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Challenges and potentials in using alternative landscape futures during climate change: A literature review and survey study

This study focuses on the feasibility of applying alternative futures and scenario analysis in landscape planning during climate change to provide a wider perspective and deeper understanding of this approach for better use and more effective application in the future. The study consists of a literature review and an analysis of recent applied projects carried out worldwide. In addition, an electronic survey was conducted from March to September 2014 to examine viewpoints on the use and application of this approach with reference to climate-change impacts. The survey participants were a group of highly experienced researchers from eighteen countries involved in at least one applied project since 2000 relating to this topic. After analysis of more than forty applied projects, the survey results were incorporated into the analysis to create a comprehensive picture regarding the potentials and limitations of alternative futures and scenario analysis in landscape planning with particular attention to climate change. The findings show that this method is one of the most effective decision-making approaches for adopting landscape policies where landscapes change rapidly under the pressure of urbanisation and climate change. Nevertheless, there is a gap between the advances offered by the approach in various dimensions and the complexity of patterns, uncertainties and upheavals in landscapes due to climate-change impacts in the urbanising world. The research indicates that the approach opens up a great opportunity for decision-makers to expand their perspective and adopt appropriate landscape policies before reaching a point of no return from the sustainability point of view. Meanwhile, there are challenges and barriers in the application of alternative futures and scenario analysis for envisioning the landscapes influenced by climate change and urbanisation that should be pushed back. Although informative, this research raises new questions about this approach and its applications in the future, providing a basis for further research.

Keywords: alternative landscape futures, scenario analysis, climate change, urbanisation, survey study, experts' viewpoint

1 Introduction

The world is increasingly becoming urbanised like never before (see Mulligan & Crampton, 2005; Pimentel & Pimentel, 2006). The growing demand for living in urban regions due to their inherent socioeconomic attractions (see, e.g., Acharya & Barragán Codina, 2012; Cheng, 2012; Zhang et al., 2012) has had far-reaching consequences for natural landscapes in recent years, and this has generated a great impetus for researchers to come up with new methods and techniques to measure, predict, depict and manage changes in landscape patterns and processes (e.g., Turner, 1989; Jenerette & Wu, 2001; Bender et al., 2005; Deng et al., 2008; Jenerette & Potere, 2010). Since 2000, some ecologically based studies have especially emphasised the relationship between haphazard urban development and the depletion of natural resources worldwide (e.g., Dale et al., 2000; Pickett et al., 2001; Jongman, 2002; Alberti & Marzluff, 2004; Kupfer, 2006; Ahern, 2007; Breuste et al., 2008; Mehaffy & Haas, 2012; Obeng-Odoom, 2012). In line with this trend, climate-change impacts on the urbanised world have also been examined. Climate change is one of the most powerful driving forces behind land-use and land-cover change, and it has led to unprecedented landscape upheaval in urbanised landscapes. Floods, droughts, storms and rises in sea level are major consequences of climate change in urban areas worldwide (see Hamin & Gurran, 2009). Recently, some researchers have sought new ways to find a sustainable cure for this destructive phenomenon. Among all of the efforts, some researchers show that making assumptions about possible changes in landscapes with particular attention to climate-change impacts and other important variables, and then envisioning these changes in landscapes, can be a sufficient means of informing decision-makers about the likely effects of each set of landscape policies on the entire landscape beforehand (e.g., Bryan et al., 2008; Morley et al., 2012). Landscape policies can address climate change. Similarly, climate change can result in a wide range of landscape changes. Therefore, under conditions of urbanisation and climate change, envisioning changes in landscapes caused by both urbanisation and climate change provides a basis for informed decisions on adopting appropriate landscape policies. Because each set of land-use and land-cover policies causes specific changes in a landscape, it is clear that the level of landscape vulnerability and resiliency in the face of climate-change impacts is different in each case. Therefore, depicting the likely effects of these policies on a landscape's future can be an integral part of mitigation and adaptation strategies when planning urbanised landscapes. To adopt sustainable landscape policies against the adverse effects of climate change, it is necessary to explore and understand the rules governing landscape change over time.

Incorporating information about landscape ecology into landscape planning may hold the key to addressing climate-change impacts on cities through mitigation and adaptation strategies (see Opdam et al., 2009). Addressing climate change, urban development and landscape ecology simultaneously may make it possible to overcome current landscape-planning dilemmas. In response to climate change–induced urban and regional challenges, this research proposes using alternative futures and scenario analysis as an efficient tool supporting informed decisions on land-use and land-cover policies. Defining alternative futures for landscapes under climate-change pressure can inform society concerning what the future might bring. Applying this approach can ensure the accuracy and reliability of landscape policies formulated based upon technological facilities, social values, ecological knowledge and collective wisdom. Nevertheless, there remain many questions regarding the use and application of this approach for making informed decisions about the interrelationships between landscape change, urbanisation and climate change based on envisioning different landscape futures. This research addresses two major questions: 1) Is alternative futures and scenario analysis an appropriate and reliable tool for depicting future landscapes, and consequently adopting landscape-planning policies during climate change? 2) What are the current challenges and potentials in applying this decision-making tool in the real world?

2 Methodology

In this study, the term *landscape* refers to a combination of various anthropogenic land uses and natural land covers interacting with each other in a large scale over time. The research combines international literature and information from experts' practical experiences to provide better insight into the role of alternative futures and scenario analysis in ecologically based landscape planning with regard to climate change. A multi-approach strategy was used for the research. The study's cornerstone was an in-depth review of case studies using an alternative futures and scenario analysis approach in different countries. The case studies were analysed in detail by applying a content-analysis method. Then, to strengthen the review, an informative survey was carried out with the collaboration of a small number of experienced experts worldwide.

Multiple sources of information were used (see Wang & Hofe, 2007; Deming & Swaffield, 2011) to collect the required data. To start with, a wide array of publications, including recently published papers in peer-reviewed journals, well-established books and technical reports, were collected, filtered, classified and reviewed. After reviewing the international literature, key concepts were derived using a complex description strategy to provide a basis for designing an informative questionnaire. A twenty-four-question e-questionnaire, with various types of questions, was circulated via e-mail to relevant persons. Questionnaires were sent to a broad group of potential participants, ranging from university instructors to professionals in landscape architecture, urban and regional planning, biodiversity conservation, soil sciences, habitat management, bioagriculture, geology, geography, rural planning and landscape restoration.

One of the strengths of the questionnaire was the diversity of question types, such as closed-ended, open-ended, yes/no, and ranking-based questions. Closed-ended questions were designed based on a Likert scale to systematically obtain experts' judgments concerning important issues. More importantly, to scrutinise the issues studied in detail, several open-ended questions were also used to reveal matters that are unlikely to be discovered using ordinary multiple-choice questions. To find relevant individuals whose academic and professional experiences were appropriate for inclusion in the survey, a keyword-based search was used in well-established scientific databases such as Science Direct to find the name of authors that published their research in peer-reviewed journals since the late 1990s. To increase the accuracy of research to the highest possible degree, a filter question was also designed at the beginning of the questionnaire. This question asked respondents to complete the questionnaire only if they had been involved in at least one applied alternative landscape futures project since 2000. In addition, to avoid omitting influential people in this area, a snowballing approach was applied to identify additional relevant persons. The researcher thus asked participants to suggest relevant persons whose work and experience were relevant to this study. The snowballing approach was used to identify overlooked relevant persons and expand the search. By using the snowballing approach, several participants were added.

Ultimately, forty-two respondents from eighteen countries returned questionnaires (Table 1). Among them, thirty-one participants answered all of the questions on the questionnaire and eleven questionnaires were incomplete. Incomplete questionnaires were excluded from in-depth analysis and the study concentrated on thirty-one questionnaires. Nonetheless, useful information from the incomplete questionnaires was also taken into consideration. Whereas in ordinary surveys sample size is calculated by a formula, statistical tables, and referring to similar studies or a combination of such methods, in research when the respondents are highly qualified and well-informed it is enough to reach a saturation point (see Flick, 1998; Guest et al., 2006) where the researcher does not observe new items in responses. Moreover, when responses are repeated in a regular pattern, this can be considered a sign of achieving an acceptable level of error in sampling. From another angle, because the sample was geographically diverse, this ensured the reliability of the survey. Furthermore, the diversity of participants in various academic disciplines also potentially guaranteed the accuracy of survey results. In this study, the responses were monitored by the researcher while questionnaires were gradually sent to appropriate persons. More than six months of research went into achieving the saturation point where it was no longer necessary to increase the sample size.

Table 1: Geographical distribution of participants

Region	Country	Number
North America	Canada	2
	US	10
Europe	Czech Republic	1
	Estonia	1
	Finland	2
	France	3
	Germany	3
	Italy	4
	Latvia	1
	Netherlands	2
	Slovakia	1
	Slovenia	1
	Spain	1
	Sweden	2
	Switzerland	1
	UK	2
Oceania	Australia	4
Asia	Japan	1

Statistical graphics and conceptual figures were used to visualise useful information. The survey results reflect a broad range of concerns relating to the use of alternative futures in landscape planning with reference to future climate change. Overall, the combination of key concepts derived from in-depth analysis of applied case studies plus information gained from the survey represents the most important potential feature of using alternative futures and scenario analysis in landscape planning during climate change.

3 Mapping the historical trend

Alternative futures and scenario analysis is an approach for making informed decisions regarding possible futures. According to Remi Barre (2004: 116, cited in Kosow & Gabner, 2008), "scenarios allow for looking far and wide". In many cases, "they provide support for more long-term and more system-oriented observations than other approaches" (Kosow & Gabner, 2008: 19). Sandra Greeuw et al. (2000: 7) emphasise the fact that "the approach is perhaps most effective when seen as a powerful tool to broaden perspectives, raise questions and challenge conventional wisdom." Various variables and factors should be taken into consideration when addressing the use and application of alternative futures and scenario analysis in the contemporary history of landscape planning. In general, the academic emergence of alternative futures and scenario analysis can be seen in William F. Ogburn's research on social trends and their consequences in the US from 1930 to 1933 (Odum, 1951). During the 1950s and 1960s, this approach was applied in business management and marketing. The book *The Limits to Growth* (Meadows et al., 1972) was another initiative for using alternative futures and scenario analysis in the twentieth century. The book offered a computer-aided simulation of the outcomes of the interactions between environmental and human systems. The book took world population, pollution, industrialisation, resource depletion and food production into consideration as major variables in constructing an exponential model. Nevertheless, using alternative futures in landscape planning was dependent on requirements and technological tools that developed later over three decades, from the 1960s onwards.

Along with the invention of primitive computers, quantitative techniques in landscape planning were developed during the 1960s (Fabos, 1985). This, in turn, was a quantum leap towards envisioning landscapes in later decades. In line with this development, a geographic information system (GIS) was introduced by Roger Tomlinson (1968) in Canada. One year later, the book *Design with Nature* was written by Ian McHarg (1969) in support of applying ecological knowledge in landscape planning. McHarg (1969) proposed a sieving technique to analyse the relationship between various layers of a landscape, ranging from fully natural to anthropogenic features. During the 1970s, GIS was developed by many researchers across the world. Breakthroughs in nonlinear systems, fractals and chaos theory started in the 1980s, and led to significant progress in urban modelling (Liu, 2009: 16) and landscape simulation. Since then, cellular automata (CA), as a powerful technique for landscape simulation, has been used to model urban growth and landscape change. These advancements paved the way for using alternative futures in landscape planning. Concurrent with these trends, the term *climate change* was first used by the geochemist Wallace Broecker (1975) and this led to defining a new branch of knowledge involving climate change and landscape planning. Afterwards, several seminal publications linked urban development and landscape planning to climate change from various angles (e.g., Crichton et al., 2009; Condon et al., 2009; Hodson & Marvin, 2010; Wilson & Piper, 2010; Calthorpe, 2011; Rosenzweig et al., 2011; Watson & Adams, 2011; Cartwright et al., 2012; Moser & Boykoff, 2013; Lee, 2014; Prutsch et al., 2014). In particular, application of alternative futures and scenario analysis in landscape planning emerged in the 1990s (Botequilha Leitão & Ahern, 2002) in the Netherlands (Harms et al., 1993; Schooenboom, 1995) and the US (Landis, 1995; Steinitz et al., 1996; Freemark et al., 1996; Hulse et al., 1997; Ahern, 1997; White et al., 1997; Ahern, 1999). Afterwards, the approach was widely used across the US (e.g., Hulse et al., 2000; Theobold & Hobbs, 2002; Hunter et al., 2003; Steinitz et al., 2003; Aycrigg et al., 2004; Berger & Bolte, 2004; Hulse et al., 2004; Nassauer & Corry, 2004; Reyes et al., 2004; Santlemann et al., 2004; Schumaker et al., 2004; Corry & Nassauer, 2005; Kepner et al., 2008; Hulse et al., 2009; Sleeter et al., 2012; Penteado, 2013), in Australia and Europe (e.g., Patel et al., 2007; Bryan et al., 2008; Soliva et al., 2008; Verburg et al., 2010; Oana et al., 2011; Morley et al., 2012), in Asia (e.g., Wang, 2011; Sun et al., 2012; Pan et al., 2014; Shoyama & Yamagata, 2014) and even in the developing world (e.g., Ferraz et al., 2005; Bao Le et al., 2010; Sheikh-Goodarzi et al., 2012).

Alternative futures and scenario analysis has been recognised as an important contribution to landscape research. For example, Elen Deming and Simon Swaffield (2011: 111) define it as a "distinctive application of dynamic simulation modelling used to improve understanding about the landscape consequences of different policy decisions." Applying alternative futures in landscape planning has been a multipurpose approach to addressing a broad range of landscape-related issues. Either directly or indirectly, most of them are related to climate change. A review of recent studies conducted by researchers shows that the metrics by which climate change are measured have been explored. David Theobald and Thompson Hobbs (2002), for example, examined the importance of biodiversity protection on private land in the Lower Blue Basin. They emphasise the crucial role of stakeholders throughout the study. In another study, Carl Steinitz et al. (2003) placed particular emphasis on water and biodiversity in the Upper San Pedro River Basin, recognising urbanisation and agricultural activities as the major environmental stresses affecting the region. In that study, biodiversity was considered as a main criterion during the investigation. In some instances (e.g., Hunter et al., 2003), alternative futures have been postulated to establish a relationship between demographic dynamics and land-use change associated with it. The influence of land-use change on natural habitats in particular has been studied. Lori Hunter et al. (2003) concluded from their study of California's Mojave Desert that desert environments have a fragile ecology and are therefore susceptible to human pressures. They suggest that high-density development could reduce conflict with such regions by over 80%, providing a potential habitat for threatened or endangered species. A study by Joan Nassauer and Robert Corry (2004) demonstrated the application of normative scenarios in landscape ecology in Iowa agricultural watersheds using three scenarios: production, water quality and biodiversity. David Hulse et al. (2004) applied alternative landscape futures in the Willamette River Basin to examine the likely effects of various sets of land- and water-use policies on the landscape future. This study is an example of applying alternative futures in landscape planning due to the diversity and quantity of participants while making assumptions, as well as the considerable number of land-cover types defined for maps. More importantly, the research provides a conservation and restoration opportunities map created for use in a conservation scenario showing the importance of climate change–related concerns among researchers.

Robert Lilieholm et al. (2005) studied the relationship between urban development and the protection of environmental quality and public health in Utah to identify the likely conflicts between these variables over time. Emphasising the quality of life, this research presented a framework for envisioning the likely effects of urban development on environmental conditions. Focusing on the concept of sustainability in applying alternative futures in the Georgia Basin in British Columbia, Tara Sharma et al. (2005) argue that one of the main advantages of applying alternative futures in landscape planning is that this approach provides a basis for stakeholders to adopt informed land-use decisions and policies for the transition to a sustainable future. In a socio-environmental study, David Mouat et al. (2006) addressed the relationship between desertification and poverty using alternative futures. William Kepner et al. (2008) addressed potential water quality problems as a result of land-cover change in the American Pacific Northwest to provide options that could be useful for sustainable management of natural resources.

This review demonstrates that all alternative futures studies have concentrated on the concept of collective wisdom in landscape planning. Joan Baker et al. (2004) believe that community decision-making typically involves stakeholders with widely divergent viewpoints and values. The most important end product is developing consensus, or compromise, about desired goals and priorities; that is, shared vision for the future. The purpose of an alternative futures analysis is to facilitate this consensus-building. Mouat et al. (2006) believe that analysis of alternative futures is a forum for exchanging concerns, issues, and hopes for the future.

Having examined the advantages and strengths of using alternative futures in landscape planning over more than two decades, this approach can be applied in landscape envisioning relating to the likely effects of climate change. Over the last decade, applying alternative futures and scenario analysis for envisioning landscape policies with regard to climate change impacts has increased. In Australia, two major alternative landscape futures studies in Lower Murray (Bryan et al., 2008) and New South Wales (Morley et al., 2012) are clear examples proving that climate change and its effects on landscapes have become the most important concern among researchers, authorities and policymakers. For example, Brett Bryan et al. (2008) address dry land areas and focus on climate change as a major factor affecting landscapes. Philip Morley et al. (2012) carried out a study on alternative landscape futures and climate change adaptation to show how alternative futures and scenario analysis can be a powerful tool for anticipating climate change impacts on coastal settlements and communities. Another alternative futures-centred study in Australia (Meyer et al., 2013) discussed the importance of addressing food production and conservation during climate change. The study invited other researchers to engage in new research on the current gaps and challenges in applying this approach. This trend can be also seen in European studies. In the UK, in a case study of the Humberhead Levels, Trudie Dockerty et al. (2006) documented an approach to constructing scenarios that can incorporate potential climate change impacts and reflect the uncertainty in climate change projections due to different environmental policies. Peter Verburg et al. (2010) argue that land-use change in Europe is affected by a variety of local conditions and global processes. They took climate change into consideration as an important factor affecting these variables. There is also further evidence indicating that applying alternative futures for climate change with particular concentration on spatially explicit landscape patterns has been recognised as a priority and necessity in landscape planning. In addition to these studies, there are still questions that should be answered in the future. Some important challenges, gaps and potentials relating to the use and application of alternative futures and scenario analysis in landscape planning with reference to climate change are discussed below.

4 Results and discussion

Applying alternative futures and scenario analysis is an emerging approach for addressing the likely effects of climate change on urbanising landscapes. Since the 1990s, many studies have been conducted on alternative landscape futures and scenario analysis around the world, especially in developed countries. Although the majority of studies have minor differences in practice, a similar mechanism was used in all projects. In this study, this mechanism was represented in four main parts: definition, depiction, evaluation and synthesis (Table 2). The following section summarises the results of the research. The results consist of diverse findings from a comprehensive review of the international literature, an analysis of applied projects and survey findings. For better understanding and functionality, the results derived from data analysis and a literature review are presented in as descriptive a manner as possible.

4.1 Definition

4.1.1 Data collection

To collect various types of data, including verbal and environmental, various methods and tools should be applied. From ordinary data such as demographic trends, the trajectory of change in land price, housing demands, dwelling patterns and water consumption, to more specific climate change–related data such as climate change–induced immigration rate, energy demand, food security, the change in rainfall and temperature patterns, and the volume of greenhouse gas emission, should all be taken into consideration. In this process, it is important to constantly overlap verbal and environmental data to ensure that the accuracy of data is at an acceptable level. In the case of verbal data, it is also important to define a suitable framework for stakeholder participation in decision-making. Stakeholders are social forces and can be classified into four major groups: laypeople, influential persons, experts and local authorities. To reach a consensus among such a large group of stakeholders around the issues investigated, a comprehensive plan should be mapped to guarantee the active and effective role of each group in the entire process. Experiences from previous landscape-planning projects show that researchers constantly faced difficulties during data collection (e.g., Hulse et al., 2004; Sheikh-Goodarzi et al., 2012). Paying particular attention to climate-change impacts can make the situation even more difficult because climate change–related data are not available everywhere. Moreover, collecting the relevant data is time-consuming and expensive in many cases because researchers have to rely on technological tools such as satellite images, visual and numerical data, and technical maps. In addition, the methods by which accurate data are collected are extremely diverse and complex. The situation becomes even worse when researchers need to collect data based on field measurements.

Another concern is the accuracy of data. For the greatest accuracy of data, various data-collection methods should be applied in parallel. Although effective sometimes, remote sensing cannot be used as the only method for collecting climate change–related data on the landscape studied. In some cases, direct observation and field measurements should be a complimentary tool. Data collection is important and crucial in that landscape simulation and making assumptions will be based on the dataset collected using different methods, from different sources. Morley et al. (2012) listed a number of challenges while collecting data, including data access, time for assembly, and poor data quality. In addition, providing a rich set of correct data opens the opportunity for landscape depiction in, for example, restoration and rehabilitation projects in the long run. Biogeoclimatic maps (see Bell, 1999) including all historical land-cover and land-use types, are essential for understanding the past conditions of the landscape and its ecological requirements. Such maps contain a wide range of spatial data about the landscape and provide a reliable basis for comparison and analysis of the landscape in the past, present and future.

4.1.2 Making assumptions

Mouat et al. (2006) state that alternative futures and scenario analysis in landscape planning is a forum for the exchange of concerns, issues and hopes for the future. The content of the assumptions is the rules under which landscapes change over time. Landscape transformation should be logically formulated and coded to achieve a set of landscape-change rules. Rules depend strongly on a broad range of variables that can be classified into abiotic, biotic and cultural resources (see Botequilha Leitão, 2006). On the one hand, the inherent complexity of natural ecosystems and, on the other hand, the diversity and uncertainty of anthropogenic activities in landscapes provide complicated conditions for making justifiable and plausible assumptions. If researchers pay more attention to climate-change impacts, making assumptions becomes more complicated due to the emergence of new variables and uncertainties. Although it is a fashionable term, climate change is not yet a concern among local authorities. It is also not a widely understood phenomenon among laypeople. Therefore, without pre-educational programs, it is unlikely that justifiable and plausible assumptions will be made for climate change–related alternatives.

Running an alternative landscape futures project requires two sets of assumptions (Figure 1). To start with, a set of general assumptions are made for all scenarios based on the overall conditions of the landscape studied, and then specific assumptions should be made for each specific alternative according to specific conditions. Making specific assumptions is a major task because it involves various types of knowledge.

Reaching a comprehensive agreement is indispensable for making justifiable and plausible assumptions, and this in turn can build a positive consensus around decision-making issues. Such consensus is a robust basis for the following steps of the process. To ensure the greatest possible accuracy of assumptions, it is essential to pay attention to concepts such as collective wisdom, synergy and strategic thinking.

To reach a comprehensive consensus on assumptions, various methods should be applied due to various stakeholders involved (Figure 2). Conducting a semi-structured informative interview with local authorities, experts and influential people,

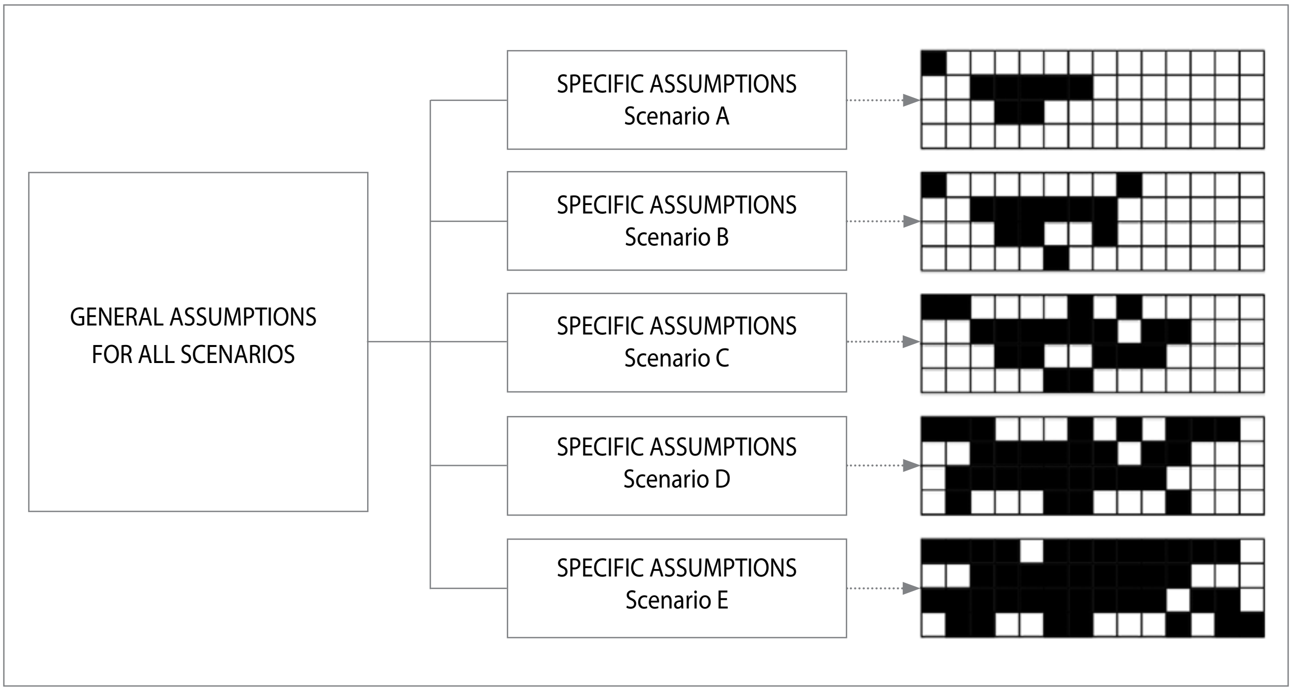

Figure 1: Making general and specific assumptions for constructing alternative futures.

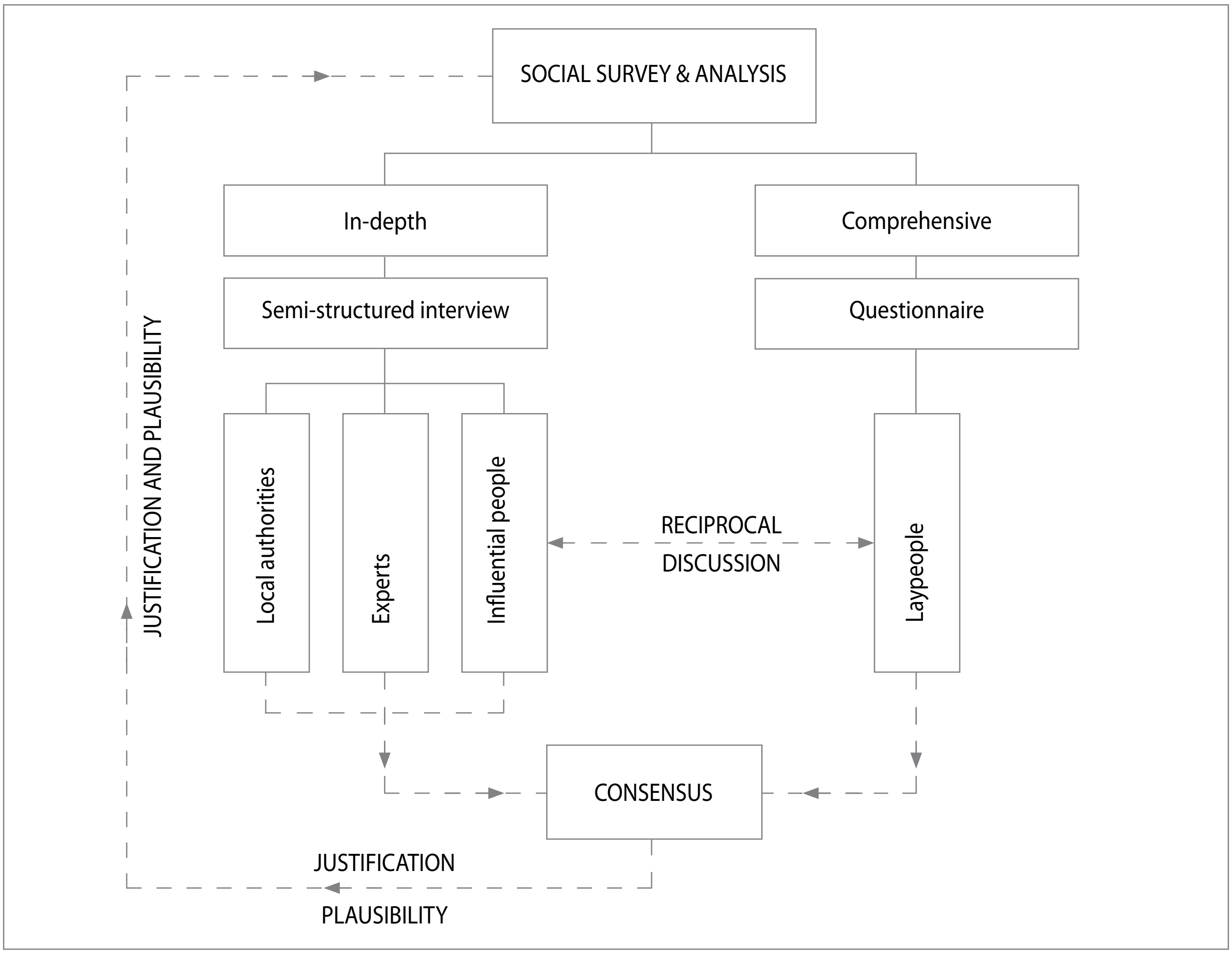

Figure 2: A proposed model for reaching a comprehensive consensus on assumptions due to various stakeholders involved.

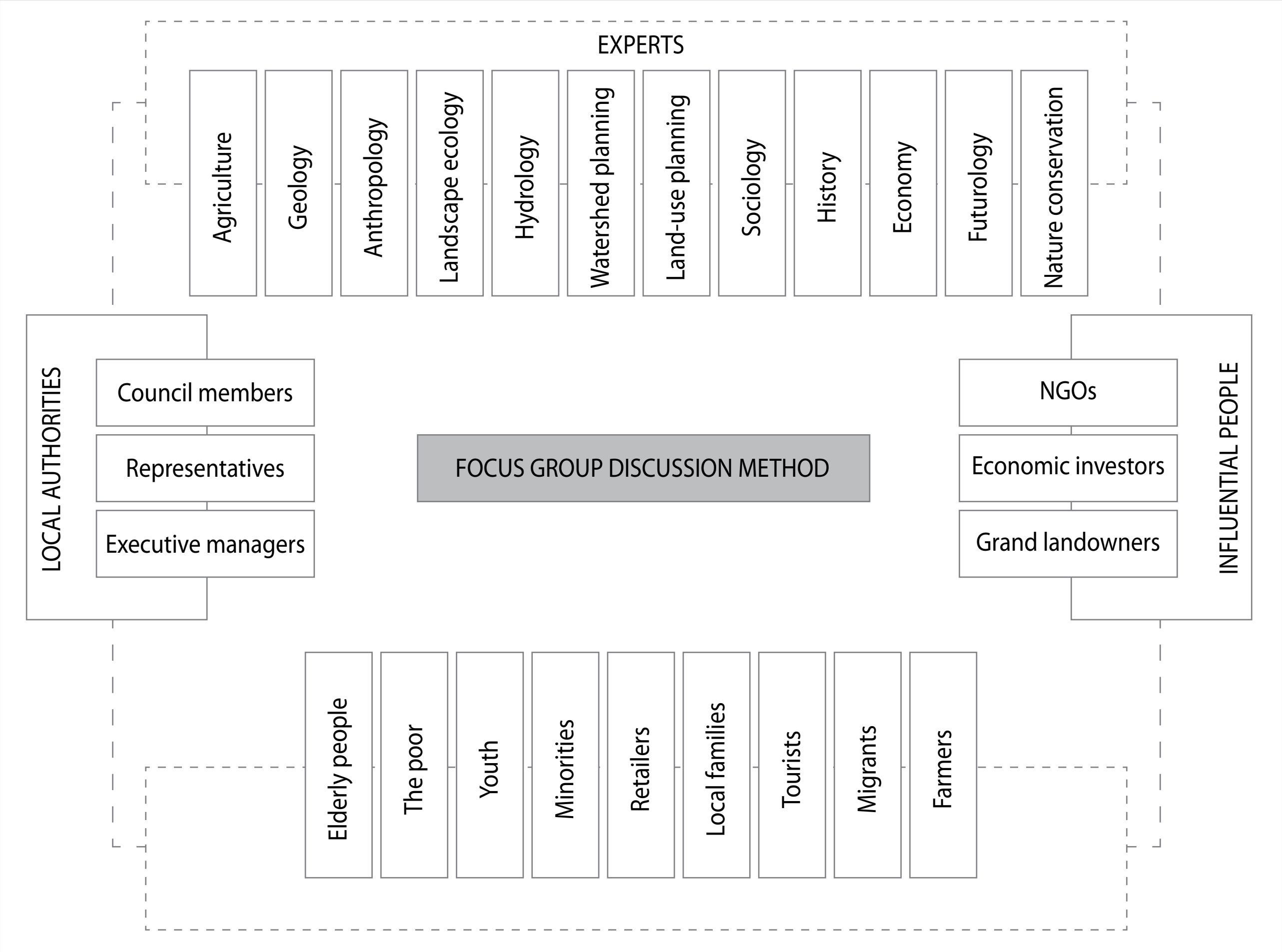

Figure 3: A proposed model for launching focus group discussion among experts, influential people, local authorities and laypeople.

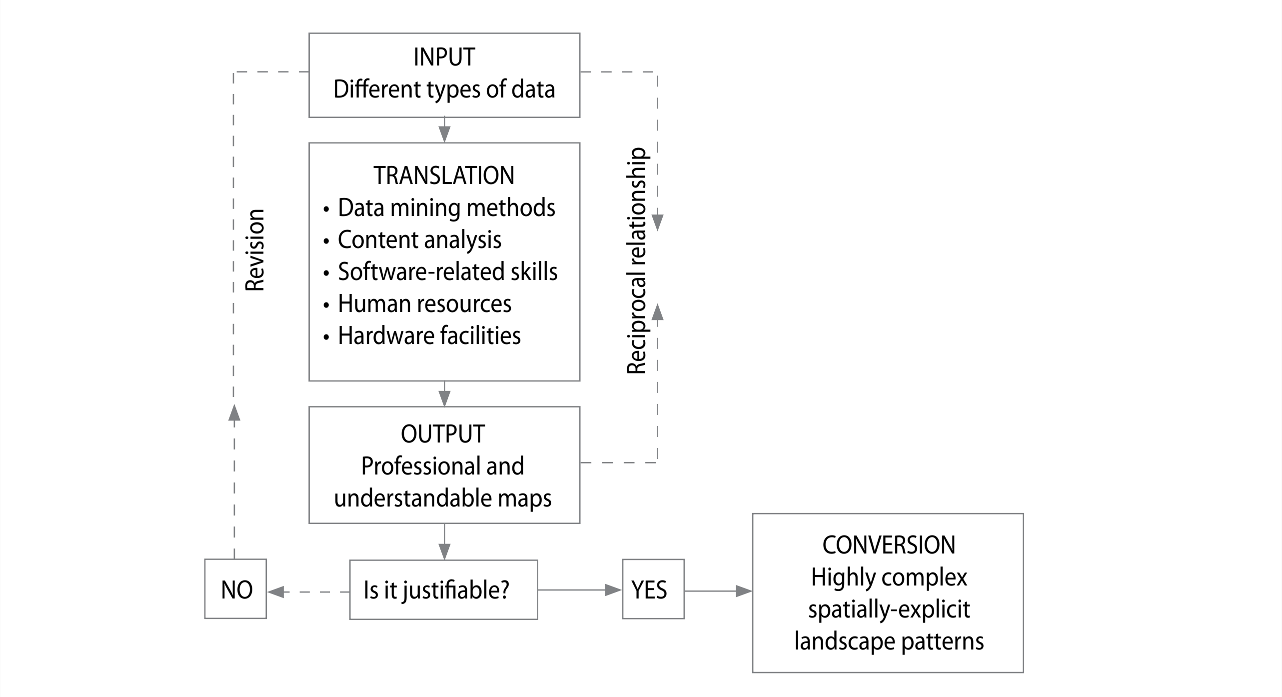

Figure 4: A simplified process of translating verbal, environmental and written data into spatially explicit landscape patterns based on assumptions.

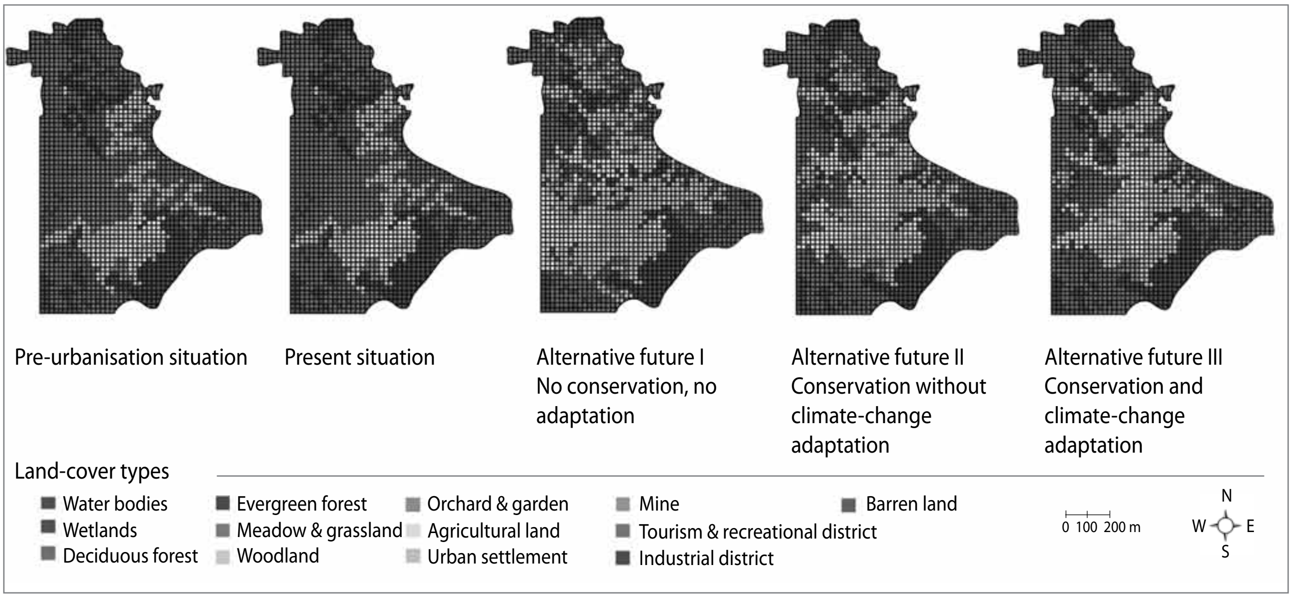

Figure 5: A normal depiction of the present and pre-urbanisation situations as well as three alternatives consisting of "no conservation no adaptation", "conservation without climate change adaptation" and "conservation and climate change adaptation" in a simulated landscape.

as well as a questionnaire-centred survey of laypeople, is important for collecting the attitudes, needs, demands, expectations and goals of the social groups related to the landscape and its likely change over time. To increase the validity in an interview-centred survey and decrease survey error, a snowballing approach is strongly recommended to create a conceptual link among experts, local authorities and influential people, and especially to avoid potential omissions among these groups of interviewees. Based on previous experience (see Hulse et al., 2004), it is also common for local people to elect representatives to regularly engage in discussion sessions during the project.

The significance of focus group discussion has been approved in social studies (see Wilson, 1997). This method is the key to increasing the public participation rate. Although it is time-consuming and sometimes complicated, focus group discussion is a strong method for linking laypeople to experts, local authorities and influential people (Figure 3). In addition, it is applied to derive hidden/latent problems and desires from in-depth interviews and group discussion through a series of sessions. The output of such sessions is a wide array of cause-and-effect diagrams and suggestions that can be used to make assumptions. In a more intellectual manner, holding workshops with experts is another way to construct logical goals and make assumptions for alternatives (see Nassauer & Corry, 2004). Beyond these, referring to well-established sources is indispensable, especially when making specific assumptions. In ecologically based landscape planning, for example, the four indispensable spatial patterns introduced by Richard Forman (1995), the illustrative patterns presented by Wenche Dramstad et al. (1996), Lauri Karvonen's guidelines for ecological landscape planning (Karvonen, 2000), the specific guidelines offered by Virginia Dale et al. (2001), and The Environmental Law Institute's conservation thresholds for land-use planners (Environmental Law Institute, 2003) are examples of scientifically based sources through which assumptions can be formulated for ecologically based alternatives (see Penteado, 2013).

4.2 Depiction

The necessity of applying spatially explicit landscape modelling has been delineated and proved (Costanza & Voinov, 2004). Depicting assumptions made in the second step of the process inevitably depends on such models. Translating verbal data – including local knowledge, people's attitudes, needs, demands, expectations and goals relating to the landscape – into spatially explicit landscape patterns plays a pivotal role in the effectiveness and success of decision-making in which alternative futures and scenario analysis is the main tool. Using appropriate software and choosing appropriate models is essential (see Cartwright, 2008; Pettit & Wyatt, 2009). This step of the process is highly important because translating assumptions in the form of sets of words and phrases into digital maps is an integral part of defining different trajectories and, consequently, depicting different futures. The level of accuracy and validity of spatially explicit landscape patterns greatly depends on the accuracy and quality of this translation. Researchers, as translators, should be highly qualified and trained in order to ensure that assumptions are translated correctly. This conversion, in itself, reflects stakeholders' attitudes and goals relat-

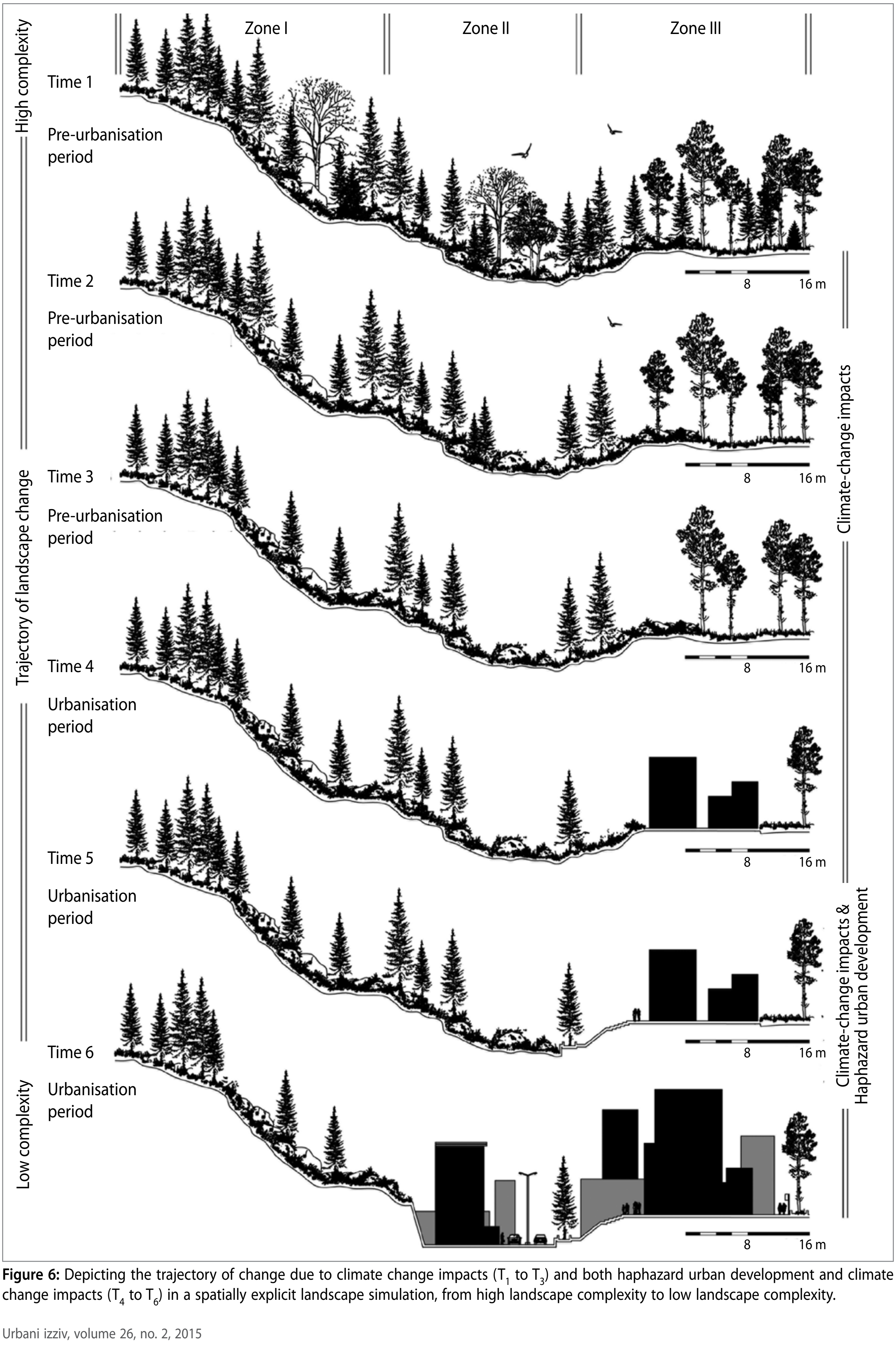

Figure 6: Depicting the trajectory of change due to climate change impacts (T_1 to T_3) and both haphazard urban development and climate change impacts (T_4 to T_6) in a spatially explicit landscape simulation, from high landscape complexity to low landscape complexity.

Table 2: Four general steps in applying alternative futures and scenario analysis in landscape planning for climate change

General steps	Sub-steps	Requirements and issues under investigation
Definition	Data collection	Verbal data: stakeholders' attitudes, needs, demands, expectations and goals. Environmental data: abiotic, biotic and cultural resources, land-cover changes, geo-hydrological dynamics, soil structures, wildlife dispersal patterns, human-built development, urban and rural growth patterns and demographic trends over time.
	Making assumptions	General assumptions: a set of general rules that is defined for all alternative landscape futures to define the trajectory of landscape change over time. Specific assumptions: a set of specific rules that is defined for each alternative landscape future specifically to define the trajectory of landscape change under particular circumstances over time.
Depiction		Basic definitions: scale, resolution, land-cover classification in map legend. Software and hardware requirements: possibility of using software such as Arc GIS, FRAGSTATS, 3-D Studio Max, Cry Engine and Esri City Engine. Human resources: availability of collaboration with highly qualified researchers for translating assumptions into spatially explicit landscape patterns. Consensus mechanism: a justifiable mechanism to guarantee the interactions between researchers, policymakers and stakeholders in translation.
Evaluation		Defining indicators and metrics: a set of qualitative and quantitative indicators and landscape metrics to systematically analyse each alternative landscape future. Analysers: a group of highly qualified experts that participate in a team to describe alternative landscape futures and explore their advantages and disadvantages. Multi-criteria decision-making techniques: the possibility of applying quantitative methods such as SAW (simple additive weighted), TOPSIS (technique for order preference by similarity to ideal solution) and ELECTRE (elimination and choice expressing reality) and combine them with qualitative methods such as a Delphi panel.
Synthesis		Trade-offs: ranking alternative landscape futures based on socioeconomic, cultural, ecological and environmental priorities. Selection: choosing the most justifiable alternative landscape futures.

ing to the landscape's future. Since 2000, three-dimensional depictions of alternative futures have become a commonplace method to enhance the level of laypeople's perception regarding spatial and temporal concepts (e.g., Hulse et al., 2004; Nassauer & Corry, 2004; Berger & Brown, 2008; Mansergh et al., 2008). In addition, using new techniques such as cellular automata (CA) in running scenarios is crucial (see Maxwell et al., 2004; Clarke, 2008; Liu, 2009). In the survey, most participants agreed that translating data into spatially explicit landscape patterns is still a challenging issue in alternative futures–based landscape-planning projects. According to the survey, about 90% of participants "strongly agree" or "agree" with this view. Having analysed a considerable number of case studies around the world, a simple and important model can be proposed for translating non-spatial data into spatially explicit landscape patterns (Figure 4). The model illustrates how different types of data can be converted to useful spatially explicit landscape patterns after a long process. Ultimately, the outputs should be illustrations that can be easily understood (Figure 5 and Figure 6).

4.3 Evaluation and synthesis

Despite all advancements, evaluating alternatives still faces a wide range of limitations (Corry & Nassauer, 2005). In general, a group of highly experienced experts should be engaged in the evaluation to analyse alternatives based on the criteria selected. To do so, quantitative methods, including multiple attribute/criteria decision-making approaches such as SAW (simple additive weighting), TOPSIS (Technique for order preference by similarity to ideal solution) and ELECTRE (elimination and choice expressing reality), and qualitative methods such as a Delphi panel would be beneficial as well as appropriate (see Hwang & Yoon, 1981; Pimerol & Romero, 2000; Linstone & Turoff, 2002). In this step, the most difficult task is to find a shared language between experts from different disciplines to evaluate alternatives and scenarios. Arc GIS can be a sufficient tool to facilitate this communication.

In evaluation, landscape metrics relating to climate change should be defined. Both climate change and anthropogenic

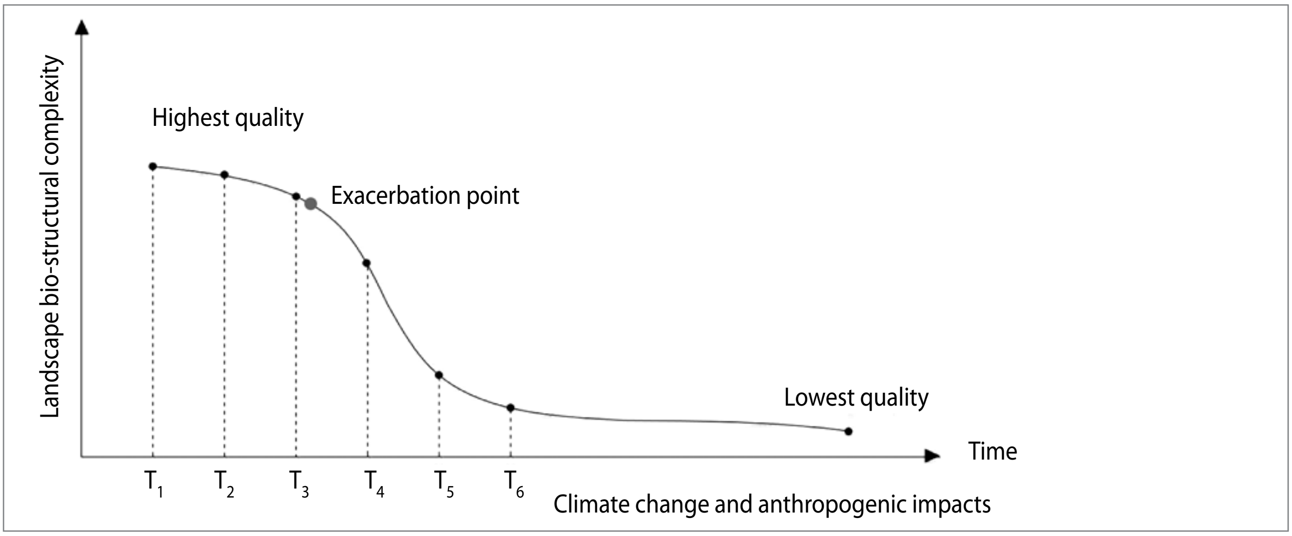

Figure 7: Trajectory of bio-structural landscape change with reference to the change in the quality of life over time from the pre-urbanisation period (T_1 to T_3) to the urbanisation period (starting from the exacerbation point).

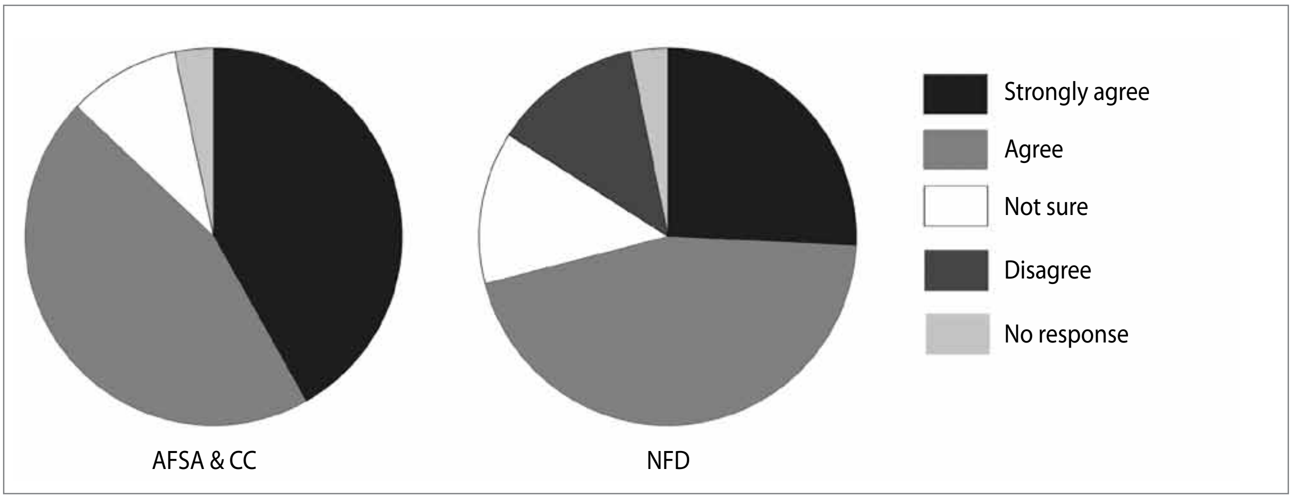

Figure 8: a) The role of alternative futures and scenario analysis in climate-change mitigation and adaptation; b) and the need for the approach development over the coming decades.

Note: a) AFSA & CC: "strongly agree" = 42%, "agree" = 45%, "not sure" = 10%, "no response" = 3%; b) NFD: "strongly agree" = 26%, "agree" = 45%, "not sure" = 13%, "disagree" = 13%, "no response" = 3%

impacts can be addressed by quantitative methods. New metrics from a careful combination of common metrics can be taken into consideration. Landscape bio-structural complexity, for example, is a suggested metric that can be examined as a basis for comparing landscape change over an extended period of time during evaluation and synthesis (Figure 7). In this instance, a set of landscape composition and configuration metrics can be merged to define a more powerful metric for evaluation.

4.4 Perspectives, challenges and gaps

In general, there is a robust consensus among experts regarding the effectiveness of alternative futures and scenario analysis as a decision-making approach in landscape planning. According to the survey results, approximately 74% and 23% of participants strongly agree and agree with this viewpoint. No disagreement was recorded in the responses. This result proves that using alternative futures is a valid tool for envisioning the landscape future across the world. These numbers show that participants have a united voice in the inevitable role of this approach regarding landscape-planning issues. An increase in the use of this approach in landscape-related decision-making in various countries is also confirmed by the results of the survey. The results indicate that this approach can also be a way to develop knowledge of landscape ecology in applied landscape-planning projects. According to the survey, about 90% of participants strongly agree, or at least agree, that using alternative futures and scenario analysis in landscape planning can contribute to an awareness relating to landscape ecology knowledge and vice versa. The surprising finding is that no disagreement was documented among respondents in this case.

Furthermore, the responses to the survey show that this approach can be used more widely in the twenty-first century. It has been argued that this approach is clearly a horizontal tool of landscape planning for different purposes. The vast majority of participants (about 87%) feel that alternative futures and scenario analysis can be an effective approach for addressing climate change through depicting spatially explicit landscape patterns and climate change–induced spatial changes over time. About 71% of respondents believe that this approach is still in its initial stages and should be developed during the coming decades (Figure 8). This finding indicates that there is special attention to climate change among researchers working on alternative landscape futures. Despite this, some statement reflected a degree of scepticism about the role of this approach as a tool for making decisions about landscapes through depicting climate-change mitigation strategies. For example, one participant stated:

> At this time, I doubt that alternative futures can be a useful tool for climate change mitigation. There is too much uncertainty about how the climate will change and more even uncertainty about how ecosystems will respond to climate change. If climate change and ecosystem models greatly improve such that uncertainty is greatly reduced, then it may make sense to incorporate them into an alternative futures process.

Nonetheless, there is still a divergence of opinions around some issues. For example, in the case of practical aspects, there is no agreement on the exact number of alternatives that should be defined in a given landscape-planning project. Whereas 16%, 13%, 10% and 19% of respondents stated that the number of alternatives should be three, four, five or more than five, about 29% of them believe that it cannot be determined. In addition, three respondents are convinced that the number of alternatives should be between three and five, and only one participant left the question unanswered.

Despite all advancements and achievements in applying this approach in making decisions and landscape planning, there are still challenges and problems in practice that should be addressed. To diagnose the most challenging steps of the approach in applied activity, numerous projects were examined (e.g., Theobold & Hobbs, 2002; Hunter et al., 2003; Steinitz et al., 2003; Aycrigg et al., 2004; Berger & Bolte, 2004; Hulse et al., 2004; Nassauer & Corry, 2004; Schumaker et al., 2004; Sharma et al., 2005; Bryan et al., 2008; Patel et al., 2007; Kepner et al., 2008; Soliva et al., 2008; Hulse et al., 2009; Verburg et al., 2010; Oana et al., 2011; Morley et al., 2012). Respondents were then asked to state the challenges and difficulties that they encountered. According to the survey results, the factor "making assumptions" (MA) was selected seventeen times by respondents as the most challenging step of the approach. After that, "definition of alternatives" (DA) based on the project requirements, goals and research questions was identified as the second most challenging step. Next, "data collection" (DC) was selected ten times by the respondents. These three steps are defined in "definition", the first step of the mechanism, and this reemphasises the fact that the first step of such projects is highly important. According to the results, "simulation and depiction of scenarios" (SD) and "scenario analysis" (SA) were seen as less challenging (Figure 9). In some cases, participants also provided additional information in their responses. For example, one expert stated that all steps are important, but data collection and collecting historical landscape records is a requisite for the following steps:

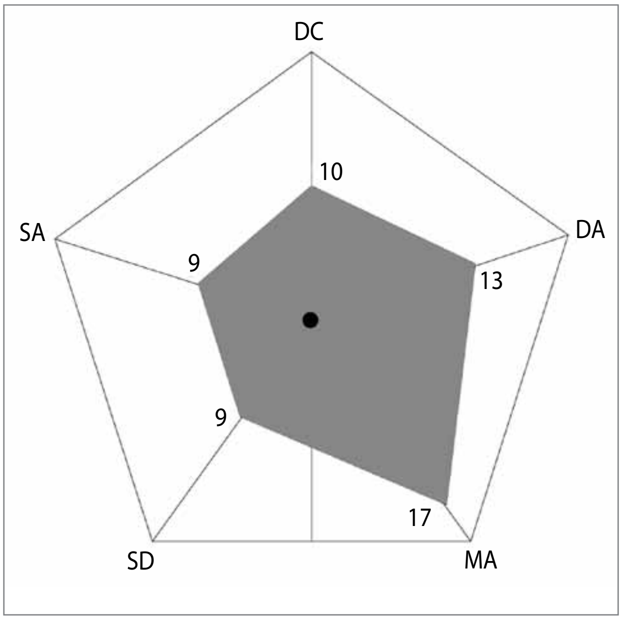

Figure 9: Five major steps in applying alternative futures and scenario analysis in landscape planning: data collection (DC), definition of alternatives (DA), making assumptions (MA), simulation and depiction of scenarios (SD) and scenario analysis (SA). The degree of being challengeable in practice was identified based on the number of selections by the participants.

> . . . I picked the first one [data collection and collecting historical landscape record], for the reason that if you fail in that you will fail in all the next phases as well. If collecting historical data based on non-spatial data, for example interviewing people, results can be good in the best case but often people do not remember things accurately in terms of time and place, and stories of different people can be different. If collecting spatial data, e.g. historical maps, the mapping process and its purpose has to be known as those maps differ greatly from the present ones. In our project, for example, we used historical parceling maps which aimed at distributing good-productive and bad-productive agricultural land evenly between

Table 3: The most important statements derived from open-ended questions regarding the appropriate scale in alternative futures and scenario analysis.

Attitudes	Variables mentioned	Examples of the most important statements
No specific scale	Nature of problem, nature of participants	This strongly depends on the nature of the problem and the nature of the participants. However, it should not be too small (i.e., smaller than around 10 × 10 km^2) or too large (i.e., larger than 100 × 100 km^2). Note that scenarios can be developed for regions that are much larger (up to global), but the planning needs to be for smaller areas.
		This depends on who needs this information. However, given the current level of understanding and the uncertainty associated with climate change projections, there is little genuine value in considering areas that are less than 105 ha.
	Research question, landscape type	It depends on the research question and the type of landscape.
		The size of the area depends on the questions about landscape change being asked.
		It depends on the research question and the type of landscape.
		The alternative futures can pertain to the entire study area or only a portion of it, depending on the variable.
	Aim of project, landscape characteristics	It depends on the aims of the project, on the landscape characteristics and extension.
		It depends on the scope of the project (regional, sub-regional, catchment, landscape matrix) and its context.
		It depends on the study area.
		It might vary according to the fragmentation of the area.
		It depends on the city: the entire urban area should be included.
	Data availability	As the spatial extent of analysis becomes smaller, the spatial grain of data must become finer and both the data and models must be more accurate.
	Resolution	I prefer as large as possible. Resolution is important.
		It depends on land cover data available down to 30 by 30 m^2.
Specific scale determined		$A > 100$ km^2; $A > 1000$ km^2; $1 \le A \le 100$ km^2; $10 \le A \le 100$ km^2.
		$100 \le A \le 10{,}000$ km^2; $5{,}000 \le A \le 50{,}000$ km^2.
Other responses		At least three scales are needed.
		Could be at any scale: site to global.
		The scale is less significant than taking the area and issue as a whole.

Table 4: Dependency of the approach on eight qualitative factors affecting the approach implementation in landscape-planning projects.

Factors	Likert scale (%) weighted from 5 to 1						
	Strongly agree (%) w = 5	Agree (%) w = 4	Not sure (%) w = 3	Disagree (%) w = 2	Strongly disagree (%) w = 1	No response (%) w = 0	Total score (Σ S_i × W_j)
LPP	36	45	19	0	0	0	417
LEK	32	42	16	10	0	0	396
SRF	26	42	19	10	0	3	375
SCM	6	52	26	13	3	0	345
MA	61	26	10	3	0	0	445
LCT	7	23	45	16	3	6	297
QHR	36	61	3	0	0	0	433
MMT	26	29	19	23	0	3	349
Average (~)	28.6	40	19.5	9.2	0.6	2.1	389

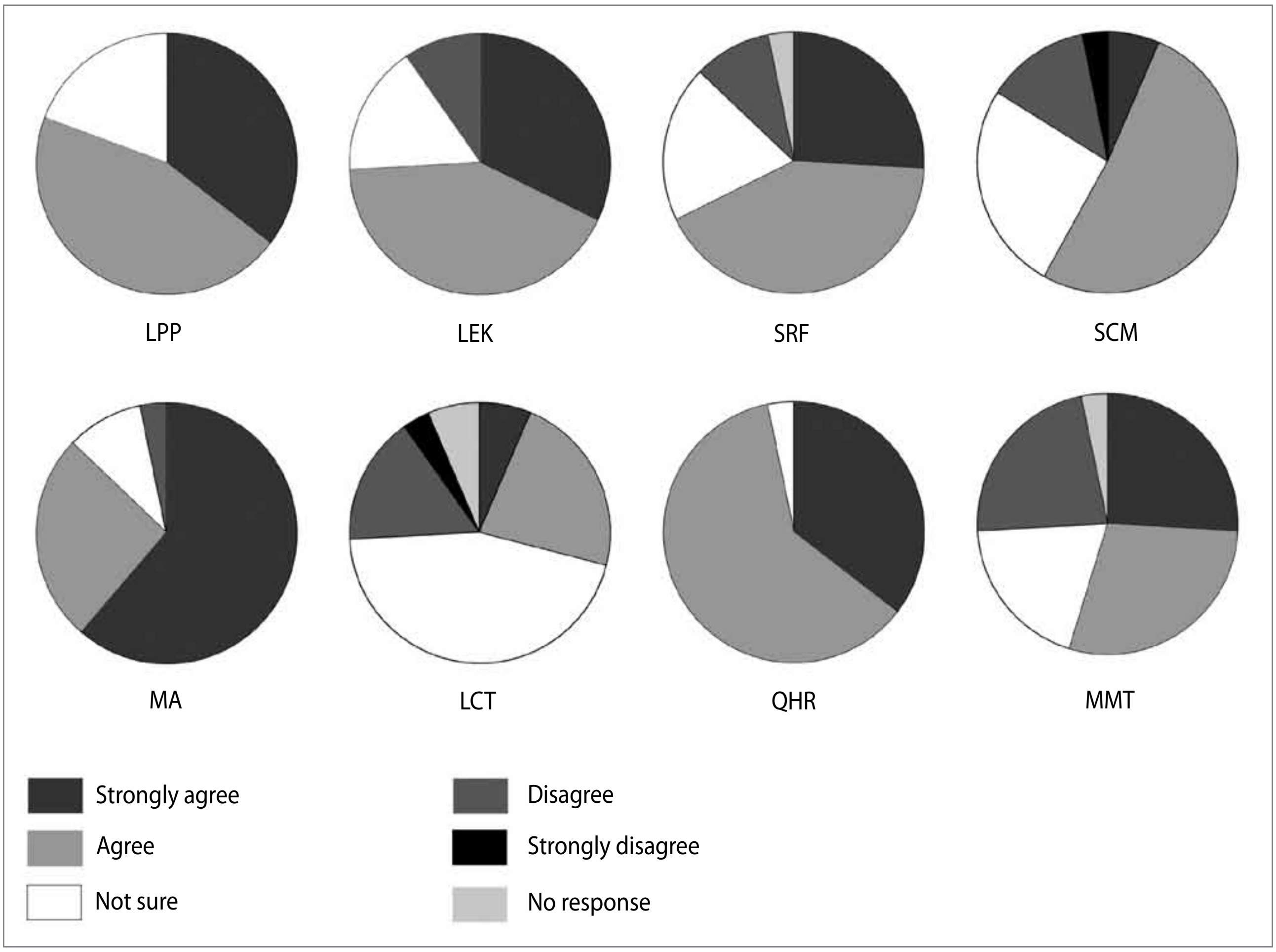

Figure 10: Dependency of the approach on eight qualitative factors affecting the approach implementation in landscape-planning projects. Note: LPP = Local people participation, LEK = Local ecological knowledge, SRF = Software-related facilities, SCM = Statistical concepts and methods, MA = Making assumptions, LCT = Land-cover types, QHR = Qualified human resources, MMT= Modelling methods and tools.

> the different households. To be able to interpret those maps, you have to initially understand that all the map categories are based on land productivity, and only those good-productive plots have been mapped in high accuracy . . .

Another important challenge reflected in the completed questionnaires is choosing the appropriate scale and resolution. Many participants believe that the scale of study should be spatially broad, but there is no consensus regarding the exact scale for applying alternative futures and scenario analysis in landscape planning. Analysis of case studies reveals that the issue of scale varies from individual site to global, as shown by the survey results (Table 3). Although there seem to be similarities in applying logical criteria for choosing appropriate scale and resolution, some researchers prefer to choose different scales in different situations. One of the most important reasons is the lack of accessibility to accurate spatial data, including updated satellite images and aerial photos. Although some respondents specified a particular scale and resolution, the majority of respondents cited no specific standard for choosing scale and resolution. The latter group mentioned diverse variables that shaped their responses. The responses reflect that the scale should be selected case by case, according to the study goals and objectives.

Beyond these controversial issues, there are deeper challenges and gaps that should be investigated for further development of the approach in the future. According to the responses, some practical challenges deserve more attention. One participant stated:

> . . . the biggest challenge is actually getting the planners and decision-makers to use the information and outputs that are generated by scenario analyses . . .

Applying alternative futures and scenario analysis depends on a broad spectrum of requirements and prerequisites ranging from human resources to technological tools. In many cases, failure in applying this approach has been the result of shortcomings and weaknesses in these requirements and prerequisites. Using

Table 5: Information excerpts depicting the current concerns and challenges in applying alternative futures and scenario analysis in landscape planning

Category	Current concerns and challenges
Scale and size	Lack of appropriate scale and resolution due to the absence of effective technological infrastructures and tools. Lack of accurate land-based data.
Consensus building on definition of alternatives	Difficulty of establishing vertical and horizontal relationships between people, local authorities, experts, and researchers. Divergence of objectives relating to landscape due to deep differences in stakeholders' cultural, economic, and social backgrounds. Difficulty of providing a long-term platform for people and their representatives to be engaged in building consensus on defining alternatives.
Making assumptions	Lack of historical data regarding the landscape under study and investigation. Being time-consuming, especially in making specific assumptions for each specific alternative. Discernible differences between people's visions about landscape future. Uncertainties about the future. Lack of sufficient confidence in the future.
Spatially explicit patterns	Complexity of translating words, phrases, texts, sketches, flowcharts, and diagrams into spatially explicit landscape patterns. Dearth of simulation and spatial modelling skills.
Evaluation	Complexity of selecting appropriate qualitative and quantitative indicators for making comparison between alternatives. Difficulty of overlapping evaluations provided by each group of experts.

multiple-choice questions based on a Likert scale, the approach depends on eight factors: local people participation)LPP), local ecological knowledge (LEK), software-related facilities (SRF), statistical concepts and methods (SCM), making assumptions (MA), land-cover types (LCT), qualified human resources (QHR), and modelling methods and tools (MMT). The results show that making assumptions (MA) and qualified human resources (QHR) are the most important factors in applying alternative futures and scenario analysis in landscape planning affecting the quality and accuracy of the project. Next, local people participation (LPP), local ecological knowledge (LEK), software-related facilities (SRF), modelling methods and tools (MMT), statistical concepts and methods (SCM) and ultimately the number of land-cover types (LCT) stand in the next places. Weighted numbers and scores were calculated to form a meaningful statistical picture of the value and importance of each factor (Table 4 and Figure 10).

It is clear that the use of alternative futures and scenario analysis in decision-making for landscapes has been recognised. More importantly, there has been progress in the development of this approach that facilitates its application in climate change–related decision-making. Despite this, there are concerns and challenging issues that should be examined. These concerns and challenges have been categorised according to the findings of the literature review as well as the results of the survey (Table 5). Many reasons have been cited by participants for the existence of such problems. The analysis of applied projects, as mentioned above, demonstrates a need to refine, upgrade, develop, and update this approach to make it more applicable under conditions of climate change. These actions should encompass all issues relating to the application of alternative futures from the beginning to the end.

5 Conclusion

This study showed that applying alternative futures and scenario analysis in landscape planning can provide a perfect platform for examining the likely effects of adaptation and mitigation strategies on a landscape's future in the face of climate change impacts. The approach opens up a great opportunity for decision-makers to extend their perspective and adopt appropriate landscape policies before reaching a no-return point, from the sustainable point of view. Inappropriate use of this method can be misleading, causing detrimental effects on decision-making and consequently policies adopted for landscapes. In fact, this approach can be a key policy instrument for how to integrate climate change impacts, social values and ecological conditions into decision processes when planning landscapes. Applying this approach *can* reduce the common conflicts among stakeholders whose values and attitudes are completely different. Alternative futures and scenario analysis is a multidimensional mechanism through which informed decisions can be made based on collective wisdom.

Thanks to recent technological advancements, this approach can be effective more than ever before. In the future, for example, satellite images can make collecting historical landscape data easier than in the past. Because software is developing rapidly, landscape simulation is becoming increasingly realistic and understandable, like never before. At the same time, the use of these technological tools is becoming increasingly sophisticated and this in turn requires more trained human resources. While technologies are progressing, landscape datasets should also be updated and enriched. For example, preparing biogeoclimatic landscape maps in each region provides a perfect basis for defining restorative as well as climate change–proof alternatives. When a biogeoclimatic map is available, it becomes possible to formulate a road map for converting current landscape patterns into ecologically restored ones through defining specific alternatives. Familiarity with the natural history of a landscape is another important factor ensuring that restorative and climate change–proof alternatives are defined accurately.

This study shows that there is still an essential need to develop methods and technologies through which justifiable and reliable assumptions can be translated into realistic spatially explicit landscape patterns. In this case, using pictorial questionnaires and illustrative sketches can build up an understanding of climate-change impacts on a landscape's future especially among laypeople. People's participation plays an important role in collecting data and making assumptions. Therefore, it is essential to facilitate people's engagement in these activities through various incentives. Some online facilities (e.g., internet-based social networks) are available options that can be used to push back geographical distances and help researchers tackle some problems relating to public participation. People that live in a landscape can increase the odds of achieving success if they play their role correctly. All beneficiaries should have their own voice in the entire process of making decisions and adopting landscape policies. Justice is the key in this instance. It is society's right to choose its destiny based on active participation and informed decisions. Where people have a sense of attachment to the project, they strive to actively take part in all steps of the project. Local landowners as a potential driving force behind landscape restoration plans can also play a crucial role to guarantee the success of the decisions made based on comprehensive consensus.

To adopt landscape policies with regard to climate change impacts, new types of data should be gathered, new assumptions should be made, new simulation techniques should be applied and new metrics should be defined for evaluating alternatives. Beyond these, landscape ecology, as a trans-disciplinary science, should be taken into consideration when addressing climate change issues because these principles hold the key to defining new alternatives in the initial steps, as well as providing metrics to evaluate them at the end of the project. This research paves the way for examining the potential advantages of this approach in making decisions and adopting policies for a landscape's future, where urbanisation and climate change are two powerful driving forces behind inevitable changes. Furthermore, it invites other researchers to address the current gaps, challenges and perspectives for better use and more effective application of the approach in the future.

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