Journal of Mediterranean Cities

2026, Volume 6, Number 1, pages 01–23

Landscape Scenario Archetypes for Desertification-Prone Oases: A Resilience Framework for the Drâa Valley

* **Salwa Alhejazi**[1], **Carlotta Maria Serena Fontana**[2]

Sustainable Architecture and Landscape Design, Politecnico di Milano, Milan, Italy[1]

Department of Architecture and Urban Studies (DAStU), Politecnico di Milano, Milan, Italy[2]

E-mail[1]*: Alhejazi.Salwa@gmail.com, E-mail*[2]*: carlotta.fontana@polimi.it*

ABSTRACT

Oasis regions in southern Morocco are increasingly under the threat of desertification, water scarcity and socio-economic pressures that undermine their long-term resilience. This study develops landscape scenario archetypes as an operational framework that links future scenarios with spatial design for the desertification-prone Drâa Valley, to address the gap between scenario narratives and implementable landscape strategies. The methodology integrates STEEP trend analysis, impact–uncertainty prioritisation and landscape assessment, along with a two-component online participatory survey in M'hamid oasis. Forty-seven drivers were identified and prioritised, structuring four contrasting socio-ecological scenarios, namely Oasis Minimisation, Oasis Emancipation, Rural Abandonment and Rural Refuge. These scenarios were translated into scenario-specific spatial design principles through a landscape building-block framework and compared through a multi-criteria assessment. The respondents consistently preferred futures that combine traditional oasification practices along with contemporary landscape strategies. Landscape scenario archetypes provide a transferable mechanism that aids in translating uncertainty into design action, supporting resilience-oriented planning, water management and adaptive capacity in desertifying oasis regions.

JOURNAL OF MEDITERRANEAN CITIES (2026), 6(1), 01-23

https://doi.org/10.38027/mediterranean-cities_vol6no1_1

ARTICLEINFO:

Article history:

Received: May 23, 2026

Revised: July 16, 2026

Accepted: July 27, 2026

Available online: Aug 03, 2026

Keywords:

Landscape Scenario Archetypes; Desertification; Oasis Resilience; STEEP Drivers; Participatory Plannina

1. Introduction

Desertification is considered one of the most critical environmental challenges in the drylands, with significant implications regarding ecosystem services, agricultural production and the livelihoods of local communities (Barbero-Sierra et al., 2015). According to the United Nations Convention to Combat Desertification, this phenomenon refers to the degradation of land in arid, semi-arid and dry sub-humid zones, driven by the combined action of climatic variability and human pressures (UNCCD, 2017). Morocco, particularly its southern regions, faces acute desertification threats driven by water scarcity, soil salinization, sand encroachment, and socio-economic transformations that collectively undermine the resilience of traditional oasis systems (Karmaoui, 2015).

Corresponding Author:
Salwa Alhejazi
Sustainable Architecture and Landscape Design, Politecnico di Milano, Milan, Italy
E-mail: Alhejazi.Salwa@gmail.com

How to cite this article:
Alhejazi, S., & Fontana, C. M. S. (2026). Landscape Scenario Archetypes for Desertification-Prone Oases: A Resilience Framework for the Drâa Valley. Journal of Mediterranean Cities, 6(1), 01-23. https://doi.org/10.38027/mediterranean-cities_vol6no1_1

The Drâa Valley in southern Morocco exemplifies these challenges. As one of Morocco's most important oasis territories, the valley has sustained human settlement for centuries through sophisticated traditional water management systems, multi-layered agricultural practices, and vernacular architecture adapted to extreme aridity (Lightfoot, 1996; Baglioni et al., 2016). However, contemporary pressures - including climate change, groundwater depletion, rural-urban migration, and evolving governance structures - have destabilized these time-tested systems, raising urgent questions about the region's environmental and social future (Berger et al., 2021; Johannsen et al., 2016).

Although desertification is increasingly acknowledged as a multidimensional phenomenon demanding holistic responses, research on oasis resilience has largely focused on technical interventions in water management or agricultural productivity, with limited attention to scenario-based design approaches that could guide long-term strategic planning (Karmaoui & Moumane, 2016). Existing studies have documented the environmental degradation of Moroccan oases (Lamqadem et al., 2017; Ait Lamqadem et al., 2018), analysed socio-economic transformations (de Haas, 2003; Sobczak, 2008), and examined traditional knowledge systems (Laureano, 2012), yet few have systematically explored alternative futures through integrated landscape scenarios that link environmental drivers with spatial design.

This research addresses this gap by developing landscape scenario archetypes as a framework for exploring plausible futures for the Drâa Valley and informing resilience-oriented design strategies. Building on scenario planning methodologies from landscape ecology and futures studies (Hunt et al., 2012; Börjeson et al., 2006), this study constructs scenarios that represent distinct socio-ecological trajectories shaped by governance structures and social values. The research explicitly positions scenarios not as predictions but as exploratory tools that mediate between uncertainty and design action, enabling stakeholders to envision alternative pathways and their spatial implications (Dockerty et al., 2006).

The aim of this research is achieved through three objectives: firstly, to analyse the key STEEP drivers shaping desertification in the Drâa Valley; secondly, to construct four landscape scenario archetypes representing alternative futures for the region; and thirdly, to translate these scenarios into spatial design principles for the Drâa Valley's desertification-prone oases, demonstrated through M'hamid as a representative site. The research asks: How can landscape scenario archetypes inform resilience strategies for desertification-prone oases? What spatial interventions emerge from contrasting governance and social paradigms? And how do traditional oasification practices relate to contemporary landscape strategies in scenario-based planning?

Unlike conventional scenario-based approaches that remain at the level of narrative exploration, this research introduces a landscape scenario building block framework that establishes a direct and operational link between identified drivers and spatial design interventions. This enables scenarios to function not only as exploratory tools but as implementable design mechanisms within landscape planning processes.

It should be mentioned how this framework differs from existing scenario-to-design methodologies. Established approaches, namely scenario typologies and construction techniques (Börjeson et al., 2006), formal scenario-development protocols (Mahmoud et al., 2009), scenario-based landscape planning (Dockerty et al., 2006; Albert, 2011) and archetype analysis (Boschetti et al., 2016; Oberlack et al., 2019), provide solid procedures for constructing and communicating alternative futures. However, they generally stop at the level of narratives, indicators or visualisations. In the landscape scenario building-block framework developed in this research, each prioritised driver is carried through to a discrete and mappable landscape intervention. Thus, the scenario logics can be recombined, compared and evaluated as spatial configurations rather than remaining narrative constructs. In doing so, the study responds to the calls for participatory and place-based scenario practice in social-ecological research (Oteros-Rozas et al., 2015) and contributes an operational bridge between scenario planning and landscape design in arid regions.

2. Theoretical Background and Key Concepts

2.1. Desertification and Oasis Systems

Desertification is a multi-layered process that influences natural systems along with human settlements. Its effect is intensified in oasis environments, where the limited water resources, agricultural production and socio-economic stability are held in a fragile equilibrium (Mahmoud et al., 2009). Traditionally, oasis systems have functioned as highly adaptive landscapes, structured around a symbiotic relationship between human activity and natural resources. The typical oasis model is characterised by a multi-layered agricultural system, where date palms form the upper protective layer, followed by fruit trees and ground crops. This configuration creates a controlled microclimate that maximises productivity while minimising water loss (Oberlack et al., 2019). However, increasing pressures such as water scarcity, soil salinisation, and climate variability have disrupted this balance, leading to declining ecological performance and increased vulnerability to desertification. Socio-economic transformations, namely migration, land-use change and the weakening of local management institutions, further compound these dynamics (Boschetti et al., 2016; Hunt et al., 2012). The structure and functioning of oasis systems are illustrated in Figure 1.

Figure 1. Cross-section of oasis system illustrating vegetation stratification, water management, and microclimatic regulation

2.2. Scenario Planning and Landscape Approaches

Scenario planning has been widely used as a tool to explore uncertain futures, particularly in contexts where long-term environmental and socio-economic changes are difficult to predict. Unlike predictive models, scenario approaches allow for the exploration of multiple plausible futures, providing a framework for understanding the potential consequences of different development pathways (Baker et al., 2004; Mahmoud et al., 2009). Within landscape architecture, scenario-based approaches enable the integration of spatial, ecological, and social dimensions into a coherent structure. They support the interpretation of complex systems and facilitate communication between different stakeholders involved in planning processes. However, while scenario planning is effective in generating future narratives, its application in spatial design often remains limited, with a lack of clear mechanisms for translating scenarios into actionable interventions.

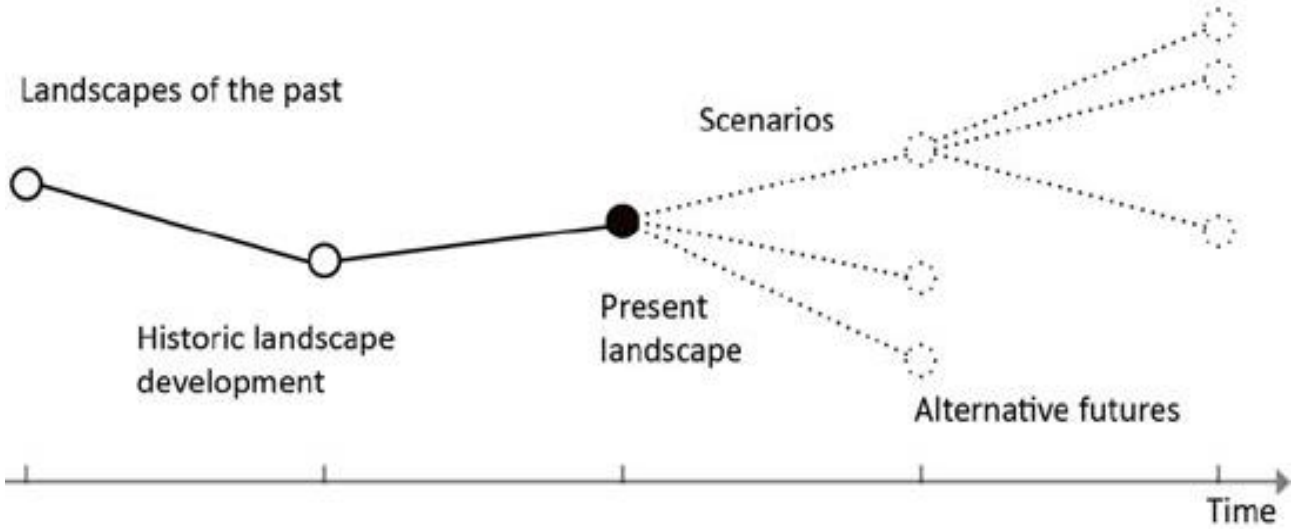

Figure 2. Scenario framework illustrating alternative futures and archetypal trajectories (based on Hunt et al., 2012).

2.3. Scenario Archetypes and STEEP Drivers

To construct meaningful future scenarios, it is necessary to identify and organise the driving forces that influence system dynamics. Scenario archetypes provide a structured approach to this process, allowing for the classification of trends and the development of comparable future conditions (Boschetti et al., 2016). The number of scenarios typically ranges between three and six, with four scenarios being the most commonly adopted configuration in scenario planning studies (Hunt et al., 2012). This structure enables the representation of contrasting yet plausible futures within a clearly defined framework.

The identification of key drivers is supported with analytical tools such as the impact–uncertainty matrix, which ranks drivers according to their level of influence and degree of uncertainty (Maack, 2001). This process allows for the selection of the most critical variables that shape future outcomes. To ensure a comprehensive understanding of the system, the STEEP framework (Social, Technological, Economic, Environmental, Political) is employed to categorise and analyse the drivers influencing desertification processes. This approach enables the integration of multiple dimensions of change and supports the development of holistic and context-specific scenarios (Maack, 2001; Hunt et al., 2012). Furthermore, the use of archetype-based scenarios has been applied in various environmental contexts to explain large-scale transformations and their impacts on local systems (Oberlack et al., 2019). This reinforces the relevance of scenario archetypes as a methodological tool for addressing complex socio-ecological challenges.

2.4. From Scenario Narratives to Spatial Design

To construct plausible scenarios, it is necessary to define a set of variables that reflect the identified drivers and their interactions (Mahmoud et al., 2009). However, a key limitation in existing scenario-based approaches lies in the gap between conceptual scenario development and practical spatial implementation. While scenarios effectively describe potential futures, they often remain abstract and lack direct applicability within design processes. This limitation is particularly evident in landscape architecture, where the translation of narratives into spatial strategies is essential for implementation.

This research addresses this gap by introducing the concept of landscape scenario building blocks, which function as an intermediate layer between scenario narratives and spatial design. These building blocks represent specific landscape interventions derived from STEEP drivers and scenario conditions, enabling the operationalisation of scenarios within the design process. By structuring scenarios into spatially explicit components, this approach facilitates the evaluation and comparison of alternative interventions, supporting decision-making in complex and uncertain environments.

3. Study Area: The Drâa Valley

3.1. Regional Context: Drâa Valley

The Drâa Valley stands out among the oasis territories of southern Morocco in regard to its scale and cultural significance, extending as a linear corridor organised by the Drâa River. Its climate ranges from arid to hyper-arid, combining scarce and strongly seasonal rainfall along with high evapotranspiration rates. These environmental conditions make the valley highly dependent on controlled water management systems for sustaining agricultural production and human settlements.

Historically, the valley has functioned as a continuous oasis network, where settlements are closely linked to irrigation systems and agricultural land. The spatial organisation of the valley reflects this dependency, with palm groves, cultivated fields, and compact settlements forming an integrated socio-ecological system. However, over recent decades, this system has been increasingly affected by reduced water availability, irregular rainfall patterns, and upstream water regulation, leading to a decline in agricultural productivity and increased land degradation.

3.2. M'hamid Oasis: A Representative Lower-Valley Site

M'hamid oasis, at the southern edge of the Drâa Valley, is taken here as a representative case of the lower valley's desertification-prone oases for detailed spatial demonstration; it marks the transition between the cultivated landscape and the Sahara Desert. Due to its geographical position, the area is particularly exposed to desertification processes, including sand dune encroachment, soil degradation, and water scarcity.

The oasis has historically relied on traditional irrigation systems and agricultural practices to sustain local livelihoods. However, the reduction in water flow and the deterioration of irrigation infrastructure have significantly weakened these systems. As a result, agricultural land has progressively declined, and the ecological balance of the oasis has been disrupted.

In addition to environmental challenges, M'hamid is affected by socio-economic pressures, including population decline, migration, and limited economic opportunities. These factors contribute to the abandonment of agricultural land and the deterioration of the built environment, further accelerating desertification processes (Domínguez Martínez et al., 2017).

3.3. Key Challenges and System Dynamics

The challenges faced by the oases of the Drâa Valley are the result of interconnected environmental and socio-economic processes. Water scarcity remains the most critical factor, influencing agricultural productivity, settlement viability, and ecosystem stability. The reduction of water resources is linked to both climatic variability and upstream water management, highlighting the multi-scalar nature of the problem. At the same time, land degradation is intensified by soil salinisation, overexploitation of resources, and the expansion of desert conditions. These environmental pressures are closely linked to social and economic dynamics, including changes in land use, shifts in livelihood strategies, and reduced community engagement in traditional management systems.

The interaction of these factors reflects the complexity of desertification as a socio-ecological process, where environmental degradation cannot be separated from governance structures, economic conditions, and social behaviour. This complexity reinforces the need for integrated approaches that consider multiple dimensions of change, as addressed through the STEEP framework applied in this research.

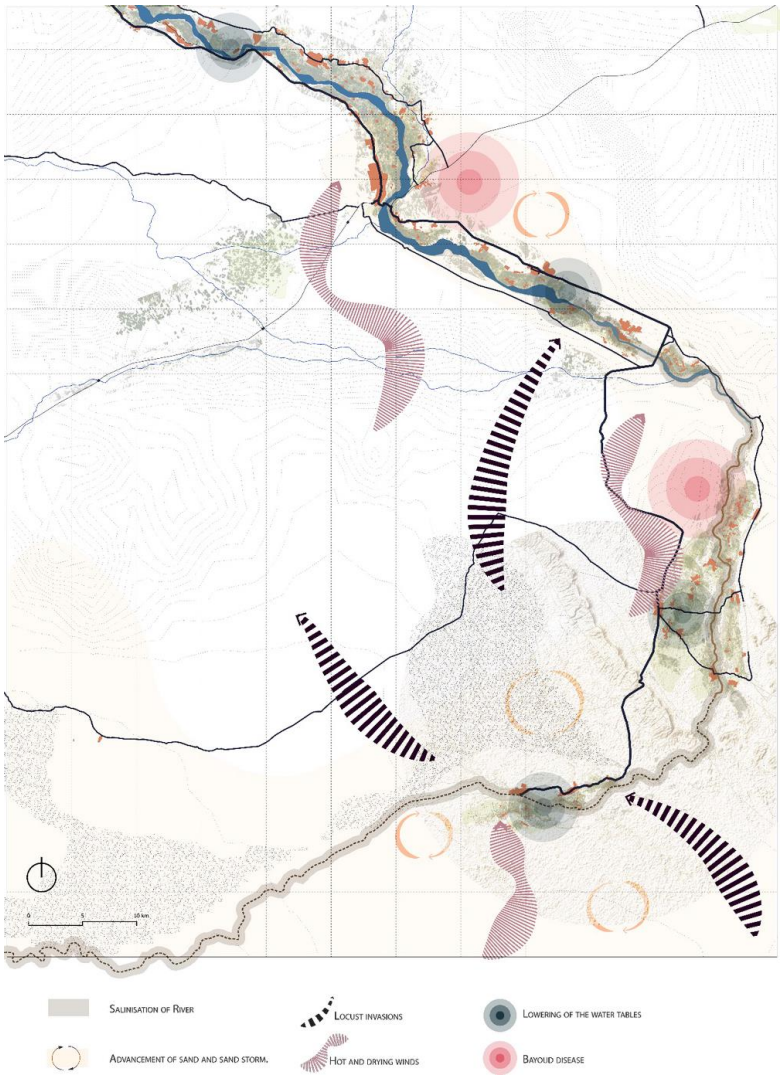

Figure 3. Threats and concerns map of the lower Drâa Valley illustrating sand encroachment, water scarcity, and environmental pressures.

4. Methodological Framework

This research employed a mixed-methods approach integrating descriptive analysis, scenario development, and participatory inquiry. The methodological framework consisted of four phases: (1) literature review and STEEP driver analysis; (2) landscape assessment and cultural landscape documentation; (3) scenario prototype development through iterative refinement; and (4) participatory validation through an online community survey. This approach aligns with established scenario planning protocols while incorporating spatial design translation specific to landscape architecture (Dockerty et al., 2006; Albert, 2011). The overall research process is summarised in Figure 4 and Table 1.

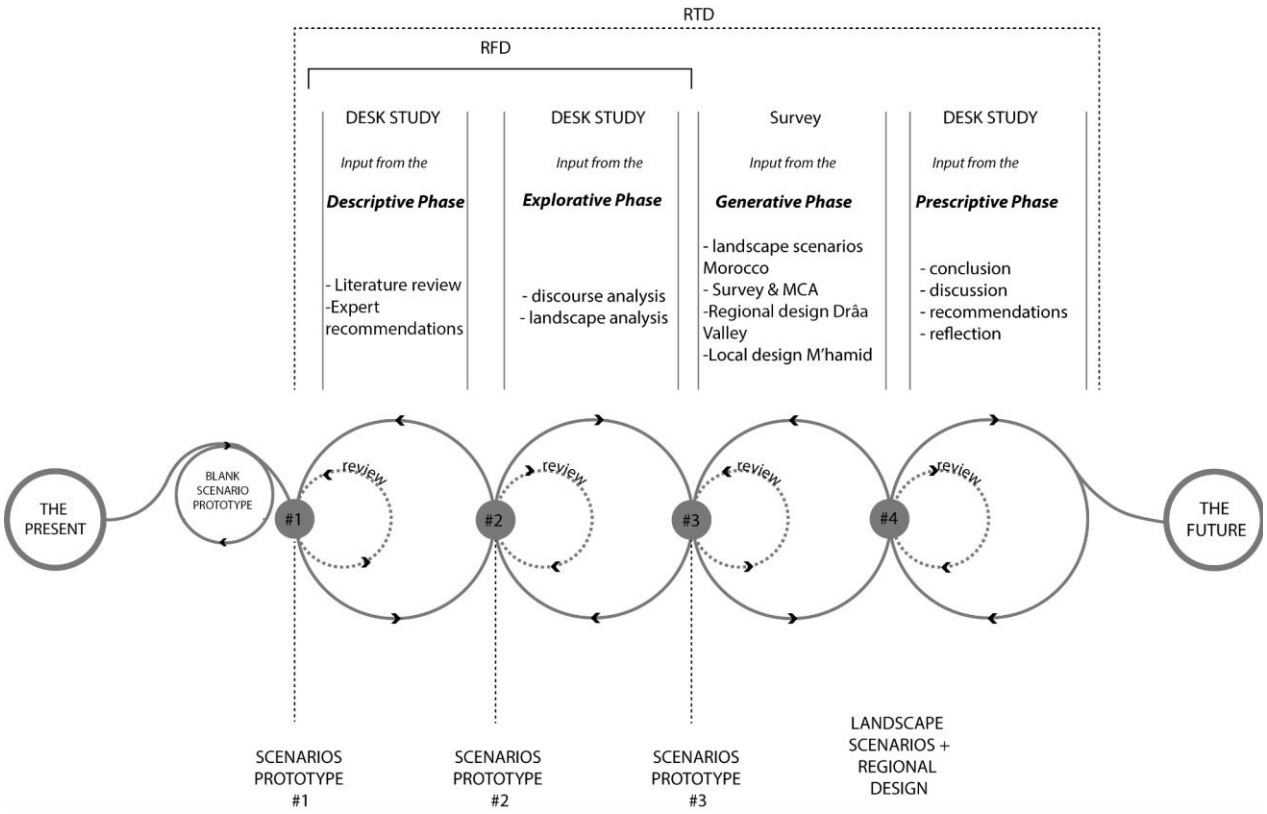

Figure 4. The methodological framework illustrates four iterative phases (descriptive, exploratory, generative, and prescriptive), including evaluation loops for scenario refinement.

Table 1. Summary of the methodological framework: phases, data sources, analytical procedures and outputs.

Phase	Data / participants	Analytical procedure	Output
1. STEEP driver analysis	Peer-reviewed literature, governmental reports, virtual observation of M'hamid (2020–2022); survey-nominated driving forces	STEEP categorisation; qualitative impact–uncertainty rating (low/medium/high) triangulated across three evidence streams	47 drivers; prioritised scenario axes (governance mode; social values)
2. Landscape assessment	Cartographic and remote-sensing sources; cultural landscape documentation; virtual site reconnaissance	Descriptive spatial analysis of oasis structure, threats and dynamics	Threats and concerns mapping (Figure 3); landscape system understanding
3. Scenario development	Outputs of Phases 1–2; scenario literature	Three iterative prototypes; cross-checking narratives against drivers; archetype structuring in a 2×2 scenario space	Four scenario archetypes and narratives

4. Online participatory survey (2 components)	Scenario/building-block evaluation: n = 20 residents (6 farmers, 8 tourism operators, 2 construction professionals, 4 government employees); driving-forces questionnaire: n = 15; posted 1 July 2022, open ≈ 1 month	Structured and open-ended questions; frequency comparison and thematic interpretation	Plausibility check; community preferences; scenario refinement
5. Spatial translation and evaluation	Building blocks derived from drivers; survey and expert input	Mapping of building blocks to scenarios; qualitative multi-criteria assessment across five equally weighted criteria	Scenario-specific spatial principles; synthesis strategy for M'hamid (Section 5.5)

4.1. STEEP Driver Analysis

Following Hunt et al. (2012), desertification drivers were systematically categorized across five domains: Social (demographic patterns, education, cultural values, migration), Technological (irrigation methods, agricultural mechanization, infrastructure), Economic (market forces, poverty, tourism), Environmental (water availability, soil degradation, biodiversity loss, climate variability), and Political (governance structures, legislation, resource management policies). Driver identification drew from peer-reviewed literature, governmental reports, along with a structured virtual observation of M'hamid oasis, namely satellite imagery, cartographic material and documentary sources, undertaken between 2020 and 2022.

Each driver was assessed for importance (impact magnitude on landscape change) and uncertainty (predictability of future state) through a structured qualitative evaluation combining the literature review, the participatory survey and the landscape analysis. Drivers exhibiting high importance and high uncertainty were prioritized as scenario-defining axes, following established scenario construction protocols (Börjeson et al., 2006). This categorisation provides transparent criteria for driver prioritisation and scenario axis selection. The prioritisation of key drivers is conducted using an impact–uncertainty matrix (Figure 5). Drivers were assessed using a qualitative ranking approach (low, medium, high) based on triangulation between literature review, survey responses, and virtual landscape observation, ensuring consistency in the identification of high-impact and high-uncertainty variables.

The driving forces nominated by the survey participants, as each respondent was asked to list at least three forces they considered the most important, were consolidated with those identified through the literature review and landscape analysis. After eliminating any redundancies, they were condensed into fifteen aggregate change driving forces, classified according to their direct (n = 6) or indirect (n = 9) impact on the oasis ecosystem. The importance was ranked through pair comparison, combining the frequency with which each force is mentioned in the literature along with the participants' votes, and drawing on the landscape analysis to separate the forces occupying the same rank. The uncertainty was assessed based on the tendencies of each force's past evolution within the current socio-economic context, and it was cross-checked against the participants' own ratings: around half of the respondents judged governance to be highly uncertain, while roughly 70% rated poverty and changing social values as both highly important and highly uncertain. The four forces that combine the highest importance and uncertainty, namely inadequate governance, changing social values, land-use change and poverty, underpinned the selection of the governance and social-values axes structuring the scenario space. Since the ratings are qualitative, no numerical weighting or inter-rater reliability statistic was computed; the implications of this choice are discussed in Section 6.4.

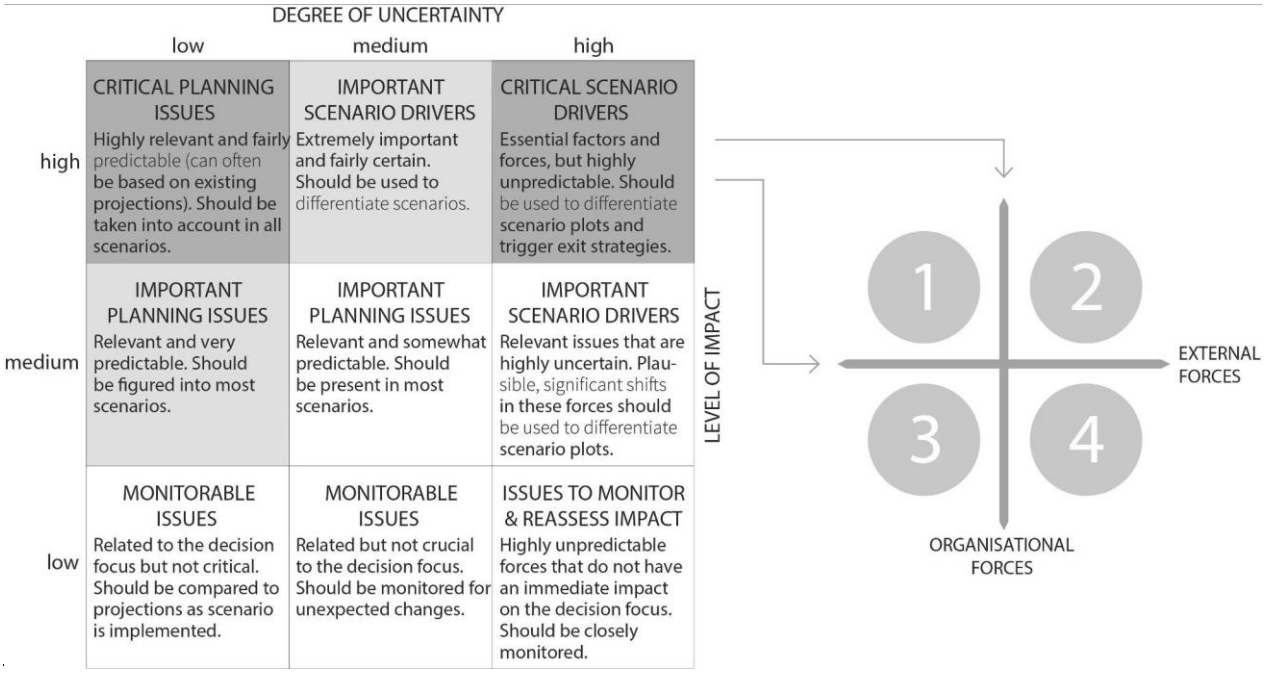

Figure 5. Impact–uncertainty matrix used to prioritise STEEP drivers based on their level of influence and uncertainty (adapted from Maack, 2001).

4.2. Scenario Development Process

Scenario construction followed a three-stage iterative process. In Prototype 1, preliminary scenarios were drafted based on STEEP analysis and existing desertification literature. Prototype 2 refined these scenarios by incorporating critical uncertainties around governance mode (top-down versus bottom-up) and social values (reactive individualism versus proactive solidarity), creating a two-dimensional scenario space. Prototype 3 validated internal consistency through cross-checking scenario narratives against identified drivers and ensuring that scenario combinations represented genuinely distinct futures rather than variations on similar themes.

The four final scenarios -Oasis Minimisation, Oasis Emancipation, Rural Abandonment, and Rural Refuge- were developed as archetypes rather than precise forecasts. This archetypal approach, widely recognized in scenario literature, enables pattern recognition across case studies while acknowledging local specificity (Hunt et al., 2012; Eisenack, 2012).

4.3. Landscape Building Blocks and Spatial Translation

To translate abstract scenarios into spatial design frameworks, landscape building blocks were identified as discrete spatial elements responding to specific STEEP drivers. Examples include mixed-cropping systems (responding to environmental and social drivers for biodiversity and self-sufficiency), solar energy parks (responding to technological and economic drivers), and rural revitalization programs (responding to political and social drivers for population retention). Each building block was mapped to its driving forces and then recombined within scenario contexts to generate scenario-specific spatial configurations for the Drâa Valley's oases, demonstrated through the representative site of M'hamid.

4.4. Participatory Survey

A participatory survey was conducted to validate the scenarios and to collect the community preferences. Due to travel restrictions, the survey was conducted online. The questionnaire was prepared in English and translated into the local languages (Arabic and French) to ease the communication with the community. It was posted on the first of July 2022 in different community groups on social media, specifically Facebook, along with being circulated by direct e-mail to local business owners and professionals. The survey remained open for approximately one month, with around two weeks of back-and-forth communication with the community after the post was uploaded. The instrument combined open-ended, dichotomous and multiple-choice questions with visual representations of the scenarios, which were presented in random order so that the participants' opinions were not influenced by the order.

The survey comprised two components. In the scenario and building-block evaluation (n = 20 Drâa Valley residents: 6 farmers, 8 tourism operators, 2 construction professionals and 4 government employees), participants assessed the plausibility of the scenario prototypes and the landscape building blocks, identified preferred futures and suggested additions or removals; their feedback informed the revision of the scenario prototypes and the final selection of building blocks reported in Section 5.5. In the driving-forces questionnaire (n = 15 completed responses), respondents nominated and ranked at least three driving forces they considered most important, feeding the driver consolidation described in Section 4.1. Female participation remained limited (n = 2), reflecting broader gender marginalisation in public discourse within the study region. The sample is small and self-selected; therefore, it is not statistically representative. The survey feedback has been weighed alongside the literature and landscape analysis within the multi-criteria assessment, rather than being the sole factor, and the results were used to test plausibility and elicit preferences rather than to generalise to the wider population.

4.5. Validation and Consistency

To ensure consistency between scenarios and their corresponding spatial strategies, the research employs an iterative evaluation process across all phases of development. Scenario prototypes are continuously refined through the integration of literature findings, landscape analysis, and participatory feedback. Validation is achieved through:

- cross-referencing identified drivers with existing literature
- comparing scenario outcomes against survey responses
- evaluating building blocks through multi-criteria assessment

This approach ensures that the developed scenarios remain coherent, context-specific, and grounded in both empirical data and stakeholder perspectives. The survey combined structured questions with open-ended responses, allowing both quantitative comparison of preferences and qualitative insights into local perceptions. Responses were analysed through frequency comparison and thematic interpretation.

5. Results

5.1. STEEP Driver Characterization

Analysis identified 47 distinct drivers distributed across STEEP categories. Environmental drivers dominated in both numbers (n=14) and assessed impact, with water scarcity, sand encroachment, and soil salinization identified as critical threats. Social drivers (n=12) centered on demographic shifts, particularly youth out-migration and declining agricultural succession. Economic drivers (n=9) reflected tension between traditional subsistence agriculture and emerging tourism-based economies. Technological drivers (n=7) encompassed both traditional systems (khettara, seguia) and modern interventions

(motorized wells, greenhouse agriculture). Political drivers (n=5) highlighted governance gaps in water allocation, land-use planning, and environmental regulation enforcement.

Table 2. Classification of desertification drivers based on STEEP categories and their impacts on the landscape system.

Driver category (STEEP)	Key drivers and indicators
Desertification drivers by STEEP category	
Socio-cultural	Age, family, household and ethnic structures; regional and national migration patterns; spatial distribution of population; wealth distribution, including regional and national poverty rates.
Technological	Farming methods, water management and mechanical structures to fight sand encroachment; level of technology in key industries; emerging technologies; capacity to manufacture technology for export.
Economical	Change in size, type and ownership of firms; formal and informal labour-force structure by region; employment rate; changes in economies of scale and structure of key industries; style of tourism; consumer spending patterns (urban/rural, national/regional); international demand for key exports; distribution and efficiency of rural and urban markets; impact of the informal sector; sources of competition (national, regional, international).
Environmental	Energy prices and availability (likelihood and impact of an oil shock); raw materials (rate of depletion, ease of access); sustainability (strategic use of resources); regional distribution of natural resources.
Political	Change in governmental development strategy and policy (privatisation); changes in legislation (regulation, creation of an enabling environment); changes in the structure and responsibility of ministries; changes in rules governing the formation and functioning of parties; stability of government and likelihood of change; governmental environmental action.
Associated concerns for the oasis landscape system	
Water scarcity	Weak mobilisation of surface waters; population growth; oasis communities no longer isolated; urban sprawl; tourism development; agricultural expansion and intensification; extension onto rangelands; low level of awareness; non-application of, or insufficient respect for, the laws in force.
Biodiversity degradation	Population growth creating additional needs for food and medicine; expansion of residential and infrastructural building at the expense of natural areas; absence of ex-situ conservation programmes and gene banks; irrational water management; changing consumption patterns; change in land use; market forces; locust invasion; tourism development.
Sand encroachment	Unsuitable means and techniques to fight sand encroachment; excessive livestock; agricultural expansion; anarchic construction that eliminates natural barriers.
Oasis lifestyle	Accentuation of poverty; ignorance and illiteracy; exclusion and marginalisation; new needs created by necessity or the pursuit of luxury and well-being; market forces; lack of communication and transport.

Four cross-cutting issues emerged as highest priority: water deficit (affecting 89% of agricultural households; Alhejazi, 2022), sand dune advancement (threatening 12 of 28 settlements; Alhejazi, 2022), biodiversity degradation (a 22% loss of vegetated oasis area between 1984 and 2016, with the densely

vegetated area contracting to roughly one third of its former extent; Lamqadem et al., 2017), and deteriorating living conditions (45% poverty rate, 68% youth unemployment; Alhejazi, 2022). These issues exhibit complex interdependencies: water scarcity drives agricultural abandonment, which reduces vegetation cover, which accelerates sand encroachment, which further degrades soil and water resources.

5.2. Scenario Archetypes

Four distinct landscape scenarios emerged from the iterative development process, positioned along axes of governance structure (top-down to bottom-up) and social values (reactive individualism to proactive solidarity). Each scenario represents a coherent socio-ecological trajectory with specific implications for desertification processes, landscape configuration, and community well-being. The four scenarios are positioned within a structured scenario space, as illustrated in Figure 6.

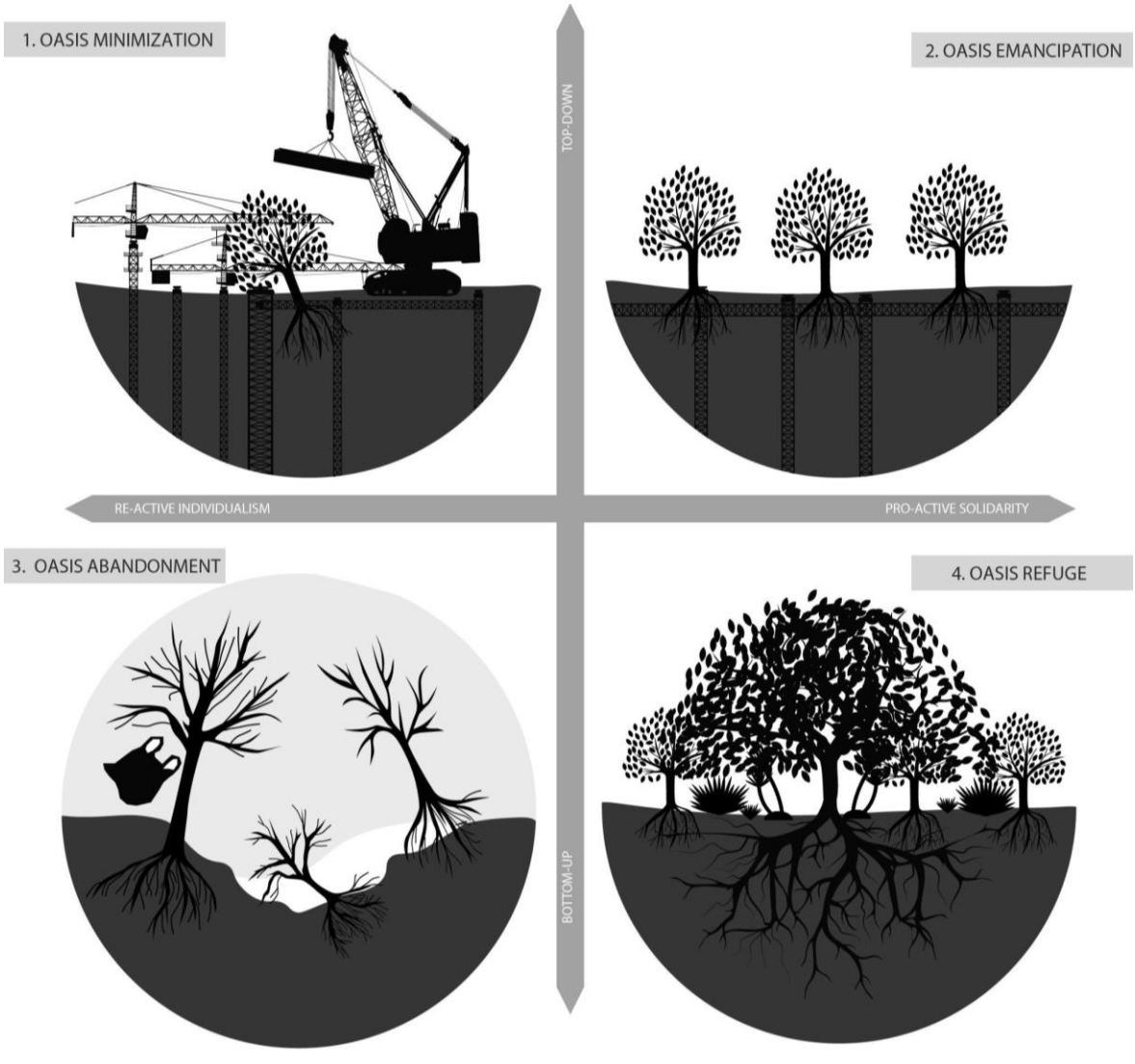

Figure 6. Scenario space illustrating four landscape archetypes structured along governance and social value axes.

5.2.1. Scenario 1: Oasis Minimisation

This scenario depicts strong state intervention combined with market-driven individualism. Large-scale agricultural corporations operate precision-farmed monocultures using sensor networks and automated irrigation. Settlement concentrates in planned urban zones with controlled access and protective infrastructure against sand encroachment. Traditional oasis areas are abandoned or repurposed for industrial agriculture and solar energy generation. Water resources are managed through centralized infrastructure connecting to national grids. Desertification accelerates in unmanaged areas as vegetation removal and soil compaction from industrial operations trigger erosion and gullying. Social outcomes include high migration rates, loss of traditional knowledge, economic polarization between corporate employees and displaced farmers, and dissolution of community-based resource management institutions.

5.2.2. Scenario 2: Oasis Emancipation

This scenario features coordinated state-led environmental restoration combined with collective social values. Comprehensive reforestation programs stabilize dunes using native species. Urban areas implement green infrastructure and mandate earthen construction. Agricultural systems transition to certified organic and regenerative practices supported by technical extension services. Water management integrates modern wastewater treatment with restored traditional systems. Eco-tourism and Agri-tourism generate economic value while preserving cultural heritage. Environmental sensors monitor ecosystem health, with data informing adaptive management. Desertification is slowed or stabilized through systematic intervention, though urban expansion continues creating localized land-use pressures. Social outcomes include reduced out-migration, revitalized rural settlements, improved environmental quality, but potential loss of local autonomy to bureaucratic structures.

5.2.3. Scenario 3: Rural Abandonment

This scenario portrays governance failure coupled with fragmented individualistic responses. Weak or absent state presence creates regulatory vacuums filled by informal practices. Illegal well drilling proliferates as households prioritize immediate survival over collective resource management. Agricultural land is progressively abandoned as youth migrate and elderly farmers cannot sustain labour-intensive traditional systems. Sand dunes advance unchecked, engulfing settlements and palm groves. Urban areas fragment into disconnected enclaves with inadequate infrastructure. Water pollution from untreated sewage contaminates remaining aquifers. Desertification accelerates dramatically through compound degradation: vegetation loss, soil erosion, groundwater depletion, and biodiversity collapse. Social outcomes include extreme poverty, educational collapse, health crises from waterborne disease, gender-based violence, ethnic conflict over dwindling resources.

5.2.4. Scenario 4: Rural Refuge

This scenario envisions bottom-up community organization guided by solidarity values. Self-organizing cooperatives manage water, agriculture, and land stewardship through revitalized traditional institutions. Mixed agroforestry systems combine date palms with vegetables, medicinal plants, and nitrogen-fixing species. Scattered reforestation efforts by community groups protect settlements from encroaching dunes. Households generate energy through small-scale solar installations. Eco-tourism operates on community-controlled terms emphasizing cultural exchange over profit maximization. Improved rural connectivity through enhanced roads and digital communication enables market access while maintaining settlement character. Desertification is locally managed through nature-based solutions and traditional ecological knowledge, though coordination challenges limit landscape-scale effectiveness.

Social outcomes include strong community cohesion, preservation of cultural practices, environmental stewardship, but potential vulnerability to external economic shocks.

5.3. Spatial Design Principles by Scenario

Translation of scenarios into spatial configurations for M'hamid oasis revealed distinctive landscape patterns. In Oasis Minimisation, urban expansion occurs on desert margins with defensive perimeters, large-scale solar parks occupy abandoned palm groves, and precision agriculture operates in consolidated parcels. In Oasis Emancipation, urban growth is contained by green belts, reforestation creates continuous corridors, wastewater treatment enables grey-water reuse, and revitalized ksour serve as cultural tourism nodes. In Rural Abandonment, urban fragmentation creates disconnected patches, abandoned farmland converts to wilderness with advancing sand. In Rural Refuge, scattered community forests protect settlements, mixed agriculture maintains palm grove structure, and community-managed commons provide shared spaces. The translation of STEEP drivers into spatial elements is represented through landscape scenario building blocks (Figure 7). The integration of these elements into spatial strategies is illustrated in Figure 8.

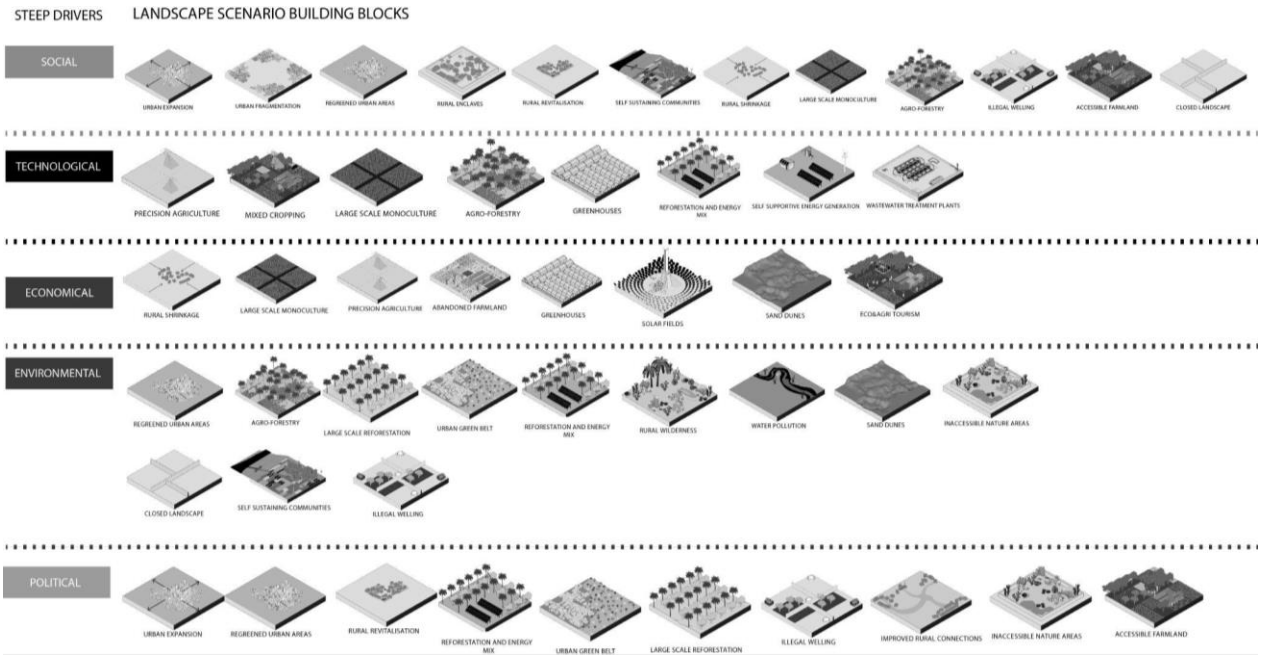

Figure 7. Landscape scenario building blocks derived from STEEP drivers and their relationships within the landscape system

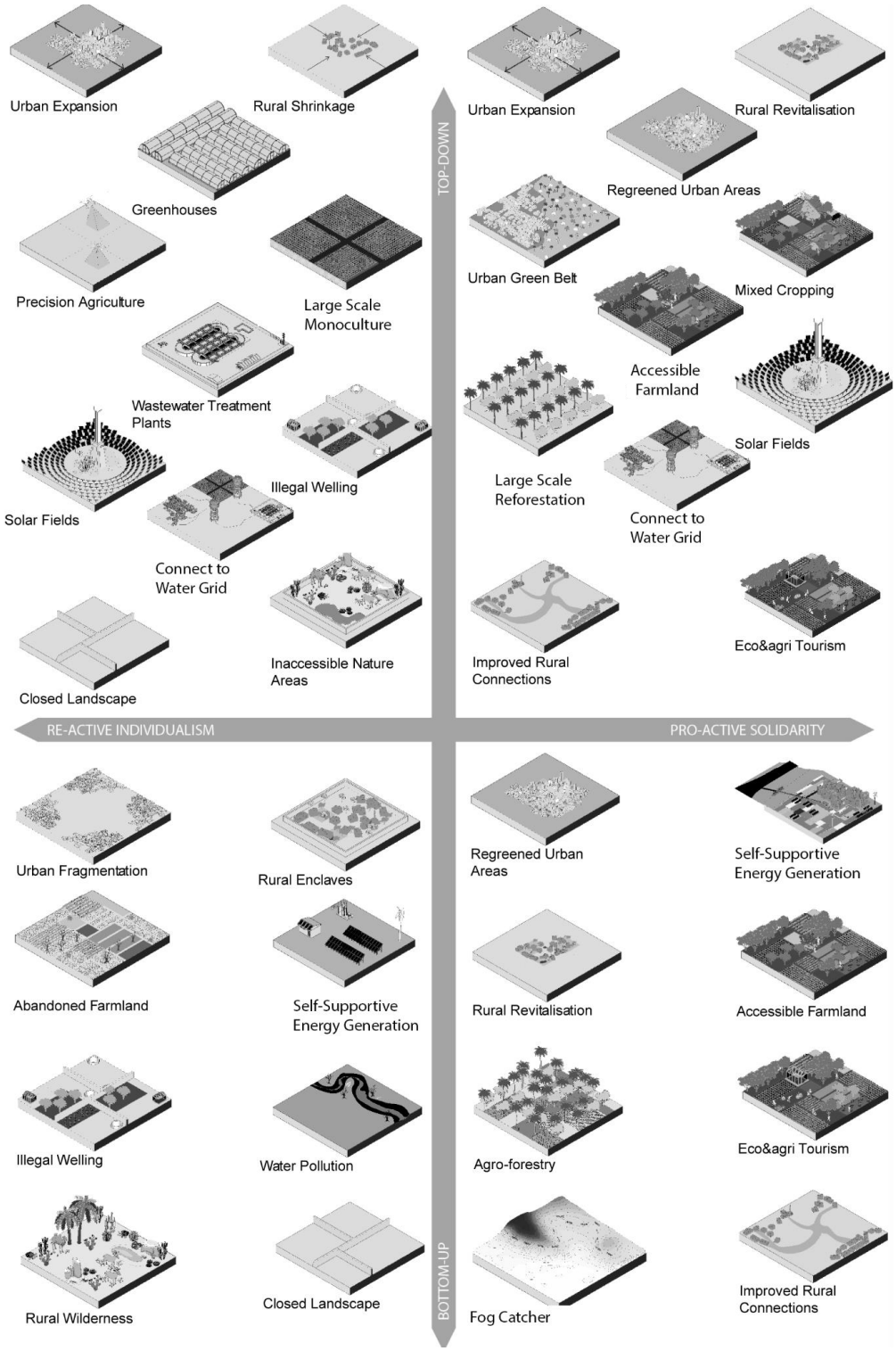

Figure 8. Spatial configuration of landscape scenario building blocks within the four scenario frameworks for M'hamid oasis.

5.4. Evaluation of Landscape Interventions

The landscape scenario building blocks are evaluated through a multi-criteria assessment framework, based on five dimensions:

- social acceptance
- political feasibility
- economic viability
- environmental impact
- technological feasibility

This evaluation process allows for the comparison of different interventions across scenarios, supporting the identification of the most desirable and feasible strategies. The results indicate that interventions combining ecological restoration with socio-economic benefits, such as agroforestry systems, water harvesting techniques, and eco-tourism, demonstrate higher levels of acceptance and feasibility across multiple criteria. The conducted evaluation was a comparative qualitative scoring approach, enabling the identification of interventions that perform consistently across multiple criteria rather than optimising a single dimension.

Each building block was scored qualitatively (low / medium / high) against the five criteria by the research team, drawing on the survey responses, the literature and the landscape analysis, with the survey feedback weighed alongside the other evidence rather than being the sole factor. The criteria were weighted equally, and the building blocks attaining an aggregate score above 1.0 across the five indicators were retained for the design synthesis. The respondents' judgements fed directly into this scoring: around 50% of the respondents considered the urban green belt an undesirable development, since it increases the separation between the palm groves, the agricultural lands and urban life; precision agriculture was viewed negatively by most of the farmer participants; while the solar fields received a generally positive perception, along with some concerns in regard to their maintenance and cooling-water demand. The full scoring matrix is available from the authors on request.

5.5. Synthesis into Spatial Strategy

The final stage of the results integrates the selected building blocks into a coherent spatial strategy for the Drâa Valley's oases, demonstrated through M'hamid as a representative site. The strategy aims to:

- reduce desertification through ecological restoration
- improve water availability and management
- rehabilitate degraded land through alternative agricultural practices
- strengthen socio-economic resilience through diversified activities

The building blocks retained through the multi-criteria assessment comprised the regreening of urban areas, self-sustaining communities, rural revitalisation, mixed cropping and agroforestry, urban green belts, large-scale reforestation and reforestation–energy mixes, self-supporting energy generation, eco- and Agri-tourism, accessible farmland, fog catchment, dune stabilisation and improved rural connections. This synthesis reflects the transition from scenario exploration to design implementation, where selected interventions are combined to form a context-specific and adaptive landscape strategy.

6. Discussion

6.1. Theoretical Contributions to Resilience and Scenario Planning

This research advances theoretical understanding of landscape scenarios as mediators between uncertainty and design action in complex socio-ecological systems. The study extends scenario methodology by explicitly linking archetypal narratives to spatial design through the landscape building block framework, addressing a persistent challenge in translating exploratory scenarios into actionable design guidance.

The research positions landscape scenario archetypes within resilience theory and socio-ecological systems thinking, specifically engaging debates around adaptive versus transformative responses to environmental change. Scenarios 2 and 4 emphasize adaptive resilience - maintaining system function through responsive management. Scenario 1 represents transformative change toward an industrialized system. Scenario 3 depicts system collapse from failed adaptation.

6.2. Linking Scenarios to Resilience Outcomes

This research hypothesizes that scenarios emphasizing traditional knowledge integration, participatory governance, and nature-based solutions (Scenarios 2 and 4) enhance oasis resilience more effectively than technology-substitution or laissez-faire approaches. This hypothesis derives from resilience theory principles: diversity supports adaptive capacity, modularity prevents cascading failure, and social capital enables collective action.

In resilience terms (Walker et al., 2004; Folke et al., 2010), the four scenarios can be compared against four qualitative indicators, namely the diversity of crops, livelihoods and water sources; the connectivity and modularity of the landscape mosaic; the retention of traditional ecological knowledge; and the capacity for self-organisation. Scenarios 2 and 4 rank the highest on all four indicators, Scenario 2 through institutionalised restoration and extension services and Scenario 4 through community self-organisation. On the other hand, Scenario 1 substitutes technological control for diversity, while Scenario 3 erodes every indicator simultaneously. This comparative reading, rather than any single quantitative measure, underpins the interpretation of Scenarios 2 and 4 as the more resilient trajectories. Developing measurable resilience indicators for oasis systems remains a priority for future research.

Survey participants with direct experience overwhelmingly favoured scenarios preserving mixed agriculture, community-based resource management, and cultural continuity. Historical analysis demonstrates that traditional oasis systems sustained populations for centuries by balancing resource extraction with regeneration. Contemporary case studies from other arid regions show that combining traditional practices with modern ecological engineering yields superior outcomes to purely technical interventions (Li et al., 2015). However, these scenarios may face limitations under conditions of weak institutional support or external economic pressures, highlighting the importance of governance capacity and long-term policy continuity in sustaining resilience-oriented strategies.

6.3. Scenario Plausibility, Hybrid Futures and Mediterranean Relevance

The four archetypes are exploratory rather than predictive, and their plausibility is uneven. Elements of Scenario 3 (Rural Abandonment) are already observable in the lower valley, namely the declining palm-grove density, out-migration and illegal well digging. On the other hand, the coordinated public investment assumed in Scenario 2 (Oasis Emancipation) depends on sustained national policy attention and funding continuity that cannot be guaranteed. The most likely future is therefore a hybrid condition combining features of several archetypes: community-based stewardship (Scenario 4) operating within selective state programmes (Scenario 2), or corporate agricultural enclaves (Scenario 1) co-existing with abandonment elsewhere (Scenario 3). Reading the scenario space as a continuum rather than as four

discrete futures allows planners to monitor which trajectory is being approached and to adjust interventions accordingly. The survey responses support this reading, as the participants judged a combination of Scenarios 3 and 2 to be the most likely future. They noted that the present condition of the valley is closest to Scenario 3, while the ongoing governmental agricultural programmes, along with some social movements and community activities, are working towards a future like Scenarios 2 and 4. Furthermore, the expansion of tourism facilities and commercial agriculture seems to suggest elements of Scenario 1.

Scenario trajectories will also be shaped by drivers beyond the local scale, including upstream dam operation and basin-scale water allocation, national rural development and renewable-energy policy, international tourism markets, remittance economies and migration regimes. Long-term climate projections reinforce the urgency of anticipatory planning: the Mediterranean Basin is warming considerably faster than the global average, with projected declines in precipitation and increasing drought frequency across North Africa (MedECC, 2020; IPCC, 2022), conditions under which all four scenarios face tightening water constraints. Potential conflicts between ecological restoration and development pressures, namely tourism construction, solar development and agricultural intensification, will therefore require negotiated land-use arrangements along with a phased implementation.

Positioning the findings within the wider Mediterranean and North African context underlines their transferability. Remote-sensing studies confirm ongoing desertification and field abandonment in the ancient oases of southern Morocco (Rayne et al., 2023), systematic reviews identify water-related pressures as the principal threat to traditional North African oasis agroforestry systems (Santoro, 2023), and recent work documents how rural–urban transformation reshapes oasis agriculture in Morocco (Boubou et al., 2025). The building-block approach developed here is consistent with the growing evidence base for nature-based solutions as cost-effective adaptation strategies in arid and semi-arid regions (Seddon et al., 2020; Chausson et al., 2020) and complements Mediterranean urban research linking spatial configuration to resilience (Bechlem et al., 2024). Comparable scenario exercises in other Maghreb oases and Mediterranean drylands would test the framework's transferability and refine its building-block vocabulary.

6.4. Methodological Validation and Limitations

The participatory survey process provides internal validation of scenario plausibility. However, limitations warrant acknowledgment. First, the small, self-selected online sample (15–20 respondents across the two survey components) and its composition (predominantly male, tourism-sector-biased) limit generalizability. Systematic exclusion of women's perspectives represents a critical gap. Second, while STEEP analysis provides systematic driver categorization, assessments incorporate the authors' qualitative judgement alongside survey and literature evidence. Third, scenarios represent synchronic cross-sections rather than dynamic temporal progressions.

In addition to these sampling constraints, further uncertainty is introduced by the subjective and qualitative ranking of the drivers, the narrative scenario construction that was undertaken without formal consistency algorithms or uncertainty-propagation analysis, along with validation procedures that relied on qualitative triangulation rather than statistical testing. These limitations bound the confidence with which the scenario outcomes can be compared and reinforce the exploratory status of the framework.

Findings hold direct implications for regional development planning. First, governance mode profoundly shapes landscape outcomes. Effective policy likely requires hybrid governance balancing state capacity with community participation. Second, nature-based solutions integrating traditional knowledge offer cost-effective resilience strategies. Third, scenarios highlight the inadequacy of single-sector interventions. Addressing desertification requires integrated approaches simultaneously tackling water, agriculture, energy, infrastructure, and social equity.

7. Conclusions

Addressing the three objectives set out at the outset, namely identifying the STEEP drivers of desertification, developing landscape scenario archetypes, and translating them into spatial design principles, this research demonstrates that landscape scenario archetypes provide an effective framework for exploring alternative futures in desertification-prone oases and for converting exploratory narratives into spatial design. Four distinct scenarios - Oasis Minimisation, Oasis Emancipation, Rural Abandonment, and Rural Refuge - emerged from systematic analysis of STEEP drivers and participatory validation, representing coherent socio-ecological trajectories shaped by governance structures and social values. Consistent with the study's guiding hypothesis, scenarios emphasising traditional-knowledge integration, participatory governance and nature-based solutions (Scenarios 2 and 4) were consistently preferred by participants and rank highest against the qualitative resilience indicators developed in Section 6.2.

The research makes three original contributions. First, it extends scenario methodology by developing the landscape building block framework as an explicit mechanism for translating scenarios into spatial design. Second, it positions scenarios within resilience theory, exploring how different governance-society paradigms enable adaptive versus transformative change. Third, it demonstrates the value of integrating traditional ecological knowledge with contemporary landscape strategies.

Findings indicate that combining traditional oasification practices - mixed agriculture, community-based water management, earthen construction - with nature-based solutions and appropriate technologies can enhance ecological functioning, improve resource efficiency, and strengthen social adaptive capacity. Survey results showing strong preference for scenarios emphasizing these elements suggest alignment between community values and sustainability principles.

For policy and practice, three priorities follow. Firstly, hybrid governance arrangements should pair the state investment in water infrastructure and dune stabilisation with legally recognised community water and land institutions, balancing state capacity with local participation. Secondly, the near-term implementation should prioritise the building blocks that performed consistently across scenarios and criteria, namely the agroforestry-based palm-grove rehabilitation, water harvesting and grey-water reuse, along with community-managed windbreak and reforestation belts. These interventions should be sequenced from low-cost community measures towards larger infrastructure as the institutional capacity grows, and where restoration competes with development pressures, the land-use trade-offs should be negotiated through community institutions. Thirdly, monitoring and evaluation should track early-warning indicators drawn from the scenario logics, namely groundwater levels, palm-grove density and out-migration rates, so that the strategies can be adapted as the valley's trajectory becomes clearer.

Future research directions include: (1) developing quantitative models to simulate scenario trajectories; (2) expanding participatory engagement to systematically include marginalized voices, particularly women; (3) conducting cross-case scenario development in other North African oases; and (4) implementing pilot interventions informed by preferred scenarios to assess practical feasibility. By advancing scenario-based planning for dryland regions, this research contributes methodological and substantive insights toward sustainable development in environmentally challenged yet culturally rich landscapes.

Acknowledgements
The authors gratefully acknowledge the Drâa Valley communities who participated in surveys and shared their knowledge. Special thanks to local NGOs and municipal authorities in M'hamid El Ghizlane for facilitating the survey outreach, Professor Marwa Dabaieh for insights on vernacular architecture, and Marwa Ichibane for assistance with survey translation and community outreach.

Funding, Conflicts of Interest
No specific grant was received for this work from funding bodies in the public, commercial or not-for-profit sectors. The authors report no conflicts of interest.

Data Availability Statement
The survey data and the multi-criteria scoring matrix underlying this study can be obtained from the corresponding author on reasonable request.

Institutional Review Board Statement
All procedures followed established ethical research principles: survey participation was voluntary and anonymous, and every respondent gave informed consent before taking part.

CRediT Author Statement
Salwa Abdalla Alhejazi: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Visualization, Writing - original draft. Carlotta Maria Serena Fontana: Supervision, Conceptualization, Writing - review and editing, Project administration. All authors have read and approved the final manuscript.

Contribution to the Field statement
This study contributes an operational bridge between scenario planning and landscape design in desertification-prone oases. It introduces the landscape scenario building-block framework, through which each prioritised STEEP driver is carried into a discrete and mappable landscape intervention, allowing alternative futures to be compared as spatial configurations rather than remaining narrative constructs. Applied to the Drâa Valley, with M'hamid oasis as a representative site, the framework combines driver analysis, participatory input and multi-criteria assessment to identify resilience-oriented strategies, namely palm-grove rehabilitation through agroforestry, water harvesting and community-managed reforestation. The approach is transferable to other Maghreb oases and Mediterranean drylands.

References

Ait Lamqadem, A., Saber, H., & Pradhan, B. (2018). Quantitative assessment of desertification in an arid oasis using remote sensing data and spectral index techniques. Remote Sensing, 10(12), 1862. https://doi.org/10.3390/rs10121862

Alhejazi, S. (2022). Towards a desired future in oases settlements: A landscape scenarios approach to enhance the Draa Valley oasis resilience against desertification [Master's thesis, Politecnico di Milano].

Albert, C. (2011). Scenario-based landscape planning: Influencing decision-making through substantive outputs and social learning [Doctoral dissertation].

Baglioni, E., Rovero, L., & Tonietti, U. (2016). Drâa valley earthen architecture: Construction techniques, pathology and intervention criteria. Journal of Materials and Environmental Science, 7(10), 3499-3508

Baker, J. P., Hulse, D. W., Gregory, S. V., White, D., van Sickle, J., Berger, P. A., Dole, D., & Schumaker, N. H. (2004). Alternative futures for the Willamette River Basin, Oregon. Ecological Applications, 14(2), 313-324. https://doi.org/10.1890/02-5011

Barbero-Sierra, C., Marques, M. J., Ruiz-Pérez, M., Escadafal, R., & Exbrayat, W. (2015). How is desertification research addressed in Spain? Land versus soil approaches. Land Degradation and Development, 26(5), 423-432. https://doi.org/10.1002/ldr.2344

Bechlem, R., Djouad, F.-Z., & Salah-Salah, H. (2024). Morphological analysis of public spaces and their contribution to urban resilience in Guelma, Algeria. Journal of Mediterranean Cities, 4(1), 167–177. https://doi.org/10.38027/mediterranean-cities_vol4no1_10

Berger, E., Bossenbroek, L., Beermann, A. J., Schäfer, R. B., Znari, M., Riethmüller, S., Sidhu, N., Kaczmarek, N., Benaissa, H., Ghamizi, M., Plicht, S., ben Salem, S., el Qorchi, F., Naimi, M., Leese, F., & Frör, O. (2021). Social-ecological interactions in the Draa River Basin, southern Morocco: Towards nature conservation and human well-being using the IPBES framework. Science of the Total Environment, 769, 144492. https://doi.org/10.1016/j.scitotenv.2020.144492

Börjeson, L., Höjer, M., Dreborg, K.-H., Ekvall, T., & Finnveden, G. (2006). Scenario types and techniques: Towards a user's guide. Futures, 38(7), 723-739. https://doi.org/10.1016/j.futures.2005.12.002

Boschetti, F., Price, J., & Walker, I. (2016). Myths of the future and scenario archetypes. Technological Forecasting and Social Change, 111, 76–85. https://doi.org/10.1016/j.techfore.2016.06.009

Boubou, Y., Fastner, K., & Buerkert, A. (2025). Rural-urban transformation shapes oasis agriculture in Morocco's High Atlas Mountains. Scientific Reports, 15, 3433. https://doi.org/10.1038/s41598-024-81569-7

Chausson, A., Turner, B., Seddon, D., Chabaneix, N., Girardin, C. A. J., Kapos, V., Key, I., Roe, D., Smith, A., Woroniecki, S., & Seddon, N. (2020). Mapping the effectiveness of nature-based solutions for climate change adaptation. Global Change Biology, 26(11), 6134–6155. https://doi.org/10.1111/gcb.15310

de Haas, H. (2003). Migration and development in Southern Morocco: The disparate socio-economic impacts of out-migration on the Todgha oasis valley [Doctoral dissertation, Radboud University Nijmegen].

Dockerty, T., Lovett, A., Appleton, K., Bone, A., & Sünnenberg, G. (2006). Developing scenarios and visualisations to illustrate potential policy and climatic influences on future agricultural landscapes. Agriculture, Ecosystems and Environment, 114(1), 103-120. https://doi.org/10.1016/j.agee.2005.11.008

Domínguez Martínez, O., Colmenares Fernández, M., & García Hermida, A. (2017). Cultural heritage and development: The M'hamid Oasis in southern Morocco. Journal of Cultural Heritage Management and Sustainable Development, 7(1), 2-13. https://doi.org/10.1108/JCHMSD-05-2016-0030

Eisenack, K. (2012). Archetypes of adaptation to climate change. In M. Glaser, G. Krause, B. M. W. Ratter, & M. Welp (Eds.), Human-nature interactions in the Anthropocene: Potentials of social-ecological systems analysis (pp. 107-122). Routledge. https://doi.org/10.4324/9780203123195-17

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. Ecology and Society, 15(4), 20. https://doi.org/10.5751/ES-03610-150420

Hunt, D. V. L., Lombardi, D. R., Atkinson, S., Barber, A. R. G., Barnes, M., Boyko, C. T., Brown, J., Bryson, J., Butler, D., Caputo, S., Caserio, M., Coles, R., Cooper, R. F. D., Farmani, R., Gaterell, M., Hale, J., Hales, C., Hewitt, C. N., Jankovic, L., ... Rogers, C. D. F. (2012). Scenario archetypes: Converging rather than diverging themes. Sustainability, 4(4), 740-772. https://doi.org/10.3390/su4040740

IPCC. (2022). Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://doi.org/10.1017/9781009325844

Johannsen, I. M., Hengst, J. C., Goll, A., Höllermann, B., & Diekkrüger, B. (2016). Future of water supply and demand in the Middle Drâa Valley, Morocco, under climate and land use change. Water, 8(8), 313. https://doi.org/10.3390/w8080313

Karmaoui, A. (2015). Sustainability of the Moroccan oasean system (Case study: Middle Draa Valley). Global Journal of Technology and Optimization, 6(1), 1-9. https://doi.org/10.4172/2229-8711.1000170

Karmaoui, A., & Moumane, A. (2016). Changes in the environmental vulnerability of oasean system (desert oasis), pilot study in Middle Draa Valley, Morocco. Expert Opinion on Environmental Biology, 5(3). https://doi.org/10.4172/2325-9655.1000135

Lamqadem, A. A., Saber, H., & Rahimi, A. (2017). Spatiotemporal changes of vegetation in the Middle Draa Valley oasis: A study case of M'hamid El Ghizlane oasis (Morocco). European Scientific Journal, 13(24), 115. https://doi.org/10.19044/esj.2017.v13n24p115

Laureano, P. (2012). Traditional knowledge in coping with desertification. International Journal of Environmental Studies, 69(6), 1002-1003. https://doi.org/10.1080/00207233.2011.585015

Li, C., Lei, J., Zhao, Y., Xu, X., & Li, S. (2015). Effect of saline water irrigation on soil development and plant growth in the Taklimakan Desert Highway shelterbelt. Soil & Tillage Research, 146, 99-107. https://doi.org/10.1016/j.still.2014.03.013

Lightfoot, D. R. (1996). Moroccan khettara: Traditional irrigation and progressive desiccation. Geoforum, 27(2), 261-273. https://doi.org/10.1016/0016-7185(96)00008-5

Maack, J. N. (2001). Scenario analysis: A tool for task managers. In R. A. Krueger, M. A. Casey, J. Donner, S. Kirsch, & J. N. Maack, Social analysis: Selected tools and techniques (Social Development Papers No. 36, pp. 62–87). World Bank.

Mahmoud, M., Liu, Y., Hartmann, H., Stewart, S., Wagener, T., Semmens, D., Stewart, R., Gupta, H., Dominguez, D., Dominguez, F., Hulse, D., Letcher, R., Rashleigh, B., Smith, C., Street, R., Ticehurst, J., Twery, M., van Delden, H., Waldick, R., … Winter, L. (2009). A formal framework for scenario development in support of environmental decision making. Environmental Modelling & Software, 24(7), 798–808. https://doi.org/10.1016/j.envsoft.2008.11.010

MedECC. (2020). Climate and environmental change in the Mediterranean Basin – Current situation and risks for the future: First Mediterranean Assessment Report. Union for the Mediterranean, Plan Bleu, UNEP/MAP. https://doi.org/10.5281/zenodo.4768833

Oberlack, C., Sietz, D., Bürgi Bonanomi, E., de Bremond, A., Dell'Angelo, J., Eisenack, K., Ellis, E. C., Epstein, G., Giger, M., Heinimann, A., Kimmich, C., Kok, M. T. J., Manuel-Navarrete, D., Messerli, P., Meyfroidt, P., Václavík, T., & Villamayor-Tomas, S. (2019). Archetype analysis in sustainability research: Meanings, motivations, and evidence-based policy making. Ecology and Society, 24(2), 26. https://doi.org/10.5751/ES-10747-240226

Oteros-Rozas, E., Martín-López, B., Daw, T. M., Bohensky, E. L., Butler, J. R. A., Hill, R., Martin-Ortega, J., Quinlan, A., Ravera, F., Ruiz-Mallén, I., Thyresson, M., Mistry, J., Palomo, I., Peterson, G. D., Plieninger, T., Waylen, K. A., Beach, D. M., Bohnet, I. C., Hamann, M., … Vilardy, S. P. (2015). Participatory scenario planning in place-based social-ecological research: Insights and experiences from 23 case studies. Ecology and Society, 20(4), 32. https://doi.org/10.5751/ES-07985-200432

Rayne, L., Brandolini, F., Makovics, J. L., Hayes-Rich, E., Levy, J., Irvine, H., Assi, L., & Bokbot, Y. (2023). Detecting desertification in the ancient oases of southern Morocco. Scientific Reports, 13, 19424. https://doi.org/10.1038/s41598-023-46319-1

Santoro, A. (2023). Traditional oases in Northern Africa as multifunctional agroforestry systems: A systematic literature review of the provided ecosystem services and of the main vulnerabilities. Agroforestry Systems, 97(1), 81–96. https://doi.org/10.1007/s10457-022-00789-w

Seddon, N., Chausson, A., Berry, P., Girardin, C. A. J., Smith, A., & Turner, B. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B, 375(1794), 20190120. https://doi.org/10.1098/rstb.2019.0120

Sobczak, K. (2008). Changes in the environment and migration in Southern Morocco – Example of the Mhamid oasis. Miscellanea Geographica – Regional Studies on Development, 13(1), 239–250. https://doi.org/10.2478/mgrsd-2008-0024

UNCCD. (2017). The global land outlook (1st ed.). United Nations Convention to Combat Desertification.

Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. Ecology and Society, 9(2), 5. https://doi.org/10.5751/ES-00650-090205