. Furthermore, international donor organisations have a strong influence through research emphasis (e.g. International Livestock Research Institute (ILRI); International Centre for Insect Physiology and Ecology (ICIPE)), policies and recommendations (e.g. the United Nations' World Health Organisation (WHO), Food and Agriculture Organisation (FAO) and International Atomic Energy Agency (IAEA), and the Office Interna-

tional des Epizooties (OIE)), and through funding of projects and programmes (e.g. the African Development Bank (ADB), the European Commission (EC), and the United Kingdom's Department for International Development (DFID)).

4.1.2. Materials and methods

A single objective: ''controlling animal trypanosomiasis to alleviate poverty'', was set during a consultative workshop, involving 17 Ugandan veterinary, medical and agricultural specialists, drawn from the Ministry of Agriculture, Animal Industries and Fisheries (MAAIF), the Ministry of Finance, Planning and Economic Development (MFPED), the Ministry of Health (MOH), the Farming in Tsetse Controlled Areas (FITCA) project, Makerere University, NARO, COCTU and ILRI. Staff from COCTU and ILRI had been developing and collating spatial datasets relevant to trypanosomiasis control, from which decision criteria were selected. Sources and year of primary data used are listed in Table 3. Following the method described above (somewhat simplified in this single objective example), six decision criteria were identified by the workshop participants, who then divided into two groups to rank and score these, using pair wise comparison.

Table 3 Primary data layers used to target trypanosomiasis control interventions in Uganda.

Data	Source	Year
District and sub-county administrative boundaries	National Biomass Study, Ministry of Natural Resources	1997
Human population density	Uganda Bureau of Statistics	1997
Cattle density	National Biomass Study, Ministry of Natural Resources and Ministry of Agriculture, Animal Industry and Fisheries	1996 and 1997
Percentage crop cover	Ministry of Agriculture,	1995
Length of growing period	FAO	1983
Density of 'poor livestock keepers'	(Thornton *et al.*, 2002)	2001
Trypanosomiasis risk index	Derived from coarse resolution predictions of tsetse distributions for Africa (Ford and Katondo, 1977), following method described by (Rogers and Robinson, 2004)	2001

4.1.3. Results

The resulting weights were quite similar between the two groups, and, moreover, the ranking of variables was identical. Table 4 shows these weights, normalised to give values of between 0 and 1 with all weights adding up to 1, and the averages of the two groups. Trypanosomiasis risk was considered the most important criterion followed by

the density of poor livestock keepers. All other criteria were considered much less important. The averaged weights were then applied in a weighted linear combination model to the scaled criteria to give the priority map shown in Figure 2a, which indicates that the major tsetse and trypanosomiasis problem was located in the north-west with much less of a problem in the south-east, where the EC-funded FITCA project was located.

Table 4 Criteria weights for targeting trypanosomiasis control interventions given by the two groups of Ugandan experts.

Criteria	Weights		
	Group 1	Group 2	Average
Livestock density	0.1712	0.0759	0.1236
Human population density	0.0395	0.0271	0.0333
Percentage crop cover	0.0651	0.0555	0.0603
Length of growing period	0.0772	0.0672	0.0722
Density of poor livestock keepers	0.2355	0.2139	0.2247
Trypanosomiasis risk index	0.4116	0.5603	0.4860

Calculating the suitability map with averaged criteria weights could be criticised, as the weights given by the two groups to one of the criteria (livestock density) varied by more than a factor 2. A simple sensitivity analysis was conducted by comparing the map in Figure 2a with suitability maps calculated with each of the groups' results. No dramatic change in suitability pattern was observed, since the influence of livestock density was overshadowed by the two criteria with substantially higher weights.

The results were also tested for database uncertainty. Trypanosomiasis risk and poverty rates are the most important factors, but also those for which the least accurate data were available. To test the sensitivity of the calculated suitability map with regard to these criteria, the analysis was re-conducted, removing trypanosomiasis risk and poverty sequentially from consideration. This was achieved by setting all pixels for these variables to a value of 1 so that the effects of their weights are nullified, whilst leaving the rest of the analysis intact.

Figure 2b shows the result of removing the trypanosomiasis risk index from the analysis (using the average weights) and Figure 2c shows the result of removing both the trypanosomiasis risk index and the density of poor livestock keepers. It is clear from Figure 2b that removing the effect of disease risk changes the picture considerably, reducing the importance of the north-west area of Uganda and introducing the south-east as higher priority. Further removing poverty estimates from the equation leaves a model based, in order of importance with weights in brackets, on: livestock density (0.1236), length of growing period (0.0722), percentage crop cover (0.0603) and human population density (0.0333). This model clearly highlights a band of highest priority, from south-east Uganda to just north-west of Lake Kyoga.

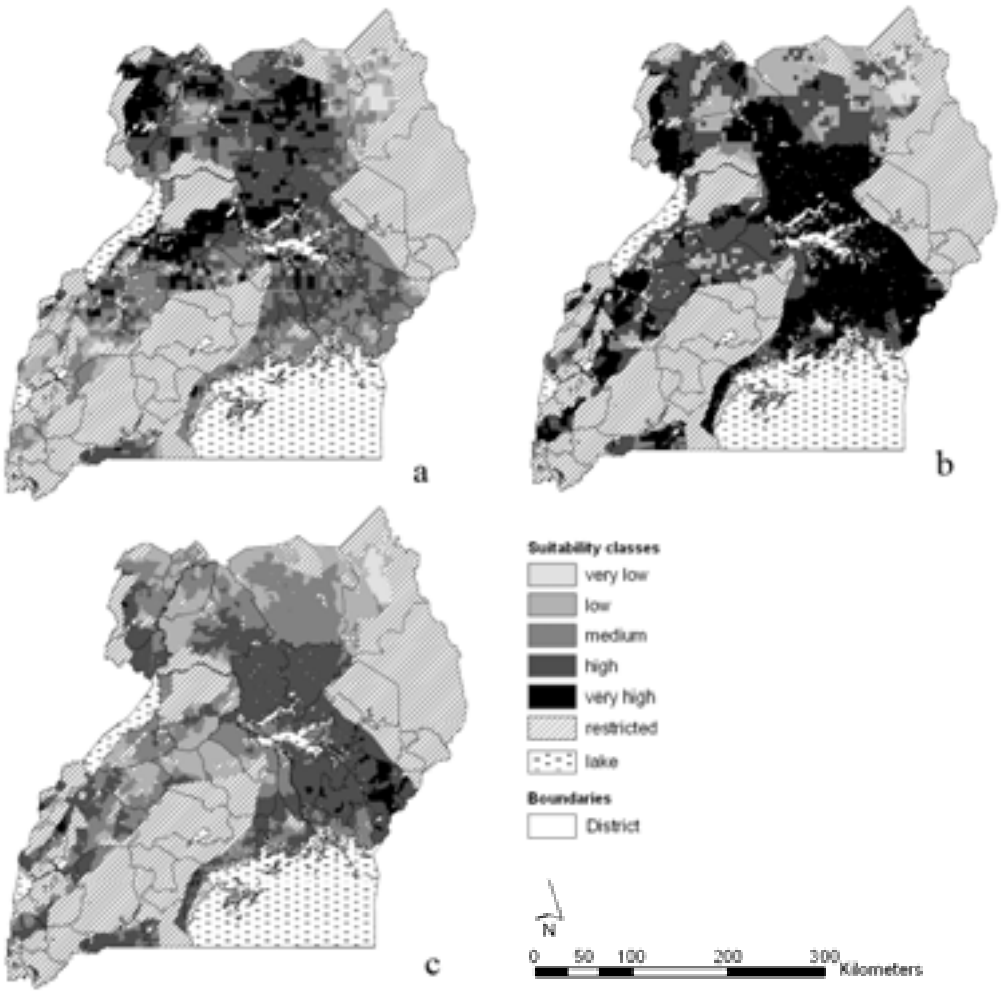

Figure 2 Group average trypanosomiasis control priority map (a) including all criteria; (b) excluding trypanosomiasis risk index; and (c) excluding trypanosomiasis risk index and poverty estimates.

Whilst the results of this sensitivity analysis indicate that the priority maps produced here were not based on sufficiently high quality data for their practical application to targeting disease control interventions, the application of the methodology was of value for two main reasons. First, involving technical experts and other stakeholders to prioritise areas for intervention made the policy process much more inclusive and broad-based. Second, it highlighted important data gaps, which are now being addressed by MAAIF and COCTU.

4.2. Spatial planning of pig production development in Southeastern Thailand

4.2.1. Background

The case study area spans nine provinces in the southeast of Thailand (see Figure 3), a region of approximately 38,000 km^2 (7.4% of the national area). With 19% and 26% of national pig and broiler stock, respectively (DLD, 2003), livestock production in the area is much higher than the national average, and its rate of expansion is one of the fasted in the country. Consequently, impacts on the environment, public health and rural development are already severe (Menzi, 2001; Rattanarajcharkul et al., 2000). Thailand is currently undertaking an export promotion programme, for which the study area has been selected due to its vicinity (i) to major consuming centres (Bangkok and Chachoengsao), (ii) to feed producing areas and feed mills and (iii) to ports for importing inputs and exporting products. Pigs are planned to feature most prominently in this programme, followed by poultry. It is expected that the pig population and production levels will rise sharply over the next 10 years, and that an overwhelming share of this growth will come from newly established intensive pig production units.

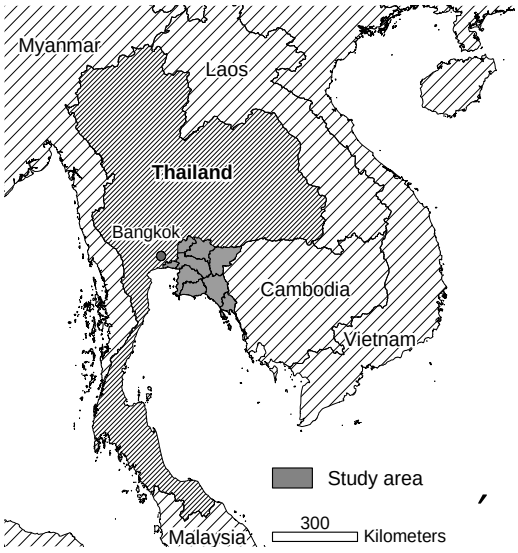

Figure 3 Case study area location in Thailand.

Whilst there is currently no formal policy for spatial planning (zoning) of livestock development in Thailand, zoning of livestock production was identified by the Department of Livestock Development (DLD) in the Ministry of Agriculture and Cooperatives as an effective policy measure to improve the social benefits, and to mitigate negative impacts of livestock development. A procedure for establishing new livestock farms is being proposed by the DLD which would involve the Provincial Livestock Development Office receiving applications, which it would assess using

information provided by the DLD, in particular in the form of suitability maps (FAO/LEAD, 2004). In this context, the objective of the present case study was to test the possibility of developing such suitability maps (FAO/LEAD, 2004).

4.2.2. Materials and methods

The two-step approach described in Section 3 was implemented in full in this example of multiple criteria and multiple objective decision making. The policy workshop involved 39 participants, from central and provincial offices of Ministry of Agriculture, Ministry of Natural Resources, Ministry of Finance and Ministry of Public Health, National Economic and Social Development Board, Livestock producers, Environmental Non Governmental Organisations and Provincial Council members. Twenty experts participated in a technical workshop, which addressed the following thematic areas: animal health, public health, animal production economics, transport economics, livestock production, manure management, rural development, soil sciences, agronomy, natural resources management and environmental protection. The primary data used to carry out this case study are listed Table 5.

Table 5 Primary data used for the spatial planning of pig production development in South-eastern Thailand.

Data	Source	Date of production	Resolution
Digital maps			
Administrative boundary	LDD[(a)]	1995	1:50,000
Transport	LDD	1995	1:50,000
Elevation (raster)	SRTM–FAO/GLCN[(b)]	2004	3 arc-second
Streams and water bodies	LDD	1995	1:50,000
Land use	LDD	2000	1:50,000
Soil	LDD	1995	1:50,000
Water Table	GWD[(c)]		1:50,000
FMD disease free	DLD[(d)]	2003	1:50,000
Protect areas	LDD	1995	1:50,000
Feed mills and slaughterhouses (plots)	DLD	2003	20 m
Leaching and runoff risks	LDD	2003	1:50,000
Statistics			
Poverty index	RDD[(e)]	2003	Sub-district
Human Population	DLD	2003	District
Livestock stocks (pigs, poultry cattle and buffalo)	DLD	2003	Sub-district
Number of large farms (stock > 1000 pigs or 10,000 poultry)	DLD	2003	Sub-district

[(a)] Thai Department of Land Development.

[(b)] Shuttle Radar Topography Mission – Global Land Cover Network based at Food and Agriculture Organisation of the United Nations.

[c] Thai Ground Water Department.
[d] Thai Department of Livestock Development.
[e] Thai Rural Development Division.

Distances were calculated using buffering and cost weighted functions included in ARC-GIS 8.3 software developed by Environment Systems Research Institute. Nutrient balances were computed using the methods described by Gerber et al. (2005). All geographical data were converted in raster files with 100 m resolution.

4.2.3. Results

The policy workshop participants set the following goal: ‘‘sustainable development of pig production fostered through its better geographical distribution’’, with the following four contributing objectives: (i) economic profitability of pig production is maximised – or pig producers’ profit is maximised, (ii) environmental impacts of pig production are minimised, (iii) public and animal health are protected, and (iv) rural development and poverty reduction are fostered. Table 6 presents the weights for these objectives, derived by three groups using analytical hierarchical process. The protection of animal and public health was considered the most important criteria by all three groups.

Table 6 Objectives’ weights for the spatial planning of pig production in southeastern Thailand given by three groups of local policy makers and stakeholders.

Objective	**Weights**		
	Group 1	Group 2	Group 3
Economic profitability of pig production is maximised	0.3072	0.1410	0.0612
Environmental impacts of pig production are minimised	0.1524	0.0918	0.2033
Public and animal health are protected	0.4866	0.4919	0.4322
Rural development and poverty reduction are fostered	0.0538	0.2753	0.3033

The results from the technical workshop are presented in Table 7. A total of 18 criteria were identified. Subsets were chosen for each objective, and the criteria standardised and ranked. For the objective ‘‘economic profitability of pig production is maximised’’, the three criteria that were considered most important were: distance to feed mills, distance to slaughterhouses, and distance to roads, together accounting for some 70% of the total, and clearly reflecting the importance of transport costs in the location economics. For the objective ‘‘environmental impacts of pig production are minimised’’, distance to inhabited areas was the highest-ranking criterion and distance to mangroves or wetlands was ranked second, weight half as strongly.

Table 7 Standardized and ranked criteria for selected objectives contributing to the sustainable spatial distribution of pig production development in south eastern Thailand, as provided by local experts gathered in a technical workshop.

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	Weight
Objective: **Economic profitability of pig production is maximised**								
Distance to feed mill	km			>50	10-50	<10		0.2802
Distance to slaughterhouse >10	km	>100		61-100		5-60	< 5	0.2164
Distance to main road	km	>15		5-15		<5		0.1945
Poverty index	-		"progress"	"moderate"	"backward"			0.1288
Planned Foot and Mouth Disease free zone	-			elsewhere	buffer zone	free zone		0.0656
Human population density	indiv./km^2		<72	72-170	>170			0.0648
Current livestock density	pig/km^2		>1000	201-1000	0-200			0.0497
Objective: **Environmental impacts of pig production are minimized**								
Distance to inhabited area	m	<200	200-400	401-600	601-800	>800		0.3222
Distance to mangroves/wetlands	m	<200	200-400	401-600	601-800	>800		0.1445
Runoff risk	-	"very high"	"high"	"medium"	"low"	"very low"	"restricted"	0.1335
Leaching risk	-	"very high"	"high"	"medium"	"low"	"very low"	"restricted"	0.1041
Number of large pig and poultry farms in district	farm	>8	7-8	5-6	2-4	<2		0.0947
Current nutrient balance (P_2O_5)	%	>1	0.71-1.0	0.51-0.7	0.3-0.5	<0.3		0.0926
Current livestock densities	LU/km^2	>50	31-50	21-30	10-20	<10		0.0475
Distance to main road	m	<100	100-200	201-300	301-400	>400		0.0411
Current land use	-	"paddy"; "rice"; "agriculture useless"; "forest"; "lowland"; "bamboo"	"vegetables"	"field crops"; "grassland"	"fruit trees"; "orchards"	"plantations"	"protected areas"; "mangrove"; "wetland"	0.0198

(continued on next page)

Table 7 ***(continued)***

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	Weight
Objective: **Public and animal health are protected**								
Distance to inhabited area	km	<5		5 to 10		>10	"populated areas"; "water bodies"	0.1725
Distance to streams and water bodies	m	0-100		101-500		>500		0.1604
Human population density	indiv./km^2	>200	151-200	101-150	51-100	<51		0.1374
Distance to slaughterhouse	km	<2		2-5		>5		0.1364
Planned Foot & Mouth Disease free zone	-	elsewhere	buffer zone			free zone		0.0699
Current livestock densities	LU/km^2	>80	61-80	41-60	21-40	0-20		0.0435
Leaching risk	-	"very high"	"high"	"medium"	"low"	"very low"	"restricted"	0.0399
Distance to feed mill	km	<5		5-10		>10		0.0385
Number of large pig and poultry farms in district	farm	>5		3-5		0-2		0.0227
Poverty index	-		"backward"	"moderate"	"progress"			0.0148
Objective: **Rural development and poverty reduction are fostered**								
Distance to main road	km	>15		5-15		<5		0.2127
Poverty index	-	"backward"	"progress"		"moderate"			0.1846
Human population density	pers./km^2	>170		72-170		<72		0.1452
Current land use	-	"agr. 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"	0.1085
Planned Foot & Mouth Disease free zone	-		elsewhere	buffer zone		free zone		0.0677
Current nutrient balance (N_{total})	%	96-150		26-95		0-25		0.0660
Distance to slaughterhouse	km	>100		61-100		5-60	<5	0.0611
Current nutrient balance (P_2O_5)	%	76-150		26-75		0-25		0.0604
Distance to feed mill	km			>50	10-50	<10		0.0515
Number of large pig farms in district	farm			1-4	5-8	>8		0.0423

The group responsible for the objective ‘‘public and animal health are protected’’ ranked three public health related criteria at top of the list, followed by animal health related criteria. Finally, amongst the top-ranking criteria for the objective ‘‘rural development and poverty reduction are fostered’’ were distance to roads, poverty levels and population density.

Suitability maps for each of the four objectives are presented in Figure 4a–d, showing contrasting geographical patterns. These needed to be combined into a single suitability map. Three techniques were evaluated, showing progressively increasing levels of risk aversion. Two of them use the different weights for each objective derived by the three groups in the policy workshop. The first consists in computing a unique weighted linear combination using averaged weights, on the assumption that the preferences expressed by the three groups could be merged (Figure 5a). In the second technique, suitability maps are evaluated for each of the three groups' sets of weights, and each alternative (pixel) is then assigned the lowest of the three suitability scores (Figure 5b). The underlying rationale to this more risk-averse technique is that if a group had identified a risk with regard to one of the objectives, this should be reflected in the suitability map, whatever the results of the other groups. The third technique that was evaluated consists in calculating the combined suitability map by assigning to each alternative (pixel) the lowest score from all four single objective suitability maps (Figure 4a–d). This last technique, which essentially ignores objectives' weights given by the policy groups, results in an even more conservative suitability map (Figure 5c).

The results obtained using the two techniques based on working groups' weights resulted in similar overall geographical patterns, although detailed examination reveals differences at a sub-district level. A drawback of such aggregation methods, recognised also by Eastman (2003), is that a low score for one objective may be compensated by high scores among other objectives; in this example, an area might be selected for farm development, even though it scored very poorly against one of the objectives, such as environmental impact. This compensatory effect is avoided by the third method, which results in a similar overall pattern of suitability, but attributes significantly lower scores.

Each approach has its merits, and the selection of a technique to derive the final suitability map depends on the risk-taking behaviour of the policy maker and on the size, in terms of square kilometres or number of pixels, of the target area to be selected. In this example, the second approach (Figure 5b) was favoured by the DLD, as it was reasonably conservative but did not select too few pixels, which would result in an over-concentration of growth in pig production.

The suitability maps calculated at a resolution of 100 m (Figure 5) can be used directly for local level zoning (micro-location). However, to improve the macro-location of livestock production, provincial or national level policies are required to foster or prevent the development of livestock production in given administrative jurisdictions. To support the formulation of such policies, the information in the raster map can be cleaned of scattered pixels and summarised at any administrative level.

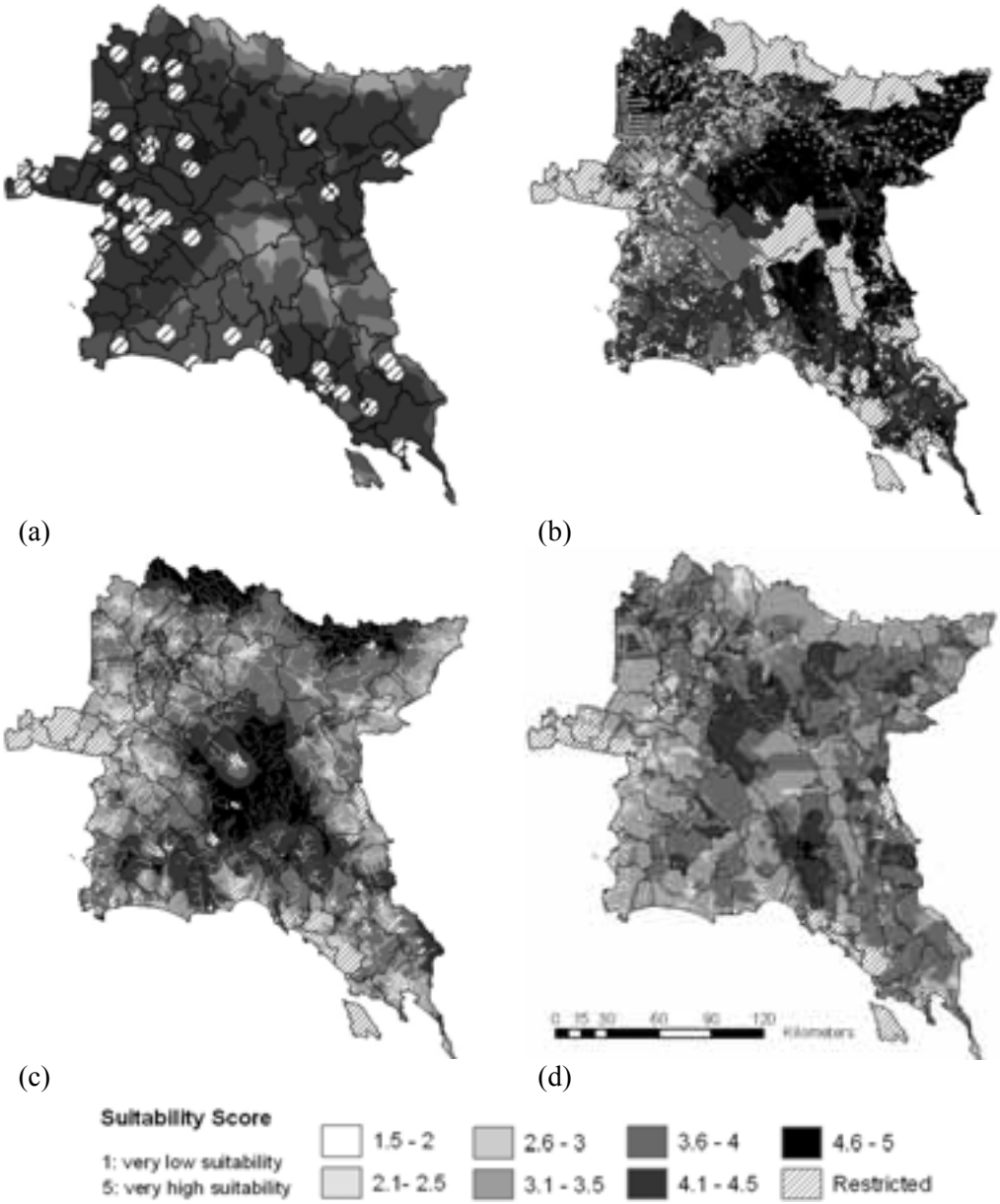

Figure 4 Suitability map for the objectives: (a) economic profitability of pig production is maximised; (b) environmental impact of pig production is minimised; (c) public and animal health are protected; and (d) rural development and poverty reduction are fostered.

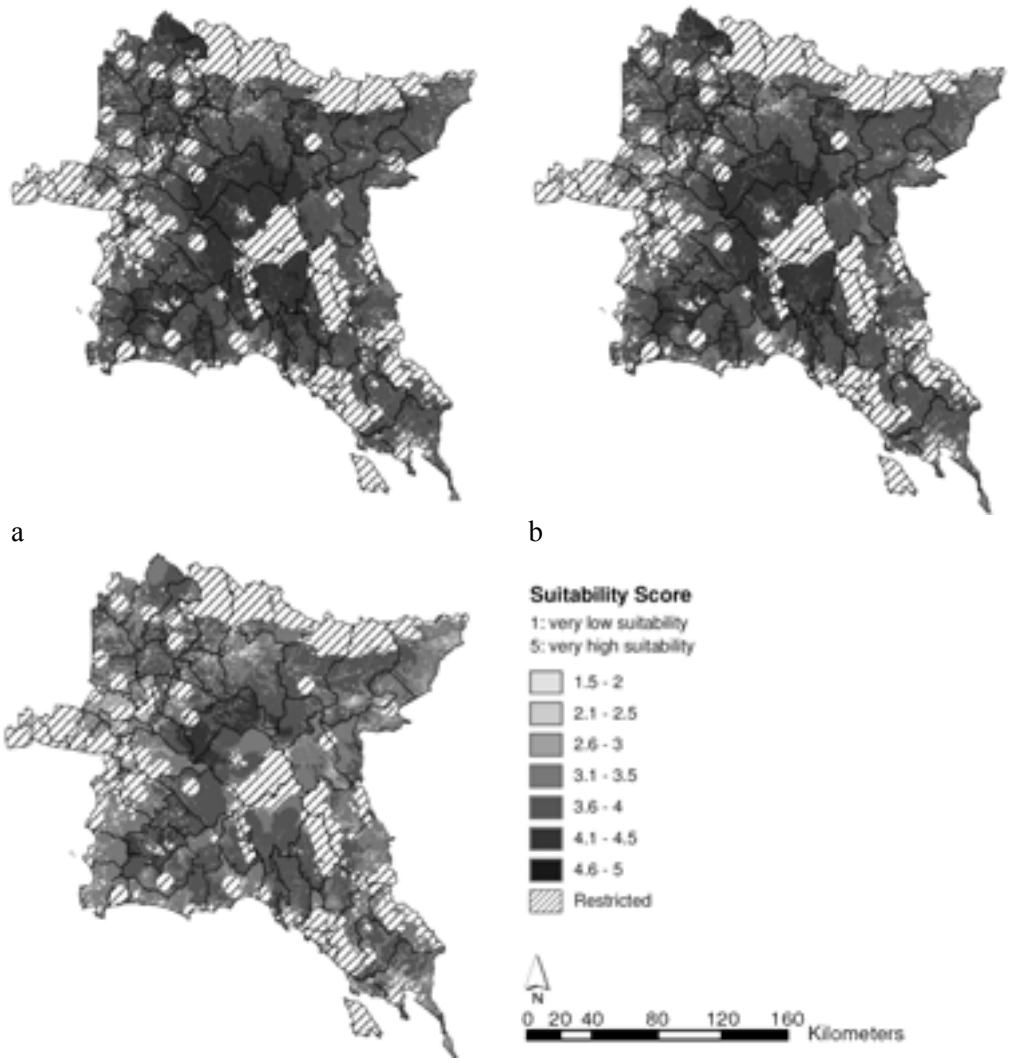

Figure 5 Combined suitability maps computed by: (a) a single weighted linear combination using averaged weights from the three policy groups; (b) three weighted linear combination, using weights given by the three policy workshop working groups, and the attribution of the lowest value to each pixel; and (c) assigning to each pixel the lowest score from all four single objective suitability maps.

The result is presented in Figure 6, where sub-districts with less than 10 ha classified as ‘‘highly suitable’’ to ‘‘very highly suitable’’ (i.e. score ≥ 4) are coloured in black. The map can contribute to the design and implementation of disaggregated public policy at sub-district level. There are various policy instruments that can be put in place to implement the results of this decision support exercise, and thus drive industrial pig-production into suitable areas; mitigating the trend towards peri-urban concentra-

tion. Such instruments at the national level include tax rate differentials across provinces and districts, public infrastructure development (e.g. slaughterhouses and transport), and subsidies to land acquisitions and farm investments in prioritised areas. At local level, sub-district administrations can use these suitability maps to guide decisions as to whether to authorise requests for establishment of new pig farms. Decisions thus based on analysis rather than intuition, and are less subject to local pressure.

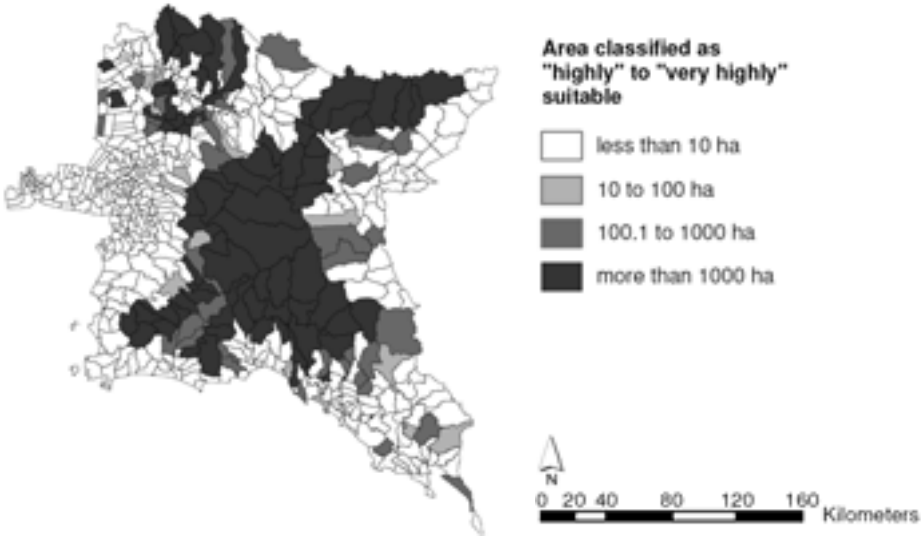

Figure 6 Area within sub-districts with a score greater than 4 for all three suitability maps computed on the basis of each policy workshop working group sets of criteria weight.

5. Discussion

Introducing a novel method to support decision-making raises a number of questions relating to its validity and to the institutional requirements for its effective uptake, as compared to other options.

5.1. Evaluation

Verification and validation are generally recognised as the two components by which to evaluate a decision support system. Verification is to ensure that the model is correctly built from a formal point of view, whereas validation assesses the model's usefulness to the user, i.e. its ability actually to improve the decision-making process (Sojda, 2007; Qureshi et al., 1999). Sojda (2007) further suggests that sensitivity analysis can further contribute to validating decision support systems.

5.1.1. Verification

Malczewski (2000) and Robinson et al. (2002) highlight three assumptions regarding the definition of factors (criteria or objectives) when using weighted linear combination in a GIS environment: factors must be complete (i.e. they should cover all relevant aspects of the decision problem), independent and linear. The experience from the two applications described above shows that the selection of factors is necessarily driven by data availability, which may not allow all relevant factors to be included. It is, however, important to ensure that no key factor is missing from the analysis and that, if data for a given factor are unavailable and can not be replaced by a proxy, the relative factor is explicitly removed from the decision support model, and the results interpreted accordingly. Independence is more difficult to deal with. In the two examples here, some of the variables are in fact highly correlated with others. It is not always possible simply to drop one of a pair of correlated variables (e.g. livestock and people) since areas where the correlation breaks down are often particularly important: for example where people occur but cannot keep livestock because trypanosomiasis risk is high. More research is probably needed to develop techniques that can overcome such issues. Finally, problems of non-linearity of factors can be readily addressed by applying appropriate transformations, and by scaling factors using suitability classes.

Similarly, four axioms have been identified that underpin the analytical hierarchical processes (Saaty, 1999): (i) the intensity by which element a is preferred to element b is inverse to the intensity by which element b is preferred to element a, (ii) the elements under comparison are of similar nature and magnitude, (iii) elements from the same level are independent while each element of a given level should be related to at least one element in the higher and/or lower level and (iv) the hierarchical network structure of criteria and elements should include the most relevant aspects of the decision-making context. Except for the issue of independence, discussed above, these do not raise major concerns and can usually be handled by a facilitator acquainted with analytical hierarchical processes.

5.1.2. Validation

The sensitivity analysis conducted for the Uganda case demonstrated that results (and thus method's usefulness to decision makers) rely heavily on the quality of input data. The Thai example showed that detailed information is already available in some countries, and this is likely to be increasingly so.

Participatory decision-making processes require both the will to involve the relevant stakeholders in the decision-making process and the skills to implement a challenging process (Norton, 2004). The success of the participatory process also depends on the ability of stakeholders to make definitive, consensual and consistent decisions. The analytical hierarchy process and the production of maps can facilitate this by structuring and informing debate. To be successful, the participatory process will also require specialist input in the areas of stakeholder analysis and negotiation techniques (Norton, 2004). The application in Thailand highlighted the method's strengths and limita-

tions in this regard. The spatial information provided helped the diverse groups to reach a common view on the identification of areas for pig-sector development, however due to a poor analysis of stakeholders, the policy workshop was rather biased towards public veterinary services, which accounted for about a third of participants.

At the core of this approach to decision support is the reliance on technical experts to parameterise the decision rule, whereas other approaches, based on economic and biophysical models and in particular those relying on systems dynamics modelling, may provide more robust ways to capture complex sets of interrelations and to predict dynamic policy outcomes (Sterman, 2000). The use of complex models to support policy making may, however, be undermined by their lack of transparency. This has been identified as a major reason for the limited use of planning support systems in Europe and North America, where, for example, Vonk et al. (2005) and Couclelis (2005) concluded that the many years of research emphasising the development of transparent and easy-to-use systems have not substantially improved users' perception. This assessment can probably be extended to countries with limited modelling capacity and less familiarity with models. The method proposed here avoids this pitfall by calling on expert knowledge to parameterise the decision rule. However, the validity of the resulting models is highly dependent on the quality of that expert knowledge.

The method and its results can be validated further by assessing the relative cost effectiveness of policies whose design benefits from spatial information. For example, in the case of environmental policies for intensive livestock operations, the cost effectiveness of policy instruments designed to control animal waste management on the production site can be compared with the cost effectiveness of instruments designed to improve the spatial distribution of production sites. Results of such analysis conducted by Gerber (2006) showed that the location of farms in areas with good potential for waste recycling on land achieves a partial reduction of environmental impacts associated with manure management and lowers the cost of compliance associated with policy instruments designed to control environmental impacts on the production site.

5.2. Relevance and conditions for adoption

Where resource constraints prevent complex spatial modelling, the method proposed here provides a more accessible alternative, requiring basic computing hardware, software and analytical skills, allowing results to be tested frequently and updated regularly, as new data and decision criteria become available. In order for new decision support tools to be taken up operationally, decision makers will need to be convinced that they are reliable, and that they add some value over existing approaches. These examples from Uganda and Thailand shown here, do suggest that this approach has much to offer; particularly with respect to its ability to incorporate expert knowledge and stakeholder opinion into decision-making processes. Decision makers have much more confidence in results that have drawn upon local knowledge and skills, and this confidence places them in a stronger position to apply the results when formulating policies (Geertman and Stillwell, 2004; Uran and Janssen, 2003).

6. Conclusion

The objective of this paper was to bridge the gap between the increasingly available spatial data in the developing world, and their practical application in support of livestock policy formulation. A method is proposed that is simple and robust, enables spatial information to be consolidated and analysed with limited modelling resources, promotes participation in policy processes, and presents results to decision makers in a way that is readily assimilated. For the outcomes of such analyses to be used effectively requires specific policy instruments to be developed and implemented. In this respect, the trypanosomiasis control priority map produced for Uganda is at the centre of a policy document and intervention strategy developed by MAAIF, COCTU and PATTEC, with initial funding from ADB. In parallel, the approach developed in Thailand is a core element of a regional cooperation project amongst the governments of Thailand, Vietnam and Guangdong province of China, supported by FAO's Livestock Environment and Development Initiative (LEAD) and the Global Environment Facility (GEF). This project will further develop this approach to policy formulation by preparing guidelines to support participatory decision making processes, and developing a user-friendly interface by which to implement the method described here.

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References

Ben-Haim, Y., 2001. Information-gap Decision Theory: Decisions under Severe Uncertainty. Academic Press, San Diego.

Carver, S.J., 1991. Integrating multi-criteria evaluation with geographic information systems. International Journal of Geographic Information Systems 5, 321–339.

Charnes, A., Cooper, W.W., 1977. Goal programming and multiple objective optimizations. European Journal of Operational Research 1, 39–54.

Chopra, K., Leemans, R., Kumar, P., Simons, H. (Eds.), 2005. Ecosystems and Human Well-being: Policy Responses. Millenium Ecosystem Assessment, vol. 3. Island Press, Washington-Covelo-London.

Costales, A., Gerber, P., Steinfeld, H., 2006. Underneath the livestock revolution. In: McLeod, A. (Ed.), The 2006 Livestock Report. FAO, Rome.

Couclelis, H., 2005. ''Where has the future gone?'' Rethinking the role of integrated land-use models in spatial planning. Environment and Planning A 37, 1353–1371.

de Haan, C., Steinfeld, H., Blackburn, H., 1998. Livestock and the Environment, Finding a Balance. European Commission Directorate general for Development, Food and Agricultural Organization of the United Nations, Rome.

de Haan, C., Schillhorn van Veen, T.W., Brandenburg, B., Gauthier, J., Le Gall, F., Mearns, R., et al., 2001. Livestock Development, Implications for Rural Poverty, the Environment, and Global Food Security Directions in Development. The World Bank, Washington.

Delgado, C., Rosegrant, M., Meijer, S., 2002. Livestock to 2020: The Revolution Continues. World Brahman Congress, Rockhampton. DLD, 2003. Statistical Yearbook. Department of Livestock Development, Ministry of Agriculture And Cooperatives, Bangkok.

Eastman, J.R., 2003. In: IDRISI Kilimanjaro – Guide to GIS and Image Processing, vol. 1. Clark University, Worcester.

Eastman, J.R., Jin, W., Kyem, P.A.K., Toledano, J., 1993a. Participatory multi-objective decision-making in GIS. In: Proceedings: AUTO-CARTO vol. 11, pp. 33–43.

Eastman, J.R., Kymen, P.A.K., Toledano, J., 1993b. A procedure for multi-objective decision making in GIS under conditions of conflicting objectives. European Conference on Geographical Information Systems, 438–447.

FAO/LEAD, 2004. Livestock Waste Management In East Asia Project Preparation Report. Food And Agricultural Organization of the United Nations/Livestock Environment and Development Initiative, Rome.

FAO, 2003. World Agriculture: Towards 2015/2030. Food And Agricultural Organization of the United Nations, Rome.

Feiring, B.R., 1986. Linear Programming: An Introduction. Sage Publications, London.

Ford, J., Katondo, K.M., 1977. Maps of tsetse fly (Glossina) distribution in Africa, 1973, according to sub-generic groups on a scale of 1:5,000,000. Bulletin of Animal Health and Production in Africa 15, 188–193.

Forman, E.H., Dougherty, R., Devlin, J.P., 2005. Expert choice. http://www.expertchoice.com.

Gantmacher, F.R., 1960. The Theory of Matrices. Chelsea, New York.

Geertman, S., Stillwell, J., 2004. Planning support systems: an inventory of current practice. Computers, Environment and Urban Systems 28, 191–310.

Gerber, P., 2006. Putting pigs in their place, Environmental policies for intensive livestock production in rapidly growing economies, with reference to pig farming in

Central Thailand. Doctoral thesis number 16696, Swiss Federal Institute of Technology, Zurich.

Gerber, P., Chilonda, P., Franceschini, G., Menzi, H., 2005. Geographical determinants and environmental implications of livestock production intensification in Asia. Bioresource Technology 96, 263–276.

Heywood, I., Olivier, J., Tomlinson, S., 1995. Building an exploratory multi-criteria modelling environment for spatial decision support. In: Fisher, P. (Ed.), Innovations in GIS 2. Taylor and Francis, London, pp. 127–136.

Kaliszewski, I., 2004. Out of the mist – towards decision-maker-friendly multiple criteria decision making support. European Journal of Operational Research 158, 293–307.

Lahdelma, R., Salminen, P., Hokkanen, J., 2000. Using multicriteria methods in environmental planning and management. Environmental Management 26, 595–605.

Lakshminarayan, P.G., Johnson, S.R., Bouzaher, A., 1994. A multi-objective approach to integrating agricultural economic and environmental policies. Journal of Environmental Management 45, 365–378.

Malczewski, J., 2000. On the use of weighted linear combination method in GIS: common and best practice approaches. Transactions in GIS 4, 5–22.

Malczewski, J., 2004. GIS-based land-use suitability analysis: a critical overview. Progress in Planning 62, 3–65.

Malczewski, J., Jackson, M., 2000. Multicriteria spatial allocation of educational resources: an overview. Socio-Economic Planning Sciences 34, 219–235.

Menzi, H., 2001. Needs and Implications for Good Manure and Nutrient Management in Intensive Livestock Production in Developing Countries, Area Wide Integration Workshop. Food And Agricultural Organization of the United Nations, Rome.

Minch, R.P., Sanders, G.L., 1986. Computerised information systems supporting multicriteria decision making. Decision Sciences 17, 395–413.

Nijkamp, P., Van Delft, A., 1977. Multi-criteria Analysis and Regional Decision-making. Studies in Applied Regional Science. Leiden, Amsterdam.

Nijkamp, P., Rietveld, P., Voogd, H., 1990. Multicriteria Evaluation. North Holland, Amsterdam.

Norton, R.D., 2004. Agricultural Development Policy – Concepts and Experiences. Wiley for the Food and Agriculture Organisation of the Unated Nations, West Sussex.

Pratt, J., Raiffa, H., Schlaifer, R., 1994. Introduction to Statistical Decision Theory. The MIT Press, Cambridge.

Qureshi, M.E., Harrison, S.R., Wegener, M.K., 1999. Validation of multicriteria analysis models. Agricultural Systems 62, 105–116.

Rattanarajcharkul, R., Rucha, W., Sommer, S., Menzi, H., 2000. Area-wide integration of specialized livestock and crop production in eastern Thailand. In: Sangiorgio, F. (Ed.), RAMIRAN Conference. University of Milan, pp. 295–300.

Robinson, T.P., 2000. Spatial statistics and geographical information systems in epidemiology and public health. Advances in Parasitology 47, 81–128.
Robinson, T.P., Harris, R.S., Hopkins, J.S., Williams, B.G., 2002. An example of decision support for trypanosomiasis control using a geographic information system in eastern Zambia. International Journal of Geographical Information Science 16, 345–360.
Rogers, D.J., Robinson, T.P., 2004. Tsetse distribution. In: Maudlin, I., Holmes, P., Miles, M. (Eds.), The Trypanosomiaises. Cabi, Wallingford.
Saaty, T.L., 1977. A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology 15, 234–281.
Saaty, T.L., 1987. Rank generation, preservation, and reversal in the analytic hierarchy decision process. Decision Sciences 18, 157–177.
Saaty, T.L., 1999. Decision making for leaders: the analytic hierarchy process for decision in a complex world: 1999/2000 edition. Rws Publications.
Sojda, R., 2007. Empirical evaluation of decision support systems: Needs, definitions, potential methods, and an example pertaining to waterfowl management. Environmental Modelling and Software 22, 269–277.
Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., de Haan, C., 2006. Livestock's Long Shadow, Environmental Issues and Options. Food And Agricultural Organization of the United Nations, Rome.
Sterman, J.D., 2000. Business Dynamics: Systems Thinking and Modeling for a Complex World. Irwin/McGraw-Hill, Boston.
Thornton, P.K., Kruska, R.L., Henninger, N., Kristjanson, P.M., Reid, R.S., Atieno, F., et al., 2002. Mapping Poverty and Livestock in the DevelopingWorld. International Livestock Research Institute, Nairobi.
Tkach, R.J., Simonovic, S.P., 2001. A new approach to multi-criteria decision making in water resources. Journal of Geographic Information and Decision Analysis 1, 25–43.
Uran, O., Janssen, R., 2003. Why are spatial decision support systems not used? Some experiences from the Netherlands. Computers, Environment and Urban Systems 27, 511–526.
Vennix, J.A.M., 1996. Group Model Building: Facilitating Team Building using System Dynamics. John Wiley and Sons, Chichester.
Vonk, G., Geertman, S., Schot, P., 2005. Bottlenecks blocking widespread usage of planning support systems. Environment and Planning A 37, 909–924.
Voogd, H., 1983. Multicriteria Evaluation for Urban and Regional Planning. Pion, London.
Winkler, R.L., 1982. Research directions in decision making under uncertainty. Decision Sciences 13, 517–533.

Chapter 5

Discussion

The preceding chapters explored the adoption and use of spatial planning support systems (PSS) in planning practice, with special emphasis on PSS for regional, strategic spatial planning of metropolitan landscapes. Some case studies were presented that focus on the development and use of PSS that support the balancing of economic against environmental objectives in spatial planning. This concluding chapter will reflect on the results from the perspective of the theory and literature that were presented in the Chapters 2 and 3. The Sections 5.1 and 5.2 answer and discuss the two research questions that were raised in the introduction chapter. The final conclusions and recommendations for future research are presented in Section 5.3.

5.1 Strategic spatial planning for metropolitan landscapes

This section answers and discusses the first research question: *What strategic spatial planning approaches and methodologies are required to deal with the complex and dynamic development of metropolitan landscapes?*

Chapter 2 described the growing concern in society about the rapid urbanization worldwide, resulting in a loss of farmland and natural resources. The challenge of contemporary land-use planning is to find a balance between economic and urban development on the one hand, and environmental protection on the other. This task is becoming more and more complex as planners and decision-makers have to deal with a diversity of increasingly involved stakeholders with often conflicting objectives. Moreover, while cities and their influences on the rural area tend to expand beyond local administrative and political boundaries, management and governance shows a shift toward decentralization of decision making. Spatial planning showed a similar shift toward local, participatory planning. However, many local governments are not well equipped with the capacity and means to deal with the complexity of the metropolitan landscape (Montgomery et al. 2003). Traditionally, local administrations cherish their independence (Needham & Zwanikken 1997) and, in general, tend to focus primarily at the area within their administrative boundaries. Planning practice shows a general lack of willingness and ability to cooperate closely with neighboring local administrations, especially when it comes to urban and economic development, and sharing profits. Local administrations tend to balance economic development and environmental protection from their own, local perspective. This is especially relevant in developing countries where economic development is usually the top priority. In such circumstances it will be extremely difficult to keep a balance between the general call for economic development and the urgent need for environmental protection. The AWI and LWMEA experiences show that environmental protection can only be achieved if the objective of economic development is secured.

In general, regional governments (such as provinces) will be essential for the success of more sustainable spatial policies, but this requires that they adapt their style of governance and be prepared to be unpopular (Needham & Zwanikken 1997). Regional governments will need to coordinate the spatial developments at the local level more strictly, and use their regulatory instruments to reconcile the competing demands of

economic development and environmental protection (see also ESPON 2004). This requires that provincial as well as local governments think both in long-term and short-term policies and actions, by creating strategic visions on the future spatial development of a region as a whole, as well as short-term measures to direct the regional and local spatial developments in a more sustainable way. Given the increased role of public actors in communicative planning, the challenges for regional and local administrations are to exploit the financial and other powers of the private sector, but simultaneously manage developments in a sustainable way (Dimitriou & Thompson 2007b). As discussed in Chapter 2, these challenges require a planning approach which combines the creation of strategic visions at the regional level with the ability to involve regional and local administrations and relevant stakeholders to the planning and decision-making process. Albrechts (2004a) promotes a (strategic) planning process which allows constructing alternative futures in an open and creative way, mobilizing the plurality of actors with often competing interests, goals and strategies, in order to develop creative and territorial differentiated solutions to problems and challenges. An example of such a combined approach stems from the Wageningen planning program, which promotes the intertwining of the decision- and design-oriented view of planning (van der Valk & Carsjens 2005). Both views have much in common, as was shown with Table 2-6 in Chapter 2. Besides the many common characteristics and interchangeable elements of decision- and design-oriented planning, it was also argued that the weaknesses of the one approach are generally the strengths of the other, backing the assumption that decision- and design-oriented planning are complementary.

The basic elements of the approach of intertwining decision- and design-oriented planning include identifying focal issues or decision areas, and constructing alternative futures (scenarios) and packages of short- and long-term actions (commitment packages). The process is dynamic and creative, and does not flow smoothly from one phase to the next; a useful strategy for decision-making in environments of varying stability and actors with varying control and consensus-building capacities (Etzioni 1967, Albrechts 2004a). But as a consequence, linking the long-term vision and the commitment package is a difficult step, which was illustrated with the experiences in strategic spatial planning courses at the Wageningen University. The students were confronted with difficulties due to differences in the object of planning, the timeframe and sometimes also the spatial scale of the long-term vision and the commitment package. The prescriptions taken from planning methodology classes are, of course, a starting point for dealing with these issues, but these need to be put into and adapted to the specific context of the planning task at hand. The process of adaptation includes generating and revising new knowledge ("learning by planning") as well as monitoring, evaluating and adjusting strategies and outcomes ("learning by doing") (Wiek et al. 2006). Friend and Hickling (2005) argue that such complex situations require so-called 'open technology' which supports communication and interaction between many different experts, to cut across the inter-meshed decision areas, for instance about finance, location, techniques, marketing, people, contractual and procedural issues.

The task of managing developments in a sustainable way may also need entirely different approaches. For example, Von Schomberg (2002) argues that it is "[…] not plausible that a much needed long-term sustainable development policy can get off the ground, if we are for the achievement of consensus on such a policy, fully dependent on the usual arenas of societal conflict resolution, e.g. the arenas of the 'market' and of '(Party) politics'." (von Schomberg 2002: p. 1). He makes a plea for a so-called third institutional arena for long-term policy and planning, which allows dealing with the conflicting interests between individuals, society and the environment (i.e. the limited availability of natural resources across generations). Such an arena should not be based on equal distribution, but on equal conservation or maintenance of resources in a way which does not compromise the ability of future generations to meet their own needs. Von Schomberg (2002) concludes that the ambition level of Brundtland's definition of sustainability is too high if this is associated with maintaining present wealth-levels. Instead he suggests a down-grading to a level of balancing the present, individual focused and market-based needs and the collective needs of future generations. The enormous size of the task that lies ahead for us can be exemplified with concepts like the ecological footprint (Wackernagel & Rees 1996), the water footprint (Chapagain & Hoekstra 2004) and the carbon footprint (Wiedmann & Minx 2007), e.g. showing the present over-consumption of world resources by the developed countries.

The AWI and LWMEA projects illustrate the entirely different socio-political situation in the growing economies such as China. Despite the comprehensive regulatory and institutional framework for environmental and urban growth management, which has been set up during the last decade in China, these policies have not been very effective (OECD, 2005, Beyer, 2006). The current Chinese spatial planning system is unable to manage and guide the process of urbanization, involving many different stakeholders, conflicting interests and rapid transformations. Main reasons are the traditional top-down character of policy and planning, conflicting interests at the different administrative levels, and a lack of engaging relevant stakeholders and the general public (Friedmann 2004). Claims generating from adjacent policy domains, such as transport planning and water management, are generally not taken into consideration in regional spatial planning. As a result, an integrated approach incorporating various land-use claims is hampered. The OECD (2005) states that promoting public participation in environmental policy and decision-making and removing barriers for the development of environmental non-governmental groups should be key objectives of the state and local administration in China. However, in contemporary China the scope of public participation and independent political activism is still limited (Beyer 2006). Furthermore, the system lacks an administrative body which takes the responsibility for implementing and monitoring the process of regional land-use planning, and is unable to engage relevant stakeholders and manage the communication between different administrations. The AWI cases identified the expertise to drive action as a weak point for success in addressing environmental issues. Continuous effort to develop and strengthen professional capacity shows to be a key factor of success.

5.2 Planning support systems for the spatial planning of metropolitan landscapes

This section answers and discusses the second research question: *What type of planning support systems (PSS) are needed to support the strategic spatial planning of metropolitan landscapes and what are the requirements for the successful implementation and use of such PSS in planning practice?*

The complexity and dynamics of strategic spatial planning for metropolitan landscapes require making difficult choices and understanding the complex trade-offs associated with different options and developments. In such a context, planners face the task to acquire an overview and make the actors and decision-makers aware of the potential spatial implications of the choices at hand. If people have a better understanding of the links between choices and consequences, it is more likely they make a well balanced and sustainable choice (Sharma et al. 2006). Planning support tools can support planners and decision makers with this complex task, by improving their understanding of present and future problems and options. Chapter 2 revealed some distinct characteristics regarding the context and process of strategic spatial planning which are important to consider when constructing and implementing PSS: (a) context specifity, (b) the ability to support an integrated approach, and (c) the ability to involve actor and stakeholder interests. The results of the case studies, with respect to these characteristics, will be discussed below.

Ad a. Context specificity

The presented planning support systems differ in their context and embedding in the decision making process. But all show the importance to start the development of a PSS with clearly identifying the specific user needs and requirements, linking to the elements of their day-to-day planning and decision making. The research illustrates that the better a PSS fits to its specific context, such as commonly accepted data, workflows, procedures, tools and instruments, the more likely it is that the PSS will be applied successfully and used on a more regular base. This is consistent with other research, e.g. of Batey & Breheny (1978) and Wong (1998) who concluded that planning support tools should be as much concerned with the political and social context as with their more specific substantive content. Consequently, it is important to make clear how the results of the planning process can benefit from the use of these tools. In order for a new decision support tool to be taken up operationally, decision makers will need to be convinced that the tool is reliable, and that it adds some value over existing approaches. A typical example of the barriers that have to be breached is the quote “We haven't got a GIS. It isn't a problem for us; why is it a problem for you?” (Higgs 2004, p. 285), which was the response in a survey among information managers in the UK. In general, the acceptance of planning support tools will improve if there are transparent connections with generally accepted elements of planning practice, availability of suitable data, and functions that target specific regulations and procedures to be undertaken on a regular basis.

In this respect, recent literature on the diffusion of new technology increasingly emphasizes the organizational, social and cultural factors that influence the adoption of technology (Couclelis 2004). For example, Allen (2000) argues that technological innovation has to compete for scarce resources with established practices, and is often regarded as taking a risk with uncertain returns. The involved disciplines may also have their own views of what the technological innovation is about, what problems it can solve, and what the benefits and costs of adoption will be (Couclelis 2004). Therefore, the seemingly best technology will not always win in the long run, while usually other (even inferior) alternatives will be developed and used (Allen 2000). Allen (2000) identified two themes underlying more recent approaches to study technological innovation: The concepts of social commitment and problem framing. Communities of practice usually have a history of making social commitments by employing their resources in ways that may be difficult to reverse, making the changes involved with the introduction of new technology difficult to implement (Allen 2000). Problem framing refers to the differences in views between technology developers and potential users about the problem that a technology should solve. The development of PSS seems to be mainly driven by geo-ICT ('technology-push') rather than the needs of humans and organizations ('user-pull'). PSS developers are often more interested in developing cutting-edge analysis and spatial modeling systems, while users are demanding much simpler systems, mainly for storage, retrieval, visualization, and communication of information during problem analysis and exploration (e.g. Couclelis 2005, Vonk et al. 2007b, te Brömmelstroet 2007). The AWI and LWMEA projects show that this is even more relevant in countries with limited modeling capacity and less familiarity with computer models. For that reason, the methods and PSS described in the presented cases are simple and robust, enabling spatial and statistical information to be consolidated and analyzed with minimal modeling resources.

Ad b. Ability to support an integrated approach

Dealing with the complex issues of metropolitan landscapes asks for an integrative approach in exploring alternative options and working towards a common vision. But this requires that the disciplines involved are willing to communicate and cooperate on an equal basis in the early phases of the process, and are enabled to monitor and intervene in the process from the early beginning. The STEPP cases illustrate the importance of dealing with internal communication, given the very traditional view of the disciplines involved on their role in the process. This requires a change in mentality from a monodisciplinary to an interdisciplinary focus. But disciplinary worldviews are difficult to change, and most likely will frustrate a successful implementation of PSS that stem from different communities of practice with different kinds of problem framing. In order to be successful a PSS should therefore provide a shared representation of the planned objects and thus improve the level of understanding and communication. With respect to the adoption of a PSS, Couclelis (2004) argues that "[…] the cost-benefit calculus of adoption must be made more transparent to potential adopters so as to make the departure from old ways of doing things less stressful and professionally risky." (Couclelis 2004, p. 17).

Ad c. Ability to involve actor and stakeholder interests

The case studies demonstrate the importance of dealing with external communication as well, given the wide range of stakeholders that participate in spatial planning and decision-making processes nowadays. This requires a systematic and process-oriented approach that enables to incorporate expert knowledge and stakeholder opinion into planning and decision-making. Decision makers tend to have much more confidence in results that draw upon local knowledge and skills, and this confidence places them in a stronger position to apply the results when formulating policies (Geertman & Stillwell 2004; Uran & Janssen 2003). External communication played a critical role in the process of developing planning support systems in the LWMEA project. Decision-makers, planning professionals and relevant stakeholders, including the intended end-users of the PSS, were involved from the early phases of the project and communicated intensively with experts and PSS developers. This approach meets with recent planning literature which promotes communities of practice (COP) (Brown & Duguid 1991) as a common ground for sharing knowledge and experimenting with and testing PSS in practice (Vonk et al. 2007a). In fact, the LWMEA project can be regarded an example of a community of practice, in which policy makers, planning professionals, geo-information specialists and professional stakeholders expressed their common concern about the problems related to the current livestock production in Asia, and are cooperating closely to develop appropriate policies, regulations and planning support systems.

The use of a planning support tool in an interactive setting for identifying future options requires that the tool is valuable to the range of stakeholders and actors involved in the process. Especially in complex situations, with many stakeholders involved, the interface of the tool should be simple and easy-to-understand, e.g. by avoiding technical terms (see also Sharma et al 2006). However, Carsjens & van der Knaap (2002) also stress the importance to keep the analysis process itself transparent and to avoid integrating too many different issues; otherwise even simple tools may loose their simplicity and become a 'black-box'. In general, this is also a major risk with external communication. A PSS can easily become a 'black box' if the users of the output do not fully recognize the limitations of the tool and its output. Despite the fact that output maps may look very detailed and can suggest a high degree of accuracy, these are often not. Regional scale maps, which are typical for strategic spatial planning, can be used in an indicative way only, especially given the many uncertainties involved (see also Section 3.1). The distribution of such output, like in the LWMEA project, might therefore require more sketch like presentations e.g. using fuzzy borders.

5.3 Concluding remarks

Some general conclusions can be drawn from the research with respect to PSS supporting strategic spatial planning of metropolitan landscapes. First of all, PSS should be as much concerned with their context and processes of use as with their more specific substantive content. This conclusion, though, is not very innovative, as

similar conclusions have been drawn for long by, for instance, Batey & Breheny (1978) and Wong (1998). Apparently, the situation has not improved much in the last three decades, and probably demonstrates the sheer difficulty of convincing planning practitioners of the added value of geo-ICT, as well as the struggle of PSS developers to provide the kinds of tools that planners really need (cf. Couclelis 2005). The approach of introducing communities of practice (COP) (Brown & Duguid 1991, Vonk et al. 2007), as applied in the LWMEA project, may offer a potential breeding ground to break through these barriers. However, the STEPP research demonstrates that the successful use of PSS tools also may rely heavily upon an initiator or individual team member. Although the STEPP tool has been used successfully in several projects at the SAB office for urban planning, the PSS has not been used since the two project members at SAB changed their jobs. This matches similar experiences of Godet (2000) who concluded that a future study rarely survives after the departure of the initiator. He argues that if one had months or a few years to finish the task, the risk of change of team members or even the team leader is inherent in the startup phase.

The research shows that the successful use of the results of a PSS requires a translation of these results into real action. The impact of a PSS will depend on how the output can and will be used in the planning and decision making process, and if the output can actually make a change. Therefore, the embedding of the PSS in the specific context and process, as discussed above, becomes even more important. In developing countries the successful use of the output of a PSS often requires additional policy instruments that need to be developed, and even more important, implemented and enforced, as was shown in the LWMEA project.

The thesis provides some lessons for the development and effective integration of planning support systems in strategic spatial planning of metropolitan landscapes. These lessons are related to the design of PSS and their output (content related) as well as the embedding in the planning process (process related). Both are very much intertwined and should be fully taken into account from the first start of the design process of the PSS, in order to improve the chance of a successful implementation and use in planning practice. Several topics have not or only marginally been addressed in this research and deserve more attention in future research. These include:

- Experimenting with developing PSS in communities of practice (COP). This is a main challenge in the LWMEA project, which aims to present its final results in 2011.
- Dealing with the differences in problem framing and roles of disciplines in spatial planning processes.
- Assessing the options for communicating uncertainty to the users of a PSS and its output. The methods which have been discussed in Chapter 2 provide several ways of dealing with uncertainties, and will be relevant in this context. But these should be extended to address the uncertainty related to the reliability of planning support models (UM) and their output (see Couclelis 2005). Efforts to pin down and communicate uncertainty "[…] are all the more important at an age when spatial data jump from the desktop to the handheld and ride unchecked along the web […]" (Couclelis 2003, p. 174). This is another

important topic that is currently being addressed in the LWMEA project. The aim is to develop a comprehensive meta-data assessment system as an integrated part of the PSS. The system should provide the users of the PSS and its output with supporting information on the reliability of the output and the shortcomings due to unreliable or missing input data (Carsjens & Chen Wenbo 2008).

It should be reminded that the scope of this research was restricted to PSS for supporting strategic spatial planning processes, and the research specifically focused at the use of PSS in two particular case studies: (1) the spatial-environmental issues related to urban development in the metropolitan landscape in the Netherlands, (2) the spatial-environmental issues related to the development of intensive livestock farming in the metropolitan landscape in South-East Asia. Although the research only addresses a small part of the complex and dynamic reality of metropolitan landscapes, it makes clear that each specific planning problem will require a unique combination of people, skills and tools. Given the dynamics and complexity of the domain, PSS will never provide 'push-button' solutions, but instead can support strategic spatial planning by offering a range of options as input in the process. A general conclusion which can be drawn from the research is that PSS should be tailor-made to the potential users, context and process. This requires that users and other stakeholders are involved from the early beginning in the process of development of a PSS, and that PSS developers become a part of a community of practice before they even start to think about what technology has to offer.

Appendix

Zhao Xiaomin, Gerrit J. Carsjens, Pierre Gerber, 2006. Regional planning of pig husbandry with environmental protection using GIS, Transactions of the Chinese Society of Agricultural Engineering 22: 184-188. (For the English translation: see page 241).

GIS在环保型养猪业区域规划中的应用

摘 要：快速发展的养猪业在带来巨大社会效益和经济效益的同时也带来了许多环境问 题，FAO从1998年开始启动了养殖业环境与发展项目，目的是为了在促进养殖业发展、增加经济效益的同时大幅度减少养殖业对环境的不利影响。该文是FAO项目中的一部分，主要是应用GIS技术工具，通过建立养猪业选址的指标体系，发展了可持续的畜牧业生产建设区域规划的决策辅助工具，以减少养猪业发展对环境带来的负面影响；并且将该技术在江西省的养猪大县万年县进行了具体的应用。

关键词：GIS；养猪业；区域规划；废物处理；环境保护

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0 引 言

随着人口增加、经济发展、都市化进程和人们对畜产品需求的增加，养殖业在东亚迅速发展，别是规模化、工厂化的养殖业发展发生了巨大的变化[1]。但是，快速发展的养殖业却同时也带来了巨大的环境问题[2,3]：大量排放的畜粪和污水带来富营养化、污染和病菌对地表水和地下水造成污染，难闻的气味造成对空气的污染，养殖场之间的病菌传播感染等等。规模化养殖业已经成了农业面源污染的主要来源[4,5]。

为了研究和解决这些问题，联合国粮农组织(FAO)从1998年开始启动了养殖业环境与发展项目，目的是为了在促进养殖业发展、增加经济效益的同时大幅度减少养殖业对环境的不利影响[6]。项目的研究内容主要包括3个部分：(1)畜牧业生产及其环境影响的经济效益和政策分析；(2)畜牧业产生的固体和液体废弃物的数量、组成和用于农业的营养成分分析，以及所引起的环境影响及其解决途径；(3)空间分析，主要是利用GIS为工具对未来畜牧业发展的选址和为处理固体废弃物建立有机肥厂的选址。

本文是FAO在江西万年县养猪业可持续发展项目中的一部分。是应用GIS强大的空间分析功能[7]，通过建立万年县养猪区域规划的指标体系，发展了可持续的养猪业区域规划的决策辅助技术，以减少养猪业发展对环境带来的负面影响。

1 应用的方法和资料

GIS(ArcGIS8.3)，特别是其中的空间分析模块和3D分析模块被作为主要的技术工具[8,9]，结合多目标的选择标准和土地利用规划技术共同应用[10,11]。

所应用的基础资料主要包括：万年县大中型养猪场分布图；万年县生猪密度图；万年县人口密度图；万年县海拔高程图(10m等高距)；万年县乡镇分布图；万年县道路和水系图；万年县土地利用图；万年县土壤类型图，等。有关人口、作物生产、经济指标和社会指标等来源于《万年县社会经济统计年鉴》。

2 项目研究区概况及养猪场的环境影响

2.1 研究区概况

万年县位于江西省东北部，其地理位置坐标为东经116°46′48″~117°15′10″，北纬28°30′15″~28°54′5″。土地总面积 1139.5 km^2，是一个以平原、低山丘陵为主的县。 该县水资源丰富，年降雨量 1800 mm，水系发育成网状，向东北方向流人中国第一 大淡水湖——鄱阳湖。经济状况相对落后，全县有 16个乡(镇)，总人口 32万，2001年 人均GDP为 2953元，只有全国平均 7546元的 39.1% 。

万年县是一个农业大县，以种植粮食作物一水稻和养殖业一养猪和养珍珠为主。每个农户的农业生产耕地面积都很小，全县平均为 0.3 hm^2 。农民的人均年收入为 1969元，其中 73% 来自于农业生产(粮食生产来源 45%，畜牧业生产来源 28%)。万年县农业生产中畜牧业与作物的效益比值为 40 : 60，说明在该县畜牧业占有较重要 的位置(全国平均比值为 30 : 70)。

生猪养殖是万年县畜牧业的支柱产业。2001年，万年县出栏生猪 310000头，其中 10% 用火 车销往香港和澳门，25% 在本县销售，65% 用汽车销往国内其他地区如上 海、广东等地。其他的养殖业为 5% 的家禽和 2% 肉牛养殖。现在，万年县有 10000 头以上的商品养猪场 10个，1000～10000头之间的中型养猪场 5个，500～1000头之间 的小型养猪场 50个，另外有 4个万头养猪场在建设中，将于2006年投产，商品猪场养 殖占全县养猪业的 60%。其余 的 40% 生猪是在农户家庭内分散养殖。

2.2 万年县养猪业的环境影响

商品养猪业的发展，带动了万年经济的发展，但也带来了一些环境问题，特别是大中型养猪场的环境问题明显。

在大中型养猪场，每天用水冲洗 4～5次。冲洗的废水(含固体废物)被排入到沉降池中，固体废物沉降后部分用做蔬菜、果树的有机肥，大部分堆积在附近或倒入附近的农田；而含有大量有机物和重金属的废水被排入农田、河流或水塘中，引起周围土地和水体的严重污染。根据在养猪场的污水排放口、污水排入河流的入水口及入水口上、下游各 50 m 处采 水样，实验室分析有关数据如表 1。

从表1中检测数据可知，尽管河水会稀释养猪场废物的污染，但污染仍然有一定的程度，特别是对养猪场附近的土地和水体污染大。

对小型和家庭方式的养猪，由于分散和废物主要用于家庭沼气发酵，残渣用做有机肥，因此不会有显著的环境影响。

Table 1 Environmental influence of pig farm wastewater on river water (mg·L^{-1}).

表1 养猪场污水对河水的环境影响

分析项目	排放口	入河口	入河口 下游 50 m	入河口 下游 50 m
总固体悬浮物(TSS)	2912	328	50	38
生物需氧量(BOD)	636	40	3.6	2.6
化学需氧量(COD)	1023.0	94.0	15.5	10.0
总氮(TN)	595.0	66.2	14.7	7.4
总磷(TP)	81.6	12.9	0.1	0.1
总钾(TK)	441.0	33.0	4.1	1.7
锌(Zn)	0.70	0.03	0.0037	0.001
铜(Cu)	0.66	0.054	0.024	0.019
砷(As)	0.0120	0.0016	0.0008	0.0005
大肠杆菌数量(Coli) / 个·L^{-1}	5400	1100	720	690
细菌总数(Bacteria) / 个·L^{-1}	75 x 10^4	2.5 x 10^4	2.2 x 10^4	1.8 x 10^4

3 环保型畜牧业的空间规划

万年县畜牧业空间规划的主要目的是评价适合未来商品养猪场建设的潜在区域，以减少因养猪业发展引起的环境问题。因此，GIS被作为主要的技术工具，以国内外土地可持续利用指标体系为基础[12-14]，结合应用多目标的选择标准和土地利用规划技术。

3.1 大中型养猪场的适宜性分析

3.1.1 确定建设大中型养猪场的限制区或不适宜区

这些区域包括：

1) 所有的耕地，特别是基本农田保护区。包括灌溉水田、望天田、旱地、蔬菜地等;
2) 城乡居民点区域及其周边 300 m 的缓冲区。目的是防止对居民生活区的废水和大气污 染;
3) 现有大中型养猪场及其周边 2 km 的缓冲区。是为了生猪传染病的卫生防疫;
4) 主要水体 (湖泊、大中型水库、河流) 及其周边 200 m 的缓冲区，以防止对地表水的 污染;
5) 坡度大于 25° 的区域;
6) 为了卫生防疫的要求，主干公路及其两侧100 m 的区域;
7) 小于 20000 m^2 的区域，因为面积太小无法建设大中性养猪场及其废物处理设施。

3.1.2 建设养猪场区域的适宜性分级标准

对适宜建设养猪场的区域进行适宜性分级评价，分级时采用人为赋以适宜性分值的方法。分级的标准主要有4个：

1) 与主干道路的距离。在离道路 100～600 m 之间，是最适宜的区域，赋适宜性分值 100；在万年县内距离主干道最远的为 8 km，赋适宜性分值 0；600～8000 m 之间 的区域分值按照距离从 100～0 直线衰减。
2) 与主要水体的距离。在距离水体 200～1500 m 之间，是最适宜的区域，赋适宜性分 值 100；同主干道一样，1500 m 以外的区域离水体越远分值越低，按照距离从 100～0 直线衰减。
3) 与城乡居民点的距离。距居民点 300 m 内分值为 0，从 300～1000 m 赋分 100； 在距居民点 1000 m 以外，距离越远分值越低，按距离从 1000~0 直线衰减。
4) 与其他大中型养猪场的距离。在距离大中型养猪场 2 km 的范围内，赋分为 0；在 2 km 以外，距离越远越有利于卫生防疫，因此按照距离越远分值越高直线增加。
5) 地面坡度。以 0° 为最适宜，赋分值 100；20° 赋分值为 0；0°～20° 之间随坡度增大分值以直线衰减的形式降低。
6) 每个乡镇的主要农作物养分平衡。从分析和计算各个乡镇的 N、P、K 农作物养分平衡结果，磷的平衡是影响环境的主导因子。各个乡镇磷的平衡数据及其赋分见表 2。

3.1.3 万年县养猪业发展的方莱

将赋分得出的与主干道距离、与水体距离、地面坡度和农作物养分平衡等 4 张地图进行叠加
分析，可以得出万年县未来养猪场建设的适宜性区域及其等级。为了适应经济、环境等方面的要求，采用多目标决策技术，分别对 4 张地图叠加时给以不同的权重，
从而设定 3 个养猪业的发 展方案，分别是：环境可持续性方案(简称方案 1)、中间方案(方案2)、有利于生产和运输的方案 (方 案3)。在进行 4 张地图叠加时，不同方案的权重见表3。

Table 2 Crop P balance and its score at each village and town.

表2 各个乡镇农作物磷(猪粪为主要来源)平衡及其分值

乡镇	P收收 /kg	有机P /kg	缺P范围 /kg	赋分值
茅路	18645	14820	3825	11
石镇	36638	24228	12410	35
青云	66680	36152	30528	85
梓埠	89525	53702	35822	100
大源	24448	24877	9571	27
裴梅	52314	33794	18520	52
浮云	53648	40261	13387	37
齐埠	68239	62277	5962	17
大黄	48671	32909	15762	44
王家	46541	41780	4760	13
朱山	46597	35407	11190	31
上坊	75060	64646	10414	29
苏桥	53277	21503	31775	89
南溪	45342	40681	4660	13
富林	21393	18132	3261	9
朱田	40044	38753	1291	4
总计	797061	583925	213137	

3.2 养猪场空间分析的结果

主要是对万年县适宜建设新养猪场的区域进行空间分析，对已经及正在建设的大中型养猪场进行评价。

Table 3 Weights of hog industry scheme.

表3 养猪业发展方案的权重

标　准	权　　重		
	方案 1	方案 2	方案 3
与主干道的距离	1	2.5	4
与主要表水的距离	1	2.5	4
坡度	4	2.5	1
磷养分平衡	4	2.5	1

3.2.1 养猪场发展建设适宜性分析

将影响养猪场建设的单因素适宜性等级图分别按照权重进行叠加分析，得出万年县养猪场建设适宜性的3套等级方案，将适宜性分为7个等级(分别见图1、图2、图3)。从图中可以发现，万年县有92%的土地是不适宜建设养猪场，而其中的大部分区域又集中在东北部和东南部，主要集中的乡镇有石镇、大黄、汪家、梓埠、齐埠、湖云、苏桥、南溪和裴梅，这些乡镇3套方案的适宜性评价分值主要集中在701～1000之间。

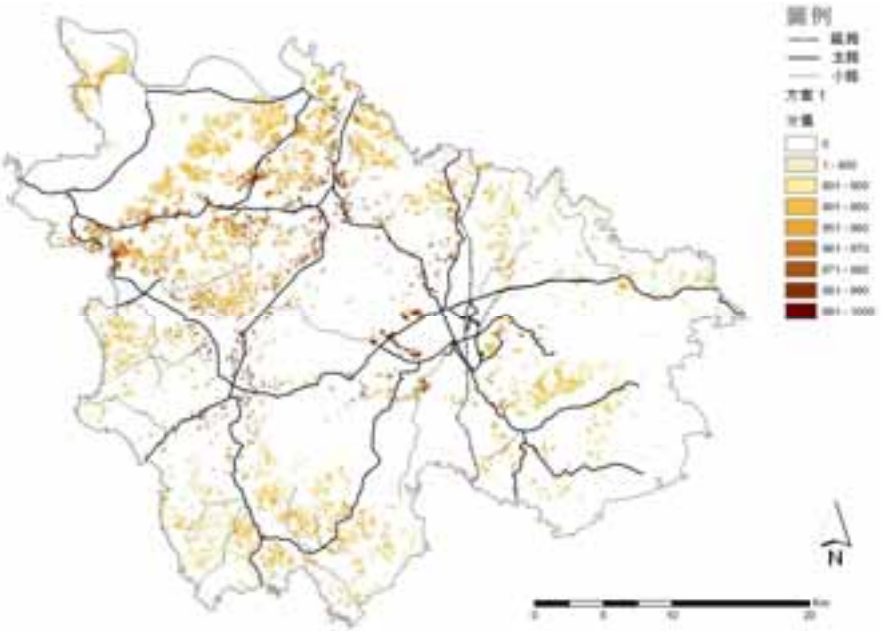

Figure 1 Final suitability map for new pig farming with Scheme 1: Sustainability.

图1 万年县养猪场建设适宜性等级图(环境可持续方案)

三个方案中，方案2是既有利于环境的可持续、又有利于生产和运输的中间方案。根据专家论证并征求当地群众与政府的意见，以方案2为万年县畜牧业发展的优选方案。表4是方案2(中间方案)中各个乡镇的适宜性评价分值，可以看出，最适宜的区域(分值在901～1000之间)全部集中在梓埠、苏桥和青云3个乡镇。

Table 4 Suitable area for pig farming per township and category with Scheme 2 (hm^2).

表4 万年县各乡镇养猪场建设中间方案(方案2)的适宜性面积

乡镇	各适宜性分值的面积						
	1~700	701~750	751~800	801~850	851~900	901~950	951~1000
[illegible]	0	0	0	0	0	0	0
石镇	390	87	220	416	0	0	1
青云	37	53	16	6	8	58	52
梓埠	72	114	46	44	82	225	282
大源	153	12	72	92	0	0	0
裴梅	222	54	48	128	131	0	0
浮云	252	17	95	226	0	0	0
齐埠	395	97	371	2	0	0	0
大黄	326	44	12	279	80	0	0
王家	270	116	271	1	0	0	0
朱山	101	6	12	87	0	0	0
上坊	74	18	55	23	0	0	0
苏桥	43	64	67	33	31	114	212
南溪	454	118	363	0	0	0	0
富林	126	58	25	0	0	0	0
朱田	375	165	42	0	0	0	0

根据万年县的农作物养分平衡结果，磷是对养猪业影响最大的因素。在全县主要农作物施用的全部为有机肥时且养猪场产生的有机废物全部应用在万年县，全县磷素短缺总量213137kg。按平均每头生猪每年产生的固、液体废物中含磷量2.1kg计，全县每年可以增加养殖生猪101684头。

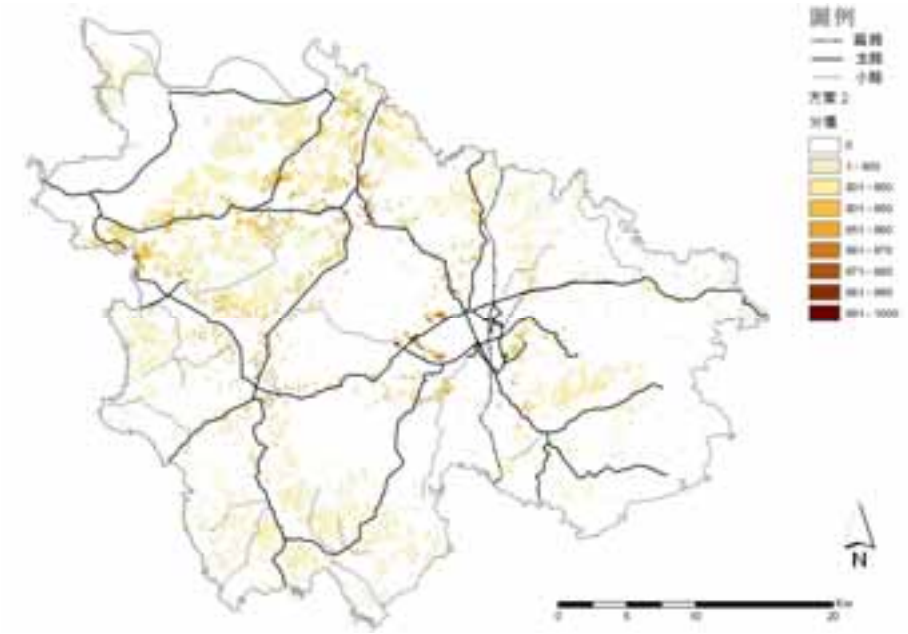

Figure 2 Final suitability map for new pig farming with Scheme 2: Neutral.

图2 万年县养猪场建设适宜性等级图(中间方案)

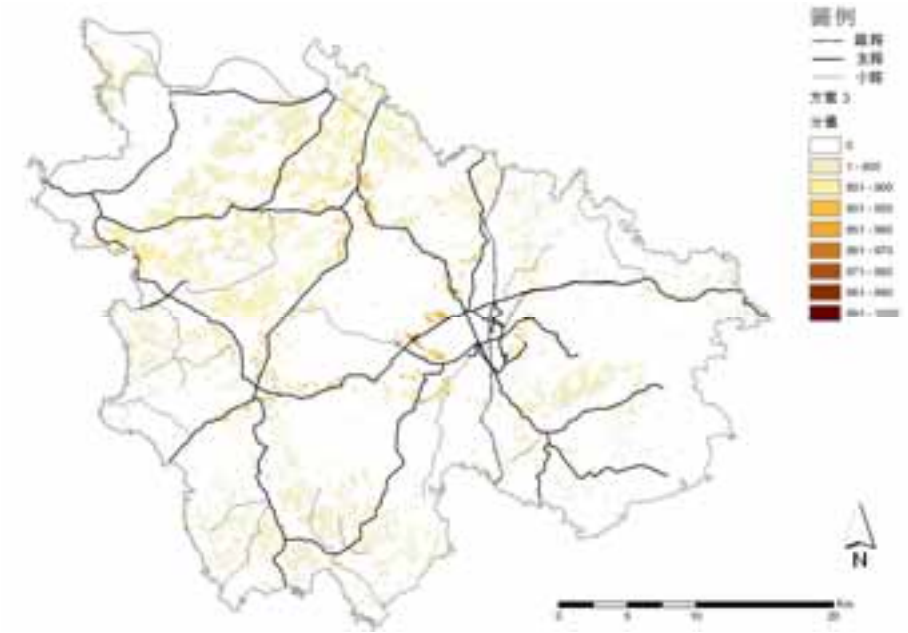

Figure 3 Final suitability map for new pig farming with Scheme 3: Production and distribution convenience.

图3 万年县养猪场建设适宜性等级图(有利于生产和运输的方案)

3.2.2 现有大中型养猪场的适宜性分析

应用评价未来养猪场建设的标准对已建和正在建设的22个大中型养猪场进行评价，得出现有大中型养猪场在建设选择时存在一些问题(表5)。其中有一个养猪场建设在耕地上，3个在离道路 100 m 的范围内，有14个建设在村庄附近(<300 m)，有9个相互的距离太近(<2 km)，不利于居民点的环境保护和猪场的卫生防疫。

Table 5 Assessment of the locations of the present medium and large pig farms.

表5 对现有大中型养猪场选址的评价结果

养猪场	类型	建设在不适宜的区域			
		在耕地上	距村庄 300 m 内	与其它猪场距离	距主于道 100 m 内
省外贸养猪场	大型	否	是	是	否
中新岭猪场	大型	否	是	是	否
山庄猪场	大型	否	否	是	否
金星猪场	大型	否	是	否	是
浮云猪场	大型	否	是	否	否
益友猪场	大型	否	是	是	否
浮云麓山猪场	大型	否	否	是	否
大黄猪场	大型	否	是	否	否
万年种猪场	大型	否	是	是	否
下家埠猪场	大型	否	是	是	否
马垅山猪场	中型	否	是	否	否
珠溪猪场	中型	否	否	是	否
洪来猪场	中型	否	是	否	否
西山蔡家猪场	中型	否	是	是	否
马家猪场	中型	否	是	否	是
南港猪场	大型	否	否	否	否
翟山猪场	小型	否	否	否	否
李家猪场	小型	否	否	否	否
毛公山猪场	大型	否	否	否	否
奇顺猪场	大型	否	是	否	是
青云猪场	大型	否	是	否	否

5 结 论

万年县养猪场适宜性分析得出万年县新建大中型 养猪场的适宜性面积只有 91.2 km^2,占全县土地面积的 8，其中最适宜的区域(分值在 901~1000 之间)全部集中在梓埠、 苏桥和青云 3 个乡镇，面积为 9.43 km^2。对已建或正在建设的养猪场分析得出，根据 环境保护、保护耕地和卫生防疫等方面的要求，有相当一部分养猪场都不符合要求。

从限制性养分元素一磷的分析，在养猪产生的万年县未来固体有机肥都应用在万年县的前提下，万年县新增养猪数量为100000头。

从研究中可知：应用GIS为主要技术工具，辅之以多目标评价的标准，在畜牧业环境和经济可持续发展规划中，有非常重要的、不可替代的作用。证明GIS是进行可持续发展规划和土地利用多目标空间规划的有效技术工具[15,16]。

本次可持续养猪业发展的空间分析和规划结果对FAO的万年项目是有力的技术支持，同时采用的技术方法和多目标决策标准也为FAO在东南亚地区其他项目(广东、越南、泰国)的完成提供了技术方法和经验。当然，空间分析只是FAO可持续畜牧业发展的一个部分，而且分析规划的适宜性结果也应该在不同时间随着可持续目标的发展而不断更新。

[参 考 文 献]

[1] 熊远．展望新世纪我国养猪业的发展方向与趋势 [J]. 动物科学与动物医学, 2003(8): 1-2．

[2] HJ / T81-2001. 畜禽养殖业污染防治技术规范 [S].

[3] 戴万源．集约化养猪场对城镇环境污染与治理效果观察 [J], 福建畜牧兽医, 2005, 27(4): 79-80．

[4] 高增月，杨仁全，程存仁．规模化养猪场粪污综合处理的试验研究 [J]. 农业工程学报, 2006, 22(2): 198-200.

[5] 彭 里，王定勇．重庆市畜禽粪便年排放量的估算研究 [J]. 农业工程学报, 2004, 20(1): 288-292.

[6] FAO. GEF Livestock Waste Management in East Asia Project [R]. Rome: FAO, 2004: 2-4.

[7] 宋力，王宏．GIS在国外环境及景观规划中的应用 [J]. 中国园林, 2002, 18(6): 56-59.

[8] 刘盛和．何书金，土地利用动态变化的空间分析测算模型 [J]. 自然资源学报, 2002, 17(5): 533-540.

[9] 赵小敏，艾亮辉，张宁珍．基于GIS的江西省农田划分等级研究 [J]. 中国生态农业学报, 2002, 10(1): 65-67.

[10] 赵小敏，陈美球．土地利用总体规划的技术方法研究 [M]. 北京：新华出版社, 2004, 12, 45-123.

[11] 郭 熙，赵小敏．鄱阳湖区土地资源评价 [J]. 江西农业大学学报, 2000, 22(4): 543-550.

[12] FAO. FESLM: An international Framework for Evaluating Sustainable Land Management [A]. World Soil Resources Report 73, Rome: FA0, 1993.

[13] 周 勇，田有国，任 意．定量化土地评价指标体系及评价方法探讨 [J]. 生态环境, 2003, 12(1): 37-41.
[14] 董家华．生态农业土地综合评价指标体系研究 [J]. 中国生态农业学报, 2002, 13(3): 25-28.
[15] 刘 字，曲 波，朱仲英，等．一种土地使用模糊空间决策方法 [J]. 武汉大学学报 (信息科学版), 2003, 28(2): 208-211.
[16] 张利华，薛重生．“3S”技术在土地可持续利用决策中的应用 [J]. 国土与自然资源 研究, 2004, (2): 50-51.

English translation of: Zhao Xiaomin, Gerrit J. Carsjens, Pierre Gerber, 2006. Regional planning of pig husbandry with environmental protection using GIS, Transactions of the Chinese Society of Agricultural Engineering 22: 184-188.

Regional planning of pig husbandry with environmental protection using GIS

Livestock production in China is growing fast, but the industrialization of production also created some serious environmental problems. In 1998, The Food and Agricultural Organization of the United Nation (FAO) started the Area-Wide Integration (AWI) research and development project with the aim of significantly reducing the environmental impacts of livestock production. This paper describes the results of the AWI project in Wannian County, with respect to the assessment of the spatial distribution and regional planning of pig husbandry. A site selection tool for future pig farms was developed and implemented in GIS. The use of the GIS tool can support a more sustainable regional development of livestock husbandry and production.

Keywords: GIS; pig husbandry; regional planning; waste disposal; environmental protection

0. Introduction

Livestock production in East Asia is growing fast, mainly supported by industrial systems. The demand for animal products has increased as a result of human population growth, economic growth and increasing urbanization [1]. However, the rapid growth in production has also created some serious environmental problems [2, 3], such as the excessive discharge of manure polluting surface and groundwater, odor nuisance and transmission of gasses to the atmosphere, and the spread of pathogens within the livestock production system. Industrial livestock production has become a main source of environmental degradation of the rural environment [4, 5].

In 1998, the Livestock Environment and Development (LEAD) initiative, based at the Food and Agricultural Organization of the United Nations (FAO), initiated the Area-Wide Integration research project with the aim of significantly reducing the adverse environmental impacts from livestock production, by integrating specialized livestock production with cropping activities on a regional scale. The project deals with three main issues [6]: (1) the assessment of current manure management strategies, and the financial, environmental and policy analysis of these strategies, (2) the design and evaluation of technical and policy options for a more sustainable future development of livestock production, and (3) the spatial analysis and planning of future livestock production areas, using GIS as a supporting tool.

This paper describes the results of the FAO case study project in Wannian County, Jiangxi Province, P.R. of China [7]. The paper will especially address the use

of GIS to support the regional spatial planning and decision making of future pig production areas.

1. Data and method

The assessment of potential locations for future pig farming was carried out using GIS (ArcGIS 8.3) spatial analysis modeling techniques [8, 9], and multi-criteria and land-use assessment techniques [10, 11]. The geo-data used include a pig farm distribution map, an elevation map with contour lines of 10 m interval, a map with administrative areas, a transport infrastructure map, a surface water map, a land-use map, and a soil map. The statistical data, derived from annual statistical reports of Wannian County, include human population, animal numbers, crop growth, and economic and social indicators.

2. Case study area and environmental impacts of pig farms

2.1. Case study area

Wannian County is located in the northeast of Jiangxi province, China, at 116º46'48" to 117º15'10" E longitude and 28º30'15" to 28º54'05" N latitude. It covers and area of 1,139.5 km^2. Large parts of the county are plain and low hills. Water resources are very abundant in the county, with an annual rainfall of 1,800 mm and a thick network of rivers and streams running northwest to the Poyang Lake, the largest freshwater lake in China. The county is one of the national poverty-stricken counties, and consists of 16 townships with a total population of 0.32 million people. The per capita GDP of the county is well below the national average. In 2001 the per capita GDP was 2,953 Yuan, or US$ 360, less than one dollar per day. The corresponding national average was US$ 920.

Wannian County is a typical agricultural county and one of the 500 commercial-food production bases in China. Agriculture is the key economic sector in the county. More than 80% of the population lives in the rural area and depend on the own agricultural production for their food supply. The average farm size is very small, just 0.3 ha. The average yearly farmers' income in Wannian County is US$ 240, of which 73% is derived from agricultural activities. Crop production covers 45% and livestock production 28%. The livestock-crop ratio of agricultural production is about 40:60, indicating the relative high importance of the livestock sector in Wannian County (the average national ratio is 30:70).

The meat production sector in the county is dominated by pig production, covering 93% of the total meat production. In 2001 a total of 310,000 pigs were marketed from the county, of which 10% for export to Hong Kong and Macao, 25% for the local market, and 65% for other domestic markets, such as Shanghai and Guangdong. The other livestock production includes 5% poultry and 2% beef. At present, Wannian County holds 10 large, 5 medium, and approximately 50 small commercial pig farms,

while 4 new large pig farms are being constructed and will be operational by the year 2006. The large farms each produce 10,000 heads or more annually, the medium size farm over 1,000 heads, and the small farms between 500 and 1,000 pigs. The commercial farms produce 60% of the pigs. The remaining 40% is produced in backyard operation of small household farms, usually with less than five pigs.

2.2. Environmental impacts of pig farms

The industrialization of pig production promotes economic growth in Wannian County, but it is also accompanied by adverse environmental problems, especially related to large commercial pig farms. In most of these farms the standard housing system facilitates waste removal from the pig house in a slurry form. Manure (solid and liquid) is washed down with groundwater 4 to 5 times a day, and collected in a sedimentation pond. Some solid manure is collected occasionally after sedimentation, e.g. by fruit farmers, and used as organic fertilizer. The remaining wastewater is being discharged into rivers or reservoirs, and causes serious environmental problems due to its high nutrient content.

In order to verify the potential contamination of rivers by wastewater, some samples were taken at a representative large pig farm. The river water upstream (50 m) and downstream (50 m) of the entry point of wastewater into the river was sampled, together with the wastewater at the discharging exit as well as the entry point into river. Several indexes were determined, such as total suspended solid (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen, phosphorus, and potassium. The results are shown in Table 1.

Table 1 Measured effect of pig wastewater on river water.

Tested items	Discharge exit	Entry into the river	Down stream (50m)	Up stream (50m)
TSS (mg/l)	2,912	328	50	38
BOD (mg/l)	636	40	3.6	2.6
COD (mg/l)	1,023	94	15.5	10
TN (mg/l)	595	66.2	14.7	7.35
TP (mg/l)	81.6	12.9	0.1	0.1
TK (mg/l)	441	33.0	4.07	1.66
Zn (mg/l)	0.700	0.030	0.0037	0.001
Cu (mg/l)	0.660	0.054	0.024	0.019
As (mg/l)	0.012	0.0016	0.0008	0.0005
The number of coli form bacteria per liter	5,400	1,100	720	690
The total number of bacteria per liter	7.5×10^5	2.5×10^4	2.2×10^4	1.8×10^4

The results show that for all tested indexes the river water downstream has considerable higher pollution levels than the river water upstream of the entry point. The

results also show that the wastewater purified much before entering the river, due to the relative long distance from the discharge exit to the entry point into river.

Small commercial pig farms and households tend to apply manure treatment techniques, including biogas digestion and composting. In general, these small farms do not cause major environmental impacts.

3. Sustainable spatial planning of future pig production

The assessment of potential areas for future pig farming, using a geographical information system (GIS), multi-criteria and zoning techniques, aims to support a more sustainable regional spatial planning and decision making [12-14].

3.1. Suitability assessment for large commercial pig farms

3.1.1. Identifying restricted and unsuitable areas for pig farming

The first step of the analysis of potential locations for future pig farming is to exclude areas restricted (due to provincial regulations) or unsuitable for pig farming. These areas include:

1. All arable land, especially in prime farmland zones, including irrigated paddy fields, rain-fed paddy fields, irrigated land, dry land and vegetable fields.
2. A 300 meter buffer zone around built-up areas, in order to prevent smell impacts. The built-up area is derived by selecting the urban area and villages from the land-use map.
3. A 2 kilometer buffer zone around the present and future large and medium size pig farms, for veterinary reasons.
4. A buffer zone of 200 m around main water areas (lakes and large rivers).
5. Areas with slopes larger than 20%.
6. A buffer zone of 100 meter around all present roads, for veterinary reasons.
7. Remaining parcels surrounded by unsuitable areas and smaller than 20,000 m^2, because these are considered too small for establishing a large commercial pig farm, including waste treatment facilities.

3.1.2. Suitability criteria for pig farming

The second step of the analyses is to classify the remaining areas for their suitability for pig farming. Four criteria are used: (1) the distance to main roads, (2) the distance to main surface water, (3) the slope of the area, and (4) the nutrient balance per township.

Distance to main roads

The areas most close to a road have a higher suitability, with exception of the excluded areas in the 100 m buffer zone. The locations within 600 m of a main road are considered the most suitable (suitability score 100). Subsequently, the largest distance from a main road to any point in the county is calculated. This maximum distance,

approximately 8 km, is classified as not suitable (suitability score 0). Between 600 m and 8,000 m the suitability score is assumed to decrease linearly from 100 to 0.

Distance to main surface water

For surface water the same type of calculations as with roads are used. Locations within 1,500 m of surface water are considered most suitable (100), with exception of the 200 m buffer zone. The score decreases linearly from 100 to 0 between 1,500 m and the maximum distance to surface water in the county.

Slope of the area

Flat areas with slope of 0º are considered the most suitable (100), while areas with slopes over 20% (approximately 10 degrees) are unsuitable (0). The suitability scores decreases linearly between both.

Nutrient balance per township

The AWI-concept aims to establish a land-livestock balance at the regional level. Ideally, townships with more livestock compared to the area of arable land, should be classified less suitable for new pig farms compared to townships with less livestock. Therefore, a nutrient balance was calculated for each township. In the assessment, the absolute difference between the crop uptake of P and the availability of P from manure is used to calculate a score (see Table 2).

Table 2 Land-livestock P-balance and scores per township.

Township	P uptake	P manure	P shortage	Score
Chen Yun	18645	14820	3825	11
Shi Zhen	36638	24228	12410	35
Qing Yun	66680	36152	30528	85
Zi Bu	89525	53702	35822	100
Da Yuan	34448	24877	9571	27
Pei Mei	52314	33794	18520	52
Hu Yun	53648	40261	13387	37
Qi Bu	68239	62277	5962	17
Da Huang	48671	32909	15762	44
Wang Jia	46541	41780	4760	13
Zhu Shan	46597	35407	11190	31
Shang Fang	75060	64646	10414	29
Shu Qiao	53277	21503	31775	89
Nan Xi	45342	40681	4660	13
Fu Lin	21393	18132	3261	9
Zhu Tian	40044	38753	1291	4
Total	797061	583925	213137	

The township with the largest P-shortage gets a suitability score of 100, while the situation with an equal P-balance (no shortage) gets a score 0. The score decreases gradually between both.

3.1.3. Scenarios for pig production in Wannian County

The four suitability maps are then integrated in order to derive a final suitability map for future pig farming, using multi-criteria techniques. Three different scenarios are introduced, involving different sets of weights for the four criteria. These are a scenario 1 with a set of weights representing an environmental sustainability perspective, scenario 2 with a neutral set of weights and scenario 3 with a set of weights representing a production and distribution perspective. The corresponding weights, for each scenario totaling 10, are presented in Table 3.

Table 3 Weights for the three scenarios.

	Weights		
Criteria	Scenario 1	Scenario 2	Scenario 3
Distance to main road	1	2.5	4
Distance to main surface water	1	2.5	4
Slope of the area	4	2.5	1
P-balance	4	2.5	1

3.2. Results

This section describes the results of the assessment of suitability of potential locations for future pig farming. The locations of the present large commercial pig farms are also assessed for their suitability.

3.2.1. Identification of suitable areas for pig production

The suitability maps for the four criteria were integrated using weighted linear combination, for each of the three scenarios of Table 3. The resulting final suitability maps are shown in the Figures 1 to 3. Seven suitability classes are used. The analysis showed that 92% of the area of Wannian County is restricted area or unsuitable for pig farming. The remaining potential areas are concentrated in the northwest, south en southeast of the county. Large clusters of potential areas are situated in Shi Zen, Da Huang, Wang Jia, Zi Bu, Qi Bu and Hu Yun townships in the northwest. Some other large clusters of potential areas are located in Shu Qiao, Nan Xi and Pei Mei townships in the south.

The suitable areas per suitability class and township for scenario 2 are shown in Table 4. Scenario 2 is a neutral scenario, balancing the production and distribution and the sustainability perspectives of the other two scenarios.

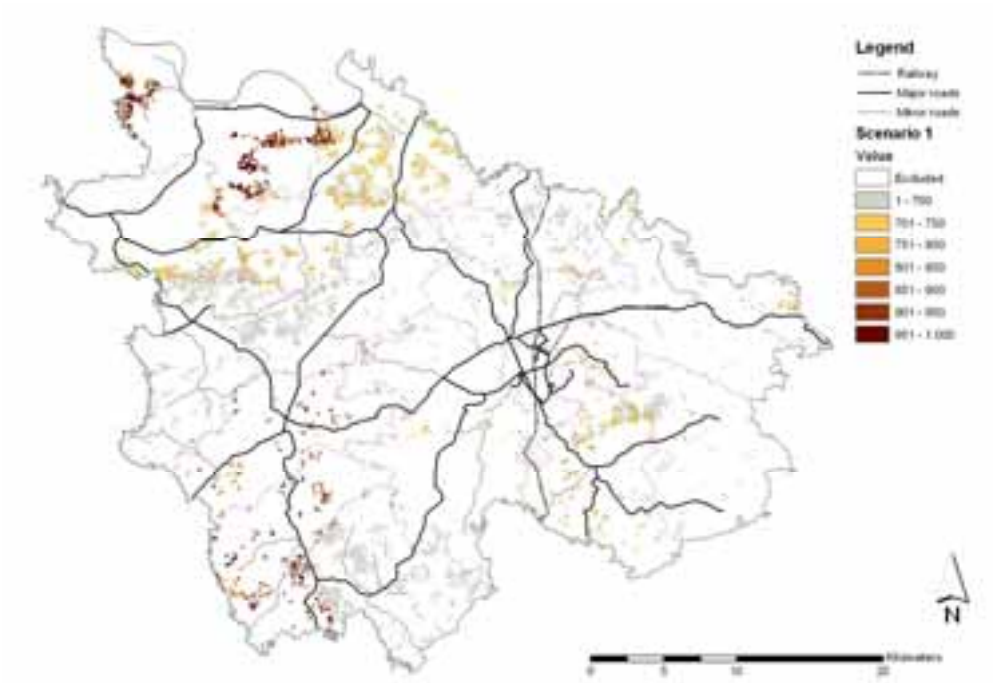

Figure 1 Final suitability map scenario 1: environmental sustainable.

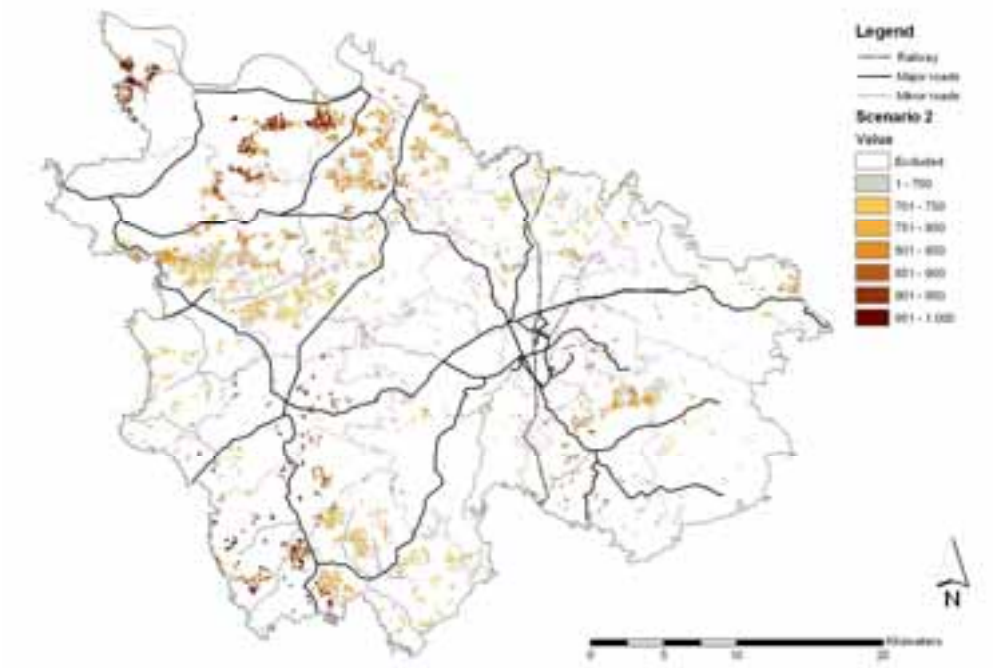

Figure 2 Final suitability map scenario 2: neutral.

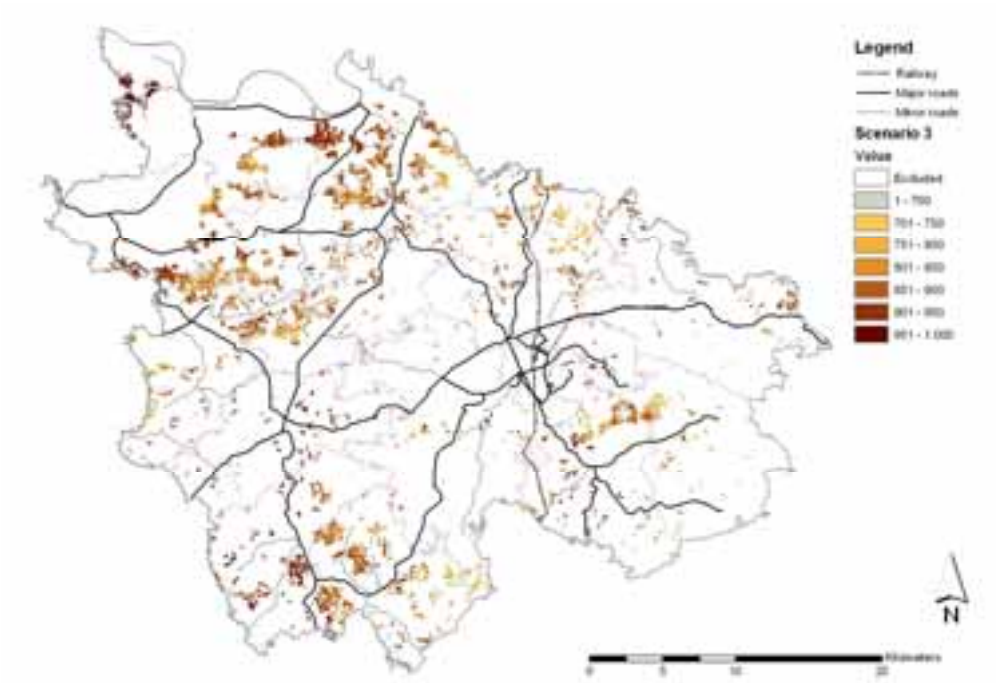

Figure 3 Final suitability map scenario 3: production and distribution.

Table 4 Suitable areas for pig farming per township for scenario 2.

Township	**Area (ha) per suitability class**						
	1-700	701-750	751-800	801-850	851-900	901-950	951-1000
Chen Yun	0	0	0	0	0	0	0
Shi Zhen	390	87	220	416	0	0	1
Qing Yun	37	53	16	6	8	58	52
Zi Bu	72	114	46	44	82	225	282
Da Yuan	153	12	72	92	0	0	0
Pei Mei	222	54	48	128	131	0	0
Hu Yun	252	17	95	226	0	0	0
Qi Bu	395	97	371	2	0	0	0
Da Huang	326	44	12	279	80	0	0
Wang Jia	270	116	271	1	0	0	0
Zhu Shan	101	6	12	87	0	0	0
Shang Fang	74	18	55	23	0	0	0
Shu Qiao	43	64	67	33	31	114	212
Nan Xi	454	118	363	0	0	0	1
Fu Lin	126	58	25	0	0	0	0
Zhu Tian	375	165	42	0	0	0	0

Table 4 shows that the most suitable locations for pig farming can be found in Qing Yun, Zi Bu, and Shu Qiao townships (901-1000 classes). The high ranking of these three townships can be explained by the scores for the P-balance, which is significantly higher compared to the scores of the other townships. The nutrient balance also allows calculating a theoretical number of pigs that can be housed in the county if all pig manure will be applied in crop production in Wannian County. The balance shows a total P-shortage of 213,137 kg (see Table 2). Based on an average excretion value of 2.10 kg P per pig per year, the maximum growth in pig production in the county is estimated at 101,684 pigs.

3.2.2. Assessment of present medium and large pig farms

The locations of the present commercial pig farms, and those under construction, were confronted with the outcomes of the excluded areas in the first step of the suitability assessment. The results are shown in Table 5.

Table 5 Assessment of the locations of present medium and large commercial pig farms.

	Farm	**Type**	**Located in restricted area**			
			arable land	300 m village	other farm	100 m road
1	Wan Nian Branch, COFIE Company	large	no	yes	yes	no
2	Zhong Xin Ling Pig Farm	large	no	yes	yes	no
3	Shan Zhuang Livestock Farm	large	no	no	yes	no
4	Jin Xing Pig Farm	large	no	yes	no	yes
5	Hu Yun Ren Livestock Company	large	no	yes	no	no
6	Yi You Livestock Company	large	no	yes	yes	no
7	Hu Yun Zhai Shan Pig Farm	large	no	no	yes	no
8	Xin Tian Di Pig Farm (closed)	-	-	-	-	-
9	Da Huang Pig Farm	large	no	yes	no	no
10	Wan Nian Breeding Farm	large	no	yes	yes	no
11	Xia Jia Pu Pig Farm	large	no	yes	yes	no
12	Ma Long Shan Pig Farm	medium	no	yes	no	no
13	Zhu Xi Pig Farm	medium	no	no	yes	no
14	Hong Lai Pig Farm	medium	no	yes	no	no
15	Xi Shan Cai Jia Pig Farm	medium	no	yes	yes	no
16	Ma Jia Pig Farm	medium	no	yes	no	yes
17	Nan Gang Pig Farm (new)	large	yes	no	no	no
18	Zai Shan Pig Farm	small	-	-	-	-
19	Li Jia Pig Farm	small	-	-	-	-
20	Mao Gong Shan pig farm (new)	large	no	no	no	no
21	Qi Shun pig farm (new)	large	no	yes	no	yes
22	Qing Yun pig farm (new)	large	no	yes	no	no

Although the results are indicative, the outcomes can be interpreted as a signal for potential problems, which should be analyzed in more detail at farm level. Table 5 shows that one pig farm (# 17) is located on arable land, and three pig farms (# 4, 16, and 21) are located within 100 m of a main road. Potentially more serious problems occur due to farms that are located too close to a village or town (14 farms) or to one another (9 farms).

4. Conclusions

The suitability assessment shows that only a small part of Wannian County, covering 91.2 km^2 or 8% of the total area, is potentially suitable for future pig farming. The most suitable locations, covering 9.4 km^2, are located in Qing Yun, Zi Bu, and Shu Qiao townships in the northwest part of the county. The suitability assessment also suggests that the majority of the present medium and large commercial pig farms may cause environmental problems due to their location in restricted areas. The nutrient balance indicates that theoretically 100,000 more pigs can be produced in Wannian County, provided that all manure can be applied in crop production in the county.

The case study project demonstrates that the GIS maps are a useful tool to support the local government with the spatial allocation of new pig farming. Although other methods can be applied [15, 16], the presented approach effectively incorporates sustainability issues in spatial planning. However, it should be realized that the approach only offers maps, while an effective implementation and enforcement will also require additional measures and regulations. The results initiated a follow-up FAO project in Southeast Asia (Guangdong Province of China, Thailand and Vietnam).

References

[1] Xiong, Y., 2003. Perspective on pig farm development and tendency in China in the new century [J]. Animal Sciences and Animal Medical Sciences 2003(8): 1-2 (in Chinese).

[2] HJ/T81, 2001. Technology standard for pollution prevention of poultry raising [S] (in Chinese).

[3] Dai, W.Y., 2005. A study on environmental pollution from intensive pig farming and its prevention [J]. Livestock Husbandry and Veterinary Medicine of Fujian Province 27(4): 79-80 (in Chinese).

[4] Gao, Z.Y., Yang, R.Q., Cheng, C.R., 2006. A study on waste treatment of industrial pig farming [J]. Transactions of the CSAE 22(2): 198-200 (in Chinese).

[5] Peng, L., Wang, D.Y., 2004. An estimation of annual waste discharges of livestock in Chongqi city [J]. Transactions of the CSAE 20(1): 288-292 (in Chinese).

[6] FAO, 2004. GEF Livestock Waste Management in East Asia Project [R].Rome: FAO.

[7] Song, L., Wang, H., 2002. The application of GIS in environmental and landscape planning [J]. China's Landscape Architecture 18(6): 56-59 (in Chinese).

[8] Lu, S.H., He, S.J., 2002. A spatial analysis model of land-use dynamics [J]. Journal of Natural Resources 17(5): 533-540 (in Chinese).
[9] Zhao, X.M., Ai, L.H., Zhang, N.Z., 2002. A study on farmland valuation based on GIS [J]. Journal of Ecological Agriculture in China 10(1): 65-67 (in Chinese).
[10] Zhao, X.M., Chen, M.Q, 2004. Technology of land-use master planning [M]. Beijing: Xinhua Press 2004(12): 45-123 (in Chinese).
[11] Guo, X., Zhao, X.M., 2000. Land resources assessment of Poyang Lake region [J]. Journal of Jiangxi Agricultural University 22(4): 543-550 (in Chinese).
[12] FAO, 1993. FESML: An international framework for evaluating sustainable land management [A]. In: World Soil Resources Report 73, Rome: FAO.
[13] Zhou, Y., Tian, Y.G., Ren, Y., 2003. A study on quantifying land-use assessment and evaluation [J], Ecological Environment 12(1): 37-41 (in Chinese).
[14] Dong, J.H., 2002. A study on integrated indicators for ecological agriculture [J]. Journal of Ecological Agriculture in China 13(3): 25-28 (in Chinese).
[15] Liu, Y., Qu, B., Zhu, Z.Y. et al., 2003. A study on fuzzy decision making of land use [J]. Journal of Wuhan University (Information Sciences Edition), 28(2):208-211(in Chinese).
[16] Zhang, L.H., Xue, C.S., 2004. Application of “3S” technology for sustainable land-use [J]. Researches on Land and Natural Resources 2004(2): 50-51 (in Chinese).

References

Aarts, N., and M. Maarleveld, 1999. Interactieve beleidsvorming. In: C. van Woerkum and P. van Meegeren (Eds.), Basisboek communicatie en verandering, Communication Sciences, Wageningen University, pp. 59-77. Boom, Amsterdam.

Albrechts, L., 2004a. Strategic (spatial) planning reexamined. Environment and Planning B: Planning and Design 31(5): 743-758.

Albrechts, L., 2004b. Strategic (spatial) planning challenged or the challenge of strategic (spatial) planning. Comment 5 in: J. Friedmann, Strategic spatial planning and the longer range, pp. 63-64. Planning Theory & Practice 5: 49-67.

Albrechts, L., and S.J. Mandelbaum (Eds.), 2005. The network society: A new context for planning? Routledge, London.

Alexander, E.R., 2001. What do planners need to know? Journal of Planning Education and Research 20: 367-380.

Al-Kodmany, K., 2002. Using web-based technologies and geographic information systems in community planning. Journal of Urban Technology 7: 1-30.

Allen, J.P., 2000. Information systems as technological innovation. Information, Technology & People 13: 210-221.

Almendinger, P., 2002a. Planning theory. Palgrave Macmillan, Houndmills, UK.

Almendinger, P., 2002b. Towards a post-positivist typology of planning theory. Planning Theory 1(1): 77-99.

Alter, S., 1980. Decision support systems: Current practice and continuing challenges. Addison-Wesley, Reading.

Antrop, M., 2004a. Uncertainty in planning metropolitan landscapes. In: G. Tress, B. Tress, B. Harms, P. Smeets and A. van der Valk (Eds.), Planning metropolitan landscapes: Concepts, demands, approaches, pp. 12-25. Delta Series 4, Wageningen, the Netherlands.

Antrop, M., 2004b. Rural-urban conflicts and opportunities. In: R.H.G. Jongman (Ed.), The new dimensions of the European landscapes, Chapter 6, pp. 83-91. Springer, Berlin.

Arents, F., 2006. De interimwet stad-en-milieubenadering. Bulletin RO Totaal 3: 48-49.

Arnott, D., and G. Pervan, 2005. A critical analysis of decision support systems research. Journal of Information Technology 20: 67-87.
Barredo, J.I., M. Kasanko, N. McCormick, and C. Lavalle, 2003. Modelling dynamic spatial processes: simulation of urban future scenarios through cellular automata. Landscape and Urban Planning 64: 145-160.
Batey, P.W.J., and M.J. Breheny, 1978. Methods in strategic planning: A descriptive review. Town Planning Review 49: 259-273.
Batty, M., and P.M. Torrens, 2005. Modelling and prediction in a complex world. Futures 37: 745-766.
Beauregard, R.A., 1989. Between modernity and postmodernity: The ambiguous position of US planning. Environment and Planning D 7: 381-395.
Bell, W., 2003. Foundations of futures studies: Human science for a new era: History, purposes, knowledge (Human Science for a New Era, 1). Transaction Publishers, New Brunswick.
Bertolini, L., 1999. Spatial development patterns and public transport: The application of an analytical model in the Netherlands. Planning Practice & Research 14: 199-210.
Beyer, S., 2006. Environmental law and policy in the People's Republic of China. Chinese journal of international law 5: 185-211.
Birkeland, J., 2002. Design for sustainability: A sourcebook of integrated ecological solutions. Earthscan, London.
Bocquier, P., 2005. World urbanization prospects: An alternative to the UN model of projection compatible with the mobility transition theory. Demographic Research 12: 197-236.
Börjeson, L., M. Höjer, K.H. Dreborg, T. Ekvall, and G. Finnveden, 2006. Scenario types and techniques: Towards a user's guide. Futures 38: 723-739.
Brail, R.K., and R.E. Klosterman (Eds.), 2001. Planning support systems: Integrating geographic information systems, models, and visualization tools, ESRI Press, Redlands, CA.
Brandt, J., J. Primdahl, and A. Reenberg, 1999. Rural land-use and dynamic forces: Analysis of 'driving forces' in space and time. In: R. Krönert, J. Baudry, I.R. Bowler and A. Reenberg (Eds.), Land-use changes and their environmental impact in rural areas in Europe, pp. 81-102. UNESCO, Paris.
Breheny, M., 2002. Centrist, decentrist and compromisers: Views on the future of urban form. In: M. Jenks, E. Burton, and K. Williams (Eds.), The compact city: A sustainable urban form?, pp. 13-35. Spon Press, Oxford.
Breuste, J., H. Feldmann, and O. Uhlmann (Eds.), 1998. Urban Ecology. Springer, Berlin.
Brown, J., and P. Duguid, 1991. Organizational learning and communities of practice: Toward a unified view of working, learning, and innovation. Organizational Science 2(1): 40-57.
Bruinsma, J. (Ed.), 2003. World agricultural: Towards 2015/2030. An FAO perspective. Earthscan Publications, London.

Bryson, J.M., F. Ackermann, and C. Eden, 2004. Contributions of planning under pressure. Planning Theory 3(3): 201-210.
Bürgi, M., A.M. Hersperger, and N. Schneeberger, 2004. Driving forces of landscape change: Current and new directions. Landscape Ecology 19: 857-868.
Burns, T., 2004. A practical theory of public planning: The Tavistock tradition and John Friend's strategic choice approach. Planning Theory 3(3): 211-223.
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, 37 p. FAO, Rome.
Carsjens, G.J., and A. Ligtenberg, 2007. A GIS-based support tool for sustainable spatial planning in metropolitan areas. Landscape and Urban Planning 80: 72-83.
Carsjens, G.J., and Chen Wenbo, 2008. Framework for a spatial decision support tool for policy and decision making: Technical outline. FAO GCP/RAS/215/WBG Livestock Waste management in East Asia Project, 42 p. FAO, Rome.
Carsjens, G.J., and J.F.J.M. Smits, 1997. Topological relationships integrated in land use allocation: Assessing potentials for future agriculture. In: S. Hodgson, M. Rumor and J.J. Harts (Eds.). Proceedings 3rd Joint European Conference & Exhibition on Geo-Information, Vienna, Austria. Vol. 1, p. 758-767, IOS Press.
Carsjens, G.J., and P. Gerber, 2007. Decision support tool for spatial planning and decision making. Technical support. FAO, GCP/RAS/215/WBG Livestock Waste management in East Asia Project, August 2007, 31 p. FAO, Rome.
Carsjens, G.J., and W.G.M. van der Knaap, 2002. Strategic land use allocation: dealing with spatial relationships and fragmentation of agriculture. Landscape and Urban Planning 58: 171-179.
Carsjens, G.J., H. Steinfeld, and P. Gerber, 2003a. An area-based approach for environmental problems related to livestock production. In: J.M. Tarjuelo, F.M. de Santa Olalla, and L.S. Pereira (Eds.), Proceedings 6th Inter-regional conference on EnviroWater, pp. 175-176. Albacete, Spain.
Carsjens, G.J., P. Gerber, Dan T. Vadnjal, Somchai Chantsavang, Ke Bingsheng, Li Guoxue, Luo Qixiang, Zhao Xiaomin, and H. Steinfeld, 2004. Addressing livestock and environment issues in Wannian County: Policy and technology options for the area-wide integration of crop and livestock activities. In: Guanhua Huang and L.S. Pereira (Eds.), Proceedings 7th Inter-regional conference on EnviroWater, pp. 629-639. Beijing, China Agriculture Press.
Carsjens, G.J., R.J.A. van Lammeren, and A. Ligtenberg, 2003b. STEPP: Strategic tool to integrate environmental aspects into planning procedures. In: S. Geertman and J. Stillwell (Eds.), Planning support systems in practice, Chapter 8, pp. 139-154. Springer, Berlin.
Chadwick, G., 1971. A systems view of planning: Towards a theory of the urban and regional planning process. Pergamon, Oxford.
Chapagain, A.K., and A.Y. Hoekstra, 2004. Water footprints of nations; Volume 1 main report. Value of water research report series 16. UNESCO-IHE, Delft.
Chermack, T.J., 2004. Improving decision-making with scenario planning. Futures 36: 295-309.

Clark, M., 2005. The compact city: European ideal, global fix or myth. Editorial. Global Built Environmental Review 4: 1-11.
Couclelis, H., 2003. The certainty of uncertainty: GIS and the limits of geographic knowledge. Transactions in GIS 7: 165-175.
Couclelis, H., 2004. The third domain: The spread and use of GIS within social science. Cartographica 39: 17-24.
Couclelis, H., 2005. Where has the future gone? Rethinking the role of integrated land-use models in spatial planning. Environment and Planning A 37: 1353–1371.
Crossland, M.D., B.E. Wynne, and W.C. Perkins, 1995. Spatial decision support systems: An overview of technology and a test of efficacy. Decision Support Systems 14: 219-235.
Dammers, E., 2000. Leren van de toekomst: Over de rol van scenario's bij strategische beleidsvorming. Eburon, Delft.
Dammers, E., D. Evers, and A. de Vries, 2005. Spatial scenarios in relation to the ESDP and cohesion policy. Conference paper AESOP 05, Vienna.
Dammers, E., H.L. Pálsdóttir, F. Stroeken, L. Crommentuijn, E. Driessen, and F. Filius, 2003. Scene: Een kwartet ruimtelijke scenario's voor Nederland. Ruimtelijk Planbureau. NAi Uitgevers, Rotterdam.
Daniels, T., 1999. When city and country collide: Managing growth in the metropolitan fringe. Washington, D.C., Island Press.
Davis, F., 1986. A technology acceptance model for empirically testing new end-user information systems: Theory and results. PhD-thesis MIT, Cambridge, Massachussets.
de Haan C., T. Schillhorn van Veen, B. Brandenburg, J. Gauthier, F. Le Gall, and M. Siméon, 2001. Livestock development, implications for rural poverty, the environment and global food security. Directions in development. The World Bank, Washington, DC.
de Roo, G., 2000. Environmental conflicts in compact cities: Complexity, decision-making, and policy approaches. Environment and Planning B: Planning and Design 27, 151-162.
de Roo, G., 2003. Environmental planning in the Netherlands: Too good to be true. From command-and-control planning to shared governance. Ashgate, Aldershot.
de Roo, G., and H. Voogd, 2004. Methodologie van planning; Over processen ter beinvloeding van de fysieke leefomgeving. Coutinho, Bussem.
Delgado, C.L., 2003. Rising consumption of meat and milk in developing countries has created a new food revolution. Supplement of The Journal of Nutrition 2003: 3907S-3910S.
Delgado, C.L., M. Rosegrant, and S. Meijer, 2002. Livestock to 2020: The revolution continues. World Brahman Congress, Rockhampton.
Delgado, C.L., M. Rosegrant, H. Steinfeld, S. Ehui, and C. Courbois, 1999. Livestock to 2020: The next food revolution. Food, agriculture, and the environment discussion paper 28. IFPRI, Washington DC.

Delgado, M.G., and J.B. Sendra, 2004. Sensitivity analysis in multicriteria spatial decision-making: a review. Human and Ecological Risk Assessment 10: 1173-1187.
Denzer, R., 2005. Generic integration of environmental decision support systems: State-of-the-art. Environmental Modelling & Software 20: 1217-1223.
Dieleman, F., and M. Wegener, 2004. Compact city and urban sprawl. Built environment 30: 308-323.
Dimitriou. H.T., 2007. Strategic planning thought: Lessons from elsewhere. In: H.T. Dimitriou and R. Thompson (Eds.), Strategic planning for regional development in the UK: A review of principles and practices, Chapter 4, pp. 43-65. Routledge, London.
Dimitriou. H.T., and R. Thompson, 2007a. Introduction. In: H.T. Dimitriou and R. Thompson (Eds.), Strategic planning for regional development in the UK: A review of principles and practices, Chapter 1, pp. 3-9. Routledge, London.
Dimitriou. H.T., and R. Thompson, 2007b. Strategic thought and regional planning: The importance of context. In: H.T. Dimitriou and R. Thompson (Eds.), Strategic planning for regional development in the UK: A review of principles and practices, Chapter 5, pp. 66-90. Routledge, London.
Dishaw, M., and D. Strong, 1999. Extending the technology acceptance model with task-technology fit constructs. Information & Management 36: 9-21.
DLD, 2003. Statistical Yearbook 2003. Bangkok, Department of Livestock Development, Ministry of Agriculture and Cooperatives.
Dreborg, K.H., 1996. Essence of backcasting. Futures 28: 813-828.
Dreborg, K.H., 2004. Scenarios and structural uncertainty: Explorations in the field of sustainable transport. Dissertation Royal Institute of Technology, Stockholm.
Dror, Y., 1963. Ventures in policy sciences. Elsevier, New York.
ESPON, 2004. Spatial scenarios and orientations in relation to the ESDP and cohesion policy, First Interim Report. European Spatial Planning Observation Network (ESPON), Brussels.
Etzioni, A., 1967. Mixed scanning: A 'third' approach to decision-making. Public Administration Review 27: 385-392.
Etzioni, A., 1986. Mixed scanning revisited. Public Administration Review 46: 8-14.
EU, 1996. Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control. The Council of the European Union, Brussels.
Eweg, R., 1994. Computer supported reconnaissance planning: Implementing a planning methodology with a Geographical Information System in Noord-Brabant, the Netherlands. PhD-thesis Wageningen University.
Faludi, A., 1978. Essays on planning theory and education. Pergamon press, Oxford.
Faludi, A., 1986. Critical rationalism and planning methodology. Pion, London.
Faludi, A., 1987. A decision-centred view of environmental planning. Pergamon press, Oxford.
Faludi, A., 2000. The performance of spatial planning. Planning Practice and Research 15(4): 299-318.

Faludi, A., and A.J. van der Valk, 1994. Rule and order: Dutch planning doctrine in the Twentieth Century. Dordrecht, Kluwer Academic Publishers.
Faludi, A., and A.J. van der Valk, 2001. Rationality and power: An unreconstructed rationalist's echo. International Planning Studies 6: 271-278.
FAO, 2003. World agriculture: Towards 2015/2030. Rome.
FAO, 2006. Food outlook: Global market analysis. No 2. FAO, Rome.
Forester, J., 1999. The deliberative practitioner: Encouraging participatory planning processes. MIT Press, London.
Forman, R.T.T., 1995. Land Mosaics: The Ecology of Landscapes and Regions. Cambridge University Press, Cambridge, UK.
Friedmann, J., 1987. Planning in the public domain. Princeton University Press, Princeton.
Friedmann, J., 1996. Two centuries of planning theory: An overview. In: S.J. Mandelbaum, L. Mazza, and R.W. Burchell (Eds.), Explorations in planning theory, pp. 10-29. Center for urban policy research, Rutgers, The state university of New Jersey, New Brunswick, New Jersey.
Friedmann, J., 2004. Strategic spatial planning and the longer range. Planning Theory & Practice 5: 49-67.
Friend, J.K., and A. Hickling, 2005. Planning under pressure: The strategic choice approach (Third Edition). Elsevier Butterworth-Heinemann, Oxford.
Friend, J.K., and W.N. Jessop, 1969. Local government and strategic choice: An operational research approach to the process of public planning. Tavistock Publications, London.
Friend, J.K., and W.N. Jessop, 1977. Local government and strategic choice: An operational research approach to the process of public planning (Second Edition). Pergamon, Oxford.
Fubini, A., 2004. Introduction. In: A. Fubini (Ed.), Improving planning education in Europe, pp. 15-30. Association of European Schools of Planning. FrancoAngeli, Milan.
Gaffikin, F., and K. Sterrett, 2006. New vision for old cities: The role of visioning in planning. Planning Theory & Practice 7: 159-178.
Geertman, S., 2002. Participatory planning and GIS: a PSS to bridge the gap. Environment and Planning B: Planning and Design 29, 21-35.
Geertman, S., 2006. Potentials for planning support: A planning-conceptual approach. Environment and Planning B: Planning and Design 33: 863-880.
Geertman, S., and J. Stillwell, 2003. Planning support systems in practice. Springer-Verlag, Heidelberg.
Geertman, S., and J. Stillwell, 2004. Planning support systems: An inventory of current practice. Computers Environment and Urban Systems 28: 291-310.
Gerber, P., 2006. Putting pigs in their place: Environmental policies for intensive livestock production in rapidly growing economies, with reference to pig farming in Central Thailand. Dissertation Swiss Federal Institute of Technology Zurich (ETH), Zurich.

Gerber, P., G.J. Carsjens, Somchai Chantsavang, Dan T. Vadnjal, Ke Bingsheng, Li Guoxue, Luo Qixiang, and Zhao Xiaomin, 2004. Integrated waste management in Wannian County, Jiangxi Province, People's Republic of China, TCP/CPR/0170(A), Mid-term report, FAO, Rome, 123 p.

Gerber, P., P. Chilonda, G. Franceschini, and H. Menzi, 2005. Geographical determinants and environmental implications of livestock production intensification in Asia. Bioresource Technology 96: 263–276.

Gerber, P.J., G.J. Carsjens, T. Pak-Uthai, and T. Robinson, 2008. Decision support for spatially targeted livestock policies: Diverse examples from Uganda and Thailand. Agricultural Systems 96: 37-51.

Gies, E., J. van Os, T. Hermans, and R. Olde Loohuis, 2007. Megastallen in beeld. Alterra-rapport 1581. Alterra, Wageningen.

Godet, M., 2000. The art of scenarios and strategic planning: Tools and pitfalls. Technological Forecasting and Social Change 65: 3-22.

Hall, P.G., 1988. Cities of tomorrow: An intellectual history of urban planning and design in the Twentieth Century. Basil Blackwell, Oxford.

Harris, B., 1989. Beyond geographical information systems: Computers and the planning professional. Journal of the American Planning Association 55: 85-90.

Harris, B., 1999. Computing in planning: Professional and institutional requirements. Environment and Planning B Planning and Design 26: 321-331.

Healey, P., 1997. Collaborative planning: Shaping places in fragmented societies. MacMillan, Hampshire.

Healey, P., 2003. Collaborative planning in perspective. Planning Theory 2(2): 101-123.

Healey, P., 2004. The treatment of space and place in the new strategic spatial planning in Europe. International Journal of Urban and Regional Research 28: 45-67.

Healey, P., G. McDougall, and M. Thomas (Eds.), 1982. Planning Theory. Prospects for the 1980s. Pergamon Press, Oxford.

Hidding, M.C., 2006. Planning voor stad en land. Derde herziene druk. Coutinho, Bussum.

Hidding, M.C., and A.T.J. Teunissen, 2002. Beyond fragmentation: New concepts for urban-rural development. Landscape and Urban Planning 58: 297-308.

Higgins, M., and J. Morgan, 2000. The role of creativity in planning: The 'creative practitioner'. Planning Practice & Research 15: 117-127.

Higgs, G., 2004. We haven't got a GIS. It isn't a problem for us; why is it a problem for you? Editorial. Computers, Environment and Urban Systems 28: 285-288.

Holsapple, C., and A. Whinston, 1996. Decision support systems: A knowledge-based approach. West Publishing, Minneapolis.

Humblet, A.G.M., and G. de Roo, 1995. Afstemming door inzicht: Een analyse van gebiedsgerichte milieubeoordelingsmethoden ten behoeve van planologische keuzes, Geo Pers, Groningen.

Huxley, M., 2000. The limits to communicative planning. Journal of Planning Education and Research 19: 369-377.

Inayatullah, S., 1990. Deconstructing and reconstructing the future: Predictive, cultural and critical epistemologies. Futures 22: 115-141.
Innes, J.E., 2002. Improving policy making with information. Planning Theory & Practice 3: 102-104.
Innes, J.E., 2004. Consensus building: Clarification for the critics. Planning Theory 3: 5-20.
Innes, J.E., and D.E. Booher, 1999. Consensus building as role playing and bricolage: Toward a theory of collaborative planning. Journal of the American Planning Association 65: 9-26.
Innes, J.E., and D.E. Booher, 2000. Public participation in planning: New strategies for the 21st Century. Working paper Institute of Urban & Regional Development, University of California, Berkeley.
Jankowski, P., and L. Richard, 1994. Integration of GIS-based suitability analysis and multicriteria evaluation in a spatial decision support system for site selection, Environment and Planning B 21: 323-340.
Jankowski, P., and T. Nyerges, 2001. GIS-supported collaborative decision making: Results of an experiment. Annals of the Association of American Geographers 91: 48-70.
Jarupathirun, S., and F.M. Zahedi, 2007. Exploring the influence of perceptual factors in the success of web-based spatial DSS. Decision Support Systems 43: 933-951.
Jenks, M., E. Burton, and K. Williams (Eds.), 1996. The compact city: A sustainable form? Spon Press, London.
Johnson, M.P., 2005. Spatial decision support for assisted housing mobility counseling. Decision Support Systems 41: 296-312.
Kahn, H., and A. Weiner, 1967. The year 2000: A framework for speculation on the next thirty-three years. MacMillan, New York.
Ke Bingsheng, Li Guoxue, Luo Qixiang, Zhao Xiaomin, G.J. Carsjens, Somchai Chantsavang, D.T. Vadnjal, and P. Gerber, 2005. Integrated waste management in Wannian County, Jiangxi Province, People's Republic of China, TCP/CPR/0170(A), Final Report. FAO-LEAD, Animal Production and Health Division, Rome, 78 p. + Annex 66 p.
Keen, P.G.W., and M.S. Scott-Morton, 1978. Decision support systems: An organizational perspective. Addison-Wesley, Reading.
Keenan, P., 1998. Spatial decision support systems for vehicle routing. Decision Support Systems 22: 65-71.
Keenan, P., 2004. Using a GIS as a DSS generator. DSSResources.COM, 12/17/2004.
Kleefmann, F., 1984. Planning als zoekinstrument: Ruimtelijke planning als instrument bij het richtingzoeken. Vuga, Den Haag.
Kleefmann, F., 1985. Handelen, handelingscontext and planning: Een theoretisch-sociologische verkenning. Wageningen Agricultural University.
Klijn, J.A., 2004. Driving forces behind landscape transformation in Europe: From a conceptual approach to policy options. In: R.H.G. Jongman (Ed.), The new di-

mensions of the European landscapes, Chapter 14, pp. 201-218. Springer, Berlin.
Klosterman, R.E., 1998. Computer applications in planning. Environment and Planning B: Planning and Design. Anniversary Issue: 32-36.
Klosterman, R.E., 2001. Planning support systems: a new perspective on computer-aided planning. In: R.K. Brail and R.E. Klosterman (Eds.), Planning Support Systems, pp. 1-35. ESRI Press, Redlands, CA.
Klostermann, R.E., and C. Pettit, 2005. An update on planning support systems. Environment and Planning B: Planning and Design 32: 477-484.
Korte, R.F., and T.J. Chermack, 2007. Changing organizational culture with scenario planning. Futures 39: 645-656.
Lange, E., S. Hehl-Lange, and I. Mambretti, 2004. Assessment of urban green space qualities using 3D visualization tools, in: M. Koll-Schretzenmayr, M. Keiner and G. Nussbaumer (Eds.) The real and virtual worlds of spatial planning, pp.185-198. Springer, Berlin.
Ligtenberg, A., 2006. Exploring the use of multi-agent systems for interactive multi-actor spatial planning. PhD-thesis Wageningen University.
Lindblom, C.E., 1959. The science of "muddling through". Public Administration Review 19: 79-88.
Lowry, K., P. Adler, and N. Milner, 1997. Participating the public: Group process, politics, and planning. Journal of Planning Education and Research 16(3): 181-192.
Luck, M., and J. Wu, 2002. A gradient analysis of urban landscape pattern: a case study from the Phoenix metropolitan region, Arizona, USA. Landscape Ecology 17: 327-339.
Maack, J.N., 2001. Scenario analysis: A tool for task managers. In: R.A. Krueger, M.A. Casey, J. Donner, S. Kirsch, and J.N. Maack, Social analysis: Selected tools and techniques, Social Development Paper 36, pp. 62-87. World Bank, Washington D.C.
Maguire, D.J., 1991. An overview and definition of GIS. In: D.J. Maguire, M.F. Goodchild, and D.W. Rhind (Eds.), Geographical Information Systems: Principles and applications, pp. 9-20. Longman, Essex.
Malczewski, J., 2000. On the use of weighted linear combination method in GIS: Common and best practice approaches. Transactions in GIS 4: 5-22.
Malczewski, J., 2004. GIS-based land-use suitability analysis: A critical overview. Progress in Planning 62: 3-65.
Maniezzo, V., I. Mendes and M. Paruccini, 1998. Decision support for siting problems. Decision Support Systems 23: 273- 284.
Margerum, R.D., 2002. Collaborative planning: Building consensus and building a distinct model for practice. Journal of Planning Education and Research 21(3): 237-253.
Marien, M., 2002. Futures studies in the 21st Century: A reality based view. Futures 34: 261-281.
Masini, E.B., 1993. Why futures studies? Grey Seal Books, London.

Matthies , M., C. Giupponi, and B. Ostendorf, 2007. Environmental decision support systems: Current issues, methods and tools. Preface. Environmental Modelling & Software 22: 123-127.
McHarg, I.L., 1969. Design with nature. John Wiley & Sons.
McLoughlin, J.B., 1969. Urban and regional planning: A systems approach. Faber and Faber, London.
Mennecke, B.E., M.D. Crossland and B.L. Killingsworth, 2000. Is a map more than a picture? The role of SDSS technology, subject characteristics, and problem complexity on map reading and problem solving. Mis Quarterly 24: 601-629.
Ministry of LNV, 2005. The choice for agriculture: A vision of the future of Dutch agriculture. Ministry of Agriculture, Nature and Food Quality, The Hague.
Ministry of VROM, 1990. Ministeriële Handreiking voor een voorlopige systematiek voor de integrale milieuzonering, deel 6, Integrale Milieuzonering. Directie Geluid en Omgeving, Directoraat-Generaal Milieubeheer. Ministry of Housing, Spatial Planning and the Environment (VROM), The Hague.
Ministry of VROM, 1998. Beleidsnota vernieuwing geluidhinderbeleid: een nieuwe sturingsfilosofie voor het toekomstige geluidbeleid. Ministry of Housing, Spatial Planning and the Environment (VROM), The Hague.
Ministry of VROM, 2001a. Where there's a will there's a world - working on sustainability. 4th National environmental policy plan. Ministry of Housing, Spatial Planning and the Environment (VROM), The Hague.
Ministry of VROM, 2001b. Making space, sharing space - 5th National memorandum on spatial planning 2000/2020. Ministry of Housing, Spatial Planning and the Environment (VROM), The Hague.
Ministry of VROM, 2001c. Eindrapportage onderzoeksresultaten tussenevaluatie project stad & milieu. Ministry of Housing, Spatial Planning and the Environment (VROM), The Hague.
Ministry of VROM, 2004. National spatial strategy: Creating space for development. Ministry of Housing, Spatial Planning and the Environment (VROM), The Hague.
MNP, 2006. Nature Balance 2006. Milieu en Natuurplanbureau (MNP), Bilthoven.
Montgomery, M.R., R. Stren, B. Cohen and H.E. Reed (Eds.), 2003. Cities transformed: Demographic change and its implications in the developing world. National Academy Press, Washington DC.
Morecroft, J.D.W., 1985. Rationality in the analysis of behavioral simulation models. Management Science 31: 900-916.
Narrod, C., G.J. Carsjens, Somchai Chantsavang, D. Vadnjal, Ke Bingsheng, Zhao Xiaomin, Luo Qixiang, and Li Guoxue, 2002. Integrated waste management in Wannian County, Jiangxi Province, People's Republic of China, FAO, Rome, 2002, 29 p.
Nedovic-Budic, Z., 1998. The impact of GIS technology. Environment and Planning B 25: 681-692.
Needham, B., 2000. Spatial planning as a design discipline: A paradigm for Western Europe? Environment and Planning B 27: 437-453.

Needham, B., 2004. John Friend: Advising and theorizing. Planning Theory 3(3): 237-247.
Needham, B., 2007. Dutch land use planning: Planning and managing land use in the Netherlands, the principles and the practice. Sdu Uitgevers, Den Haag.
Needham, B., and A. Faludi, 1999. Dutch growth management in a changing market. Planning Practice & Research 14: 481-491.
Needham, B., and T. Zwanikken, 1997. The current urbanization policy evaluated. Netherlands Journal of Housing and the Built Environment 12: 37-55.
Nehme, C.C., and M. Simões, 1999. Spatial decision support system for land assessment. ACM GIS, ACM Press, Kansas City.
Norton, R.D., 2004. Agricultural development policy: Concepts and experiences. Food and Agriculture Organization of the United Nations. Wiley, West Sussex.
OECD, 2005. Governance in China: China in the Global Economy. OECD Publishing.
Oi, J.C., 1995. The role of the local state in China's transitional economy. China Quarterly 144: 1132-1149.
Osawa, C.P. and E.P. Seltzer, 1999. Taking our bearings: Mapping a relationship between planning practice, theory, and education. Journal of planning education and research 18: 257-266.
Parker, P., R. Letcher, A.J. Jakeman, M.B. Beck, G. Harris, R.M. Argent, M. Hare, C. Pahl-Wostl, A. Voinov, et al., 2002. Progress in integrated assessment and modelling. Environmental modelling & software 17: 209-217.
Pedersen, Å.Ø., S. Nyhuus, T. Blindheim, and O.M. Wergeland Krog, 2004. Implementation of a GIS-based management tool for conservation of biodiversity within the municipality of Oslo, Norway. Landscape and Urban Planning 68: 429-438.
Peterson, G.D., G.S. Cumming, and S.R. Carpenter, 2003. Scenario planning: A tool for conservation in an uncertain world. Conservation Biology 17: 358-366.
Pettit, C., and D. Pullar, 1999. An integrated planning tool based upon multiple criteria evaluation of spatial information. Computers, Environment and Urban Systems 23: 339-357.
Pettit, C., and D. Pullar, 2004. A way forward for land-use planning to achieve policy goals by using spatial modelling scenarios. Environment and Planning B 31: 213-233.
Power, D.J., 2002. Decision support systems: Concepts and resources for managers. Quorum Books, Westport.
Power, D.J., 2007. A brief history of decision support systems. DSSResources.COM. http://DSSResources.COM/history/dsshistory.html, version 4.0, March 10.
Priemus, H., 2007. The network approach: Dutch spatial planning between substratum and infrastructure networks. European Planning Studies 15: 667-686.
Quist, J., and P. Vergragt, 2006. Past and future of backcasting: The shift to stakeholder participation and a proposal for a methodological framework. Futures 38: 1027-1045.
Qureshi, M.E., S.R. Harrison, and M.K. Wegener, 1999. Validation of multicriteria analysis models. Agricultural Systems 62: 105-116.

Rattanarajcharkul, R., W. Rucha, S. Sommer, and H. Menzi, 2000. Area-wide integration of specialized livestock and crop production in Eastern Thailand. RAMIRAN, Gargnano, University of Milan, Italy.
Robinson, J.B., 1990. Futures under glass: A recipe for people who hate to predict. Futures 22: 820-843.
Robinson, J.B., 2003. Future subjunctive: Backcasting as social learning. Futures 35: 839-856.
Robinson, T.P., R.S. Harris, J.S. Hopkins, and B.G. Williams, 2002. An example of decision support for trypanosomiasis control using a geographic information system in eastern Zambia. International Journal of Geographical Information Science 16: 345–360.
Rogers, E., 1995. Diffusion of innovations. Free Press, New York.
Rosenhead, J., and J. Mingers (Eds.), 2001. Rational analysis for a problematic world revisited: Problem structuring methods for complexity, uncertainty and conflict. Wiley, Chichester.
Rotmans, J., M. van Asselt, C. Anastasi, S. Greeuw, J. Mellors, S. Peters, D. Rothman, and N. Rijkens, 2000. Visions for a sustainable Europe. Futures 32: 809-831.
Saaty, T.L., 1987. Rank generation, preservation, and reversal in the analytic hierarchy decision process. Decision Sciences 18: 157-177.
Sage, A.P., 1991. Decision support systems engineering. Wiley-Interscience, New York.
Salet, W., 2000. The institutional approach to strategic planning, In: W. Salet and A. Faludi (Eds.), The revival of strategic spatial planning, pp. 13-24. Koninklijke Nederlandse Academie van Wetenschappen, Amsterdam.
Salet, W., and A. Faludi (Eds.), 2000. The revival of strategic spatial planning. Koninklijke Nederlandse Academie van Wetenschappen, Amsterdam.
Sandercock, L., 1997. Towards cosmopolis: Planning for multicultural cities. Wiley, Chichester.
Schaminée, A., 2002. De Beoordelingsmethode Milieukwaliteit: Van academie naar commerciële beroepspraktijk. Wageningen, Land Use Planning Group, Wageningen University.
Schmidt, C.W., 2002. Economy and environment: China seeks a balance. Environmental Health Perspectives 110: A516-522.
Schön, D.A., 1983. The reflective practitioner: How professionals think in action. Temple Smith, London.
Schön, D.A., 1987. Educating the reflective practitioner. Jossey-Bass, San Francisco.
Schön, D.A., and M. Rein, 1994. Frame reflection: Toward the resolution of intractable policy controversies. Basic Books, New York.
Schwartz, P., 1991. The art of the long view. Wiley, Chichester.
Schwartz, P., and J.A. Ogilvy, 1998. Plotting your scenarios. In: L. Fahey and R.M. Randall (Eds.), Learning from the future: Competitive foresight scenarios, pp. 57-80. Wiley, New York.
Sharma, T., J. Carmichael, and B. Klinkenberg, 2006. Integrated modeling for exploring sustainable agricultural futures. Futures 38: 93-113.

Shiffer, M., 1995. Interactive multimedia planning support: Moving from stand-alone systems to the World Wide Web. Environment and Planning B: Planning and Design 22: 649-664.
Shipley, R., and R. Newkirk, 1999. Vision and visioning in planning: What do these terms really mean? Environment and Planning B: Planning and Design 26: 573-591.
Shipley, R., R. Feick, B. Hall, and R. Earley, 2004. Evaluating municipal visioning. Planning, Practice & Research 19: 195-210.
Sijmons, D., 2002. The programme guide. In: D. Sijmons (Ed.), = Landscape. Architectura + Natura, Amsterdam.
Simon, H.A., 1957. Models of man, social and rational: Mathematical essays on rational human behavior in a social setting. Wiley, New York.
Sojda, R.S., 2007. Empirical evaluation of decision support systems: Needs, definitions, potential methods, and an example pertaining to waterfowl management. Environmental Modelling & Software 22: 269-277.
Sposito, V.A., R. Wyatt, and C.P. Pettit, 2006. Strategic thinking for improved regional planning and natural resources management. Applied GIS 2: 15.3-15.7.
Sprague Jr., R.H., and E.D. Carlson, 1982. Building effective decision support systems. Prentice Hall, New Jersey.
Steigenga, W., 1962. Van sociale analyse naar social-ruimtelijke konstruktie. Universiteit van Amsterdam.
Steiner, G.A., 1997. Strategic planning: A step-by-step guide. Free Press Paperbacks, New York.
Steinfeld, H., C. de Haan, and H. Blackburn, 1997. Livestock-environment interactions: Issues and options. FAO, Agency for International Development, and the World Bank. European Commission, Brussels, Belgium.
Steinfeld, H., P. Gerber, T. Wassenaar, V. Castel, M. Rosales, and C. de Haan, 2006. Livestock's long shadow: Environmental issues and options. Livestock, Environment and Development (LEAD) Initiative. FAO, Rome.
Sterk, B., 2007. A window of opportunities: The contributions of land use modelling to societal learning. PhD thesis Wageningen University.
Sterman, J.D., 2000. Business dynamics: Systems thinking and modeling for a complex world. Irwin/McGraw-Hill, Boston.
Stillwell, J., S. Geertman, and S. Openshaw, 1999. Developments in geographical information and planning. In: J. Stillwell, S. Geertman, and S. Openshaw (Eds.), Geographical information and planning, Chapter 1, pp. 3-22. Springer Verlag, Heidelberg.
Streefkerk, N., 1992. Handboek Beoordelingsmethode Milieu: Inhoudelijke achtergronden en handleiding. VNG, Den Haag.
Street, P., 1997. Scenario workshops: A participatory approach to sustainable urban living? Futures 29: 139-158.
Tapio, P., and O. Hietanen, 2002. Epistomology and public policy: Using a new typology to analyse the paradigm shift in Finnish transport futures studies. Futures 34: 597-620.

te Brömmelstroet, M., 2007. Planning support systems for the integration of land use and transport: New ways of using existing instruments. In: M. Schrenk, V.V. Popovich and J. Benedikt (Eds.), Proceedings / Tagungsband Real Corp 007, Vienna, Austria, pp. 745-754.
Tjallingii, S.P., 1996. Ecological conditions, strategies and structures in environmental planning. Dissertation TU Delft. IBN Scientific Contributions 2, Wageningen.
Tress, G., and B. Tress, 2004. Metropolitan landscapes: Contours of an emerging concept. In: G. Tress, B. Tress, B. Harms, P. Smeets and A. van der Valk (Eds.), Planning metropolitan landscapes: Concepts, demands, approaches, pp. 276-284. Delta Series 4, Wageningen, the Netherlands.
Triantaphyllou, E., 2000. Multi-criteria decision making methods: A comparative study. Kluwer Academic, Dordrecht.
Turner, B.L., D. Skole, S. Sanderson, G. Fischer, L. Fresco, and R. Leemans, 1995. Land-use and land-cover change: Science/research plan. Report no. 35/7. Royal Swedish Academy of Sciences, Stockholm.
United Nations, 2006. World urbanization prospects: The 2005 revision. Department of Economic and Social Affairs, Population Division. United Nations, New York.
Uran, O., and R. Janssen, 2003. Why are spatial decision support systems not used? Some experiences from the Netherlands. Computers Environment and Urban Systems 27: 511-526.
UTMB, 2002. Academic medical center scenarios 2002-2007. The University of Texas Medical Branch (UTMB). February 2002.
van Ark, R.G.H., 2005. Planning, contract en commitment. Naar een relationeel perspectief op gebiedscontracten in de ruimtelijke planning. Proefschrift Wageningen Universiteit. Eburon, Delft.
van den Brink, A., R. van Lammeren, R. van de Velde, and S. Däne (Eds.), 2007. Imaging the future: Geo-visualisation for participatory spatial planning in Europe. Mansholt publication series 3. Wageningen Academic Publishers.
van der Heijden, K., 1996. Scenarios: The art of strategic conversation. Wiley, Chichester.
van der Knaap, W.G.M., 1997. The tourist's drives: GIS oriented methods for analysing tourist recreation complexes. PhD-thesis Wageningen University.
van der Knaap, W.G.M., and G.J. Carsjens, 1999. Dealing with topological relationships in land use allocation problems. In: A. Musy, L. Santos Pereira and M. Fritsch (Eds.), Proceedings 2nd Inter-Regional Conference on Environment-Water, Lausanne, Switzerland, abstract book p. 12 and full paper on CD-ROM. Presses polytechniques et universitaires romandes, Lausanne.
van der Valk, A.J., 2002. The Dutch planning experience. Landscape and Urban Planning 58: 201-210.
van der Valk, A.J., and G.J. Carsjens, 2005. Feet on the ground: Engaging students with political realities. In: J. Friend, and A. Hickling (Eds.), Planning under pressure, The strategic choice approach, 3rd Edition, Chapter 13.5, pp. 315-318. Elsevier Butterworth-Heinemann.

van der Vlist, M.J., 1998. Duurzaamheid als planningsopgave: Gebiedsgerichte afstemming tussen de ruimtelijke ordening, het milieubeleid en het waterhuishoudkundig beleid voor het landelijk gebied. PhD-thesis Wageningen University.

van Lammeren, R.J.A., R. Algra, and G. van den Bosch, 1994. Evaluation of the method for assessing environmental quality (BM). In: Molenaar M (Ed.), Remote sensing and geographical information processing: Concepts and applications for land-use monitoring and agriculture. Wageningen Agricultural University, Wageningen.

van Notten, P.W.F., J. Rotmans, M.B.A. van Asselt, and D.S. Rothman, 2003. An updated scenario typology. Futures 35: 423-443.

van Slagmaat, M., A.M. van der Meer, and R.J.A. van Lammeren, 1992. Prototype Beoordeling Milieukwaliteit: handleiding. Landbouwuniversiteit Wageningen, Wageningen.

Venkatesh, V., and F. Davis, 2000. A theoretical extension of the technology acceptance model: Four longitudinal field studies. Management Science 46: 186-204.

Venkatesh, V., M.G. Morris, G.B. Davis, and F.D. Davis, 2003. User acceptance of information technology: Toward a unified view. MIS Quarterly 27: 425-478.

von Schomberg, R., 2002. From the "pursuit of happiness" to the "pursuit of sustainability". Modified version of the working paper "The objective of sustainable development: Are we coming closer?", Foresight Working Papers, Cordis website: www.cordis.lu/rtd2002/foresight/home.html.

Vonk, G.A., 2006. Improving planning support: The use of planning support systems for spatial planning. PhD-thesis Utrecht University, Faculty of Geosciences. Netherlands Geographical Studies 340, Utrecht.

Vonk, G.A., S. Geertman, and P. Schot, 2005. Bottlenecks blocking widespread usage of planning support systems. Environment and Planning A 37: 909-924.

Vonk, G.A., S. Geertman, and P. Schot, 2006. Usage of planning support systems: Combining three approaches. In: J.P. van Leeuwen and H.J.P. Timmermans (Eds.), Innovations in design & decision support systems in architecture and urban planning, pp. 263-274. Springer, Dordrecht.

Vonk, G.A., S. Geertman, and P. Schot, 2007a. A SWOT analysis of planning support systems. Environment and Planning A 39: 1699-1714.

Vonk, G.A., S. Geertman, and P. Schot, 2007b. New technologies stuck in old hierarchies: The diffusion of geo-information technologies in Dutch public organizations. Public Administration Review 67: 745-756.

Voogd, H., 1983. Multicriteria evaluation for urban and regional planning. Pion Limited, London, UK.

Voogd, H., and J. Woltjer, 1999. The communicative ideology in spatial planning: Some critical reflections based on the Dutch experience. Environment and Planning B: Planning and Design 26: 835-854.

Voss, A., I. Denisovich, P. Gatalsky, K. Gavouchidis, A. Klotz, S. Roeder, and H. Voss, 2004. Evolution of a participatory GIS. Computers, Environment and Urban Systems 28: 635–651.

Wackernagel, M., and R.E. Rees, 1996. Our ecological footprint: Reducing human impact on Earth. New Society Publishers, Gabriola Island.
Weber, C., 2003. Interaction model application for urban planning. Landscape and Urban Planning 63: 49-60.
White, S.S., and J.M. Mayo, 2004. Learning expectations in environmental planning. Predictions and interpretations. Journal of Planning Education and Research 24: 78-88.
Wiedmann, T., and J. Minx, 2007. A definition of 'carbon footprint'. ISA^{UK} Research Report 07-01, London.
Wiek, A., C. Binder, and R.W. Scholz, 2006. Functions of scenarios in transition processes. Futures 38: 740-766.
Williams, K., E. Burton, and M. Jenks (Eds.), 2000. Achieving sustainable urban form? Spon Press, London.
Wilson, I., 2000. From scenario thinking to strategic action. Technological Forecasting and Social Change 65: 23:29.
Woltjer, J., 1997. De keerzijde van het draagvlak: Ruimtelijke ordening niet altijd gebaat bij maatschappelijke discussie. Stedebouw en Ruimtelijke Ordening 4: 47-52.
Wong, C., 1998. Old wine in a new bottle? Planning methods and techniques in the 1990s. Planning Practice & Research 13: 221-236.
World Bank, 2006. Project appraisal document on a proposed grant from the Global Environment Facility trust fund in the amount of US$7 million to the Kingdom of Thailand, The People's Republic of China, The Socialist Republic of Vietnam, and the Food and Agricultural Organization of the United Nations for a livestock waste management in East Asia project. Report 32367-EAP. World Bank, Washington DC.
Xiang, W.N. and K.C. Clarke, 2003. The use of scenarios in land-use planning. Environment and Planning B 30: 885-909.
Yewlett, C., 2007. Strategic choice and regional planning. In: H.T. Dimitriou and R. Thompson (Eds.), Strategic planning for regional development in the UK: A review of principles and practices, Chapter 6, pp. 91-107. Routledge, London.
Yiftachel, O., 1989. Towards a new typology of urban planning theories. Environment and Planning B: Planning and Design 16: 23-39.
Zhao, X., G.J. Carsjens, and P. Gerber, 2006. Regional planning of pig husbandry with environmental protection using GIS. Transactions of the Chinese Society of Agricultural Engineering 22(9): 184-188.
Zonneveld, W., 2005. The Europeanization of Dutch national spatial planning: An uphill battle. DISP Journal 163: 4-15.

Summary

Contemporary land-use planning is facing the growing complexity of metropolitan landscapes, where planners and decision-makers have to deal with a diversity of stakeholders and objectives. The challenge is to find a balance between the increasing pressure on the rural area for economic and urban development and the need to preserve farmland and natural resources. The growing complexity of the metropolitan landscape cannot be properly addressed with local participative planning only. It also requires a spatial planning framework for formulating and evaluating more long-term, holistic future perspectives. As a response, recent years show a renewed interest in long-term thinking and a strong revival of strategic and regional spatial planning. But the process of strategic spatial planning is one of the most complex tasks of public organizations. Planners have to deal with a wide range of often conflicting objectives at different spatial and temporal scales, have to handle large amounts of information of various types and qualities, and need to synthesize feasible alternatives in a communicative setting with a range of stakeholders. The last decades, an increasing number of computer-based geo-information tools or spatial decision support systems (SDSS) have been developed to support such complex processes. A specific group of spatial decision support tools has materialized under the generic term Planning Support Systems (PSS). PSS intend to support planning processes, based on the assumption that an increase in access to relevant information will lead to a greater number of alternative scenarios, and thus a better informed public debate. However, recent studies show that the adoption and use of PSS is far from widespread, and PSS are far from being effectively integrated into the planning process.

The main goal of this thesis is to explore the use of spatial planning support systems (PSS) for regional, strategic spatial planning of metropolitan landscapes. The emphasis is on PSS that support the balancing of economic versus environmental objectives in spatial planning. The two basic research questions are: (1) What spatial planning approaches and methodologies are required to deal with the complex and dynamic development of metropolitan landscapes?; and (2) What type of planning support systems (PSS) are needed to support spatial planners and decision-makers with this task and what are the requirements for the successful implementation and use of these PSS in planning practice?

Since the domains of spatial planning and planning support systems (PSS) are very wide, the scope of this research is limited to PSS for supporting strategic spatial planning processes. Furthermore, the research specifically addresses the use of PSS in two case studies: (1) the spatial-environmental issues related to urban development in the metropolitan landscape in the Netherlands; and (2) the spatial-environmental issues related to the development of intensive livestock farming in the metropolitan landscape in South-East Asia.

Chapter 2 of this thesis provides the underlying planning theory by introducing the domains of land-use and environmental planning of the Wageningen spatial planning program. The domains of this program are traditionally the land-use and environmental planning issues in rural areas and the urban-rural interactions. The last decade, these domains are facing the growing complexity of the metropolitan landscapes in the Netherlands, Western Europe and many other parts of the world. The Wageningen planning program focuses at intertwining two contrasting planning philosophies: a design-oriented and a decision-oriented view of planning. It tries to find a balance between procedural, substantive and communicative knowledge and skills, all necessary to deal with the increased complexity of strategic spatial planning for the metropolitan landscape. The chapter describes the characteristics, strengths and weaknesses of design- and decision-oriented planning, and the revenues of intertwining both approaches for dealing with the complexity of metropolitan landscapes. The chapter reveals some distinct characteristics regarding the context and planning for metropolitan landscapes, which also reflect some requirements and preconditions for planning support tools.

Chapter 3 provides an overview on the field of planning support systems (PSS), and introduces the different case studies of the thesis. These case studies are described in more detail in Chapter 4 which includes a series of five papers, published in internationally reviewed journals and a book. The case studies involve the development of PSS that support the quick-scan assessment of environmental consequences of alternative spatial scenarios. Chapter 3 describes the characteristics of the PSS, and addresses the question if the PSS were successful in supporting planning and decision-making or not.

Chapter 5 discusses the overall results of the cases and answers the research questions. Some main conclusions are:

- The successful implementation of a PSS requires that potential users within a community of practice appreciate the added value of the PSS. The development of a PSS therefore requires clearly identifying the specific user needs and requirements, and linking to the elements of day-to-day planning and decision making. The better a PSS fits to its specific context, such as commonly accepted data, workflows, procedures, tools and instruments, the more likely it is that the PSS will be applied successfully and used on a more regular base. This requires avoiding a common pitfall with the development of many PSS that seem to be driven by geo-ICT ('technology-push') rather than the needs of humans and organizations ('user-pull'). It also stresses the need to keep PSS for supporting strategic spatial planning processes clear and simple, in order to prevent that the PSS will become

a black box. The methods and PSS described in the presented cases are simple and robust, also enabling spatial and statistical information to be consolidated and analyzed with minimal modeling resources. This is especially relevant in countries with limited modeling capacity and less familiarity with computer models. The case studies showed that communities of practice are a suitable common ground for sharing knowledge and experimenting with and testing the PSS in planning practice.

- The research shows the very traditional view of the disciplines involved on their role in the planning process, hindering a more integrated approach and the scanning of future options and scenarios in the early phases of the planning process. This requires a change in mentality from a monodisciplinary to an interdisciplinary focus. But disciplinary worldviews are difficult to change, and most likely will frustrate the successful implementation of PSS that stem from different communities of practice with different kinds of problem framing. PSS can provide a shared representation of the planned objects and thus improve the level of understanding and communication between disciplines.
- The wide range of stakeholders that participate in spatial planning and decision-making processes nowadays require a systematic and process-oriented approach, which enables to incorporate expert knowledge and stakeholder opinion into planning and decision-making. Policy and decision makers tend to have much more confidence in results that draw upon local knowledge and skills, which support the effective uptake and implementation of the results. PSS that aim to support these processes should therefore promote the participation of stakeholders, and also be able to present the results to decision-makers in a way that is easily assimilated.

Given the dynamics and complexity of the metropolitan landscape, PSS will never provide 'push-button' solutions, but instead may support planning processes by offering a range of options as input in a process. A general conclusion which can be drawn from the research is that PSS should match with the potential users, context and process. This requires that users and other stakeholders are involved from the early beginning in the development of a PSS, and that PSS developers become a part of the community of practice before they even start to think about what technology has to offer.

Samenvatting

Metropolitane landschappen zijn complexe gebieden, waar planners en beleidsmakers worden geconfronteerd met een diversiteit aan belangen en mondige burgers die betrokken willen zijn bij de planning en inrichting ervan. Een belangrijke opgave voor de ruimtelijke planning is om een balans te vinden tussen de toegenomen druk op de open groene ruimte door verstedelijking en economische ontwikkeling enerzijds, en de noodzaak van het behouden van deze landelijke gebieden voor natuur, recreatie, landschap en voedselproductie anderzijds. Dit complexe vraagstuk kan niet worden opgelost met behulp van lokale, participatieve planning alleen, maar het vraagt ook om een integraal, regionaal kader en perspectief voor de langere termijn. De laatste jaren laten dan ook een toenemende belangstelling zien voor lange-termijn denken en een opleving van strategische ruimtelijke planning. Strategische planning is een van de meest complexe overheidstaken. Planners en beleidsmakers hebben te maken met uiteenlopende en veelal conflicterende belangen op verschillende ruimtelijke en temporele schalen en een grote hoeveelheid informatie van verschillende aard en kwaliteit. De opgave daarbij is om tot reële, alternatieve ontwikkelingsrichtingen te komen in een interactieve setting met een groot aantal belanghebbenden. De afgelopen decennia is een groeiend aantal computersystemen ontwikkeld voor de ondersteuning van dergelijke complexe processen. Een specifieke groep systemen wordt aangeduid met de term Planning Support Systemen (PSS). PSS zijn geo-informatie systemen die speciaal zijn ontwikkeld ter ondersteuning van ruimtelijke planningsprocessen. De basisgedachte achter PSS is dat deze systemen zorgen voor een betere informatievoorziening en daarmee leiden tot een breder scala aan alternatieven en een meer zorgvuldig onderbouwd publiek debat. Helaas laten recente, inventariserende onderzoeken zien dat de meeste PSS in de planningspraktijk nauwelijks worden gebruikt.

Het doel van dit proefschrift is om het gebruik van planning support systemen (PSS) in de strategische ruimtelijke planning te verkennen. Het onderzoek is afgebakend tot PSS die ruimtelijk-economische ontwikkelingen afwegen tegen de kwaliteit van milieu en leefomgeving. De twee hoofdvragen van het onderzoek zijn: (1) Welke planningsbenaderingen en methoden zijn nodig om de complexe en dynamische ontwikkeling van metropolitane landschappen te kunnen sturen?, en (2) Welke PSS zijn

nodig om planners en beleidsmakers te ondersteunen bij deze opgave en waar moeten deze PSS aan voldoen om daadwerkelijk te worden gebruikt in de planningspraktijk?

De domeinen van ruimtelijke planning en planning support systemen (PSS) zijn erg breed en daarom beperkt het onderzoek zich tot PSS ter ondersteuning van strategische ruimtelijke planning aan de hand van een tweetal case studies, te weten: (1) de ruimte-milieu vraagstukken die samenhangen met de stedelijke ontwikkeling van het metropolitane landschap van Nederland, en (2) de ruimte-milieu vraagstukken die samenhangen met de snelle ontwikkeling van de intensieve veehouderij in de metropolitane landschappen in Zuidoost Azië.

Hoofdstuk 2 beschrijft de planningstheorie die de basis vormt van het theoretisch kader van het proefschrift. Deze theorie spitst zich toe op het domein van de omgevingsplanning of groene planologie van de Wageningse planningsopleiding. In deze opleiding ligt het accent traditioneel op de ruimtelijke vraagstukken van het landelijke gebied en de interacties tussen stad en land. De laatste decennia zijn deze vraagstukken steeds complexer geworden, vooral in de context van de sterk verstedelijkte, metropolitane landschappen in Nederland, West Europa en vele andere gebieden in de wereld. De Wageningse planningsopleiding besteedt veel aandacht aan twee contrasterende, maar ook complementaire planningsbenaderingen: een ontwerpgerichte benadering en een beslissingsgerichte benadering van planning. Het doel hiervan is om op een evenwichtige manier aandacht te besteden aan zowel procedurele, substantiële en communicatieve kennis en vaardigheden. Juist de combinatie van deze kennis en vaardigheden is nodig om te kunnen omgaan met de toenemende complexiteit van strategische ruimtelijke planning van metropolitane landschappen. De theorie in hoofdstuk 2 legt een aantal specifieke kenmerken bloot van de context en de planning van metropolitane landschappen, die een aantal randvoorwaarden en uitgangspunten opleveren voor planning support systemen die als doel hebben strategische planningsprocessen voor metropolitane landschappen te ondersteunen.

Hoofdstuk 3 geeft een beknopt overzicht van de huidige stand van zaken op het gebied van planning support systemen (PSS) en introduceert de verschillende case studies van het proefschrift. De case studies worden in meer detail beschreven in hoofdstuk 4, dat een serie van vijf wetenschappelijke artikelen en een hoofdstuk in een boek bevat. De case studies richten zich op de ontwikkeling van twee typen PSS ter ondersteuning van milieu-ruimte vraagstukken. De PSS ondersteunen het integreren van de milieu- en omgevingskwaliteit in een vroeg stadium van de planvorming, bij het ontwikkelen van ruimtelijke alternatieven. Hoofdstuk 3 beschrijft de aard en kenmerken van de PSS en het gebruik ervan in de planningspraktijk.

Hoofdstuk 5 bediscussieert de resultaten van de case studies en beantwoordt de onderzoeksvragen. De belangrijkste conclusies van het onderzoek zijn:

- Het succes van een PSS hangt in hoge mate af van het feit of potentiële gebruikers de toegevoegde waarde ervan inzien. De behoeften en eisen van deze gebruikers moeten daarom de leidraad vormen bij de ontwikkeling van PSS. PSS moeten ook goed passen bij elementen uit de dagelijkse praktijk van planning en besluitvorming. Hoe beter een PSS aansluit bij de context van deze praktijk, zoals algemeen geaccepteerde gegevens, werkprocessen, procedures, methoden en instrumenten,

des te groter de kans dat PSS ook daadwerkelijk worden gebruikt. Daarbij moet een veelvoorkomende valkuil worden vermeden, namelijk dat de ontwikkeling van veel PSS meer lijkt te zijn gestuurd door de mogelijkheden die de geo-ICT biedt ('*technology push*') dan door de behoeften van de potentiële gebruikers ('*user pull*'). Hierbij is het ook van belang om PSS voor strategische ruimtelijke planning zo transparant en eenvoudig mogelijk te houden, om te voorkomen dat gebruikers de PSS ervaren als een *black box*. De methoden en PSS in de case studies in dit proefschrift voldoen aan deze eisen. De PSS vragen slechts beperkte technologische kennis en gebruiken eenvoudige en inzichtelijke modelleringstechnieken. Dit is vooral belangrijk in ontwikkelingslanden, waar technologische kennis en mogelijkheden slechts in beperkte mate voorhanden zijn.

- Het onderzoek toont aan dat de disciplines die betrokken zijn in een planningsproces veelal een traditionele opvatting over hun rol in het proces hebben. Dit staat een meer geïntegreerde benadering en het verkennen van alternatieven aan het begin van het planproces in de weg, en vraagt om een verandering van monodisciplinair naar interdisciplinair denken en werken. Disciplinaire opvattingen zijn echter lastig te veranderen en kunnen het gebruik van PSS die een integrale benadering vragen frustreren. Het onderzoek laat echter ook zien dat PSS juist een communicatiemiddel kunnen vormen tussen disciplines en daarmee een meer integrale benadering kunnen stimuleren en het onderling begrip over de planningsopgave verbeteren.
- Het grote aantal actoren en belangengroepen dat vandaag de dag participeert in ruimtelijke planningsprocessen vraagt om een systematische en procesgeoriënteerde benadering, waarin zowel kennis van experts als kennis en opvattingen van mensen uit de praktijk een plek krijgen. Bestuurders en besluitvormers blijken ook meer vertrouwen te hebben in resultaten die mede gebaseerd zijn op kennis uit de praktijk, omdat daarmee de acceptatie van de resultaten en de effectiviteit van uitvoering worden verbeterd. PSS die deze processen ondersteunen moeten daarom de mogelijkheid bieden om kennis en meningen van belanghebbenden in te bedden in het proces en de resultaten ervan op een begrijpelijke en inzichtelijke manier aan te bieden in het besluitvormingsproces.

Gezien de dynamiek en complexiteit van metropolitane landschappen mag het duidelijk zijn dat planning support systemen nooit in staat zullen zijn om met een 'druk op de knop' kant-en-klare oplossingen te genereren. PSS kunnen de ruimtelijke planning en besluitvorming wel verbeteren door het proces te voeden met een breder scala aan keuzemogelijkheden en de consequenties van deze keuzen inzichtelijk te maken. Een algemene conclusie uit het onderzoek is dat PSS goed moeten aansluiten bij zowel de gebruikers, de context als het proces, omdat deze zich over het algemeen niet zullen aanpassen aan de PSS. Het is daarom belangrijk dat de potentiële gebruikers van PSS en andere belanghebbenden vanaf het eerste begin betrokken zijn bij de ontwikkeling ervan en dat PSS ontwikkelaars participeren in een *community of practice* voordat ze nadenken over de inbreng van technologie.

摘 要

近代土地利用规划正面临着都市景观越来越复杂的挑战。在复杂的都市景观中，规划师和决策者不得不考虑规划目标和规划利益相关者的多样性。如何在乡村景观上平衡经济与城市发展和农用地与自然资源保护的矛盾是我们面临的一大挑战。都市景观不断增长的复杂性不能单靠局部的参与式规划合理表达，它还需要一个能够界定与评价更长时间、更加综合基于未来观的空间规划框架。所以，近年来，人们对长期的规划思维产生了新的兴趣，区域尺度上的战略规划又重新进入了人们的视野。然而对于各机构而言，战略空间规划的过程是诸多复杂任务之一。规划师需要考虑在不同时间和空间尺度上经常相互矛盾的规划目标，处理大量不同类型和不同质量的信息，需要在与不同利益相关者交流的环境下综合、总结出各种可行方案。近10年来，为了辅助、支持空间规划过程，人们相继开发了许多基于计算机技术的地理信息或空间决策支持系统（SDSS）软件，在其中就有一类特殊的系统，我们统称为规划支持系统（PSS）。通常的认为是：增强对相关信息的了解会形成更多的可选预案，能导致更好的公众讨论效果，在这个意义上，规划支持系统能有效地对规划过程提供支持。但是研究表明：规划支持系统远没有得到广泛的采纳与应用，也远未能有效地融入规划过程。

本论文的主要目的是探讨如何在区域尺度都市景观的战略空间规划中应用空间规划支持系统，协调空间发展与环境保护的矛盾。两个基本的研究问题是：1）研究都市景观动态复杂的发展问题需要什么技术方法？2）对于空间规划师和决策者而言，要完成这个任务需要什么类型的规划支持系统的支持？以及

在规划实践中要成功的运行和应用规划支持系统有什么样的要求？由于空间规划和空间规划支持系统的范围非常广，本论文仅限于研究空间规划支持系统在战略空间规划过程中的应用。此外，本论文还特别强调了规划支持系统应用的两个案例，1）荷兰都市景观中与城市发展相关的空间环境问题，2）东南亚都市景观中与密集型畜牧业发展相关的空间环境问题。

论文的第二章通过介绍瓦赫宁根大学空间规划课程的土地利用和环境规划研究的领域，研究了基础规划理论。这个领域通常是乡村地区或城乡结合部的土地利用和环境规划问题。在近10年间，这个领域正面临荷兰，西欧和世界其他地方的都市景观问题的复杂化。瓦赫宁根大学规划课程致力于将两种矛盾的规划哲学观点---设计导向型和决策导向型规划观点相联系。

它试图将程式的、实体的和交流的知识与技巧相联系，这些知识和技巧对于解决都市景观越来越复杂的战略空间规划问题都是必要的。本章介绍了设计与决策导向型规划的特征，优缺点，以及将两者相联系处理都市景观复杂性的益处，揭示了一些有关都市规划和规划背景的显著特征，这些特征也反映了规划支持系统的一些要求和前提假设。

第三章对规划支持系统研究领域进行了综述，并介绍了本论文的案例研究。第四章对案例研究进行了详细的描述，它由在国际期刊和著作上发表的五篇系列论文组成。案例研究包括了可对可选空间预案的环境效应快速评价的规划支持系统的发展。本章描述了规划支持系统的特征，重点分析了规划支持系统是否可以为规划和决策提供支持的问题。

第五章讨论了案例分析的结果，回答了研究问题。主要结论有：

- 规划支持系统的成功运用需要在实践集体中的潜在用户认知规划支持系统的增益价值。因此，规划支持系统的开发者需要清楚认知特定用户的需求，需要，与日常规划与决策要素相结合。规划支持系统与特定背景结合的越好，就越有可能被普遍成功运用。它的成功应用需要克服许多开发的规划支持系统都存在的一个误区：认为地理信息技术（技术推进型）而非人和组织机构（用户推进型）是规划支持系统发展的驱动因素。这迫使规划支持系统在支持战略空间规划过程中目的必须清晰和明确，避免使规划支持系统成为一个黑箱。案例中描述的规划支持系统和方

法都是清晰和强有力的，它使用了最少的模型资源，综合与分析了空间与统计信息。这对模拟能力和计算机模型资源不足的国家显得特别有意义。案例研究结果表明，实践集体是规划实践中，分享知识、验证与检验规划支持系统有效性的基石。在规划支持系统开发者想提供任何技术之前，他们必须成为这个集体的一员。

- 研究表明，各学科在规划过程中的作用的传统观念，阻碍了在规划过程初期中应用综合方法分析未来可选方案和预案。这需要从单学科思维转向交叉学科思维。但是学科的观点是很难转变的，很可能会使源于拥有不同问题的不同实践集体的规划支持系统难以顺利实施。规划支持系统可以用对规划目标的共同表达方式来增强不同学科之间的理解和交流。
- 当今众多利益相关者参与空间规划与决策过程的现实需要一种系统的、以过程为导向的方法，它在规划和决策过程中可以综合专家知识与相关利益者的观点。政策制定与决策者面对来源于当地知识与技能的结果显得更有信心。因为当地的知识与技能可以被有效地吸收，支持规划结果的实施。规划支持系统如果要支持这些过程，就需要提高利益相关者的参与程度，也需要能为决策者容易吸收的方法来阐述结果。

考虑到规划实践的多样性和都市景观的复杂性，规划支持系统永远不会是空间规划问题的唯一解决途径。问题的特有背景总是需要人、技能与工具的特定组合。

Curriculum Vitae

Gerrit Jan Carsjens was born on March 22, 1962 in Den Helder, the Netherlands. He holds a BSc and MSc in Land and Water Use Planning from Wageningen University which he finished in 1988, majoring in land-use planning, with special interest in soil sciences and informatics.

From 1989 until 1990 he was appointed at the Dutch National Institute for Public Health and the Environment. He contributed to the national environmental survey and forecasting program. It was here that his special interest in environmental issues did awaken.

From 1990 until 1996 he was employed at the Wageningen University as an assistant professor in Land Use Planning with special emphasis on soil suitability and environmental issues. From 1996 until present he continued working at this university as an assistant professor Land Use Planning in the domain of methods and techniques for spatial planning, with special emphasis on the use of Geographical Information Systems (GIS). His educational and research work are primarily related to the strategic spatial and environmental planning of metropolitan landscapes. He published more than 50 scientific publications in the fields of spatial and environmental planning and geo-information science.

He is also engaged with several international scientific projects and organizations. At present these are: Secretary and treasurer of the International Study group On Multiple Uses of Land (ISOMUL) (since 1999); Consultant of the United Nations, Food and Agricultural Organization (FAO) and World Bank – Global Environmental Facility (GEF) (since 2002); Visiting Professor at the Mediterranean Agronomic Institute of Chania, Greece (since 2003); Board member of the International Commission of Agricultural Engineering (CIGR) Section I on Land and Water Engineering (since 2006); Editorial board member of the scientific journal Landscape and Urban Planning (since 2007) and the open access journal Landscape Studies (since 2007).

Selected publications

Lier, H.N. van & G.J. Carsjens, 2009. Ecological networks for integrated land-use planning: Lessons from the Netherlands, USA and Argentina. Chapter 13 in: F. Brouwer and S. Goetz, The dynamics of land use and ecosystem interactions: A transatlantic, multidisciplinary and comparative approach. Springer. In press.

Carsjens, G.J. & J.M.M. Neuvel, 2008. Flood risk assessment in Dutch land-use planning. In: Proceedings 11th Inter-Regional Conference on EnviroWater, Foz do Iguaçu, Brazil.

Gerber, P., G.J. Carsjens, T. Pak-Uthai, and T. Robinson, 2008. Decision support for spatially targeted livestock policies: Diverse examples from Uganda and Thailand. Agricultural Systems 96: 37-51.

Carsjens, G.J., Yajie Wang & Wenbo Chen, 2007. Regional growth management in China: The role of public participation in spatial planning. In: Proceedings 10th Inter-Regional Conference on EnviroWater, New Delhi, India. Invited lectures, pp. 154-161.

Carsjens, G.J., 2007. Spatial planning and environmental assessment. Postgraduate manual MAICh. Mediterranean Agronomic Institute of Chania, Greece, 67 p.

Carsjens, G.J., and A. Ligtenberg, 2007. A GIS-based support tool for sustainable spatial planning in metropolitan areas. Landscape and Urban Planning 80 (2007): 72-83.

Zhao Xiaomin, G.J. Carsjens, and P. Gerber, 2006. Regional planning of pig husbandry with environmental protection using GIS. Transactions of the Chinese Society of Agricultural Engineering 22(9): 184-188.

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.

Van der Knaap, W.G.M., and G.J. Carsjens (Eds.), 2006. EnviroWater2006: Concepts for watermanagement and multifunctional land-uses in lowlands. Proceedings 9th Inter-Regional Conference on EnviroWater, Delft, the Netherlands.

Broekman, R., K. van der Wel, and G.J. Carsjens, 2006. Speelruimte binnen SMB: Ervaringen vergeleken. Toets 05(06): 12-15.

Carsjens, G.J., and P. Gerber, 2005. Spatial Planning of Livestock Production in Southeast Asia. In: Proceedings 8th Inter-Regional Conference on EnviroWater. UTA, Dallas/Ft. Worth, Texas USA, Full paper at CD-ROM, pp. 6-17.

Ke Bingsheng, Li Guoxue, Luo Qixiang, Zhao Xiaomin, G.J. Carsjens, Somchai Chantsavang, D.T. Vadnjal, and P. Gerber, 2005. Integrated waste management in Wannian County, Jiangxi Province, People's Republic of China, TCP/CPR/0170(A), Final Report. FAO-LEAD, Animal Production and Health Division, Rome, 78 p + Annex 66 p.

Valk, A. van der, and G.J. Carsjens, 2005. Feet on the ground: Engaging students with political realities. In: J. Friend, and A. Hickling (Eds.), Planning under pressure, The strategic choice approach, 3rd Edition, Chapter 13.5, pp. 315-318. Elsevier Butterworth-Heinemann.

Carsjens, G.J., P. Gerber, Dan T. Vadnjal, Somchai Chantsavang, Ke Bingsheng, Li Guoxue, Luo Qixiang, Zhao Xiaomin, and H. Steinfeld, 2004. Addressing Livestock and Environment Issues in Wannian County: Policy and Technology Options for the Area-Wide Integration of Crop and Livestock Activities. In: Guanhua Huang, and Luis S. Pereira, Proceedings 7th Inter-Regional Conference on EnviroWater, Beijing, China, China Agriculture Press, pp. 629-639.

Carsjens, G.J., 2004. Spatial planning of future livestock production, Livestock waste management in East Asia, GEF project GCP/RAS/203/WB, FAO, 2004, 41 p.

Boer, I. de, G.J. Carsjens, and A. van der Valk (Eds.), 2004. Multiple landscape: Merging past and present in landscape planning. Proceedings 5th International workshop on sustainable land use planning, Wageningen, The Netherlands, ISOMUL and Wageningen University.

Gerber, P., G.J. Carsjens, Somchai Chantsavang, Dan T. Vadnjal, Ke Bingsheng, Li Guoxue, Luo Qixiang, and Zhao Xiaomin, 2004. Integrated waste management in Wannian County, Jiangxi Province, People's Republic of China, TCP/CPR/0170(A), Mid-term report, FAO, Rome, 123 p.

Carsjens, G.J., H. Steinfeld, and P. Gerber, 2003. An area-based approach for environmental problems related to livestock production. In: J.M. Tarjuelo, F.M. de Santa Olalla, and L.S. Pereira, Proceedings 6th Inter-regional conference on EnviroWater. Albacete, Spain. Abstract book pp. 175-176, full paper at CD-ROM.

Carsjens, G.J., 2003. Improving the quality of physical plans at local level. In: K. Haaland, and B. Smith (Eds.), Proceedings Fourth International Workshop on

Sustainable Land Use Planning. Bellingham, Washington State, USA, June 20-22, 2002. Abstract book p. 99, full paper at CD-ROM.

Carsjens, G.J., R.J.A. van Lammeren, and A. Ligtenberg, 2003. STEPP: Strategic Tool to integrate Environmental aspects into Planning Procedures. In: S. Geertman and J. Stillwell (Eds.), Planning Support Systems in Practice, Chapter 8, pp. 139-154. Springer, Berlin.

Carsjens, G.J., and H.N. van Lier, 2002. Fragmentation and Land Use Planning: An Introduction. Landscape and Urban Planning 58 (2002): 79-82.

Carsjens, G.J., and W.G.M. van der Knaap, 2002. Strategic land use allocation: dealing with spatial relationships and fragmentation of agriculture. Landscape and Urban Planning 58 (2002): 171-179.

Carsjens, G.J., A. Schaminée, and J. Westerdiep, 2002. Milieubeoordelingsmethoden revisited! ROM 11 (2002): 34-35.

Narrod, C., G.J. Carsjens, Somchai Chantsavang, D. Vadnjal, Ke Bingsheng, Zhao Xiaomin, Luo Qixiang, and Li Guoxue, 2002. Integrated waste management in Wannian County, Jiangxi Province, People's Republic of China, FAO, Rome, 2002, 29 p.

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Cover: West Lake, Hanoi (Vietnam)

Chapter 1: Randstad-Green Heart metropolitan area (the Netherlands)

Chapter 2: Rio de Janeiro (Brazil), Delhi (India), and Dallas-Ft. Worth (Texas, USA) metropolitan areas

Chapter 3: Hanoi metropolitan area (Vietnam)

Chapter 4: Bangkok metropolitan area (Thailand)

Chapter 5: Beijing, Guangzhou and Nanchang metropolitan areas (China)